# SPECIAL SUBJECT
# AIR WING (NCC)


EDITION 2025

**SD/SW CADETS' HAND BOOK**
**NATIONAL CADET CORPS**

National Cadet Corps



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Delhi-110030


# CONSTITUTION OF INDIA

PREAMBLE

**WE, THE PEOPLE OF INDIA, HAVING**
solemnly resolved to constitute India into
a sovereign socialist secular democratic republic
and to secure to all its citizens :

JUSTICE,
Social, Economic And Political; LIBERTY
of thought, expression, belief, faith and worship;

EQUALITY
of status and of opportunity; and to promote among them all

FRATERNITY
assuring the dignity of the individual and
the [unity and integrity of the nation];

IN OUR CONSTITUENT ASSEMBLY
this twenty-sixth day of november, 1949, do
HEREBY ADOPT, ENACT AND GIVE TO
OURSELVES THIS CONSTITUTION.

**NATIONAL ANTHEM**

Jana-Gana-Mana-Adhinayak Jaya He

Bharat-bhagya-vidhata

Punjab-Sindhu-Gujrat-Maratha

Dravid-Utkal-Banga

Vindhya-Himachal-Yamuna-Ganga-

uchchala-jaladhi-taranga

Tava Subha name jage,

tava subha asisa mage, gahe tava jaya-gatha.

Jana-gana-mangala-dayaka

jaya he Bharata-bhagya-vidhata

Jaya he, Jaya he, Jaya he, jaya jaya jaya jaya he.

**FOREWORD**

It gives me immense pleasure and pride to present the Revised NCC Précis of Common and Special Subjects, 2025 Edition, marking the culmination of a protracted effort mounted for the purpose for more than two years. This achievement has only been made possible through the collective and whole-hearted effort of all stakeholders, comprising the Directorates, the Board of Officers for revision and for printing, & my staff. Your contribution in bringing the project to fruition merits highest appreciation.

The revision was aimed at structuring and updating the syllabus to reflect contemporary thought & realities, as also equip cadets with skills to apply their NCC training in real-life situations. The challenge was to simultaneously keep the language simple for easy comprehension, avoiding too much jargon or pedantry. Endeavour was also to make the presentation interesting and the layout reader-friendly, enabling cadets to engage with each topic meaningfully even through self-study. I extend my sincere appreciation to the entire team for successfully achieving these objectives in their entirety.

This endeavour also aligns the NCC syllabus with tenets of *Vikasit Bharat* for the youth, familiarising NCC cadets with history, geo-strategy, and contemporary technological advances, while remaining rooted in our cultural heritage and ethos. I am sanguine that this vision will be carried forward by present and future generations of cadets, ensuring strong foundations for a robust nation, enabled and ready to achieve greater heights and our rightful place on the global stage.

**GOD bless and JAI HIND**

Director General,
National Cadet Corps

## MASTER INDEX

# GENERAL SERVICE KNOWLEDGE

**CHAPTER WISE INDEX : GENERAL SERVICE KNOWLEDGE (SD/SW)**

# GENERAL SERVICE KNOWLEDGE (SD/SW)

## CHAPTER I : ARMED FORCES AND IAF CAPSULE (AFCAP)

### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | : | **03 (Three)** |
| **Type** | : | **Lecture** |
| **Year** | : | **1st Yr SD/SW** |
| **Conducting Officer** | : | **ANO** |
| **Training Aids** | : | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction** | : | **05 Mins** |
| • **Part I** | : | **20 Mins** |
| • **Part II** | : | **20 Mins** |
| • **Part III** | : | **20 Mins** |
| • **Part IV** | : | **15 Mins** |
| • **Part V** | : | **25 Mins** |
| • **Conclusion and Practice** | : | **15 Mins** |

## INTRODUCTION

1. The Indian Armed Forces are the military forces of the Republic of India consisting of three uniformed services: the Indian Army, Indian Navy, and Indian Air Force. With a strength of over 1.4 million active personnel, it is the world's second-largest military force and has the world's largest volunteer army. The Indian Armed Forces have a rich history. The Indian Armed Forces have been engaged in numerous major military operations, including the Indo-Pak war of 1947, 1965, 1971, the Portuguese-Indian War, 1962 Indo-China War, the Kargil War, and many others. The President of India serves as the supreme commander of the Indian Armed Forces. However, actual control lies with the executive headed by the Prime Minister of India. The Ministry of Defence is responsible for the country's defence and security.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Indian Army

(b) Part II: Indian Navy

(c) Part III: Indian Air Force

(d) Part IV: Badges and Ranks

(e) Part V: Honours and Awards

### LEARNING OBJECTIVES

- Basic understanding of the Indian Armed Forces, their organisation and structures.
  - Badges of rank
  - Honours and awards
  - Modes of entry in IAF and civil aviation
  - Recognition of aircraft
  - Information on IAF aircraft inventory

## PART I: INDIAN ARMY

2. The Indian Army is the land-based branch, and it is the largest component of the Indian Armed Forces. It is the fourth-largest standing army in the world. The President of India is the Supreme Commander. It is headed by the Chief of Army Staff (COAS), who is a four-star General. The Chief of Army Staff is responsible for all the activities of the Indian Army. The senior officers who assist him are:-

(a) Vice Chief of Army Staff.

(b) Three Deputy Chiefs of Army Staff.

(c) Principal Staff Officers (PSOs).

(d) Heads of Arms and Services.

(e) Field Army (Commands).

3. The responsibility for national defence rests with the Cabinet. This is discharged through the Ministry of Defence (MoD), which provides the policy framework and wherewithal to the Armed Forces to discharge their responsibilities in the context of the defence of the country. Even though all elements of national defence and national security continuously strive to achieve the assigned roles and tasks, the Defence Services play the most vital role in maintaining the sovereignty and territorial integrity of our nation from both; external and internal threats. Based on the major wars fought, struggles, and the present-day relations with our neighbouring countries and strategic allies, the Defence Forces of Our Nation have transformed significantly to ensure compliance with the given mandate. Having read the overview of the current structures of the Indian Armed Forces as discussed in the succeeding paragraph, the NCC Cadets will be able to appreciate how well these organisations have emerged to meet India's needs of national defence, security, integration and other associated requirements.

4. Even though the responsibility of national defence rests with the Cabinet and is discharged through the Ministry of Defence, the President of India is the Supreme Commander of the Indian Armed Forces. Like in all other developed and developing countries, the Indian Armed Forces comprises three main constituents, namely, the Indian Army, Indian Navy and Indian Air Force, which look after the multi-dimensional defence needs of the country. Recently, the Chief of Defence Staff (CDS) was established with the intention of enhancing tri-service effectiveness, coordination, and overall integration of the Indian Armed Forces' combat capabilities. CDS is the chief advisor to the Government of India in all matters pertaining to the Indian Defence Forces. General Bipin Rawat, PVSM, UYSM, AVSM, YSM, SM, VSM, ADC was appointed as the first CDS on 27 Dec 2019.

**<u>Soldiers of the Sikh Light Infantry during a Republic Day Parade</u>**

5. Throughout this chapter, we will delve into the history, structure, and key functions of each branch of the Indian Armed Forces, enabling the Cadet to obtain a basic understanding of these vital national assets.

6. Army Command Headquarters is commanded by an officer of the rank of 'Lieutenant General', who is known as the Army Commander or General Officer Commanding–Commanding-in-Chief. The Indian Army is divided into seven Commands that have subordinate formations under them. These are:-

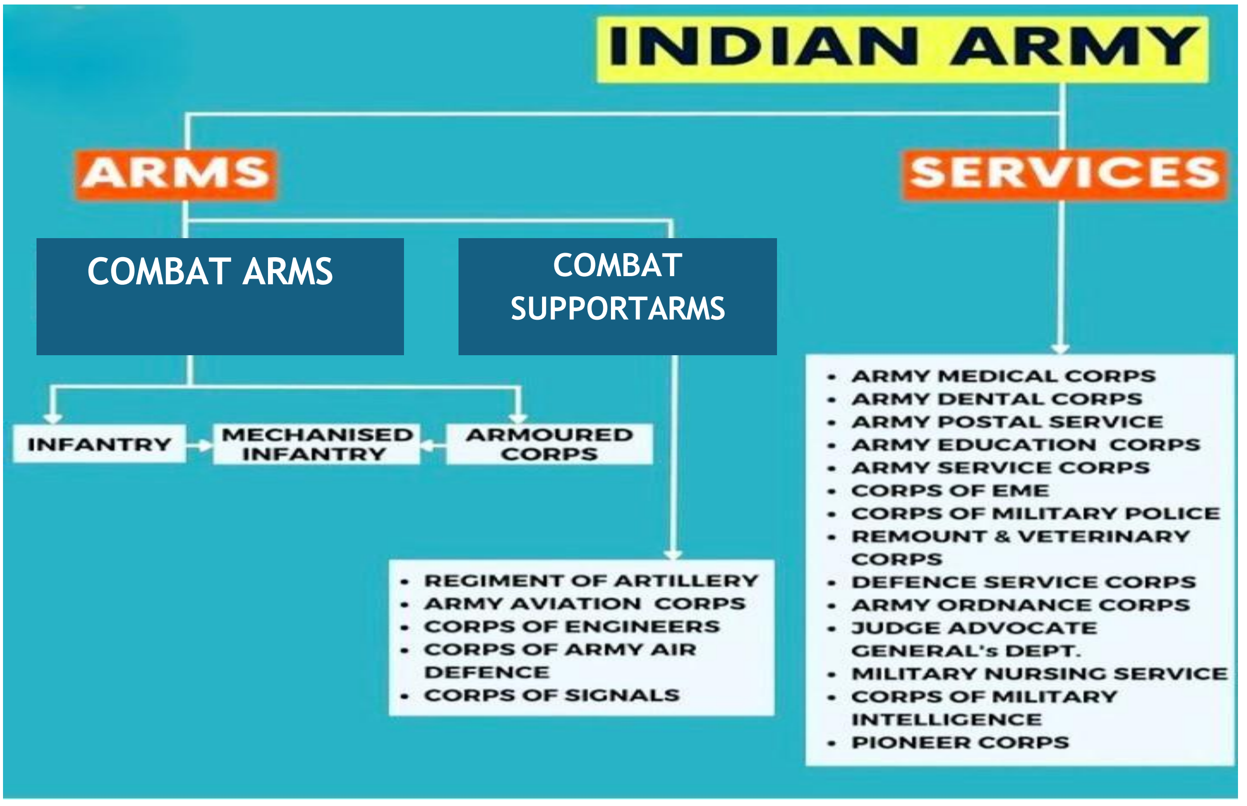
| Command Insignia | Command Name | Headquarters |
|---|---|---|
|  | Central Command | Lucknow |
|  | Eastern Command | Kolkata |
|  | Northern Command | Udhampur |
|  | Southern Command | Pune |
|  | South Western Command | Jaipur |
|  | Western Command | Chandimandir |
|  | Army Training Command | Shimla |

7 **Components of the Indian Army**. The Indian Army has three main constituents, namely the Combat Arms, the Combat Support Arms and the Services, which are organised in field formations forming the Brigades, Divisions, Corps and Commands. All three together fight the war as a team as part of the field formations. These three key constituents, namely the Combat Arm, Combat Support Arm and Services, which are further divided into sub-components, have their own unique quality and characteristics.

(a) **Combat Arms**. These are the primary fighting forces of the Army, directly involved in combat operations.

(b) **Supporting Arms**. These support the combat arms by providing essential wherewithal and capabilities vital for war fighting, which are not integral to the Combat arms, like long-range firepower, protection from hostile aircraft, mobility and communications in war-fighting areas.

(c) **<u>Services</u>**. These units provide logistical and administrative support to the Army, ensuring that combat and supporting arms can function effectively both during war and peace.




8. By manpower-wise Indian Army is one of the largest standing armies in the world. The role of the Indian Army is to deny the enemy from capturing our land and to capture enemy territory. The army is divided into three components: combat arms, combat support, arms and services. Combat arms are the ones who are in the forefront and the face of the enemy. Combat Support Arms help the Combat Arms on the battlefield to perform the assigned tasks and provide logistical support.

9. The Indian Army is the fourth-largest Army in the world and has a legacy of heroism and valour. Also, the motto of the Indian Army is “SERVICE BEFORE SELF”.

## <u>PART II: INDIAN NAVY</u>

10. India is surrounded from three sides with water and has a coastline of approximately 6000 Km. The sea around India has a great impact/ effect on India’s freedom, trade, commerce, and culture. The Indian Navy (Bhartiya Nau Sena) is the naval branch of the Forces. The President of India serves as the Supreme Commander of the Indian Navy. The Chief of Naval Staff, usually a four-star officer in the rank of Admiral, commands the Navy. The Indian Navy is the eighth largest in the world. The primary objective of the Navy is to secure the nation's maritime borders.

11. Our nation has one of the largest peninsulas and has open water on three sides with a coastline of approximately 6000 km. As it has been historically proven, the seas around our country have an impact/effect on our freedom, trade, commerce and culture. The Indian Navy (Bhartiya Nau Sena), the maritime Branch of the Indian Armed Forces, is the primary organisation which ensures our maritime security. It is also supported by the Indian Coast Guard, which protects our maritime interests and enforces maritime laws. The Indian Navy today is a multidimensional force that has been organised to safeguard India's maritime territorial integrity and other maritime interests. It plays a crucial role in securing India's vast coastline, protecting maritime trade routes and ensuring the nation's maritime sovereignty. The Navy also engages in humanitarian missions, disaster relief and international peacekeeping efforts. Established in its modern form on January 26, 1950, the Indian Navy has evolved into a formidable blue-water navy capable of operating across the globe.

12. The Indian Navy has a vast strength of personnel and a large operational fleet consisting of aircraft carriers, amphibious transport docks, landing ship tanks, destroyers, frigates, nuclear-powered attack submarines, ballistic missile submarines, conventionally-powered attack submarines, corvettes, mine countermeasure vessels, patrol vessels, fleet tankers and various other auxiliary vessels

13. As of April 2024, the Indian Navy possesses two aircraft carriers, one amphibious transport dock, four tank landing ships, 12 destroyers, 12 frigates, 2 nuclear-powered ballistic missile submarines, 16 conventionally powered attack submarines, 20 corvettes, eight landing craft utilities, ten large offshore patrol vessels, five fleet tankers as well as various auxiliary vessels and small patrol boats.

14. **Indian Navy Air Arm**. The air arm is a fighting arm of the Indian Navy which is tasked to provide an aircraft carrier-based strike capability, fleet air defence, maritime reconnaissance, and anti-submarine warfare. Some prominent fighter aircraft that the Indian Navy operates include MiG-29 K and HAWK. It also employs other aircraft, including Cheetah, Chetak and SEA KING helicopters. It was raised in 1948 and today has approximately 23 squadrons, 5000 personnel and approximately 300 various types of aircraft.

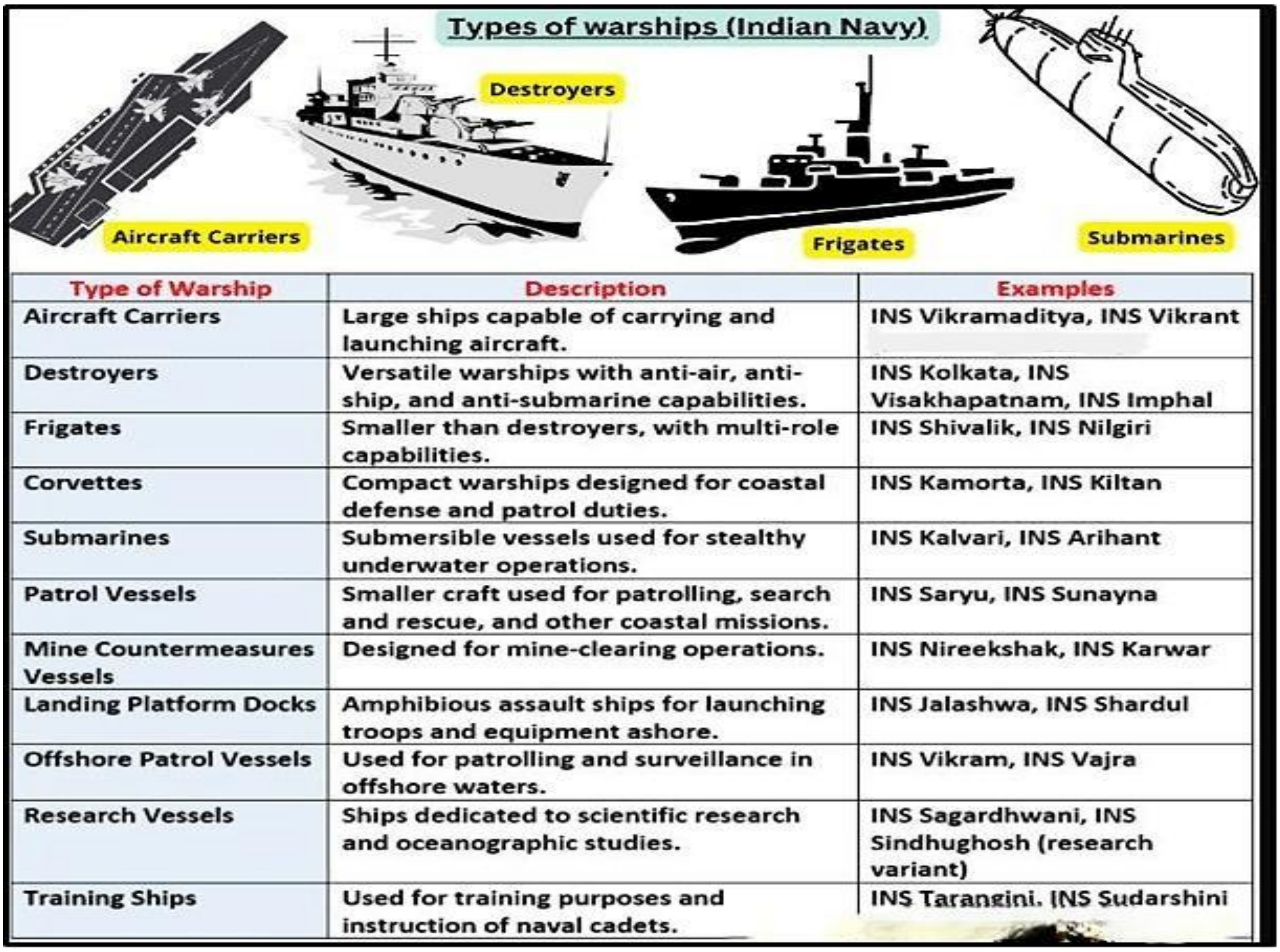

**Sea King**


**Mig-29**

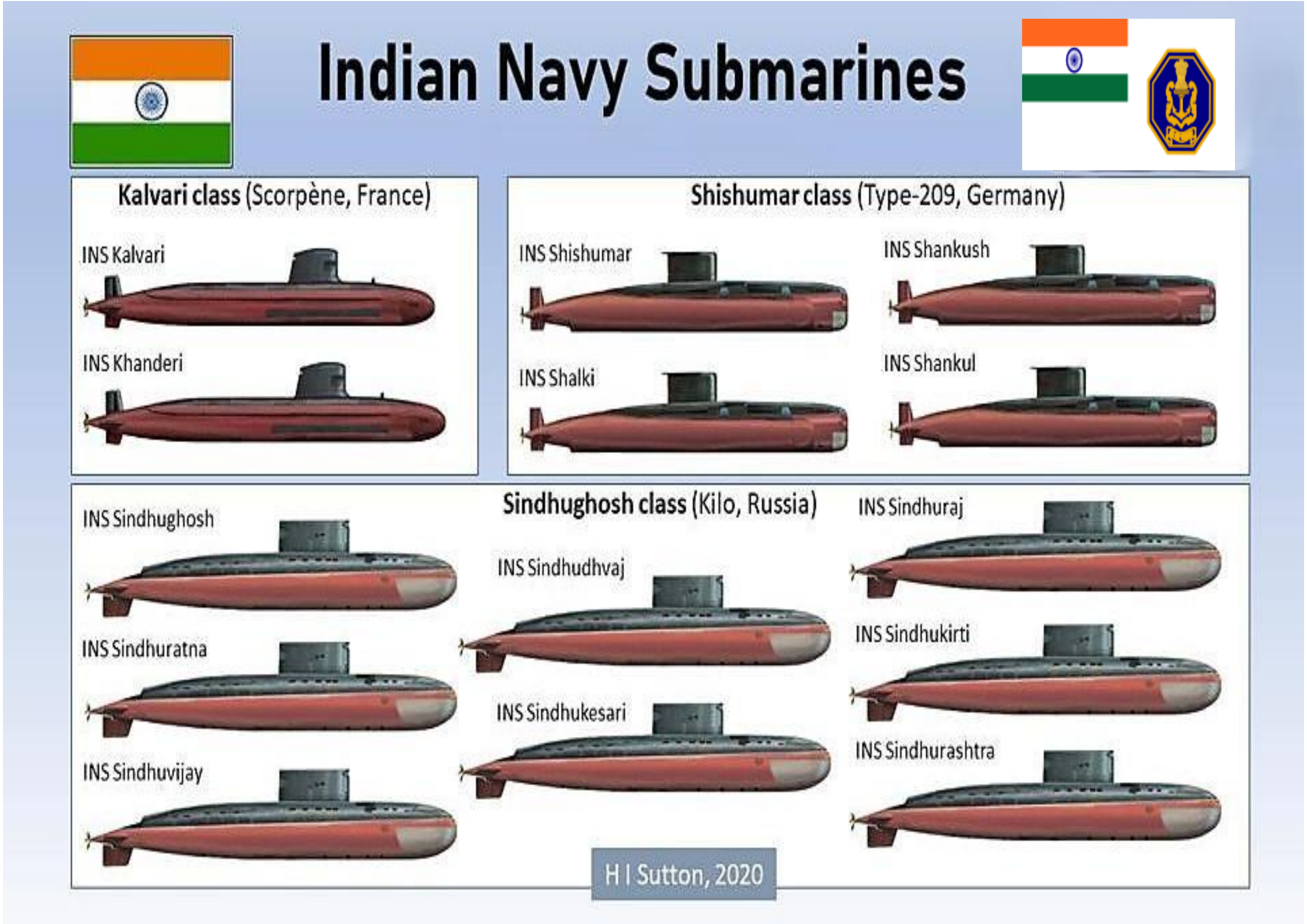
15. The Chief of Naval Staff commands the Indian Navy. Integrated Headquarters of the Ministry of Defence (Navy) is located in New Delhi. There are three commands of the Indian Navy:-

| **Command** | **Headquarter** |
|---|---|
| Western Naval Command | Mumbai. |
| Eastern Naval Command | Vishakhapatnam. |
| Southern Naval Command | Kochi. |

16. **Naval Air Stations**. The Navy operates several air stations equipped with Aircraft for reconnaissance, anti-submarine warfare, and logistics support. Key air stations include INS Hansa in Goa and INS Rajali in Arakkonam. The Indian Navy's organisational structure ensures it can effectively manage and deploy its resources to protect India's maritime interests and respond to various challenges and threats.




| Type of Warship | Description | Examples |
|---|---|---|
| Aircraft Carriers | Large ships capable of carrying and launching aircraft. | INS Vikramaditya, INS Vikrant |
| Destroyers | Versatile warships with anti-air, anti-ship, and anti-submarine capabilities. | INS Kolkata, INS Visakhapatnam, INS Imphal |
| Frigates | Smaller than destroyers, with multi-role capabilities. | INS Shivalik, INS Nilgiri |
| Corvettes | Compact warships designed for coastal defense and patrol duties. | INS Kamorta, INS Kiltan |
| Submarines | Submersible vessels used for stealthy underwater operations. | INS Kalvari, INS Arihant |
| Patrol Vessels | Smaller craft used for patrolling, search and rescue, and other coastal missions. | INS Saryu, INS Sunayna |
| Mine Countermeasures Vessels | Designed for mine-clearing operations. | INS Nireekshak, INS Karwar |
| Landing Platform Docks | Amphibious assault ships for launching troops and equipment ashore. | INS Jalashwa, INS Shardul |
| Offshore Patrol Vessels | Used for patrolling and surveillance in offshore waters. | INS Vikram, INS Vajra |
| Research Vessels | Ships dedicated to scientific research and oceanographic studies. | INS Sagardhwani, INS Sindhughosh (research variant) |
| Training Ships | Used for training purposes and instruction of naval cadets. | INS Tarangini, INS Sudarshini |




## INTERESTING FACTS

- As of August 2015, the Indian Navy is classified as a Rank 3 navy (Power projection to regions adjacent to its own) on the Todd-Lindberg navy classification system of naval strength.
- The Navy also includes specialised units such as the Marine Commandos (MARCOS) for special operations and the Indian Naval Air Arm for aerial operations.
- **Fleet Composition**. The Indian Navy's fleet includes aircraft carriers, destroyers, frigates, corvettes, submarines, and various auxiliary vessels. As of 2024, the Navy operates two aircraft carriers, INS Vikramaditya and INS Vikrant, along with a range of other advanced ships and submarines.

## PART III: INDIAN AIR FORCE

17. The Indian Air Force is the youngest force among the three Armed forces. It is the world's third-largest air force in terms of both personnel and aircraft. Its primary responsibility is to safeguard the Indian airspace and to conduct aerial warfare during a conflict. It came into existence in the year 1932. The secondary purpose of IAF is to assist civil power during natural calamities and internal disturbances. The IAF provides close air support to the Indian Army troops on the battlefield and also provides strategic and tactical

airlift capabilities. IAF also provides strategic air lift or secondary Airlift for the Indian Army. Indian Air Force comprises fighter aircraft, transporter aircraft, trainer aircraft, UAV aircraft, bombers and helicopters. The President of India serves as the Supreme Commander of the IAF.

18. The Indian Air Force is commanded by the Chief of the Air Staff, usually a four-star officer with the rank of Air Chief Marshal. The staff of Air Headquarters consists of three branches:-

(a) Air Staff Branch.

(b) Administrative Branch.

(c) Maintenance Branch.

19. The Air Force is divided into seven commands, which are controlled by Air HQ. These commands are subdivided into Operational commands and Functional commands. Each Command is placed under the command of an Air Officer Commanding-in-Chief. The Commands of the IAF are as follows:-

| **Command Headquarters** | **Location** |
|---|---|
| **Operational Commands** | |
| Central Air Command (CAC) | Prayagraj, Uttar Pradesh. |
| Eastern Air Command (EAC) | Shillong, Meghalaya |
| Southern Air Command (SAC) | Thiruvananthapuram, Kerala. |
| South Western Air Command (SWAC) | Gandhinagar, Gujarat. |
| Western Air Command (WAC) | New Delhi. |
| **Functional Commands** | |
| Training Command (TC) | Bengaluru, Karnataka. |
| Maintenance Command (MC) | Nagpur, Maharashtra. |

20. The Indian Air Force (IAF) is the aerial warfare branch of the Indian Armed Forces, tasked with securing Indian airspace and conducting aerial operations during armed conflicts. It was established on October 8, 1932, as the Royal Indian Air Force, which took part in many gallant air actions during World War II. After India gained independence, the prefix Royal was removed. On 1st Apr 1954, Air Marshall Subroto Mukherjee, one of the founding members of the Royal Indian Air Force, took over as the first Chief of the Air Staff of the Indian Air Force.

21. The primary mission of the Indian Air Force is to secure Indian airspace both during peace and war. The IAF plays the crucial role of conducting aerial warfare during armed conflicts: conducting strategic bombing, destroying enemy air assets, engaging in reconnaissance missions and providing air support to ground and naval forces where and when required. Additionally, the IAF participates in humanitarian missions, disaster relief, and international peacekeeping efforts.

22. The IAF is the world fourth fourth-largest air force in terms of both personnel and aircraft. The Indian Air Force comprises of following aircraft, helicopters and the associated equipment with which they execute their tasks and responsibilities:-

(a) Fighter aircrafts.

(b) Transport aircrafts.

(c) Attack Helicopters.

(d) Transport Helicopters.

(e) Reconnaissance Assets (aircrafts, helicopters and drones).

(f) Missiles.

(g) Radars.

**<u>Boeing C-17 Globemaster III</u>**

**<u>Rafale fighter</u>**

**<u>LCA Tejas</u>**

**<u>Sukhoi Su-30MKI</u>**

## PART IV: BADGES AND RANKS

23. The Indian Armed Forces consists of three professional uniformed services: the Indian Army, the Indian Navy, and the Indian Air Force. All three services have distinct Badges of ranks which help in identifying the personnel and their seniority. The Badges of rank are given as per professional competence and length of service in the Armed Forces.

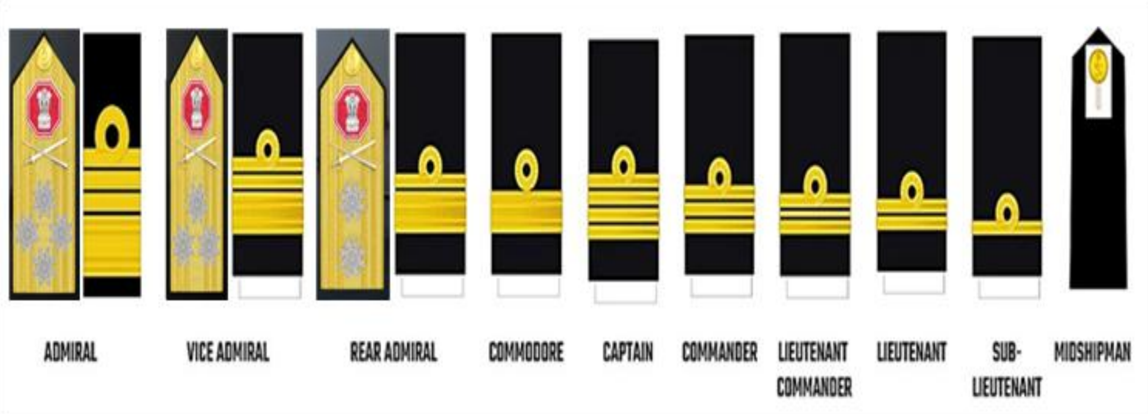
24. **Commissioned Officers–Army**. Commissioned Officers of the Indian Army who command their troops from platoon or equivalent up to armies and hold a President's commission. Field Marshal is an honorary rank and is given to a General for his valuable services. The badges of rank worn by commissioned officers are as shown:


25. **Junior Commissioned Officer (JCO)–Army**. The Changed to Rank Category Below Commisioned Officer in the Army is Junior Commissioned Officers. The soldiers who become JCOs come up through the Non-Commissioned Officer ranks. The badges of rank worn by the JCOs are as shown:


26. **Non-Commissioned Officer–(NCO) Army**. The third set of officers is the Non-Commissioned Officers (NCOs). These ranks are given to jawans according to their merit and year of service. The badges of ranks for NCOs are as shown:



27. **Commissioned Officers Navy**. Admiral of the Fleet is an honorary rank given to an Admiral for his invaluable services, and he will continue to serve the rest of his term with the honorary rank. This rank has not been used in the Indian Navy. The badges of rank worn by Naval Officers are as shown:

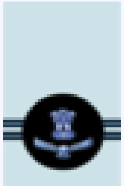
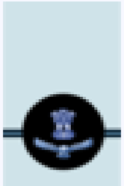
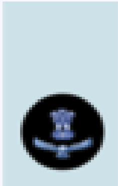
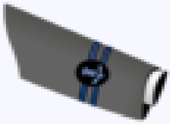
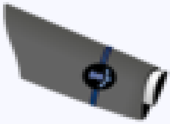
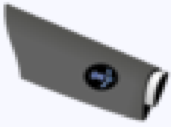



28. **Junior Commissioned Officers (JCO) Navy**. The JCOs are the Rank Category below Commisioned Officer who reached the rank of JCO because of their years of service as Non-commissioned Officers. The badges of rank worn by Junior Commissioned Officers (JCOs) of the Navy are as shown:-

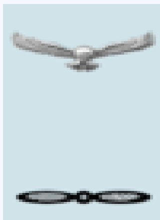
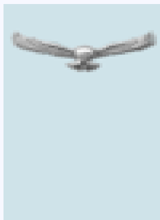
29. **Non-Commissioned Officers (NCOs) Navy**. The Rank Category below Junior Commisioned Officer in the Indian Navy are the Non-commissioned Officers. These ranks are given to the sailors according to their merit and year of experience. The badges of rank worn by the NCOs are as shown:-


30. **Commissioned Officers of the Air Force**. Marshal of the Air Force is an honorary rank given to an Air Chief Marshal for his invaluable services. In recognition of his services, the Government of India gave the rank of Marshall of the Air Force to Arjan Singh in January 2002, making him the first and only "Five Star" rank officer in the Indian Air Force to date. The badges of rank worn by officers are as shown:-

31. **Junior Commissioned Officers (JCOs), Air Force**. JCOs of IAF are the warranted rank personnel, who have been given these ranks because of their years of experience in IAF. The badges of rank worn by these Officers are as shown:

| | Junior commissioned officer | | |
|---|---|---|---|
| Shoulder |  |  |  |
| Sleeve |  |  |  |
| Rank | Master warrant officer | Warrant officer | Junior warrant officer |

32. **Non-Commissioned Officers (NCOs) Air Force**. The badges of rank worn by these NCOs the airmen of the rank of Cpl and below are known as Non-Commissioned Officers The badges of rank worn by these NCOs are as shown:

| | Enlisted | | | |
|---|---|---|---|---|
| Arm |  |  |  |  |
| | Sergeant | Corporal | Leading aircraftsman | Aircraftsman |

33. **<u>Comparison of Officer Ranks of the Armed Forces</u>**.


OFFICER RANKS OF THE

INDIAN ARMY, AIR FORCE & NAVY

COMMISSIONED OFFICERS

| ARMY | NAVY | AIR FORCE |
|---|---|---|
| Field Marshal | Admiral of the Fleet | Marshal of the Indian Air Force |
| General | Admiral | Air Chief Marshal |
| Lieutenant General | Vice Admiral | Air Marshal |
| Major General | Rear Admiral | Air Vice Marshal |
| Brigadier | Commodore | Air Commodore |
| Colonel | Captain | Group Captain |
| Lieutenant Colonel | Commander | Wing Commander |
| Major | Lieutenant Commander | Squadron Leader |
| Captain | Lieutenant | Flight Lieutenant |
| Lieutenant | Sub-Lieutenant | Flying Officer |

34. **<u>Junior Ranks of the Indian Armed Forces</u>**.

| Indian Army Rank | Indian Navy Rank | Indian Air Force Rank |
|---|---|---|
| Subedar Major | Master Chief Petty Officer I | Master Warrant Officer |
| Subedar | Master Chief Petty Officer II | Warrant Officer |
| Naib Subedar | Chief Petty Officer | Junior Warrant Officer |

35. **NCO Ranks of the Indian Armed Forces**.

| Indian Army Rank | Indian Navy Rank | Indian Air Force Rank |
|---|---|---|
| Havildar | Petty Officer | Sergeant |
| Naik | Able Seaman | Corporal |
| Lance Naik | Leading Seaman | Leading Aircraftsman |
| Sepoy | Seaman | Aircraftsman |

## PART V: HONOURS AND AWARDS

36. The Armed Forces of India have a glorious history for which it has been awarded with many military decorations, honours and awards. These awards and honours are awarded for extraordinary bravery and courage, as well as for distinguished services during times of war and peace. For the purpose of classification, Indian Armed Forces honours and awards are divided into two categories:

(a) Gallantry Awards in the Face of Enemy.

(b) Non-Gallantry Awards / Distinguished Service Awards.

37. The seawards are given on occasions of various felicitation ceremonies organised at Rashtrapati Bhawan, New Delhi, on Republic Day and on various occasions. The awards given to the Armed Forces are enumerated below.

38. Gallantry Awards in the Face of Enemy (War Time).

39. **Gallantry Awards Other than in the Face of Enemy (Peace Time)**.


40. **Non-Gallantry Awards/ Distinguished Service Awards**.

(a) Sarvottam Yudh Seva Medal.

(b) Param Vishisht Seva Medal.

(c) Uttam Yudh Seva Medal.

(d) Ati Vishisht Seva Medal.

(e) Yudh Seva Medal.

(f) Vishisht Seva Medal.

(g) Mention in the Dispatches

**INTERESTING FACTS**

- Medals like Sena medal can be given any time i.e. Gallantry award, Nongallantry award or distinguish service award to be changed

## CONCLUSION

41. The Indian armed forces are the military forces of the republic of India. It consists of the three professional uniformed services: The Indian Army, The Indian Navy, The Indian Air Forces. All three services have distinct Badges of ranks which help in identifying the personnel and their seniority. The President of India is the supreme commander of Indian Armed. Forces. Indian Armed Forces have been engaged in a number of major military operations. Indian armed forces are split into different groups based on their region of operations. The Indian Army is divided into six operational command and one training command each under control of lieutenant Generals. The Indian Navy operates three commands. Each command is headed by a flag officer commanding-in-chief with the rank of Vice Admiral. The highest wartime Gallantry Award is Param Vir Chakra and peace time Gallantry Award is Ashok Chakra.

## ASSESSMENT EXERCISES

**Multiple-Choice Questions (MCQs)**

**1. Who is the Supreme Commander of the Indian Armed Forces?**

(a) Prime Minister

(b) President of India

(c) Chief of Defence Staff

(d) Defence Minister

**2. Which ministry is responsible for national defence in India?**

(a) Ministry of Home Affairs

(b) Ministry of Defence

(c) Ministry of External Affairs

(d) Ministry of Finance

**3. What is the primary role of the Indian Army?**

(a) Maritime security

(b) Aerial warfare

(c) Ensuring national security and unity

(d) Space exploration

**4. Who was appointed as the first Chief of Defence Staff (CDS) of India?**

(a) General Manoj Pande

(b) Air Chief Marshal RKS Bhadauria

(c) General Bipin Rawat

(d) Admiral Karambir Singh

**5. How many operational commands does the Indian Army have?**

(a) 4

(b) 5

(c) 6

(d) 7

**6. What is the main function of the Army Service Corps (ASC)?**

(a) Combat operations

(b) Providing logistics, supply, and transportation

(c) Training personnel

(d) Air defence

**7. Which of the following is NOT a combat arm of the Indian Army?**

(a) Infantry

(b) Armoured Corps

(c) Corps of Signals

(d) Mechanised Infantry

**8. Where is the headquarters of the Indian Navy located?**

(a) Visakhapatnam

(b) Kochi

(c) Mumbai

(d) New Delhi

**9. What is the name of India's first indigenous aircraft carrier?**

(a) INS Vikrant

(b) INS Vishal

(c) INS Arihant

(d) INS Vikramaditya

**10. Which of the following commands is responsible for training in the Indian Navy?**

(a) Western Naval Command

(b) Eastern Naval Command

(c) Southern Naval Command

(d) Central Naval Command

**11. The Indian Air Force was established in which year?**

(a) 1930

(b) 1932

(c) 1947

(d) 1954

**12. What is the primary role of the Indian Air Force?**

(a) Securing Indian airspace

(b) Conducting naval warfare

(c) Managing ground-based logistics

(d) Providing legal support

**13. Which of the following is a fighter aircraft used by the Indian Air Force?**

(a) C-17 Globemaster III

(b) CH-47 Chinook

(c) MiG-29

(d) Apache AH-64E

**14. The Indian Armed Forces participate in which of the following international efforts?**

(a) UN Peacekeeping missions

(b) Space exploration programs

(c) Foreign elections monitoring

(d) Global financial aid distribution

**15. Which of the following is a missile system used by the Indian Air Force?**

(a) SPYDER

(b) BrahMos

(c) Prithvi

(d) Agni

**<u>Short Answer Type Questions</u>**

1. What are the three main constituents of the Indian Armed Forces?
2. Describe the role of the Chief of Defence Staff (CDS) in the Indian Armed Forces.
3. What is the primary mission of the Indian Air Force?
4. Name the three commands of the Indian Navy and their respective headquarters.
5. What is the significance of Services in the Indian Army?

**<u>Long Answer Type Questions</u>**

1. Discuss the historical evolution of the Indian Army from the British Indian Army to its current form.
2. Explain the organisational structure and key functions of the Indian Navy.
3. Describe the various components and operational capabilities of the Indian Air Force.
4. How does the Ministry of Defence (MoD) support the Indian Armed Forces in discharging their responsibilities?
5. Analyse the importance of Combat Arms and Combat Support Arms in the Indian Army?

# GENERAL SERVICE KNOWLEDGE (SD/SW)

## CHAPTER II : IAF

### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **03 (Three)** |
| **Type** | **:** | **Lecture** |
| **Year** | **:** | **1st Yr SD/SW** |
| **Conducting Officer** | **:** | **ANO** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Part I** | **:** | **20 Mins** |
| • **Part II** | **:** | **20 Mins** |
| • **Part III** | **:** | **30 Mins** |
| • **Part IV** | **:** | **40 Mins** |
| • **Conclusion and Practice** | **:** | **10 Mins** |

## INTRODUCTION

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Organisation of IAF

(b) Part II: History of IAF

(c) Part III: Aircraft Recognition

(d) Part IV: Types of Aircraft

### LEARNING OBJECTIVES

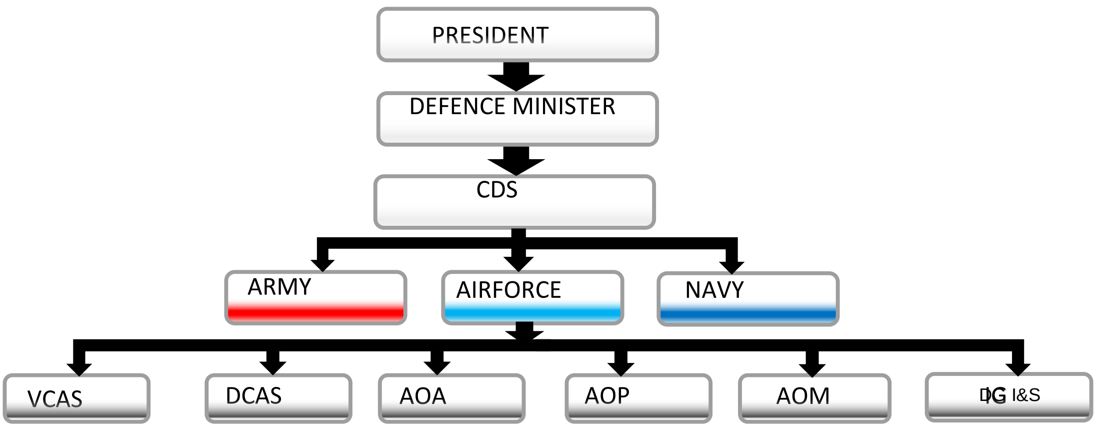
➢ Basic understanding of the Indian Armed Forces, their organisation and structure

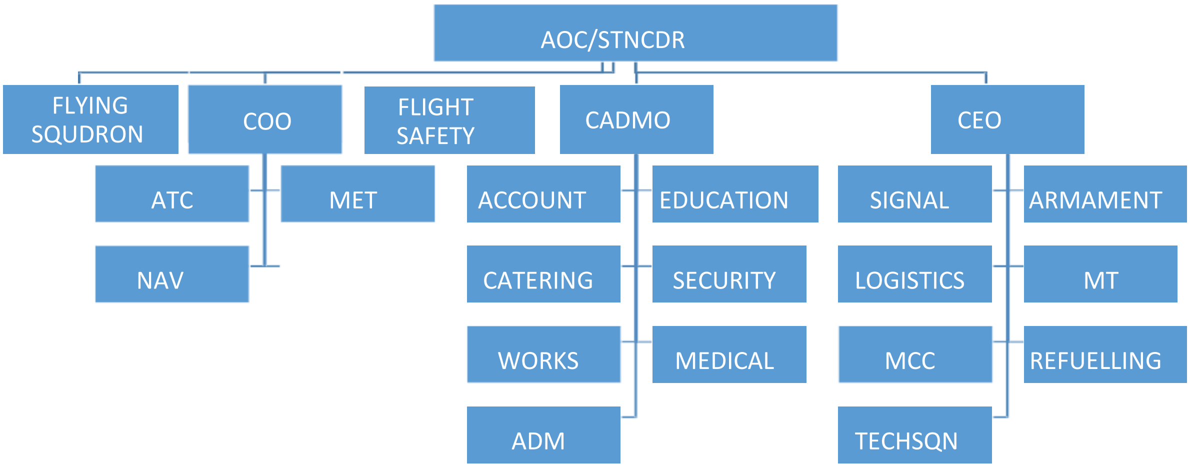
- Basic understanding of organization of IAF at air HQ and command level
- History of IAF
- Recognizing aircraft
- Aircraft inventory of IAF.

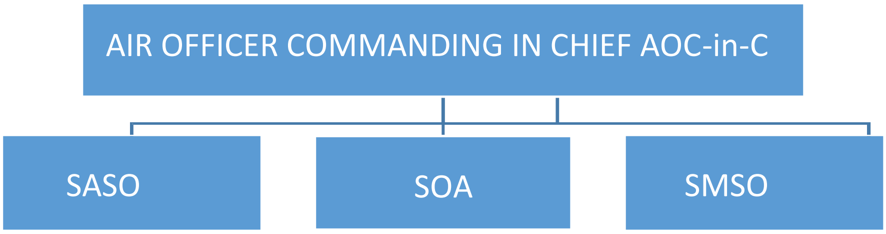
## PART I: ORGANISATION OF IAF

1. The President is the Supreme Commander of the Armed Forces of the Indian Republic. The primary role of the Air Force is to safeguard the nation from any aerial threats and also to provide support to the Army and the Navy. Its secondary role is to provide aid to the civil power in maintaining law and order and in providing relief during natural calamities.

2. Station/Wing is always what is called a self-accounting unit, i.e. it is fully capable and independently responsible for its own administration. A Sqn/lodger unit is essentially a non-self-accounting unit, and it is a lodger to a Wing/Station and depends fully on that Wing/Station for its administration. A Wing/Station exercises its functional and administrative control over its lodger units.




3. The organisational chart of an operational Command of IAF is as enumerated below:-

(a) **<u>Senior Air Staff Officer (SASO)</u>**. An officer of the rank of Air Marshal, who is responsible for operational aspects.

(b) **<u>Senior Officer Administration (SOA)</u>**. An officer of the rank of Air Vice Marshal, who is responsible for administrative aspects.

(c) **<u>Senior Maintenance Staff Officer (SMSO)</u>**. An officer of the rank of Air Vice Marshal, who is responsible for maintenance (technical) aspects.

## PART II: HISTORY OF THE IAF

4. The Indian Air Force is the youngest amongst all three military services. It has a bright history, even though it is the youngest service. The bravery, valour achievements of all the personnel of the IAF are an integral Part of its proud heritage.

5. The Government passed the IAF bill on 04 April 1932. The Indian Air Force came into existence with the promulgation of the IAF bill on 08 Oct 1932. The governor general-in-council at that time consequently ordered the establishment of the Indian Air Force with effect from 08 Oct 1932. The Indian Air Force celebrates its anniversary on 08 Oct every year.

6. In its early years, the expansion of the IAF was rather slow. In September 1939, it consisted of only one squadron with a complement of 16 officers and 144 airmen. During World War II, the increasing commitment of the RAF in Europe and the impact of the Japanese invasion in South-East Asia accelerated the pace of progress.

7. The Indian Air Force today is a modern technology-intensive force distinguished by its commitment towards excellence and professionalism, keeping pace with the demands of contemporary advancement. The IAF continues to modernise in a phased manner, and today it stands as a credible air power counted amongst the foremost professional services in the world.

8. The primacy of Air Power will be a decisive factor in shaping the outcome of future conflicts. In line with this dictum, the IAF has developed into a major 'Component of National Power', which can be applied quickly and decisively. The IAF has reoriented itself to a multi-role capability of platforms and equipment, along with a multi-skill capability of personnel. The rapid economic growth of the country dictates the need to protect our security interests extending from the Persian Gulf to the Straits of Malacca. Over the years, the IAF has grown from a tactical force to one with trans-oceanic reach. The strategic reach emerges from the induction of Force Multipliers like Flight Refuelling Aircraft (FRA), Remotely Piloted Aircraft (RPA) and credible strategic lift capabilities. There is emphasis on acquiring the best of technology.

9. The five operational commands through administrative wings control over 45 Fixed Wing Squadrons, 20 Helicopter Units and numerous surface-to-air missile squadrons with unit establishments varying from 12 to 18 aircraft. This represents a total aircraft strength of over 2000, including training and support types, manned by some1,40,000 active personnel.

10. For the smooth functioning of an organisation, it is essential to divide the staff into different branches. A vast organisation like the Indian Air Force requires various branches to make the organisation successful and flawless.

11. The Indian Air Force is divided into the following branches:-

(a) Flying Branch.

(b) Navigation Branch.

(c) Education Branch.

(d) Medical Branch.

(e) Administration Branch.

(f) Logistic Branch.

(g) Meteorology Branch.

(g) Engineering Branch.

(j) Weapon System Branch.

## PART III: AIRCRAFT RECOGNITION

12. **Introduction to Aircraft Recognition**. Visual aircraft recognition is a vital skill for military and defence personnel. Being able to distinguish between various aircraft types helps in identifying potential threats, understanding the capabilities of enemy aircraft, and knowing which aircraft are friendly. Various methods are used to recognise aircraft visually. In this lesson, we will focus on recognising aircraft based on.

(a) Wing position.

(b) Wing Shape.

(c) Canopy shapes.

(d) Fin & Tail structures.

(e) Markings.

13. **Wing Position**. The position of the wings on the fuselage of an aircraft plays a significant role in its flight characteristics and design. Aircraft can be categorised based on whether the wings are mounted high, mid, or low on the fuselage.

(a) **High Wing**. The wings are mounted near the top of the fuselage. High-wing aircraft typically have better stability and are less affected by turbulence. They also have better clearance for landing gear and cargo. Example, C-130 Hercules (Transport Aircraft)

(b) **Mid Wing**. The wings are mounted at or near the midpoint of the fuselage. Mid-wing aircraft typically have good overall stability and are more versatile in terms of aerodynamics. Example, F-16 Fighting Falcon (Fighter Jet)

(c) **Low Wing**. The wings are mounted near the bottom of the fuselage. Low-wing aircraft generally have better ground clearance for the engines and landing gear, and they are often used for high-speed flight and aerobatics. Example, Hawk

| | |
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|  | **C-130 J**<br>**(High Wing)** |
|  | **F-16**<br>**(Mid Wing)** |
|  | **Hawk**<br>**(Low Wing)** |

14. **Wing Shape**. Wing shape is a convenient method for visual identification of aircraft.

(a) **Straight Wing**. These wings extend directly out from the fuselage without a sweep (wings are perpendicular to the fuselage). Example, Cessna 172 (Light Aircraft)

(b) **Swept Wing**.The wings are angled backward or forward, which allows for faster speeds. Example, F-16 Fighting Falcon (Fighter Aircraft)

(c) **Delta Wing**. Triangular in shape, often used for high-speed aircraft (Wings form a triangle with the fuselage). Example, Mirage 2000, LCA Tejas

(d) **<u>Variable-Sweep Wing</u>**. The wings can be adjusted for different speeds, often seen on fighter jets. Example, In a Mig-27 (swing wing), the aircraft utilizes minimum sweep for take-off and landing and a sweep angle of 72 degrees for high speed flight.

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|   | **Cessna 172**<br>**(Straight Wing)** |
|  | **F-16**<br>**(Swept Wing)** |
|  | **Tejas**<br>**(Delta Wing)** |

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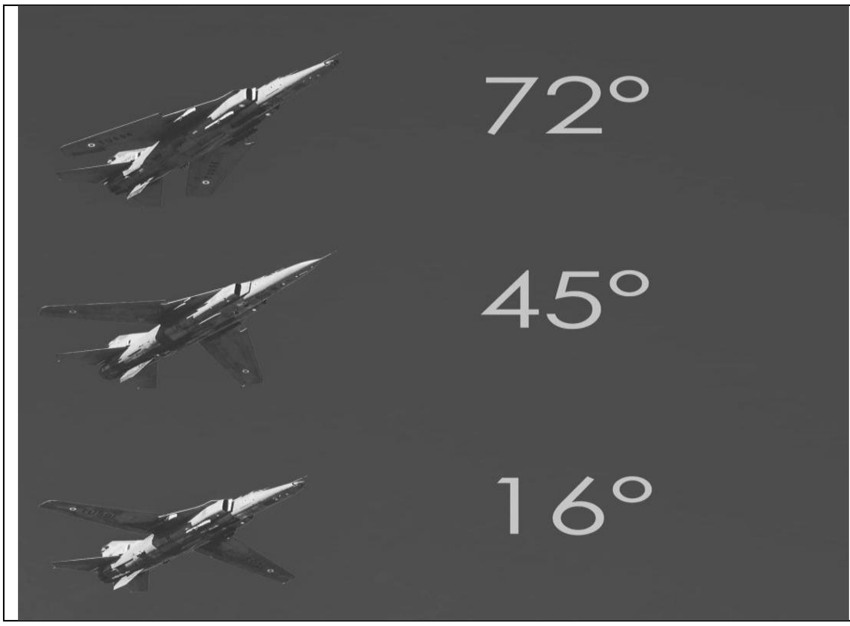
|  | | **Mig-27 (Variable Sweep Wing)** |

15. **<u>Shape of Canopy</u>**. The shape of the canopy plays a crucial role in both the pilot's visibility and the aircraft's aerodynamics. The following are the key **canopy shapes** to focus on.

(a) **<u>Inline</u>**. The inline canopy is a simple, streamlined canopy shape that is aligned with the fuselage of the aircraft. It provides a clean aerodynamic profile and is often used in earlier aircraft designs. The inline canopy offers a sleek and minimalistic design, enhancing the aircraft's speed and stability. Example, Supermarine Spitfire (World War II Fighter).

(b) **<u>Teardrop</u>**. The teardrop canopy is an elongated shape, resembling the shape of a teardrop or a droplet of water. It typically has a rounded front with a tapered rear. This canopy provides excellent visibility for the pilot, with the aerodynamic shape reducing drag and enhancing speed. Example**,** F-16 Fighting Falcon.

(c) **<u>Bubble</u>**. The bubble canopy is a large, smooth, rounded canopy that extends over the cockpit, providing panoramic visibility. This shape is one of the most recognizable and common on modern aircraft. The bubble canopy provides a wide field of vision for the pilot, especially in combat situations. Example: F-15 Eagle (Fighter Jet).

(d) **<u>Submerged</u>**. A submerged canopy is mounted lower in the fuselage, often partially recessed. This design minimises the pilot's exposure and reduces drag, while still providing adequate visibility. The submerged canopy design improves the aircraft's aerodynamics and reduces the risk of enemy fire hitting the pilot's canopy, offering some protection. Example**,** SR-71 Blackbird (Reconnaissance Aircraft).

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|  | **Spitfire**<br>**(Inline Canopy)** |
|  | **F-16**<br>**(Teardrop canopy)** |
|  | **F-15**<br>**(Bubble canopy)** |
|  | **SR-71 Blackbird**<br>**(Submerged canopy)** |

16. **Shape of Fin and Tail Plane**. The **tail position** of an aircraft refers to where the vertical stabilizer (fin) and horizontal stabilizer (tail plane) are mounted on the fuselage. The tail position plays a significant role in the aircraft's overall balance, stability, and manoeuvrability.

(a) **High Tail**. In a high-tail configuration, both the **vertical stabilizer** (fin) and **horizontal stabilizer** (tail plane) are mounted near the top of the fuselage. This tail position generally provides better stability in turbulent air. It also allows for a clean, unobstructed flow of air over the control. Example**,** IL-76.

(b) **Mid Tail**. The mid-tail configuration has the **vertical stabilizer** and **horizontal stabilizer** mounted approximately at the midpoint of the fuselage, or slightly higher or lower, depending on the aircraft's design. This configuration allows for a balanced, symmetrical distribution of lift and stability, often providing an optimal balance between control and maneuverability. Example**,** Mig-21.

(c) **Low Tail**. In the low-tail configuration, the **vertical stabilizer** and **horizontal stabilizer** are mounted closer to the bottom of the fuselage, near or just above the aircraft's landing gear. Low tails tend to provide better control at high speeds and are commonly used in aircraft where ground. Example, Piper Cherokee.

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|  | **IL-76**<br>**(High Tail and a T-Tail)** |
|   | **Mig-21**<br>**(Mid Tail)** |
|   | **Piper Cherokee**<br>**(Low Tail)** |

17. **Markings**. Aircraft markings typically include symbols, colours, and insignia on the airframe, wings, and tail. These markings help in the quick identification of the aircraft's **nationality**, **branch of service**, **squadron** and sometimes even the **aircraft's mission or role**. The **Indian Air Force (IAF)** uses a specific set of markings that help identify aircraft. These markings include the **national Roundal**, **fin flash**, **squadron markings**, and **unit badges**.

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|  | **Standard markings on IAF aircraft** |
|  | **Roundal** |
|   | **A JF-17 with standard PAF markings** |

18. **Markings on IAF Aircraft**. The IAF roundel consists of a **blue, white, and orange circle**. The colours are arranged in a concentric pattern, with the orange colour on the outer ring, white in the middle, and blue in the centre. The roundel is typically painted on the **wings** and **fuselage** for easy recognition. The roundel represents the national flag and serves to distinguish Indian aircraft from others. Example**,** HAL Tejas (Light Combat Aircraft).

## PART IV: TYPES OF AIRCRAFT

19. There are different types of aircraft used in the Indian armed forces, which are designed to undertake a specific role. These aircraft are majorly classified into fighter, transport, helicopter, trainer and UAV. Fighter aircraft are used to establish air superiority over the battlefield. The transport aircraft are designed to carry passengers and cargo

from one place to another. These transport aircraft are also used for airlifting victims of natural disasters in India, as well as our friendly neighbouring countries, such as OP MAITRI in Nepal during the 2015 Nepal Earthquake. Helicopters have multiple roles such as emergency transportation, firefighting, during natural calamities, search and rescue and cargo transportation. Attack helicopters are used to provide close air support and destroy enemy targets on the ground. UAVs are used for intelligence, surveillance, target acquisition and reconnaissance. A majority of the aircraft in the IAF inventory are listed below, along with their roles and capabilities.

## **FIGHTER AIRCRAFT**

<table>
<tr>
<td>Su-30 MKI</td>
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The SU-30MKI is a twin-engine, air superiority fighter aircraft of Russian origin designed to perform a variety of roles, including air-to-air combat, air-to-ground strikes, and long-range reconnaissance missions. It's part of the Su-30 family of aircraft, which are known for their advanced avionics, superior manoeuvrability, and long-range capabilities.<br><br>
<br><br>
<u>Key Features of the SU-30MK</u><br><br>
1. <u>Twin-Engine Power</u>. The aircraft is powered by two engines that provide excellent thrust, allowing it to reach speeds of up to 2,100 km/h.<br><br>
2. <u>Advanced Avionics</u>. The SU-30MKI is equipped with state-of-the-art radar and avionics, including a Phased Array Radar and Electronic Warfare Systems, which enhance its ability to detect and track targets in difficult environments.<br><br>
3. <u>Super Manoeuvrability</u>. The aircraft features a thrust vectoring control system that allows it to perform highly manoeuvrable actions, making it an excellent choice for air combat.<br><br>
4. <u>Multirole Capability</u>. The SU-30MKI is designed to handle multiple mission types. It can engage in air-to-air combat (fighting other aircraft), air-to-ground strikes (attacking enemy targets on the ground), and even reconnaissance (gathering intelligence).<br><br>
5. <u>Weapons Systems</u>. The aircraft is armed with a range of weapons,
</td>
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| | including **air-to-air missiles**, **air-to-ground missiles**, **bombs**, and a **30mm cannon**, giving it an edge in both offensive and defensive operations. |
| **Mirage 2000** | The **Mirage 2000** is a highly capable multirole fighter aircraft of French origin, widely used for air superiority, ground attack, and reconnaissance missions. Its lightweight design, powerful engine, and advanced avionics make it a crucial asset for the Indian Air Force.<br><br>**<u>Key Features of the Mirage 2000</u>**<br>1. **<u>Single-Engine Performance</u>**. The Mirage 2000 is powered by a single turbofan engine, which provides excellent speed and thrust. The aircraft can reach speeds of **2,450 km/h** (Mach 2.2), making it one of the fastest aircraft in service with the Indian Air Force.<br>2. **<u>Multirole Capabilities</u>**. It is capable of carrying out various types of missions, including:-<br>• **Air-to-air combat** (fighting other aircraft).<br>• **Air-to-ground strikes** (attacking enemy targets on the ground).<br>• **Reconnaissance** (gathering intelligence).<br>3. **<u>Advanced Avionics and Radar</u>**. The Mirage 2000 is equipped with an advanced **radar**, which allows the pilot to detect enemy aircraft and ground targets even in cluttered environments.<br>4. **<u>Weapons Systems</u>**. The Mirage 2000 is equipped with a wide range of weapons, including **air-to-air missiles**, **air-to-ground bombs**, **precision-guided munitions**, and a **30mm gun**. This allows it to perform a variety of roles, from engaging enemy aircraft to striking ground targets with high precision. This made it the platform of choice for the Balakot Strike.<br>5. **<u>Ergonomically Designed Cockpit</u>**. The cockpit of the Mirage 2000 is designed for ease of operation, with **hands-on throttle and stick (HOTAS)** controls. This allows the pilot to focus on flying and combat |

<table>
<tr><td></td><td>operations without distraction.<br><br>6. <u>Endurance and Range</u>. The Mirage 2000 has a good combat radius, allowing it to conduct long missions without refuelling. With air-to-air refuelling, it can extend its operational range even further.</td></tr>
<tr><td>Mig-29</td><td>The MiG-29 is a highly manoeuvrable and powerful multirole fighter aircraft of Russian origin designed for both air-to-air combat and air-to-ground operations. It is equipped with advanced radar systems, modern weapons, and a robust airframe, making it one of the most respected fighters in the world.<br><br><br><br><u>Key Features of the MiG-29</u><br><br>1. <u>Twin-Engine Power</u>. The MiG-29 is powered by two turbofan engines, which allow it to reach speeds of 2,400 km/h (Mach 2.25). These engines provide the aircraft with excellent thrust and performance during combat and high-speed intercept missions.<br><br>2. <u>Multirole Fighter</u>. The MiG-29 is designed to perform a variety of missions:<br><br>• Air-to-air combat (intercepting and fighting enemy aircraft).<br><br>• Air-to-ground strikes (attacking enemy ground targets).<br><br>• Reconnaissance (gathering intelligence).<br><br>3. <u>Superior Manoeuvrability</u>. One of the MiG-29's standout features is its agility. Its aerodynamic design, coupled with digital fly-by-wire control systems, makes it extremely manoeuvrable, especially in close-range dogfights. It can perform complex and evasive manoeuvres, making it highly effective in air combat.<br><br>4. <u>Weapons Systems</u>. The MiG-29 is armed with a wide array of weapons, including:-<br><br>• Air-to-air missiles (for combat against enemy aircraft).</td></tr>
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| | • **Air-to-ground missiles and bombs** (for striking ground targets).<br>• **30mm gun** (for close-range combat).<br>• The MiG-29 can carry a combination of these weapons on various hardpoints on its wings and fuselage. |
| **Jaguar** | The **Jaguar** is a low-level attack aircraft of Anglo-French origin, designed to carry out precision air strikes and ground support missions. The aircraft's rugged design, combined with its speed and agility, makes it highly effective in various combat scenarios.<br><br>**<u>Key Features of the Jaguar</u>**<br>1. **<u>Twin-Engine Power</u>**. The Jaguar is powered by two **engines**, which allow it to achieve speeds of **1,200 km/h**.<br>2. **<u>Multirole Capabilities</u>.** The Jaguar is primarily used for **ground attack missions**, including bombing enemy targets and providing **close air support** to ground troops. It can also be used for **reconnaissance** (gathering intelligence) and **training** purposes. Its primary role is to undertake **low level deep penetration strike missions**.<br>3. **<u>Weapons Systems</u>.** The Jaguar is equipped with a wide range of weapons, including:-<br>• **Bombs and precision-guided munitions** (for striking enemy ground targets).<br>• **Air-to-ground missiles** (for more precise, long-range attacks).<br>• **Cannons** (for close-range engagements).<br>• The aircraft can carry these weapons on various hardpoints located on its wings and fuselage.<br>4. **<u>Advanced Avionics and Radar</u>**. The aircraft is equipped with **advanced avionics**, including a **terrain-following radar**, which helps it fly at low altitudes while avoiding obstacles. This radar allows the Jaguar to make precise attacks, even in poor visibility conditions, such as during night |

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| | operations or in bad weather.<br><br>5. **<u>Upgrades for India (Jaguar DARIN Program)</u>**. The **Indian Jaguar** fleet has undergone several upgrades under the **DARIN** program (Digital Airborne Reconnaissance and Integrated Navigation), which enhanced its avionics, radar, and weapons systems, making it more effective in modern combat.<br><br>6. **<u>Combat Experience</u>.** The Jaguar has been used extensively in combat operations, including in **Kargil** (1999), where it performed critical strike missions, and more recently in **counter-insurgency operations**. Its role in the **air-to-ground** missions was particularly valuable in providing close support to Indian Army troops. |

## TRANSPORT AIRCRAFT

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| **DO-228** | The **Dornier** aircraft, specifically the **Do 228**, is a light, twin-engine aircraft of German origin used for a variety of roles by the Indian Air Force. It is especially useful for operations in remote areas where larger transport aircraft may not be able to operate effectively. In the IAF the aircraft is primarily used in training ab-initio transport pilots.<br><br><br><br>**<u>Key Features of the Dornier Aircraft</u>**<br><br>1. **<u>Twin-Engine Reliability</u>**. The Dornier aircraft is powered by **two turboprop engines**.<br><br>2. **<u>Multirole Capabilities</u>**. The Dornier aircraft is extremely versatile and can be used for several different tasks, such as:<br><br>• **Transporting personnel and cargo** to remote or forward-operating locations.<br><br>• **Search and rescue missions**, particularly in coastal and mountainous regions.<br><br>• **Surveillance and reconnaissance** (gathering intelligence and |

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| | monitoring borders or natural disasters).<br><br>• **Airborne medical evacuation**, which is essential in emergencies or difficult-to-reach areas. |
| **An-32** | The **Antonov An-32** is a **medium-lift transport aircraft** developed by the Ukrainian company **Antonov**. It is designed to transport cargo and personnel and is one of the key aircraft in the **Indian Air Force's (IAF)** transport fleet. It is particularly well-suited for operations in remote and mountainous areas, which is why it plays a critical role in logistics and supply missions.<br><br>**Key Features of the An-32 Aircraft**<br><br>1. **Twin-Engine Power**. The An-32 is powered by **two turboprop engines**, providing it with a **maximum speed of around 550 km/h**. These engines make the aircraft efficient for long-range flights, carrying significant payloads over large distances.<br><br>2. **Heavy Cargo Transport**. The primary role of the An-32 is to **transport heavy cargo**. It can carry up to **6.7 tonnes of cargo** inside its cargo hold.<br><br>3. **Ability to Operate in Extreme Conditions.** The An-32 is specifically designed to handle operations in **extreme weather** conditions, such as **high-altitude** environments (like the Himalayas) or **hot and humid tropical areas**. It can operate in **both cold and hot climates**, making it ideal for India's diverse geographical landscape.<br><br>4. **Multirole Capabilities**. The An-32 can be used for a variety of roles, such as:-<br><br>• **Transporting troops and equipment** to forward-operating bases.<br><br>• **Carrying humanitarian aid** during natural disasters.<br><br>• **Dropping supplies** to remote or cut-off areas.<br><br>• **Paratrooper operations** (airborne operations to drop soldiers or equipment. |
| **C-130 J** | C-130J Super Hercules **is a** multirole tactical transport aircraft of US origin **that plays a key role in the** Indian Air Force's (IAF) **logistical operations. Whether it's carrying** troops**,** military equipment**,** humanitarian supplies**, or** performing combat operations**, the C-130J** |

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| | **excels at getting the job done in** challenging conditions**.** |

<u>**Key Features of the C-130J Aircraft**</u>

1. <u>**Advanced Engines and Speed**</u>. The C-130J is powered by **four turboprop engines.** These engines give it a maximum speed of **670 km/h (415 mph)**, allowing it to travel quickly and efficiently over long distances. It has a cruising range of up to **3,800 km**, allowing it to perform **long-range missions**.

2. <u>**Multirole Capabilities**</u>. The C-130J is designed to carry out a variety of roles, including:-

    - **Transporting heavy cargo**, such as military vehicles, supplies, and equipment.
    - **Paratrooping operations**, dropping soldiers and equipment from the aircraft.
    - **Humanitarian aid missions**, delivering essential supplies to disaster-stricken areas.
    - **Special operations**, including **search and rescue**, **medical evacuations**, and **covert missions**.

3. <u>**Short Takeoff and Landing (STOL)**</u>. One of the standout features of the C-130J is its **STOL capability**, which allows it to take off and land on **short, unprepared airstrips**. This feature makes the aircraft ideal for operations in remote, rugged locations, such as the **Himalayas** or **desert regions** where long runways are not available. This was the first transport aircraft to land at the high altitude airstrip of Daulat Baig Oldie (DBO).

4. <u>**Cargo and Personnel Capacity**</u>. The C-130J is capable of carrying up to **20 tons of cargo** or up to **92 paratroopers**

5. <u>**Modern Avionics and Systems**</u>. The C-130J is equipped with **advanced avionics** and a **digital cockpit**, making it easier to operate, especially during **night operations** or in challenging

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| | weather conditions. The C-130J can be **refueled in the air**, which significantly extends its range. |
| **C-17** | The **C-17 Globemaster** is a **heavy-lift strategic transport aircraft** of US origin that plays a vital role in **rapid deployment** and **logistical support**. Whether it's carrying large military equipment, **tanks**, **heavy vehicles**, or **humanitarian aid**, the C-17 is designed for versatility and can operate in a variety of conditions. It is one of the most capable aircraft in the Indian Air Force's fleet.<br><br>**<u>Key Features of the C-17 Aircraft</u>**<br>1. **<u>Massive Cargo Capacity</u>**. The C-17 can carry up to **77 tons of cargo**.<br>2. **<u>Advanced Engine Power</u>**. The C-17 is powered by **four turbofan engines** which provide it with a cruising speed of around **830 km/h (515 mph)** and a range of approximately **4,500 km**.<br>3. **<u>Air-to-Air Refueling</u>**. The C-17 can be **refueled in the air**, which extends its operational range. This allows the aircraft to undertake **long-duration missions**, such as **strategic deployments** or **international humanitarian aid**, without the need to land for refueling. |
| **Embraer 2000** | The **Embraer 2000** is a **regional jet aircraft** manufactured by the Brazilian aerospace company **Embraer**. The **Indian Air Force (IAF)** uses this aircraft in various roles, with the most notable being its **airborne surveillance** and **early warning** capabilities, which are crucial for maintaining air defence and ensuring the security of Indian airspace.<br> |

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| | **<u>Key Features of the Embraer EMB 145 Aircraft</u>**<br><br>The Embraer 145 is a versatile aircraft that can be equipped for several roles, but the most important role for the IAF is its use as the **Embraer 145 AEW&C** (Airborne Early Warning and Control). This variant is equipped with advanced **radar systems** and **electronic sensors** to detect and track airborne threats such as **fighter jets**, **missiles**, and other aerial objects. The IAF also utilizes Embraer in the VVIP and VIP role. Air HQ Communication Squadron operates this aircraft and it has maintained a flawless incident/accident free track record till date.<br><br>1. **<u>Advanced Surveillance Systems</u>**. The **Embraer 145 AEW&C** is equipped with a **large phased-array radar** mounted on top of the aircraft's fuselage, which allows it to detect airborne targets at great distances. This makes the aircraft an essential tool for **air surveillance** and **early warning**, enabling the IAF to identify and respond to potential threats long before they reach Indian airspace.<br><br>2. **<u>Crew and Capacity</u>**. The **Embraer 145** can carry a crew of **3 to 5 personnel**, including **pilots**, **system operators**, and **maintenance personnel**. **Speed and Range:** The Embraer 145 has a maximum speed of around **870 km/h (541 mph)** and a range of approximately **2,000 km**. |
| **Boeing 737-200** | The **Boeing 737-200** is a **short to medium-range twin-engine jet airliner**, originally designed for commercial use but later modified for military operations by the Indian Air Force. The aircraft is mainly used in VIP roles and communication tasks.<br><br><br><br>**<u>Key Features of the Boeing 737-200</u>**<br><br>1. **<u>Capacity and Versatility</u>**. The Boeing 737-200 can carry a range of **passengers** and **cargo**. It is capable of seating up to **120 passengers,** depending on the configuration. |

## HELICOPTERS

**Chetak**

The **Chetak** is a **light utility helicopter** of French origin designed to carry out a variety of missions, including **transportation of personnel and cargo**, **search and rescue**, **air surveillance**, and **medical evacuation**.


**Key Features of the Chetak Helicopter**

1. **Multi-role Versatility**. The Chetak is capable of performing a wide range of tasks. Some of its key roles include:-

    - **Transporting personnel and cargo**. It can carry **up to 6 passengers** or small loads, such as military supplies and equipment.

    - **Search and rescue**. The Chetak is often deployed in **rescue operations**, particularly in remote areas or places where other vehicles cannot access.

    - **Medical evacuations**. It is used for **airlifting injured personnel**, providing quick access to medical care in emergencies.

    - **Surveillance and reconnaissance**. The Chetak can be used for **patrolling** and gathering **intelligence** over land or sea.

2. **Lightweight and Agile**. The **Chetak** is a **lightweight helicopter** that is **easy to maneuver**, making it ideal for operations in **confined spaces** or **challenging terrains**.

3. **Performance and Speed**. The Chetak can reach speeds of up to **220 km/h (137 mph)**, with a **range of about 550 km**.

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| **Cheetah** | The **Cheetah** is a **multi-role light helicopter** of French origin used by the **Indian Air Force (IAF)** for various tasks, including **transport**, **reconnaissance**, **search and rescue**, and **medical evacuation**. It has earned a reputation for its **reliability**, **maneuverability**, and **ability to operate in extreme conditions**, such as **high altitudes** and **remote locations**.<br><br>**<u>Key Features of the Cheetah Helicopter</u>**<br>1. **<u>Lightweight and Agile</u>**. The Cheetah is a **small, lightweight helicopter** designed for **quick deployment** and **high agility**. It weighs around **1,000 kg** and has a maximum speed of approximately **190 km/h**. Its lightweight design makes it highly maneuverable, allowing it to operate in **confined spaces** and **difficult terrains** like **mountainous regions** and **dense forests**.<br>2. **<u>High Altitude Operations</u>**. One of the Cheetah's standout features is its ability to perform in **high-altitude environments**. It is often deployed in the **Himalayan region**, including **Siachen Glacier**, one of the world's highest battlefields. The Cheetah is capable of operating in areas with low air density, which is important for missions in places where most helicopters cannot fly due to **thin air** at high altitudes. The Chital, a modified variant of Cheetah, equipped with Turbomeca TM-333 2B2 engine (used in ALH) has a much better thrust to weight ratio and is being extensively utilized in Siachen glacier.<br>3. **<u>Multi-role utility Helicopter</u>**. The Cheetah is used in a variety of roles similar to the Chetak.<br>4. **<u>Crew and Payload</u>**. The Cheetah typically operates with a **pilot** and a **co-pilot** or **crew member**. It can carry upto 3 passengers. |
| **Mi-17 V5** | The **Mi-17 V5** is a **multi-role, medium-lift helicopter** that plays a crucial role in a wide range of missions for the **Indian Air Force**. The Mi-17 V5 can carry out missions such as **transporting personnel and cargo**, **airlifting** heavy loads, **search and rescue operations**, and **disaster relief**, among others. |

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<u>Key Features of the Mi-17 V5 Helicopter</u>

1. **<u>Multi-role Capabilities</u>**. The Mi-17 V5 is known for its **multi-role capabilities**, which means it can perform a wide range of tasks.
2. **<u>Combat support</u>**. The Mi-17 V5 can also be deployed for **combat support operations**, carrying troops or supplies to forward locations in combat zones.
3. **<u>Advanced Avionics and Technology</u>**. The Mi-17 V5 comes equipped with **state-of-the-art avionics** and **navigation systems**
4. **<u>Powerful and Efficient Engines</u>**. The Mi-17 V5 is powered by two **turbo shaft engines**, which provide high power and reliability.
5. **<u>Versatile Interior</u>**. The interior of the Mi-17 V5 is designed to be highly adaptable. The cabin can be configured in multiple ways depending on the mission, allowing it to carry:-
   - **Passengers** (up to 24 soldiers or personnel).
   - **Cargo** (using internal space for supplies or equipment).
   - **Heavy external loads** using sling operations.
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<td>Mi-35</td>
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The Mi-35 is a heavily armed, multi-role combat helicopter of Russian origin, designed for various military operations, from ground attack to troop transport. The Mi-35 is primarily used for close air support, anti-tank operations, and logistical transport of soldiers and equipment in combat zones.


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| | **Key Features of the Mi-35 Helicopter**<br>1. **Combat and Attack Capabilities**. The Mi-35 is known for its **heavy firepower**, making it effective in **ground attack** and **close air support missions**.<br>2. **Troop Transport Role**. The Mi-35 is designed not just as an **attack helicopter** but also for **troop transport**. It can carry up to **8 fully armed soldiers** in its spacious cabin.<br>3. **Helicopter Gunship Design**. The Mi-35 has a distinct **gunship design**, with a **heavy armoured body** and **reinforced fuselage**, making it capable of **withstanding enemy fire**.<br>**4.** **Powerful Engine and Performance**. The Mi-35 is powered by **two engines**, which give it the ability to reach a maximum speed of around **300 km/h** and operate at a **ceiling of 5,500 meters** |
| **AH-64 Apache** | The **AH-64 Apache** is a **dedicated attack helicopter** developed by **Boeing (USA)** and used by many armed forces around the world, including the **Indian Air Force (IAF)**.<br><br>**Key Features of the AH-64 Apache Helicopter**<br>1. **Powerful Weaponry**. The Apache is equipped with a wide array of **highly effective weapon systems** for combat operations.<br>2. **Highly Maneuverable and Agile**. The Apache is designed to be **highly maneuverable** and can perform **quick maneuvers**, **hovering**, and **low-altitude operations** while staying out of reach of enemy fire. Its **speed** (around **280 km/h**) and **agility** make it capable of evading threats while **engaging ground targets**.<br>3. **Protection and Survivability**. The AH-64 Apache is built with a focus on **survivability** in hostile combat zones. Key features include **Armored Cockpit**, **Self-Sealing Fuel Tanks** and **Electronic Countermeasures (ECM)**. |
| **CH-47 Chinook** | The **CH-47 Chinook** is a **heavy-lift transport helicopter** used by the **Indian Air Force (IAF)**. Manufactured by **Boeing**, the Chinook is capable of carrying heavy loads, **troop transport**, and **equipment** in difficult and rugged environments. This helicopter plays a critical role in |

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| | providing **logistical support** during **military operations**, **disaster relief**, and **humanitarian missions**.<br><br>1. **Heavy-Lift Capability**. The CH-47 Chinook is specifically designed to carry **heavy loads**, making it one of the most versatile transport helicopters in the world. It has the capacity to carry up to **10,886 kilograms** of cargo, including **artillery**, **vehicles**, **equipment**, and **troops**.<br>2. **Tandem Rotor System**. The CH-47 is equipped with a **tandem rotor design**, which means it has **two large rotors** placed one in front of the other. This configuration provides **greater lift** and stability, allowing the Chinook to carry heavy loads while remaining **maneuverable**.<br>3. **Cargo and Troop Transport**. The CH-47 Chinook can carry **33 troops** in addition to its heavy cargo. |

## TRAINER AIRCRAFT

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| **Pilatus PC-7** | The **Pilatus PC-7** is a **turboprop trainer aircraft** used by the **Indian Air Force (IAF)** for **basic pilot training**. It is a **Swiss-made** aircraft, specifically designed as a Basic Flying Trainer. The **PC-7** is powered by a **single turboprop engine**. The aircraft is reliable and efficient, allowing pilots to learn the basics of flying, handling, and emergency procedures in a relatively simple and stable aircraft before transitioning to faster, more complex jet aircraft.<br> |

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| **HJT-16**<br><br>**Kiran** | The **Kiran** is a **jet trainer aircraft** used by the **Indian Air Force (IAF)** to train pilots at the **intermediate stage** of their flying training program. It serves as a bridge between **basic propeller-driven trainer aircraft** like the **Pilatus PC-7** and advanced **fighter jets**. The **HAL HJT-16 Kiran** was designed and developed by **Hindustan Aeronautics Limited**.<br><br>  |
| **Hawk** | The **BAE Hawk** is a **high-performance jet trainer aircraft** used by the **Indian Air Force (IAF)** for **advanced pilot training**. It plays a crucial role in training **cadets** to transition from intermediate training aircraft (like the **Kiran** or **Pilatus PC-7**) to **frontline fighter jets**.<br><br> |

## MADE IN INDIA

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| **LCA**<br><br>**Tejas** | The **LCA Tejas** (Light Combat Aircraft) is a **multirole light fighter aircraft** developed by **Hindustan Aeronautics Limited (HAL)** for the **Indian Air Force (IAF)**. It is a **fourth-generation supersonic aircraft** designed to replace older fighters in the IAF's fleet. The Tejas represents a significant milestone in India's aerospace capabilities, showcasing indigenous engineering and technological advancement. It is a vital asset for India's defence, contributing to air superiority and operational flexibility.<br><br> |

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| | **<u>Key Features of the LCA Tejas</u>**<br><br>1. **<u>Indigenous Design and Development</u>**. The LCA Tejas is a **completely indigenous** aircraft, designed and developed by **HAL** under the **Indian Ministry of Defence's (MoD) Light Combat Aircraft Program**.<br><br>2. **<u>Lightweight and Agile</u>**. The Tejas is a **lightweight** fighter, designed for **agility** and **maneuverability**. It is built using advanced **composite materials** to reduce weight and enhance performance. Its **compact design** and **low radar cross-section** give it **stealth-like features**, making it harder to detect by enemy radars.<br><br>3. **<u>Powerful Engine</u>**. The **LCA Tejas** is powered by a **GE F404** engine, which gives it a top speed of **1,350 km/h**.<br><br>4. **<u>Advanced Avionics and Cockpit</u>**. The Tejas is equipped with **state-of-the-art avionics**, including a **glass cockpit**, **digital flight control systems**, and advanced **radar systems**.<br><br>5. **<u>Multirole Capabilities</u>**. The LCA Tejas is designed to perform a variety of missions, making it a **multirole fighter**.<br><br>**6.** **<u>Weaponry</u>**. The LCA Tejas is equipped with a wide range of **air-to-air**, **air-to-ground**, and **precision-guided weapons**, making it a potent fighter in modern warfare. |
| **LCH**<br><br>**Prachand** | The **LCH Prachand** (Light Combat Helicopter) is an **indigenous attack helicopter** developed by **Hindustan Aeronautics Limited (HAL)** for the **Indian Air Force (IAF)** and **Indian Army Aviation Corps**.<br><br><br><br>**<u>Key Features of the LCH Prachand</u>**<br><br>1. **<u>Indigenous Design and Development</u>**. The **LCH Prachand** is a **100% indigenous** attack helicopter, designed and developed by **Hindustan Aeronautics Limited (HAL)**.<br><br>2. **<u>Role and Purpose</u>**. The **LCH Prachand** is primarily designed for **combat missions** and can perform a variety of tasks such as **Anti-tank warfare**, **Close air support (CAS), Air defence**, **Search and rescue**.<br><br>3. **<u>Versatile Weaponry</u>**. The **LCH Prachand** is equipped with a wide range of **advanced weaponry**: |

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| | • **<u>20mm Turret Gun</u>**. For close combat and engaging ground targets.<br>• **<u>Helina (Helicopter Launched NAG)</u>**. A **precision-guided missile** designed for **anti-tank warfare**.<br>• **<u>5-inch Rocket Pods</u>**. For **area bombardment** and attacking enemy positions.<br>• **<u>Air-to-air Missiles</u>**. To defend against enemy aircraft and **helicopter threats**.<br>• **<u>Guided and Unguided Bombs</u>**. To conduct **targeted airstrikes** on enemy positions.<br>4. **<u>Composite Materials for Stealth</u>**. The LCH Prachand is built using **advanced composite materials** that reduce its **radar cross-section**. This feature gives it a **stealthy profile**, making it harder for enemy radars to detect the helicopter. |
| **Dhruv** | **Dhruv** is a **multi-role, twin-engine light helicopter** developed by **Hindustan Aeronautics Limited (HAL)** for the **Indian Armed Forces**, including the **Indian Air Force (IAF)**. It is a highly versatile and **indigenous** helicopter that plays a crucial role in various operations such as **transporting troops**, **search and rescue missions**, and **combat operations**. The Dhruv is designed to be effective in both **peacetime operations** and **combat scenarios**, making it a valuable asset for the **IAF** and other branches of India's military.<br><br>**<u>Key Features of the Dhruv Helicopter</u>**<br>1. **<u>Indigenous Development</u>**. The **Dhruv** is a **100% indigenous** helicopter developed by **Hindustan Aeronautics Limited (HAL)**. The helicopter entered service with the **Indian Air Force** and **Indian Army** in the early 2000s.<br>2. **<u>Multi-Role Capability</u>**. The **Dhruv** is a **multi-role helicopter**, meaning it can perform a variety of tasks.<br>3. **<u>Twin-Engine Design</u>**. The **Dhruv** features **two engines**, which provide **redundancy** in case one engine fails, improving the |

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| | helicopter's **safety**.<br>4. **<u>Designed for High-Altitude Operations</u>**. The **Dhruv** is specifically designed to operate in **high-altitude areas** and **rough terrains**, such as the **Himalayan region**. It can carry out missions at altitudes of up to **6,000 meters** (20,000 feet), which is vital for operations in **border regions** like **Siachen Glacier** and **the Ladakh region**.<br>5. **<u>Advanced Avionics and Systems</u>**. The Dhruv is equipped with modern **avionics** (electronic systems), making it **highly efficient** in various operations. Some of its advanced features include:<br>• **<u>Glass Cockpit</u>**. Provides **digital displays** for better navigation and operation.<br>• **<u>Automatic Flight Control System (AFCS)</u>**. Ensures smooth flying even in **turbulent conditions**.<br>• **<u>Day and night Operational Capability</u>**. Equipped with **night vision goggles (NVG)** and **infrared sensors**, enabling it to operate in **low-visibility conditions**.<br>6. **<u>Passenger and Cargo Capacity</u>**. The Dhruv can carry up to **16 passengers** or **1.5 tons of cargo**.<br>7. **<u>Armament and Combat Role</u>**. The **armed version** of the Dhruv is equipped with a **20mm gun**, **rockets**, and **guided missiles** for **anti-tank** and **ground attack** missions. |

## **<u>CONCLUSION</u>**

20. The primary role of the Air Force is to safeguard the nation from any aerial threats and also to provide support to the Army and the Navy. Its secondary role is to provide aid to the civil power in maintaining law and order and in providing relief during natural calamities. The five operational commands through administrative wings control over 45 Fixed Wing Squadrons, 20 Helicopter Units and numerous surface-to-air missile squadrons with unit establishments varying from 12 to 18 aircraft. Visual aircraft recognition is a vital skill for military and defence personnel. Being able to distinguish between various aircraft types helps in identifying potential threats, understanding the capabilities of enemy aircraft, and knowing which aircraft are friendly.

## ASSESSMENT EXERCISES

**Multiple Choice Questions**

1. **Who is the chief of the Indian Air Force?**

   (a) Air Chief Marshal

   (b) President of India

   (c) Chief of Defence Staff

   (d) Air Marshal

2. **Which is Delta wing aircraft?**

   (a) Hawk

   (b) Jaguar

   (c) Kiran

   (d) Tejas

3. **Which is high Tail aircraft?**

   (a) Mig-21

   (b) Avro

   (c) Sukhoi-30 MKI

   (d) IL-76

4. **Name single engine aircraft?**

   (a) C-130 J

   (b) C-17

   (c) Mig-21

   (d) Jaguar

5. **C-295 is ________ aircraft?**

   (a) Transport

   (b) Fighter

   (c) Helicopter

   (d) RPAS

**6. Jaguar is ________(mark the correct option)?**

(a) Low level attack aircraft

(b) Cargo aircraft

(c) has turbo prop engine

(d) Single Engine aircraft.

**7. Which of the following is Trainer Aircraft?**

(a) AN-32

(b) Mirage

(c) Avro

(d) PC-7 Pilatus

**8. Which of the following is VIP Aircraft?**

(a) Embraer

(b) AN-32

(c) C-130J

(d) Mig-29

**9. What is the name of Heavy lift transport Aircraft?**

(a) Chinook

(b) Cheetah

(c) Chetak

(d) Mi-35

**10. Which is the attack helicopter?**

(a) Mi-8

(b) Mi-17

(c) Chetak

(d) Apache

**Answer the following questions**

1. Types of aircrafts in IAF inventory.
2. Name 5 fighter aircrafts.
3. Name any two made in India aircrafts.
4. What is the country of origin of AN-32?
5. Name any two attack helicopters.
6. Country of origin of Apache attack helicopter.
7. What are the various methods to identify the aircrafts?
8. Country of origin of Rafale.
9. Name any 5-transport aircraft.
10. Country of origin of Embraer aircraft.

**Short Notes**

1. Write a short note on organization of Indian Air Force.
2. Write a short note on history of Indian Air Force.
3. Write a short note on Rafale multirole aircraft.
4. Write a short note on attack helicopters.
5. Write a short note on the branches of Indian Air Force.

## GENERAL SERVICE KNOWLEDGE (SD/SW)

## CHAPTER III : MODERNIZATION OF IAF (MOAF)

### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| Period | : | 03 (Three) |
| Type | : | Lecture |
| Year | : | 1st Yr SD/SW |
| Conducting Officer | : | Permanent Instructor |
| Training Aids | : | Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model. |
| Time Plan | | |
| • Part I | : | 40 Mins |
| • Part II | : | 40 Mins |
| • Conclusion and Practice | : | 40 Mins |

## INTRODUCTION

1. Use of science and technology in every field always improves the work efficiency, reduces the workload and increases the production rate. Lot of technological improvements has taken place in the field of aviation also. Since the mid-1960s, computer technology has been continuously developed to the point at which aircraft and engine designs are fully automated. In this chapter, we will learn about the list of modern inventions or equipment that has revolutionized the field of aviation. Autopilot, Flyby Wire, UAV, Glass cockpit Technology etc. are the gifts of modern technology.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Latest Trends in Aviation

(b) Part II: New Acquisitions of IAF

### LEARNING OBJECTIVES

Basic understanding of the Indian armed forces, their organisation and structure.

- Basic understanding of latest trends in aviation.
- New acquisitions of IAF in making it a modern aerospace power.
- Aircraft inventory

## PART I: LATEST TRENDS IN AVIATION

2. **Autopilot**. In the early days of aviation, aircraft required continuous attention of a pilot in order to fly safely. As aircraft range increased allowing flight of extended hours, the constant attention led to serious fatigue for the pilot. An autopilot system is designed to perform some of the tasks of the pilot. A single-axis autopilot controls an aircraft in the roll axis only. An aircraft is controlled on pitch and roll axis with the help of two-axis autopilot. A three axis auto pilots controls aircraft in all three axis. Computer software is used in modern autopilot to control the aircraft. The software reads the aircraft’s current position, and then controls a Flight Control System to guide the aircraft.

3. **Fly by Wire (FBW)**. It is a system that replaces the conventional manual flight controls of an aircraft with an electronic interface. The movements of light controls are converted to electronic signals transmitted through wires (hence the fly-by-wire term), and flight control computers determine how to move the actuators at each control surface to provide the ordered response. The fly-by-wire system also allows automatic signals sent by the aircraft's computers to perform functions without the pilot's input and automatically help stabilize the aircraft.

4. **Fly by Optics**. It is sometimes used instead of fly-by-wires since it can transfer data at higher speeds because of the use of fibre cables in place of electrical cables.

## UAVs

5. The **UAV** stands for Unmanned Aerial Vehicle. UAVs are type of aircraft which are designed in a way that it doesn't require any pilot to be on board. UAVs can be controlled remotely (e.g. flown by a pilot at a ground control station) or can fly autonomously based on pre- programmed flight plans. UAVs are currently used for a number of missions, including reconnaissance and attack roles. They are predominantly deployed for military applications, but also used in a small but growing number of civil applications, such as firefighting and nonmilitary security work, such as surveillance of pipelines. UAVs are often preferred for missions that are too 'dull, dirty, or dangerous' for manned aircraft. They are classified as per following criteria:-

(a) **Target and Decoy**. Provides ground and aerial target to simulate an enemy aircraft.

(b) **Reconnaissance**. Providing battlefield intelligence.

(c) **Combat**. Providing attack capability for high-risk missions.

(d) **Endurance**. Because UAVs are not burdened with the physiological limitations of human pilots, they can be designed for maximized on-station times. The maximum flight duration of unmanned, aerial vehicles varies widely. Internal-combustion-engine aircraft endurance depends strongly on the percentage of fuel burned as a fraction of total weight and so is largely independent of aircraft size.

6. **Air to Air Refueller**. Air to Air refuelling (AAR) is a process where fuel is transferred from one aircraft to another while both are in flight. The aircraft that provides the fuel in called the tanker and the aircraft that receives the fuel is called the receiver. AAR is also known as aerial refueling, In-Flight refueling or tanking. AAR is used is used for Military purposes and is not used in civilian applications. It allows the receiver to stay airborne as far as the crew can tolerate or until engine factors like engine oil consumption limits it. In IAF, IL-78 is used as tanker for Air to Air Refueling.

7. **<u>AWACS</u>**. The Indian Air Force has multiple Airborne Warning and Control Systems (AWACS) aircrafts, including Israeli Phalcon AWACS and Netra AEW&C system. AWACS aircrafts are also known as “eye in the sky”.

(a) **<u>Phalcon AWACS</u>**. The IAF operates three Israeli Phalcon AWACS aircraft that provide 360 degree coverage. The Phalcon AWACS is a product of cooperation between India, Israel and Russia. PHALCON AWACS employs a phased array PHALCON RADAR on an IL-76 platform.

(b) **<u>Netra AEW&C System</u>**. It is an indigenously developed system, designed to reduce India's dependency on foreign AEW&C platforms. The NETRA system has been developed by **DRDO**, with support from other agencies like **Indian Air Force**, **HAL (Hindustan Aeronautics Limited)**, and **ISRO**. The Netra AEW&C system offers 240 degree coverage. In this system, the indigenously developed RADAR is mounted on Embraer EMB-145 platform. The NETRA radar has a range of around **250-300 kilometres**, depending on the altitude at which the aircraft is flying. The Netra Mk-1 AWACS played a key role in Balakot operation by providing air situational awareness to IAF fighter pilots.

8. **<u>Glass Cockpit</u>**. Before 1970’s aircraft were not sufficiently demanding to require advanced equipment like electronic flight displays. Also, computer technology was not at a level where sufficient light and powerful circuit were available. The increasing complexity of

transport aircraft, the advent of digital systems and growing air traffic congestion around airports began to change that.

9. The average transport aircraft in the mid-1970 had more than one hundred cockpit instruments and controls and the growing number of cockpit elements were competing for Cockpit space and pilot attention. As a result, NASA conducted research on displays that could process the raw aircraft system and flight data into an integrated, easily understood picture of the flight situation, finally culminating in a full glass cockpit system. A glass cockpit is an aircraft cockpit that features electronics instrument displays rather than mechanical gauge. A glass cockpit uses displays driven by flight management system that can be adjusted to displays flight information as needed. This simplifies aircraft operation and navigation and allows pilot to focus only on the most pertinent information.

## PART II: NEW ACQUISITIONS OF IAF

10. **Rafale**. The Rafale is a multi-role fifth generation fighter aircraft inducted into the Indian Air Force (IAF) in 2019, manufactured by Dassault Aviation of France. Known for its versatility, it excels in air superiority, ground attack, reconnaissance, and nuclear deterrence. The Rafale is equipped with advanced features like the AESA (Active Electronically Scanned Array) radar, SPECTRA electronic warfare system, and a glass cockpit, providing superior situational awareness and operational flexibility. Powered by the M88-2 engines, it can reach speeds of Mach 1.8 and has a combat range of 1,000 km, making it highly effective for both defensive and offensive missions. The IAF operates 36 Rafales.

11. **C-295**. The **C-295** is a versatile, medium-lift transport aircraft recently inducted into the Indian Air Force (IAF) to enhance its airlift capabilities. Manufactured by **Airbus Defence and Space**, the C-295 is designed for a variety of missions, including troop transport, cargo airlift, disaster relief, and medical evacuations. It can carry up to **71 soldiers** or **5 tons of cargo** and

has a remarkable ability to operate from short and rugged airstrips, which is particularly useful in remote and difficult-to-reach areas.In addition to its primary role of transport, the C-295 can also be equipped for specialized tasks such as surveillance, search and rescue, and maritime patrol. The IAF has plans to induct around **56 C-295 aircraft** to replace the aging fleet of **Avro HS-748** aircraft, which have been in service for over five decades.

12. **<u>S-400 TRIUMF</u>**. The **S-400 Triumf** is an advanced air defence missile system that has been inducted into the Indian Air Force (IAF) to enhance the country's defence capabilities against aerial threats. Manufactured by **Russia**, the S-400 is designed to detect, track, and destroy a wide range of aerial targets, including aircraft, cruise missiles, and ballistic missiles, at varying altitudes and distances. It has a striking range of up to **400 kilometres**, making it one of the most advanced long-range surface-to-air missile systems in the world. The S-400 can track over **100 targets** simultaneously and engage up to **6 targets** with multiple missiles, making it highly effective in countering multiple threats at once. For India, the S-400 is a crucial addition to its air defence network, offering a robust shield against potential air and missile attacks. Its integration into the Indian Air Force provides comprehensive defence against modern aerial threats, enhancing the country's strategic deterrence and national security.

## CONCLUSION

13. The Indian Armed Forces have undergone significant modernization in recent years, with investments in areas such as futuristic soldier systems and missile defence systems.

14. From the raising of Air Force, it has seen various changes and is marching towards the modernization. Since it is the youngest force, it has the responsibility of defending the Air territory of our country. It is the eye in the sky and has the nature which is devastating for the enemy of the country.

15. Many factors are involved in making an identification of an aircraft. Some of these are size, viewing angle, visibility, aircraft finish, visual characteristics, colour and external markings. India has a vast inventory of Aircraft. Cadets should be able to recognize and identify the various Fighter/Transport aircraft and Helicopters.

# ASSESSMENT EXERCISES

## Multiple Choice Questions (MCQs)

**1. Which of these aircraft is used as air-to-air refueler?**

(a) IL-76 (b) AN-32

(c) IL-78 (d) Embraer

**2. Degree of coverage of NETRA AEW & C?**

(a) 240 (b) 180

(c) 200 (d) 120

**3. Country of origin of Chinook?**

(a) UK (b) Brazil

(c) USA (d) France

**4. Country of origin of Rafale**

(a) USA (b) Italy

(c) France (d) Russia

**5. Country of origin of C-295?**

(a) Spain (b) France

(c) Russia (d) USA

**6. Country of origin of S-400?**

(a) India (b) Russia

(c) UK (d) Germany

**7. Degree of coverage of Israeli AWACS with Phalcon radar?**

(a) 300 (b) 360

(c) 180 (d) 90

**8. Number of hard points to carry weapons in Apache attack helicopter?**

(a) 4 (b) 2

(c) 8 (d) 6

**9. Operational range of s-400?**

(a) 100kms (b) 250kms

(c) 300kms (d) 400kms

**10. Number of troops that can be carried in C-295?**

(a) 120 (b) 100

(c) 50 (d) 71

**Long Answer Type Questions**

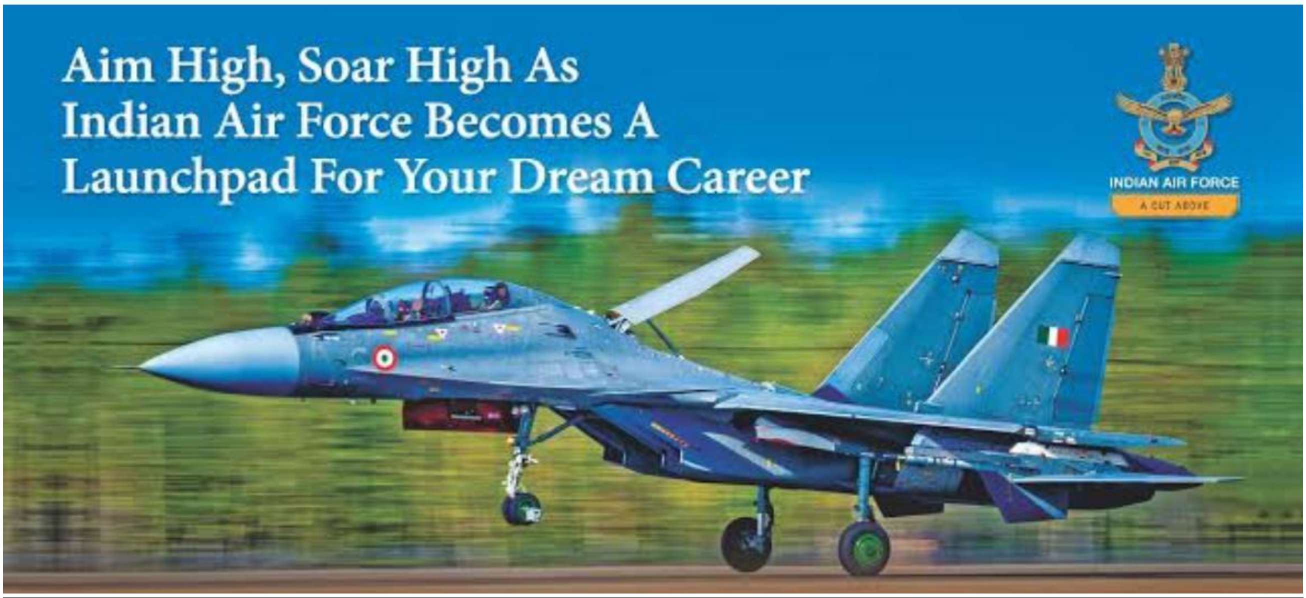
1. What is S-400 TRIUMF.
2. Write a note on Air to Air refuelling.
3. Write a note on C-295 aircraft.
4. Write difference between Netra AEW&C and AWACS.

**Short Answer Type Questions**

1. Write a short note on autopilot.
2. Write a short note on FBW.
3. Write a short note on UAV.
4. Write a short note on AAR
5. Write a short note on Glass Cockpit.

# GENERAL SERVICE KNOWLEDGE (SD/SW)

## CHAPTER IV : MODES OF ENTRY IN IAF AND CIVIL AVIATION (MOE)




### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **03 (Three)** |
| **Type** | **:** | **Lecture** |
| **Year** | **:** | **1st Yr SD/SW** |
| **Conducting Officer** | **:** | **Permanent Instructor** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Part I** | **:** | **35 Mins** |
| • **Part II** | **:** | **35 Mins** |
| • **Part III** | **:** | **30 Mins** |
| • **Conclusion and Practice** | **:** | **20 Mins** |

# INTRODUCTION

## PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Officer Entry

(b) Part II: Air warrior Entry

(c) Part III: Civil Aviation

## LEARNING OBJECTIVES

Basic understanding of the Indian armed forces, their organisation and structure

- Basic understanding of entry as an officer in IAF.
- Entry as an air warrior.
- Entry into civil aviation.

# PART I: OFFICER ENTRY

1. **Officer Entry**. An officer is a member of an armed force or uniformed service who holds a position of authority. In order to lead and control, the ability to motivate yourself, inspire others and make tough decisions efficiently is very crucial. Lessons in teamwork, developing communication skills and confidence, honing strategic and dynamic thinking are grilled into an Officer during their training. The Air Force teaches all, not only making men and women of young boys and girls but making them leaders in life. An officer's strength of character and strong moral compass make him/her stand out from the crowd at all times. Followings are the essential requirements for entry in the IAF to become Commissioned Officer:-

| Branch/ Type of Entry | Educational Qualification | Age Limit | Advertisement Schedule |
|---|---|---|---|
| **Flying Branch** | | | |
| National Defence Academy (NDA) For Men & Women | 10+2 With Physics, Chemistry & Math | 16 1/2 – 19 1/2 | Mar/Oct |
| Combined Defence Service (CDSE) For Men & Women | Any Grad. With Physics & Math10+2 or BE | 19-25 | Apr/Sep |
| Air Force Common Entrance Test (AFCAT) for both Men & Women | Any Grad. With 60% marks | 20-24 (Flying) 20-26 (Tech & Non-tech branch) | Jun/Dec |
| NCC Special Entry | Any Grad. with Physics & Math | 19-25 | Jun/Dec |

| | | | |
|---|---|---|---|
| | at10+2 or BE & NCC Air Wing Sr Div.“C’ Certificate | | |
| **Technical Branch: PC For Men/ SCC For Both** | | | |
| Aeronautical Engineering (Electronics)<br>Aeronautical Engineering (Mechanical) | First class degree in Engineering | 18-28 | Feb/Aug |
| **Ground Duty Branch: PC For Men/ SCC For Both** | | | |
| Administration | First Class Graduate or PG in | 20-23 | Mar/Sep |
| Logistics and Accounts | Subjects as per Advertisement | 20-25 | |
| Education | PG in subjects as per advertisement | 20-25 | Mar/Sep |
| Meteorology | Graduation with 60 % marks in science subjects | 20-23 | Mar/Sep |

## PART II: AIR WARRIOR ENTRY

2. **Regular Entry**. Followings are the essential requirements for entry in the IAF to become Airman:-

| **Group** | **Age on Enrolment Date** | **Educational Qualification** |
|---|---|---|
| Group ‘Y’ (Med Asst) Trade | 17-21Years | Passed Intermediate/10+2/Intermediate/equivalent exam with Physics, Chemistry, Biology and English with a minimum of 50% marks in aggregate. |

3. **Agniveer Entry**. The **Agniveer** scheme is a revolutionary initiative launched by the Government of India to bring in fresh, young talent to serve in the Indian Armed Forces, including the **Indian Air Force (IAF)**. This program offers a unique opportunity for young individuals to join the IAF for a fixed period of **four years**, with the possibility of subsequent career opportunities based on performance and the needs of the Air Force. The Agniveer scheme is part of the government’s broader efforts to modernize the Armed Forces and create a youthful, dynamic force.

## SCHEME OVERVIEW

4. The Agniveer scheme is designed to attract young individuals between the ages of **17.5 to 21 years** to serve in the Indian Air Force for a **four-year tenure**. The selected candidates, known as **Agniveers**, will be trained in a variety of skills, including physical fitness, combat training, and technical expertise, depending on their roles within the Air Force. After the completion of their service, up to **25% of the Agniveers** may be retained in the Air Force based on their performance, while the rest will be given a **severance package** and support in finding civilian employment.

**Educational Qualifications Required**

5. To join the Indian Air Force under the Agniveer scheme, candidates must meet the following eligibility criteria:

(a) **Age**. Candidates must be between 17.5 to 21 years of age at the time of application. (Note: The upper age limit may be extended depending on the government's policy and recruitment cycle.)

(b) **Educational Qualifications**.

(i) **For General Duty (GD)**. Candidates must have completed Class 12 (Higher Secondary) with Physics and Mathematics as subjects.

(ii) **For Technical Trades**. Candidates must have completed Class 12 with Physics, Mathematics, and English or have a three-year engineering diploma in relevant trades (like electronics, mechanical, or electrical engineering).

(iii) **For Non-Technical Trades**. A Class 12 certificate in any stream (Science, Arts, or Commerce) is required, depending on the specific role.

(iv) **For Medical Assistants**. Candidates must have completed Class 12 with Biology, Chemistry, and Physics.

(v) **For Airmen (Security and Administrative Roles)**. A Class 12 pass with any stream or equivalent educational qualification is sufficient.

## PART III: CIVIL AVIATION

6. India's civil aviation industry has experienced exponential growth over the past few years and is poised to become the third-largest aviation market in the world by 2025. This growth is driven by increasing air travel demand, both domestically and internationally, the expansion of airports, the rise of low-cost carriers, and the government's efforts to improve air infrastructure. As a result, the aviation sector offers numerous career opportunities for both undergraduate and graduate students. NCC cadets have several opportunities in civil aviation, especially in roles that emphasize leadership, discipline, and teamwork. This

chapter outlines the various career options available in India's civil aviation sector and the qualifications required to pursue them.

7. **Pilot**. One of the most coveted career options in the aviation industry is becoming a **pilot**. Pilots are responsible for flying aircraft and ensuring the safety of passengers and crew. There are two main types of pilots:

(a) **Commercial Pilot**. A commercial pilot is licensed to operate aircraft for commercial purposes. To pursue this career, students need to complete a **Commercial Pilot License (CPL)** from a recognized aviation training academy.

(b) **Airline Transport Pilot**. This is the highest level of certification for pilots, allowing them to act as captain on large commercial aircraft. To become an airline transport pilot, students must have a **CPL**, a **Class 1 medical certificate**, and complete the **ATPL (Airline Transport Pilot License)** training after gaining significant flying experience.

(c) **Eligibility**. A minimum of 10+2 with Physics and Mathematics, or a graduate degree in aviation-related fields.

(d) **Training**. Flight schools and academies, including the **Indira Gandhi Institute of Aeronautics (IGIA)** and **Capt. Sahil Khurana Aviation Academy**.

(e) **Licensing**. Students need to clear exams by the **Directorate General of Civil Aviation (DGCA)**.

8. **Air Traffic Controller (ATC)**. Air Traffic Controllers (ATCs) are responsible for ensuring the safe and efficient movement of air traffic. They manage the flow of aircraft in the air and on the ground, providing instructions to pilots for take-off, landing, and routing.

(a) **Eligibility**. Candidates must have a bachelor's degree (preferably in **Engineering**, **Physics**, or **Mathematics**) from a recognized university.

(b) **Training**. Air Traffic Controller training is provided by **National Civil Aviation Training Academy (NCATA)** and is regulated by the **DGCA**.

(c) **Aptitude**. A high level of concentration, quick decision-making ability, and stress management skills are essential.

9. **Cabin Crew (Flight Attendant)**. A career as a **cabin crew member**, or flight attendant, is an attractive option for those who enjoy traveling and serving passengers. Cabin crew members are responsible for ensuring passengers' safety, comfort, and well-being during flights. They assist with emergency procedures, offer in-flight services, and provide customer support.

(a) **Eligibility**. A minimum of 10+2 (Higher Secondary School) with a good level of physical fitness and communication skills.

(b) **Training**. Airlines like **Air India**, **IndiGo**, and **SpiceJet** provide specialized training to aspirants. The training includes safety protocols, first-aid, communication skills, and grooming.

(c) **Additional Skills**. Good interpersonal skills, customer service orientation, and fluency in English.

10. **Airport Operations and Management**. The aviation industry requires highly trained professionals to manage the operations of airports, which are often large and complex organizations. Careers in airport operations involve managing ground handling, baggage, cargo, and passenger services, as well as overseeing security and emergency procedures.

(a) **Eligibility**. A bachelor's or master's degree in Airport Management, Aviation Management, or related fields. Courses are available at institutions like National Institute of Aviation Management and Research (NIAMAR) and Institute of Air Transport Management (IATM).

(b) **Skills**. Knowledge of airport regulations, customer service, logistics, and operations management.

11. **Aviation Safety and Security.** Aviation safety and security professionals ensure the safe and secure operation of airlines and airports. These professionals manage safety protocols, conduct regular inspections, monitor air traffic, and deal with security threats.

(a) **Eligibility**. A bachelor's degree in **Aviation Safety**, **Aerospace Engineering**, **Engineering**, or related fields.

(b) **Training**. **DGCA** provides certification programs for safety management, risk assessment, and aviation security.

(c) **Skills**. Analytical thinking, attention to detail, knowledge of aviation regulations, and ability to manage emergency situations.

12. **Ground Staff (Ground Handling Services)**. Ground staff professionals work at the airport to ensure that passengers and cargo are managed efficiently. This includes check-in services, baggage handling, customer support, and coordination with various departments to ensure smooth operations.

(a) **Qualification**. Eligibility: A minimum of 10+2 education, though a diploma or degree in Aviation Management or Travel and Tourism can be advantageous.

(b) **Skills**. Communication skills, problem-solving, attention to detail, and teamwork.

13. **Aviation Engineering (Maintenance and Technical)**. Aviation engineers are responsible for maintaining the safety and performance of aircraft. They work on the design, construction, repair, and overhaul of aircraft and their systems. Aircraft maintenance engineers (AMEs) are certified by the DGCA and play a crucial role in ensuring the airworthiness of an aircraft.

(a) **Eligibility**. A degree in Aeronautical Engineering, Mechanical Engineering, or Aerospace Engineering from a recognized institution.

(b) **Certification**. To work as an Aircraft Maintenance Engineer, one must hold an AME license from the DGCA.

14. **Aviation Hospitality and Customer Service**. With the growing number of air travelers, aviation hospitality professionals focus on providing high-quality customer service to ensure a pleasant travel experience. Careers in aviation hospitality include roles such as customer service executives, ticketing agents, and reservation specialists.

(a) **Eligibility**. A bachelor’s degree in Hotel Management, Aviation Management, or Travel and Tourism.

(b) **Skills**. Strong communication, customer service skills, and problem-solving abilities.

## CONCLUSION

15. India’s civil aviation industry offers a wide range of career opportunities for undergraduate and graduate students, from pilots and air traffic controllers to ground staff and aviation engineers. The sector is rapidly growing, driven by increasing air travel demand and government initiatives to improve infrastructure. Pursuing a career in aviation requires specialized education, training, and certifications, but it provides a rewarding path for those passionate about the industry. Cadets should explore various fields within aviation to find the best-fit career, considering their interests, skills, and educational background.

## ASSESSMENT EXERCISES

**Multiple Choice Questions (MCQs)**

**1. The youngest service is the?**

(a) Indian Army

. (b) Indian Navy

(c) Indian Air Force

(d) None of these.

**2. The Chiefs of the three services are officers wearing?**

(a) One star

(b) Two stars

(c) Three stars

(d) Four stars

**3. Which of the following is not a branch of the IAF?**

(a) Logistics

(b) Accounts

(c) Canteen

(d) Administration

**4. The first aviator in India was?**

(a) JRD Tata

(b) SV Sippe

(c) Lt Indra Lal Roy

(d) Prof Venkata Subba Setty

**5. Which of the following is not a branch of IAF?**

(a) Navigation

(b) Operation

(c) Administration

(d) Engineering

**6. Command HQs in the army is commanded by an officer of the rank of?**

(a) Gen

(b) Lt Gen

(c) Brigadier

(d) Colonel

**7. The Western Naval Command is at?**

(a) Mumbai

(b) Kochi

(c) Delhi

(d) Visakhapatnam

**8. The supreme commander of the Indian armed forces is?**

(a) Defence minister

(b) Vice president

(c) President

(d) Chief of Defence Services

**9. The Gallantry Award Other than in the Face of Enemy is?**

(a) Mahavir Chakra

(b) Paramveer Chakra

(c) Shaurya Chakra

(d) Veer Chakra

**10. Our country is covered almost from three sides with water with a coastline of approximately over?**

(a) 4000 km

(b) 5000 km

(c) 8000 km

(d) 6000 km

**11. The Ati Vishisht Seva Medal is a an award given for?**

(a) Gallantry in the face of enemy

(b) Gallantry other than in the face of enemy

(c) Non gallantry Distinguished Service Award.

**12. Target and decoy role is one of the roles of which of the following?**

(a) Fighters

(b) UAV

(c) Transports

(d) Helicopters

**13. The Rafale is considered to be a multirole fighter of the?**

(a) $3^{rd}$ generation

(b) $4^{th}$ generation

(c) $4.5^{th}$ generation

(d) $5^{th}$ generation

**14. The Indian Air Force came into being with the promulgation of the IAF bill on?**

(a) 04 Apr 1932

(b) 04 Sep 1932

(c) 09 Oct 1932

(d) 08 Oct 1932

**15. The following is a Gp 'Y' Technical trade?**

(a) Electrical Fitter

(b) Automobile Technician

(c) Meteorological Assistant

(d) Weapon Fitter

**Short Answer Type Question**

1. Write a short note on agniveer entry.
2. Write a short note on officer entry.
3. Write a short note on Ground Duty Branch of IAF.
4. Write a short note group X technical air warrior entry.
5. Write a short note on ATC.

**Long Answer Type Questions**

1. Write a note on Civil Aviation.
2. Write a note on NCC Special Entry.
3. Write a note on Airport operations and Management.
4. Write difference between Group X and Y entry of air warrior.

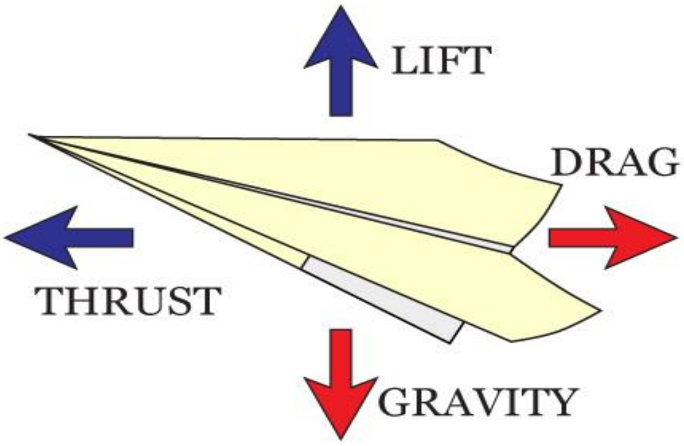
# PRINCIPLES OF FLIGHT

CHAPTER WISE INDEX : PRINCIPLES OF FLIGHT (SD/SW)

# PRINCIPLES OF FLIGHT (SD/SW)

## CHAPTER I : ELEMENTARY MECHANICS (EM)

***"A ship is always safe at the shore, but that is not what it is built for"***




## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **02 (Two)** |
| **Type** | **:** | **Lecture** |
| **Year** | **:** | **1st Yr SD/SW** |
| **Conducting Officer** | **:** | **Permanent Instructor** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction** | **:** | **10 Mins** |
| • **Part I** | **:** | **20 Mins** |
| • **Part II** | **:** | **20 Mins** |
| • **Part III** | **:** | **20 Mins** |
| • **Conclusion Practice** | **:** | **10 Mins** |

## <u>INTRODUCTION</u>

1. It is essential to have a basic knowledge of elementary mechanics to understand the various Principles of Flight, because both the aircraft and the atmosphere in which it flies are subject to the laws of mechanics. Understanding the laws of mechanics is essential for learning the principles of flight because flight is deeply rooted in physics, particularly in how forces and motion work. Here's why:-

(a) **<u>Forces in Flight</u>**. Mechanics helps us understand the four fundamental forces acting on an aircraft during flight: **lift, weight (gravity), thrust, and drag**. These forces need to be balanced and controlled to achieve stable flight. The laws of mechanics explain how these forces interact and affect the movement of the aircraft.

(b) **<u>Newton's Laws of Motion</u>**. The laws of mechanics, particularly Newton's laws, are crucial in understanding how an aircraft moves. For instance, **Newton's First Law (inertia)** explains why an aircraft resists changes in its motion unless a force is applied. **Newton's Second Law (force = mass × acceleration)** helps us understand how the aircraft accelerates or decelerates when thrust or drag is applied. **Newton's Third Law (for every action, there's an equal and opposite reaction)** explains how the engines' thrust propels the aircraft forward and how the wings generate lift.

(c) **<u>Aerodynamics and Pressure</u>**. Flight depends on how air moves around the aircraft. Mechanics, through the study of aerodynamics, helps explain the behaviour of air (fluid mechanics) and how changes in pressure and velocity around the wings generate lift. Understanding how air flows and how pressure differences are created (via Bernoulli's principle, for example) is essential to understanding how flight works.

(d) **<u>Stability and Control</u>**. Mechanics also helps explain the principles of stability and control in flight. The distribution of weight, center of gravity, and how forces act on the aircraft's control surfaces (like ailerons, elevators, and rudders) all depend on mechanical principles.

(e) **<u>Energy and Work</u>**. Mechanics explains the concept of work, energy, and power, which are vital when dealing with engines, fuel efficiency, and the overall performance of the aircraft. Without a solid understanding of these mechanical principles, it would be difficult to design, operate, or optimize an aircraft for safe and efficient flight. Essentially, mechanics provides the foundation for everything we know about how aircraft behave in the air.

**PREVIEW**

The lecture will be conducted in following parts:-

(a) Part I: Basic definitions

(b) Part II: Law of Motion

(c) Part III: Stability

**LEARNING OBJECTIVES**

Basic understanding of the Indian armed forces, their organisation and structure.

- Key definitions related to aviation.
- Laws of motion and their correlation in aviation.
- Correlation of elementary mechanics to flying.

## PART I: BASIC DEFINITIONS

2. **Speed**. Speed is the rate of change of position. Unit : feet/min, km/hretc

3. **Velocity**. Velocity is speed in particular direction. Velocity is a vector quantity having both magnitude and direction. Units: same as speed.

4. **Mass**. 'The quantity of matter in a body.' The mass of a body is a measure of how difficult it is to start or stop, ("a body", in this context, means a substance. Any substance a gas, a liquid or a solid).Unit - Kilogram (kg)

5. **Weight**. The force due to gravity'(F = m x g). The earth exerts a certain force towards its centre on all objects on its surface. This force is called Weight of the body and is equal to the mass of the body multiplied by the acceleration due to gravity 'g'. Unit - Newton (N)

6. **Displacement**. Displacement is defined as the change in position of an object. It is a vector quantity and has a direction and magnitude. It represented as an arrow that points from the starting position to the final position.

7. **Direction**. Direction is the path or orientation of an object's motion, or the location of something relative to something else.

8. **Acceleration**. Acceleration is the rate of change of velocity. The change may be in magnitude or direction or in both. Thus a body moving along a circular path at constant speed has acceleration.

9. **Density**. It is the mass per unit volume. Expressed as $\rho$ (rho).

10. **Work**. A force is said to do work on a body when it moves the body in the direction in which the force is acting. The amount of work done on a body is the product of the force applied to the body and the distance moved by that force in the direction in which it is acting. If a force is exerted and no movement takes place, no work has been done. Unit - Joule (J) Example, Work = Force x Distance (through which the force is applied)

11. **Power**: Unit - Watt (W) - Power is simply the rate of doing work, (the time taken to do work)

Example, Power (W) = $\frac{\text{Force (N) x Distance (m)}}{\text{Time (s)}}$

12. **Energy**. Mass has energy if it has the ability to do work. The amount of energy a body possesses is measured by the amount of work it can do. The unit of energy will therefore be the same as those of work, joules.

13. **Momentum**. The quantity of motion possessed by a body'. The tendency of a body to continue in motion after being placed in motion. Unit - Mass x Velocity (kg-m/s)

14. **Force**. Is that which causes or tends to cause a change in motion of a body. 'A push or a pull'. Unit - Newton (N)

Note: $F = ma$

15. **Pressure**. Pressure is force per unit area. Unit – Pascals

16. **Law of Conservation of Energy**. The sum total of all energy in the universe remains constant.

17. **Moment of a Force**. Moment of a force is the turning effect of the force about a point and is measured as the product of the force and the perpendicular distance between the point and the line of action of the force.

18. **Couple**. A couple consists of two equal and opposite and parallel forces not acting through the same point. The moment of a couple is equal to the force multiplied by the perpendicular distance between the two lines of action.

19. **Torque**. It is a measure of the rotational force applied to an object. It represents how much a force causes an object to rotate around an axis.

20. **Equilibrium**. A body needs to fulfil the following conditions to be in equilibrium.

(a) **Translational Equilibrium**. A body is in translational equilibrium if the **net force** acting on it is **zero**. This means the vector sum of all forces acting on the body cancels out. In simpler terms, this means the object is not accelerating (either moving at a constant velocity or at rest), as there is no unbalanced force to cause a change in its motion.

(b) **Rotational Equilibrium**. A body is in rotational equilibrium if the **net torque** acting on it is **zero**. This implies that the sum of all torques (moments) about any point is zero, preventing the object from rotating. i.e. there is no angular acceleration.

(c) **Combined Condition for Equilibrium**. For a body to be in **static equilibrium** (both translational and rotational), the following conditions must hold good simultaneously:

(i) The net force must be zero

(ii) The net torque must be zero

21. **Centre of Gravity (CG)**. **The** centre of gravity (CG) **is the** point at which the entire weight of an object is considered to act**.** The point through which the weight of an aircraft acts.

(a) An aircraft in flight is said to rotate around its CG.

(b) The CG of an aircraft must remain within certain forward and aft limits, for reasons of both stability and control. Example, If it is too far forward the aircraft becomes nose-heavy, making it hard to lift the nose. If it is too far aft (toward the tail) the aircraft becomes tail-heavy, which can lead to unstable flight and even loss of control.

22. Mechanical energy can be said to exist in two forms.

(a) **Potential Energy**. Potential energy is the capacity for doing work that a body possesses because of its position or condition.

PE = m·g·h where:

PE = potential energy (in joules)

m = mass (kg)

g = acceleration due to gravity (9.8 $m/s^2$ on Earth)

h = height above the ground (meters)

(b) **Kinetic Energy**. Unit - Joule (J) - 'The energy possessed by mass because of its motion'. 'A mass that is moving can do work in coming to rest'.

$KE = \frac{1}{2} mv^2$

KE = kinetic energy (in joules)

m = mass (kg)

v = velocity (m/s)

## PART II: LAWS OF MOTION

23. **Inertia**. A property of matter by which it remains at the state of rest or uniform motion in the same straight line unless acted upon by some external force. For an aircraft, this

means that an airplane wants to keep doing what it's already doing - whether that's flying straight, turning, climbing, or descending, unless something forces it to change.

24. **Newton's Laws of Motion**.

(a) **First Law**. A body will continue to be in state of rest or of uniform motion in a straight line unless acted upon by an external force. This property of all bodies is called inertia and a body in such a state is said to be in Equilibrium. This Law is also known as Law of Inertia. Examples in context of flight:-

(i) An aircraft **won't move** until a force (thrust) is applied.

(ii) In level flight, the aircraft keeps moving at a constant speed and direction unless pilots or outside forces (wind, drag, etc.) act on it.

(b) **Second Law**. The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction of the application of the said force. Examples in context of flight:-

(i) The more mass an aircraft has, the more force (thrust or lift) is needed to accelerate or change direction.

(ii) Explains why heavier aircraft need more runway to take off.

(c) **Newton's Third Law of Motion**. To every action, there is an equal and opposite reaction.

**Examples in Context of Flight**

(i) The engines push air **backward** → the aircraft moves **forward** (thrust).

(ii) The wings push air **downward** → the aircraft experiences **lift** upward.

(iii) Jet engines or propellers operate entirely on this principle—pushing air one way to move the aircraft the other way.

## PART III: STABILITY

25. **Stability in Flight**. Stability refers to how well an aircraft returns to its original flight path after it's disturbed—like by wind, turbulence, or control input. There are two main types of stability to understand:-

(a) **Static Stability**. Static stability is the aircraft's **initial reaction** to being disturbed from its original position. Example, Imagine a plane flying straight and level. A gust of wind **pitches the nose upward**.

Now observe: what does it do *immediately after*?

(i) **Positive Static Stability**. The aircraft starts to pitch back down toward its original position.

(ii) **Neutral Static Stability**. The aircraft stays at the new nose-up angle.

(iii) **Negative Static Stability**. The aircraft continues pitching up, moving further away from level.

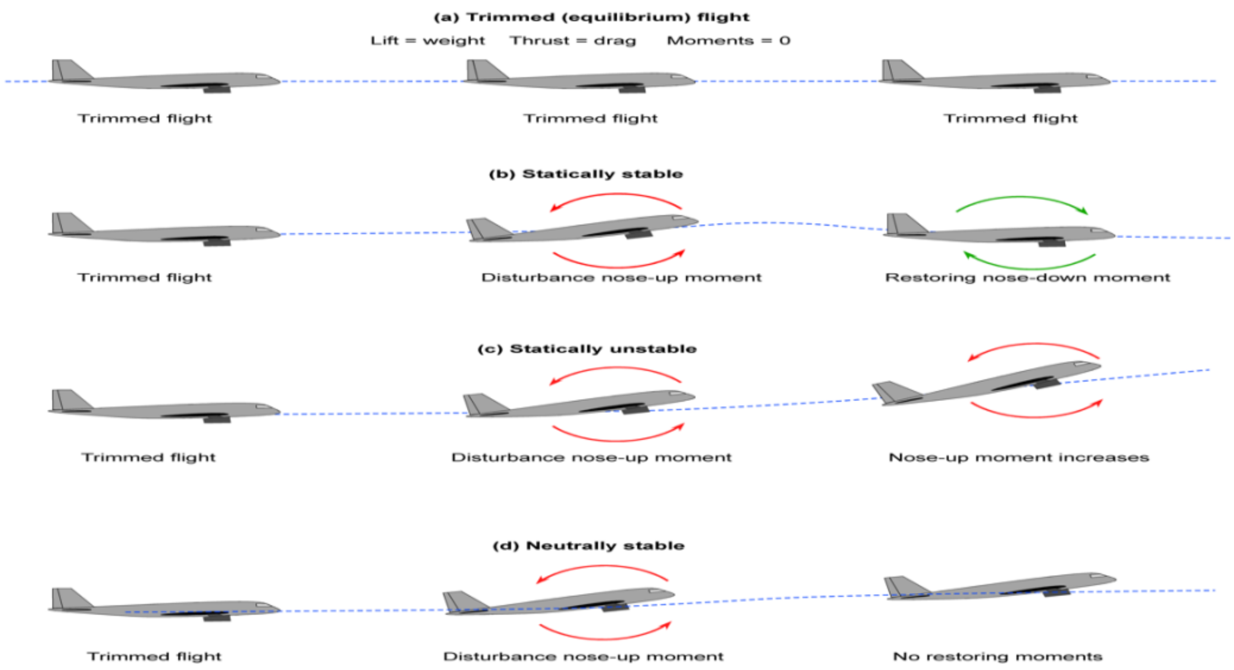
(iv) **Gist**. Static stability is about the **first response** to a disturbance.

(b) **Dynamic Stability**. Dynamic stability is how the aircraft behaves **over time** after the initial disturbance. Continuing from the same example—after the gust moves the nose up, and the aircraft begins to react:-

(i) **Positive Dynamic Stability**. The nose oscillates a bit, then settles back to level flight.

(ii) **Neutral Dynamic Stability**. The nose keeps oscillating without stopping.

(iii) **Negative Dynamic Stability**. The oscillations get worse over time, leading to a loss of control.




(iv) **Gist**. Dynamic stability is about the **long-term response**.

| Stability - Summary | | |
|---|---|---|
| **Concept** | **Definition** | **Remarks** |
| Static stability | Initial reaction to disturbance | Does it start to return to original position? |
| Dynamic Stability | Long-term behaviour after disturbance | Does it settle down or get worse over time? |

## CONCLUSION

26. Elementary mechanics, based on Newton's three laws of motion, forms the foundation for understanding how and why aircraft fly. The first law explains how an aircraft maintains its motion unless it is acted on by a force (like thrust or drag), the second law shows how mass and force determine acceleration (essential for take-off and climbing), and the third law explains how thrust works through action and reaction. These laws help us understand the balance of four main forces in flight**:** lift**,** weight**,** thrust**, and** drag**.**

27. Stability in flight depends on how the aircraft responds to disturbances. This is influenced by the centre of gravity (CG)**—**the point where weight is balanced—and the centre of pressure (CP)**—**where lift acts. For stable flight, CG should be slightly ahead of CP, allowing the aircraft to return to level after being disturbed. Understanding these principles is essential for designing, flying, and maintaining safe, controllable aircraft.

28. Basic definition of various terms i.e. Mass, Density, Motion, Speed, Velocity, Acceleration, Newton’s First Law of Motion, Momentum, Force, Pressure, Newton’s Third Law of Motion, Weight, Work, Power, Energy, Law of Conversation of Energy, Moment of a Force, Couple, and Equilibrium is to be understood by cadets.

29. Laws of motion, their application and correlation in aviation has been explained briefly and same needs to be understood by cadets

## ASSESSMENT EXERCISES

**Multiple-Choice Questions (MCQs)**

**1. Which of the following is the definition of density?**

(a) Mass per unit volume

(b) Force per unit area

(c) Mass multiplied by velocity

(d) Rate of doing work

**2. According to Newton's First Law of Motion, a body will remain in its state of rest or uniform motion unless?**

(a) It gains speed

(b) It is acted upon by an external force

(c) It has zero velocity

(d) It reaches its equilibrium point

**3. What is the unit of force?**

(a) Kilogram (kg)

(b) Newton (N)

(c) Joule (J)

(d) Watt (W)

**4. What is the formula for work done on a body?**

(a) Work = Mass × Velocity

(b) Work = Force × Distance

(c) Work = Force ÷ Time

(d) Work = Mass × Acceleration

**5. Velocity is speed in ___________direction?**

(a) Each

(b) All

(c) Particular

(d) Both

**6. Weight is the force of gravity acting on an object and this force pulls object towards___________?**

(a) Sky

(b) Earth

(c) Opposite direction

(d) Nowhere

**7. What is the unit of Power?**

(a) Watt (W)

(b) Newton (N)

(c) Joule (J)

(d) Kg

**8. Acceleration is equal to ______?**

(a) Force/ Weight

(b) Force/ Mass

(c) Force/ Time

(d) Force/ Distance

**9. Unit of kinetic energy is_______?**

(a) Watt (W)

(b) Newton (N)

(c) Joule (J)

(d) Kg

**10. Newton's first law of motion also known as _______?**

(a) Inertia

(b) Action-reaction

(c) Momentum

(d) None

**11. Newton's second law of motion also known as _______?**

(a) Inertia

(b) Action-reaction

(c) Quantitative law of motion

(d) None

**12. Newton's third law of motion also known as _______?**

(a) Inertia

(b) Action-reaction

(c) Quantitative law of motion

(d) None

**13. Law of conservation of energy is total sum of all energy in the universe remains _______?**

(a) Constant

(b) Changing

(c) Both (a) and (b) are correct

(d) None

**14. Newton’s second law of motion also known as _______?**

(a) Inertia

(b) Action-reaction

(c) Quantitative law of motion

(d) None

**15. An aircraft in flight is said to rotate around it’s _______?**

(a) Weight

(b) Centre of Gravity (CG)

(c) Both (a) and (b) are correct

(d) None

**<u>Short Question</u>**

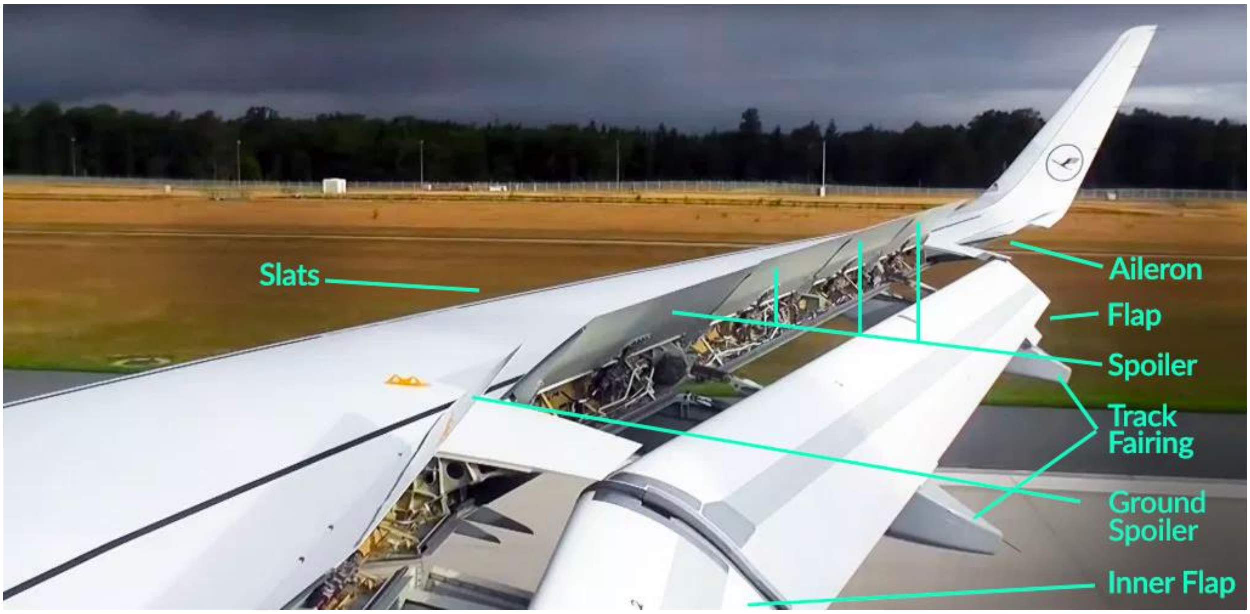
1. What do you mean by inertia and how it relate to Newton’s first law of motion?
2. What is equilibrium, and how forces play a vital role in it?
3. What do understand by stabilit
4. What is Centre of Gravity
5. Explain Torque and Momentum

**<u>Long Question</u>**

1. What is the difference between speed and velocity?
2. Explain Newton’s Third Law of Motion with an example.
3. Define kinetic energy and provide its formula.
4. Explain practical applications of laws of motion.
5. Establish a correlation of laws of motion in aviation.

# PRINCIPLES OF FLIGHT (SD/SW)

## CHAPTER II : AEROFOIL (BOA)

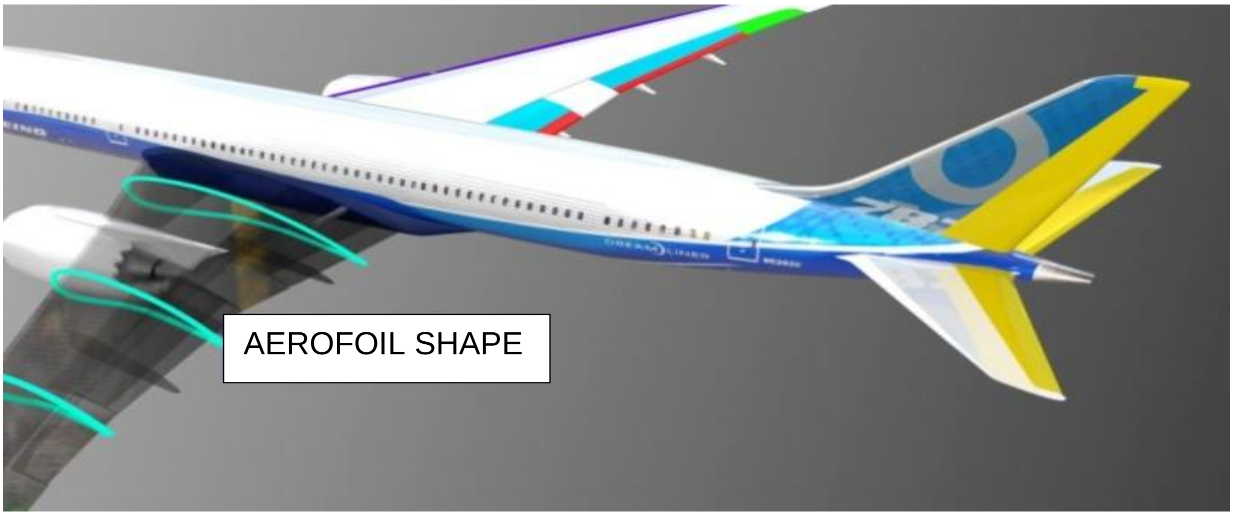



### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| Period | : | 3 (Three) |
| Type | : | Lecture |
| Year | : | 1st Yr SD/SW |
| Conducting Officer | : | Permanent Instructor |
| Training Aids | : | Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model. |
| Time Plan | | |
| • Introduction | : | 05 Mins |
| • Part I | : | 50 Mins |
| • Part II | : | 50 Mins |
| • Conclusion and Practice | : | 15 Mins |

## INTRODUCTION

1. An aerofoil is the shape of a wing or blade (of a propeller, rotor or turbine) or sail as seen in cross-section. They can also be defined as a foil that is designed to produce more lift than drag. An airfoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift. The component parallel to the direction of motion is called drag. Think of it as a specially curved surface that helps an aircraft rise into the air. It is one of the most important elements in aviation.




| PREVIEW | LEARNING OBJECTIVES |
|---|---|
| The lecture will be conducted in following parts:-<br>(a) Part I: Aerofoil<br>(b) Part II: Types of Aerofoil | Basic understanding of the Indian armed forces, their organisation and structure<br>➢ Lift generation.<br>➢ Parts of an aerofoil.<br>➢ Aerofoils and their types with usage. |

## PART I: AEROFOIL

2. A fixed-wing aircraft's wings, horizontal, and vertical stabilizers are built with airfoil-shaped cross sections, as are helicopter rotor blades. Airfoils are also found in propellers, fans, compressors, and turbines. Any object with an angle of attack in a moving fluid, such as a flat plate, will generate an aerodynamic force (called **lift**) perpendicular to the flow. Airfoils are more efficient lifting shapes-able to generate more lift (up to a point) and to generate lift with less drag.

3. You may not realize it, but aerofoils are all around us. Listed below are a few that you come across quite often.

(a) Aircraft wings-classic aerofoil design to generate lift.

(b) Fan blades- curved like small aerofoils to move air.

(c) Car spoilers- inverted aerofoils to increase downforce.

(d) Wind turbine blades- use wind like an aerofoil to generate energy.

(e) Ceiling fans- designed with aerofoil shape for efficient airflow.

4. **Why do Airplanes need Aerofoils**. Do you know that the Zen Air & Pipistrel SW-80 Virus are both powered by 80 HP Rotax engines? The engine of a common Sedan (Maruti Dzire) also has the same power output. So how is it that your microlight can take flight while the car cannot? The propeller or thrust producing device is not the answer. Fitting a propeller to the car will not necessarily make it fly. Aircraft fly because of the **lift** generated by their wings, and that is due to the **aerofoil shape**. Here's how it works:-

(a) When air flows over the curved top of the wing and the flatter bottom, it travels faster over the top.

(b) This creates **low pressure on top and high-pressure underneath**, pushing the wing **upward** – this is called **lift**.

(c) Without this effect, an aircraft would not be able to **take off, stay in the air, or manoeuvre**. We will study more about this in the subsequent chapters.

5. **Technical Definitions**. Parts of an Aerofoil are:-

(a) **Leading Edge**. The foremost/ forward edge of the aerofoil where the relative airflow first makes contact.

(i) It is typically rounded to reduce the chances of flow separation.

(ii) Plays a crucial role in maintaining smooth airflow and reducing drag.

(b) **Trailing Edge**. The aft edge of the aerofoil where the airflow over the upper and lower surfaces meets.

(i) It is usually sharp, allowing for a clean separation of the airflow.

(c) **Chord Line**. An imaginary straight line joining the leading edge and trailing edge of the aerofoil.

(i) It serves as the reference line for defining angles such as angle of attack (AoA).

(ii) The length of the chord line is referred to as the chord length.

(d) **Mean Camber Line**. A line equidistant from the upper and lower surfaces of the aerofoil.

(i) The shape of the camber line determines the lift characteristics and stability.

(e) **Camber**. The maximum distance between the mean camber line and the chord line.

(i) A positive camber means more curvature, which increases lift.

(f) **Thickness**. The maximum vertical distance between the upper and lower surfaces of the aerofoil.

(i) It affects the structural strength, drag, and aerodynamic behaviour.

(ii) The location of maximum thickness is critical (usually between 25–35% of chord from leading edge).

(g) **Upper Surface**. The top curved portion of the aerofoil where the airflow typically moves faster, resulting in lower pressure (Bernoulli's principle).

(i) Contributes most to the lift generation.

(h) **Lower Surface**. The bottom surface of the aerofoil which usually has less curvature and experiences higher pressure.

(i) Works together with the upper surface to produce net lift.

(j) **Angle of Attack (AoA)**. The angle between the chord line and the oncoming airflow (relative wind).

(i) It directly influences the amount of lift and stall characteristics.

(ii) Every aerofoil has a critical AoA beyond which stall occurs.

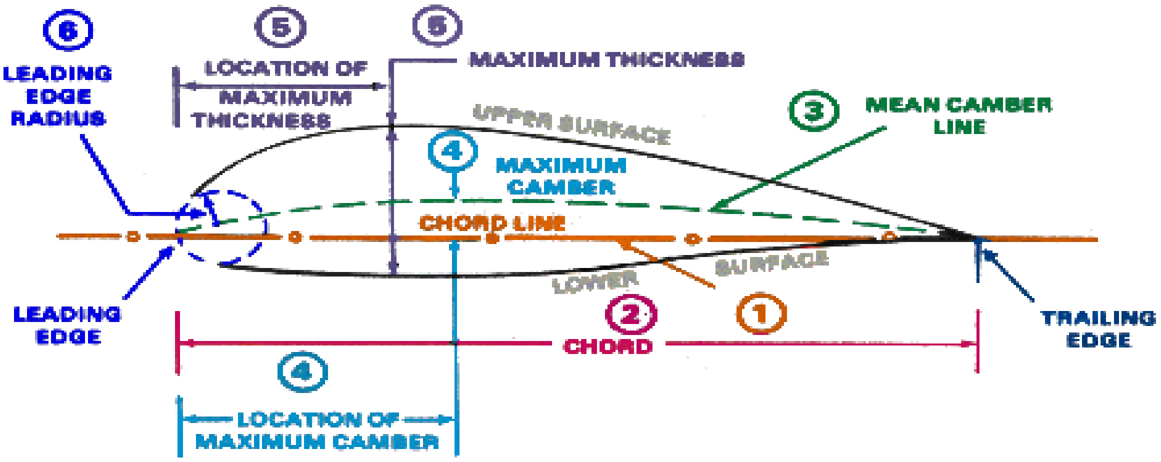



FIGURE 2-10. AIRFOIL TERMINOLOGY.

**DID YOU KNOW?**

Daniel Bernoulli was an 18th-century Swiss mathematician and physicist known for his contribution to fluid dynamics, which explains how a fluid's pressure and velocity are related. This principle is vital for understanding how air moves around airplane wings. It is crucial for understanding the principle of flight.

## PARTII: TYPES OF AEROFOIL

6. Aerofoils are designed for different missions and flight conditions. There exist a wide variety of aerofoils including laminar aerofoils (used in experimental aircraft), supercritical aerofoil (utilised in aerofoils designed to operate in supersonic regime) etc. However, the basic classification based on their purpose, is listed below.

(a) **High-Lift Aerofoils**. These aerofoils are specially designed to generate maximum lift, even at low speeds.

(i) **Use**. Gliders, short take-off and landing (STOL) aircraft, agricultural planes.

(ii) **Features**. Highly curved (cambered), thick, sometimes with flaps or slats to increase lift.

(b) **General-Purpose Aerofoils**. Balanced aerofoils that offer a mix of lift, stability, and speed – suitable for everyday flight conditions.

(i) **Use**. Commercial airliners, training aircraft, cargo planes.

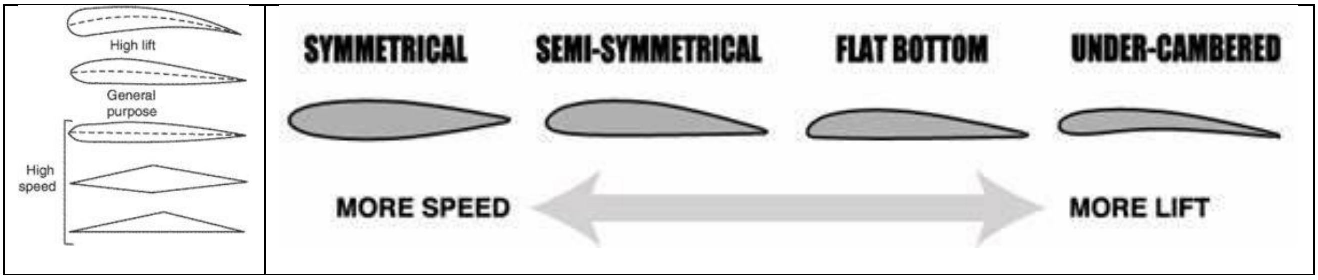
(ii) **Features**. Moderate camber, efficient at a wide range of speeds.

(c) **High-Speed Aerofoils**.

**Definition**. Designed to reduce drag and perform well at high subsonic or supersonic speeds.

(i) **Used in**. Fighter jets, supersonic aircraft, high-speed transports.

(ii) **Features**. Thin profile, swept-back design, sometimes use supercritical aerofoil shapes.




**DID YOU KNOW?**

A thin layer of contamination on an aircraft surface can increase drag, which can make the aircraft less efficient and increase fuel consumption. Ice is particularly dangerous because it can change the wing's shape and increase the plane's weight.

**INTERESTING FACTS**

- Sir, George Cayley invented the aerofoil.
- Airfoils are also used in the design of rotor blades and wind turbines.
- Supersonic airfoils are much more angular in shape and can have a very sharp leading edge, which is very sensitive to angle of attack.
- A supercritical airfoil has its maximum thickness close to the leading edge to have a lot of length to slowly shock the supersonic flow back to subsonic speeds.
- Modern aircraft wings may have different airfoil sections along the wing span, each one optimized for the conditions in each section of the wing.

## CONCLUSION

7. An airfoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift.

8. There are different types of airfoils such as symmetric, asymmetric, supersonic, and supercritical.

9. Aerodynamic lift and drag are forces that affect an object's movement through the air.

10. Aerofoils create lift by forcing air to travel further over the top of the wing than the bottom, which creates lower air pressure and an upward force on the wing.

11. Aerofoils also create drag, which acts in the same direction as the airstream.

12. Aerofoils are designed for different missions and flight conditions.

## ASSESSMENT EXERCISES

**Multiple Choice questions (MCQs)**

**1. Who has invented the airfoil?**

(a) Sir George Cayley

(b) Isaac Newton

(c) Elbert Einstein

(d) Thomas Addison

**2. Following are the types of airfoil?**

(a) Symmetric

(b) Asymmetric

(c) None of the above

(d) Both (a) and (b) are correct

**3. A thin layer of contamination on air craft surface can increase drag?**

(a) True (b) False

**4. Airfoils create lift and can also create drag as well?**

(a) True (b) False

**5. At low speeds, an aircraft needs to generate ____________with a ____________angle of attack, which results in more induced drag?**

(a) Lift, Higher

(b) Drag, Lower

(c) Both (a) and (b) is correct

(d) None of the above

**6. Flaps also increase ____________, which helps slow plane down?**

(a) Drag

(b) Lift

(c) None of the above

(d) (a) & (b) both are correct

**7. Ailerons are flaps near the back of each wing that control ___________and ___________to make plane roll?**

(a) Lift, Drag

(b) Weight, Thrust

(c) None of the above

(d) (a) & (b) both are correct

**8. Aerofoils can help aircraft fly at high speeds by displacing air, using supercritical airfoils and designing supersonic airfoils?**

(a) True (b) False

**9. ____________ airfoils are much more angular in shape and can have a very sharp leading edge, which is very sensitive to angle of attack?**

(a) Supersonic

(b) Subsonic

(c) Supercritical

(d) Transonic

**10. When an object generates lift, it also creates ___________?**

(a) Induced drag

(b) Thrust

(c) High lift

(d) None

**11. Aerofoils also Creates drag and it acts on ___________direction as the airstream?**

(a) Same

(b) Opposite

(c) Upward

(d) Downward

**12. An airfoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force___________to the direction of motion is called lift?**

(a) Perpendicular

(b) Opposite

(c) Upward

(d) Downward

**13. Changing a wing's ___________affects the speed of the air flowing over the wing and the amount of lift that the wing creates**?

(a) Color

(b) Angle of attack

(c) None of the above

(d) (a) & (b) both are correct

**<u>Short Question</u>**

1. What is difference between chord line and camber line?
2. What do you understand by symmetrical aerofoil?
3. What is the purpose of high speed aerofoil?
4. What is mean camber line?
5. Helicopter blades are aerofoil explain how?

**<u>Long Question</u>**

1. What is an aerofoil and its application in aviation?
2. Types of aerofoil and explain them briefly?
3. Define lift & drag and their role in aviation?
4. Briefly explain aerodynamics affecting lift & drag?
5. How aerofoil provides high lift, medium lift, and high speed?

# PRINCIPLES OF FLIGHT (SD/SW)

## CHAPTER III : FORCES ON AIRCRAFT (FOA)


## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **2 (Two)** |
| **Type** | **:** | **Lecture** |
| **Year** | **:** | **1st Yr SD/SW** |
| **Conducting Officer** | **:** | **Permanent Instructor** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction** | **:** | **05 Mins** |
| • **Part I** | **:** | **20 Mins** |
| • **Part II** | **:** | **20 Mins** |
| • **Part III** | **:** | **20 Mins** |
| • **Conclusion, and Practice** | **:** | **15 Mins** |

## INTRODUCTION

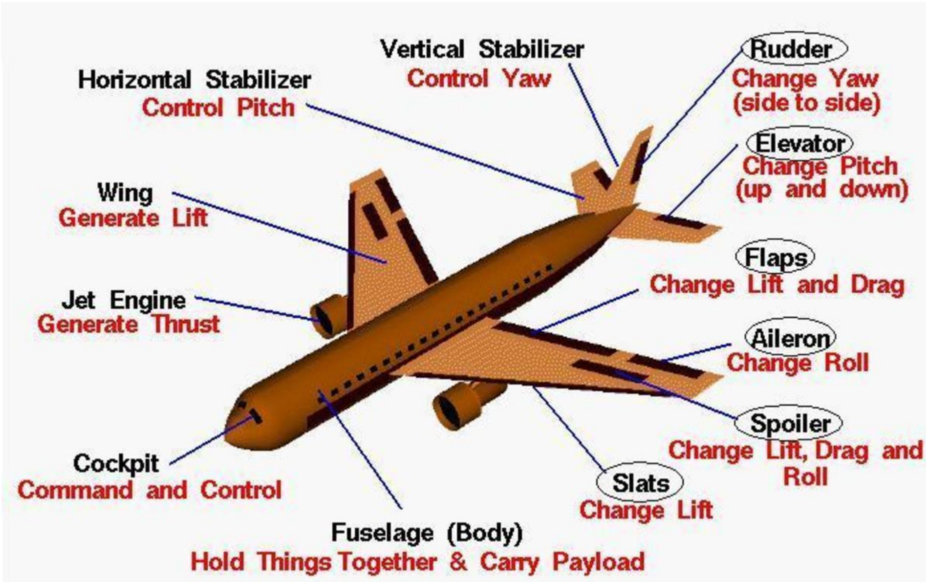
1. An aircraft is considered to be in **straight and level flight** when it is flying at a constant altitude and speed, maintaining lateral level and direction. When an aircraft is in flight, it is constantly acted upon by four fundamental aerodynamic forces. These forces determine whether an aircraft climbs, descends, or stays level in the air. To maintain steady, level flight, **all four forces must be in balance**. These forces are:-

(a) Lift.

(b) Drag.

(c) Thrust.

(d) Weight (Gravity).




## PREVIEW

The lecture will be covered in the following parts:-

(a) Part I: Forces acting on Aircraft

(b) Part II: Understanding Lift

(c) Part III: How does an Aircraft fly?

## LEARNING OBJECTIVES

- Various forces acting on aircraft.
- To understand the aerodynamic principles behind flight, including the generation of lift through Bernoulli's principle and the Venturi effect, and how the four aerodynamic forces—lift, weight, thrust, and drag—interact to maintain controlled and stable flight.
- Applying aerodynamic principles to understand flight.

## PART I: FORCES ACTING ON AIRCRAFT


2. **Lift**. It is a positive force caused by the difference in air pressure under and above a wing. The higher air pressure beneath a wing creates lift, and it is affected by the shape of the wing. Changing a wing's angle of attack affects the speed of the air flowing over the wing and the amount of lift that the wing creates.

3. **Weight**. It is the force that causes objects to fall downwards. In flight, the force of weight is countered by the forces of lift and thrust.

4. **Thrust**. It is the force that propels an object forward. An engine spinning a propeller or a jet engine expelling hot air out the tailpipe are examples of thrust. In birds and bats, thrust is created by muscles making the wings flap.

5. **Drag**. It is the resistance of the air to anything moving through it. Different wing shapes greatly affect drag. Air divides smoothly around a wing's rounded leading edge and flows neatly off its tapered trailing edge — this is called streamlining. There are two main types of drag, Zero lift drag (depends on the shape of the aerofoil) and Lift-dependent drag (induced when lift is being produced)

| **Force** | **Direction** | **Description** |
|---|---|---|
| Lift | Upward | Acts perpendicular to relative airflow; generated by pressure differences on the wing surfaces. **Acts through Centre of Pressure (CP)** |
| Weight | Downward | Caused by gravity, acts through the aircraft's **centre of gravity (CG)**. |
| Thrust | Forward | Propulsive force generated by engines or propellers to overcome drag. |
| Drag | Rearward | Aerodynamic resistance opposing motion |

**DID YOU KNOW?**

**Bernoulli's principle** explains how an airplane can stay in the air, and it's fascinating to think that the simple act of air moving over the curved surface of a wing can create enough **lift** to keep an airplane airborne.

## PART II: UNDERSTANDING LIFT

6. **Bernoulli's Principle**. Bernoulli's principle is based on the principle of the conservation of energy. It states that the total sum of the pressure energy, kinetic energy and potential energy of the fluid flow is constant. It also implies that for an in viscid & incompressible flow, an increase in the speed of the fluid occurs simultaneously with a decrease in pressure or a decrease in the fluid's potential energy. We can therefore safely conclude that in a steady, incompressible flow, an increase in the fluid's velocity leads to a decrease in its static pressure. Over the wing:-

(a) Faster airflow above → lower pressure

(b) Slower airflow below → higher pressure

(c) The pressure differential results in a net upward force—Lift.

7. **Venturi Effect**. A short piece of narrow tube between wider sections is called a venturi. In the narrow section the air speeds up, causing the static pressure to decrease. The Venturi effect describes how a fluid's velocity increases, and pressure decreases when it flows through a narrowed (constricted) section of a tube or passage.

**How?** Based on the Principle of Continuity an incompressible fluid flow (a valid assumption at subsonic speeds), mass flow rate must remain constant along a streamline.

The continuity equation states $\rho AV = constant$

Where:-

(a) $\rho$ = Air density ($kg/m^3$)

(b) A = Cross-sectional area ($m^2$)

(c) V = Air velocity (m/s)

**What this Means**.

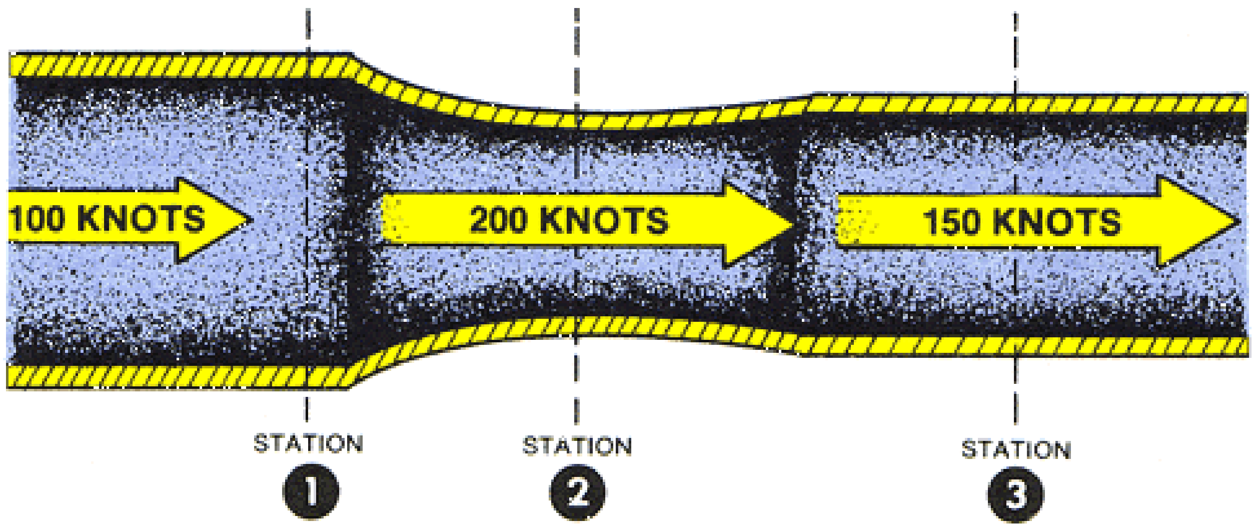
(a) If air flows into a narrower space (smaller A), and ρ remains constant then as area decreases, velocity must increase to keep the flow rate constant.

(b) $A\downarrow \Rightarrow V\uparrow$

At low flight speeds, air experiences relatively small changes in pressure and negligible changes in density. This airflow is termed incompressible since the air may undergo changes in pressure without apparent changes in density. Such airflow is similar to the flow of water, hydraulic fluid, or any other incompressible fluid. This suggests that between any two points in the tube, the velocity varies inversely with the area. Venturi effect is the name used to describe this phenomenon. Fluid flow speeds up through the restricted area of a venturi in direct proportion to the reduction in area. The Venturi effect states that when air flows through a narrower passage, it speeds up, and its pressure drops.

Think of squeezing a garden hose—the water comes out faster and thinner.

The Figure below suggests what happens to the speed of the flow through the tube discussed.

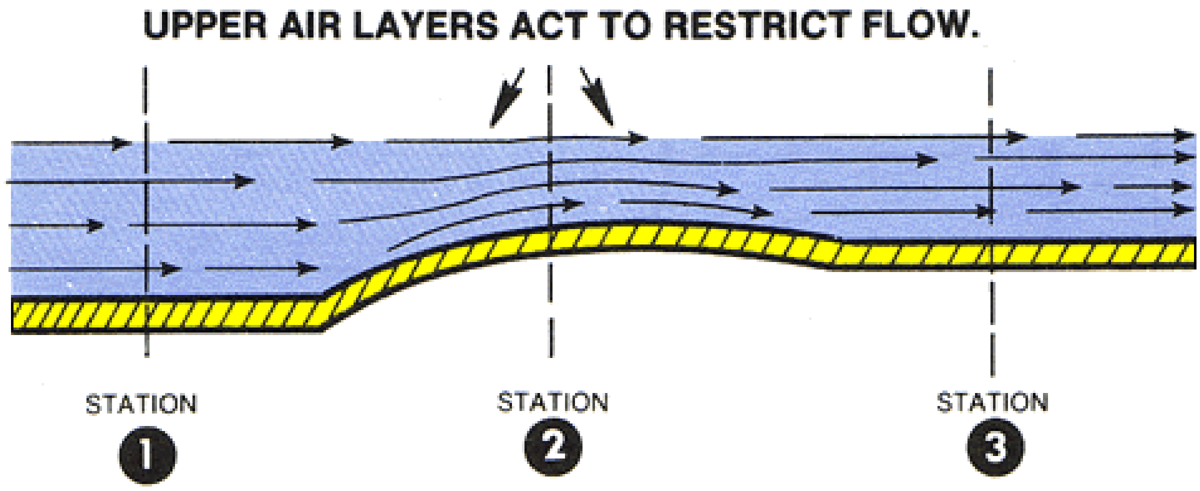



*Venturi effect.*

8. Also note that the **total energy** in a given closed system does not change, but the **form of the energy may be altered**. The **pressure of the flowing air** may be likened to energy in that the **total pressure of flowing air** will always remain constant unless energy is added to or taken from the flow. In the previous examples, there is **no addition or subtraction of energy**; therefore, the **total pressure will remain constant**.

9. **Fluid flow pressure** is made up of two components — **static pressure** and **dynamic pressure**. **Static Pressure** is that measured by an aneroid barometer placed in the flow but **not moving** with the flow. **Dynamic Pressure** is that component of total pressure due to the **motion of the air**. It is difficult to measure directly, but a **Pitot-static tube** measures it indirectly. The **sum of these two pressures** is known as the **total pressure**.

10. **Static Pressure Decreases as the Velocity Increases**. This is what happens to air passing over the curved top of an aircraft's airfoil. Consider only the bottom half of a **Venturi tube** in the figure below. Notice how the shape of the restricted area at **Station 2** resembles the top surface of an airfoil. Even when the top half of the Venturi tube is taken away, the air still accelerates over the curved shape of the bottom half. This happens because the **air layers restrict the flow**, just as the top half of the Venturi tube did. As a result, **acceleration causes decreased static pressure above the curved shape of the tube**. A **pressure differential force** is generated by the local variation of **static and dynamic pressures** on the curved surface.




*Venturi flow.*

11. **Application to a Wing (Airfoil)**.

(a) The **top of a wing** is **curved**, causing the airflow path to become **narrow**, just like a Venturi tube:

(i) Air **speeds up** over the curved top surface → $V_{top}\uparrow$

(ii) Static pressure drops over the top → $P_{top}\downarrow$

(b) The bottom of the aerofoil (wing) is less curved (lower camber) as compared to the top.

(i) Bottom surface has **slower airflow**, **higher pressure**relative to top of the aerofoil

(ii) → $P_{bottom} > P_{top}$

(c) This pressure difference creates **net upward force** = **Lift**.

12. **Equation of Lift**. The **lift force** produced by a wing or airfoil is given by the

**Lift Equation**. Lift = $\frac{1}{2}\rho V^2 S C_L$. Explanation is given in succeeding sub-paragraphs.

| Symbol | Term | Unit | Description |
|---|---|---|---|
| L | Lift | Newton (N) | Vertical component of Total Reaction |
| ρ | Air Density | $Kg/m^3$ | |
| V | True Airspeed | m/s | |
| S | Wing surface area | $m^2$ | |
| $C_L$ | Coefficient of lift | Dimensionless | Depends mainly on aerofoil shape, surface condition &AoA |

(a) **Air Density (ρ)**.

(i) Higher air density → **more lift** (since more air molecules interact with the wing).

(ii) **Affected by**.

(aa) Altitude (higher altitude → thinner air → lower density)

(bb) Temperature (hot air is less dense)

(cc) Humidity (more moisture → less dense air)

Lift decreases at high altitude or in hot/humid conditions.

(b) **True Airspeed (V)**.

(i) Lift is proportional to the square of the velocity.

(ii) Doubling the airspeed quadruples the lift.

(iii) High speed → more air flows over the wings per second → greater pressure difference → more lift**.**

(c) **Wing Surface Area (S)**.

(i) Larger wing area → more surface to generate lift.

(ii) Aircraft with high wing loading (small Srelative to weight) need **more** speed to generate required lift.

(d) **Coefficient of Lift ($C_L$)**.

(i) Depends on:

(aa) Angle of Attack (AoA) (higher AoA → higher $C_L$ - up to critical AoA)

(bb) Wing shape (airfoil) – cambered surfaces have higher base $C_L$

(cc) Flap settings – deploying flaps increases $C_L$

(ii) There is a maximum $C_L$ just before the point when the aircraft stalls (where airflow separates and lift drops suddenly).

**Summary: How Each Term Affects Lift**

| **Variable** | **Value** | **Effect on Lift** |
|---|---|---|
| ρ (air density) | Increases | Lift increases |
| V(airspeed) | Increases | Lift increases significantly (squared effect) |
| S (wing area) | Increases | Lift increases |
| $C_L$(lift coefficient) | Increases (via AoA or lift augmentation device) | Lift increases—up to stall point**(critical AoA)** |

## PART III: HOW DOES AN AIRCRAFT FLY?

### Interaction of Forces in Flight: How an Aircraft Flies

13. When an aircraft is flying, it is constantly affected by four main aerodynamic forces: lift, weight, thrust, and drag. These forces work in pairs, pulling or pushing the aircraft in opposite directions. Lift is the upward force generated by the wings as air flows over them—it must overcome the aircraft's weight, which is the force of gravity pulling it down. Thrust is the forward force provided by the aircraft's engines or propellers, and it has to overcome drag, which is the resistance caused by air pushing back against the aircraft's movement.

14. These forces form two important force couples (equal opposite & parallel forces); the **lift-weight couple** and the **thrust-drag couple**. When both couples are balanced—lift equals weight, and thrust equals drag—the aircraft will fly in a straight line at a constant speed and altitude. This is known as steady level flight.

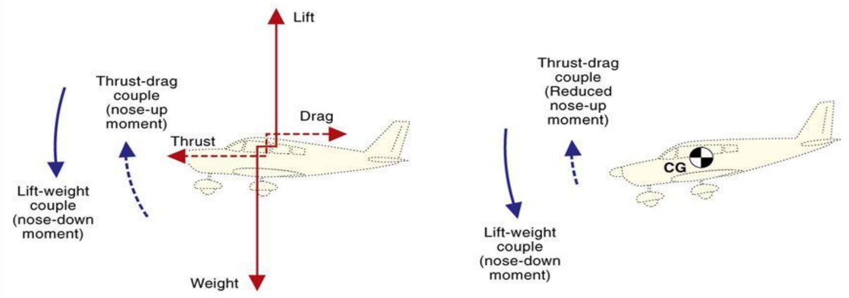



**Figure 2-10.** Following a loss of thrust the lift–weight couple pitches the airplane nose-down.

## INTERACTION OF FORCES IN FLIGHT

### Flight Phases and How the Forces Interact

15. During take-off, the engines provide more thrust than drag, and the aircraft speeds up along the runway. As the speed increases, more air flows over the wings, which increases lift. Once lift becomes equal to or greater than the aircraft's weight, the plane can lift off the ground.

16. The aircraft then enters the climb phase, where lift still exceeds weight, and thrust is greater than drag, allowing it to gain altitude.

17. In cruise flight, as the aircraft reaches a desired altitude, the pilot reduces the engine power and levels out. At this point, lift equals weight and thrust equals drag. The aircraft moves forward at a constant speed, and there's no net change in altitude or acceleration.

18. To descend, the pilot reduces the engine power, meaning thrust is now less than drag. This will result in a reduction in airspeed unless the pilot lowers the attitude to maintain airspeed which results in decreased AoA. The aircraft's weight is greater than the lift being produced, so it starts to come down. The rate of descent is controlled using the angle of the nose (called pitch) and throttle settings.

19. Finally, during landing, decrease the thrust (reduce throttle) slow down use brakes & drag chutes to bring the aircraft to a stop.

20. This is a simplified explanation of the interaction of forces in flight. However, it may be understood that the interplay of the forces is not as simple. For example, an aircraft or a rocket that can fly by utilizing thrust alone. The flight of a rocket without wings and a fixed wing aircraft in pure vertical flight (**remember lift is perpendicular to relative air flow, so in a pure vertical flight lift will not be acting upwards**) are examples where thrust is utilised to overcome both drag and weight.

## CONCLUSION

21. Understanding how an aircraft flies begins with grasping the interaction of the four fundamental aerodynamic forces: lift, weight, thrust, and drag. These forces constantly act on the aircraft during flight and must be managed and balanced through different phases, from take-off to landing. These forces interact as two opposing pairs (force couples): lift vs weight and thrust vs drag. By controlling these, pilots can change altitude, speed, and flight direction. Throughout the flight, from take-off (where lift and thrust exceed weight and drag), to climb, level flight, descent, and finally landing, these forces are continuously adjusted. Aircraft design, pilot control inputs, and environmental conditions all influence how these forces behave.

(a) Four main aerodynamic forces act on an aircraft.

(b) Lift (upward), Weight (downward), Thrust (forward), Drag (rearward).

(c) Lift vs Weight.

(d) Lift must overcome weight for take-off and climb.

(e) In level flight, lift equals weight.

(f) Thrust vs Drag.

(g) Thrust must exceed drag to accelerate or climb.

(h) In cruise, thrust equals drag for steady speed.

(j) Lift is generated by airflow over the wings, explained by Bernoulli's Principle and the Venturi Effect.

(k) Pilots control angle of attack, thrust, and flight control surfaces to manage these forces.

## ASSESSMENT EXERCISES

**Objective Questions (Tick the correct option)**

1. Which force opposes the aircraft's motion through the air?

   (a) Lift (b) Thrust (c) Drag (d) Weight

2. What must happen for an aircraft to take off?

   (a) Weight must be greater than lift

   (b) Thrust must equal drag

   (c) Lift must be equal to weight

   (d) Lift must be greater than weight

3. According to Bernoulli's principle, an increase in airflow speed leads to?

   (a) Increase in pressure

   (b) Decrease in pressure

   (c) No change in pressure

   (d) Constant velocity

4. In the Venturi effect, as the area of a passage decreases, airflow velocity?

   (a) Increases

   (b) Decreases

   (c) Remains constant

   (d) Stops completely

5. Which of these is not one of the four forces of flight?

   (a) Lift (b) Drag (c) Gravity (d) Momentum

**Short Answer Questions**

1. What are the four main aerodynamic forces acting on an aircraft in flight?
2. Define lift and explain how it is generated on a wing.
3. What is the Venturi effect and how does it apply to flight?
4. How do thrust and drag interact during level flight?

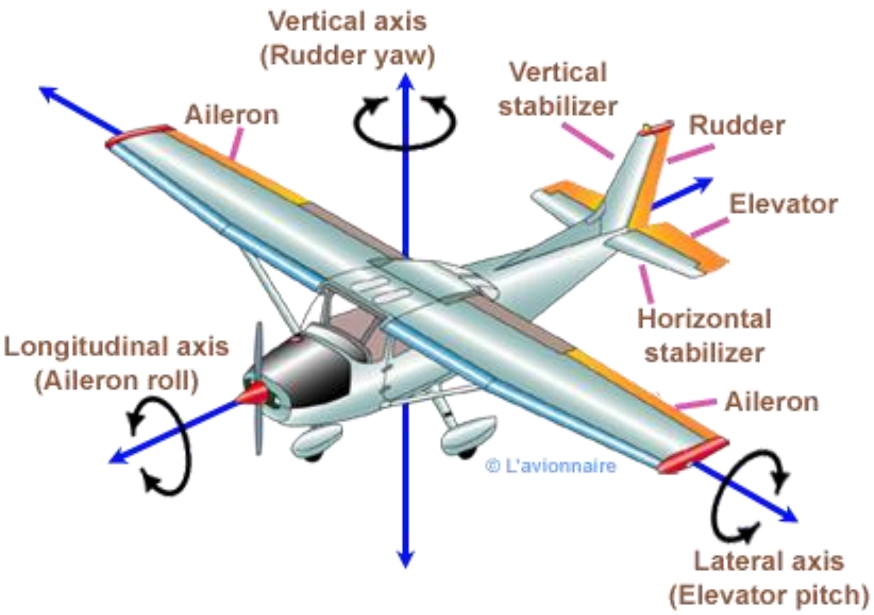
**Long Answer Questions**

1. Explain in detail how an aircraft flies by describing the interaction between lift, weight, thrust, and drag. Use an example of take-off, cruise, and landing.

2. Describe the role of the lift–weight and thrust–drag couples. How do pilots manage these forces to control the aircraft during different phases of flight?

# PRINCIPLES OF FLIGHT (SD/SW)

## CHAPTER IV : AIRCRAFT CONTROLS (AC)




## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **1 (One)** |
| **Type** | **:** | **Lecture** |
| **Year** | **:** | **1st Yr SD/SW** |
| **Conducting Officer** | **:** | **Permanent Instructor** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction** | **:** | **05 Mins** |
| • **Part I** | **:** | **15 Mins** |
| • **Part II** | **:** | **15 Mins** |
| • **Conclusion and Practice** | **:** | **05 Mins** |

## INTRODUCTION

1. A pilot needs to manoeuvre the aircraft about three axes:-

(a) Longitudinal or Fore & aft. Moment about longitudinal axis is called rolling.

(b) Lateral. Moment about lateral axis is pitching.

(c) Vertical. Moment about vertical axis is called yawing.

2. All aircraft have to be fitted with a control system that will enable the pilot to manoeuvre the aircraft in flight about each of its three axes. The aerodynamic moments required to rotate the aircraft about each of these axes are usually produced by means control surfaces positioned at the extremities of the aircraft so that they have the longest possible moment arm about the CG. There are usually three separate control systems and three sets of primary control surfaces, namely:-

(a) Rudder for control in yaw.

(b) Elevator for control in pitch.

(c) Ailerons for control in roll.

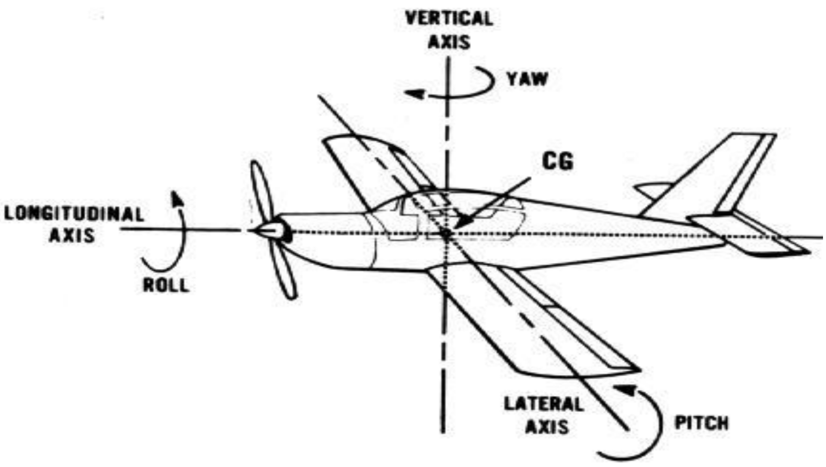



Figure 3–8 Axes of the Airplane

### PREVIEW

The lecture will be covered in the following parts:-

(a) Part I: Primary Controls

(b) Part II: Secondary Controls

### LEARNING OBJECTIVES

- Understanding aircraft controls.
- Differentiate between primary & secondary controls.
- Functioning of primary controls
- Functioning of secondary controls

3. A conventional wing aircraft flight control system consists of flight control surfaces, the respective cockpit controls, connecting linkages, and the necessary operating mechanisms to control an aircraft's direction in flight. Aircraft engine controls are also considered as flight controls as they change speed. Generally basic aircraft control can be classified as follows **Primary controls and Secondary controls.**

4. The basic aircraft controls of conventional fixed wing aircraft are as follows:-

(a) A control yoke (also known as a control column), centre stick or side-stick governs the aircraft's roll and pitch by moving the ailerons, when turned or deflected left and right and moves the elevators when moved backwards or forwards.

(b) Rudder pedals, to control yaw, which move the rudder; left foot forward will move the rudder left for instance.

(c) Throttle controls to control engine speed or thrust for powered aircraft.

5. In an aircraft, the **primary flight controls** are responsible for controlling the aircraft’s basic orientation and movement around its three axes: pitch, roll, and yaw. These controls include the **ailerons**, **elevators**, and **rudder**. The ailerons, located on the wings, control roll by tilting the aircraft left or right. The elevators, mounted on the horizontal stabilizer, control pitch, allowing the nose of the aircraft to move up or down. The rudder, on the vertical stabilizer, manages yaw, which moves the nose left or right. These surfaces are essential for normal flight; without them, a pilot cannot safely manoeuvre the aircraft.

6. On the other hand, **secondary or auxiliary controls** assist the primary controls and enhance the aircraft’s performance, efficiency, and safety during specific phases of flight. These include **flaps**, **slats**, **spoilers**, **trim tabs**, and **speed brakes/ air brakes**. For instance, flaps and slats are used during takeoff and landing to increase lift at lower speeds. Spoilers and speed brakes help reduce speed and altitude more efficiently. Trim tabs are small surfaces that reduce the need for constant control input by the pilot, helping maintain steady flight.

7. The key difference between the two is that primary controls are essential for flying and manoeuvring the aircraft, while secondary controls support and fine-tune the flight experience, particularly during complex or transitional phases like take-off, descent, or landing.

8. **<u>What are Primary Controls</u>**. Primary controls are the **main flight control systems** that allow a pilot to control the aircraft’s orientation and movement along its three axes: **pitch, roll, and yaw**. These are essential for basic flight manoeuvres such as climbing, turning, and descending. There are **three main primary control surfaces**, each affecting a specific axis of movement:-

(a) **Elevators**.

(i) Located on the horizontal stabilizer (tail)

(ii) **Controls**. Pitch (nose up/down)

(iii) **Axis**. Lateral axis (side-to-side)

(iv) **Effect**. Raises or lowers the nose of the aircraft

(b) **Ailerons**.

(i) Located on the trailing edge of the wings, near the tips

(ii) **Controls**. Roll (tilting wings left/right)

(iii) **Axis**. Longitudinal axis (nose to tail)

(iv) **Effect**. One aileron goes up while the other goes down, resulting in a rolling moment

(c) **Rudder**.

(i) Located on the vertical stabilizer (fin)

(ii) **Controls**. Yaw (nose left/right)

(iii) **Axis**. Vertical axis

(iv) **Effect**. Turns the aircraft left or right (side-to-side motion)

9. It is desirable that each set of control surfaces should produce a moment only about the corresponding axis. In practice, however, moments are often produced about the other axes as well, ie. adverse yaw due to aileron deflection. On some aircraft the effect of two of these controls is combined in a single set of control surfaces. Examples of such combinations include:-

(a) Elevons combine the effects of ailerons and elevators.

(b) Ruddervator is a Vee or butterfly tail, combining the effects of rudder and elevators.

(c) Tailerons are slab tail surfaces that move either together, as pitch control, or independently for control in roll.

10. **What are Secondary or Auxiliary Flight Controls**.

They are additional controls used to assist or enhance the performance of primary controls, improve efficiency, and aid specific phases of flight (e.g., takeoff, landing, trim). They are not essential for basic control, but they significantly improve handling, stability, and safety.

Few important secondary controls and their utility are listed below.

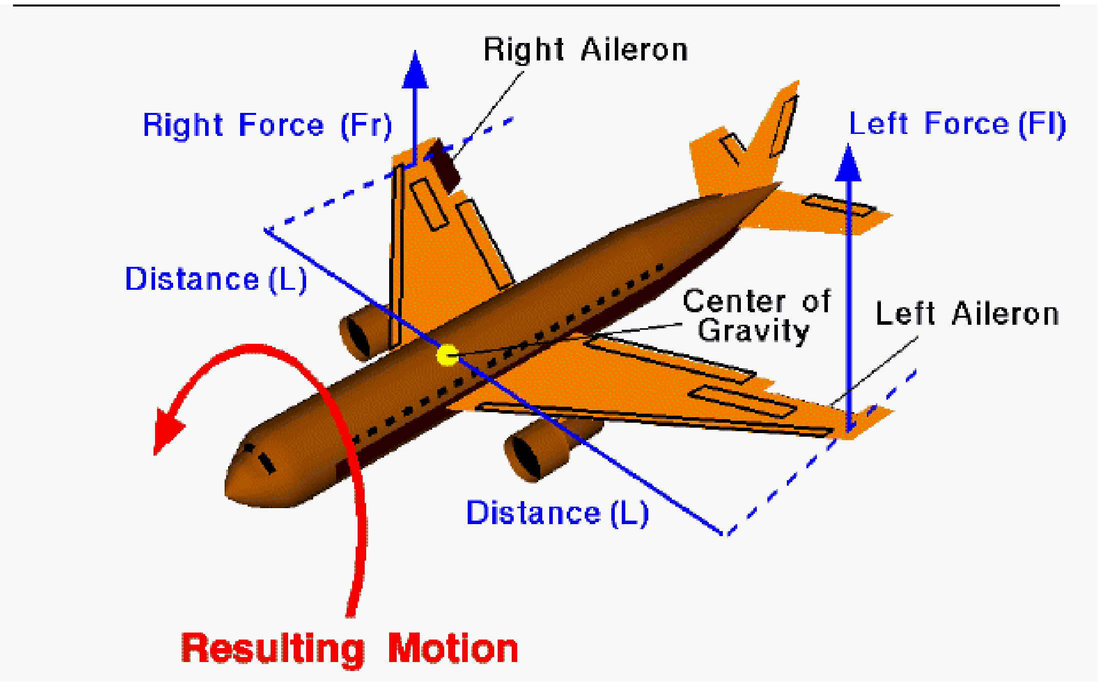
| **Surface** | **Purpose/Effect** |
|---|---|
| **Flaps** | Increase lift and drag—used during takeoff/landing |
| **Slats** | Improve airflow over wings at low speeds |
| **Spoilers** | Reduce lift and increase drag (help descend/slow) |
| **Trim Tabs** | Relieve control forces—help maintain steady flight |
| **Speed Brakes** | Increase drag to reduce speed rapidly |
| **Leading-edge Devices** | Delay stall by improving airflow over the wing |

11. **Difference between Primary and Secondary (Auxiliary) Controls in Aircraft**

| **Aspect** | **Primary Controls** | **Secondary/Auxiliary Controls** |
|---|---|---|
| **Main Function** | Control pitch, roll, yaw (attitude) | Support, fine-tune, or enhance flight |
| **Essential?** | Yes – Required for basic flight | No – But important for performance/safety |
| **Examples** | Ailerons, elevators, rudder | Flaps, slats, spoilers, trim tabs, etc. |

## PART I : PRIMARY CONTROLS

12. **How does an Aileron Work.** When you move the **control stick** or **yoke** to the left or right, you're sending a command to the aircraft's **ailerons (causing them to deflect)**, which are located on the trailing edge of both wings. These ailerons move in **opposite directions**. So, if you push the stick or yoke to the **right**, the **right aileron goes up**, and the **left aileron goes down**. The raised aileron on the right wing **reduces lift** on that side, while the lowered aileron on the left wing **increases lift**. This creates a **rolling moment**—a rotational force that causes the aircraft to roll or bank to the right. As the aircraft banks, it starts turning in that direction because the **lift vector** tilts with the aircraft, pulling it into a curved path. To **maintain the angle of bank**, you need to **neutralize the ailerons**—that means returning the control stick or yoke to the **centre position**. This stops the roll and holds the wings at a steady bank angle. If you keep the control input applied, the bank angle will keep increasing, so it's important to readjust controls once the desired angle is reached. To **roll out of the turn**, simply apply **opposite aileron**. For example, if you're in a right bank, gently move the stick or yoke to the **left**. This will raise the left aileron and lower the right, reversing the lift difference and rolling the aircraft back to level flight. As the wings come back to level, **neutralize the controls** again to keep the aircraft flying straight and steady. During all of this, the **rudder** is used as needed to keep the turn coordinated and prevent skidding or slipping.

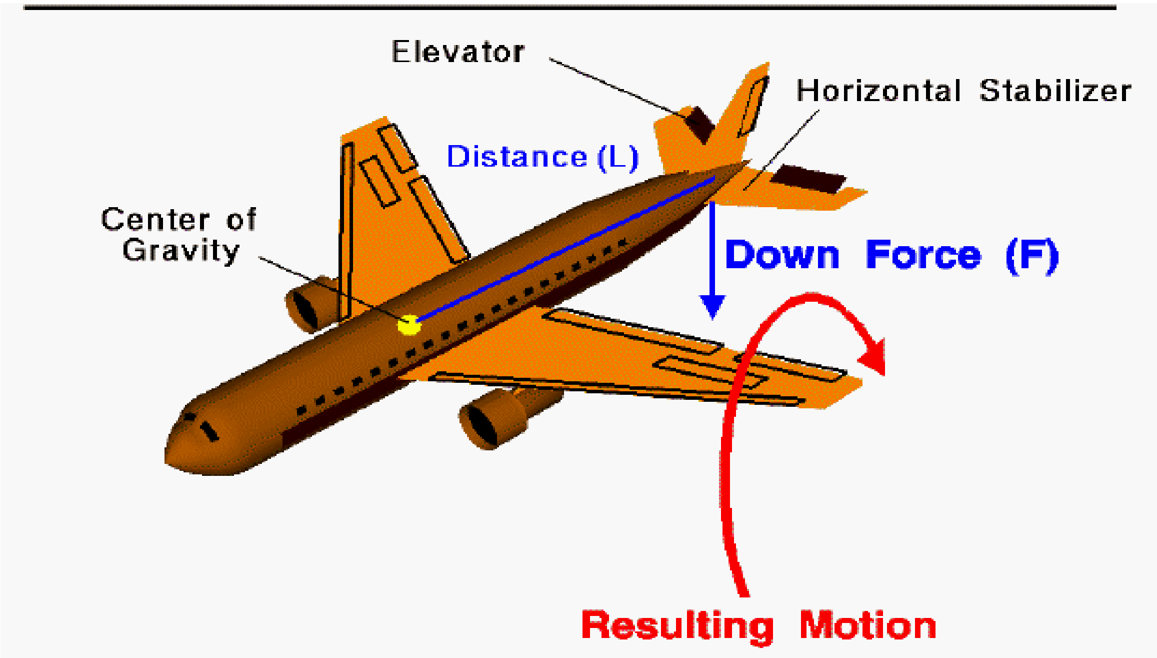



13. **How does an Elevator Work**. When you move the control stick or yoke forward or backward, you're changing the deflection of the elevator, which is the movable surface on the horizontal stabilizer at the tail of the aircraft. This deflection changes the aerodynamic forces acting on the tail, which in turn causes the aircraft to pitch nose up or nose down. Let's break it down:

(a) **Elevator Up → Nose Up (Pitch Up)**. When you pull back on the control stick or yoke, the elevator deflects upward. This changes the camber (curvature) of the tailplane in a way that reduces lift or creates negative lift (downward force) at the tail. Since the tail is behind the centre of gravity, this downward force causes a pitching moment that raises the nose of the aircraft. This is how you begin a climb or control pitch during slow flight or flare on landing.

(b) **Elevator Down → Nose Down (Pitch Down)**. When you push forward on the controls, the elevator deflects downward. This increases the lift at the tail (less downward force), which causes the tail to rise, and as a result, the nose drops. The pitching moment acts in the opposite direction—nose down.

(c) **Maintaining Pitch**. To hold a pitch angle, once the nose reaches your desired attitude, you must neutralize the elevator by centering the controls. The aircraft's trim can help maintain this pitch with minimal input. If you don't neutralize, the elevator remains deflected, and the pitch will continue to change. So, it's a combination of setting the pitch with the elevator, and holding or trimming to maintain it.

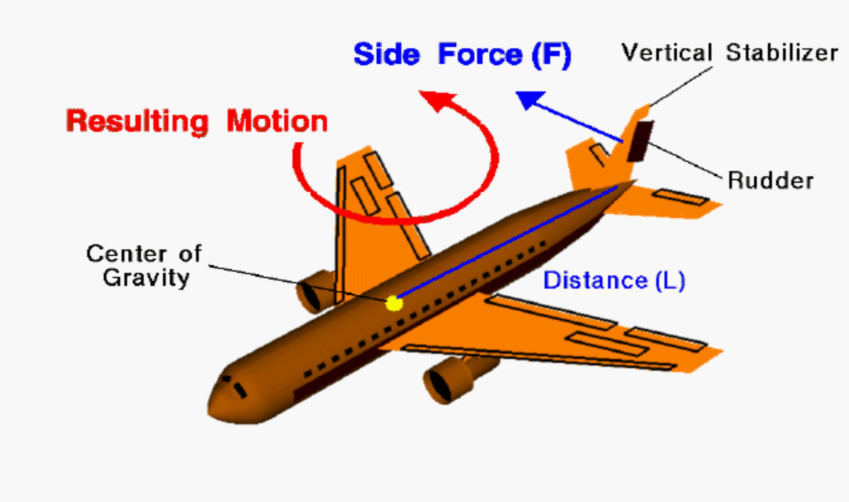



14. **<u>How does a Rudder Work</u>.** The rudder is the movable control surface on the vertical stabilizer (fin) at the tail of the aircraft. It controls the aircraft's movement about the vertical axis, which is called yaw—that is, the left or right movement of the aircraft's nose.When you move the rudder pedals, you're deflecting the rudder either to the left or right. This changes the aerodynamic force acting on the vertical tail surface, which in turn creates a yawing moment that rotates the aircraft around its vertical axis.

(a) **<u>Rudder Deflected Right → Yaw Right</u>**. When you press the right rudder pedal, the rudder deflects to the right. This increases the side force on the left side of the tail (because the rudder is now pushing air to the left). As a result, the tail is pushed to the left, and the nose yaws to the right. This yawing moment acts around the center of gravity, which is forward of the vertical stabilizer. It causes the entire aircraft to rotate to the right around the vertical axis.

(b) **<u>Rudder Deflected Left → Yaw Left</u>**. Likewise, when you press the left rudder pedal, the rudder deflects to the left, producing a side force to the right on the tail. This pushes the tail to the right, and the nose swings or yaws to the left.

(c) **<u>Slip and Skid</u>**. If too much or too little rudder is applied in a turn, it results in a **slip** or **skid**. These can be monitored using the **ball in the turn coordinator**, which helps the pilot apply the correct rudder input. In a balanced turn the ball needs to be in the centre.




| FOOD FOR THOUGHT |
|---|
| ➢ What are flaperons, elevons & stabilators? |
| ➢ How is the camber of the horizontal tail plane in your microlight. Ever wonder as to why it is different to the mainplane or wings? |

## PART II: SECONDARY CONTROLS

15. They are additional controls used to assist or enhance the performance of primary controls, improve efficiency, and aid specific phases of flight (e.g., takeoff, landing, trim). They are not essential for basic control, but they significantly improve handling, stability, and safety. Both Zen Air and Virus microlights utilise secondary controls such as flaps & slats (high lift devices) as well as elevator trim tabs. We shall be discussing these secondary details in the subsequent paras.

16. **High lift devices or lift augmentation devices** like flaps and slats are crucial in aviation for increasing lift during takeoff and landing allowing aircraft to operate efficiently lower speeds. Slats and Flaps are the two high lift devices described below.

17. **What are Flaps**. Flaps are movable surfaces located on the trailing edge of the wing, usually near the wing root, closer to the fuselage. They are part of the aircraft's secondary (or auxiliary) flight controls and are typically extended or retracted using a lever or switch in the cockpit. Unlike primary control surfaces (like the ailerons, rudder, and elevator), flaps are not used to steer the aircraft in normal flight—they are used to modify the lift and drag characteristics of the wing, especially during take-off and landing.

(a) **Why are Flaps Used**.

(i) The main purpose of flaps is to allow the aircraft to fly safely at slower speeds, which is particularly important during landing and take-off. When extended, flaps:-

(aa) Increase the camber (curvature) of the wing

(ab) Sometimes increase the wing area

(ac) Result in a higher coefficient of lift

(ii) This means the wing can **generate more lift at lower speeds**, allowing the aircraft to:

(aa) Take off from shorter runways

(ab) Land at slower speeds with a steeper descent angle

(ac) Maintain better control during approach and landing

(b) **Advantages of Using Flaps**.

(i) **Improved Lift at Lower Speeds**. Flaps allow for a lower stalling speed, improving safety during takeoff and landing. You can operate at a lower speed as compared to clean aircraft.

(ii) **Shorter Takeoff and Landing Distances**. Aircraft can operate on shorter runways.

(iii) **Steeper Approach Path**. Increased drag with flaps allows for steeper descents without increasing airspeed. This also results in increase visibility for the pilot.

(iv) **Better Control at Low Speeds**. The aircraft remains more stable and responsive during slow flight.

(c) **Disadvantages of Using Flaps**.

(i) **Increased Drag**. While lift increases, drag also increases significantly—especially at full flap settings. This reduces forward acceleration.

(ii) **Reduced Climb Performance**. If flaps are left extended after takeoff, the aircraft may struggle to climb efficiently due to high drag.

(iii) **Structural Limits**. Using flaps above certain speeds can damage them or the wing. The maximum forward speed in level flight is consequently lower with flaps in comparison to a clean configuration. That's why flap extension speeds ($V_{FE}$) are clearly marked.

18. In short, **flaps are a critical tool for safe low-speed flight**, especially in approach and landing. They help the wing perform better at slow speeds but must be used properly to avoid excess drag or structural issues. As a pilot, understanding when and how to use flaps

is key to smooth, safe flight operations.

19. **<u>What is a Slat</u>**. Slats are aerodynamic surfaces located along the leading edge of an aircraft's wing. Like flaps, they are part of the secondary flight controls, but while flaps are at the trailing edge, slats are at the front. Slats may be either fixed or movable (deployable). When deployed, slats extend forward and down from the leading edge of the wing, creating a narrow gap between the slat and the wing surface, often referred to as a slot.

(a) **<u>Why are Slats Used</u>**. Slats are used to improve airflow over the wing at high angles of attack, which helps delay the stall and increase lift during critical flight phases like take-off and landing. At high angles of attack, the airflow tends to separate from the upper surface of the wing, which leads to a stall. When slats are deployed, they change the local camber and increases the curvature at the leading edge. This softens the adverse pressure gradient, making it easier for air to stay attached longer thereby delaying stall and allowing the wing to operate effectively at higher angles (**increases the critical AoA**).

(b) **<u>Advantages of Slats</u>**.

(i) **<u>Increased Lift at High Angles of Attack</u>**. They allow the aircraft to fly safely at slower speeds by delaying stall. Slats help in delaying stall by allowing the aerofoil to operate at higher AoA. Critical angle of attack is higher viz-a-viz clean aerofoil.

(ii) **<u>Improved Low-Speed Handling</u>**. Particularly useful during take-off, landing, and tight manoeuvres.

(iii) **<u>Steeper Climb-Outs and Approaches</u>**. Like flaps, slats can aid in shorter takeoff and landing distances.

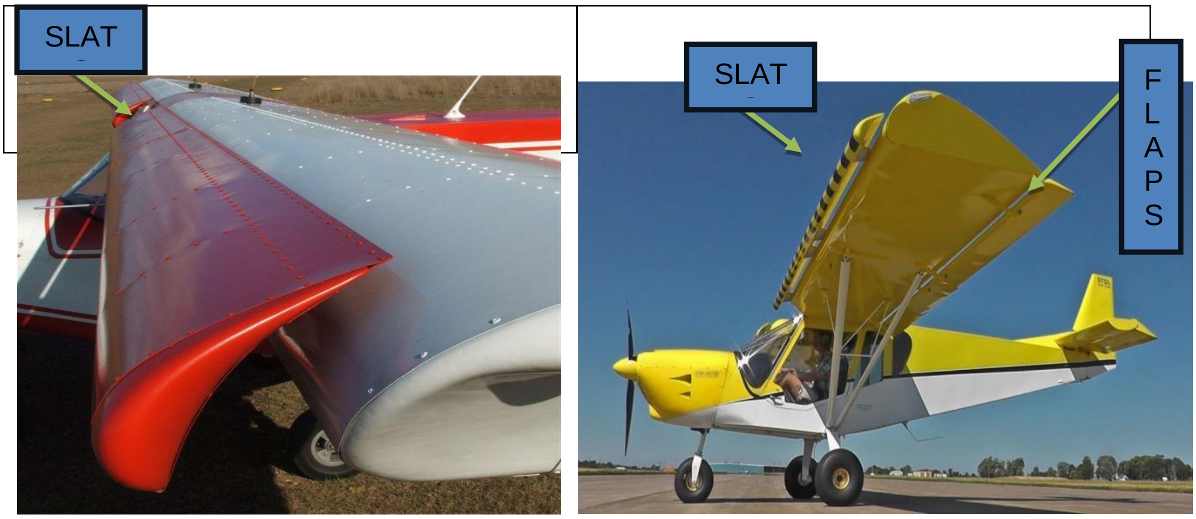
(c) **<u>Disadvantages of Slats</u>**.

(i) **<u>Added Complexity and Weight</u>**. Deployable slats require mechanical systems, increasing aircraft weight and maintenance.

(ii) **<u>Increased Drag When Deployed</u>**. This reduces efficiency and climb rate if not retracted after take-off.

(iii) **<u>Structural Limits</u>**. Like flaps, slats must not be deployed above certain speeds to prevent damage.

20. In essence, **slats improve the wing's performance during slow flight or high-angle manoeuvres** by maintaining smooth airflow and delaying stall. When used in combination with flaps, they significantly increase the total lift produced by the wing, making them extremely valuable for **safe low-speed operations**.




21. **<u>What is an Elevator Trimmer</u>**. A trimmer is a secondary flight control device used to relieve the pilot from having to apply constant pressure on the controls to maintain a desired attitude. An elevator trimmer is typically a smaller control surface (adjustable tab) hinged to the larger primary control surface (located on the trailing edge of the elevator in this case). Think of the trimmer as a way to help the aircraft "hold itself" in a certain pitch attitude without requiring continuous manual input—like a cruise control for pitch! The trim tab can be operated manually, electrically or hydraulically. How is it operated in your microlight?

22. **<u>Why is the Elevator Trimmer Used</u>**. In flight, various factors such as changes in speed, power, or configuration (like flap deployment or gear extension) can create pitching moments that the pilot must counteract. Without a trimmer, the pilot would need to apply continuous forward or backward pressure on the yoke or stick, which can be fatiguing over time. By adjusting the elevator trimmer, the pilot can balance out these aerodynamic forces, making the aircraft easier and more comfortable to fly.

23. **<u>How does the Elevator Trimmer Work</u>.** When you move the trimmer:-

(a) **<u>Nose-Up Trim</u>**. The trim tab moves downward, causing the elevator to move upward, which pitches the nose up.

(b) **<u>Nose-Down Trim</u>**. The trim tab moves upward, causing the elevator to move downward, which pitches the nose down.

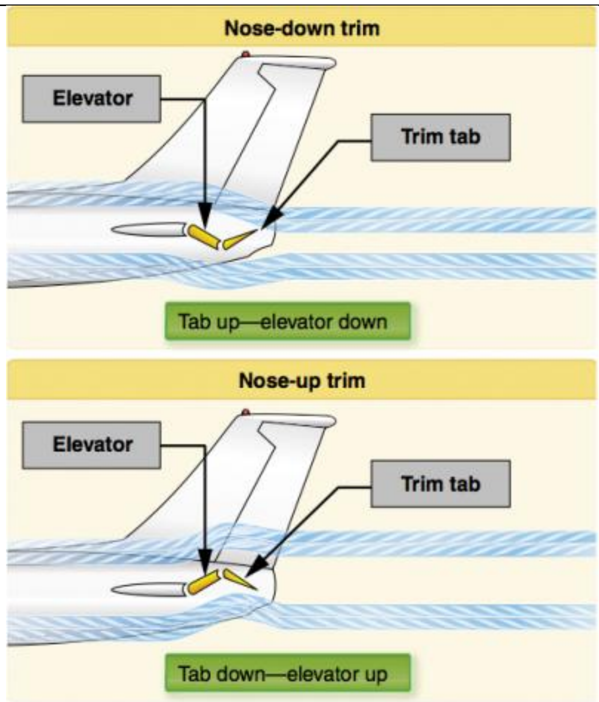
24. Trim tab changes the **aerodynamic load** on the elevator, allowing the pilot to set and maintain a desired pitch without extra effort on the controls. As a result:

(a) **<u>Pilot Workload is Reduced</u>**. Prevents the need for constant manual input.

(b) **<u>Stability and Comfort is Improved</u>**. Especially during cruise, climb, or descent.

(c) **<u>Fuel Efficiency Improves</u>**. A well-trimmed aircraft maintains more stable flight.

(d) In short, the elevator trimmer is a critical aid to smooth, efficient, and comfortable flight, helping to maintain desired pitch attitudes with minimal effort.


25. **<u>Control Power and Effectiveness</u>**. The main function of a control is to allow the aircraft to fulfil its particular role. This aspect is decided mainly by:

(a) **<u>Size and Shape of the Control</u>**. The size and shape of an aircraft's control surfaces play a crucial role in determining how effectively it can manoeuvre. Larger control surfaces generate more aerodynamic force when deflected, allowing the aircraft to perform quicker and more powerful movements in pitch, roll, or yaw. This is why high-performance aircraft, such as fighter jets, often feature oversized control surfaces to enable rapid, aggressive manoeuvres. In contrast, smaller surfaces provide more gradual, stable responses, which is ideal for commercial aircraft prioritizing passenger comfort and fuel efficiency. The shape of a control surface also affects its performance. Long, narrow surfaces (high aspect ratio) are more aerodynamically efficient and provide smoother control inputs, while short, wide surfaces (low aspect ratio) produce stronger but less efficient responses and typically increase drag. Overall, aircraft designers balance control surface size and shape based on the specific performance goals of the aircraft, trading off between agility and stability.

(b) **Deflection Angle**. The deflection angle of a control surface—how far it moves from its neutral (centered) position—directly affects the magnitude of the aerodynamic force it produces, and thus how the aircraft manoeuvres. When a control surface (like an elevator, aileron, or rudder) is deflected, it changes the airflow over part of the aircraft, creating a pressure difference that generates a force. The greater the deflection angle, the larger this force becomes, resulting in a stronger response in pitch, roll, or yaw. However, there's a limit—after a certain point, increasing the deflection angle yields **diminishing returns** or can even cause **flow separation**, where the airflow becomes turbulent and the surface loses effectiveness (**called control saturation**). Excessive deflection can also introduce more drag and stress on the structure. Therefore, pilots and flight control systems carefully manage deflection angles to ensure precise, efficient manoeuvring without overstressing the aircraft or causing instability.

(c) **Air Speed**. Airspeed has a significant impact on control effectiveness—that is, how responsive an aircraft is to control surface inputs. As airspeed increases, more air flows over the control surfaces, which means that even small deflections can generate larger aerodynamic forces. This makes the controls more effective and responsive at high speeds. At low airspeeds, however, there is less airflow over the control surfaces, so the same deflection produces weaker forces, making the aircraft feel sluggish or slow to respond. This is why take-off and landing—when airspeeds are lower—require larger or more deliberate control inputs to achieve the same manoeuvring effect.

(d) **Moment Arm (Distance from CG)**. The moment arm—the distance between a control surface and the aircraft's center of gravity (CG)—has a direct effect on control effectiveness because it influences the torque (or turning force) that the surface can generate. Torque is the product of **force and distance ($T = F \times d$)**, so for a given aerodynamic force from a control surface, a longer moment arm produces more torque, resulting in greater rotational effect around the aircraft's axis (pitch, roll, or yaw). For example, elevators are placed far back on the tail to maximize their moment arm from the CG, making them more effective at pitching the nose up or down. Similarly, a rudder mounted far back on the vertical tail provides stronger yaw control. Conversely, if a control surface is located closer to the CG, it needs to generate more force (or be larger) to have the same effect.

## CONCLUSION

26. Aircraft flight controls are divided into primary and secondary (or auxiliary) controls. The primary controls-ailerons, elevator, and rudder-are essential for controlling the aircraft’s motion around its three axes: roll, pitch, and yaw. Ailerons, operated by the yoke or control stick, control roll by increasing lift on one wing while decreasing it on the other. The elevator, moved by pushing or pulling the yoke/stick, controls pitch by changing the angle of attack of the tailplane. The rudder, operated by the rudder pedals, controls yaw by deflecting airflow over the vertical stabilizer to turn the aircraft left or right. Together, these surfaces allow the pilot to manoeuvre the aircraft in all directions and maintain stable flight.Secondary controls include flaps, slats, and trimmers, which enhance the aircraft's performance and ease of control. These auxiliary systems, while not responsible for basic flight, are vital for improving control precision, reducing pilot workload, and enhancing aircraft efficiency and safety during different phases of flight.

(a) Aircraft controls are divided into Primary (essential) and Secondary (supportive) controls.

(b) Ailerons control roll around the longitudinal axis.

(c) Elevator controls pitch around the lateral axis.

(d) Rudder controls yaw around the vertical axis.

(e) Flaps (secondary) increase lift and drag for take-off and landing.

(f) Slats delay stall by allowing higher angles of attack.

(g) Trim tabs reduce pilot effort by stabilizing control surfaces.

(h) Coordinated use of all controls is essential for smooth and safe flight.

## DID YOU KNOW?

- Why is the max speed with flaps below $V_{NE}$ in your microlight?
- What is the effect of slats on fuel economy of your microlight?
- Can you operate the trim tab without switching on the battery in your microlight? Why or why not?
- What is the stalling speed of your microlight
  - With flaps
  - Without flaps

## ASSESSMENT EXERCISES

**Multiple-Choice Questions**

1. **Which control surface controls the pitch of an aircraft?**
   (a) Rudder
   (b) Elevator
   (c) Aileron
   (d) Flaps

2. **Which axis does the aileron primarily control?**
   (a) Vertical axis
   (b) Lateral axis
   (c) Longitudinal axis
   (d) Neutral axis

3. **The rudder is used to control movement about the?**
   (a) Longitudinal axis
   (b) Lateral axis
   (c) Vertical axis
   (d) Pitch axis

4. **Which flight control helps reduce the need for constant control input during level flight?**
   (a) Flaps
   (b) Slats
   (c) Trimmer
   (d) Spoilers

5. **What are flaps primarily used for?**
   (a) Increasing speed
   (b) Enhancing roll control
   (c) Increasing lift and drag at lower speeds
   (d) Decreasing drag in cruise flight

6. **Slats are deployed from which part of the wing?**
   (a) Trailing edge
   (b) Wingtip
   (c) Leading edge
   (d) Underside

**7. What is the function of ailerons?**

(a) Control pitch

(b) Control yaw

(c) Control roll

(d) Control lift

**8. Which of the following is a secondary control surface?**

(a) Elevator

(b) Aileron

(c) Rudder

(d) Flap

**9. Which control is operated by foot pedals in most aircraft?**

(a) Elevator

(b) Rudder

(c) Aileron

(d) Trim tab

**10. When rolling into a turn, which control surface is primarily used?**

(a) Rudder

(b) Elevator

(c) Flaps

(d) Ailerons

**Short Answer Questions (Comprehension-Based)**

1. What are the three primary flight controls and what does each control?
2. Which axis does the rudder control, and how is it operated?
3. What is the main function of the elevator trim tab?
4. Why are flaps deployed during landing?
5. How does an aileron cause the aircraft to roll?
6. What is the difference in location between flaps and slats on a wing?
7. What is the aerodynamic effect of deflecting the elevator upwards?
8. What are secondary (or auxiliary) flight controls used for?
9. How do slats improve low-speed handling of the aircraft?
10. When do pilots typically use elevator trim?

**Long Answer Questions (Application-Based)**

1. Explain how the movement of the control yoke affects the elevator and results in a pitching moment. How does this affect lift and drag?

2. Describe the function of each primary control surface and the axis of motion it affects.

3. Differentiate between primary and secondary flight controls with examples. How do they complement each other in flight?

4. How do flaps and slats modify wing aerodynamics during take-off and landing? Discuss their advantages and disadvantages.

5. Explain how aileron deflection results in rolling motion. What role does the rudder play in coordinating a turn?

6. Describe the process of entering, maintaining, and exiting a banked turn using ailerons and elevator.

7. Discuss the role of trim controls in reducing pilot workload. How is elevator trim typically used in flight?

8. Explain how the rudder works aerodynamically to control yaw, and why it's important in coordinated flight

# PRINCIPLES OF FLIGHT (SD/SW)

## CHAPTER V: STALL (ST)

***"A superior pilot uses his superior judgment to avoid situations which require the use of his superior skill."***

—Frank Borman.

## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **1 (One)** |
| **Type** | **:** | **Lecture** |
| **Year** | **:** | **1st Yr SD/SW** |
| **Conducting Officer** | **:** | **Permanent Instructor** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction** | **:** | **05Mins** |
| • **Part I** | **:** | **15 Mins** |
| • **Part II** | **:** | **15 Mins** |
| • **Conclusion, Summary and Practice** | **:** | **05 Mins** |

## INTRODUCTION

1. **Stall**. It is a reduction in the lift coefficient generated by a foil as angle of attack increases. This occurs when the critical angle of attack of the foil is exceeded. The critical angle of attack is typically about 15 degrees, but it may vary significantly depending on the fluid and airfoil. Stalls in fixed-wing flight are often experienced as a sudden reduction in lift as the pilot increases angle of attack and exceeds the critical angle of attack (which may be due to slowing down below stall speed in level flight). A stall does not mean that the engine(s) have stopped working, or that the aircraft has stopped moving — the effect is the same even in an unpowered glider aircraft.

### PREVIEW

The lecture will be covered in the following parts:-

(a) Part I: Boundary layer & flow separation

(b) Part II: Science behind Stall

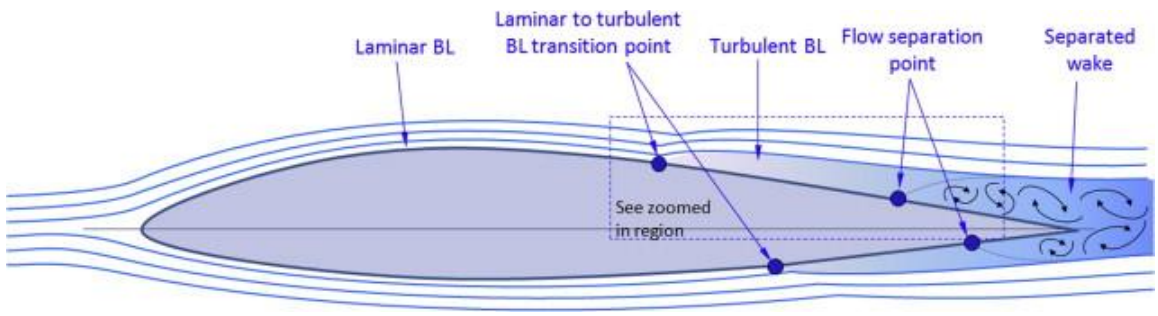
### LEARNING OBJECTIVES

- Understand the technical definition and cause of a stall.
- Interpret the CL (Coefficient of Lift) vs. Angle of Attack graph.
- Describe how airflow and pressure distribution change during a stall.
- Identify symptoms and warning signs of an impending stall.
- Understand the concept of basic stalling speed.
- Analyze the factors affecting stall and stalling speed.
- Learn standard stall recovery procedure.

## PART I: BOUNDARY LAYER & FLOW SEPARATION

2. **Glossary of Terms**. To help understand stall, we need to understand the following terminologies.

(a) **Boundary Layer**. The boundary layer is the thin region of fluid (air) adjacent to a solid surface, such as an aircraft wing, within which the effects of viscous forces are significant, causing the fluid velocity to vary from zero at the surface to approximately 99% of the free-stream velocity at its outer edge. This layer is critical in determining how the airflow interacts with the surface, influencing dragand flow separation. The boundary layer can be laminar or turbulent, and its behaviour has a direct impact on lift generation, stall characteristics, and overall aerodynamic efficiency.




(b) **Laminar vs Turbulent Flow**. There are two main types of flow within the boundary layer. In practice, airflow over a wing transitions from laminar near the leading edge to turbulent further back along the chord.

(i) **Laminar Flow** is smooth, orderly, and flows in parallel layers with little mixing between them. It produces less drag and is efficient in terms of lift production. However, it is also more **fragile**—more likely to separate from the surface under adverse conditions like increased angle of attack.

(ii) **Turbulent Flow** is chaotic, with eddies and more mixing of air particles. Although it produces **higher skin-friction drag**, turbulent flow adheres better to the wing surface and is **more resistant to separation**. This means that in many cases, a turbulent boundary layer is actually helpful in delaying a stall.

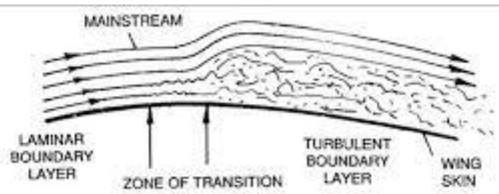
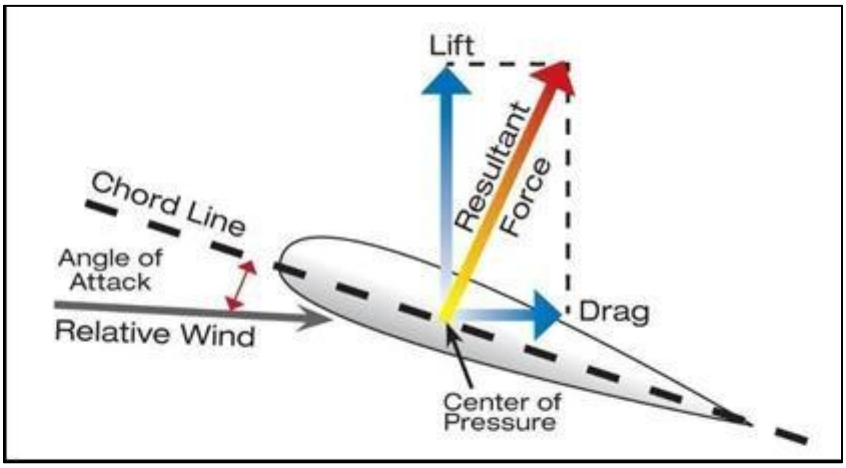
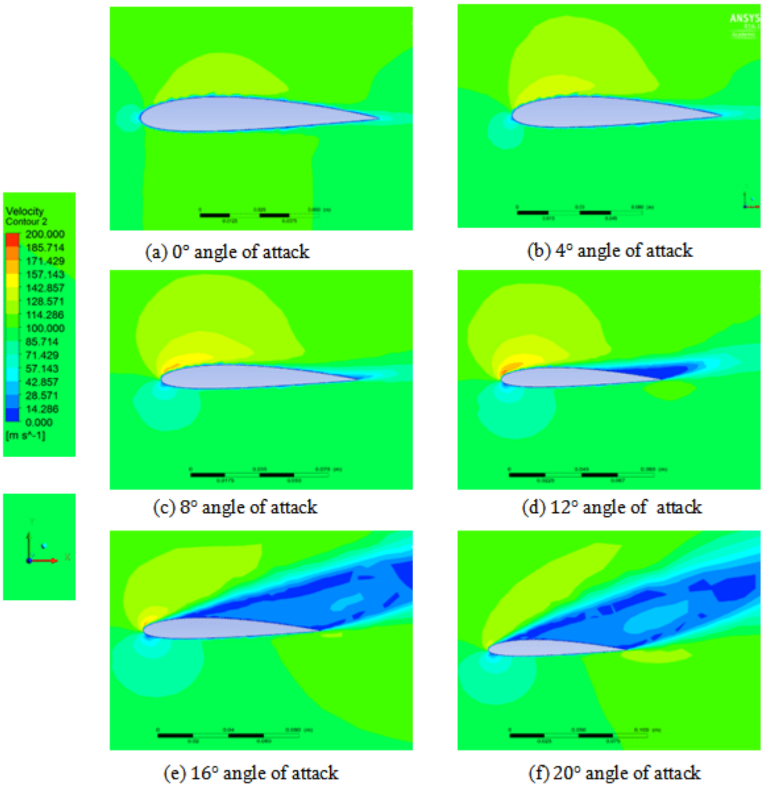



Figure 3.24 Boundary layer transition on full-sized aircraft

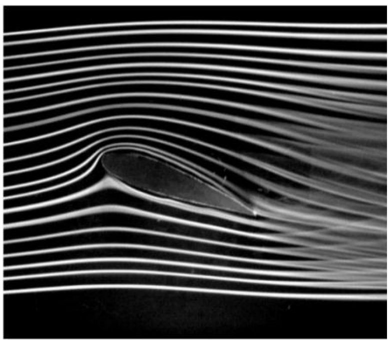
(c) **Angle of Attack (AoA or $\alpha$)**. The angle between the chord line of the aerofoil and the direction of the oncoming airflow (also called the relative wind).



(d) **<u>Flow Separation and Stall</u>**. As the **angle of attack increases**, the pressure gradient on the upper surface of the wing becomes more **adverse**—that is, the pressure increases as the air moves toward the trailing edge. This makes it harder for the air in the boundary layer to continue moving against the pressure, especially in the laminar portion of the flow. Eventually, the airflow loses the energy to overcome this resistance and **separates** from the surface. Once a large portion of the upper surface is experiencing separated (turbulent and reversed) flow, the wing can no longer generate enough lift to support the aircraft's weight—that's when a **stall** occurs.



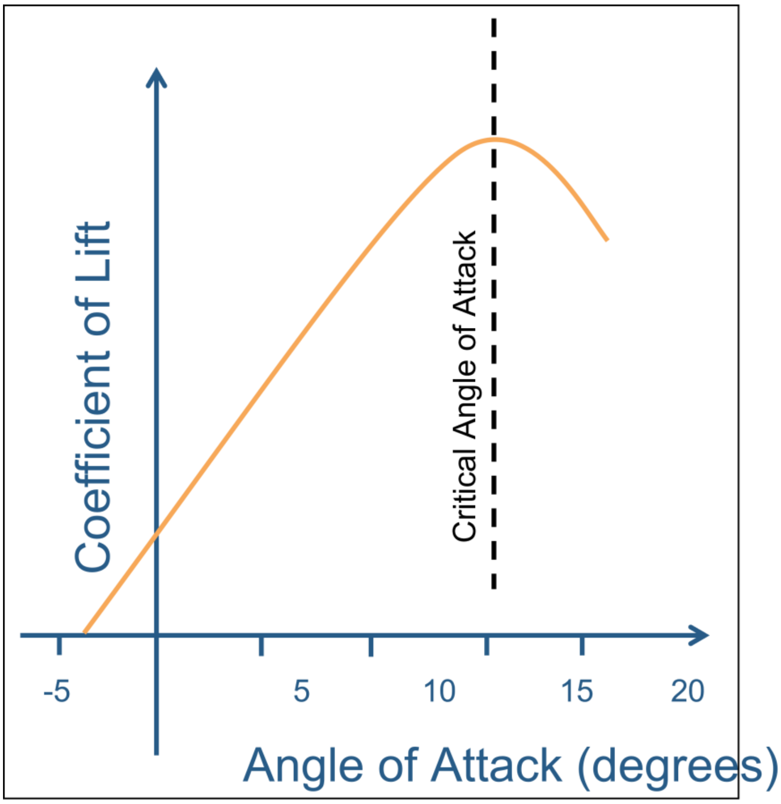

**<u>Interaction of Boundary Layer & Flow Over Aerofoil</u>**


**<u>Flow at Low *a*</u>** **<u>Flow at Higher *a*</u>** **<u>Separated Flow at Critical *a*</u>**

3. **<u>$C_L$ vs AoA</u>**. To understand the stall, it is essential to look at the relationship between the Coefficient of Lift (CL) and the angle of attack. As the AoA increases, the CL also

increases, resulting in more lift. However, this increase only continues up to the critical angle of attack. Beyond this point, the lift coefficient drops sharply, even if the angle continues to increase. This is the stall point. A graph of CL vs AoA clearly shows this peak followed by a rapid decline. This graph illustrates that stall is not directly caused by low speed, but rather by exceeding the critical AoA, which often happens at low speeds because the pilot is attempting to increase AoA to maintain lift.




## PART II: SCIENCE BEHIND STALL

4. **How does an Aircraft Stall**. The stall of an aerofoil is an aerodynamic condition that occurs when the angle of attack (α) increases beyond a certain critical value, causing a sudden loss of lift. To understand how stall happens, it's essential to examine the relationship between the lift coefficient $C_L$ and α.

(a) Initially, as the angle of attack increases, the lift coefficient increases nearly linearly. (Refer graph in para 4) This is because the airflow over the aerofoil remains attached, creating a strong pressure differential between the upper and lower surfaces — the primary mechanism for lift.

(b) This trend continues up to a point known as $C_{Lmax}$ the maximum lift coefficient, which corresponds to the critical angle of attack.

(c) Beyond this critical angle, the airflow can no longer adhere to the surface of the aerofoil due to an **adverse pressure gradient**. The boundary layer, which is the thin layer of air in direct contact with the wing surface, starts to **separate** from the upper surface.

(d) This **flow separation** causes a breakdown of the smooth, laminar airflow, resulting in turbulent wake formation, increased drag, and a sharp reduction in lift — this condition is referred to as **stall**.

(e) The aerofoil is no longer able to generate sufficient lift, the aircraft loses height and control effectiveness is significantly reduced.

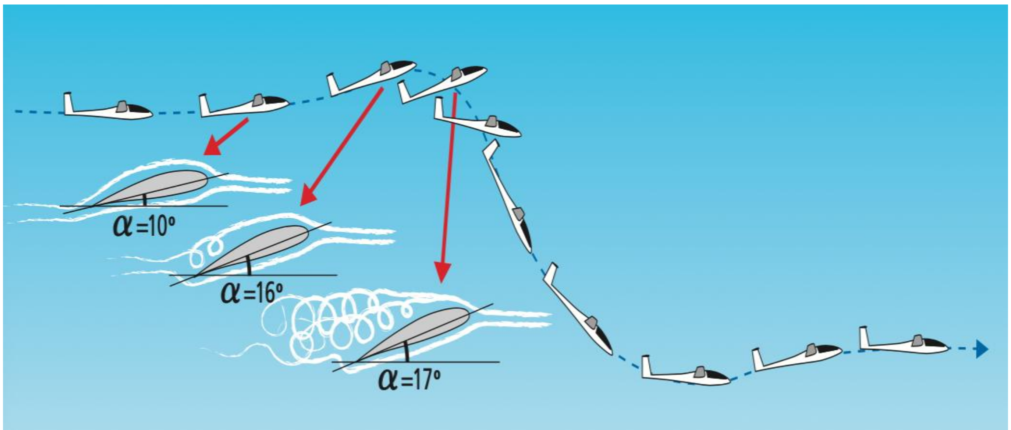
5. Under normal flight conditions, stall is often associated with low-speed flight, and the connection lies in the **lift equation**: **Lift =** $\frac{1}{2}\rho V^2 S C_L$:-

(a) Suppose the pilot reduces throttle and drops the airspeed in level flight. As the aircraft slows down, the airspeed (V) decreases, and since lift is proportional to the square of velocity, lift also drops.

(b) To maintain the same amount of lift (to maintain altitude) at a lower speed, the aircraft must compensate by increasing the **lift coefficient**, which can be achieved by increasing the angle of attack (aerofoil area & density at a given altitude is constant).

(c) However, if the pilot continues to increase the angle of attack to compensate for lost lift, the aerofoil may exceed its critical angle, triggering a stall.

(d) This critical angle is dependent upon the profile of the wing, its platform, its aspect ratio, and other factors, but is typically in the range of 8 to 20 degrees relative to the incoming wind for most subsonic airfoils. Therefore it can also be implied that the critical angle of attack is the angle of attack on the lift coefficient versus angle-of-attack curve at which the maximum lift coefficient occurs.




6. In essence, stall is the result of an attempt to sustain lift at low speeds by increasing α beyond the aerofoil's aerodynamic limits. This illustrates the critical interplay between airspeed, angle of attack, and lift generation - a foundational concept in flight dynamics. **Recovery from stall involves reducing the angle of attack, typically by pitching the nose down, and increasing airspeed to reattach the flow and restore lift**.

7. **Stall & its Effects**. Stalls do not occur without warning. A pilot who is attentive to the aircraft's behavior can usually detect signs of an approaching stall. These include a noticeable loss of control effectiveness, and often a buffeting or vibration (Buffeting is the turbulent shaking or vibration of an aircraft caused by airflow disruptions, often indicating an impending stall), as turbulent airflow strikes the tailplane. During a stall, a plane may experience buffeting or a change in its attitude. The aircraft's nose may appear to be unusually high, and the airspeed will be decreasing. In some aircraft, audible stall warnings such as horns or stick shakers may be present. Recognizing these early signs is crucial, especially during critical phases of flight like takeoff or landing. Most planes are designed to stall gradually, with features that warn the pilot and allow time to react. In steady, level flight, a plane can only reach the critical angle of attack at low speeds. Trying to increase the angle at higher speeds can cause a high-speed stall.

8. **Stalling Speed**. Since staff primarily depends on angle of attack and not speed, there is no particular stalling speed. However, it's essential to understand that this speed is not fixed—it is based on specific conditions such as weight, configuration, and load factor. Most operators therefore refer to the Basic Stalling Speed. It is the stalling speed corresponding to the critical angle of attack in straight and level flight. **It may be defined as the speed below which a clean aircraft of stated weight, with the engines throttled back, can no longer maintain straight and level flight**. This speed is listed in the Aircrew Manual for a number of different weights.

9. **Factors affecting Stalling Speed**. Several factors influence both the onset of a stall and the stalling speed. These include:

(a) **Weight**. A heavier aircraft has a higher stalling speed.

(b) **Manoeuvre**. In a turn or maneuver, the load factor increases, raising the stall speed. For example, in a 60° banked level turn, the stall speed increases by about 41%.

(c) **Aircraft Configuration**. Extending flaps increases the lift coefficient and lowers the stall speed by allowing the wing to produce more lift at lower speeds.

10. **Stall Recovery: Understanding Alpha, Attitude, and Control Inputs**. Recovering from a stall is fundamentally about **reducing the angle of attack (α or Alpha)** back below the **critical angle** at which smooth airflow over the wing can be re-established. A stall is not caused by loss of engine power but by an excessively high Alpha that disrupts airflow over the wing. Therefore, effective stall recovery focuses on controlling **α**, not just pitch or speed.

11. **Alpha and Attitude During Stall**. During a stall, the angle of attack is beyond the critical limit. Therefore, the pilot must consciously reduce α by adjusting (lowering) the aircraft's attitude. The control inputs required and the methodology of recovery depending upon the type of aircraft. However, the basic gist of recovery is Rudder-Stick-Throttle.

(a) Level wings using rudders in case of wing drop

(b) Move the stick forward to reduce **α,** The goal is to reattach the airflow by decreasing the AoA below the critical point.

(c) Apply maximum power to reduce height loss & recover (climb or level out) at a safe airspeed

The key point here is:-Stall is an angle-of-attack problem, not a speed, engine (even a glider can stall) or altitude problem.

## **CONCLUSION**

12. Understanding stall is fundamental to safe flying. A stall occurs not because of engine issues or solely because of low speed, but because the wing's angle of attack exceeds the critical limit, causing airflow separation and loss of lift. It can happen in any aircraft and at any airspeed, especially during high AoA maneuvers or inattentive flying. Symptoms like control mushiness, buffeting, and nose-high attitudes should be taken seriously. The stalling speed varies with aircraft configuration, weight, and flight conditions, emphasizing the need for situational awareness. Recovery requires reducing the angle of attack first, then restoring lift with power and coordinated control inputs. Mastery of stall recognition and recovery is one of the cornerstones of a competent pilot's skill set.

(a) **Definition of Stall**.

(i) A stall occurs when the angle of attack (Alpha) exceeds the critical value,

(ii) Causing airflow separation over the wing and a sudden loss of lift.

(b) **Lift Coefficient vs Angle of Attack**.

(i) Lift increases with angle of attack up to a point.

(ii) Beyond the critical angle lift drops sharply as flow separates.

(c) **Flow Separation Mechanics**.

(i) At high Alpha, airflow can no longer adhere to the upper surface.

(ii) This leads to **turbulence and pressure loss**, causing the wing to stall.

(d) **Boundary Layer Behaviour**.

(i) Laminar flow is smooth but separates easily.

(ii) Turbulent flow resists separation better.

(iii) Stall begins when the boundary layer separates near the leading edge.

(e) **Symptoms of an Impending Stall**.

(i) Airframe buffet or vibration.

(ii) Degraded control response, especially in roll.

(iii) Stall warning horn or stick shaker.

(iv) High nose attitude with low or decreasing airspeed.

(f) **Stalling Speed**. Varies with weight, configuration, and load factor (bank angle).

(g) **Common Misconception**. Stalls are not speed-dependent alone-they are angle of attack dependent.

## ASSESSMENT EXERCISES

**Multiple Choice Questions**

**1. What best describes the boundary layer on an aerofoil surface?**

(a) Region of high pressure above the wing

(b) Zone where lift is generated

(c) Thin layer of air where viscous forces dominate

(d) Stream of free airflow over the aircraft

**2. Which of the following statements about laminar and turbulent boundary layers is correct?**

(a) Laminar flow resists separation better than turbulent flow

(b) Turbulent flow offers more drag but delays flow separation

(c) Turbulent flow only occurs during stall

(d) Laminar flow produces higher lift than turbulent flow

**3. What happens to the coefficient of lift (CL) as the angle of attack increases, up to the critical point?**

(a) It decreases steadily

(b) It increases linearly

(c) It remains constant

(d) It fluctuates irregularly

**4. At what condition does a stall occur?**

(a) When the aircraft exceeds the critical speed

(b) When the wing's angle of attack exceeds the critical angle

(c) When the aircraft attitude exceeds 30 degrees nose up

(d) When engine power is reduced to idle

**5. What is the main aerodynamic reason for the loss of lift during a stall?**

(a) High altitude

(b) Flow separation over the wing

(c) Low airspeed

(d) Excessive elevator deflection

**6. Which factor increases the stalling speed of an aircraft?**

(a) Deploying flaps

(b) Decreasing weight

(c) Banked turn (increased load factor)

(d) Flying straight and level

**7. During stall recovery, what is the first and most important step?**

(a) Apply full rudder

(b) Increase engine power

(c) Reduce angle of attack

(d) Pull back on the control column

**8. Why is relying only on airspeed misleading in stall recognition?**

(a) Stall only happens at high speeds

(b) AoA is the critical factor, not speed

(c) Stall never happens below stall speed

(d) Altitude influences stall more than airspeed

**9. In a wing drop stall, why should ailerons be used cautiously?**

(a) They are ineffective at high speeds

(b) They can worsen the stall by deepening the wing drop

(c) They cause too much drag

d. They increase lift instantly

**10. What effect does a bird hit & fuselage damage have on the stall?**

(a) Increases lift and delays stall

(b) Decreases drag and lowers stall speed

(c) Increases stall speed and causes earlier stall onset

(d) No effect unless visible ice is present

**<u>Short Answer Questions</u>**

1. Define the term boundary layer in the context of airflow over an aerofoil.

2. What is meant by critical angle of attack, and why is it important?

3. Mention any two symptoms that indicate an impending stall.

4. How does deploying flaps affect the stall speed of an aircraft?

5. State one reason why turbulent boundary layer delays flow separation compared to laminar flow.

**Long Answer Questions**

1. Explain with a diagram how the coefficient of lift (CL) changes with increasing angle of attack, and describe what happens beyond the critical point.

2. Describe the mechanism of airflow separation over an aerofoil leading to stall, including the role of boundary layer and pressure distribution.

3. Discuss the various factors that affect stall speed, including aircraft weight, configuration, and load factor.

4. Explain in detail the procedure for stall recovery, emphasizing control inputs, angle of attack reduction, and coordinated flight.

5. Differentiate between laminar and turbulent boundary layers, and explain their significance in delaying or accelerating stall.

# ATC & AIRMANSHIP, NAVIGATION & METEOROLOGY

3

## CHAPTER WISE INDEX: ATC & AIRMANSHIP, NAVIGATION & METEOROLOGY (SD/SW)

# ATC & MET AIRMANSHIP NAVIGATION (SD/SW)

## CHAPTER I : ATC & AIRMANSHIP (AM)

## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Total Period** | **:** | **06 (Six)** |
| **Type** | **:** | **Lecture and Practical** |
| **Year** | **:** | **2ND Year SD/SW** |
| **Conducting Officer** | **:** | **ANO/CTO** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |

**Time Plan**

| | | |
|---|---|---|
| • **Introduction** | **:** | **10 Mins** |
| • **Part I** | **:** | **20 Mins** |
| • **Part II** | **:** | **20 Mins** |
| • **Part III** | **:** | **20 Mins** |
| • **Part IV** | **:** | **20 Mins** |
| • **Part V** | **:** | **20 Mins** |
| • **Part VI** | **:** | **40 Mins** |
| • **Conclusion and Practical** | **:** | **10 Mins** |

- **The Class will be covered as theoretical and practical on the airfield. The visit to the airfield will be of : 80 Mins.**

## INTRODUCTION

1. The chapter on *Airmanship* introduces cadets to the operational and structural aspects of an airfield, with emphasis on its layout, terminologies, and safety procedures. Through this chapter, cadet gain s insights into airfield operations, markings, lighting systems and the roles of various services like Air Traffic Control (ATC), fire and rescue at airport and various radar systems. This theoretical knowledge, combined with practical exposure during airfield visits, equips cadet to understand various support services required for operations and ground procedures to be followed at an aerodrome.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Visit to Airfield, Airfield Layout,

(b) Part II: Aerodrome Markings and Lighting Systems

(c) Part III: Basic Terminologies and Definitions

(d) Part IV: Air Traffic Control (ATC) and Function of Rescue Services

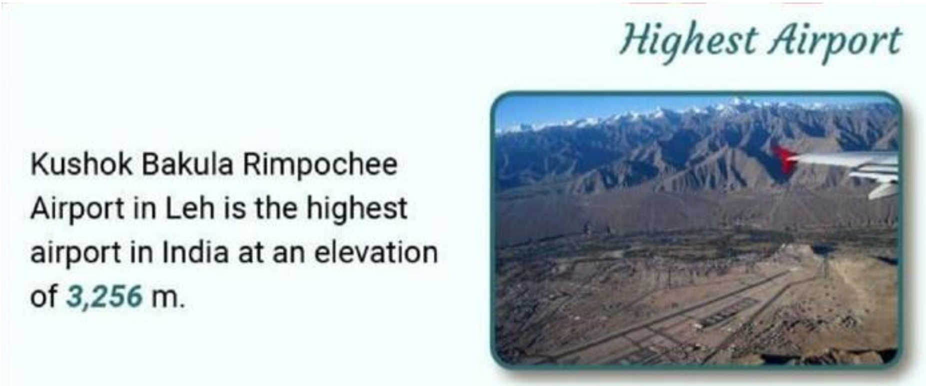
(e) Part V: Radar Services in Airfield Area

(f) Part VI: Rules of the Air

### LEARNING OBJECTIVES

- Understand the Layout of an Airfield.
- Understand various Markings and Lighting Systems on the taxi tracks and runway.
- Understand key terminologies related to Aerodrome and Aviation.
- Understand the Functions of Air Traffic Control (ATC).
- Understand the aerodrome.
- Importance of Rescue and Fire Services at an Aerodrome Understand different types of Radar and their usage at an aerodrome.
- Understand basics of Radio Telephony (RT) procedures.

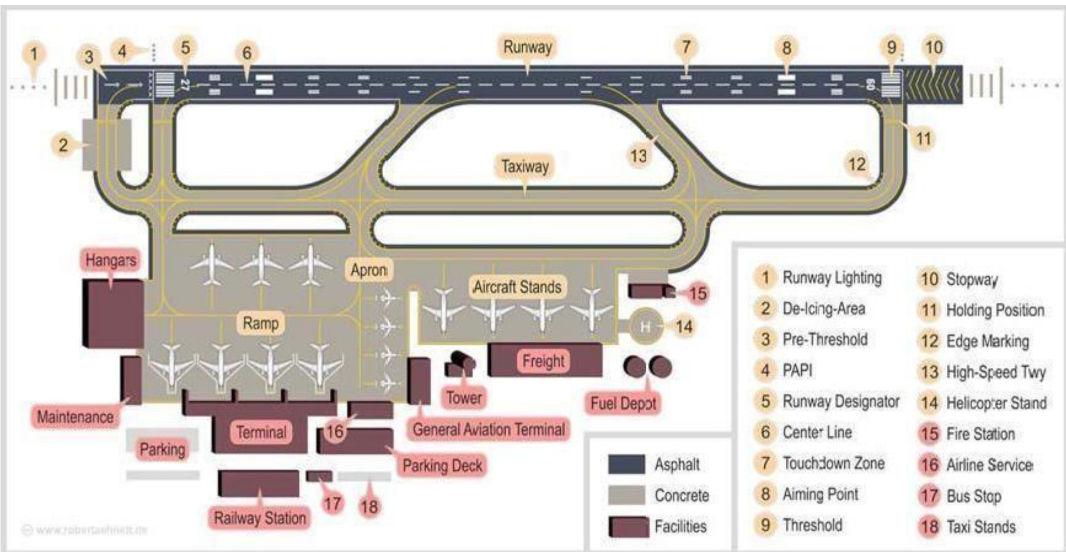
## INTERESTING FACTS


## PART I: VISIT TO AIRFIELD AND AIRFIELD LAYOUT

2. **Visit to Airfield**. Before commencing flying, the cadets visit to ATC and Meteorology Section should be planned. At the ATC the cadets are to be shown the Airfield Layout and RT procedures. The basics of meteorology need to be explained at the Met Section for better understanding and assimilation.

3. **Airfield Layout.** Following are the areas laid down at the airfields to facilitate safe and expeditious conduct of aircraft operations



4. **Movement Areas**. Movement areas are that part of an airfield intended for the surface movement of the aircraft. These are paved areas and include runways, taxiways, dispersal areas, aprons etc.

5. **Runways**. Runways are paved surfaces intended for take -off and landing of ac. The number and orientation of runways at an airfield will depend upon the volume of traffic, runway occupancy time and climatological data on surface winds.

6. **Taxiways**. These are paved surfaces provided for the taxing of aircraft and intended to provide a link between one part of the aerodrome and another.

## PART II: AERODROME MARKINGS AND AIRFIELD LIGHTING

7. **Aerodrome Markings**. This consist of signs on surface of movement areas to convey aeronautical information. Aerodrome ground markings shall consist of the following:

(a) Runway markings.

(b) Taxiway markings.

(c) Unserviceability markings.

8. **Runway Markings**. Runway markings shall consist of the following:-

(a) **Runway Designation Markings.** Runway designation markings shall consist of a two-digit number and on parallel runways shall be supplemented by a letter. The two- digit number shall be the whole number nearest to one tenth of magnetic azimuth of centre line measured clockwise from magnetic North when viewed from direction of approach.

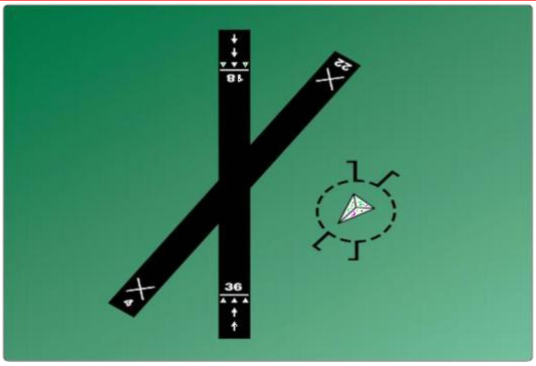
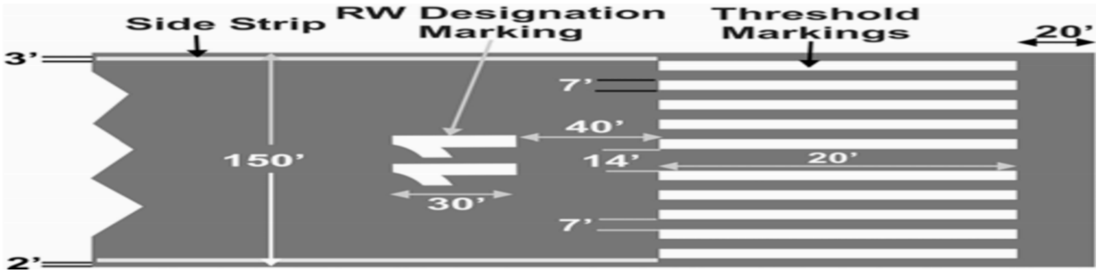


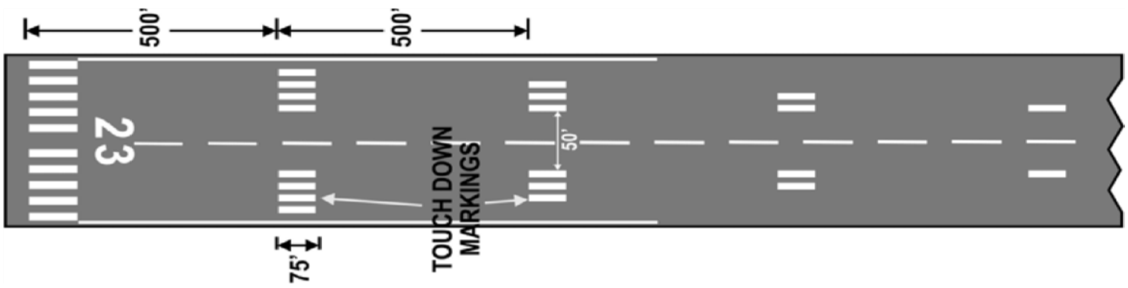

**Figure 49.** Airport Diagram ©ASA

(b) **Runway Centre Line Markings**. Runway centre line markings shall consist of a series of broken longitudinal lines along the runway centre line and extending along the whole length of the runway.

(c) **Runway Threshold Markings**. The markings shall consist of a series of longitudinal strips of uniform dimensions symmetrically placed on both sides of runway centre line and extending laterally to 1.5 m (5 ft) from the edge of runway.



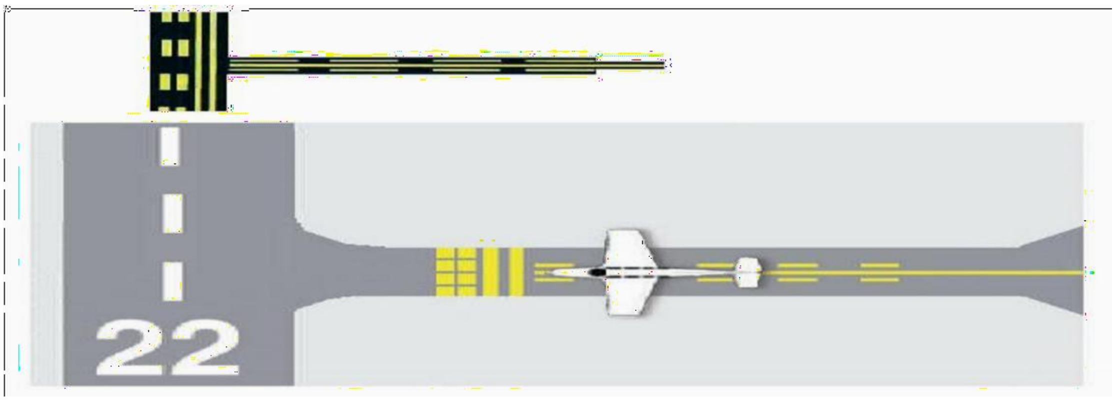

(d) **<u>Runway Touch Down Zone Markings</u>**. Touch down zone markings shall be located over the first 600 m (2000 ft) of instrument runways at longitudinal spacing of 150 m (500 ft).



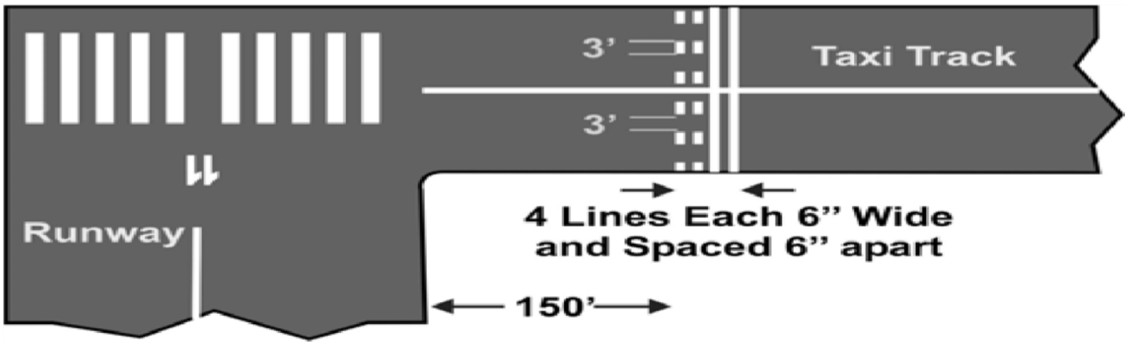

(e) **<u>Runway Side Strip Markings</u>**. Side strip markings shall be provided on all paved runways. These markings shall consist of two lines extending the whole length of the runway parallel to and equidistant from runway centre line.

9. **<u>Taxiway Markings</u>**. These markings shall consist of:

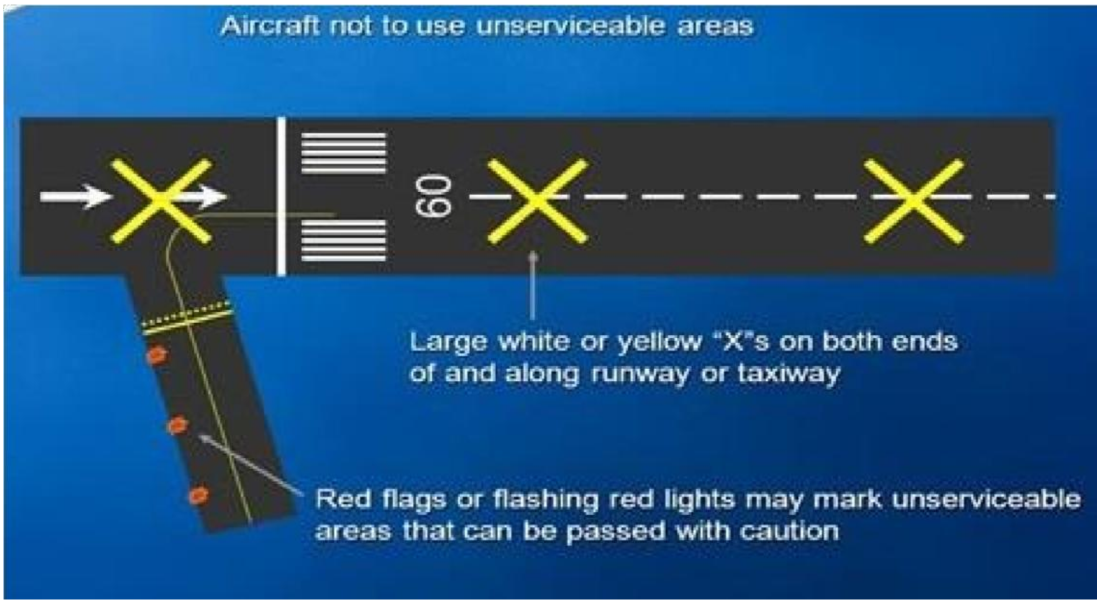
(a) **<u>Taxiway Centre Line Markings</u>**. These markings shall be single unbroken lines 0.15 m (6") wide along the centre line of taxiway.




(b) **<u>Runway Holding Position Markings</u>**. These markings shall consist of four lines of 0.15 m (6") width each with spacing of 0.15 m (6").



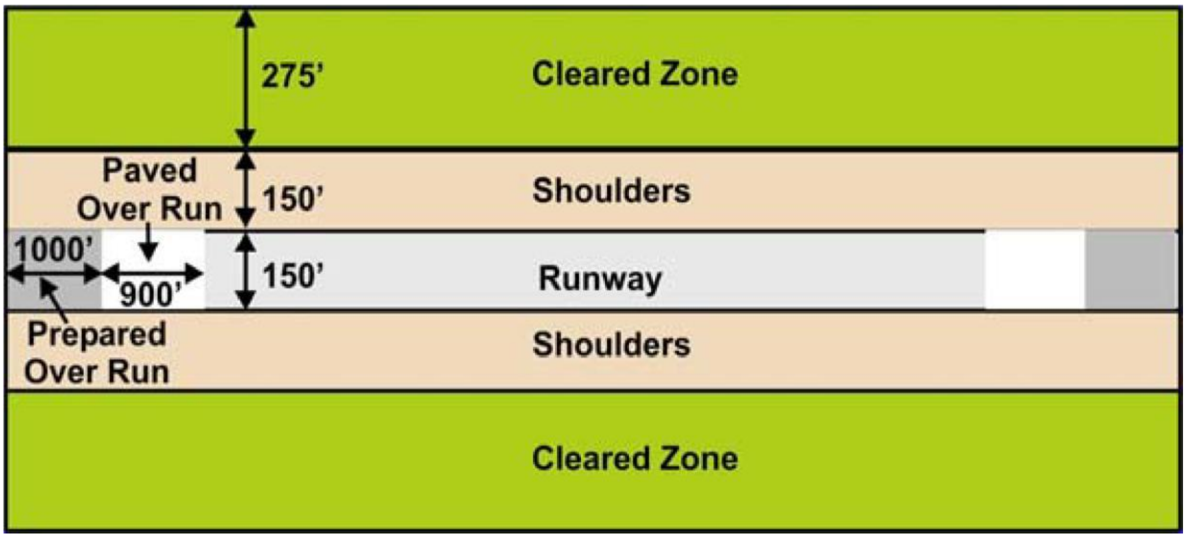

(c) **Unserviceability Markings**. Unserviceability markings shall be displayed on those parts of movement area, which are unfit for landing, take-off or surface movement of aircraft. Unserviceability markings shall be in the form of a cross as given.



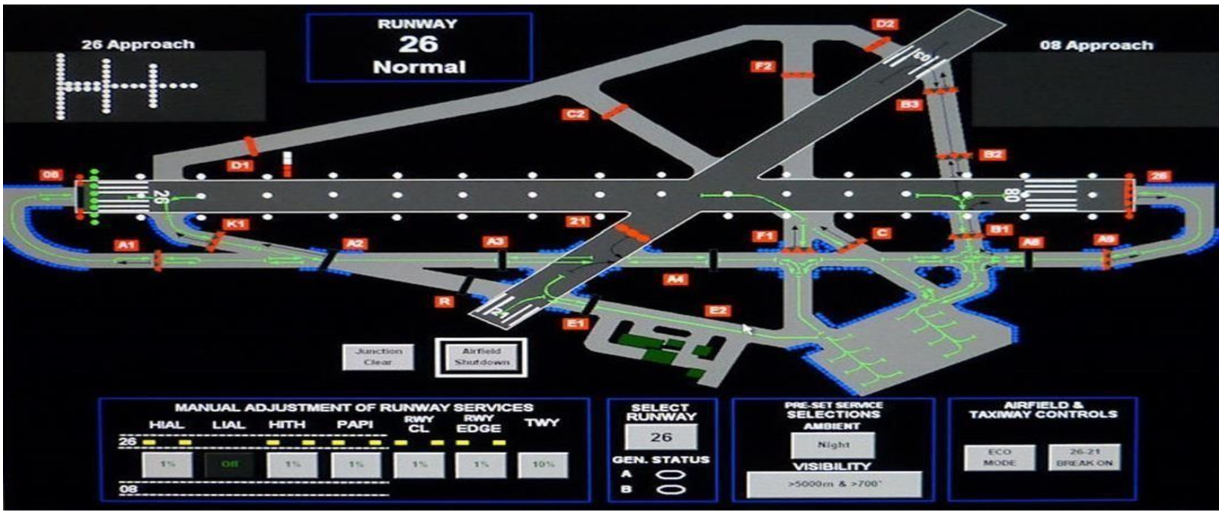

10. **Shoulders**. These are areas immediately adjacent to the edges of the runway, taxiways, overruns and SGAs prepared for accidental or emergency use in the event of an aircraft running off the paved surface.

11. **Cleared Zones**. These are those areas of the flight strip adjacent to the shoulders, which for safety of aircraft operations, should be levelled and be free of obstructions as far as possible.

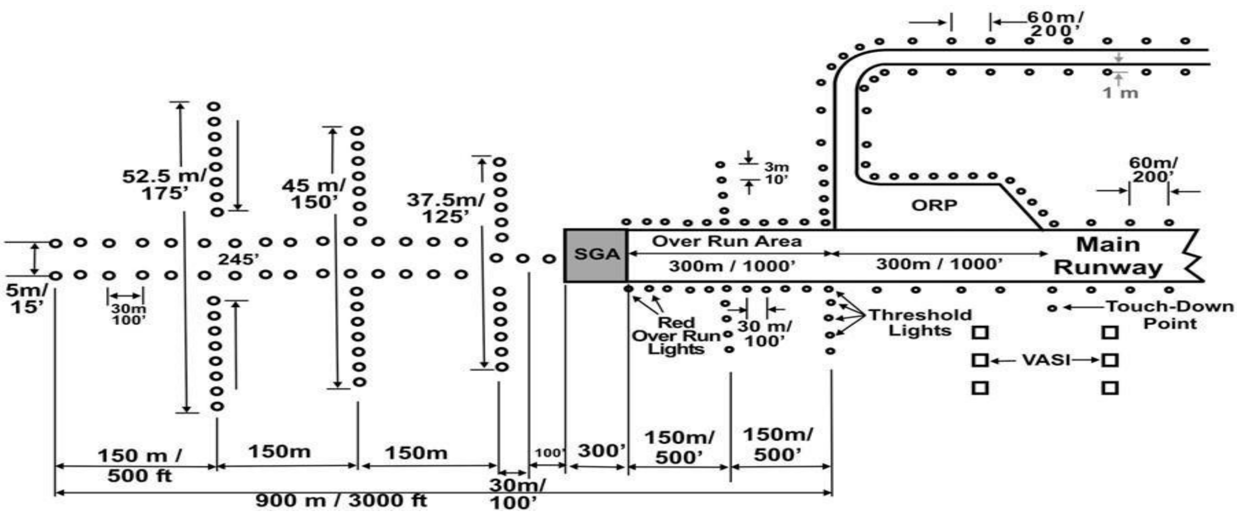
12. **Over-Run Areas**. A defined rectangular area on ground at the end of runway in the direction of take -off prepared as a suitable area in which an aircraft can be stopped in case of abandoned take off, or during a landing emergency.



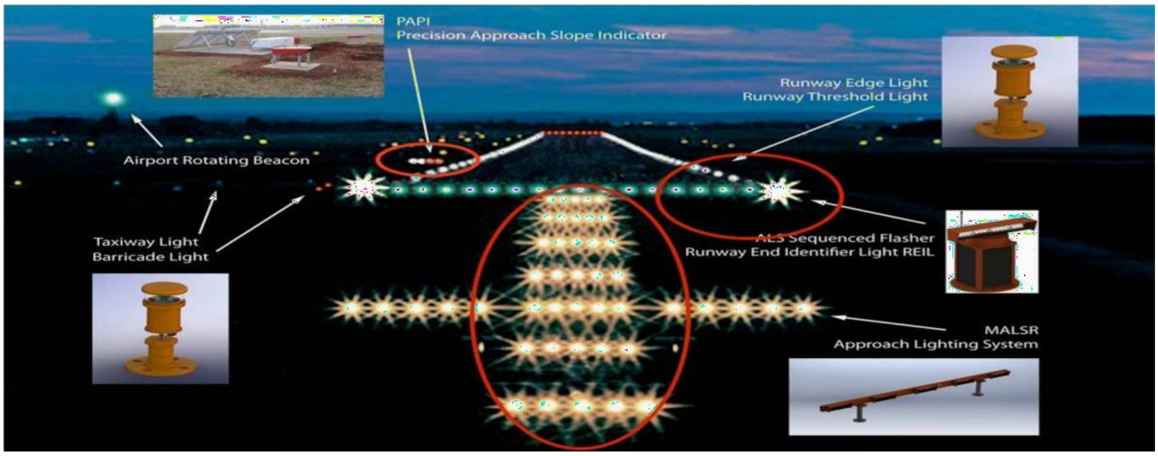

13. **Aerodrome Lighting**. There are several types of approach and airfield lighting in use in the service. All permanent installations are normally on the mains electricity supply but also have some alternative arrangements for use in the event of power failure. Aerodrome ligh ting is considered under two headings.




(a) **Approach Lighting**. This is to assist the pilots to make an approach for landing in poor visibility or at night.

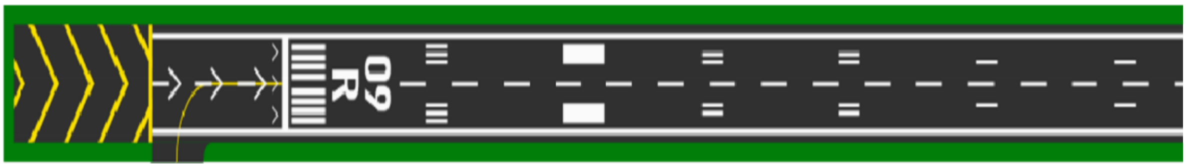


(b) **Airfield Lightings**. Modern installation consists of raised high intensity white lights along each side of the runway, beamed towards the landing aircraft. At the beginning of runway, called the thresh hold, is a bar of green lights going across the full width of the runway.




## PART III: BASIC TERMINOLOGIES AND DEFINITIONS

14. **Aerodrome**. Defined area on land or water including any buildings, installations and equipment intended to be used either wholly or in part for the arrival, departure and movement of aircraft.



15. **Aerodrome Reference Point (ARP)**. It is a designated geographical location of an aerodrome, normally taken as the geometrical centre of Runway

16. **Air Report**. It is a report passed during the course of a flight in conformity with requirements for position, operational, or meteorological reporting in the AIREP or POMAR (Position, Operation Meteorology Air Report) forms.

17. **Air Route**. The navigable airspace between two points, identified to the extent necessary for the application of flight rules.

18. **Air Traffic Control**. It is a service provided by groundbased air traffic controllers who direct aircraft on the ground and through a given controlled airspace and can provide advisory services to aircraft in non- controlled airspace.

19. **Alerting Service**. A service provided to notify appropriate organizations regarding ac in need of search and rescue aid, and assist such organizations as required.

20. **Alternate Aerodrome**. An aerodrome specified in the flight plan to which a flight may proceed when it becomes inadvisable to land at planned aerodrome.

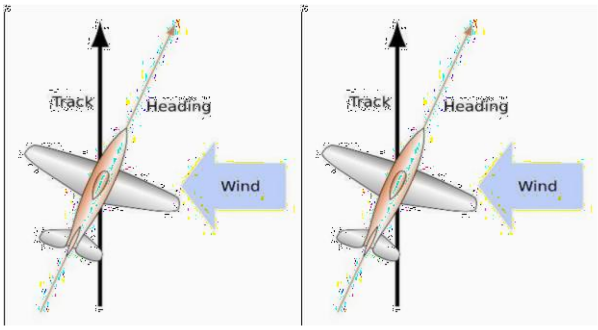
21. **Altitude**. The vertical distance of a level, a point or object considered as a point measured from mean sea level (MSL).

22. **Distress Message**. Emergency message to be used when an aircraft is threatened by serious or imminent danger and the crew is in need of immediate assistance.

23. **Elevation**. The vertical position of a point or a level, above, on or affixed to the surface of the earth, measured from mean sea level.

24. **Estimated Time of Arrival (ETA)**. For IFR flights, the time at which it is estimated that the ac will arrive over a designed point, defined by reference to navigation aids, from which it is intended that an instrument approach procedure will be commenced, or, if no navigational aid is associated with the aerodrome, the time at which the ac will arrive overhead. For VFR flights, it is the time at which it is estimated that the ac will arrive over the aerodrome.

25. **Heading**. The direction in which the longitudinal axis of an aircraft is pointed usually expressed in degrees from North (magnetic).




26. **Height**. The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

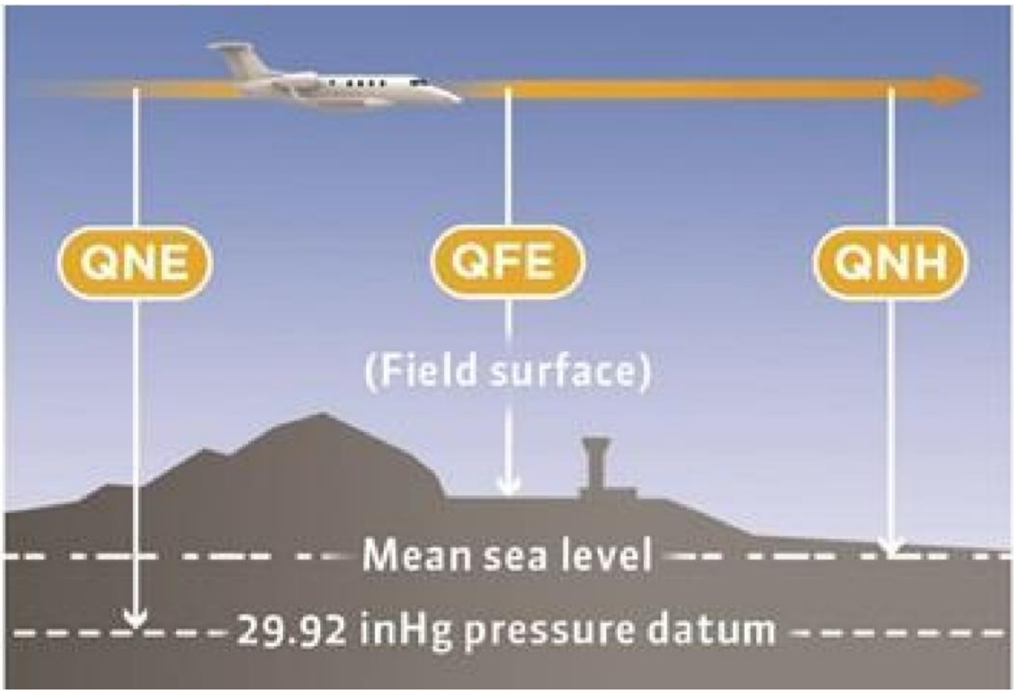
27. **Load Classification Number (LCN)**. The bearing strength of a pavement or runway is defined by a number. This is associated with an indication of the characteristics and type of construction of the pavement

28. **Prohibited Area**. Airspace of defined dimensions, above the land areas of territorial waters of a State, within which the flight of aircraft is prohibited.

29. **QFE**. Aerodrome pressure corrected for temperature. When set on the altimeter on the ground, the Altimeter should read zero.

30. **QNH**. Aerodrome pressure corrected for temperature and adjusted to Mean Sea Level, using the ICAO formula. When set on the altimeter on the ground, the altimeter should read aerodrome elevation

31. **QNE**. It is a term used in aviation to refer to the altimeter setting that is used when flying at flight levels (FL) above transition altitude. It represents the standard atmospheric pressure used to set the aircraft's altimeter to measure flight levels (in feet) based on a standard atmospheric pressure of 1013.25 hPa (hectopascals) or 29.92 inches of mercury (inHg). When an aircraft is flying at high altitudes, the pressure around the aircraft may vary due to weather conditions. To ensure consistent altitude readings and standardization across all aircraft, the altimeter is set to QNE above the transition altitude, and the aircraft's altitude is then expressed in flight levels (e.g., FL350 for 35,000 feet).




32. **Restricted Area**. An airspace of defined dimensions, above the land areas or territorial waters of a State, within which the flight of aircraft is restricted in accordance with specified conditions.

33. **Transition Altitude (TA)**. The altitude in the vicinity of an aerodrome at or below which the Vertical position of an aircraft is controlled by reference to altitudes above mean sea level or height above the aerodrome depending on whether QNH or QFE is set on the altimeter.

34. **Transition Layer**. The airspace between the transition altitude and the transition level. The depth of the layer will normally be insignificant, and will in any case never exceed 1500 ft.

35. **Transition Level**. The lowest flight level above the transition altitude. It will vary in accordance with the relationship between the QNE and the standard pressure datum.

36. **Visibility**. The ability, as determined by atmospheric conditions and expressed in units of distance, to see and identify prominent lighted objects by night.

## PART IV: AIR TRAFFIC CONTROL (ATC) AND FUNCTION OF RESCUE SERVICES

37. An organisation established to provide:-

(a) Air traffic control within a control area (where established).

(b) Flight information service within a flight information region.

(c) Alerting service for search and rescue within its flight information region.

38. Air Traffic Control Services are provided by licensed Air Traffic Controllers. It is a service provided for the purpose of:-

(a) Preventing collisions between air craft in the air.

(b) Prevent collisions on the manoeuvring area between a/c and obstructions

(c) Expediting and maintaining an orderly flow of traffic.

(d) Provide information and support for pilots.

**Functions of Rescue Services**

39. The rescue and fire services at an airport in India are responsible for a number of functions including:-

(a) **Emergency response**. The rescue and fire services are responsible for responding to emergencies at the airport, including aircraft accidents and incidents.

(b) **Fire protection**. The rescue and fire services are responsible for maintaining fire protection at the airport, including in the terminal building and other vital installations.

(c) **Egress routes**. The rescue and fire services are responsible for creating and maintaining egress routes for occupants in the event of an emergency.

(d) **Rescue**. The rescue and fire services are responsible for rescuing occupants who are unable to escape without assistance.

(e) **Airport emergency plan**. The rescue and fire services are responsible for managing the airport emergency plan, which coordinates the efforts of mutual aid agencies.

## PART V: RADAR SERVICES IN AIRFIELD AREAS

40. **Basic Radar Services in an Airfield**.

(a) **Primary Functions**.

(i) **Surveillance**. Monitor aircraft movement and weather conditions.

(ii) **Separation**. Prevent collisions of aircraft.

(iii) **Guidance**. Provide navigational assistance.

(b) **Radar Services**.

(i) **Surface Movement Radar (SMR)**. To provide Surface movement control of all aircraft and vehicles.

(ii) **Airport Surveillance Radar (ASR)**. This radar system detects and displays the location of aircraft in the airspace around an airport within designated airspace usually upto 60 Nautical miles and below 25000 feet.

(iii) **Terminal Radar**. This radar guide aircraft as they approach and depart from an airport within designated coverage area and vertical limits.

(iv) **Precision Approach Radar (PAR)**. Precisely guides aircraft in 3D during approach and landing. This is extremely useful in bad weather wherein visibility is low and precision approach navigation facilities such as Instrument Landing system (ILS) is not available at an airport.

## PART VI: RULES OF THE AIR

41. Flying, in general is of a complex nature, therefore there are many rules and regulations, which must be observed by pilots and air traffic control personnel alike if the maximum degree of safety is to be ensured to aircraft, flying personnel, civilians and property.

### Visual Flight Rules

42. **Visual Meteorological Conditions**. Visual Meteorological Conditions are said to exist when the prevailing visibility, distance from cloud, and ceiling are equal to or better than the specified minimum. In Flight the criteria are:-

(a) Visibility: 5 nm / 8 km.

(b) Distance from cloud: 200 yards / 1.5 km horizontally and 1000 feet / 200 meters vertically.

43. **Special VFR Flights**. VFR Flights, specially authorised can be permitted even in weather conditions below VMC, subject to obtaining ATC clearance. Such flights are known as special VFR flights.

44. **Inflight Operation**. VFR Flight shall be flown only in condition of visibility and distance from clouds equal to or greater than those specified for VMC in the laid down orders.

45. **Restrictions**.VFR Flights except those operated in the immediate vicinity of the aerodrome, shall not be operated:-

(a) At night.

(b) Above flight level 200 (above flight level 150 in South East Asia).

(c) More than 100 nm seawards from the shoreline in controlled air space.

**Instruments Flight Rules**

46. **Instrument Flight rules (IFR)**. are a set of regulations that govern how aircraft are flown in conditions where it's not safe to rely on visual cues.

47. **Aircraft Equipment**. Aircraft shall be equipped with suitable instruments and with navigational aids appropriate to the route to be flown.

48. **Change from IFR Flight to VFR Flight**. An IFR flight electing to change to Visual Flight Rules, shall notify the appropriate unit, specifically, that the IFR flight is cancelled and communicate the change to be made to its current flight plan.

**Right of Way Rule**

49. The following are some of the basic rules laid down to reduce the risk of collision:-

(a) **Right of way procedure**. Aircraft are to give way to each other in the following orders: -

(i) Aero plane.

(ii) Helicopters.

(iii) Airships.

(iv) Tug and glider combinations.

(v) Gliders.

(vi) Balloons.

(vii) For example, aero planes give way to all other types of aircraft.

(b) **Converging**. When two aircrafts are on the paths which cross, the aircraft which has the other on its right is to give way.

(c) **Approaching Head On**. When two aircrafts are approaching head on, each is to alter heading to the right.

(d) **Overtaking**. An aircraft overtaking another aircraft is to avoid the overtaking aircraft by altering heading to the right, and is to keep clear until all risk of collision is past. Sub para (a) does not apply to this rule. An aircraft is overtaking another aircraft, when it is approaching from the rear at an angle of less than 70 degree to the fore and aft axis of the overtaken aircraft.

(e) **Landing**. Aircraft in the final stage of landing have the right of way over aircraft in the air and on the ground.

(f) **Approaching to Land**. The aircraft at the lower altitude on the approach has the right of way; normally, however, as a matter of courtesy, captains of light manoeuvrable aircraft give way for the heavier types in which the overshoot procedure is involved.

(g) **Emergency Landing**. An aircraft seen, or known to be carrying out an emergency landing has the right of way over all others. Every aircraft obliged by the above rules to keep out of the way of another, is, if possible, to avoid passing over or under the other or crossing ahead of it. The aircraft having the right of way should normally maintain its heading and speed.

50. The airfield circuit is the path that aircraft fly near an aerodrome in a predefined manner at specified height and distance from the airfield. When flying in the circuit, a pilot is to:-

(a) Keep a sharp look out for other aircraft in the vicinity.

(b) Conform with or avoid the traffic pattern. Maintain a continuous listening watch on the aerodrome R/T frequencies and keep a sharp look out for any visual signals which may be displayed.

(c) Obtain, by R/T or visual means, authorization for any movements.

**Circuit Procedures**

51. A pattern for traffic movement has been established for use at all aerodromes. It is called a traffic circuit and it expedites and separates airplanes using the same aerodrome. It is the responsibility of every pilot, for safety and efficiency, to learn and follow the proper traffic procedures when coming in to land at an aerodrome. The circuit pattern to be followed on respective aircraft types is elaborated in type SOP.

52. **Standard Altimeter Setting Procedure**.

(a) A transition altitude is specified for each aerodrome or designated area which is minimum 1500 feet above aerodrome elevation.

(b) The transition level is the lowest flight level available for use above the transition altitude.

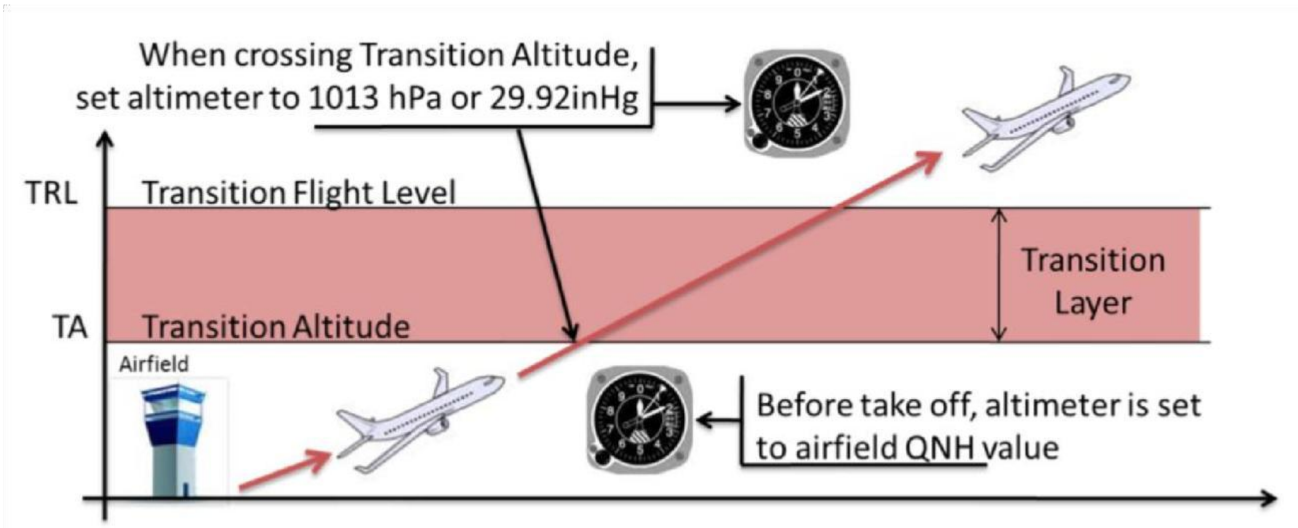
(c) The transition layer is the airspace between the transition altitude and the transition level. (Due to changes in pressure, the vertical extent of the layer will vary).

(d) Reports of vertical position of aircraft will be expressed as follows:

(i) When at or below transition altitude express vertical position in terms of altitude indicated by the altimeterset to QNH.

(ii) When at or above transitions level vertical position in terms of flight levels indicated by the altimeter set to 1013.2 mb.

(e) During climb after take-off, use QNH until transition altitude is reached, thereafter use flight levels. During descent for landing, use flight levels until transition level is reached, thereafter use QNH.




**Note**. The vertical position of an aircraft flying through the transition layer will be reported as 'altitude' when descending and as a 'flight level' when ascending.

53. As an Air Wing NCC cadet it is must to know about ATC &RT procedure prior to start flying. Timely information of weather, wind speed, position are the essential parameters for flying. To access all the timely required information for a safe operation we must know the ATC & RT procedure.

**Definitions**

54. **Air Traffic Services**. Services provided for the safe and efficient conduct of flight are termed as air traffic services.

55. **Objectives of Air Traffic Services**.

(a) To prevent collision between aircraft.

(b) To prevent collision between aircraft on the manoeuvring area and obstructions on that area.

(c) To expedite and maintain an orderly flow of traffic.

(d) To provide advice and information useful for the safe and efficient conduct of flights.

(e) To notify appropriate organisations regarding aircraft in need of search and rescue aid and assist such organisation as required.

56. The ATS include the following: -

(a) Air Traffic Control Services:

(i) Area Control Service.

(ii) Approach Control Service.

(iii) Aerodrome Control Service.

(b) Flight Information Service.

(c) Air Traffic Advisory Service.

(d) Alerting Service

57. **Automatic Terminal Information Service (ATIS)**. The provision of current, routine information to arriving and departing aircraft by means of continuous and repetitive broad cast throughout the day or specified portion of the day. The transmissions contain weather, QNH, runway is use and any other relevant information.

58. **Approach Control Service**. ATC service for arriving or departing controlled flights.

59. **Aerodrome Control Service**. ATC service for aerodrome traffic.

60. **Air Traffic Service Units**.

(a) **Approach Control Office**. A unit established to provide air traffic control service to controlled flights arriving at or departing from, one or more aerodromes.

(b) **Aerodrome Control Tower**. A unit established to provide air traffic control service to aerodrome traffic.

61. **Diversion**. Diversion is the act of flying to an aerodrome, other than that originally intended, for the purpose of landing. This term applies both when the captain of the aircraft makes the decision and when the advice or order emanates from an appropriate ground authority.

62. **Reason for Diversions**. Diversions are normally made for any of the following reasons:-

(a) Aircraft unserviceability or shortage of fuel.

(b) When the weather enroute is hazardous.

(c) When the weather at the aerodrome of first intended landing is reported to be below the pilot's break-off altitude for the aid to be used.

63. When there is a reported failure of the essential ground aids necessary for use at the proposed time of landing.

**RT PRODUCER AND PHRASEOLOGY**

| **Letter** | **Word** | **Pronunciation** |
|---|---|---|
| A | Alfa | Alphah |
| B | Bravo | BrahVoh |
| C | Charlie | Charlee (or Shar Lee) |
| D | Delta | Dell Tah |
| E | Echo | Eck Oh |
| F | Foxtrot | Foks Trot |
| G | Golf | Golf |
| H | Hotel | Hohtell |
| I | India | In Dee Ah |
| J | Juliet | Jew Lee Et |
| K | Kilo | Key Loh |
| L | Lima | Lee Mah |
| M | Mike | Mike |
| N | November | No Vem Bar |
| O | Oscar | Oss Car |

| | | |
|---|---|---|
| P | Papa | PahPah |
| Q | Quebec | Qeh Beck |
| R | Romeo | Row Me Oh |
| S | Sierra | See Airrah |
| T | Tango | Tang Go |
| U | Uniform | You Nee Form |
| V | Victor | VikTah |
| W | Whiskey | Wiss Key |
| X | X-Ray | Ecks Ray |
| Y | Yankee | Yan Key |
| Z | Zulu | Zoo Loo |

**Pronunciation of Numbers**

| **Number** | **Word** | **Pronunciation** |
|---|---|---|
| 1 | One | Wun |
| 2 | Two | Too |
| 3 | Three | Tree |
| 4 | Four | Fower |
| 5 | Five | Fife |
| 6 | Six | Six |
| 7 | Seven | Saveen |
| 8 | Eight | Ait |
| 9 | Nine | Niner |
| 0 | Zero | Zee Row |
| . | Decimal | Day - See - Mal |
| 1000 | Thousand | Tou - Sond |

| All numbers except whole thousand will be transmitted by pronouncing each nu mber separately. Whole thousands shall be transmitted by prono uncing each digit in the number of thousand followed by the word thousand. Some of the examples are: | | |
|---|---|---|
| 10 | One Zero | |
| 75 | Seven Five | |
| 100 | One Zero Zero | |
| 583 | Five Eight Three | |
| 5000 | Five Thousand | |
| 25000 | Two Five Thousand | |

64. **Distress Signals**. The air-to-ground and ground-to-air distress signals (light) are essential tools for aviation communication, especially in emergency situations when radio communication may not be possible or effective. These light signals help pilots and ground personnel quickly understand the status or requirements of an aircraft, ensuring safety, coordination, and appropriate responses during flight operations. Here's how these signals are used:-

(a) Signal Type Signal Description Signal Pattern Purpose Air-to Flashing red light To alert ground personnel of an Distress Signal Ground (at intervals) emergency.

(b) Air-to Indicating a request Flashing white light To request information or assistance.

(c) Ground for information (at intervals).

(d) Continuous red light or alternating.

(e) Air-to Indicating a specific to signal distress or a need for red and white light Ground emergency immediate assistance. (depending on situation).

(f) Ground-to Indicating distress Flashing red light.

(g) To indicate an emergency or distress.

(h) Air or emergency (at intervals).

(j) Ground-to Indicating a safe Continuous green to signal that the area or airstrip is Air condition light safe.

(k) Ground-to Indicating readiness Flashing white light Air for aircraft to land (at intervals).

(l) Ground-to Indicating no Flashing red light Air landing (at intervals).

(m) To signal aircraft to land.

(n) To signal aircraft not to land

**DID YOU KNOW?**

- Aircraft can be landed, stopped and taxi in zero visibility also, provided the aircraft is suitably equipped, pilot is trained and cleared for such operations and the airfield has appropriate class of precision approach and instrument landing system av ailable. (CatIII C).
- ALG stands for advanced landing ground. Nyoma ALG in eastern Ladakh is India's highest advanced landing ground loacted at an altitude of around 13,700 Ft.

## CONCLUSION

65. The understanding of various aspects of Airmanship helps develop a better situational awareness and readiness to conduct safe operations. The purpose of this subject is as follows:

(a) **Airfield Layout**. Understanding the airfield layout, including runways, taxiways, dispersal areas, aprons and differentiate between aircraft manoeuvring areas and normal areas. Enables cadets to identify the key components that ensure smooth and safe movement of aircraft. This knowledge emphasizes the importance of proper design and maintenance of movement areas for efficient airfield operations.

(b) **Aerodrome Markings and Lighting Systems**. The study of aerodrome markings, such as runway designations, centrelines, and threshold markings, highlights their role in providing visual guidance to pilots. Similarly, aerodrome lighting systems, including approach and airfield lighting, assist pilots in landing and taxiing, especially during low visibility or night operations.

(c) **Air Traffic Control (ATC) and Its Functions**. Air Traffic Control plays a critical role in preventing collisions, expediting traffic flow, and providing essential information to pilots. By understanding ATC operations and the use of radar systems like **SMR, ASR, and PAR**, cadets appreciate the importance of communication, monitoring, and navigation in ensuring aviation safety.

(d) **Rescue and Fire Services**. The study of rescue and fire services highlights their vital role in emergency response, fire protection, and passenger safety. Their preparedness ensures quick and effective action during aircraft accidents or incidents, reinforcing the safety culture in aviation.

(e) **Radar Services in Airfield Area**. Radar systems, such as **Surface Movement Radar (SMR), Airport Surveillance Radar (ASR), and Precision Approach Radar (PAR)**, are essential for aircraft monitoring, separation, and navigation. These services ensure the safe movement of aircraft on the ground and during landing or departure, especially under poor weather conditions.

66. **ATC RT Procedure**. This is the way to communicate with ATC for timely information of weather, wind speed, position, and all other essential parameters for flying.

(a) Understand various terminologies and definitions related to an airfield layout.

(b) The Runway designation markings consist of two-digit number indicating the magnetic directions of the Runway central line, measured clockwise from the magnetic north.

(c) Understand other markings to differentiate between the meaning they convey.

(d) Understanding that the vacant areas around the main runway are for safety of aircraft which while experiencing emergencies which may lead aircraft to loose directional control.

(e) The approved kind of lightning is extremely important for operations in low visibility.

(f) ATC is the organisation that has vital role in operations of aircraft from an airfield.

(g) Fire and rescue services are for quick response to save lives in case of emergencies faced by an aircraft and its occupants.

(h) Radar has come a long way in from of a sensor, that can be applied for identifying, controlling and guiding various airborne elements at an airport. They are primarily classified based on their functions and services.

(j) Understanding Visual Flight Rules (VFR), Instrument Flight Rules (IFR), and the right-of-way procedures for aircraft to avoid collisions and maintain safe operations.

## ASSESSMENT EXERCISE

**Multiple Choice Questions**

**Q1. What is the primary function of runways at an airfield?**

(a) Parking of aircraft

(b) Take-off and landing of aircraft

(c) Aircraft maintenance

(d) Passenger boarding

**Q2. What are movement areas in an airfield?**

(a) Areas for aircraft maintenance

(b) Restricted zones for parking

(c) Areas intended for surface movement of aircraft

(d) Meteorological stations

**Q3. What is the "transition altitude"?**

(a) A fixed altitude for navigation corrections

(b) The altitude at which vertical position is referenced to mean sea level

(c) The lowest level of navigable airspace

(d) The standard level for meteorological calculations

**Q4. What are the components of aerodrome markings?**

(a) Threshold lights, tower lights, and runway lights

(b) Obstruction markings and parking lines

(c) Radar systems and visual landing aids

(d) Runway markings, taxiway markings, unserviceability markings

**Q5. What is an Air Report (AIREP)?**

(a) A flight path calculation

(b) A report including position, operational, and meteorological data

(c) A document for runway specifications

(d) A manual for ATC procedures

**Q6. What is an aerodrome?**

(a) Structure for aircraft parking

(b) A runway marking zone

(c) A facility for air traffic control operations

(d) A defined area for aircraft arrival, departure, and movement

**Q7. What is traffic circuit designed for?**

(a) Ensuring safe and efficient aircraft movement near aerodromes

(b) Providing refueling stops during landing

(c) Marking navigation paths for take-off

(d) Diverting traffic during emergencies

**Q8. What is the function of the aerodrome control service?**

(a) Directs taxiways and parking areas

(b) Provides air traffic control for aerodrome traffic

(c) Manages emergency landings

(d) Handles aircraft maintenance schedules

**Q9. What is a distress message used for**

(a) Informing about the runway status

(b) Requesting immediate assistance during serious or imminent danger

(c) Communicating routine weather reports

(d) Reporting taxiway issues

**Q10. What does the "right of way" rule state for converging aircraft?**

(a) Aircraft on the left gives way

(b) Aircraft on the right gives way

(c) Both aircraft must turn left

(d) The lower aircraft takes priority

**Q11. What is the purpose of Automatic Terminal Information Service (ATIS)?**

(a) Directs taxiway movement

(b) Guides pilots in poor visibility

(c) Alerts pilots about traffic patterns

(d) Provides current weather and runway information to arriving and departing aircraft

**Q12. What is the definition of a "restricted area"?**

(a) A zone with no flight restrictions

(b) Airspace where flight is restricted under specific conditions

(c) A section used for emergency landings

(d) A temporary maintenance zone

**Q13. Which aircraft has the highest priority for right of way?**

(a) Gliders

(b) Airships

(c) Emergency landing aircraft

(d) Aeroplanes

**Q14. What is the standard width of runway center-line markings?**

(a) 0.10 m

(b) 0.15 m

(c) 0.30 m

(d) 0.45 m

**Q15. When two aircraft approach head-on, what action should they take?**

(a) Both should turn right

(b) Both should turn left

(c) The higher aircraft gives way

(d) The heavier aircraft has priority

**Short Answer Type Questions**

(1) What is the function of a runway at an airfield?

(2) Define "aerodrome" ?

(3) What does QNH stand for in aviation?

(4) What is the purpose of approach lighting?

(5) What is the importance of the "right of way" rule in aviation?

**Long Answer Type Questions**

(1) What are the basic radar services provided at an airfield?

(2) Explain the conditions for Visual Flight Rules (VFR) ?

(3) What is the purpose of aerodrome lighting?

(4) What are the objectives of Air Traffic Services (ATS)?

(5) Describe the responsibilities of rescue and fire services at an airport?

# ATC & MET AIRMANSHIP NAVIGATION (SD/SW)

## CHAPTER II : NAVIGATION (NAV)

**““Aviation is not just about the destination; it's about the journey and the experiences along the way.”**


## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| Total Period | : | 03 (Three) |
| Type | : | Lecture and Practical |
| Year | : | 2ND Year SD/SW |
| Conducting Officer | : | ANO/CTO |
| Training Aids | : | Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model. |

**Time Plan**

| | | |
|---|---|---|
| • Introduction | : | 05 Mins |
| • Part I | : | 05 Mins |
| • Part II | : | 05 Mins |
| • Part III | : | 05 Mins |
| • Part IV | : | 05 Mins |
| • Part V | : | 05 Mins |
| • Part VI | : | 05 Mins |
| • Part VII | : | 05 Mins |
| • Part VIII | : | 05 Mins |
| • Part IX | : | 10 Mins |
| • Part X | : | 10 Mins |
| • Part XI | : | 10 Mins |
| • Part XII | : | 10 Mins |
| • Part XIII | : | 10 Mins |
| • Part XIV | : | 10 Mins |
| • Part XV | : | 10 Mins |
| • Conclusion and Practical | : | 05 Mins |

## INTRODUCTION

1. Air Navigation is the art of guiding an aircraft through the air, so that it arrives at a desired position at a pre-calculated time. Air Navigation differs from surface navigation in several ways such as the aircraft travels at relatively high speeds, leaving less time to calculate their position enroute. Aircraft also normally cannot stop in mid-air to ascertain their position at will.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part – I: Requirement of Navigation & Importance in Navigation

(b) Part – II: Glossary of Terms

(c) Part – III: Maps

(d) Part IV: Symbols Used in Maps

(e) Part V: Scales of Maps

(f) Part VI: Scale Factor

(g) Part VII: Global Positioning System

(h) Part VIII: Feeding of Points in GPS

(i) Part IX: Manual Input

(j) Part X: Using a Mobile App or Web Interface

(k) Part XI: Waypoints or PsOI (Points of Interest)

(l) Part XII: Modern Nav, Aids in Civil Aviation (Airbus & Boeing)

(m) Part XIII: NAVAIDS (Navigational Aids)

(n) Part XIV: Notable Systems

(o) Part XV: Air Force Perspective

### LEARNING OBJECTIVES

- Basic understanding of maps and types of maps.
- Basic understanding of conventional signs. Identify conventional signs commonly used in maps and their significance.
- Map symbols and their usage.
- Understanding the scale and grid system. Its requirement, implication and usage.

2. **Requirements of Navigation**.

(a) Pilots must navigate their aircraft, especially in single-seat or navigator-less aircraft, requiring thorough navigation knowledge.

(b) Pilots focus on flying and cannot perform detailed navigator tasks like chart plotting but must be skilled in map reading and mental dead reckoning (DR).

> **INTERESTING FACTS**
>
> - The Survey of India prepares the topographical map in India for the entire country.
> - The science of making maps is called as Cartography.

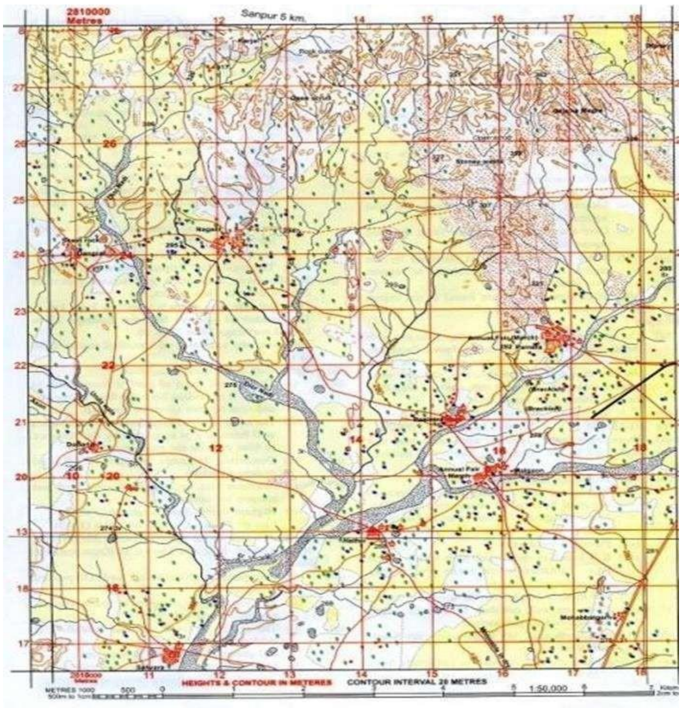
(c) Air navigation techniques are classified into:

(i) Visual Flight Rules (VFR): Uses dead reckoning, visual observations, and maps; may include radio navigation aids.

(ii) Instrument Flight Rules (IFR): Relies on instruments and radio aids like beacons or radar guidance from air traffic control.

## PART I: REQUIREMENT OF NAVIGATION & IMPORTANCE IN NAVIGATION

3. **Importance of Navigation in Aviation**. Apart from map reading and mental DR (mental dead – reckoning) the pilot navigator should also be able to fly the aircraft accurately. Variation in speed, heights and directions often results in unexpected gross errors and place the aircraft quite faraway from the desired track and time. A good pilot will plan a good flight meticulously and fly that good plan. Successful air navigation involves piloting an aircraft from place to place without getting lost, breaking the laws applying to aircraft or endangering the safety of those on board or on ground. The Types of Maps:-



(a) Physical map

(b) Political map

(c) Geographical Map

(d) Statistical Map

(e) Relief Map

(f) Topographical Map

**INTERESTING FACTS**

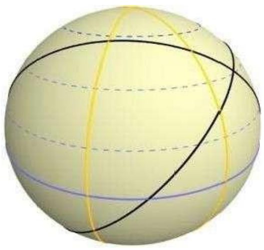
**Topographical Maps** are the maps we are concerned in Map reading. Survey of India maps are all Topographical. One of the main features that distinguish topographical maps from other maps.

## PART II: GLOSSARY OF TERMS

In order to simplify Identification and measurement of directions, the earth has been marked by number of imaginary but well defined lines. Over the years, these lines have been recognized and accepted as important symbols by all countries.

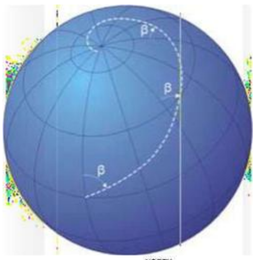
4. **Lines on Earth**. The earth is an oblate spheroid whose polar diameter is 23NM less than the equatorial diameter which is 6884NM. However, for the purpose of air navigation, earth is considered to be a perfect sphere. On this sphere a number of imaginary lines are drawn to understand and simplify air navigation. It is essential to understand these lines before proceeding further in the subject of air navigation.

5. **Definitions**.

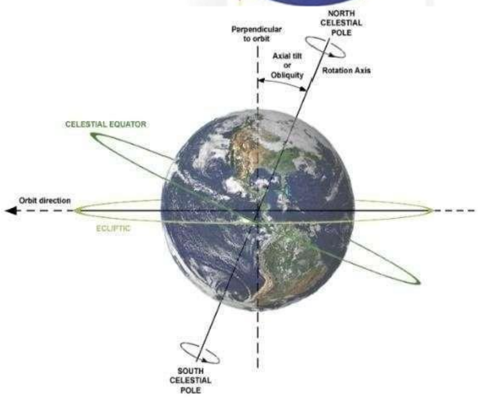


(a) **Great Circle**. The circle drawn on the surface of the earth whose plane cuts the earth into two equal halves, eg- the Equator, meridians together with their anti-meridians.

(b) **Small Circle**. The circle on the surface of the earth which cuts the earth into two parts which are unequal. It follows that the plane of a great circle always passes through the centre of the earth but that of a small circle does not. e.g.- parallels of a latitude.



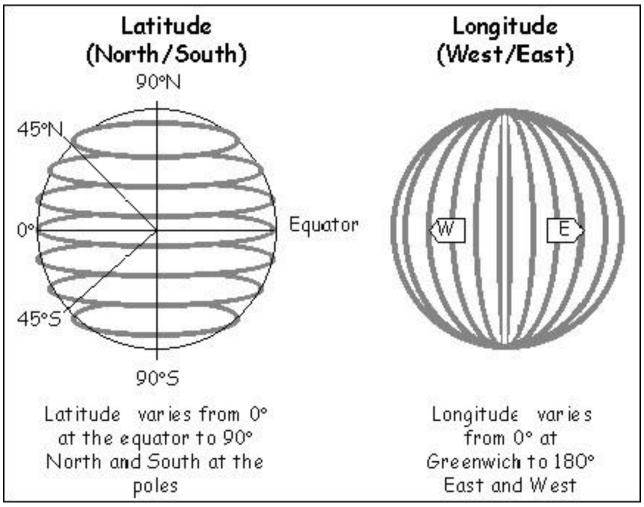
(c) **Rhumb Line**. The line cutting all the meridians at the same angle. It thus becomes a regularly curved line. examples are the Equator and all the meridians.




(d) **Equator**. It is a great circle whose plane is perpendicular to axis of rotation of the earth. The equator lies in a east-west direction and divides the earth into northern and southern hemispheres.

(e) **Earth Axis**. It is a vertical line joining the two poles of the earth, lying perpendicular to the equator and passing through the centre of the earth.

(f) **Meridian**. A meridian is a half great circle joining the two poles. Every great circle joining the two poles is a meridian and its ante-meridian indicates the North-South direction. A meridian together with its ante meridian is a great circle.




(g) **Latitude**. These are the angular distances along the meridians. The latitude of a place is defined as the arc of its meridian between the equator and the place and is named North or south depending upon its corresponding position in respect to the equator. The latitude is measured in degrees, minutes and seconds from 0° to 90° from the equator.

(h) **Longitude**. These are angular distances along the equator on east or west of the prime-meridian. The longitude of a place is defined as the shorter arc of the equator between the meridian of the place and the prime-meridian. It is measured in degrees, minutes and seconds from 0° to 180°alongwith suffix East or West of the Prime-Meridian.

(j) **Prime-Meridian**. The meridian passing through Greenwich Village of England which is the datum for record.

## PART III: MAPS

6. Topographical map is one in which a good pictorial representation of a country is portrayed and is provided mainly to be used for map reading. Actual map used in Flying should be used to explain this chapter.

**Types Of Maps**.

7. The four basic elements required in a map are:-

(a) Areas will be shown correctly.

(b) Bearing measurement anywhere on the reduced earth will be identical to the measurement on the earth.

(c) Shapes will be correct.

(d) Distances will be measured accurately by use of a graduated scale which is provided at the bottom of each map.

(e) The distances are given in:-

(i) Kilometers.

(ii) Nautical miles.

(iii) Statute miles.

8. In aviation both maps and charts are used for Navigation. When a projection has a graticule of latitudes, longitudes and an abundance of ground features it is called a map. A chart has a projection on which it contains a graticule of latitude and longitude with very few geographical features.

**DID YOU KNOW?**

- The basic idea of 'Global' Positioning System or GPS was based on LORAN and Decca Navigation System, which were used during World War II to help in the navigation of ships and planes at a long range.

9. Relief. Mountains, hills, coast lines and other natural features are of considerable interest to a pilot as they are valuable landmarks for navigation purpose or are, sometimes pose dangerous barriers for flight. Relief is indicated on maps and charts in one or more of five different ways:-

(a) Spot heights or depths.

(b) Contours and form lines.

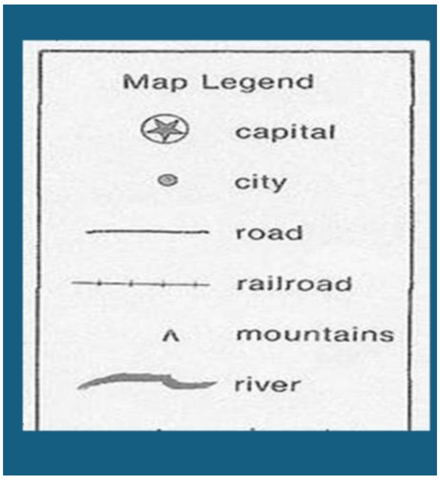
(c) Layer tints.

(d) Hachures.

(e) Hill shading.

## PART IV: SYMBOLS USED IN MAPS

10. The details on topographical maps are shown by symbols. Some of which are pictorial in nature, while others are given by a symbol which is accepted internationally. These symbols are used to denote the details of a map and these are called as conventional signs.




11. The beginner is sometimes confused by the amount of detail confronting to his untrained eye. He must learn to distinguish the more significant features and to remain undistracted by irrelevant background. The following may help to indicate the types of which is of value to the map reader.

(a) Coast line.

(b) Water Features.

(c) Mountains and hills.

**INTERESTING FACTS**

- Scale Lines are at the Bottom of the Map.

(d) Towns and Villages.

(e) Railways.

(f) Roads.

## PART V: SCALES OF MAPS

12. The scale is the ratio of a distance measured on the map to the corresponding distance on the earth surface.

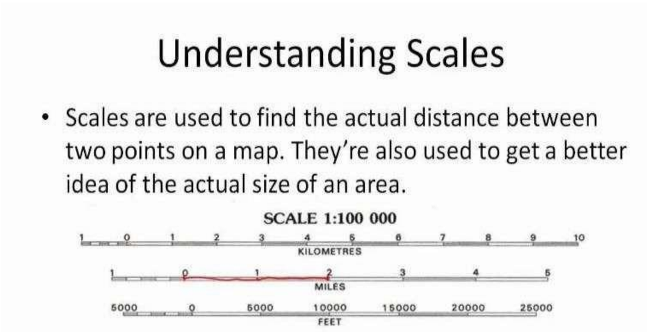
13. Scale on a map is represented commonly by:-

(a) Representative fraction

(b) Graduated scale line

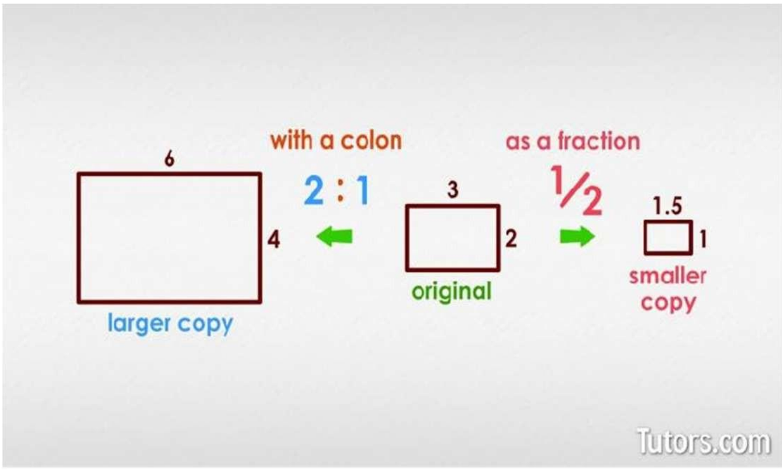
(c) Statement in words

14. Most common maps used in aviation are ¼ million maps, ½ million maps and 1 million maps.¼ million maps have larger scale than ½ million and ½ million have scale larger than 1 million. A larger scale map represents comparatively lesser ground distance and consequently more ground details can be inserted.




## PART VI: SCALE FACTOR

15. A scale factor is a conversion factor that changes the size of a figure without altering its shape, either by enlarging or reducing it proportionally. It is calculated using the dimensions of the original and the altered figures. For example, a rectangle with dimensions 5 units by 2 units enlarged by a scale factor of 2 will have new dimensions of 10 units by 4 units. The formula is: New dimensions = Original dimensions × Scale factor. If a rectangle measuring 3 units by 2 units is enlarged by a factor of 3, it becomes 9 units by 6 units; if reduced by a factor of 1/2, it becomes 1.5 units by 1 unit.



1. Map is the geographical representation of land on a paper.

2. Scale is a proportion of two points on map and two points on the ground.

3. Methods of Expressing a Scale. There are two methods of expressing a scale: -

(a) In Words- 1 inch to 1 mile, it means that 1 inch on the map represents 1 mile on the ground.

(b) As a Representative Fraction (RF)- This is the scale expressed in the form of a fraction. If the scale of a map is given as 1/100000 this means that one unit of the map

4. A grid system is a regular pattern of purple or red colour lines intersecting each other at right angles forming squares or rectangles that would help to locate the place accurately.

5. Easting Grid lines - The vertical lines whose Numbers increases to the east of the map are called Eastings Grid lines.

6. Northing grid lines – The horizontal lines whose numbers increases to the north of the map are called Northing Grid lines.

7. Always count along the Easting lines first from the West to East and then Northing from South to North.

## PART VII: GLOBAL POSITIONNING SYSTEM

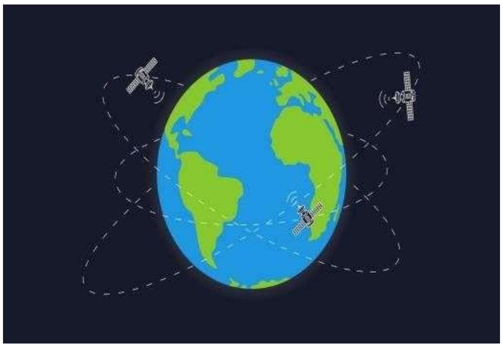
16. Aviators worldwide rely on the Global Positioning System (GPS) to enhance flight safety and efficiency. GPS provides accurate, continuous, and global satellite navigation services that meet aviation needs for all flight phases-from departure, enroute, and arrival to airport surface navigation. GPS enables three-dimensional positioning and supports Area Navigation (RNAV), allowing aircraft to fly direct routes from waypoint to waypoint without relying on ground infrastructure. Thus, capability is crucial in regions lacking ground-based navigation aids. GPS has facilitated the creation of more efficient air routes, reducing travel time, fuel consumption, and costs, particularly over remote areas like oceans, where aircraft can safely reduce separation distances, improve overall route efficiency and increasing cargo revenue.

### DID YOU KNOW?

- The magnetic compass was invented in ancient China. During the Han Dynasty in China, the invention of the magnetic compass revolutionized navigation.
- The Global Positioning System (GPS) was developed by the United States Department of Defence.

## PART VIII: FEEDING OF POINTS IN GPS

17. In a GPS (Global Positioning System) system, points can be fed into the system for various purposes such as navigation, tracking, or mapping. These points, often referred to as waypoints, coordinates, or positions, are usually defined by latitude and longitude values. Here's how points are typically fed into a GPS system:



## PART IX: MANUAL INPUT

18. Latitude and Longitude: Most GPS devices allow users to manually enter latitude and longitude values. For example, you might enter a coordinate such as:

(a) **Latitude**. 51.5074° N

(b) **Longitude**. 0.1278° W (for a location like London)

(c) Degrees, Minutes, and Seconds (DMS): Some systems also support the

(d) DMS format, where coordinates are divided into degrees, minutes, and seconds.

## PART X: USING A MOBILE APP OR WEB INTERFACE

19. **Map-Based Input**. Many modern GPS apps (e.g., Google Maps, Waze) allow users to tap on a map to select a location or point. The system converts this action into coordinates. Copy-Pasting Coordinates: Some apps let you paste coordinates directly from other sources like websites or messages.

## PART XI: WAYPOINTS OR POIs (Points of Interest)

20. **Preset Points**. Some GPS systems come preloaded with points of interest (POIs) like restaurants, gas stations, and landmarks. Users can add new waypoints manually or by selecting a location on the map.

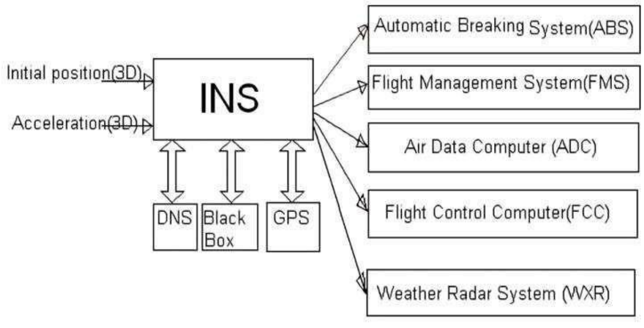
21. **Navigating to a Contact**. Some systems integrate with your contact list, allowing you to feed a point based on a saved address.

## PART XII: MODERN NAV, AIDS IN CIVIL AVIATION (AIRBUS & BOEING)

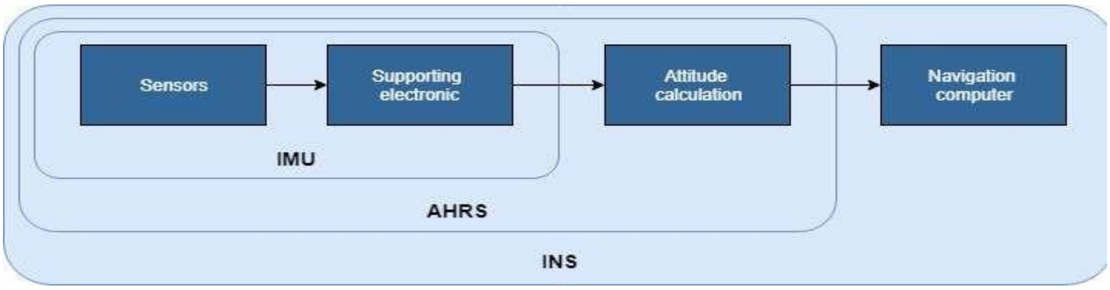
22. Modern Navigation Aids in Civil Aviation (Airbus & Boeing) as per Air Force*

(a) **Airbus**. Airbus aircraft use the Inertial Navigation System (INS),often coupled with the Global Navigation Satellite System (GNSS), air data, magnetometers, and sensor fusion for improved accuracy and fault detection. INS data supports flight envelope protection,autopilot, and yaw damper systems for pitch, roll, and altitude guidance.

(b) **Boeing**. Boeing aircraft similarly employ INS, updated byGNSS for precise positional detection and navigation. Rockwell Collins provides flight deck display systems and pilot controls, including an Earth reference system with inertial navigation components.




Airborne INS Interfaces




(c) **Commonalities**. Both Airbus and Boeing use GNSS-updated solid-state INS with ring laser gyros for navigation. INS serves as a backup or cross-check for GNSS, particularly when GNSS signals are unavailable or unreliable.

## PART XIII: NAVAIDs (Navigational Aids)

23. **Visual NAVAIDs**. Used by VFR flights or as supplementary data, these include landmarks, beacons, and other visual aids visible outside the cockpit.

24. **Radio NAVAIDs**. Provide guidance and position data, including systems like Instrument Landing Systems (ILS), TACAN, and DVOR/DME.

## PART XIV: NOTABLE SYSTEMS

25 **TACAN**. A military navigation system providing bearing and distance to a ground-based station.

26 **ILS**. A precision runway approach aid offering vertical and horizontal guidance during landings.

## PART XV: AIR FORCE PERSPECTIVE

27. Modern navigation aids used in Airbus and Boeing aircraft, combining INS, GNSS, and other sensors, are crucial for accurate and reliable navigation. These systems ensure safe flight operations, integrating and validating to meet airworthiness and regulatory standards.

## CONCLUSION

28. **Navigation Proficiency**. Pilots must possess solid navigation skills, especially in aircraft without navigators, to ensure safety and mission success.

29. **Dependence on Modern Systems**. The integration of INS and GNSS, supported by advanced NAVAIDs, is critical for accurate navigation throughout all flight phases.

30. **Operational Impact**. These systems enable aircraft to follow more efficient routes, optimize fuel consumption, and enhance overall airspace management, meeting regulatory and safety standards. This streamlined, precise approach is vital for maintaining the high standards required in modern civil aviation.

Modern navigation aids are essential for ensuring safe and efficient flight operations in civil aviation, particularly for aircraft like Airbus and Boeing. The primary systems include:

31. **Inertial Navigation System (INS)**. Both Airbus and Boeing aircraft use INS, often integrated with Global Navigation Satellite System (GNSS), air data, magnetometers, and sensor fusion. This combination enhances accuracy, fault detection, and provides data for flight envelope protection, autopilot, and yaw damper systems.

32. **GNSS and INS Integration**. INS, updated by GNSS, provides reliable positional detection and serves as a backup or validation for GNSS, especially when signals are weak or unavailable. Both systems use solid-state INS with ring laser gyros.

33. **Navigational Aids (NAVAIDs)**.

(a) **Visual NAVAIDs**. Used during Visual Flight Rules (VFR), relying on visible landmarks, beacons, and other external visual cues.

(b) **Radio NAVAIDs**. Include Instrument Landing Systems (ILS), Tactical Air Navigation (TACAN), and DVOR/DME systems, providing critical guidance during Instrument Flight Rules (IFR).

34. **Notable Systems**.

(i) **TACAN**. Offers military-grade navigation with precise bearing and distance data.

(ii) **ILS**. Delivers precision guidance during runway approaches, enhancing landing accuracy under low visibility.

## ASSESSMENT EXERCISE

**Multiple Choice Question**

1. **Which system is primarily used for position detection in modern aircraft?**
   (a) INS
   (b) GNSS
   (c) Both
   (d) None
2. **What is the primary function of TACAN?**
   (a) Provides altitude
   (b) Bearing and distance
   (c) Fuel measurement
   (d) Weather data
3. **Which rule involves navigating mainly by visual cues and maps?**
   (a) IFR
   (b) TACAN
   (c) INS
   (d) VFR
4. **What is the role of the Inertial Navigation System (INS) in aviation?**
   (a) Weather data
   (b) Position detection
   (c) Communication
   (d) Cabin pressure control
5. **What type of maps are commonly used in aviation for detailed ground navigation?**
   (a) Topographical
   (b) Political
   (c) Relief
   (d) Statistical
6. **Which navigation aid provides precise runway approach guidance?**
   (a) GPS
   (b) ILS
   (c) TACAN
   (d) DVOR/DME

**7. What is the primary purpose of Radio NAVAIDs?**

(a) Visual assistance

(b) Point-to-point guidance

(c) Weather updates

(d) Fuel estimation

**8. Which navigation aid is primarily used by military aircraft?**

(a) ILS

(b) DME

(c) VOR

(d) TACAN

**9. What is the scale factor used for in navigation?**

(a) Altering shape

(b) Time calculation

(c) Changing size proportionally

(d) Fuel management

**10. What kind of maps use latitude and longitude grids with minimal ground features?**

(a) Maps

(b) Charts

(c) Statistical maps

(d) Political maps

**11. The line that cuts all meridians at the same angle is known as?**

(a) Rhumb Line

(b) Great Circle

(c) Small Circle

(d) Equator

**12. What does the term "Latitude" refer to?**

(a) East-West distance

(b) North-South distance

(c) Altitude

(d) Speed

**13. Which organization prepares topographical maps in India?**

(a) ISRO

(b) Naval Survey

(c) Air Force

(d) Survey of India

**14. Which of the following is not a representation of scale on a map?**

(a) Representative fraction

(b) Graduated scale line

(c) Latitude

(d) Statement in words

**15. What system was GPS originally based on?**

(a) INS

(b) LORAN

(c) ILS

(d) GNSS

**<u>Fill in the Blanks</u>**

1 The art of making maps is called ____________.

2 The ________is a great circle dividing the Earth into northern and southern hemispheres.

3 ______is the system that provides precise vertical and horizontal guidance during landings.

4 The primary purpose of the _____system is to measure bearing and distance to a station.

5 ______refers to the angular distance along the equator from the prime meridian.

6 ______Navigation involves using visible landmarks and maps, supplemented by radio aids if necessary.

7 The __________line passes through both poles and divides the Earth into equal halves vertically.

8 The _________Navigation System (INS) uses ring laser gyros and sensors to determine an aircraft's position.

9 ______maps are used in aviation to display detailed terrain, including grid lines and landmarks.

10 ______is the angular distance of a place north or south of the equator.

**Short Answer type Question**

1. Write short note on importance of navigation in aviation.
2. Write a short note on INS.
3. Draw minimum 5 symbols used in maps.
4. What is meridian?
5. Is Equator a great circle explain?

**Long Answer Type Questions**

1. Write a note on types of maps.
2. Write a note on scale system.
3. Write a note on GPS.
4. Write difference between Rhumb line and great circle.

# ATC & MET AIRMANSHIP NAVIGATION (SD/SW)

## CHAPTER III: MET

***"Man must rise above the Earth – to the top of the atmosphere and beyond – for only thus will he fully understand the world in which he lives"***

## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **04 (Four)** |
| **Type** | **:** | **Lecture** |
| **Year** | **:** | **2nd Year SD/SW** |
| **Conducting Officer** | **:** | **Permanent Instructor r** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction to Met** | **:** | **05 Mins** |
| • **Part I** | **:** | **35 Mins** |
| • **Part II** | **:** | **35 Mins** |
| • **Part III** | **:** | **35 Mins** |
| • **Part IV** | **:** | **35 Mins** |
| • **Conclusion and Assessment** | **:** | **15 Mins** |

## INTRODUCTION

1. Meteorology is the study of the atmosphere and the weather processes that occur in it. Since an aircraft is flown through a medium of the atmosphere, an aviator must have adequate knowledge of meteorology and an appreciation of the effect of weather on all aspects of flying.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Importance of Met

(b) Part II: Salient Features of Met

(c) Part III: Atmosphere

(d) Part IV: Important Weather Phenomena

### LEARNING OBJECTIVES

Basic understanding of the Indian armed forces, their organisation and structure

- Basic definition.
- Importance of met in aviation.
- Salient features on weather charts.
- Layers of atmosphere.
- Clouds & its classification.
- Types of precipitation.
- Important weather phenomena.

## INTERESTING FACTS

- A Thunderstorm can produce wind upto 160kmph.
- 1 billion tonnes of rainfall on the earth every minute of the day.

## PART I: IMPORTANCE OF MET

2. Since meteorology is the science dealing with the study of atmosphere and an aircraft is designed to fly through this medium, various weather processes and changes that occur in the atmosphere has great significance for aviators.

3. Meteorological forecasts and observations forms an integral part of flight planning for safe execution of flight. Meteorological occurrences like thunder storm, snow storm, heavy rains, low visibility, high temperatures, dense fog, wind shear etc have disastrous consequences to conduct of flight. Hence it is mandatory for aviators to be briefed about the likely occurrences of any such phenomena which is likely to endanger a safe flight and take avoidance action.

4. Meteorological briefing is undertaken to explain to the aircrew the prevailing met conditions and expected conditions (forecast) over the required areas of operation. The met officer gives the following information:-

(a) Salient features observed on latest weather charts.

(b) Present state of weather at base and diversionary air fields with emphasis on the aspects that are adverse for flying.

(c) Forecast for base and diversionary airfields for the next 6-12 hours with specific mention of weather warnings that may be in force and the likelihood of its extension.

5. Met briefing always precedes the flight planning stage. Cooperation between met section and aircrew are essential to maintain a high standard of accuracy in forecasting weather.


**The Robinson Anemometer**

## PART II: SALIENT FEATURES OF MET

6. Salient features on a weather chart refer to the key elements that stand out and provide important information about the weather. Here are some of the most common salient features on a weather chart:-

(a) **Isobars**. Lines that connect areas of equal atmospheric pressure. Closely spaced isobars indicate strong winds, while widely spaced ones suggest calm weather. High and Low-Pressure Systems:

(i) H (High Pressure): Usually indicates clear, calm weather.

(ii) L (Low Pressure): Associated with clouds, storms, or precipitation

(b) **Fronts**.

(i) **Cold Front**. Shown with blue lines and triangles, indicates where cold air is moving in, often bringing cooler temperatures and possible storms.

(ii) **Warm Front**. Red lines with semicircles, showing where warm air is moving, usually leading to warmer weather and steady rain.

(iii) **Stationary Front**. A mix of blue triangles and red semicircles, representing a boundary between cold and warm air that isn't moving much.

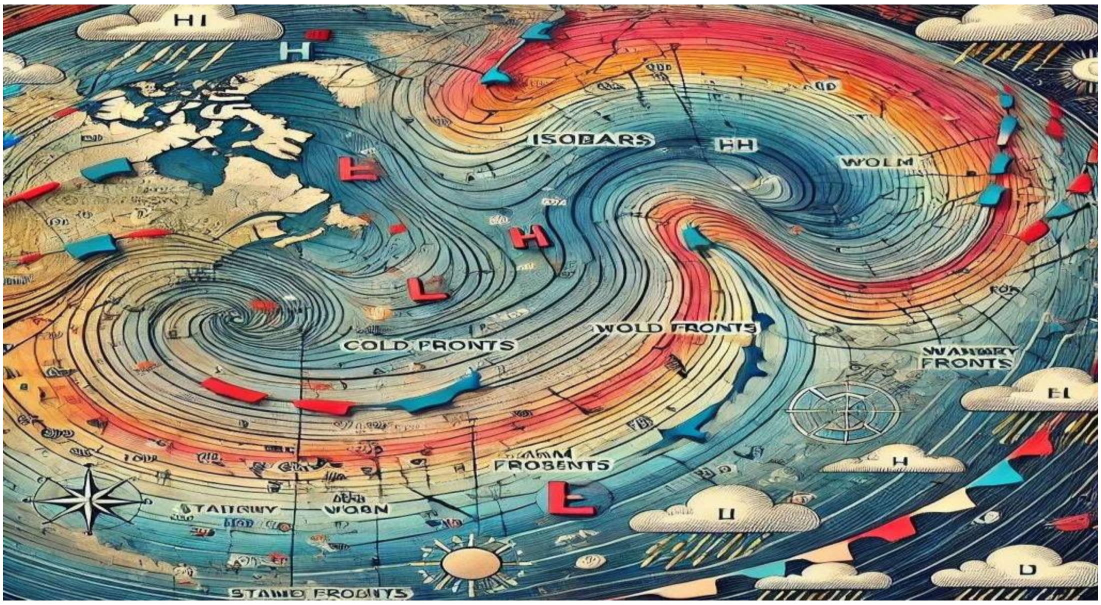
(iv) **Occluded Front**. A purple line with alternating triangles and semicircles, indicating a complex system where cold air overtakes warm air.

(v) **Temperature Gradients**. Areas where temperatures change rapidly over short distances, usually shown by different color shadings.

(c) **Wind Direction and Speed**. Indicated by arrows or lines with "feathers" (barbs) that show the wind's direction and strength. More feathers mean stronger winds.

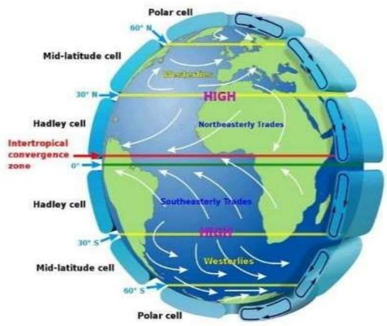
(d) **Cloud Cover and Precipitation**. Shaded areas or symbols (e.g., rain, snow, or thunderstorms) that show where clouds and precipitation are likely.

(e) These features help forecasters and people interpret the current and future weather conditions.




7. The invisible and odorless gas which we breathe, which sustains life and produces an infinite variety of phenomena is what we call air.

The envelope of air surrounding the earth and extending to great heights is the atmosphere where physical processes occur, giving rise to the ever-changing weather phenomena.




**<u>Composition of Air</u>**.

8. Air is a mechanical mixture of a variety of gases. The main constituents of this mixture are nitrogen and oxygen, accounting for almost 99% of the whole, with roughly three parts of nitrogen to one part of oxygen.There are small amounts or traces of other gases. This composition is more or less the same up to about 60 kilometers.

9. The composition of dry air by volume is as:-

(a) Nitrogen 78.09 %.

(b) Oxygen 20.95 %.

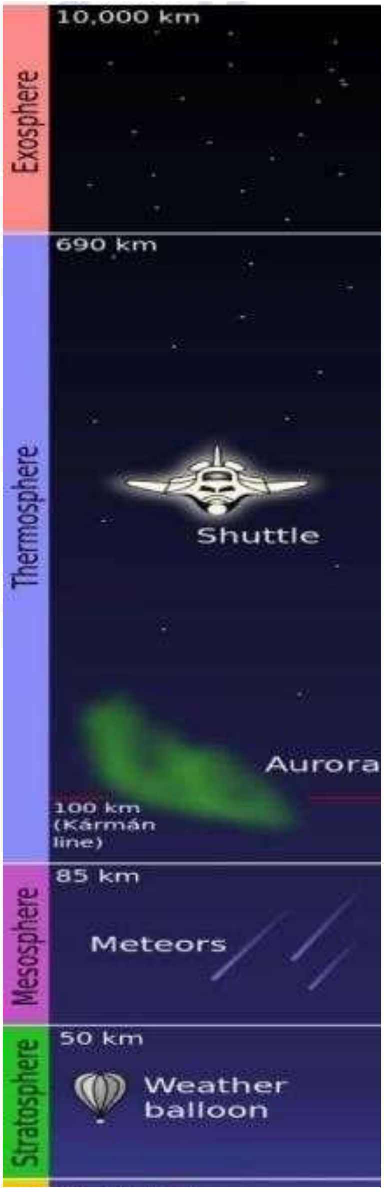
(c) Argon 0.93 %.

(d) Carbon dioxide 0.03 %.

10. **<u>The atmosphere is never Completely Dry</u>**. Water vapour is always present in varying amounts. Water vapour also behaves as a gas. It is the change in the amount and state of the water vapours (solid, liquid, gas) which is important in the physics of the weather processes in the atmosphere .Apart from water vapours suspended particles like dust, smoke transparency of and other impurities the atmosphere affect the causing reduction in visibility. In the higher layers there is a concentration of Ozone between 30 and 50 km.

## PART III: ATMOSPHERE

11. **Layers of Atmosphere**. While the pressure and density decrease as the height increases, the variation of temperature is different. Due to this there is a tendency for the atmosphere to be divided into several spheres as mentioned below:-




(a) Troposphere- Up to about 11-16 km

(b) Stratophere- Up to about 50 km above troposphere

(c) Mesosphere 50 to 85 km

(d) Thermosphere above 85 km

12. **Troposphere**. The troposphere is the region nearest to the earth and is generally the region of weather. It has a more or less uniform decrease of temperature with height.

The lapse rate is roughly 6.5°c /km (1.98°c /1000feet). The upper boundary of the troposphere is called the tropopause whose height varies from equator to the poles, being highest at the equator (16-18 km) and lowest over poles (8-10 km).

13. **Stratosphere**. The stratosphere is the layer extending from the tropopause to about 50 km. The temperature in this region is steady or increases with height. In the higher stratosphere the temperature is of the order of 0°c. The upper boundary of the stratosphere is the stratopause.

14. **Mesosphere**. The layer above the stratosphere is the mesosphere, where the temperature again decreases with height. The boundary of the mesosphere is the mesopause, about 85 km high, where the lowest temperatures in the atmosphere is found (about - 90°c).

15. **Thermosphere**. Above the mesosphere is the thermosphere. Its upper limit is undefined. However at about 700 km, the gravitational pull of the earth is practically absent and the particles can escape from the atmosphere into space. This region is often referred to as exosphere.

16. **Ionosphere**. The lower thermosphere is in a highly ionized state and is hence called ionosphere. This layer causes reflection of radio waves communication possible and makes long wave radio possible.

17. **International Standard Atmosphere**. A standard average atmosphere has to b e specified for various purposes like the design and testing of aircraft, evaluation of aircraft performance, calibration of pressure altimeter etc. For this purpose a standard atmosphere is defined and used as a basis of references. The most widely used atmosphere for reference purposes is the one defined by ICAO, known as International Standard Atmosphere (ISA) whose specifications are :-

(a) Mean Sea level temperature 15°c.

(b) Mean Sea level pressure1013.25 mb.

(c) Surface density1225 g/m3.

(d) Acceleration due to gravity980.665 cm / sec2.

(e) Rate of fall of temp with height up to 11 km 6.5°c /km (1.98°c / 1000 ft).

**Atmospheric Pressure**

18. Pressure as weight of the air above: Atmospheric pressure at any level in the atmosphere refers to the w e i g h t of the column of air of unit cross section vertically above the point of observation. In other words air has weight and therefore exerts a pressure which is equivalent to a column of air extending vertically till the total height of atmosphere. This pressure is expressed in various units per square inch etc. like millibars, pounds When an aircraft climbs away from the earth surface the height of the column of air above it decreases and therefore the weight and pressure exerted by that column decreases (Atmospheric pressure decreases with height).This rate of decrease of atmospheric pressure is found to be 1millibar for every 30 feet of height (and vice- versa).

19. **Layers of Atmosphere**

(a) Troposphere - Up to about 11-16 km.

(b) Stratosphere - Up to about 50 km above troposphere.

(c) Mesosphere - 50 to 85 km.

(d) Thermosphere - Above 85 km.

## PART IV: IMPORTANT WEATHER PHENOMENA

20. **Clouds and Precipitation**. Clouds and precipitation are major aviation weather hazards and need to be well understood. From a brief observation of the sky two fundamental characteristics of clouds become apparent. Their infinite variety of form and their continual change in appearance. The study of the cloud is one of the fascinating aspects of weather science and important tool of weather forecasting. Clouds form in the

sky, develops, take different shapes and dissolve. Each process is an indication of some physical state in the atmosphere.

21. **Clouds**. The clouds may be defined as visible aggregate of minute particles in the of water free air. Or ice or Clouds both are Formed by cooling of masses of damp air, generated by upward motion and its accompanying expansion with fall of pressure. The essential difference between clouds of various formsor types are due to their varying nature of the ascending produces them. motion which The Ascending motions which may be effective in producing clouds may be classified in the following manner.

(a) Turbulent motion, leading to numerous small scale upward currents.

(b) Uphill currents over sloping grounds.

(c) Large scale convection as a result of surface heating.

(d) Currents of warm moist air moving upward over a wedge of cold air and cold air acting in the same way as the sloping ground cited above.

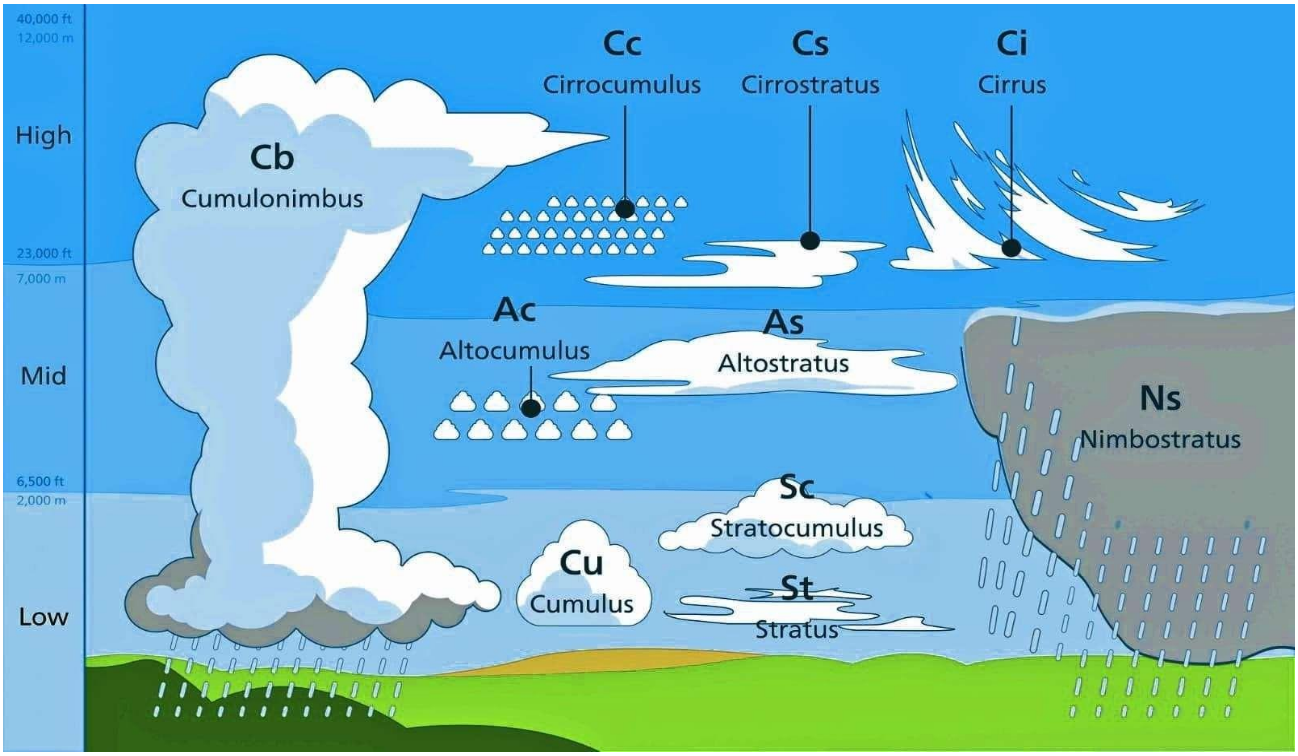
22. **Classification of Clouds**. The number of forms which clouds may take, is almost infinite, but for the purpose of description, it is necessary to adopt some kind of classification. The system of classification which have been proposed, have sometimes been based on the observed appearance of the clouds and at the other times on the supposed method of formation. There can be no doubt that the former is the correct method since an observer is able to judge definitely the appearance, whereas, the method of the formation must be, to some extent, a matter of opinion. The international cloud classification is based upon the appearance of clouds and consists of four families of classes depending upon the heights at which they form. Each class is further sub-divided into two or three forms according to their appearance.

**INTERESTING FACTS**

- Fog is a cloud which develops at the earth's 'surface' and not 'centre'.

| Class of family | Average height | Forms |
|---|---|---|
| High Clouds | 20,000 feet and above | Cirrus, Cirro-Stratus, Cirro-cumulus |
| Medium Clouds | 6500 feet to 20,000feet | Alto-Stratus,Alto-Cumulus, |
| Low Clouds | Ground level to 6500 feet | Stratus, Strato-Cumulus. |
| Clouds with vertical development but tops reaching high and medium cloud levels | Base 1500 feet to 6500 feet | Cumulus, Cumulo-Nimbus. |

23. **Significance of Prefixes and Suffixes**. Cirrus or prefix 'Cirrro' means high clouds, prefix alto means medium clouds, stratus means layer type and cumulus means heap type.




24. **Precipitation**. Precipitation is the general term used for drizzle, rain, shower, sleet and snow i.e. water droplets or ice crystals falling from clouds.

25. **Types of Precipitation**. Water droplets or ice crystals in a cloud are usually of such small dimension that they are kept suspended in mid- air by the vertical current at the base of the cloud. These vertical currents are a necessary contribution for the formation of clouds and their maintenance. For the water droplets or ice crystal to overcome the vertical currents and fall under the force of gravity, their diameter should be of the order at least a millimeter or more.

(a) **Drizzle**. Minute water drops falling from the clouds. The drops are so small that they look like spray and are at times blown and carried by wind.

(b) **Rain**. Medium size water drops falling from layer types of clouds.

(c) **Snow**. Frozen rain in the form of flakes or ice crystal.

(d) **Sleet**. Mixture of rain and snow.

(e) **Shower**. Large drops falling from heap type of clouds.

(f) **Thunderstorm**. A phenomenon in which thunder is heard, and lightning is seen. Generally accompanied by sharp shower. They are associated with clouds.

(g) **Hailstorm**. A storm in which solid pellets of ice fall on the ground.

26. **Precipitation**. Precipitation is any form of water particle, whether liquid or solid, that falls from the atmosphere and reaches the ground. The different types of precipitation are:-

27. **Rain**. Most commonly observed; water drops larger than drizzle (0.02 inch / 0.5 mm or more) are considered rain. However, smaller drops are also considered raindrops if, in contrast to drizzle, they are widely separated.

28. **Drizzle**. Fairly uniform precipitation composed exclusively of fine drops very close together. Drizzle appears to float while following air currents, but unlike fog droplets, it falls to the ground. Quite often, fog and drizzle occur together

29. **Ice Pellets (Sleet)**. Precipitation of transparent or translucent pellets of ice, which are round or irregular hard grains of ice consisting of frozen raindrops or largely melted then refrozen snowflakes.

30. **Hails**. Precipitation in the form of small balls or other pieces of ice falling separately or frozen together in irregular lumps. Associated with thunderstorms, individual hail stones are ¼ inch (5 mm) or greater in diameter. Hail sizes of 1 inch (2.5 cm) or more are indicative of severe thunderstorms.

31. **Graupel (Small Hail, Snow Pellets)** . Precipitation of white, opaque grains of ice that are round or conical size less than ¼ inch (5 mm).

32. **Snow**. Precipitation of snow crystals that are mostly branched and in the form of six-pointed stars.

33. **Snow Grains**. Precipitation of very small, white, and opaque grains of ice. Basically, this is frozen drizzle.

34. **Ice Crystals**. Generally occurring in very cold regions, they are falling crystals of ice in the form of needles, columns, or plates. Also called "diamond dust", ice crystals appear like fog but with individual water particles forming directly as ice. The shape of the individual ice crystals causes the "light pillar" optical effect above a light source.

35. **Obscuration Types**. An obscuration is any phenomena in the atmosphere, other than precipitation, that reduces the horizontal visibility. The most common is fog. Obscurations include:

36. **Mist**. Visible minute water particles suspended in the atmosphere that reduce visibility to fewer than 7 miles (11 km) but more than or equal to 5/8 mile (1 km). There is often not much difference in the appearance of "haze" and "mist", but it is called mist when the difference between the air temperature and dew point is 3°F (1.7°C) or less

37. **Fog**. Visible minute water particles (droplets) at the Earth's surface that reduce horizontal visibility to less than 5/8th mile (1 km). Unlike drizzle, fog does not fall to the ground but remains suspended.

38. **Smoke**. Small particles produced by combustion and suspended in the air. A transition to haze may occur when smoke particles have traveled great distances, 25 to 100 miles (40 to 160 km) or more, and larger particles have settled out, leaving the remaining particles widely scattered through the atmosphere.

39. **Volcanic Ash**. Fine particles of rock powder that originate from a volcano and that may remain suspended in the atmosphere for long periods

40. **Dust**. Fine particles of earth or other matter, raised or suspended in the air by the wind, that may restrict horizontal visibility.

41. **Sand**. Sand particles raised by the wind to a height sufficient to reduce horizontal visibility.

42. A suspension in the air of extremely small, dry particles that are invisible to the naked eye and sufficiently numerous to give the air an opalescent appearance. That is the scientific way of saying haze is air pollution. There is often not much difference in the appearance of "haze" and "mist". It is called haze when the difference between the air temperature and dew point is greater than 3°F (1.7°C).

43. **Other Weather Types**. Significant types of weather are related to wind. These other forms of weather include:-

(a) **Squall**. A strong wind characterized by a sudden onset in which the wind speed increases at least 18 mph (16 knots, 30 km/h) and is sustained at 25 mph (22 knots, 41 km/h) or more for at least one minute. These often occur from thunderstorms, where the term "squall line" originates. However, the term "squall" only refers to the wind speed increase, not any other associated weather. In the image, the low arcing clouds are not the squall line but mark the approximate location of the squall.

(b) **Tornado**. A violent, rotating column of air touching the ground.

(c) **Funnel Cloud**. A violent, rotating column of air which does not touch the surface

(d) **Waterspout**. A violent, rotating column of air that forms over a body of water and touches the water surface. If it does not touch the water surface, then it is called a funnel cloud.


(e) **Sandstorm**. Particles of sand carried aloft by a strong wind. The sand particles are mostly confined to the lowest ten feet and rarely rise more than fifty feet above the ground.


(f) **Dust Storm**. A severe weather condition characterized by strong winds and dust-filled air over an extensive area. Particle size is typically smaller than in sand storms. These are sometimes called "haboobs.

(g) **Well-Developed Dust/Sand Whirls**. Particles of dust or sand, sometimes accompanied by small litter, raised from the ground in the form of a whirling column of varying height with a small diameter and an approximately vertical axis. Commonly called a "dust devil".

## INTERESTING FACTS

- Many Flying accidents can be attributable to flying in clouds and through heavy precipitation.
- Apart from disorientation it causes difficulty in judgment & controllability of aircraft.
- Under poor weather conditions it is always wise to avoid or divert the aircraft to a suitable base reporting good weather.
- Most of the weather occurs in the Troposphere.
- Heating of atmosphere is because of heat radiated from surface of the Earth.
- During the day breeze blows from Sea to Land and it is called Sea Breeze.
- During the night and early morning, breeze blows from land to sea and it is called Land Breeze.
- During day winds blow uphill and are known as Anabatic winds.
- During night winds blow downhill and are known as Katabatic winds.
- Temperature decrease with increase in altitude only in the troposphere and above that it is constant at -56.5 deg celcius.

## CONCLUSION

44. An aviator must have adequate knowledge of meteorology and an appreciation of the effect of weather on all aspects of flying. Meteorological forecasts and observations forms an integral part of flight planning for safe execution of flight. Meteorological occurrences like thunder storm, snow storm, heavy rains, low visibility, high temperatures, dense fog, wind shear etc. have disastrous consequences to conduct of flight. Hence it is mandatory for aviators to be briefed about the likely occurrences of any such phenomena which is likely to endanger a safe flight and take avoidance action. Pressure as weight of the air above: Atmospheric pressure at any level in the atmosphere refers to the weight of the column of air of unit cross section vertically above the point of observation

# ASSESSMENT EXERCISE

## Multiple Choice Questions

**Q1. Met briefing always precedes the following stage?**

(a) Flight Planning (b) Flying

(c) Taxing (d) Approach

**Q2. Air is a mixture of which variety gases?**

(a) Collective (b) Mechanical

(c) Colourless (d) Odourless

**Q3. The Atmosphere is never completely?**

(a) Dry (b) Wet

(c) Warm (d) Cool

**Q4. The Stratosphere is the layer extending from the troposphere to about?**

(a) 20km (b) 25km

(c) 50km (d) 100km

**Q5. In the mesosphere, the temperature with height?**

(a) Increase (b) Constant

(c) Equal (d) Decrease

## Short Answer Questions

Q1. The upper boundary of the troposphere is known as?

Q2. Which layer is above the mesosphere?

Q3. What is general term used for drizzle, shower, sleet and snow?

Q4. Which layer is the region of weatsher?

Q5. Which layer is in a highly ionized state?

## Long Answer Questions

Q1. Briefly explain the layers of Atmosphere?

Q2. What are the types of cloud?

Q3. Explain types of cloud?

Q4. Explain Fronts?

Q5. What are the composition of Atmosphere?

4

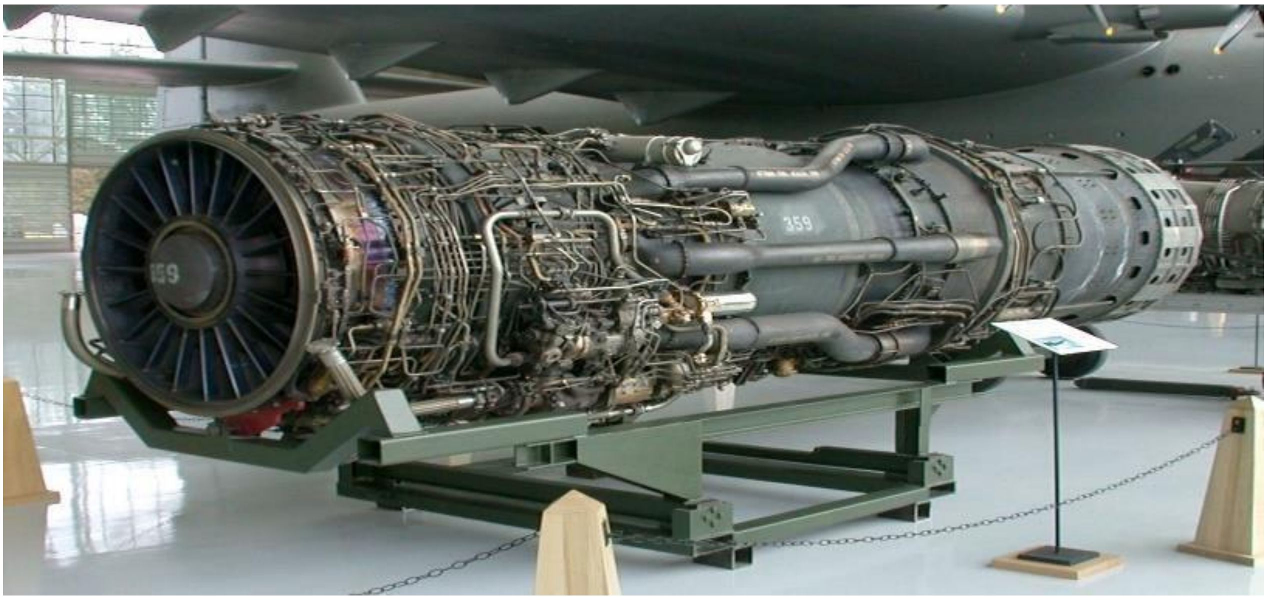
# AIRFRAME & ENGINE

4

**CHAPTER WISE INDEX : AIRFRAME & ENGINE (SD/SW)**

# ENGINE (SD/SW)

## CHAPTER I : INTRODUCTION AND TYPES OF ENGINE (ANE-I)



### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **03 (Three)** |
| **Type** | **:** | **Lecture/ Demo** |
| **Year** | **:** | **2nd Yr SD/SW** |
| **Conducting Officer** | **:** | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction** | **:** | **10 Mins** |
| • **Part I** | **:** | **30 Mins** |
| • **Part II** | **:** | **30 Mins** |
| • **Part III** | **:** | **30 Mins** |
| • **Conclusion & Exercise** | **:** | **20 Mins** |

## INTRODUCTION

1. An aircraft engine, often referred to as an aero engine, is the power component of an aircraft propulsion system. Aircraft using power components are referred to as powered piston engines or gas turbines.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Definition

(b) Part II: Piston Engine

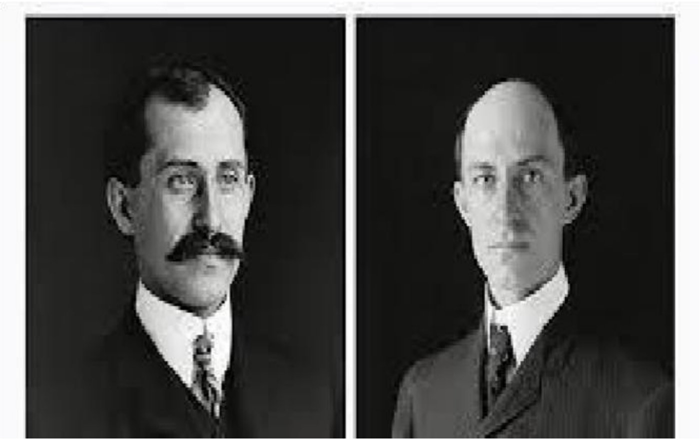
(c) Part III: Propeller Engine

### LEARNING OBJECTIVES

- Basic Definitions.
- Understanding the working principle of piston engine.
- Understanding the basic propeller engine.
- Demonstrated learning on microlight.

### INTERESTING FACTS

- Did you know that the wright brothers' engine is considered the first aero engine powering the first powered flight on 17 December 1903. The engine was a 12 horsepower, water cooled, inline engine with four cylinders.



## PART I: DEFINITIONS

2. **Engine**. The name given to a machine, which develops power. It is derived from the Latin word 'ingenium' that means skilful.

3. **Work**. A force is said to do work when it displaces the body from rest or from a path of uniform motion.

4. **Energy**. It is the capacity to do work.

5. **Power**. It is the rate of doing work. When rate is 550 ft. lbs. per sec. it is said to be one horse power.

6. **Heat**. It is the total amount of energy contained in a body.

7. **Temperature**. It is the measure of intensity of heat energy in a body.

8. **Combustion**. It is the process of chemical combination of fuel with oxygen (air), evolving heat.

9. **Compression**. The action of compression of fuel air mixture inside the combustion chamber by the upward movement of the piston.

10. **Compression Ratio**. It is the ratio between the overall volume of the cylinder and the clearance volume.

Mathematically: $$\text{Compression Ratio (CR)} = \frac{\text{Clearance Vol} + \text{Swept Vol}}{\text{Clearance Vol}}$$

11. **Indicated Horse Power (IHP)**. Is the actual power developed inside the cylinder above the piston but is never available in full for useful work.

12. **Brake Horse Power (BHP)**. It is the actual power available for useful work and is always less than IHP, due to frictional and mechanical losses within the engine and its systems.

13. **Thrust Horse Power (THP)**. It is the available horsepower at the propeller of an aero engine, it is dependent on the propeller efficiency.

THP = BHP X $\eta$ (propeller efficiency)

14. **Pre-ignition**. A condition which occurs in an engine when the mixture is ignited prematurely by incandescence of excessive carbon deposit in the combustion chamber or by some 'Hot Spot" in the combustion chamber caused by overheating.

15. **Safety Gap.** A gap provided in the HT circuit of a magneto to prevent excessive electrical strain on the armature winding when the magneto is run without a closed circuit.

16. **Scoring**. Scratch like marks found on bearings or cylinder walls and piston due to lack of lubrication or the ingress of foreign matter between two surfaces.

17. **Sump**. The lower portion of the crankcase, which forms a container for the engine lubricating oil.

18. **Thermo Siphon**. The principle of convection currents by which heat is distributed in a liquid, advantage of which is taken to obtain circulation of coolant in the cylinder block and radiator.

19. **Knocking**. A peculiar hard thumping noise, which is produced within the engine cylinder due to incorrect ignition timing or incorrect mixture of fuel or unsuitable fuel.

20. **Spark plug**. The sparking plugs provide the air gap which produces spark for ignition of the fuel/air mixture in the combustion chamber. There are two plugs in each cylinder, so that burning of the charge from two points will give more efficient burning and greater power, and also provide an alternative source of ignition should one fail.

21. **Magneto**. The magneto is an engine-driven electrical generator designed to supply high voltage current to the plugs in sequence, and at the precise time in the compression stroke.

22. **Fuel Injectors**. Fuel injectors differ fundamentally from float-type and injection carburettors in that the airflow to the engine is not measured by a venturi. They are thus, strictly speaking, not carburettors but engine-driven pumps which supply fuel to the cylinders via the supercharger in accordance with engine requirements.

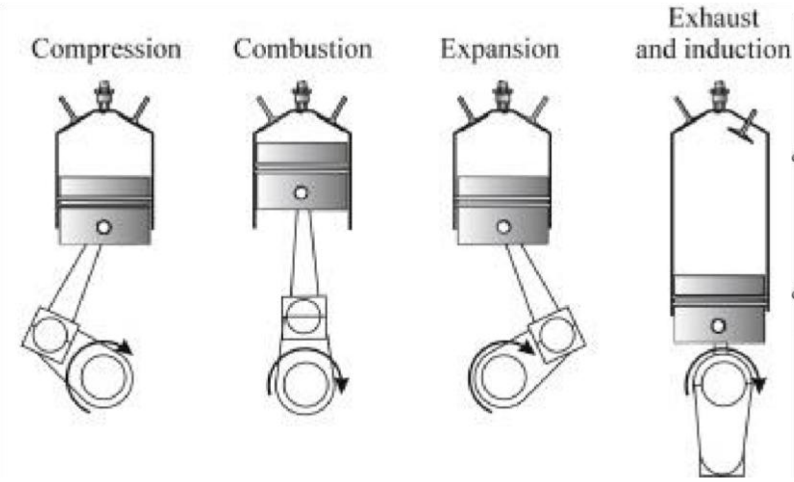
## PART II: PISTON ENGINE


**Image of Zennith STOL CH 701**

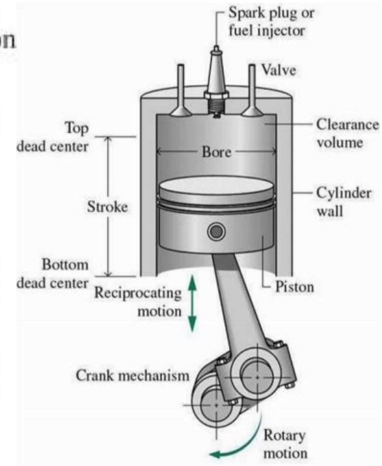
## INTRODUCTION

23. The internal combustion piston engine consists basically of a cylinder, which is closed at one end, a piston that slides up and down inside the cylinder and a connecting rod and crank by which reciprocating movement of the piston is converted to rotary movement of the crankshaft. In the closed end of the cylinder, known as the cylinder head, inlet and exhaust valves and a sparking plug are present

24. The sequence of operations by which the engine converts heat energy into mechanical energy is known as the four-stroke constant volume cycle, shown in figure below. This is also known as the Otto Cycle, after the inventor, Herman Otto. A mixture of fuel and air is introduced into the cylinder during the induction stroke and compressed during the compression stroke. At this point the fuel is ignited. The heat generated causing a rapid increase in pressure, which drives the piston down on its power stroke. Finally, the waste products of combustion are ejected during the exhaust stroke.




**Four Stroke Cycle (Otto Cycle)**




**Internal Combustion Engine**

25. **Induction Stroke**. On the induction stroke, throughout which the inlet valve is open, the mixture of fuel and air is forced in by the pressure outside. As the power output of the engine depends on the weight of gas which can get in during the short period (1/30 second or less at normal speeds) of the induction stroke, these passages must be free from sharp bends or constrictions, intentional reduction of power being obtained by means of a variable obstruction known as the throttle. However well the induction system is designed it is not possible to fill the cylinder up to quite the same pressure as exists outside. The ratio of the weight of gas in the cylinder at the end of the induction stroke to that which would be there if there were no resistance or inertia is called the volumetric efficiency.

26. **Compression Stroke**. As the piston moves upwards, the inlet valve closes and the gas is compressed. By squeezing the gas into a smaller space, the pressure is proportionately increased. The ratio of its volume at bottom dead centre (BDC), i.e. when the piston is at its lowest point of travel in the cylinder, to that at top dead centre (TDC) is known as the compression ratio, which in aero engines is usually in region of 6.5 to 1. It should be noted that the compression ratio is a ratio of volumes and is not measure of the increase of pressure in the cylinder. As the gas is compressed it becomes heated adiabatically in the same way that a bicycle pump warms up in action, as well as by conduction from hot surroundings, and press rises consequently to a higher value than that to be expected from the reduction in volume alone.

27. **Power Stroke**. Just before the piston reaches TDC on the compression stroke the gas is ignited by a spark. As the flame spreads through the combustion chamber the intense heat raises the pressure rapidly to a peak value, which is reached when the piston is about $10^0$ past TDC. The gas continues to burn and its pressure falls as the piston is forced down until, towards the end of the power stroke, combustion is completed and the pressure on the piston is comparatively small.

28. **Exhaust Stroke**. With the exhaust valve open, the piston ascends, forcing out the spent gases. Here again it is important that the flow should be as free as possible, for, not only would an obstruction cause a back pressure to be exerted on the piston, but it would also result in an undesirable amount of burnt gas remaining in the cylinder thus contaminating the fresh charge. At the end of the exhaust stroke the exhaust valve closes, the inlet valve opens, and the cycle begins again.

## PART III: PROPELLER ENGINE

29. With a propeller engine, the engine power produced drives a shaft which is connected to a propeller usually via a gearbox. The propeller cuts through the air accelerating it rearwards. The blade of a propeller behaves in the same way as the aerofoil of an aircraft, the air speeds up over the leading face of the propeller blade causing a reduced pressure with a corresponding increase of pressure on the rearward face.

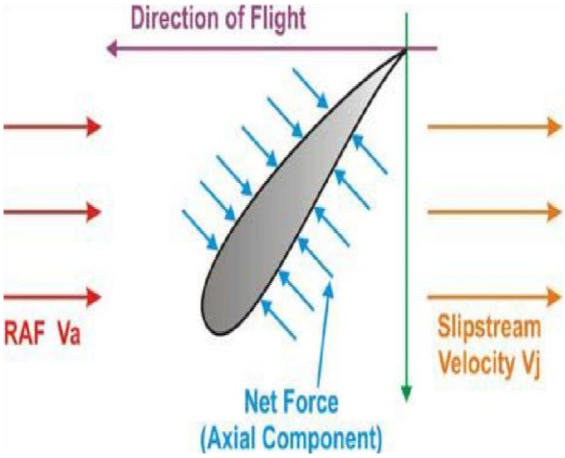
30. This leads to a net pressure force over the propeller were:

Pressure X Area = Force, thus providing thrust, e.g.

If Net pressure = 40 kPa (Pa = N/m$^2$)

Blade area = 1 m$^2$

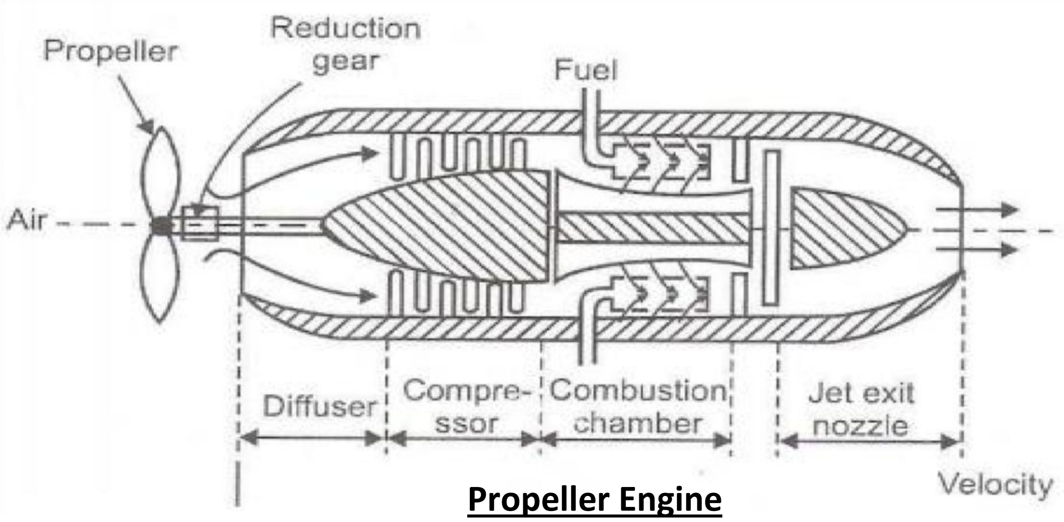
Then, Thrust = 40 kPa X 1m$^2$ = 40 kN




31. **Forces on a Propeller**. The main components of turbo-prop engine are a propeller, gear reduction unit, a compressor, a combustor gas turbine and the nozzles. In this engine 80 to 90% of the total propulsive thrust is generated by the gas turbine and the remainder is developed by the expansion of the gases in nozzles. Due to this the power generated in the gas turbine is used for driving the compressor and the propeller, while in case of turbojet engines the turbine power is only used to drive the compressor and the auxiliaries. The gas turbine drives the propeller through the reduction gear unit and it draws a large amount of

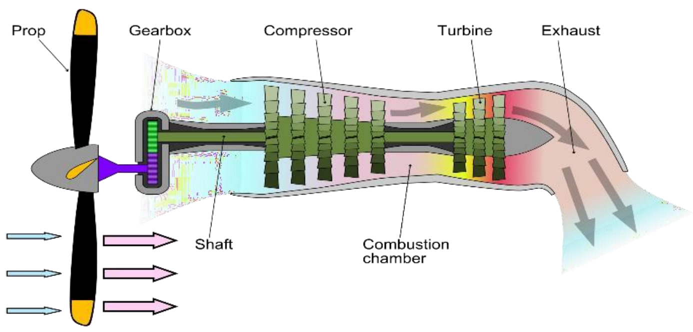
air. Fuel is burnt in the combustor and the resultant high temperature gases are expanded in the turbine and finally in the nozzles. The total thrust developed is the sum of thrust developed by the propeller and the nozzle. The turboprop engines are widely used for commercial and military air crafts, due to the low specific fuel consumption and high flexibility of operation at reasonably high speed.

32. **Types of Turbo Prop Engines.** Two types of turbo prop engines are single shaft engine and free turbine engine.



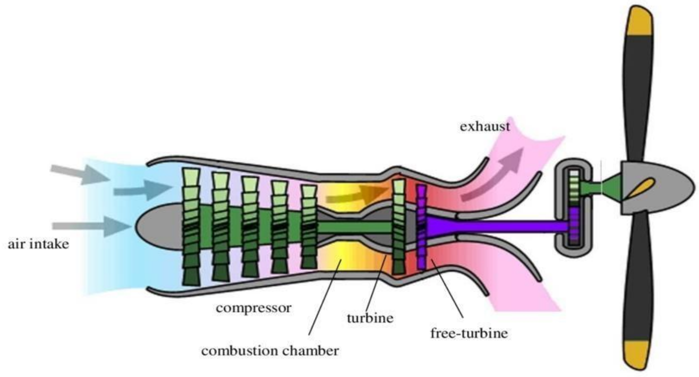

**Propeller Engine**

(a) **Single Shaft**. In a single-shaft engine, the propeller is driven by the same shaft (spool) that drives the compressor. Because the propeller needs to rotate at a lower RPM than the turbine, a reduction gear box reduces the engine shaft rotational speed to accommodate the propeller through the propeller drive shaft.




**Single Shaft**

(b) **Free Turbine**. In a free-turbine engine, the propeller is driven by a dedicated turbine. A different turbine drives the compressor; this turbine and its compressor run at near-constant RPM regardless of the propeller pitch and speed. Because the propeller needs to rotate at lower RPM than the turbine, a reduction gearbox converts the turbine RPM to an appropriate level for the propeller.




**Free Turbine**

## CONCLUSION

33. The cadet needs to understand that in any engine, the basic working principle remains the same. The cadet needs to understand the basic principle, components and different phases of operation in a piston and jet engine.

(a) There are basically two types of engines: the piston engine and the jet engine.

(b) A piston (or reciprocating) engine is a device for converting the heat energy of a fuel into mechanical energy, by internal combustion. In a piston engine, a fuel/air mixture is drawn or forced into a cylinder, compressed and ignited, thus increasing temperature and pressure; acts on a piston and forces it down in the cylinder.

34. Turboprop engines have many advantages like better fuel efficiency at lower altitudes, lesser cost compared to jet engines and lesser maintenance. Turboprop engines can take off and land on shorter runways and has lesser noise levels.

## ASSESSMENT EXERCISE

**Multiple Choice Questions**

**Q1. ______________ is said to be done when a force displaces the body from rest or from a path of uniform motion?**

(a) Power

(b) Work

(c) Compression

(d) Ignition

**Q2. ______________ is the capacity to do work?**

(a) Power

(b) Work

(c) Energy

(d) Displacement

**Q3. The distance covered by the piston while it moves from TDC to BDC?**

(a) Swept volume

(b) Stroke

(c) Clearance Volume

(d) Displacement

**Q4. ________________ is an engine-driven electrical generator designed to supply high voltage current to the plugs in sequence?**

(a) Spark Plug

(b) Magneto

(c) Generator

(d) Alternator

**Q5. With a propeller engine, the engine power produced drives a shaft which is connected to a propeller usually via a ________?**

(a) Turbine

(b) Gear Box

(c) Compression

(d) Compressor

**Q6. The operating cycle (pressure / volume cycle) of a basic aero-engine is______?**

(a) Reversed Joule cycle

(b) Bell Coleman cycle

(c) Otto cycle

(d) Brayton cycle

**Q7. The inside diameter of a cylinder is expressed in inches or millimetres?**

(a) Piston

(b) Bore

(c) Compression

(d) Clearance Volume

**Q8. The space enclosed by the cylinder head and piston when the piston is at TDC?**

(a) Swept Volume

(b) Clearance Volume

(c) Bore

(d) Compression

**Q9. The actual power developed inside the cylinder above the piston but is never available in full for useful work?**

(a) IHP

(b) BHP

(c) SHP

(d) THP

**Q10. Lever or arm formed on a shaft, its object being to convert reciprocating motion to a rotary motion?**

(a) Crank

(b) Crank Shaft

(c) Piston

(d) Ignitor

**Q11. When corrosion, intense heat or hammering action has caused shallow irregular depressions in the surface?**

(a) Scoring

(b) Pitting

(c) Rusting

(d) Denting

**Q12. In a single-shaft engine, the propeller is driven by the same shaft (spool) that drives the ___________?**

(a) compressor

(b) Combustion chamber

(c) Turbine

(d) Compression

**Q13. In a free-turbine engine, the propeller is driven by a dedicated _______?**

(a) Turbine

(b) Combustion chamber

(c) Compression

(d) compressor

**Q14. It is the ratio between the overall volume of the cylinder and the clearance volume?**

(a) Swept Volume

(b) Stroke

(c) Compression Ratio

(d) Clearance Volume

**Q15. ____________________ is the available horsepower at the propeller of an aero engine, it is dependent on the propeller efficiency?**

(a) Shaft Horse Power

(b) Thrust Horse Power

(c) Brake Horse Power

(d) Indicated Horse Power

**Q16. _________________ is the ratio between BHP and IHP and is expressed in percentage?**

(a) Hydraulic Efficiency

(b) Volumetric Efficiency

(c) Thermal Efficiency

(d) Mechanical Efficiency

**Q17. The sequence of operations by which the engine converts heat energy into mechanical energy is known as the?**

(a) Four-stroke cycle

(b) four-stroke constant volume cycle

(c) Two-stroke cycle

(d) Two-stroke constant volume cycle

**<u>Short Answer Questions: Write a Short Note on Following</u>**

1. Piston
2. Bore
3. Compression
4. Clearance Volume
5. Volumetric Efficiency
6. Supercharging
7. Knocking
8. Pitting Scoring
9. Fuel injectors
10. Thermo Siphon

**<u>Long Answer Questions</u>**

1. Write down the operation cycles of Piston Engine.
2. Write down the purpose of Spark plug, how it associates with magneto during engine operation.
3. Explain the thrust generation on a propeller with the help of a diagram.

# AERO ENGINE (SD/SW)

## CHAPTER II: PRINCIPLE & PROPULSION OF ENGINES (ANE-I)

### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **Three (03). 120 Minutes** |
| **Type** | **:** | **Lecture** |
| **Year** | **:** | **2nd Year SD/SW** |
| **Conducting Officer** | **:** | **Permanent Instructor** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction** | **:** | **15 Mins** |
| • **Part I** | **:** | **20 Mins** |
| • **Part II** | **:** | **25 Mins** |
| • **Part III** | **:** | **10 Mins** |
| • **Part IV** | **:** | **15 Mins** |
| • **Part V** | **:** | **15 Mins** |
| • **Part VI** | **:** | **05 Mins** |
| • **Summary and Revision** | **:** | **15 Mins** |

## INTRODUCTION

1. A jet engine is a type of internal combustion engine that propels aircraft forward by expelling a high-pressure, high temperature jet of gas. Jet engines are also known as gas turbines.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Basic Theory

(b) Part II: Principle of Operation

(c) Part III: Components of Jet Engine

(d) Part IV: Operating Phases

(e) Part V: Rocket Engine

(f) Part VI: Turboshaft Engine

### LEARNING OBJECTIVES

- Basic theory of jet engines.
- Principle of operation of jet engines.
- Types of jet engines.

### INTERESTING FACTS

- Did you know that the average jet engine is extremely complex and typically consists of about 40,000 parts. It can take up to 50-60 days to disassemble an engine.

## PART I: BASIC THEORY

2. Jet engines move the aeroplane forward with a great force that is produced by a tremendous thrust and causes the plane to fly very fast. All jet engines, which are also called gas turbines, work on the same principle. Jet propulsion is a practical application of Sir Issac Newton's 'third law of motion' which states that for every force acting on the body there is an equal and opposite reaction. For aircraft propulsion, the

"body" is atmospheric air that is caused to accelerate as it passes through the engine. The force required to give this acceleration has an equal effect in the opposite direction acting on the apparatus producing the acceleration.

## PART II: PRINCIPLE OF OPERATION

2. The principle of operation of a jet engine is similar to a piston engine in that the processes such as induction, compression, ignition and exhaust are the same. The main difference from piston engine is that in case of a jet engine, the processes are continuous and not intermittent which is the case with a piston engine.

3. Jet engines are machines which transform the potential energy contained in fuel and air either into kinetic or mechanical energy. The gas energy is produced by the combustion of an air-fuel mixture. The forward thrust is produced as per Newton's third law of motion. The operating cycle (pressure/volume cycle) of a basic aeroengine is **Brayton cycle.**

## PART III: COMPONENTS OF JET ENGINES

4. The main components of a jet engine are:-

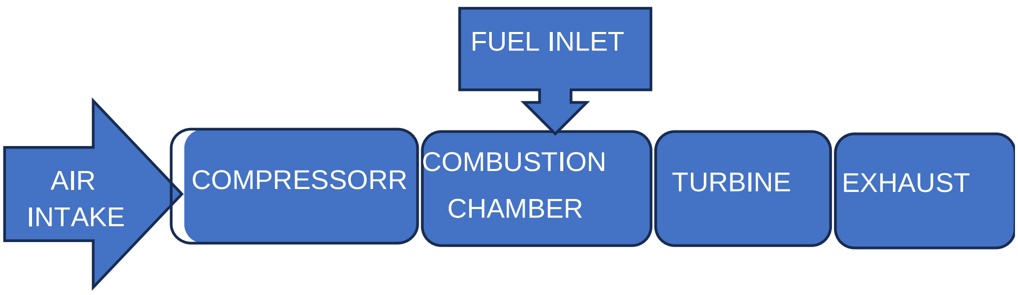
(a) **Air Intake**. Air Intake draws in cold air from the atmosphere

(b) **Compressor**. Compresses the air into smaller areas, increasing the air pressure and energy potential.

(c) **Combustion Chamber**. The combustion chamber is where the air and fuel are mixed and ignited.

(d) **Turbine**. The high-energy airflow from the combustion chamber spins the turbine blades, which are connected to a shaft.

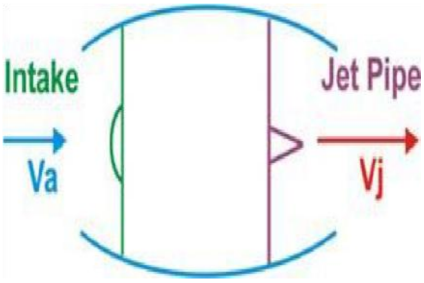
(e) **Exhaust**. Expels the gases produced by the combustion chamber




## PART IV: OPERATING PHASES

5. There are basically five operating phases for any jet engine. Each of these operating phases is achieved with the help of components. They are as follows:-

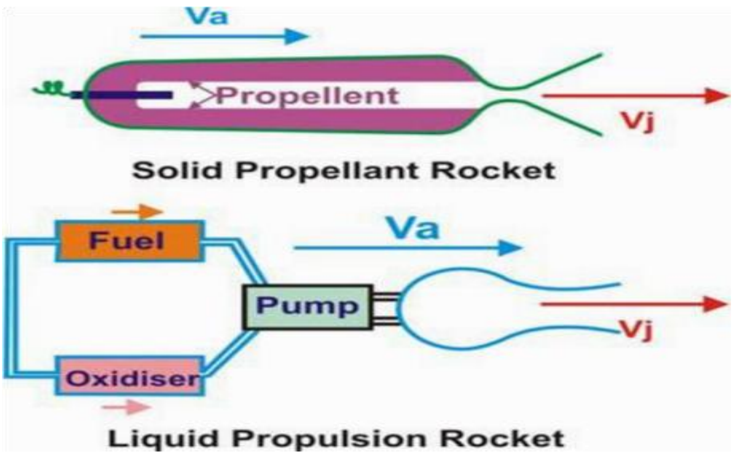
| | Phase | Component | Function |
|---|---|---|---|
| **1st** | Induction | Air intake | Assists in induction of air |
| **2nd** | Compression | Compressor | Assists in compression of air |
| **3rd** | Combustion | Combustion chamber | Assists in combustion of fuel and air |
| **4th** | Expansion | Turbine assembly | Assists in expansion of combustion gas |
| **5th** | Exhaust | Exhaust assembly | Assists in exhaust of gas |




6. In all cases of the jet engine, a high velocity exhaust gas is produced, the velocity of which, relative to the engine, is considerably greater than the TAS. Thrust is produced according to the equation Thrust = M X ($V_j$ - $V_a$) Where M is the mass of air, Va is intake velocity and Vj is now the velocity of the gas stream at the propelling nozzle. This represents a simplified version of the full thrust equation as the majority of thrust produced is a result of the momentum change of the gas stream.

## PART V: THE ROCKET ENGINE

7. In the rocket engine the gases which leave the engine are the products of the combustion of the rocket propellants carried, therefore no intake velocity term Va is required. The simplified version of the equation giving the thrust produced thus becomes: Thrust = Mass flow rate of propellant




## PART VI: THE TURBOFAN (BY-PASS) ENGINE

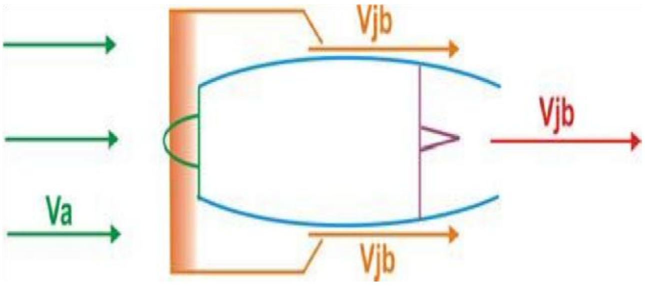
8. The Turbofan or by-pass engine powers the vast majority of modern aircraft, and is likely to do so for the foreseeable future. It can be seen as the link between the Turbo propeller and the Turbojet engine. The thrust from a by-pass engine is derived from the mass air flow from the ‘fan’ plus the mass air flow from the core engine and can be exhausted separately or mixed prior to entering the jet pipe.

9. The thrust for a mixing turbofan engine can be treated in the same way as a simple turbojet, as the mass flows are mixed prior to entering a common exhaust and propelling nozzle. However, where the bypass air flow is exhausted separately the simplified thrust calculation becomes:

Thrust = Mass flow rate of air through fan duct X (Vjb - Va)

+ Mass flow rate of air through core engine X (Vje - Va)

= $M_{fan}$ X (Vjb - Va) + $M_{core}$ X (Vje - Va)



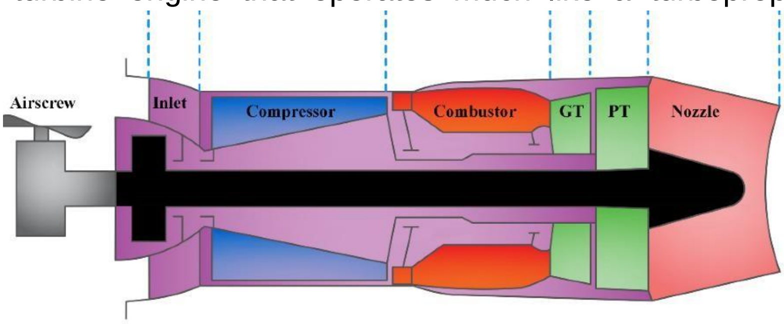

10. **<u>The Turbofan (by-pass) Engine</u>**. The ratio $M_{fan}$ / $M_{core}$ is called the by-pass ratio and is quoted for both mixing and non-mixing turbofans. Values below about 1.5 are termed low bypass ratio turbofans while at ratios above about 1.5, turbofans are considered high bypass.

**<u>DID YOU KNOW</u>**

Boeing's newest aircraft, the 777X, flies exclusively with GE's GE9X engine, the largest and most powerful commercial aircraft engine ever built. It holds the Guinness World Record for its powerful thrust, measured at 134,300 lbs (597kN)

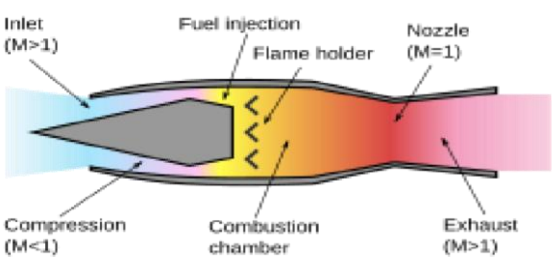
## <u>PART VII: TURBOSHAFT ENGINE</u>

11. This is another form of gas-turbine engine that operates much like a turboprop system. It does not drive a propellor. Instead, it provides power for a helicopter rotor. The turboshaft engine is designed so that the speed of the helicopter rotor is independent of the rotating speed of the gas generator. This permits the rotor speed to be kept constant even when the speed of the generator is varied to modulate the amount of power produced.




## <u>PART VIII: RAMJETS</u>

12. The ramjet is the simplest jet engine and has no moving parts. The speed of the jet "rams" or forces air into the engine. It is essentially a turbojet in which rotating machinery has been omitted. Its application is restricted by the fact that



its compression ratio depends wholly on forward speed. The ramjet develops no static thrust and very little thrust in general below the speed of sound. As a consequence, a ramjet vehicle requires some form of assisted take off, such as another aircraft. It has been used primarily in guided-missile systems. Space vehicles use this type of jet.

## CONCLUSION

13. The study of jet engines is extremely complex. This chapter has aimed at giving a basic understanding as to how the jet engine produces thrust. Jet engines have several advantages like high power to weight ratio, higher mechanical and thermal efficiency, lesser vibrations and simplicity of components. Hence, the study of jet engines forms a very important and integral part of aeroengines.

(a) Jet propulsion is a practical application of Sir Issac Newton's 'third law of motion' which states that for every force acting on the body there is an opposite and equal reaction.

(b) The jet engine produces thrust in a similar way to the propeller/engine combination, but whereas the propeller gives a small acceleration to a large weight of air, the jet engines gives a large acceleration to small weight of air.

(c) The Turbofan engine powers the vast majority of modern aircraft, and is likely to do so for the foreseeable future.

14. A turboshaft engine is another jet engine primarily used by helicopters, where the engine thrust is used to drive the rotors.

## ASSESSMENT EXERCISE

**Multiple Choice Questions**

**Q1. The processes are continuous is the case of a_____________?**

(a) Jet engine

(b) Rocket engine

(c) piston engine

(d) All of above

**Q2. The operating cycle (pressure/volume cycle) of a basic aero-engine is______?**

(a) Reversed Joule cycle

(b) Bell Coleman cycle

(c) Otto cycle

(d) Brayton cycle

**Q3. Combustion chamber assists in combustion of _____?**

(a) Spark

(b) Fuel and air

(c) Heat

(d) Gases

**Q4. In _______ phase, compressor assist compression of air?**

(a) Expansion

(b) Induction

(c) Compression

(d) Exhaust

**Q5. Jet propulsion is a practical application of Sir Issac Newton's ______?**

(a) First law of motion

(b) Second law of motion

(c) Third law of motion

(d) All of above

**Q6. Jet engines transform the __________ contained in fuel and air either into kinetic or mechanical energy?**

(a) Mechanical Energy

(b) Potential Energy

(c) Thermal Energy

(d) Kinetic Energy

**Q7. The part of a jet engine where the air and fuel are mixed and ignited?**

(a) Compressor

(b) Turbine

(c) Combustion Chamber

(d) Exhaust

**Q8. Helicopters primarily use _____________ type of engines?**

(a) Turboshaft

(b) Turbofan

(c) Piston

(d) Ramjet

**Q9. ______________ is the simplest jet engine and has no moving parts?**

(a) Turboshaft

(b) Turbofan

(c) Piston

(d) Ramjet

**Q10. ____________ of the engine drives the aeroplane forward?**

(a) Lift

(b) Thrust

(c) Exhaust

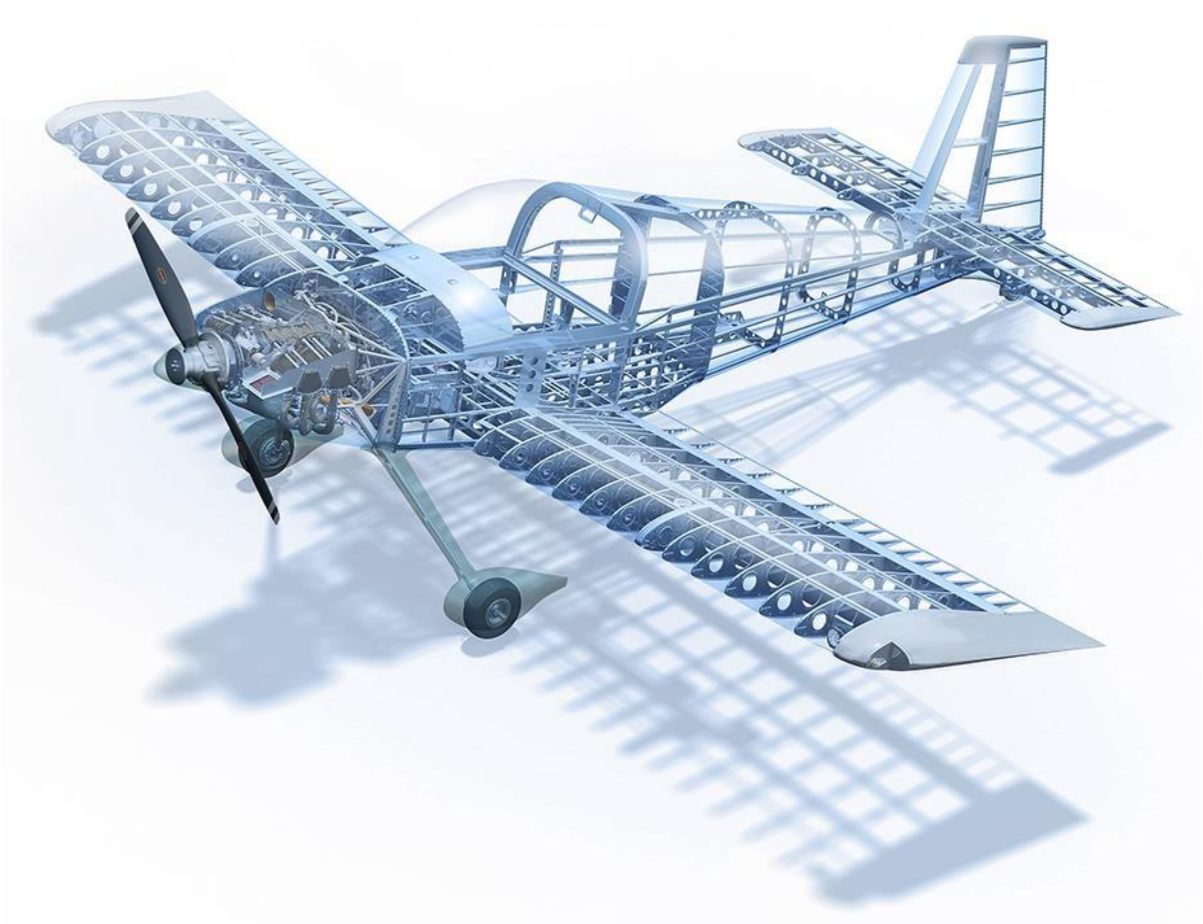
(d) Inlet Air

**<u>Short Answer Questions</u>**

1. State Newton's third law of motion?
2. List out the main components of Jet Engine.
3. List the different phases of operation of Jet Engine.
4. Write a short note on Turboshaft Engine.
5. Write a short note on Ramjets.

**<u>Long Answer Questions</u>**

1. What is basic theory of Jet engine and explain its operation phases?
2. With the help of a diagram explain the thrust production in a Jet Engine.
3. Write a short note on Turbofan Engine and explain the thrust production.

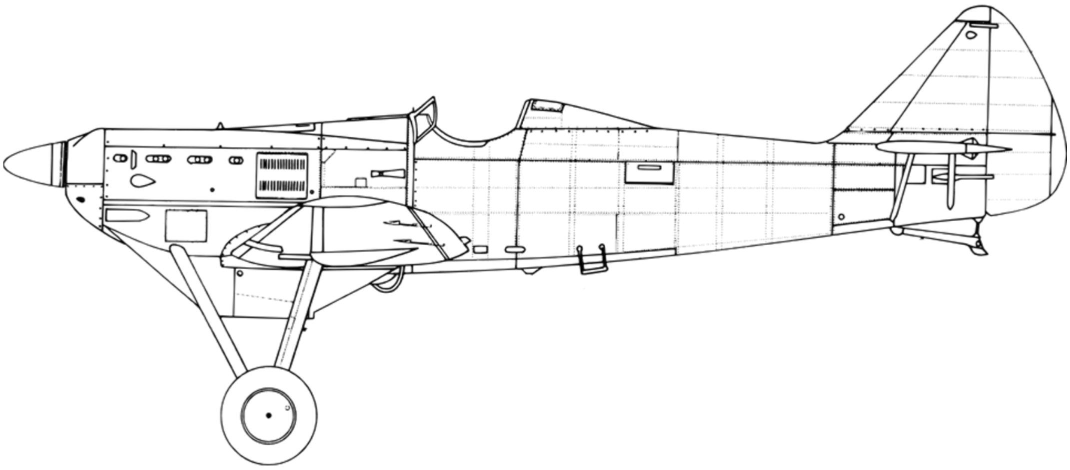


# AIRFRAME

# AIRFRAME (SD/SW)

## CHAPTER I: AIRCRAFT PARTS AND CONTROLS (AF)

***"Once you have tasted flight you will forever walk the earth with your eyes turned skyward"***



## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **Three (03). 120 Minutes** |
| **Type** | **:** | **Lecture and Practical** |
| **Year** | **:** | **3rd Year SD/SW** |
| **Conducting Officer** | **:** | **Permanent Instructor** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |

**Time Plan**

| | | |
|---|---|---|
| • **Introduction** | **:** | **05 Mins** |
| • **Part I** | **:** | **10 Mins** |
| • **Part II** | **:** | **15 Mins** |
| • **Part III** | **:** | **20 Mins** |
| • **Part IV** | **:** | **20 Mins** |
| • **Part V** | **:** | **10 Mins** |
| • **Demonstrated Learning on** | **:** | **40 Mins** |

- **Microlight**
- **The clasas will be taken as a theoretical as well as practical class on the microlite.**

## INTRODUCTION

1. The airframe of a fixed-wing aircraft is generally considered to consist five principle units, the fuselage, wings, stabilizers, flight control surfaces, and landing gear. Similarly helicopter airframes consist of the fuselage, main rotor (on helicopters with a single main rotor), and related gearbox, and the landing gear.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Definition

(b) Part II: Aircraft Parts

(c) Part III: Aircraft Controls

(d) Part IV: Main Control Surfaces

(e) Part V: Landing Gear

### LEARNING OBJECTIVES

- Basic definitions.
- Understanding the airframe structure.
- Understanding the control surfaces.
- Landing gear systems.
- Demonstrated learning on microlight.

### INTERESTING FACTS

- Loss of control has been the cause of many air disasters. Aeroflot Flight 8641. Metal fatigue I the jackscrew of the horizontal stabilizer caused the components to fail while the plane was enroute from Leningrad to Kyiv, Ukraine, on 28 June 1982. The crew lost control of the plane, and at 10:50 crashed just south of the city of Mazyr in Belarus, killing all on board.

## PART I: DEFINITIONS

2. **Aeroplane**. A mechanically driven heavier than air aircraft (fixed wing) supported by dynamic reactions of the air upon its wings.

3. **Aerofoil**. A surface designed to produce lift when driven through the air.

4. **Aileron**. A horizontal control surface usually hinged to rear spar of main plane near wing tip for the purpose of lateral (roll) control (Fig 1-1).

5. **Aircraft**. Any weight carrying device designed to be supported by the air, either buoyant or dynamic.

6. **Airframe**. An aircraft without its engine/engines.

7. **Air Brake**. Any device primarily used to increase the air drag of an aircraft at will.

8. **Angle of Attack**. The angle which the chord line makes with the relative airflow.

9. **Camber**. The curvature of a surface of an aerofoil.

10. **Cantilever.** A spar or beam fixed rigidly at one end only.

11. **Centre of Gravity**. That point at which the total weight is considered to act, irrespective of the position of the body concerned.

12. **Centre of Pressure**. The point, usually on the chord line, through which the total reaction may be considered to act.

13. **Centre Section**. The portion of the fuselage or hull forming a continuous structure with the mainplane.

14. **Chord**. The distance between the leading and trailing edge of an aerofoil measured along the chord line.

15. **Cockpit**. The portion of a fuselage designed to accommodate pilot and crew.

16. **Control**. The intentional manoeuvring of the aircraft into any desired position.

17. **Control Column.** The lever (or the pillar supporting hand wheel) by which the elevator and aileron controls are operated.

18. **Control Surface**. A surface movable in flight, whose primary function is to govern the motion of aircraft in pitch, roll or yaw.

19. **Longerons**. The principle longitudinal members of the fuselage which run from front to rear and is usually supported at various points along its length by other structural members

20. **Longitudinal Axis**. An imaginary line running fore and aft through the centre of gravity.

21. **Lateral Axis.** An imaginary line through aircraft's centre of gravity considered to be parallel to line joining the wing tips.

22. **Incidence Angle**. The angle which the chord line makes with the horizontal.

23. **Fuselage**. The main structure or body of most types of the aircraft to which wings, tail plane, fin, rudder and other surfaces are attached.

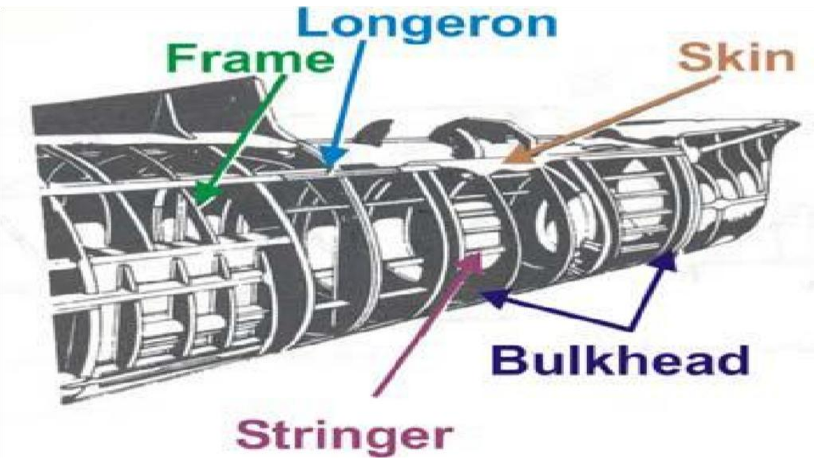
24. **Frames**. Transverse structural members of the fuselage supporting the longerons.

25. **Fairing**. Additions to any structure to reduce its drag.

26. **Glider**. A non-power driven heavier than air aircraft.

## PART II: AIRCRAFT PARTS

27. **Introduction**. The airframe components are constructed of a wide variety of materials and are joined by rivets, bolts, screws, and welding or adhesives. The aircraft components are composed of various parts called structural members (i.e., stringers, longerons, ribs, bulkheads, etc.).




**Cut Out of a Fuselage.**

28. Aircraft structural members are designed to carry a load or to resist stress. A single member of the structure may be subjected to a combination of stresses. In most cases the structural members are designed to carry end loads rather than side loads that is, to be subjected to tension or compression rather than bending. Strength may be the principal requirement in certain structures, while others need entirely different qualities. For example, cowling, fairing, and similar parts usually are not required to carry the stresses imposed by flight or the landing loads. However, these parts must have such properties as neat appearance and streamlined shapes.

29. **Fuselage**. The fuselage is the main structure or body of the aircraft. It provides space for cargo, controls, accessories, passengers and other equipment. In single engine aircraft, it also houses the power plant. In multi-engine aircraft the engines may either be in the fuselage, attached to the fuselage, or suspended from the wing structure. There are three general types of fuselage construction: the truss type, monocoque type and the semi-monocoque type.

30. **Basic Design**. The basic design of fuselage should satisfy the following: -

(a) Smooth skin of the required aerodynamic form.

(b) Sufficient strength to withstand aerodynamic loads, landing loads and handling loads.

(c) Sufficient stiffness to retain its correct shape under all loads.

(d) Mounting points for engine, armament, fuel tanks and equipment.

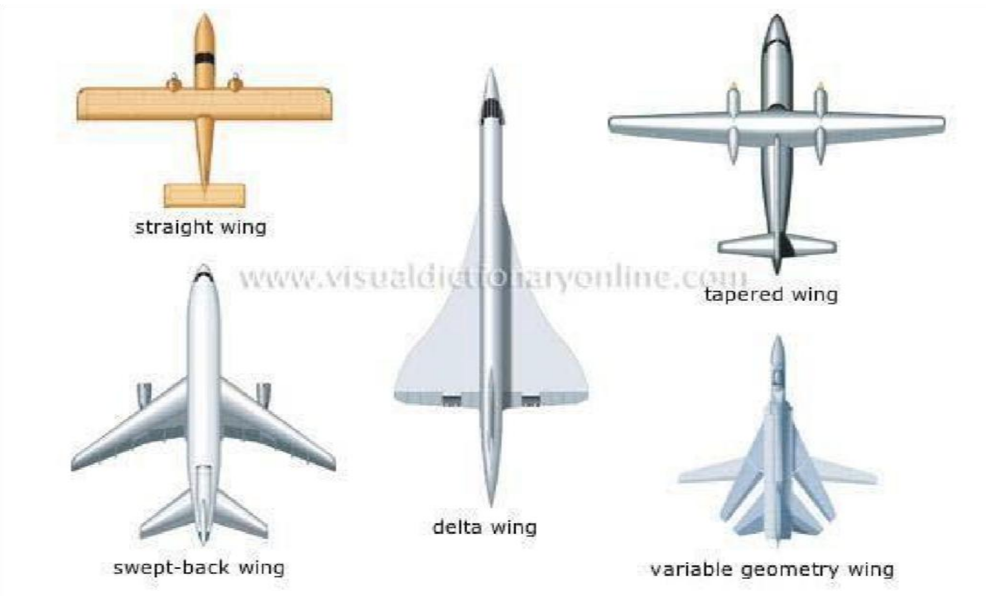
(e) Protection of aircrew and passengers from ambient conditions.

(f) Sufficient break down points for easy dismantling for transportation and port-holes accessible for inspection and servicing.

(g) Design itself should be economical and easy for production and repairs.

31. **Materials Used**. Early aircraft were constructed of wood frames covered in fabric. As monoplanes became popular, metal frames improved the strength, which eventually led to all-metal aircraft with metal covering all surfaces. Some modern aircraft are constructed with composite materials for major control surfaces, wings or the entire fuselage such as the Boeing 787. Hence the various types of materials used are wood, metals and composites.

32. **Wing Structure**. The wings of an aircraft are surfaces which are designed to produce lift when moved rapidly through the air. The particular design for any given aircraft depends on a number of factors, such as size, weight, use of the aircraft, desired speed in flight & at landing, and desired rate of climb.



**DID YOU KNOW**

- THE Antonov AN-225 was the largest aircraft ever built, with a maximum take-off weight of 640 tons. It was designed in Ukraine and first flew in 1988. The An-225 was used to transport the Soviet space shuttle Buran and other oversized cargo. However, the only An-225 was destroyed during the Russian invasion of Ukraine in 2022.


33. **Different types of Wings**. There are various types of wings as shown in figure. They are as follows straight wing, swept back wing, delta wing, tapered wing and variable geometry wing.

## PART III: AIRCRAFT CONTROLS

34. **Aircraft Controls**. A conventional wing aircraft flight control system consists of flight control surfaces, the respective cockpit controls, connecting linkages, and the necessary operating mechanisms to control an aircraft's direction in flight. Aircraft engine controls are also considered as flight controls as they change speed. Generally basic aircraft control can be classified as follows **Primary controls and Secondary controls.**

35. The basic aircraft controls are classified in to following:-

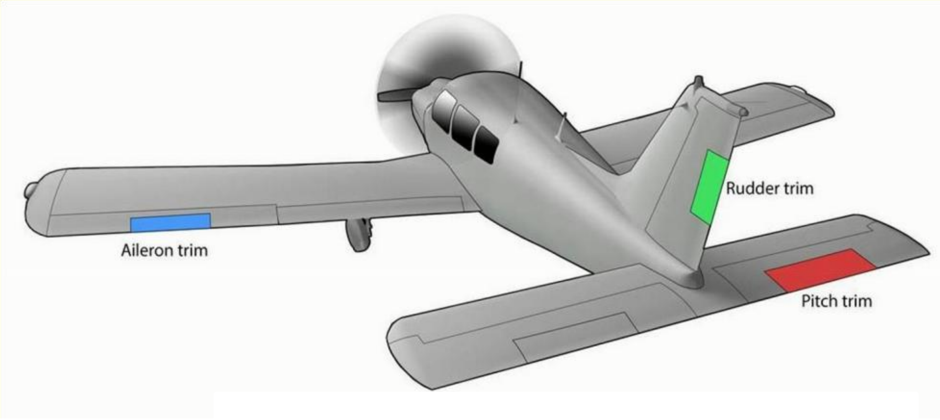
(a) **Primary Controls**. The primary aircraft controls are as follows:-

(i) A control yoke (also known as a control column), centre stick or side-stick governs the aircraft's roll and pitch by moving the ailerons, when turned or deflected left and right and moves the elevators when moved backwards or forwards.

(ii) Rudder pedals, to control yaw, which move the rudder; left foot forward will move the rudder left for instance.

Throttle controls to control engine speed or thrust for powered aircraft.

(b) **Secondary Controls**. The secondary controls are trim tab, flaps, air brakes, spoiler, leading edge slats and variable-sweep wing.




**Secondary Controls**

(i) **Trim Tabs**. These are small control surfaces connected to the trailing edge of a larger control surface of aircraft, used to control the trim of the controls, i.e. to counteract aerodynamic forces and stabilise the aircraft in a particular desired attitude.

(ii) Type of flight control surface used on an aircraft to increase drag. Spoilers are designed to increase drag while making little change to lift.

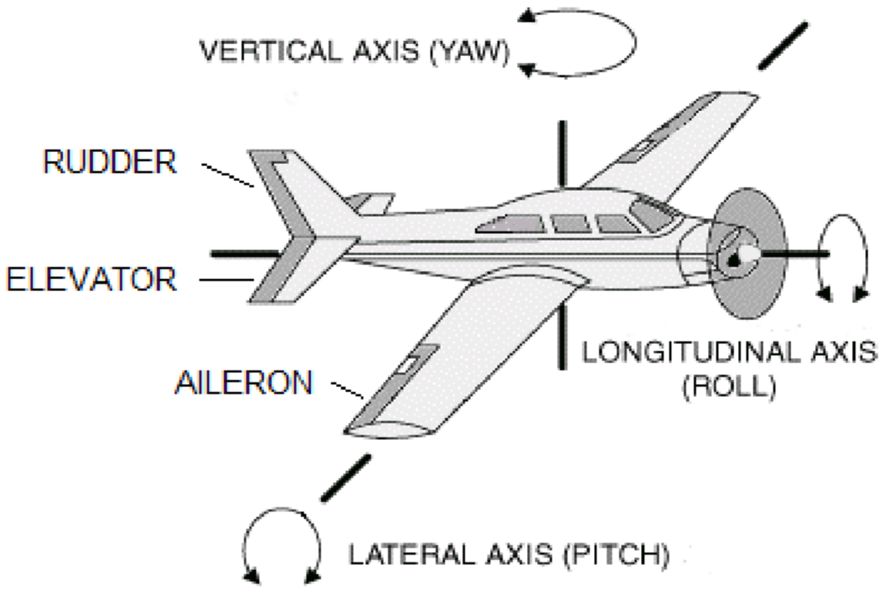
(iii) **Slats**. Slats are aerodynamic surfaces on the leading edge of the wings of fixed wing aircraft which, when deployed, allow the wing to operate at a higher angle of attack. A higher coefficient of lift is produced as a result of angle of attack and speed, so by deploying slats an aircraft can fly at slower speeds, or take off and land in shorter distances. They are usually used while landing or performing manoeuvres which take the aircraft close to the stall, but are usually retracted in normal flight to minimize drag.

(iv) **Variable - Sweep Wing**. A variable-sweep wing, also known as "swing wing", is an aeroplane wing that may be swept back and then returned to its original position during flight. It allows the aircraft's planform to be modified in flight, and is therefore an example of a variable-geometry aircraft.

(v) **Flaps**. Flaps are hinged surfaces mounted on the trailing edges of the wings of a fixed- wing aircraft to reduce the speed at which an aircraft can be safely flown and to increase the angle of descent for landing. They shorten take-off and landing distances. Flaps do this by lowering the stall speed and increasing the drag.

## PART IV: MAIN CONTROL SURFACES

36. The main control surfaces are Aileron, Elevator and Rudders and are attached to the airframe on hinges or tracks so that they may move and thereby deflect the air stream passing over them.




### Main Controls

37. **Ailerons**. Ailerons are mounted on the trailing edge of each wing near the wingtips and move in opposite directions. When the pilot moves the stick left, or turns the wheel counter-clockwise, the left aileron goes up and the right aileron goes down. A raised aileron reduces lift on that wing and a lowered one increases lift, so moving the stick left causes the left wing to drop and the right wing to rise. This causes the aircraft to roll to the left and begin to turn to the left.

38. **Elevators**. An elevator is mounted on the trailing edge of the horizontal stabilizer on each side of the fin in the tail, as shown in the figure above. They move up and down together. When the pilot pulls the stick backward, the elevators go up. Pushing the stick forward causes the elevators to go down. Raised elevators push down on the tail and cause the nose to pitch up. This makes the wings fly at a higher angle of attack, which generates more lift and more drag.

39. **Rudder**. The rudder is a fundamental control surface, typically controlled by pedals rather than at the stick. It is the primary means of controlling yaw-the rotation of an airplane about its vertical axis. On an aircraft, the **rudder** is a directional control surface. The rudder is usually attached to the fin (or vertical stabilizer) which allows the pilot to control yaw about the vertical axis, i.e. change the horizontal direction in which the nose is pointing. The

rudder's direction in aircraft has been manipulated with the movement of a pair of foot pedals by the pilot.

## PART V: LANDING GEAR

40. The functions of a landing gear are to support an aircraft during ground manoeuvres, dampen vibration, and absorb landing shocks; when required, it also performs the functions of steering and braking. These objectives are achieved by many different designs, depending on the type of aircraft to which the landing gear is fitted and the degree of sophistication required. A landing gear usually takes the form of two or more main undercarriage units in the wings or fuselage, and an auxiliary undercarriage unit at the nose or tail which carries only a small proportion of the total load and is used for steering purposes.

**Landing Gears**

41. With slow, light aircraft, and some larger aircraft on which simplicity is of prime importance, a fixed (non-retractable) landing gear is often fitted; the reduced performance caused by the drag of the landing gear during flight is offset by the simplicity, reduced maintenance and low initial cost. With higher performance aircraft, drag becomes progressively more important, and the landing gear is retracted into the wings or fuselage during flight; there are however, penalties of increased weight, greater complication and additional maintenance.

## CONCLUSION

42. Airframe materials must be strong, lightweight, and reliable to support the weight of the aircraft and the additional loads it experiences during flight and landing. They must also be able to withstand extreme temperatures, moisture, and ultraviolet radiation. When an aircraft is flying, the wings and fuselage experience stresses from acceleration and deceleration. These stresses include tension, compression, shear, bending, and torsion. The landing gear absorbs the forces from take-offs and landings. Airframes must be designed to meet airworthiness requirements.

(a) An airframe is the mechanical structure of an aircraft, excluding the power plant and instrumentation. The main components of an airframe are the wings, fuselage, tail assembly, and landing gear. The wings are considered the most important component because they provide lift to keep the aircraft airborne.

(b) Primary controls and secondary **controls** are the most essential control systems for all types of aircraft.

(c) The functions of flight control systems such as ailerons, elevators, elevens, **flaps** and flaperons are the most important to the understanding of aircraft controls.

(d) The functions of a landing gear are to support an aircraft during ground manoeuvres, dampen vibration, and absorb landing shocks

# ASSESSMENT EXERCISE

## Multiple Choice Questions

**Q1. What is the primary function of an aircraft's fuselage?**

(a) To provide lift

(b) To reduce drag

(c) To support aircraft components and cargo

(d) To control flight

**Q2. Which aircraft structural component provides additional lift during take off and landing?**

(a) Ailerons

(b) Elevators

(c) Flaps

(d) Rudder

**Q3. Which aircraft structural component controls roll?**

(a) Ailerons

(b) Elevators

(c) Rudder

(d) Flaps

**Q4. What is the purpose of an aircraft's rib?**

(a) To provide structural support to the wing

(b) To control airflow over the wing

(c) To reduce wing vibration

(d) To increase lift

**Q5. Which wing shape provides improved roll control?**

(a) Tapered

(b) Rectangular

(c) Swept-back

(d) Delta

**Q6. A surface designed to produce lift when driven through the air?**

(a) Trim tab

(b) Aerofoil

(c) Wing Tip

(d) Propeller

**Q7. A horizontal control surface usually hinged to rear spar of main plane near wing tip for the purpose of lateral (roll)?**

(a) Trim Tab

(b) Rudder

(c) Aileron

(d) Elevator

**Q8. The curvature of a surface of an aerofoil?**

(a) Wing

(b) Camber

(c) Aileron

(d) Parachute

**Q9. The principle longitudinal members of the fuselage which run from front to rear?**

(a) Longeron

(b) Spar

(c) Frame

(d) Fairing

**Q10. Parts usually that are not required to carry the stresses imposed by flight or the landing loads?**

(a) Tail Plane

(b) Wing Spar

(c) Tyre

(d) Fairing and cowling

**Q11. In single engine aircraft, ____________also houses the power plant?**

(a) Wing

(b) Fuselage

(c) Cockpit

(d) Cargo Compartment

**Q12. Boeing 787 Dreamliner wing is constructed mainly with?**

(a) Wood

(b) Metal

(c) Composite

(d) Glass

**Q13. Transverse structural members of the fuselage supporting the longerons?**

(a) Longeron

(b) Spar

(c) Frame

(d) Fairing

**Q14. A non-power driven heavier than air aircraft?**

(a) Balloon

(b) Glider

(c) Para Motor

(d) Aerostat

**Q15. Change of direction is achieved by?**

(a) Roll

(b) Pitch

(c) Yaw

(d) Yaw, Pitch and Roll

**Q16. What is the primary function of the landing gear?**

(a) To provide propulsion

(b) To control direction

(c) To absorb shock

(d) To support aircraft during landing

**<u>Short Answer Questions</u>**

1. What is the function of an aircraft's fuselage?
2. What materials are commonly used in aircraft structures?
3. Write a short note on various wing types?
4. Describe the purpose of landing gear.

**Long Answer Questions**

1. What are the basic design features of a fuselage?
2. Explain the function of the flight control system.
3. Describe various types of secondary flying controls?
4. With the help of a diagram explain the primary control surfaces.

# BASIC FLIGHT INSTRUMENTS

5

## CHAPTER WISE INDEX: BASIC FLIGHT INSTRUMENTS (SD/SW)

# BASIC FLIGHTS INSTRUMENTS (SD/SW)

## CHAPTER I : BASIC FLIGHT INSTRUMENTS (BFI)

***"A pilot's best friend is not just the aircraft but the instruments that provide the wisdom to navigate the skies safely."***


## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **01 ( One)** |
| **Type** | **:** | **Lecture/ Demo** |
| **Year** | **:** | **2nd Yr SD/SW** |
| **Conducting Officer** | **:** | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction** | **:** | **02 Mins** |
| • **Part I** | **:** | **35 Mins** |
| • **Summarise** | **:** | **03 Mins** |

## INTRODUCTION

1. The best medium for flying an aircraft is the natural horizon, where the earth and sky meet. This visual reference helps pilots maintain proper orientation during flight. However, in conditions such as clouds or night-time, the horizon may be obscured, making it challenging for pilots to gauge their position and attitude. To address this, aircraft are equipped with basic flight instruments that provide essential information when the natural horizon is not visible. These instruments—like the attitude indicator, altimeter, and airspeed indicator—enable pilots to maintain control and ensure safe navigation, regardless of external conditions. Understanding and effectively using these instruments is crucial for successful flight operations.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Working Principle

### LEARNING OBJECTIVES

- Identify key flight instruments and their functions.
- Understand how these instruments work.
- Recognise when to rely on visual vs. Instrument navigation.
- Ensure safe navigation and control during flight.

### DID YOU KNOW

- The first aircraft instruments were developed in the early 20th century, with the first artificial horizon created in 1912. This innovation significantly improved pilots' ability to fly in low visibility conditions; ultimately leading to safer and more reliable aviation as it helped them maintain control and orientation in challenging weather.

### INTERESTING FACTS

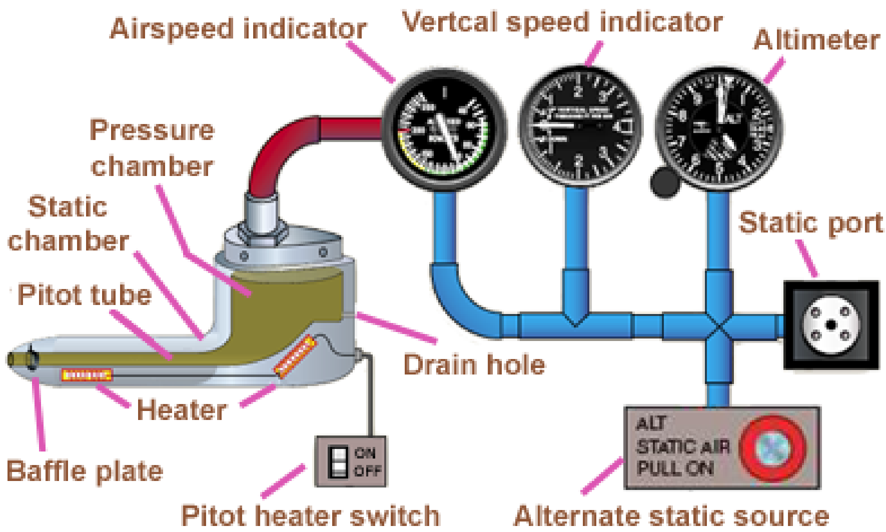
- Attitude Indicator: Mimics the natural horizon for orientation.
- Airspeed Indicator: Shows airspeed, not ground speed.
- Magnetic Compass: Simple yet essential, works without power.
- Turn Coordinator: Helps keep turns safe and coordinated.

## PART I: WORKING PRINCIPLE

2. The basic flight instruments are typically divided into a few categories that each serve a unique function. Key instruments include the altimeter, which measures altitude; the airspeed indicator, which shows the speed of the aircraft; the attitude indicator, which provides the orientation of the aircraft relative to the horizon; the heading indicator, which helps maintain directional control; and the vertical speed indicator, which shows the rate of

climb or descent. These instruments, collectively known as the "six-pack," are essential for situational awareness and safe flight management. These instruments operate based on different principles such as pitot-static pressure, gyroscopic motion, and magnetic fields.

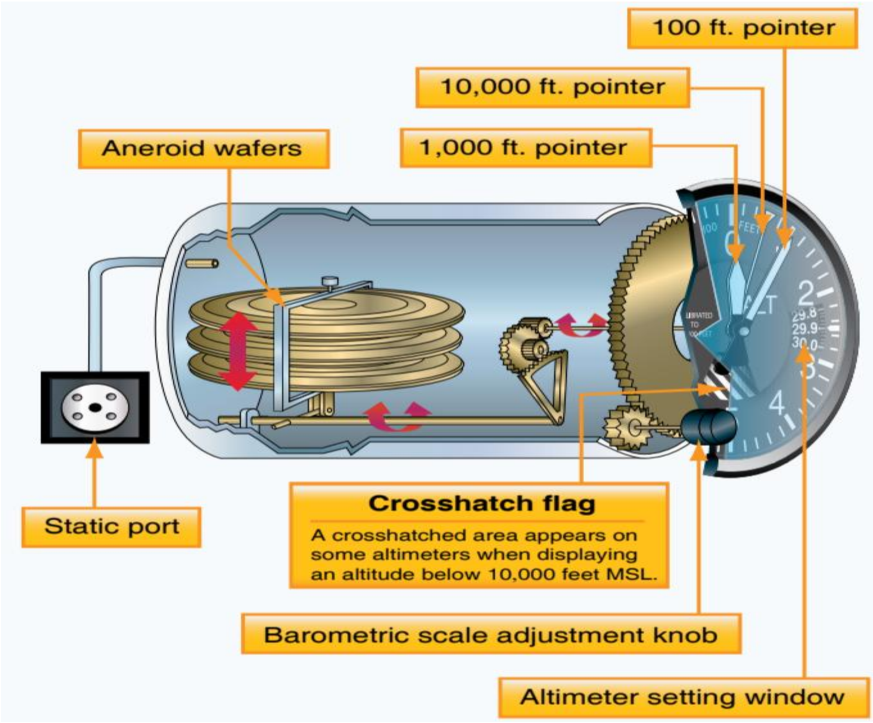

3. **Pressure Instruments**. Altimeter, ASI and VSI are the basic flight instruments that utilize air pressure to convey information.




Source: www.faa.gov/handbooks_manuals/media

4. **Altimeter**. An altimeter is an essential instrument used in aviation to measure the altitude of an aircraft above sea level. It plays a critical role in navigation, safety and air traffic management.

(a) **Barometric Altimeter**. The most common type, it measures altitude based on changes in atmospheric pressure. As altitude increases, air pressure decreases.

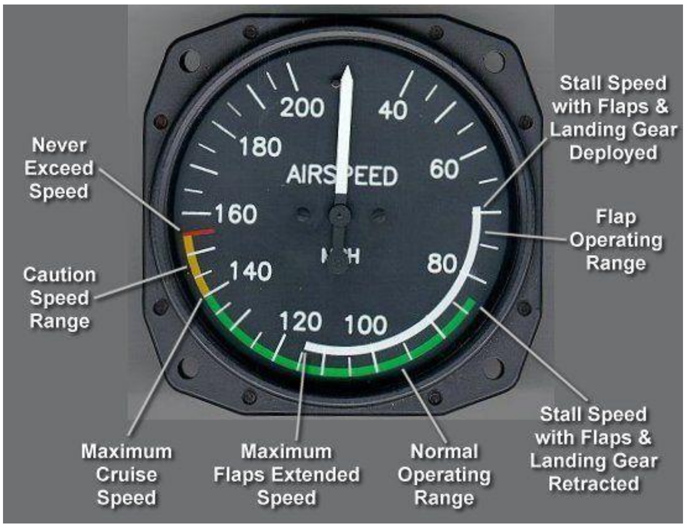



(b) **Principle of Operation**. The altimeter detects reduction of atmospheric pressure (static atmospheric pressure which decreases at a fairly uniform rate of approx. 1 mb for every 30 feet of height gained and vice versa) with increase in altitude and is calibrated to read altitude.

(c) **Radio Altimeter**. Measures the altitude above the ground by sending radio waves to the terrain below and measuring the time it takes for the signal to return. This type is typically used during approaches and landing

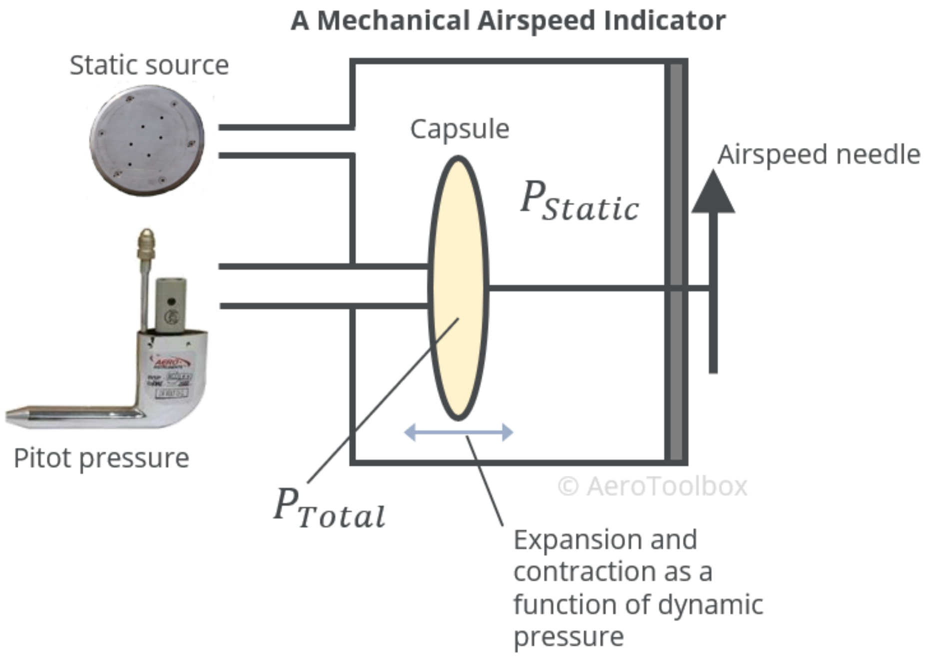
5. **Airspeed Indicator**. The airspeed indicator (ASI) is a crucial flight instrument that measures and displays the speed of an aircraft relative to the surrounding air. It is vital for safe and effective flight operations.

6. **Principle of Operation**. ASI works by measuring the difference between the dynamic pressure (from the pitot tube) and static pressure (from the static port) to determine the aircraft speed relative to the surrounding air.




(a) Dynamic air pressure refers to the pressure exerted by the air due to its motion. It is associated with the kinetic energy of the moving air particles and is a function of the aircraft's speed. The faster an aircraft moves, the greater the dynamic pressure. In aviation, dynamic pressure is measured using the pitot tube, which captures the airflow directly in front of the aircraft. Dynamic pressure increases with the velocity of the aircraft and is a key factor in determining the airspeed of the aircraft, as it helps the airspeed indicator calculate how fast the aircraft is moving relative to the surrounding air.

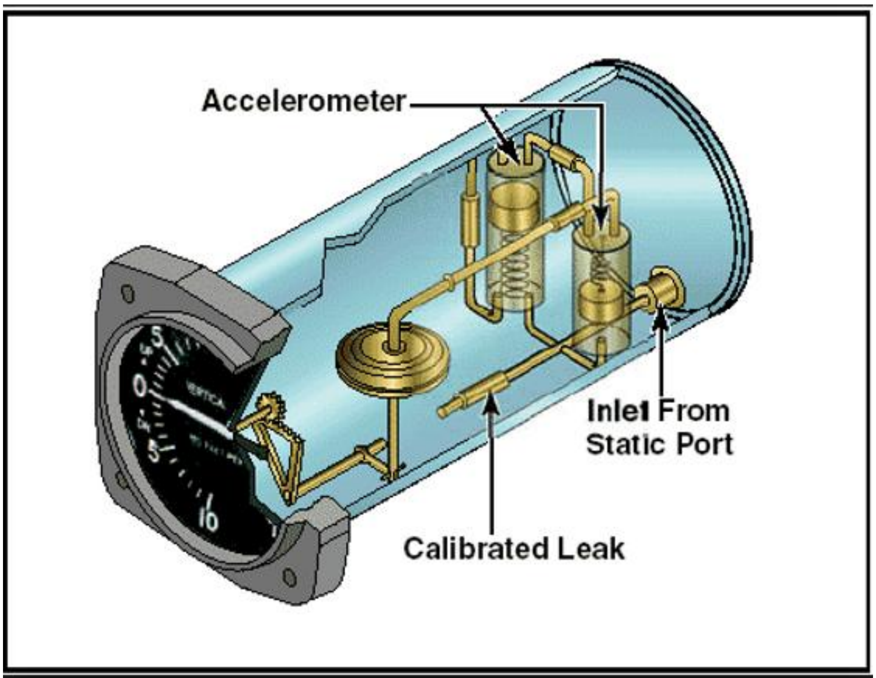
(b) Static air pressure, on the other hand, is the pressure exerted by the atmosphere when the air is at rest or not moving. It is the result of the weight of the air column above a given point and is generally measured at a point unaffected by the motion of the air, such as in a static port on the aircraft. Static pressure is critical in determining the altitude and is used by instruments like the altimeter and the vertical speed indicator to assess the aircraft's altitude relative to sea level. While dynamic pressure fluctuates with speed, static pressure remains relatively constant and is primarily influenced by altitude and atmospheric conditions.




7. **Vertical Speed Indicator (VSI)**. The **Vertical Speed Indicator (VSI)** is an essential flight instrument that measures the rate at which an aircraft is climbing or descending. It operates based on the principle of **pressure differences**. The VSI consists of a sealed capsule that is sensitive to changes in static air pressure. When the aircraft climbs or descends, the outside air pressure changes, which in turn causes a change in the pressure inside the capsule. The VSI uses this difference in pressure to determine the rate of altitude change.

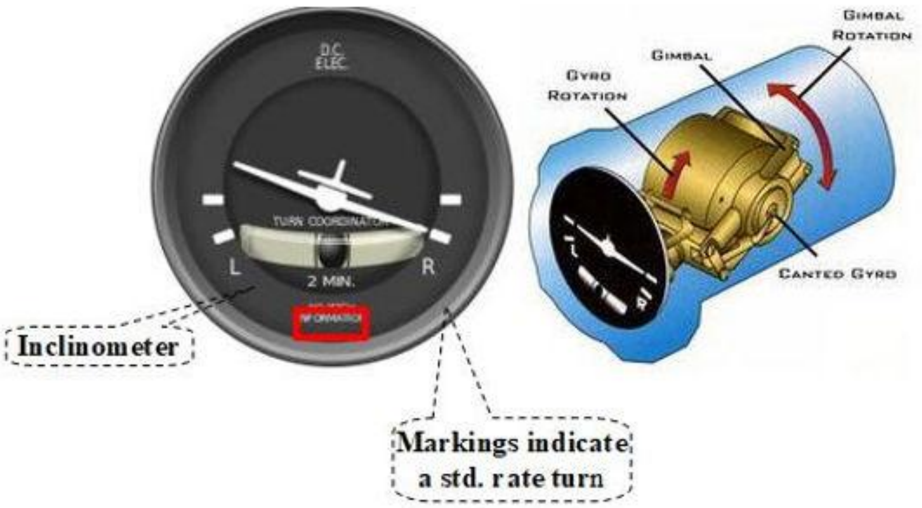
(a) **Principle of Operation of VSI is called Measurement of Delayed Static Pressure**. The instrument's design includes a calibrated leak in the capsule, allowing it to react to changes in pressure over time. During a climb, the aircraft's altitude increases, and the static pressure outside decreases, which causes the air inside the capsule to expand. In contrast, during a descent, the pressure outside the aircraft increases, and the air inside the capsule contracts. These pressure changes are translated into needle movements on the VSI dial, which indicates the vertical speed in feet per minute (fpm).

(b) The VSI provides pilots with crucial information about the aircraft's vertical movement (rate of climb or descent in m/s or fpm), whether the aircraft is climbing, descending, or in level flight. By continuously monitoring the VSI, pilots can maintain a controlled and safe rate of ascent or descent, ensuring smooth transitions during different flight phases. The instrument helps pilots avoid rapid altitude changes, reducing the risk of sudden airspeed or altitude discrepancies.

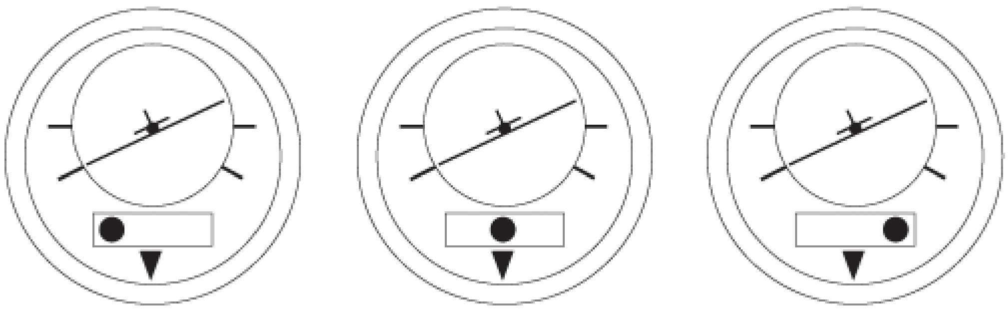



**Vertical Speed Indicator (VSI)**

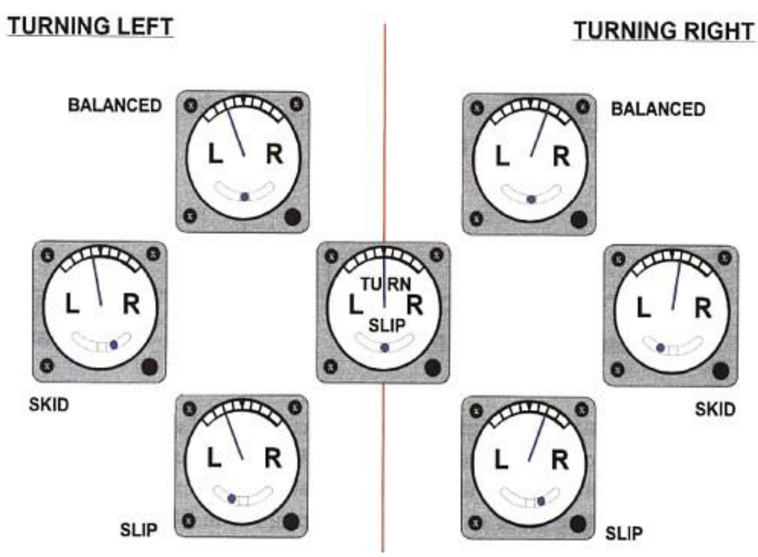
8. **Turn & Slip Indicator**. The Turn and Slip Indicator is a crucial flight instrument that helps pilots monitor the aircraft's rate of turn and coordination. It operates on the principle of gyroscopic precession and measures the aircraft's rotation around its vertical axis. The indicator consists of a small gyroscope that is mounted in a gimbaled system, allowing it to stay stable while the aircraft turns. As the aircraft rolls into a turn, the gyroscope resists the change in direction, and the indicator's needle moves to show the rate of turn. The turn indicator on the instrument displays the rate of turn in degrees per second, usually with markings such as "standard rate" for a 2-minute turn (a turn that completes 360 degrees in 2 minutes). If the needle is centered, it indicates a standard rate turn. A turn rate that exceeds the standard rate may be shown by the needle moving beyond the standard markings, warning the pilot of excessive turning speeds.




9. The slip indicator shows whether the aircraft is in coordinated flight (resultant between centrifugal force and gravitational force) or experiencing a "slip" or "skid." A ball, housed in a curved tube filled with liquid, moves based on the forces acting on the aircraft during the turn. If the aircraft is not turning correctly (e.g., too steep or not enough rudder), the ball will move away from the center, indicating a need for correction. When the ball is centered, it means the turn is well-coordinated, and the aircraft is not skidding or slipping. This helps pilots maintain proper control and avoid inefficient or unsafe flight maneuvers.



Slipping Turn Coordinated Turn Skidding Turn



10. **<u>Magnetic Compass</u>**.The magnetic compass is a fundamental flight instrument used in aviation to indicate the aircraft's heading relative to magnetic north. It is one of the oldest and most reliable navigation tools, providing essential information for pilots.


**<u>Magnetic Compass</u>**

11. **<u>Principle of Operations</u>**. The magnetic compass works by utilizing the Earth's magnetic field, causing a magnetized needle to align itself with the magnetic north pole, indicating direction.

(a) **<u>Heading Reference</u>**. Displays the aircraft's current heading in degrees (0 to 360) relative to magnetic north.

(b) **<u>Navigation</u>**. Assists pilots in navigating and maintaining the desired flight path, especially in visual flight rules (VFR) conditions.

(c) **<u>Cross-checking</u>**. Serves as a backup to other navigation instruments, helping pilots verify their heading.

## <u>CONCLUSION</u>

12. Basic flight instruments are essential for ensuring safe and effective flight, particularly in conditions where visual references are limited, such as in bad weather, at night, or during instrument-only flying. These instruments provide critical information about the aircraft's speed, altitude, attitude, heading, and rate of climb or descent, helping pilots maintain control and situational awareness. Instruments like the **altimeter**, **airspeed indicator**, **attitude indicator**, and **vertical speed indicator** are fundamental for monitoring the aircraft's performance and navigation. They allow pilots to make informed decisions about the aircraft's flight path, ensuring a safe and smooth journey. Understanding and interpreting these instruments is vital for ab initio pilots as they form the foundation for more advanced flying techniques, including instrument flying and the use of modern avionics. Overall, basic flight instruments are key to flight safety, assisting pilots in maintaining accurate control of the aircraft and avoiding dangerous situations.

(a) Understanding basic flight instruments is essential for safe and effective aviation operations.

(b) These instruments, including the Altimeter, Airspeed Indicator, Vertical Speed Indicator, Attitude Indicator, Heading Indicator, Turn Coordinator, and Magnetic Compass, provide pilots with critical information regarding altitude, speed, orientation, and direction.

(c) Each instrument operates on specific principles—such as pressure changes or gyroscopic effects—and is designed to enhance situational awareness, especially when visual references are unavailable.

13. The reliance on these instruments ensures that pilots can navigate effectively and maintain control of the aircraft in various flying conditions.

## ASSESSMENT EXERCISE

**Multiple Choice Questions**

1. **What is the primary function of an altimeter?**

   (a) Measure ground speed

   (b) Measure altitude above sea level

   (c) Indicate airspeed

   (d) Display heading direction

2. **Which instrument is commonly referred to as the "artificial horizon"?**

   (a) Magnetic Compass

   (b) Attitude Indicator

   (c) Altimeter

   (d) Turn Coordinator

3. **What principle does a barometric altimeter use to measure altitude?**

   (a) Changes in air temperature

   (b) Changes in atmospheric pressure

   (c) Sound wave reflection

   (d) Magnetic field variations

4. **What does the airspeed indicator (ASI) measure?**

   (a) True ground speed

   (b) Rate of climb

   (c) Speed of the aircraft relative to surrounding air

   (d) Distance covered per minute

5. **Which type of airspeed is corrected for altitude and temperature?**

   (a) Indicated Airspeed (IAS)

   (b) True Airspeed (TAS)

   (c) Ground Speed

   (d) Vertical Speed

6. **What does the vertical speed indicator (VSI) display?**

   (a) The rate of ascent or descent

   (b) The altitude above sea level

   (c) The speed relative to ground

   (d) The rate of turn

**7. The heading indicator shows the aircraft's direction relative to:**

(a) True north

(b) Magnetic north

(c) Ground level

(d) The natural horizon

**8. What does the turn coordinator measure?**

(a) Angle of climb or descent

(b) Bank angle and coordination of turns

(c) Rate of altitude change

(d) Speed relative to air

**9. Which instrument can operate without electrical power?**

(a) Heading Indicator

(b) Vertical Speed Indicator

(c) Magnetic Compass

(d) Airspeed Indicator

**10. What type of altimeter is typically used during landing?**

(a) Barometric Altimeter

(b) Laser Altimeter

(c) Radio Altimeter

(d) Pressure Altimeter

**11. Which of the following instruments helps pilots maintain safe and coordinated turns?**

(a) Attitude Indicator

(b) Airspeed Indicator

(c) Turn Coordinator

(d) Magnetic Compass

**12. What feature does the attitude indicator provide?**

(a) Aircraft pitch and bank angles

(b) Altitude above ground level

(c) True heading direction

(d) Rate of descent

**13. What is the main limitation of the magnetic compass in flight?**

(a) It requires a power source

(b) It is affected by acceleration and deceleration errors

(c) It cannot display altitude

(d) It only works in clear weather

**14. What does the heading indicator require for accurate operation over time?**

(a) Calibration with the vertical speed indicator

(b) Manual correction using the magnetic compass

(c) Alignment with GPS signals

(d) Continuous power from an external source

**15. Which of the following is a function of the altimeter in aviation?**

(a) Helps pilots maintain a safe turn angle

(b) Provides the aircraft's altitude above sea level

(c) Indicates the speed of the aircraft through air

(d) Measures distance travelled on the ground

**Short Answer Questions**

1. Explain the function of the Altimeter in aviation.
2. What are the different types of airspeed measured by the Airspeed Indicator?
3. Describe how the Attitude Indicator assists pilots during flight.
4. What is the primary purpose of the Vertical Speed Indicator?
5. How does the Magnetic Compass work, and why is it important in aviation?

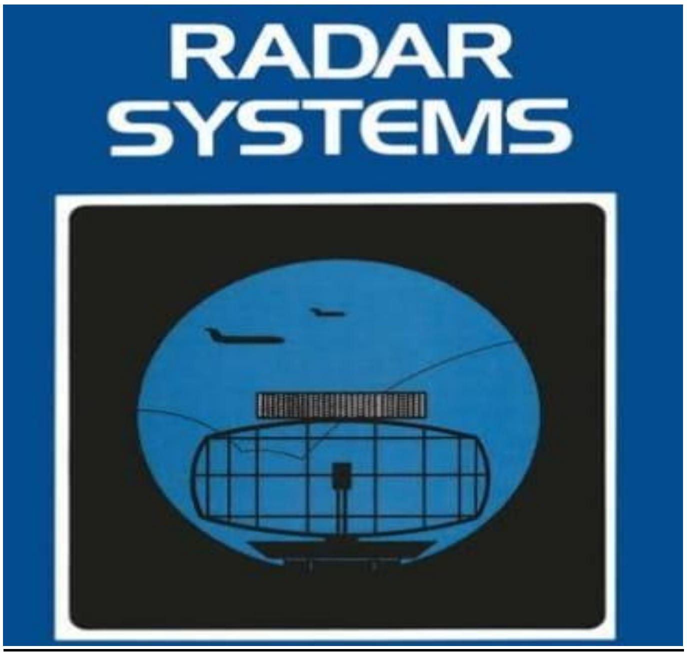
**Long Answer Questions**

1. What is the importance of the altimeter in aviation, including its types and working principles?
2. How does the airspeed indicator function, and why is it critical for safe flight operations?
3. What role does the vertical speed indicator play in managing altitude changes during flight?
4. How does the attitude indicator assist pilots in maintaining aircraft orientation in low-visibility conditions?
5. What are the functionalities of the heading indicator and magnetic compass in navigation and flight safety?

# BASIC FLIGHTS INSTRUMENTS (SD/SW)

## CHAPTER II : INTRODUCTION TO RADAR (IR)

***"In the dance of air and distance, radar is the eye that sees beyond the horizon"***




### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **02 (Two)** |
| **Type** | **:** | **Lecture/ Demo** |
| **Year** | **:** | **2nd Yr SD/SW** |
| **Conducting Officer** | **:** | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |
| **Time Plan** | | |
| • **Introduction to Radar** | **:** | **05 Min** |
| • **Part I** | **:** | **35 Min** |
| • **Part II** | **:** | **35 Min** |
| • **Conclusion** | **:** | **05 Min** |

## INTRODUCTION

1. RADAR, or Radio Detection and Ranging, is a crucial technology that uses radio waves to detect and locate objects. It measures distance, speed, and direction, with applications in aviation, maritime navigation, weather monitoring, and military operations. A radar system usually consists of a transmitter and a receiver to catch any reflected energy from targets. Radar underwent rapid development during the 1930's and 40's to meet the needs of the air force. It is still widely used by the armed forces where many technological advances have originated. Simultaneously radar has found an increasing number of important civilian applications notably air traffic control, weather observation, space surveillance and planetary observations.

## PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Definitions of Radar

(b) Part II: Principle and Working of Radar

## LEARNING OBJECTIVES

- Understand radar fundamentals: learn how radar emits and processes radio waves.
- Identify key components: recognize functions of the transmitter, receiver, and antenna.
- Explore applications: discover uses in aviation, maritime, weather, automotive sectors.
- Analyze advantages: evaluate benefits like real-time data and all-weather functionality.
- Discuss future trends: examine emerging innovations in radar technology.

## DID YOU KNOW

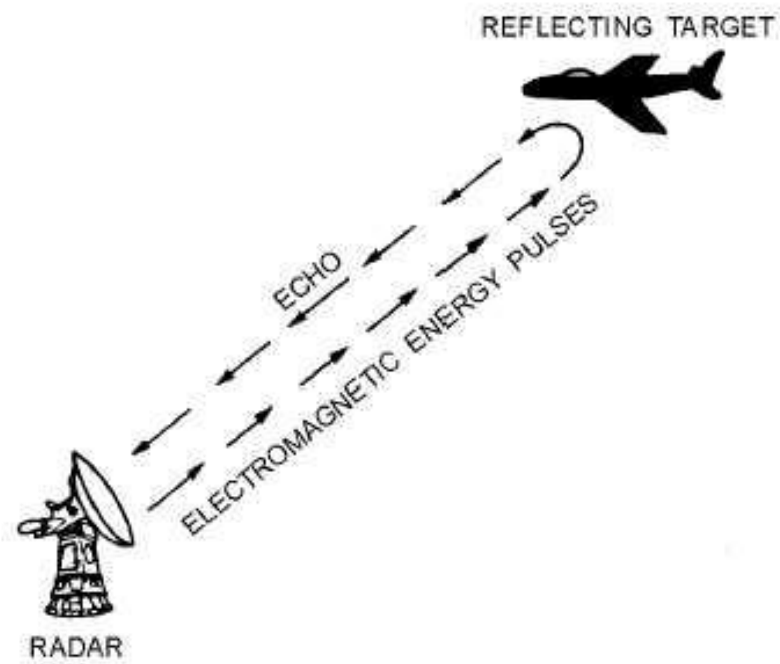
- RADAR can detect objects in all weather conditions, including fog, rain, and snow, making it highly reliable for navigation and tracking.

## PART I: DEFINITION OF RADAR

2. RADAR (Radio Detection and Ranging) is a system that uses radio waves to detect, locate, and track objects. It works by transmitting radio signals, which reflect off objects and return to the radar receiver. By analysing the reflected signals, radar can determine the distance, speed, direction, and shape of objects, even in low visibility conditions like

darkness, fog, or rain. Radar is widely used in aviation, maritime navigation, weather forecasting, military defence, and speed enforcement.

## PART II: PRINCIPLE AND WORKING OF RADAR




3. **Working Principle of RADAR (Radio Detection and Ranging)**. The working principle of RADAR is based on electromagnetic wave reflection and time measurement to detect objects, determine their distance, speed, and direction. The step-by-step operation of a basic radar system is as enumerated below.

(a) **Signal Generation**. The radar system begins by generating a high-frequency electromagnetic wave (radio wave or microwave). This is done by a transmitter, which converts electrical energy into electromagnetic energy, produces a pulse of energy at a specific frequency and sends it into the air via the antenna.

(b) **Transmission of the Radar Wave**. The generated electromagnetic wave is transmitted from the radar antenna in a specific direction, typically in a narrow beam. This beam is directed towards the area being monitored for detecting objects.

(c) **Propagation of the Radar Wave**. The radar wave travels through the atmosphere, and when it encounters an object (such as an aircraft, ship, or weather phenomenon), it is reflected back toward the radar system. The nature of the reflection depends on the size, shape, and material of the object.

(d) **Reception of the Echoed Signal**. The receiver in the radar system detects the reflected electromagnetic wave (echo) that returns from the object. The receiver is usually located near the transmitter and is often the same antenna that sends the signals. The radar system needs to distinguish between the transmitted pulse and the received echo to ensure accurate data collection.

(e) **Time Delay Measurement**. The radar system calculates the time delay between when the signal was transmitted and when the echo is received. This time delay is crucial for determining the distance to the object. The radar system knows the speed of electromagnetic waves (the speed of light), and by multiplying the time delay by the speed of the signal and dividing by two, it can calculate the range (distance) to the object.

(f) **Angle Determination**. The radar also measures the angle at which the radar wave was reflected. This is done by analysing the direction in which the antenna was pointing when the echo was received. The radar's scanning mechanism (typically through antenna rotation) allows it to determine the azimuth angle (horizontal direction) and, in some cases, elevation angle (vertical direction) of the object.

(g) **Identification of Additional Information**. The radar system may use additional features, such as Doppler shift (change in frequency) or signal strength, to determine the object's **speed** and **direction** of movement. For example, if the object is moving, the Doppler effect causes a change in the frequency of the returned signal, which is used to measure the relative velocity of the object.

(h) **Signal Processing.** The received signal is then processed to extract useful information.

(j) **Display and Interpretation**. The processed data is displayed on a radar screen or monitor, where the operator can view the object's position, movement, and other characteristics.

(k) In summary, a basic radar system generates a signal, transmits it, detects the reflected signal, measures the time delay to calculate distance, processes the data to determine location and movement, and then displays the results for the operator. This process allows radar to detect and track objects effectively over large distances, providing valuable information in aviation, navigation, and weather monitoring.

4. **Basic Components of RADAR**. The radar system consists of four main components:

(a) **Transmitter**. Generates and transmits radio waves.

(b) **Antenna**. Directs the transmitted waves and receives the reflected signals.

(c) **Receiver & Signal Processor**. Processes the received signals to extract information about the object's position, speed, and direction.

(d) **Display Unit**. Shows the detected objects on a screen for interpretation.

5. **Application of Radar in Aviation**. Radar is an essential tool in aviation, providing critical information for navigation, safety, and efficient flight operations. Here are some key applications of radar in aviation:

(a) **Air Traffic Control (ATC)**. Radar is used by air traffic controllers to track the position and movement of aircraft in the airspace. This helps in managing traffic, ensuring safe separation between aircraft, and providing guidance for safe takeoffs, landings, and en-route navigation.

(b) **Weather Detection and Monitoring**. Weather radar helps pilots and air traffic controllers detect and track severe weather conditions such as thunderstorms, precipitation, turbulence, and wind shear. This allows pilots to avoid dangerous weather and optimize flight paths for safety and comfort.

(c) **Navigation and En-Route Guidance**. Radar assists pilots in determining their position during flight, especially in areas with poor visibility. It helps provide situational awareness when flying in conditions such as fog, clouds, or at night.

(d) **Collision Avoidance**. Radar is used for detecting nearby aircraft to avoid mid-air collisions. **Traffic Collision Avoidance Systems (TCAS)** use radar data to alert pilots when another aircraft is in close proximity and recommend course or altitude changes to avoid a collision.

(e) **Ground Surveillance and Surface Traffic Management**. Ground radar at airports helps in monitoring aircraft on the ground, including during taxiing, to ensure safe movement on runways and taxiways. It assists ground control in managing aircraft traffic at busy airports.

(h) **Precision Approach and Landing**: **Precision Approach Radar (PAR)** is used during the final stages of approach and landing, especially in poor visibility path during their approach.

(j) **Search and Rescue (SAR)**. Radar plays a crucial role in search and rescue operations by helping locate aircraft in distress or lost in remote areas. It can track the position of distress signals, identify aircraft wreckage, or assist in locating survivors in emergency situations.

(k) **Terrain Avoidance**: **Ground Proximity Radar**. assists in terrain avoidance, helping pilots identify potential obstacles or terrain during low-level flight or when flying in mountainous areas. It enhances situational awareness, reducing the risk of controlled flight into terrain (CFIT) accidents.

(l) **Military and Surveillance Operations**. In military aviation, radar is used for detecting and tracking enemy aircraft, missiles, and other threats. It provides real-time information about the location, speed, and altitude of hostile objects, helping with defense and tactical operations.

## CONCLUSION

6. RADAR technology plays a vital role in modern society, enabling the detection and tracking of objects over vast distances with high precision. Its ability to operate effectively in various weather conditions makes it indispensable in fields such as aviation, maritime navigation, military operations, and automotive safety. As technology advances, RADAR systems continue to evolve, integrating with other technologies to enhance their functionality and efficiency. Understanding the principles and applications of RADAR is essential for leveraging its capabilities in diverse scenarios, from air traffic control to weather monitoring and beyond. RADAR (Radio Detection and Ranging) is a powerful technology that detects and locates objects by emitting radio waves and analyzing the reflected signals. Its key components include transmitters, antennas, and receivers, all working together to provide real-time data on the distance, speed, and direction of objects. RADAR is widely used in various applications.

## ASSESSMENT EXERCISE

**Multiple-choice Questions (MCQs)**

1. **What does RADAR stand for?**

   (a) Radio Distance and Reflection

   (b) Radio Detection and Ranging

   (c) Radio Data and Response

   (d) Radio Direct Analysis and Range

2. **What type of waves does RADAR emit?**

   (a) Sound waves

   (b) Infrared waves

   (c) Radio waves

   (d) X-rays

3. **Which component generates the radio waves in a RADAR system?**

   (a) Antenna

   (b) Transmitter

   (c) Receiver

   d) Processor

4. **What is the function of the antenna in a RADAR system?**

   (a) Processes reflected signals

   (b) Amplifies radio waves

   (c) Sends out waves and receives echoes

   d) Measures speed and distance

5. **What does the receiver in a RADAR system do?**

   (a) Reflects radio waves

   (b) Captures and processes the reflected signals

   (c) Transmits data to other devices

   (d) Emits continuous signals

6. **Which of the following is NOT an application of RADAR technology?**

(a) Maritime navigation

(b) Medical imaging

(c) Weather monitoring

(d) Air traffic control

7. **How does RADAR measure the distance to an object?**

(a) By calculating the time taken for reflected waves to return

(b) By analyzing the amplitude of the transmitted wave

(c) By detecting color changes in the object

(d) By using gravitational wave interference

8. **What makes RADAR advantageous in adverse weather conditions?**

(a) It uses sound waves

(b) It operates at high frequencies

(c) It is unaffected by rain, fog, or darkness

(d) It requires no external power source

9. **Which sector uses RADAR for advanced driver-assistance systems (ADAS)?**

(a) Aviation

(b) Military

(c) Automotive

(d) Maritime

10. **What is a key advantage of RADAR in detecting objects?**

(a) It provides real-time data

(b) It can capture 3D images of objects

(c) It detects underground objects

(d) It requires minimal energy

**11. What type of RADAR system is used to track the speed of a moving object?**

(a) Pulse RADAR

(b) Continuous-wave RADAR

(c) Bistatic RADAR

(d) Phased array RADAR

**12. Which of the following is an emerging application of RADAR technology?**

(a) Weather balloons

(b) Smart home automation

(c) Autonomous vehicles

(d) Underwater photography

**13. What is a key principle of RADAR operation?**

(a) Wave refraction

(b) Electromagnetic wave reflection

(c) Acoustic wave propagation

(d) Gravitational wave interaction

**14. Which RADAR advantage is particularly important in military applications?**

(a) Colour detection

(b) Real-time target tracking

(c) Sound wave analysis

(d) Data encryption

**15. What is one of the primary innovations in the future of RADAR technology?**

(a) Use of higher power transmitters

(b) Integration with artificial intelligence for better object recognition

(c) Development of analogue-only systems

(d) Reduction of RADAR's operational range

## Short Answer Questions

1. Explain how RADAR works in basic terms.
2. What are the main applications of RADAR?
3. Describe the role of the transmitter in a RADAR system.
4. What is the importance of real-time data provided by RADAR?
5. Discuss one limitation of traditional RADAR systems.

## Long Answer Questions

1. How does RADAR detect objects using transmission, reflection, and data processing?
2. What are the functions of the transmitter, antenna, and receiver in a RADAR system?
3. How is RADAR applied in aviation, maritime, military, and automotive industries?
4. Elaborate the key components of radar?
5. Elaborate the applications of radar?

# BASIC FLIGHTS INSTRUMENTS (SD/SW)

## CHAPTER III: 'DETAILED' STUDY OF RADAR AND GPS

***"In the dance of air and distance, radar is the eye that sees beyond the horizon"***


## TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Period** | **:** | **01** |
| **Type** | **:** | **Lecture/ Demo** |
| **Year** | **:** | **3rd Yr SD/SW** |
| **Conducting Officer** | **:** | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |

**Time Plan**

| | | |
|---|---|---|
| • **Introduction to Radar and** | | |
| • **GPS** | **:** | **10 Mins** |
| • **Primary Radar** | **:** | **25 Mins** |
| • **Secondary Radar** | **:** | **30 Mins** |
| • **GPS** | **:** | **40 Mins** |
| • **Summary of Radar** | **:** | **05 Mins** |
| • **Review Questions** | **:** | **05 Mins** |
| • **Multiple Choice Questions** | **:** | **05 Mins** |

**Note: The class on GPS will be covered as a practical class on the Virus microlite.**

## INTRODUCTION

1. Radar (Radio Detection and Ranging) and GPS (Global Positioning System) are important technologies used for navigation and detection. Radar works by sending out radio waves and analysing the signals that bounce back to locate objects like airplanes and ships. It's widely used in air traffic control and weather monitoring. GPS uses a network of satellites to provide accurate location information anywhere on Earth. It allows users to determine their precise position, making it essential for navigation in cars, smartphones, and outdoor activities. Together, radar and GPS improve safety and efficiency in many areas of our lives.

### PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: Detail study of Radar

(b) Part II: Global Positioning System

### LEARNING OBJECTIVES

- Understand basic principles of radar and GPS.
- Learn the difference between primary and secondary radar.
- Explore how GPS uses satellites to determine location.
- Recognize the role of waypoints in GPS navigation

### DID YOU KNOW

- **Primary radar** doesn't require any equipment on the target to detect it, as it relies solely on reflected radio waves.

## PART I: DETAIL STUDY OF RADAR

### Primary Radar

2. **Primary Radar**. Primary radar is a passive radar system that detects and determines the location of objects by transmitting radio waves and receiving their reflections. It does not require any cooperation from the target, meaning the object being detected does not need to have a transponder or any other active device.

3. **Principle of Operation**. Primary radar works on the principle of radio wave reflection (echo principle):-

(a) The radar transmits electromagnetic pulses.

(b) If the pulse encounters an object, part of the signal **reflects** back to the radar.

(c) The radar receives the reflected signal and measures the time delay to determine the object's distance.

(d) Additional processing can estimate the object's speed and direction.

4. **Components of Primary Radar**.

(a) **Transmitter**. Generates high-frequency radio pulses.

(b) **Antenna**. Sends out the radar signals and receives the reflected signals.

(c) **Receiver & Signal Processor**. Amplifies and processes the returned signal to determine object location.

(d) **Display.** Visual representation of detected objects, commonly shown as blips on a screen.

5**.** **Applications of Primary Radar**. Primary radars are used in all applications where the target is not actively cooperating in the detection process such as monitoring aircraft without transponders, target recognition, weather monitoring, surveillance and navigation.

6. **Advantages of Primary Radar**.

(a) No cooperation required from the target.

(b) Works in almost all weather conditions (fog, rain, darkness).

(c) Can detect unknown or non-cooperative targets, including unidentified aircraft.

7. **Disadvantages of Primary Radar**.

(a) Limited target information (cannot identify aircraft type or altitude without secondary radar).

(b) Less accurate than secondary radar due to signal interference and clutter.

(c) Susceptible to noise and reflections from unwanted surfaces (ground clutter).

(d) Lesser detection range than primary radar, all other conditions remaining the same.

(e) Power requirements are higher than secondary radar.

**Secondary Radar**

8. **Secondary Radar (Secondary Surveillance Radar - SSR)**. Secondary Radar, also known as Secondary Surveillance Radar (SSR), is an advanced radar system that not only detects aircraft but also gathers additional information such as identity, altitude, and speed. Unlike Primary Radar, which relies on reflected radio waves, Secondary Radar requires a cooperative target (transponder) in the aircraft or object.

9. **<u>Principle of Operation</u>**. Secondary Radar operates on a **request-response principle**, where:-

(a) The ground radar station (interrogator) transmits an interrogation signal.

(b) The aircraft's transponder receives this signal and responds with a coded reply containing information such as:

(i) Aircraft ID (Flight number)

(ii) Altitude

(iii) Speed and other parameters

(c) The radar receives and processes the response, displaying detailed aircraft data on an air traffic control screen.

10. **<u>Components of Secondary Radar</u>**.

(a) **<u>Interrogator (Ground Radar Station)</u>**. Sends interrogation signals to aircraft.

(b) **<u>Transponder (Aircraft System)</u>**. Receives interrogation and responds with coded data.

(c) Receiver & Signal Processor. Decodes and processes the response.

(d) **<u>Display System</u>**. Shows aircraft position, altitude, and ID on an air traffic control screen.

11. **<u>Advantages of Secondary Radar</u>**.

(a) Provides more information than primary radar (identity, altitude, speed).

(b) Longer range, lower power and higher accuracy than primary radar.

(c) Less affected by weather conditions (e.g., rain, clouds, and ground clutter).

12. **<u>Disadvantages of Secondary Radar</u>**.

(a) Requires a transponder in the target (active cooperation of target is required).

(b) Susceptible to transponder failure (if the aircraft's transponder is off, it won't be detected).

(c) Prone to signal interference in high-traffic airspace.

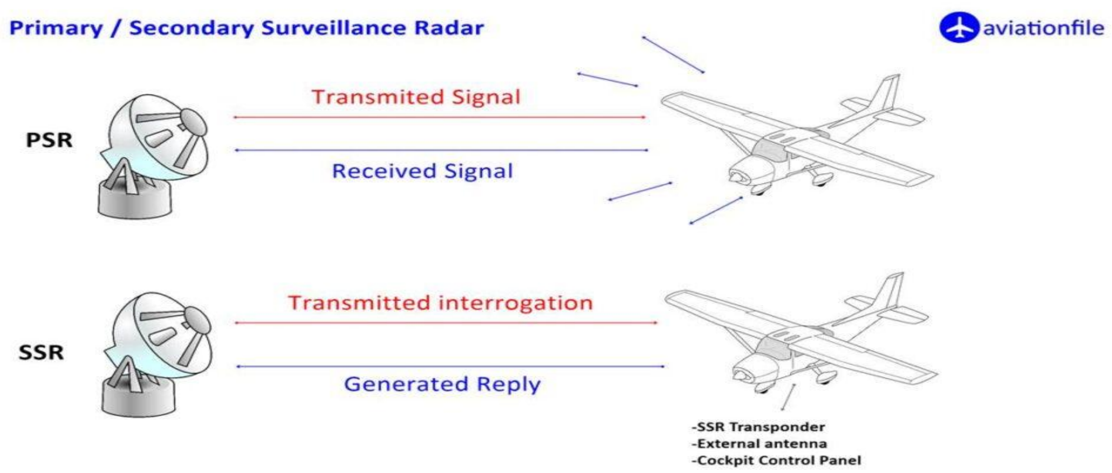
13. **<u>Applications of Secondary Radar</u>**.

(a) **<u>Air Traffic Control (ATC)</u>**. Positive aircraft identification.

(b) **Military IFF (Identification Friend or Foe)**. Distinguishes friendly and enemy aircraft.

14. **Comparison of Primary and Secondary Radar**.

| **Feature** | **Primary Radar** | **Secondary Radar** |
|---|---|---|
| **Detection Method** | Reflects radio waves from objects | Uses transponder signals |
| **Target Cooperation** | Not required | Required (needs a transponder) |
| **Information Provided** | Position and movement | Position, identity, altitude, speed |
| **Usage** | Military, weather, maritime | Air traffic control, military IFF |




## PART II: GLOBAL POSITIONING SYSTEM

15. **Principle of Operation of Geo Positioning System**. The Geo-Positioning System operates based on the principle of **triangulation**, which is the process of determining the position of a point by measuring its distance from three or more known points. A minimum coverage by three satellites can give a 2D fix, however four satellites are required to give a 3D fix. The most commonly used Geo-Positioning is the Global Positioning System designed by USA. Here's a step-by-step breakdown of how GPS works:

(a) **Satellites**. The GPS system consists of a network of at least 24 satellites orbiting Earth at about 20,000 kilometers above the surface. These satellites continuously transmit signals containing their location and the exact time the signal was sent.

(b) **Receiver**. The GPS receiver, which is installed in an aircraft or any other device, picks up signals from at least four satellites. Each satellite transmits a unique signal that includes the satellite's location and the precise time the signal was sent.

(c) **Distance Calculation**. The receiver calculates the distance to each satellite based on the **time delay** between the transmission of the signal and its reception. Since the signals travel at the speed of light, the receiver can calculate how far away each satellite is.

(d) **Trilateration/ triangulation**. By measuring the distances from at least four satellites, the GPS receiver can calculate the aircraft's **latitude**, **longitude**, and **altitude**. The receiver uses the known positions of the satellites to determine its exact location on Earth.

16. **Uses of GPS in Aviation**.

GPS has become a critical tool in modern aviation, offering a wide range of applications:

(a) **Navigation**. GPS allows pilots to determine their exact position anywhere on Earth, making it a powerful tool for both en-route navigation and approach procedures.

(b) **Instrument Flight Rules (IFR) Operations**. With GPS, pilots can perform precise instrument approaches and landings, especially at airports without radar or traditional ground-based navigation aids.

(c) **Route Planning**. GPS helps in more efficient flight planning, enabling optimal routes based on current conditions, airspace structure, and waypoints, especially in remote regions where traditional navigation aids may be unavailable.

(d) **Enhanced Safety**. GPS provides real-time positional data, reducing the risk of disorientation or navigational errors, especially in poor visibility conditions like fog, thunderstorms, or at night.

(e) **Search and Rescue**. GPS is invaluable in search and rescue operations, as it can quickly determine the exact location of an aircraft in distress, helping rescue teams respond efficiently.

17. Geo-positioning systems are satellite-based navigation systems that provide location and timing information to users worldwide. While GPS (Global Positioning System) is the most widely known, several other global and regional positioning systems also exist. Here's a breakdown of the key systems:

| | |
|---|---|
| Global Positioning System (GPS) | USA |
| Global Navigational Satellite System (GLONASS) | Russia |
| Galileo | European Union |
| Beidou | China |
| NavIC | India |
| Quazi Zenith Satellite System | Japan |

## CONCLUSION

18. Both **geo-positioning systems** and **radar** are fundamental to modern aviation, significantly enhancing safety, navigation, and operational efficiency. GPS and other satellite-based systems provide precise location data, enabling accurate route planning, navigation in challenging conditions, and support for critical operations like instrument approaches and landings. Simultaneously, radar systems play a vital role in monitoring aircraft, detecting hazardous weather, and ensuring safe separation in airspace, as well as guiding movements on the ground. Together, these technologies improve situational awareness, reduce risks, and enable more efficient, secure air travel worldwide.

(a) RADAR (Radio Detection and Ranging) and GPS (Global Positioning System) are two critical technologies in modern navigation, communication, and tracking.

(b) RADAR uses radio waves to detect and locate objects. It has two types:-

(i) Primary Radar, which transmits radio waves and analyses the return signal to calculate the distance, size, and speed of objects.

(ii) Secondary Radar involves communication between a radar system and a transponder on the target, providing additional data like identification and altitude.

(c) GPS works by receiving signals from satellites and calculating the distance between them and the receiver to determine precise geographic locations. GPS relies on trilateration, to fix a user's position and provide real-time navigation updates.

19. Both technologies play pivotal roles in aviation, maritime, and land transportation, ensuring safety and efficiency in route planning and tracking

## ASSESSMENT EXERCISE

**Multiple Choice Questions (MCQs).**

**1. What is the primary function of RADAR?**

(a) Detecting objects using sound waves

(b) Determining geographic location

(c) Emitting radio waves and analysing their reflections to locate objects

(d) Transmitting satellite signals

**2. Which RADAR type does NOT require any equipment on the target for detection?**

(a) Secondary RADAR

(b) GPS

(c) Primary RADAR

(d) Phased Array RADAR

**3. What key information does Secondary RADAR provide in addition to object detection?**

(a) Weather patterns

(b) Altitude and identification

(c) GPS coordinates

(d) Distance and size

**4. How does GPS determine a user's position?**

(a) By analysing radar echoes

(b) By triangulation from ground stations

(c) By trilateration using at least four satellites

(d) By using transponders on the target

**5. What component of RADAR emits radio waves?**

(a) Transmitter

(b) Receiver

(c) Transponder

(d) Processor

**6. Which technology relies on satellites to provide location information?**

(a) Primary RADAR

(b) Secondary RADAR

(c) GPS

(d) Phased Array RADAR

**7. What are GPS waypoints used for?**

(a) Tracking weather conditions

(b) Defining geographic reference points for navigation

(c) Identifying transponders on objects

d) Measuring signal strength

**8. What is one limitation of Secondary RADAR?**

(a) It cannot detect moving objects

(b) It requires targets to have transponders

(c) It provides inaccurate altitude readings

(d) It operates poorly in adverse weather

**9. Which of the following is an application of RADAR?**

(a) Calculating fuel efficiency

(b) Air traffic control

(c) Mobile data communication

(d) Mapping underwater terrain

**10. What is the purpose of a transponder in Secondary RADAR?**

(a) To reflect radio waves

(b) To enhance signal strength

(c) To respond to interrogation signals with information

(d) To amplify satellite signals

**11. What is the principle of Primary RADAR operation?**

(a) Satellite communication

(b) Reflection of radio waves from an object

(c) Continuous signal emission without reflection

(d) Using transponders to send signals back

**12. Which of the following best describes GPS?**

(a) A ground-based detection system

(b) A satellite-based navigation system

(c) A weather forecasting tool

(d) A military communication network

**13. Which feature is exclusive to Secondary RADAR?**

(a) It can detect objects without equipment

(b) It provides detailed target information, including altitude and ID

(c) It works in all weather conditions

(d) It does not require a transponder

**14. What is one advantage of RADAR in adverse weather conditions?**

(a) It uses high-frequency light waves

(b) It is unaffected by rain, fog, or darkness

(c) It directly communicates with satellites

(d) It operates without power

**15. What is trilateration in GPS?**

(a) The method of calculating altitude using ground stations

(b) Determining location using signals from at least four satellites

(c) Using radar reflections to detect object speed

(d) Analysing sound waves to measure distance

**Short Answer Questions**

1. What is the difference between Primary Radar and Secondary Radar?
2. How does GPS calculate a user's position?
3. What role do waypoints play in GPS navigation?
4. How does radar determine the distance to a target?
5. What is the primary use of RADAR and GPS in aviation?

**Long Answer Questions**

1. Elaborate on Primary Radar?
2. Elaborate on GPS?
3. Elaborate on Secondary Radar?
4. How does primary radar detect and locate objects using radio waves?
5. What is the purpose of a transponder in secondary radar?

# AEROMODELLING

6

**CHAPTER WISE INDEX: AEROMODELLING (SD/SW)**

**(SD/SW)**

## AEROMODELING (AE)


### TEACHING INSTRUCTIONS

| | | |
|---|---|---|
| **Total Period** | **:** | **24** |
| **Theory Period** | **:** | **2 (1st year)/8(2nd year)/14(3rd year)** |
| **Practical Period** | **:** | **21 (in which cadets will make and fly aero models and drones)** |
| **Type** | **:** | **Lecture and Practical** |
| **Year** | **:** | **1st Year SD/SW** |
| **Conducting Officer** | **:** | **AMI** |
| **Training Aids** | **:** | **Classroom, OHP, Board, Screen, Pointer, Marker, Book Flagged, or Lesson Plan, File and Aircraft Model.** |

**Time Plan**

| | | |
|---|---|---|
| • **Introduction** | **:** | **10 Mins** |
| • **Part I** | **:** | **20 Mins** |
| • **Part II** | **:** | **20 Mins** |
| • **Part III** | **:** | **20 Mins** |
| • **Part IV** | **:** | **10 Mins** |
| • **Part V** | **:** | **15 Mins** |
| • **Part VI** | **:** | **15 Mins** |

- **Conclusion and Summary : 10 Mins**

## INTRODUCTION

1. Aeromodelling is one of the finest hobbies, which is very popular worldwide among people of various age groups. It has often been the starting point of many pilot/ aero-nautical careers. The aim of including aeromodelling in the NCC curriculum is to enhance the interest among NCC cadets. If taken on the right lines, it can be extremely thrilling for all, as by constructing the models by one's own hands, it will make understanding of various principles of flight and problems of construction etc. very easy, apart from providing great personal satisfaction to the aero- modeler.

2. There are quite a number of variants of aero models, which are classified according to the role and utility of the particular type, the main types are described in the following parts.

3. International competitions for different aeromodelling events are organized at various levels across the world. In India the apex body for aeromodelling is known as 'All India Aeromodellers Association' which conducts Pan-Indian competitions in various events. Gradually, aeromodelling is becoming increasingly popular all over the country specially amongst the NCC Airwing Cadets.

## PREVIEW

The lecture will be conducted in following parts:-

(a) Part I: History of Aeromodeling

(b) Part II: Types of Aeromodels

(c) Part III: Flying / Buildings of Aeromodels

(d) Part IV: History of Drones

(e) Part V: Rules and Regulations for Drones

(f) Part VI: Elements Involved in Drone Building

## LEARNING OBJECTIVES

- Aeromodeling and its history.
- Types of Aeromodels and material used in building.
- Flying procedure of an Aeromodel.
- Introduction to drone flying and procedure.

## PART I: HISTORY OF AEROMODELING

4. Aeromodeling is a costly hobby. The material and equipments are expensive and can only be procured conveniently by people forming various clubs and associations. As a result, there have come up hundreds of such clubs all over the world, where like-minded people get together and have access to approved materials and equipment in sufficient quantity. International competitions for different aeromodelling events, have now become a regular feature. In India the apex body for aeromodelling is known as 'All India Aeromodellers Association' which conducts Pan-Indian competitions in various events. Gradually, aeromodelling is becoming increasingly popular all over the country specially amongst the NCC Airwing cadets.

5. It can thus be seen that Aeromodelling provides an earnest approach to the understanding of an otherwise highly technical subject, i.e. *aerodynamics.* The *air-minded* Aeromodeller of today is the potential aircraft designer of tomorrow. Although, Aeromodelling is a technical hobby and is usually cluttered up with complicated calculations

and formulae, it need not necessarily discourage the beginners and the non-technical persons, as they can still derive immense pleasure and satisfaction from this hobby.

6. The history of Aeromodelling goes back much further than the history of real aircraft. The successful experiments, however, started in the nineteenth century. Dr. Thomas Young was the first person to discover the *lifting* property of a cambered surface in comparison to the flat surface. Sir George Caley built a helicopter model, based on a design of Leonardo-da-Vinci, in 1796. Another great name amongst the pioneers of aeromodelling is of Alphones Penand, who invented models fitted with tail surfaces and wings with dihedral angles. This gave substantial stability of flight to aero models, which till this time had lasted for very short duration. After this, came the era of miniature petrol-driven engines. In 1878, Professor Langley builds a petrol driven model called 'Aerodrome No.5'. This revolutionalized the concept of aeromodelling, as there was now an ideal power plant small enough for the requirement, available to the enthusiasts. Hundreds of varieties of petrol models were subsequently built. Later, these gave ways to more powerful diesel engines, which are in use even today.

7. **Materials Used in Aeromodelling**. Aeromodelling requires a variety of materials. Selection of correct material and proper use of the same is important factor of Aeromodelling. The following are the main substances from which the Aero models can be made:

(a) Balsa Wood.

(b) Spruce.

(c) Japanica Wood fast.

(d) Plywood.

(e) Cement.

(f) Setting Epoxy.

(g) Cyanoacrylate Glue (Cyano).

(h) Putty.

(j) Metal Paste.

(k) Dope.

(l) Paint.

(m) Sand Paper.

(n) Fiber glass.

(o) Carbon Fibre.

(p) Silver foil.

(q) Monokote & etc.

8. **Wood**. Types of wood used in construction of aero models is as follows:-

(a) **Balsa**. This wood is very light and can be easily worked for almost every purpose in aeromodelling. Balsa, however, is a short-grained wood and should not be used for highly stressed parts of the model. It is also prone to absorb moisture and rubber lubricants. Balsa was found in the forests of South America from where it has since spread all over the world. There are many varieties of Balsa, the best of the type is known as medium hard Balsa, which gives the best combination of strength and lightness. Balsa wood is available in a variety of sections and thickness of sheets.

(b) **Spruce**. Next to Balsa wood comes silver spruce, which is light as well as strong. It has been used extensively in manufacturing full sized aircraft and heavier type of models. It is mainly used for fuselage, longerons, bracing struts and wing spars.

(c) **Birch**. It is stronger than silver spruce but also heavier. It is used where extreme strength is required i.e. heavy power models.

(d) **Bass Wood**. It is mainly used as a Balsa substitute. Its working properties are similar to Balsa except that it is much stronger. Basswood blocks are found ideal for making propellers and wings of solid models.

(e) **Cane and Bamboo**. They are ideally suited for tail and rudder frames as they are strong, light and flexible Under car - ridges are generally made of bamboo.

(f) **Plywood**. Plywood sheets are used for paneling work, formers and wing tips. Plywood is a very strong material.

(g) **Pine**. white wood and Mahogany Propeller blades are sometimes made of these types of wood.

9. **Fabric and Tissue**. Tissue paper sheets are used to cover the model aircraft after construction. They are available in various weights and colors. For heavier and power-driven models, silk fabric (Chinese or Japanese) and-bamboo paper are all needed, being strong. Synthetic silk is not useful since it dissolves out by the action of dope.

10. **Dope**. Doping is used for the following purposes:-

(a) For airproofing of surface.

(b) For tightening the surface skin by plasticising effect.

(c) For making the model hardy and less vulnerable to weather conditions.

Dope is a liquid which has celluloid and thinner as basic materials. It is available in a variety of colours. Several thin (diluted) sprays are preferable to one or two heavy coats. These applications should be allowed to dry naturally for best effects. Extremely light models are not doped but sprayed with water and left to dry.

11. **Adhesives**. These comprise of glues and cements of various types and are used for joining various parts of model aircraft.

12. **Wire**. Common piano wire is used for under-carriages of aero models. Wing tips, propeller shafts, rudder frames, all are generally fixed with hooks etc. made out of such wires and springs.

13. **Rubber**. Rubber bands are used for making various types of rubber- models. They are also used for keeping various a/c parts attached in their respective positions. Rubber bands should be stored in air tight containers with French chalk powder, and should be lubricated before use. There is also a variety of other materials which is used in aeromodelling i.e. metal tubings made of brass and aluminium, cello-phane, small nails, celluloid etc.

14. **Basic Tools**. Majorly using tools used in aeromodelling are listed below:-

(a) Screwdriver.

(b) Hand drill.

(c) Sandpaper and pins.

(d) Pliers.

(e) Knives with different blades.

(f) Different kinds of saw.

(g) Files.

(h) Soldering irons.

(i) RC set (Transmitter and receiver, servos).

15. After selection of good materials and required tools, one has to handle these tools carefully. Mishandling of tools may cause serious injuries to the Aeromodellers/builders.

## PART II: TYPES OF AEROMODELS

16. **Introduction**. There are quite a number of variants of aero models, which are classified according to the role and utility of the particular type, the main types are described in the following pages.

17. **Static Models**. These are the miniature replicas of the original, full sized aircraft types and attract the best skills of the model maker. The scope of this particular type is boundless and depends upon the ideas of the individual concerned. It requires only an elementary knowledge of carpentry and involves fitting together of the various parts as well as finishing and painting of the models.

18. **Gliders**.

**(a) Chuck Gliders**. These are solid balsa models which have to be hand-catapulted. These are available in kit forms and are precut to the required sizes. They just have to be cemented together. Chuck gliders are further classified as:

(i) Hand launched

(ii) Catapult Launched

(b) **Towline Glider**. These models have a far superior performance as compared to the chuck glider. They are quite robust and professional looking, and have stable flight characteristics. There are normally 3 components to the model when completely built up i.e. wing, fuselage and tailplane. It is therefore convenient to carry them to the flying grounds and assemble them with rubber bands. The standard methods of launching them it either from the shoulder or by a towline.

(c) **Sail Plain**. These are advanced type of gliders. These beautiful models are intended for contest flying. Their building method is same as earlier models. They are however a little complicated in structure. The launching methods is same as previous. In a strong wind, the model will climb on the line without even pulling on the towline.

19. **Rubber Models**. These models get their power to fly from rubber strips. One end of the strip is attached to the fuselage as an anchorage, and the other end is tied to the propeller hook. The propeller is now wound a number of given turns and when the models is launched the rubber unwinds itself, spurning the propeller and propelling the model forward.

20. **Power Models**. The power models have a long history. The main types are listed below.

(a) **Free Flight Model**. These required large, open fields to perform. They are usually hand- launched although some modellers often prefer an ROG (Rise off ground). These models are divided into 2 categories i.e (i) sport and (ii) contest. The SPORT type possesses a reasonable degree of stability, whereas the CONTEST type has exceptional flying characteristics.

(b) **Control Line Model**. This type is CONTROLLED from the ground by its PILOT. Two wires are attached to the model and terminate at a CENTRAL HANDLE which is held by the PILOT. These wires control the up and down movement of the elevator or flap of the model. By pulling the handle up, the elevators or flaps of the model move up, resulting in the model climbing. Similarly, by moving the handle down or forward, the elevator of the model moves down, resulting in the closest a person can get to physically controlling a model. Control a model. Control models can be further divided into 4 main categories.

(i) Trainer Model.

(ii) Stunt Mode.

(iii) Speed Model.

(iv) Team Racer.


(c) **Radio Controlled Models**.This type of model is fitted with radio receiver sets which, through a set of actuators operate the control surfaces of the model. The radio receiver receives the signals from the control box which is operated by the PILOT. The control box is nothing, but a transmitter with various channels for operating the respective controls including throttle. This way, the model can be operated without physical contact.

**DID YOU KNOW?**

- It is a popular pastime that requires both technical skills and creativity to create miniature replicas of real-life planes and helicopters.
- Aeromodelling can be a great way to learn about aviation and engineering.
- Another important aspect of aeromodelling is propulsion. The engines or motors that power model airplanes must be carefully chosen and configured to provide the right amount of power and thrust for the size and weight of the aircraft. This involves knowledge of mechanics and physics, including the principles of torque, power, and energy.

21. **Jetex Models**. These models illustrate the operation of the jet aircraft. They get their power from jetex power units which can be fixed on to the model by a simple clip. It does not produce any torque, like a propeller driven aircraft and the thrust is almost straight and constant, the trimming of this type is quite simple also.

22. **Engines for Aeromodels**. There are four different types of miniature engines used in aeromodels. Although their basic features are similar, they differ in the manner of their operation. These are listed below:-

(a) Spark Ignition.

(b) Diesel.

(c) Glow-plug.

(d) Jet.

23. **Fuel**. Following are the two most commonly used fuel mixture:-

(a) Diesel oil.

(i) Ether.

(ii) Lubricating oil.

(b) Mobile oil SAE-40.

(i) Paraffin.

(ii) Ether.

## PART III: FLYING / BUILDING OF AEROMEODELS

24. **Construction of Static Models**. These are the miniature replicas of original aircrafts, full sized aircraft types and attract the best skill of the model maker. The scope of this particular type is boundless and depends upon the ideas of the individual concerned. It requires only an elementary knowledge of carpentry and involves fitting together of various parts as well as finishing and painting of the models.

25. Constructions plans are provided normally with all model kits. These should be studied thoroughly. Then follow the shaping of various parts using sandpaper and sand blocks as shown in the blue print. After which the whole plan is fixed on the drawing board. Then the individual parts are placed on the blue print and make sure it is proper as per the blue print. Parts are then assembled together as per the dimensions provided in the blue print. Dope is applied with brush but only in thin coats two to three times. Sand the excess dope using a fine emery paper.

26. **Painting**. Apply a coat of surfacer using a brush or spray gun and make sure it has covered all the wooden area. After the surfacer is dried up check for dents and apply putty or metal paste to cover the dents. After it dries up using a wet emery paper, sand the model to get a clean surface till it is suitable for painting. Etch rivet marking as shown in the blueprint. Spray a thin layer of base coat and paint the model as per the required colour scheme. Add details, undercarriage, wheels, drop tanks etc. & apply lacquer or polish if required.

## Construction of Control Line Models

27. Each and every part of a model aero plane is important as it would not function in the absence of even one component. Construction plans are provided normally with all model kits. These should be studied thoroughly. Then follows the actual construction of various parts. The power units are, also available in readymade forms, and are required to be installed as they are, as per the power/weight combination prescribed by the manufactures

28. First, the whole plan is fixed on to the drawing board. Then the individual parts are fixed on it with the help of pins parts are then glued together with cement. After drying, the various components are assembled together with correct alignment. Sand papers of various grades are used for smoothening out of edges and curves. Patience and meticulous operation is needed at this point. Assemble the bell crank assembly with the lead outs carefully. Model is then covered with sliver foil, monokote or tissue paper. Dope may be applied with brush, in thin coats two to three times.

29. Before engine installation, ensure that the engine compartment is properly treated with paint work. While installing the engine, extreme care is needed to be taken to ensure that the thrust line of the propeller is in line with the fuselage. Out of line thrust will result in the model going hay wire and crashing. Engines are mounted either by projection made of hard wood beams or on screws against the plywood.

30. Install the Radio-control servos as per the requirement to make sure the control rods should move freely without causing any disturbance to the other control rods. Wrap the receiver and the battery pack in foam and place it in the model in such a way that the CG of the model is correct as per the marking shown in the plan by the manufacturer of the kit. Then assemble the wing using a pairs of rubber bands or nylon screws.

### INTERESTING FACTS

- The first recorded Aeromodellers were the Wright Brothers and L.H. Hargrave
- Aeromodelling is highly educational as it combines hands-on learning with scientific and engineering principles, making it an engaging way for students to understand complex concepts.
- Aeromodelling has real-world applications in fields such as aerospace engineering, aviation, drone technology, and even remote sensing

31. **Flying the Models**. The necessity of choosing a large field for flying the aero models is obvious. However, trees and wooded areas are the greatest hazards for the aeromodeller. Trees cause air pockets and down-draughts and often 'suck' the model into their branches.

32. **Flying Sequence**. The flying sequence can be arranged as:-

(a) Gliding test.

(b) Trail flight.

(c) Launching.

(d) Trouble Shooting.

33. **Gliding test**. First check the model for correction of alignment. The wing and tail must be checked from the front and rear for setting and must not be warped or out of plane. Testing is carried out during mid-day when there is little or no wind. The model is held on the point of balance i.e. approximately 1/3$^{rd}$ back from leading edge of the wing, and is gently launched into wind slightly nose down attitude. If the model is set properly and trimmed correctly, it will glide forward gracefully and will land on wheels. Use plasticine or lead weight at the nose and tail for balance as required.

34. **Trial Flight**. Power flight is not advisable till the gliding test is carried out successfully. For trial flight, a small amount of fuel is put into the fuel tank and the engine started by rotating the propeller. And the model launched gently the model should fly short distance and land perfectly.

35. **Launching**. A good launching is the result of proper coordination between the aero-modeler and his helper. The checks which are listed in the gliding test should be followed meticulously in order to achieve best results. Any short cuts or slip-shod procedures would only result in frustration to the aero-modeler.

36. **Trouble Shooting**.

(a) **During Gliding Test**.

(i) If the glide angle is too steep, it may be due to the model being under-elevated. The remedy is to move the mainplanes forward along the fuselage.

(ii) If the model ascends first or glides in a series of sweeps, it may due to over-elevation i.e. the center of pressure is situated too much ahead of the e.g. This may also induce stalling. In the case, the mainplanes are moved back along the fuselage. In this case, the tail plain should also be checked for high angle of incidence and corrected if so required.

(b) **<u>During Power Flight</u>**.

(i) If the model files steeply to the ground (even after correcting for under elevation), it indicates that engine is under-powered and should be changed.

(ii) If the nose goes up, a small packing of bales under the tail-plane leading edge should correct it. If the model nose-dives, the bales packing should be reduced.

(iii) If the model persistently turns to one side, it may be due to torque effect. This should be corrected by adjustment of rudder fin, However, if the torque is excessive, the engine should be shifts to one side by giving packing of bales at the side of the engine compartment. The shift should be such that the propeller shaft should point to the opposite direction to which the aircraft tends to turn. When the correction is complete the packing should b made permanent.

(iv) If the model side-slips, it indicates inadequate dihedral angle of the main planes which should be increased.

(v) If the model to wallow – it indicates excessive dihedral angle which should be corrected accordingly.

37. It is advisable to keep a log of corrections made for future reference and easier understanding of model flying.

38. **<u>General Safety Code</u>**. The following is the general safety code:-

(a) I will not fly my model aircraft in competition or in the presence of spectators until it has been proven to be airworthy by having been previously successfully flight tested.

(b) I will not fly my model higher than approximately 400 feet within 3 miles of an airport without notifying the airport operator. I will give right of way to and avoid flying in the proximity of full-scale aircraft. Where necessary an observer shall be utilized to supervise flying to avoid having models fly in the proximity of full-scale aircraft.

(c) I will abide by the safety rules for the flying site I use, and I will not willfully and deliberately fly my models in a careless, reckless, and/or dangerous manner.

39. **Radio Control Safety Code**. The following is the radio control safety code:-

(a) I will have completed a successful radio equipment ground range check before the first flight of a new or repaired model.

(b) I will not fly my model aircraft in the presence of spectators until I become a qualified flyer, unless assisted by an experienced helper.

(d) I will perform my initial turn after takeoff away from the pit, spectator, and parking areas, and I will not thereafter perform maneuvers, flights of any sort, or landing approaches over a pit, spectator, or parking area.

## PART IV: HISTORY OF DRONES

40. The history and evolution of drones, or unmanned aerial vehicles (UAVs), dates back over a century, with their development driven by military, technological, and industrial needs. The first prototypes of UAVs were created during the early 20th century, primarily for use in training military personnel. However, it wasn't until the mid-1900s that drones began to gain practical significance.

41. In the 1930s and 1940s, the U.S. developed early UAVs for target practice. The first notable UAV, the radio plane, was created by actor and inventor Reginald Denny in 1939. This device was essentially a radio-controlled aircraft used to simulate enemy aircraft for training purposes. During World War II, drones were also used for reconnaissance and bombing missions, though these were primarily simple, uncrewed aircraft with limited capabilities.

42. The post-war era saw substantial progress in drone technology, especially during the Cold War. In the 1960s and 1970s, the U.S. military began using UAVs for intelligence, surveillance, and reconnaissance (ISR) missions, notably the Ryan Firebee and the AQM-34 Lightning Bug. These drones were primarily designed for military use, as the technology was largely focused on providing tactical advantages in espionage and combat situations.

43. In the 1990s and early 2000s, the technological advancements in GPS, microprocessors, and lightweight materials revolutionized the UAV industry. Drones like the Predator and Global Hawk were introduced, offering real-time video feeds and significantly improving military reconnaissance and combat operations. These UAVs were also

equipped with advanced sensors, making them invaluable for intelligence gathering and targeted strikes in conflict zones like the Middle East.

44. Simultaneously, civilian drone development began to gain momentum. In the early 2000s, hobbyists and engineers began experimenting with drones for recreational and commercial purposes. By the 2010s, the commercial drone market exploded, driven by advancements in drone flight control software, battery technology, and miniaturization. Drones began to be used in agriculture, film production, surveying, and even delivery services.

45. By the mid-2010s, drones became increasingly accessible to the general public, with models like DJI's Phantom series offering affordable, user-friendly options. This period also marked the beginning of regulatory frameworks for drone operations in many countries, as safety concerns grew alongside the technology's widespread adoption.

46. Today, drones are an integral part of numerous industries, from agriculture to logistics, and are continuously evolving. Advancements in artificial intelligence, autonomous flight systems, and battery technology are shaping the future of drones, making them even more versatile and efficient. As drone technology continues to improve, their potential applications in both military and civilian sectors are virtually limitless.

## PART V: RULES AND REGULATIONS FOR DRONES

47. The Directorate General of Civil Aviation (DGCA) in India has laid out a set of rules and regulations for the operation of drones in the country. These guidelines are designed to ensure the safe use of drones, also known as Remotely Piloted Aircraft Systems (RPAS), while maintaining public safety and national security. Below are the key points regarding the rules and regulations for drones in India as of 2024:

(a) **Categories of Drones**.

(i) **Nano**. Less than or equal to 250 grams.

(ii) **Micro**. More than 250 grams but less than or equal to 2 kilograms.

(iii) **Small**. More than 2 kilograms but less than or equal to 25 kilograms.

(iv) **Medium**. More than 25 kilograms but less than or equal to 150 kilograms.

(v) **Large**. More than 150 kilograms.

(b) **Remote Pilot License (RPL)**.

(i) **Remote Pilot Training Organizations (RPTOs)**. Remote pilots must undergo training at a DGCA-approved RPTO to obtain a Remote Pilot License (RPL).

(ii) For drones weighing above 2 kg, operators must hold a valid RPL. For drones below 2 kg, no RPL is required for non-commercial use, but they must follow the operational guidelines.

(c) **Drone Registration**.

(i) All drones weighing over 250 grams must be registered with the DGCA on the Digital Sky Platform.

(ii) Drones should be uniquely identified by an identification number (UID) that can be tracked by authorities.

**INTERESTING FACTS**

- A Hollywood actor developed the first hobby drone
- They were developed by the military. Drones were invented because they are needed in small spaces where a normal helicopter can't go or in war zones where it is too dangerous to send pilots.
- These devices are also used to enable communication in an area less accessible. Also, drones can be used to deliver food and medicines in war zones where it is too dangerous to send helicopters.

(d) **Permission for Operations**.

(i) *Permission for Aerial Work (PFA)* is required for commercial operations.

(ii) Operations beyond the visual line of sight (BVLOS), overpopulated areas, and near airports require specific permissions from DGCA.

(iii) For certain operations, such as in controlled airspace or near sensitive areas, prior approval from the relevant authorities must be obtained.

(e) **Operational Restrictions**.

(i) Drones must not be flown:-

(aa) Above 400 feet in non-controlled airspace.

(bb) Within 5 km of airports, unless specific permissions are obtained.

(cc) Over congested areas or large gatherings of people.

(dd) In restricted or prohibited areas such as near military installations,

(ee) Sensitive government buildings and high security zones.

(ff) At night (unless special approval is granted).

(ii) *No-fly zones* are designated around airports, military areas, and certain other critical infrastructure

(f) **Safety and Maintenance**.

(i) Drone operators must ensure that their drones are well-maintained and undergo periodic safety checks.

(ii) Operators should also have insurance coverage for drone operations in case of damage to property or injury to persons.

(iii) The drone should be equipped with safety features such as geo-fencing, return-to-home (RTH) functionality, and automatic altitude control to prevent accidents.

(g) **No Fly Zones and Geofencing**.

(i) The DGCA requires drones to have geofencing capabilities to ensure they stay within permissible areas. These geofenced areas are updated regularly by the authorities.

(ii) Drones flying in restricted airspace (e.g., near airports, military zones) will be blocked by geofencing.

(h) **Operational Guidelines for Drones**.

(i) Drones to be flown only in daylight and in favorable weather condition.

(ii) Drone operators must maintain a *visual line of sight* (VLOS) of the drone at all times during flight.

(iii) In the case of operations in controlled airspace, operators must coordinate with ATC (Air Traffic Control).

(iv) No drone may fly over or near sensitive infrastructure without the necessary clearance.

(j) **<u>Data Privacy</u>**.

(i) Drone operators are responsible for ensuring that they respect privacy laws when operating drones, particularly with respect to capturing images or video of individuals or private property.

(k) **<u>Penalties and Violations</u>**.

(i) Non-compliance with DGCA regulations can result in penalties, suspension of the operator's license, or other legal actions.

(ii) Violations may include flying in no-fly zones, failure to register drones, or conducting commercial operations without the appropriate permissions.

(l) **<u>Aero Modelers</u>**.

(i) Individuals flying drones for non-commercial or hobby purposes under the weight of 250 grams do not require DGCA approval but must still adhere to safety guidelines.

(m) **<u>BVLOS (Beyond Visual Line of Sight) Operations</u>**.

(i) Special permissions are required for BVLOS operations, which may be granted under specific conditions, including safety protocols, monitoring, and air traffic control coordination

(n) **<u>UAS Traffic Management (UTM) System</u>**.

(i) The DGCA is working on implementing a UTM system to ensure safe integration of drones into the airspace, with the goal of preventing mid-air collisions and streamlining drone operations.

(n) **<u>Drone Delivery Operations</u>**.

(i) Drone delivery services (e.g., for e-commerce or medical deliveries) are subject to specific DGCA guidelines and require appropriate permissions, including safety protocols, flight monitoring, and air traffic coordination.

48. The DGCA's drone regulations aim to promote the safe, secure, and sustainable use of drones in India. Compliance with these guidelines is essential to ensure the protection of public safety, airspace management, and privacy. Drone operators are encouraged to stay updated with any new changes in the regulatory framework through the DGCA's official channels.

## PART VI: ELEMENTS INVOLVED IN DRONE BUILDING

49. The construction of drones, particularly *Remotely Piloted Aircraft Systems (RPAS)*, involves integrating various components that ensure the drone functions effectively, safely, and efficiently. Here's a breakdown of the key elements involved in building a drone, whether for hobbyist or professional use:

(a) **Frame**.

(i) The *frame* is the foundation of the drone and provides the structural support for all other components.

(ii) Common materials for drone frames include carbon fiber, plastic,

(iii) aluminum, and *fiber composites*, chosen for their strength-to-weight ratio.

(iv) The frame design must ensure balance, durability, and ease of assembly. It must also provide mounting points for other components like motors and sensors.

(b) **Motors**.

(i) *Brushless DC motors (BLDC)* are most commonly used in drones because they are efficient, durable, and require less maintenance.

(ii) The size and power of the motors are selected based on the drone's weight and the desired performance. For example, larger drones will require larger motors capable of lifting heavier payloads.

(iii) Motors are typically connected to the frame through a *motor mount*, which is also designed to absorb vibration and improve stability.

(c) **Electronic Speed Controllers (ESCs)**.

(i) *ESCs* regulate the speed of the motors by controlling the power supplied to each motor.

(ii) Each motor requires its own ESC. ESCs communicate with the flight controller to adjust motor speed based on inputs (such as throttle and directional commands).

(iii) ESCs must be chosen based on the motor's power requirements and the drone's overall electrical needs.

(d) **Propellers**.

(i) *Propellers* are responsible for generating the lift that keeps the drone in the air.

(ii) The size, material, and pitch of the propellers must match the drone's motor specifications to ensure optimal thrust and efficiency.

(iii) Most drones use *plastic* or *carbon fiber* propellers, with carbon fiber being stronger and more efficient, but also more expensive.

(e) **Flight Controller**.

(i) The *flight controller (FC)* is the brain of the drone. It interprets data from the drone’s sensors (e.g., accelerometer, gyroscope) and uses that data to adjust the flight characteristics, such as stabilizing the drone in the air.

(ii) The flight controller maintains the balance of the drone, making sure that the drone stays level and stable during flight.

(iii) Some flight controllers include additional features, such as GPS for navigation, altitude hold, and advanced autonomous flight capabilities.

(f) **Power System (Battery)**.

(i) Drones are typically powered by *LiPo (Lithium Polymer)* or *Li-ion (Lithium- ion)* batteries due to their high energy density and lightweight properties.

(ii) The size and capacity of the battery depend on the weight of the drone and the required flight time. Battery voltage and current are matched to the motors and ESCs to ensure efficient power delivery.

(iii) Battery management systems (BMS) are important for preventing overcharging, over-discharging, and overheating of the battery.

(g) **GPS Module**.

(i) A *GPS module* provides the drone with positioning and navigation capabilities.

(ii) It allows the drone to maintain altitude hold, fly autonomously, and even return to its home location (via the *Return to Home (RTH)* feature).

(iii) Higher-end drones may use *RTK GPS* (Real-Time Kinematic) for centimeter- level accuracy, which is crucial for precision flying, particularly in mapping, surveying, or inspection applications.

(h) **Gimbals and Cameras (for Drones with Imaging Capabilities)**.

(i) *Gimbals* are mechanical or electronic stabilizers that keep the camera steady and level during flight, ensuring smooth video footage and clear images.

(ii) *Cameras* are mounted on gimbals for aerial photography or video, with specifications ranging from standard video cameras to high-resolution cameras used in surveying, mapping, or professional cinematography.

(iii) Cameras can be equipped with features like zoom, thermal imaging, or infrared for specialized use cases (e.g., drone inspections or search and rescue operations).

(j) **Radio Transmitter and Receiver**.

(i) The *transmitter* is the device the operator uses to control the drone remotely, while the *receiver* on the drone receives these commands.

(ii) The operating range of the transmitter and receiver system depends on the frequency (commonly 2.4 GHz or 5.8 GHz) and the power of the transmitter.

(iii) Transmitter systems are available in both *analog* (for video signals) and *digital* (for more precise control and telemetry).

(k) **Sensors and Payloads**.

(i) Drones can be equipped with a variety of sensors and payloads depending on the purpose. These include:

(aa) *Ultrasonic Sensors* for altitude sensing.

(bb) *LIDAR (Light Detection and Ranging)* for 3D mapping and surveying.

(cc) *Thermal cameras* for inspections, surveillance, and search and rescue.

(dd) *Proximity sensors* for obstacle detection.

(ii) The payload is typically mounted on a separate platform to ensure it is stable and can function correctly without interfering with the drone's flight.

(l) **Telemetry System**.

(i) The *telemetry system* provides real-time data transmission between the drone and the operator's ground station.

(ii) It includes information like battery status, GPS coordinates, altitude, speed, and even sensor data.

(iii) Some advanced drones offer *live video feed* and *real-time flight data* for a better user experience.

(m) **Software and Firmware**.

(i) Flight Control Firmware: The flight controller needs custom firmware to function properly. Open-source options like Betaflight, INAV, or *ArduPilot* are popular among hobbyists.

(ii) *Ground Control Software*: Many drones, particularly for commercial use, also require ground control software that allows operators to plan flights, monitor drone status, and analyze the data collected during operations.

(iii) *Autonomous Flight Software*: Drones can be programmed for autonomous flight via GPS waypoints or custom scripts.

(n) **Assembly and Calibration**.

(i) Once all the components are selected, the drone must be carefully assembled, ensuring proper wiring, mounting, and balancing.

(ii) After assembly, *calibration* is a crucial step. This includes calibrating the compass, accelerometer, gyroscope, and GPS module to ensure precise control and stability.

(o) **Safety Features**.

(i) Fail-Safe Mechanisms: Drones are often equipped with safety systems like *return-to-home (RTH)* in case of signal loss or battery depletion.

(ii) *Geofencing*: Modern drones come with geofencing, which prevents them from entering restricted airspace such as near airports, military zones, or national borders.

(iii) *Altitude Hold* and *Barometric Pressure Sensors* ensure stable flight in varying weather conditions.

50. **Drone Construction Process**.

(a) **Design and Planning**. Determine the type and purpose of the drone (e.g., recreational, surveying, racing).

(b) **Select Components**. Choose the frame, motors, ESCs, flight controller, GPS, battery, and other sensors based on your design.

(c) **Attach Components**. Attach the motors to the frame, wire the ESCs, connect the flight controller, install the GPS, and mount the camera (if applicable).

(d) **Install Software and Firmware**. Flash the flight controller with the necessary firmware and configure the drone settings.

(e) **<u>Calibration and Testing</u>**. Perform calibration of sensors, check the power system, and run test flights to ensure stability and functionality.

(f) **<u>Flight and Fine-Tuning</u>.** Conduct test flights and make adjustments to ensure optimal performance and reliability.

## <u>CONCLUSION</u>

51. The 'aeromodelling provides an earnest approach to the understanding of an otherwise highly technical subject, i.e. 'aerodynamics. This 'air-minded' aero-modeler of today is the potential aircraft designer of tomorrow. Although, aeromodelling is a technical hobby and is usually cluttered up with complicated calculations and formulae, it need not necessarily discourage the beginners and the non- technical persons, as they can still derive immense pleasure and satisfaction from this hobby. Gradually, aeromodelling is becoming increasingly popular all over the country specially amongst the NCC Airwing cadets as it aligns with STEM (Science, Technology, Engineering, and Mathematics) education by integrating multiple disciplines, promoting experiential learning, and inspiring students to pursue careers in these fields. Today, drones are an integral part of numerous industries, from agriculture to logistics, and are continuously evolving. Advancements in artificial intelligence, autonomous flight systems, and battery technology are shaping the future of drones, making them even more versatile and efficient. As drone technology continues to improve, their potential applications in both military and civilian sectors are virtually limitless.

(a) Aeromodeling is one of the finest & costly hobbies, which is very popular worldwide among people of various age groups.

(b) In India the apex body for aeromodelling is known as 'All India Aeromodellers Association'.

(c) Types of wood used in construction of aero models are balsa, spruce, birch, bass, cane, bamboo, plywood and pine.

(d) Types of Aeromodels are static, gliders, rubber models, power models and jetex models.

(e) Flying of Aeromodels involves gliding test, trial flight, launching and trouble shooting.

(f) Drones are categorised according to their size as nano, micro, small, medium and large.

(g) Directorate of General of Civil Aviation (DGCA) – managing body of civil aviation in India.

(h) RPAS-Remotely Piloted Aircraft Systems.

## ASSESSMENT EXERCISE

**Multiple Choice Questions**

**Q1. Aeromodelling provides an earnest approach to the understanding of highly technical subject called?**

(a) Aerodynamics

(b) Thermodynamics

(c) Optics

(d) Electricity

**Q2. In India the apex body for aeromodelling is known as?**

(a) All Asia Aeromodellers Association

(b) International Aeromodellers Association

(c) All India Aeromodellers Association

(d) Indian Aeromodellers Association

**Q3. _______ wood is very light and can be easily worked for almost every purpose in aeromodelling?**

(a) Balsa

(b) Teak

(c) Pine

(d) Willow

**Q4. __________are found ideal for making propellers and wings of solid models?**

(a) Basswood blocks

(b) Balsa Blocks

(c) Spruce Blocks

(d) Birch Blocks

**Q5. In 1878, Professor Langley built a petrol driven model called?**

(a) Aerodrome No.5

(b) Aerodrome No.6

(c) Aerodrome No.7

(d) Aerodrome No.4

**Q6. ________ is used for air-proofing of surface and tightening the surface skin by plasticizing effect?**

(a) Fabrication

(b) Resizing

(c) Filing

(d) Doping

**Q7. _________ are the miniature replicas of the original, full sized aircraft types?**

(a) Rubber Models

(b) Chuck Gliders

(c) Catapult Gliders

(d) Static Models

**Q8. Control models can be further divided into _____ main categories**

(a) 3

(b) 4

(c) 5

(d) 6

**Q9. Which type of model is fitted with radio receiver sets which, through a set of actuators operate the control surfaces of the model?**

(a) Static Models

(b) Radio Controlled Models

(c) Gliders

(d) Jetex Models

**Q10. Which among these is not a type of miniature engines used in Aeromodels?**

(a) Spark Ignition

(b) Diesel

(c) Glow-plug

(d) Petrol

**Q11. The flying sequence can be arranged as?**

(a) Trail flight- Gliding test- Launching- Trouble Shooting

(b) Gliding test- Launching- Trail flight- Trouble Shooting

(c) Trouble Shooting- Gliding test- Trail flight- Launching

(d) Gliding test- Trail flight- Launching- Trouble Shooting

**Q12. A good launching is the result of proper coordination between ______ & _______?**

(a) Aero-modeller and aircraft

(b) Aero-modeller and his helper

(c) Aircraft and engine

(d) Remote and Receiver

**Q13. If the model files steeply to the ground (even after correcting for under elevation), it indicates that engine is ___________ and should be changed?**

(a) Under powered

(b) Over powered

(c) Heavy

(d) Light

**Q14. If the model persistently turns to one side it may be due to _________ effect?**

(a) Energy

(b) Banking

(c) Torque

(d) Power Variation

**Q15. The 'air minded' aeromodeller of today is the potential ________ designer of to-morrow?**

(a) Aircraft

(b) Runway

(c) Ship

(d) Weapon

**Q16. Which among these is not among the 3 components to the Towline Glider model when completely built up, and?**

(a) Wing

(b) Fuselage

(c) Propeller

(d) tailplane

**Long Answer Type Questions**

1. Write a note on materials used in aero model.
2. What are the types of aeromodel?
3. Describe construction of control line.
4. Describe construction of RC model.
5. Explain how models are tested in air.

**Short answer type Question**

1. Write short note on how aero models are powered.
2. Name categories of drone
3. What are the parts of drone?
4. Explain drone construction process
5. Name 3 sensor or payload of drone.

# STANDARD OPERATING PROCEDURE

## (VIRUS SW 80)


## TEACHING INSTRUCTIONS 2nd Year SD/SW Cadets

| | | |
|---|---|---|
| **Period** | **:** | **01 ( 2nd Yr SD/SW)** |
| **Type** | **:** | **Lecture/ Demo** |
| **Year** | **:** | **2nd Yr SD/SW** |
| **Conducting Officer** | **:** | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | **:** | **Classroom, Computer with OHP, Board and Markers, Screen, Pointer Staff, Presentation, and Aircraft Model.** |

**Time Plan**

| | | |
|---|---|---|
| • **Introduction** | **:** | **02 Mins** |
| • **Basics of Aircraft** | **:** | **20 Mins** |
| • **Technical Specifications** | **:** | **15 Mins** |
| • **Summarise** | **:** | **03 Mins** |

| | | |
|---|---|---|
| **Period** | **:** | **02 ( 2nd Yr SD/SW)** |
| **Type** | **:** | **Lecture/ Demo** |
| **Year** | **:** | **2nd Yr SD/SW** |
| **Conducting Officer** | **:** | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | **:** | **Classroom, Computer with OHP, Board and Markers, Screen, Pointer Staff, Presentation and Aircraft Model.** |

**Time Plan**

| | | |
|---|---|---|
| • **Recap Of Class 1** | **:** | **03 Mins** |
| • **Technical Specifications** | **:** | **10 Mins** |
| • **Limitations** | **:** | **10 Mins** |
| • **Normal Operating Procedure** | **:** | **15 Mins** |
| • **Summarise** | **:** | **02 Mins** |

| | | |
|---|---|---|
| **Period** | **:** | **03 ( 2nd Yr SD/SW)** |
| **Type** | **:** | **Lecture/ Demo** |
| **Year** | **:** | **2nd Yr SD/SW** |
| **Conducting Officer** | **:** | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | **:** | **Classroom, Computer with OHP, Board and Markers, Screen, Pointer Staff, Presentation, and Aircraft Model.** |

**Time Plan:**

| | | |
|---|---|---|
| • **Introduction to Emergencies** | **:** | **05 Mins** |
| • **Engine Failure During T/O** | **:** | **15 Mins** |
| • **Rough Engine Operation or Engine Failure in Flight** | **:** | **10 Mins** |
| • **Emergency Landing / Landing Off Airport** | **:** | **05 Mins** |
| • **Summarise** | **:** | **05 Mins** |

## TEACHING INSTRUCTIONS 3rd Year SD/SW Cadets

| | | |
|---|---|---|
| **Period** | : | **01 (3rd Yr SD/SW)** |
| **Type** | : | **Lecture/ Demo** |
| **Year** | : | **3rd Yr SD/SW** |
| **Conducting Officer** | : | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | : | **Classroom, Computer with OHP, Board and Markers, Screen, Pointer Staff, Presentation and Aircraft Model.** |

**Time plan**

- **Recap of 2nd Yr Syllabus : 15 Mins**
- **Normal Operating Procedure Checks & Proc : 23 Mins**
- **Summarise : 02 Mins**

| | | |
|---|---|---|
| **Period** | : | **02 (3rd Yr SD/SW)** |
| **Type** | : | **Lecture/ Demo** |
| **Year** | : | **3rd Yr SD/SW** |
| **Conducting Officer** | : | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | : | **Classroom, Computer with OHP, Board and Markers, Screen, Pointer Staff, Presentation, and Aircraft Model.** |

**Time Plan**

- **Recap of Last Class : 08 Mins**
- **Normal Operating Procedure Checks & Proc : 30 Mins**
- **Summarise : 02 Mins**

| | | |
|---|---|---|
| **Period** | : | **03 (3rd Yr SD/SW)** |
| **Type** | : | **Lecture/ Demo** |
| **Year** | : | **3rd Yr SD/SW** |
| **Conducting Officer** | : | **Technical PI staff/ Commanding Officer** |
| **Training Aids** | : | **Classroom, Computer with OHP, Board and Markers, Screen, Pointer Staff, Presentation, aircraft model.** |

**Time Plan**

- **Recap of Last Class : 08 Mins**
- **Circuit Pattern : 30 Mins**
- **Summarise : 02 Mins**

**Period** : **04 (3rd Yr SD/SW)**

**Type** : **Lecture/ Demo**

**Year** : **3rd Yr SD/SW**

**Conducting Officer** : **Technical PI staff/ Commanding Officer**

**Training Aids** : **Classroom, Computer with OHP, Board and Markers, Screen, Pointer Staff, Presentation and Aircraft Model.**

**Time plan**

- **Recap of Emergencies covered in 2nd Yr : 05 Mins**
- **Engine Fire on Ground : 12 Mins**
- **Engine Fire in the Air : 10 Mins**
- **Smoke in Cockpit : 05 Mins**
- **Carburettor Icing : 05 Mins**
- **Summarise : 03 Mins**

**Period** : **5 (3rd Yr SD/SW)**

**Type** : **Lecture/ Demo**

**Year** : **3rd Yr SD/SW**

**Conducting Officer** : **Technical PI staff/ Commanding Officer**

**Training Aids** : **Classroom, Computer with OHP, Board and Markers, Screen, Pointer Staff, Presentation and Aircraft Model.**

**Time Plan**

- Recap of Last Class : 05 Mins
- Electrical System Failure : 08 Mins
- Flutter : 07 Mins
- Exceeding VNE & Ditching : 08 Mins
- Icing & Electrical Fuel Pump Failure : 07 Mins
- Summarise : 05 Mins

# ANSWER KEY: MULTIPLE CHOICE QUESTIONS (MCQ)

## MASTER ANSWER KEY

| | AFCAP | IAF | MOAF | MOE | EM | BOA | FOA | AC | ST | AM | NAV | MET | ANE-I | ANE-II | AF | BFI | IR | BFI 3 | AE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | b | a | c | c | a | a | b | b | d | b | c | a | a | a | c | b | b | c | a |
| 02 | b | d | a | d | b | d | d | c | a | c | b | b | c | d | c | b | c | c | c |
| 03 | c | d | c | c | b | a | b | c | a | b | d | a | b | b | a | b | b | b | a |
| 04 | c | c | c | a | b | a | a | c | b | d | b | c | b | c | a | c | c | c | a |
| 05 | c | a | a | b | c | a | d | c | b | b | a | d | b | c | b | b | b | a | a |
| 06 | b | a | b | b | b | a | | c | c | b | b | | d | c | b | a | d | c | d |
| 07 | c | d | b | a | a | c | | c | c | a | b | | b | c | c | a | a | b | d |
| 08 | d | a | a | c | b | a | | d | b | b | d | | b | a | b | b | b | b | a |
| 09 | a | a | d | c | c | b | | b | b | b | c | | a | d | a | c | c | d | b |
| 10 | c | d | d | c | a | a | | d | c | a | b | | b | b | d | c | a | c | a |
| 11 | b | | | c | d | b | | | | d | a | | b | | b | c | b | b | d |
| 12 | a | | | b | b | a | | | | b | b | | a | | c | a | c | b | c |
| 13 | c | | | d | a | b | | | | c | d | | a | | b | b | b | b | a |
| 14 | a | | | d | d | | | | | c | c | | c | | b | c | b | a | b |
| 15 | a | | | b | b | | | | | a | b | | c | | d | b | b | b | a |
| 16 | | | | | | | | | | | | | d | | d | | | | c |
| 17 | | | | | | | | | | | | | d | | | | | | |
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