Module – 1

INTRODUCTION TO AIRCRAFT & AIRCRAFT STRUCTURES AND MATERIALS

Syllabus:

Introduction to Aircrafts: History of aviation; Atmosphere and its properties; Classification of aircrafts; Basic components of an aircraft; aircraft axis system; aircraft motions; control surfaces and high lift devices; conventional design configurations; principle of operation of each major part; Helicopters, their parts and functions.

Aircraft Structures and Materials: Introduction; structural members;general types of construction; monocoque, semi-monocoque and geodesic structures; typical wing and fuselage structure; metallic and non-metallic materials for aircraft application.

1. Explain with neat sketch monocoque, semi monocoque and truss structures of aircrafts.
Or
With suitable diagrams explain Fuselage structures.

Types of Fuselage Structures / Types Aircraft Constructions

Truss or framework Type:

- A truss is a rigid framework made up of members, such as beams, struts, and bars to resist deformation by applied loads. The truss-framed fuselage is generally covered with fabric.
- This consists of light gauge steel tubes which form a frame triangular shape to give the most rigid of geometric forms. Each tube carries a specific load, the magnitude of which depends on whether the aircraft is airborne or on the ground.
- The truss-type fuselage frame is usually constructed of steel tubing welded together in such a manner that all members of the truss can carry both tension and compression loads.
- This type of fuselage is commonly found on the first few generations of aircraft. They are strong, moderately easy to manufacture, but did not necessarily implement the concept of aerodynamic.

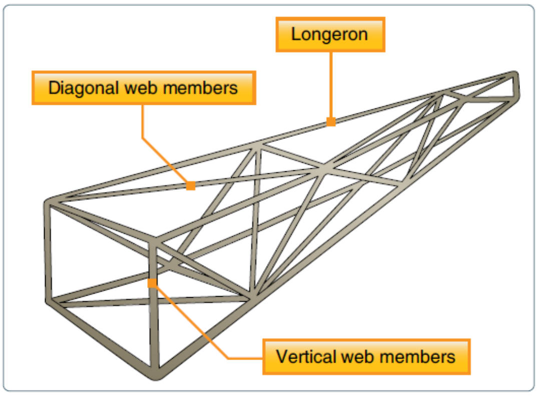


Figure 1-15. *A truss-type fuselage. A Warren truss uses mostly diagonal bracing.*

Monocoque Construction:

- 'Monocoque' is a French word meaning 'single shell'. All the loads are taken by a stressed skin with just light internal frames or formers to give the required shape. Monocoque structure was the improved version of truss structure.
- It provides the close structure by covering the entire body by sheet of metal and achieves the smooth flow of air that reduces the drag.
- Since it is basically egg shell like structure, most of the strength is provided by skin (sheet of metal). As the results it increases the internal space.
- Although it practically can carry more load, the drawback of this type is that it may require maintenance more compared to the other designs, as the structure needs to be reinforced in order to maintain the structural integrity.

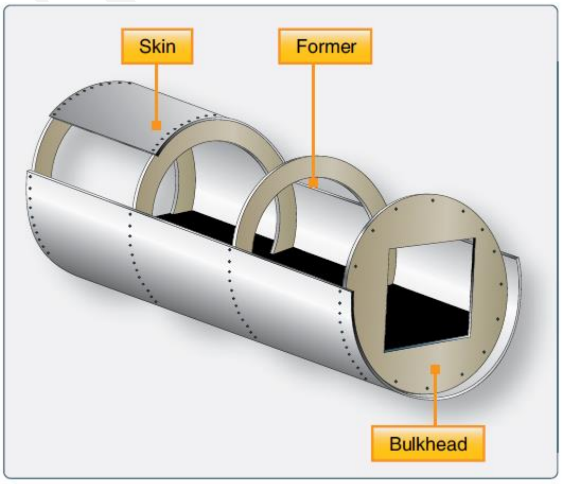


Figure 1-16. *An airframe using monocoque construction.*

Semi-Monocoque Construction:

- As aircraft became larger, the pure Monocoque was found not to be strong enough.

- Designers came with a new concept to make fuselage stronger; the Longerons run lengthwise along the fuselage joining the frames together.
- The light alloy skin is attached to the frames and longerons by riveting or adhesive bonding.
- Doublers are required when cut-outs are made to provide access panels, doors or windows.
- Bulkheads isolate different sections of the aircraft, for instance the engine compartment from the passenger compartment. Bulkheads are of much stronger construction than frames or formers, as the loads upon them are so much greater.
- This concept is widely used both in military and also in the commercial industry.

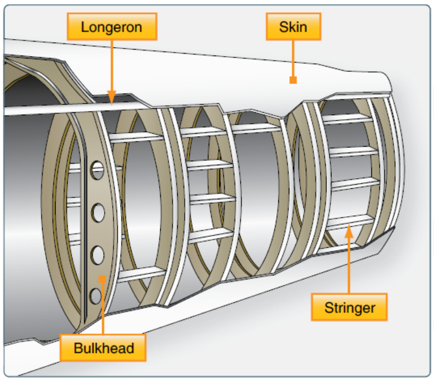
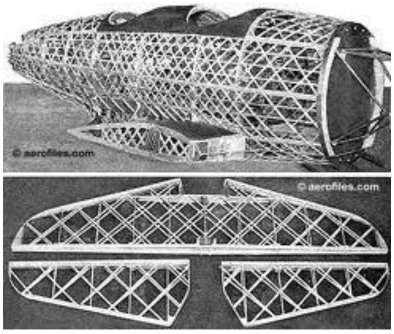


Figure 1-17. *The most common airframe construction is semimonocoque.*

Geodesic Construction:

- It is the very recent approach of building the structure adopted in the fighter jets.
- Here the structure is divided into small panel like structure and each panel is strengthen by the separate structural members, so the each panel is independent of taking load and not depends upon the neighboring panel to take its load.
- Now even though one panel fails or broken also it does not affect the entire structure.



2. Explain on detail with application metallic and non metallic materials used in aircraft.
Or
Discuss in detail about the developments in the material for an aircraft.

Metallic and non-metallic materials for aircraft application/Developments in the material for an aircraft.

An aircraft must be constructed of materials that are both light and strong. Early aircraft were made of wood. Lightweight metal alloys with a strength greater than wood were developed and used on later aircraft. Materials currently used in aircraft construction are classified as either metallic materials or nonmetallic materials.

Metallic Materials:

The most common metals used in aircraft construction are aluminum, magnesium, titanium, steel, and their alloys.

Alloys:

- An alloy is composed of two or more metals.
- The metal present in the alloy in the largest amount is called the base metal.
- All other metals added to the base metal are called alloying elements.
- Adding the alloying elements may result in a change in the properties of the base metal.
- For example, pure aluminum is relatively soft and weak. However, adding small amounts or copper, manganese, and magnesium will increase aluminum's strength many times.
- Heat treatment can increase or decrease an alloy's strength and hardness.
- Alloys are important to the aircraft industry. They provide materials with properties that pure metals do not possess.

Aluminum alloys:

- Aluminum alloys are widely used in modern aircraft construction.
- Aluminum alloys are valuable because they have a high strength-to-weight ratio.
- Aluminum alloys are corrosion resistant and comparatively easy to fabricate.

- The outstanding characteristic of aluminum is its lightweight.

Magnesium alloys:

- Magnesium is the world's lightest structural metal.
- It is a silvery-white material that weighs two-thirds as much as aluminum.
- Magnesium is used to make helicopters.
- Magnesium's low resistance to corrosion has limited its use in conventional aircraft.

Titanium alloys:

- Titanium is a lightweight, strong, corrosion resistant metal.
- Recent developments make titanium ideal for applications where aluminum alloys are too weak and stainless steel is too heavy.
- Additionally, titanium is unaffected by long exposure to seawater and marine atmosphere.

Steel Alloys:

- Alloy steels used in aircraft construction have great strength, more so than other fields of engineering would require.
- These materials must withstand the forces that occur on today's modern aircraft.
- These steels contain small percentages of carbon, nickel, chromium, vanadium, and molybdenum.
- High-tensile steels will stand stress of 50 to 150 tons per square inch without failing.
- Such steels are made into tubes, rods, and wires.

Nonmetallic Materials:

In addition to metals, various types of plastic materials are found in aircraft construction. Some of these plastics include transparent plastic, reinforced plastic, composite, and carbon-fiber materials.

Transparent Plastic:

- Transparent plastic is used in canopies, windshields, and other transparent enclosures.

- You need to handle transparent plastic surfaces carefully because they are relatively soft and scratch easily.
- At approximately 107 degree C, transparent plastic becomes soft and pliable.

Reinforced Plastic:

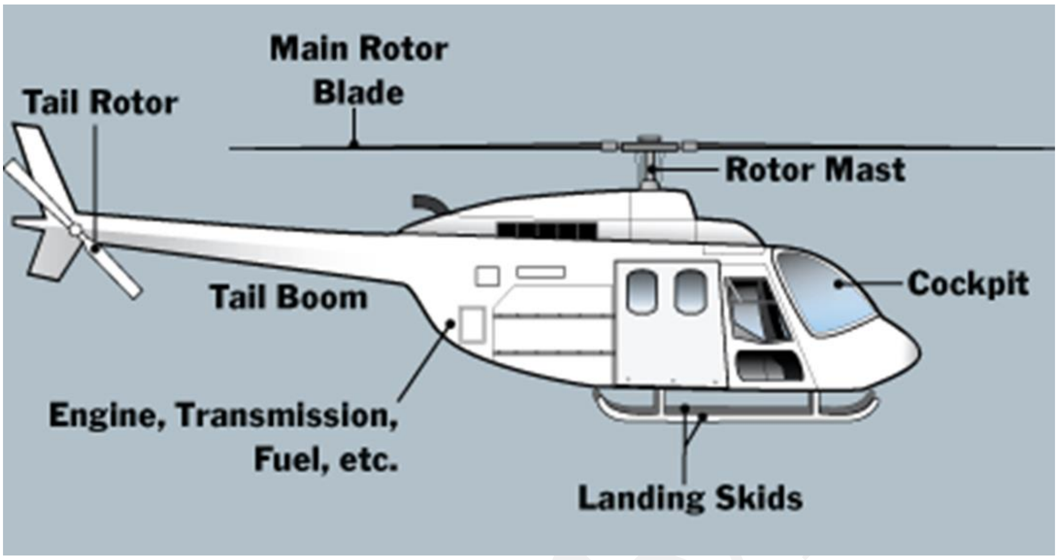
- Reinforced plastic is used in the construction of radomes, wingtips, stabilizer tips, antenna covers, and flight controls.
- Reinforced plastic has a high strength-to-weight .
- Because it is easy to fabricate, it is equally suitable for other parts of the aircraft.
- Reinforced plastic is a sandwich-type material.

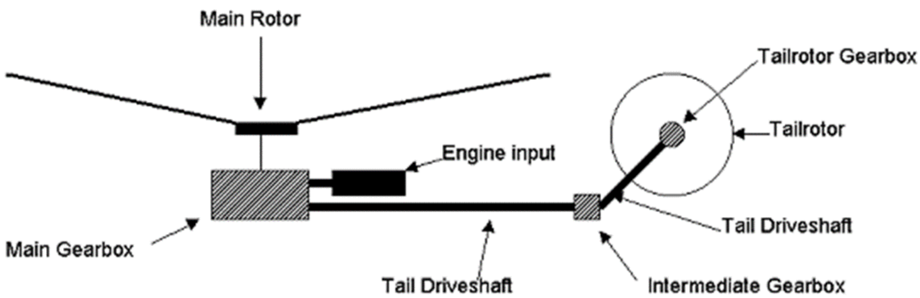
Composite and Carbon Fiber Materials:

- High-performance aircraft require an extra high strength-to-weight ratio material. Fabrication of composite materials satisfies this special requirement.
- Composite materials are constructed by using several layers of bonding materials (graphite epoxy or boron epoxy).
- These materials are mechanically fastened to conventional substructures.
- Another type of composite construction consists of thin graphite epoxy skins bonded to an aluminum honeycomb core.
- Carbon fiber is extremely strong, thin fiber made by heating synthetic fibers, such as rayon, until charred, and then layering in cross sections.

3. Explain with neat sketch, the principles operation of Helicopter and their functions.

Helicopters



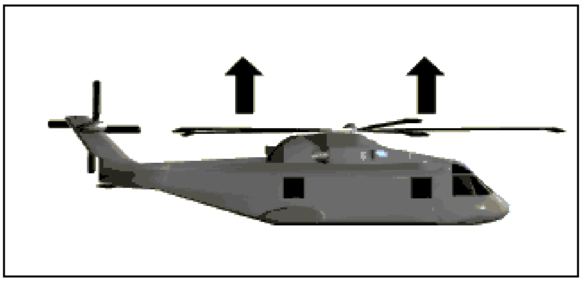


Typical Helicopter Drive Train

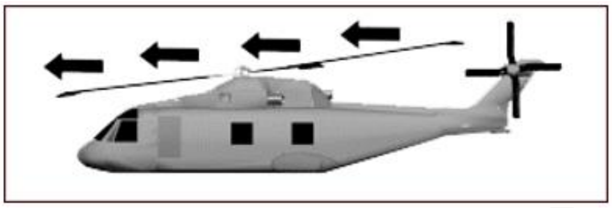
Principle of operation:

Most helicopters the engine turns a shaft that connects to an input quill on the transmission; the main rotor mast comes straight out of the top of the transmission and the tail rotor driveshaft connects to an output quill 90 degrees out from the mast.

Spinning the rotor which has an aerofoil section causes lift, allowing the helicopter to rise vertically or hover.

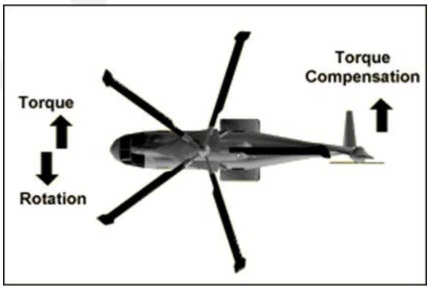


Tilting the spinning rotor will cause flight in the direction of the tilt.



The tail rotor is very important. If you spin a rotor using an engine, the rotor will rotate, but the engine and the helicopter will try to rotate in the opposite direction. This is called Torque Reaction.

The tail rotor is used like a small propeller, to pull against torque reaction and hold the helicopter straight.



Main parts and their functions:

- Main rotor blade -- The main rotor blade performs the same function as an airplane's wings, providing lift as the blades rotate -- lift being one of the critical aerodynamic forces that keeps aircraft aloft. A pilot can affect lift by changing the rotor's revolutions per minute (rpm) or its angle of attack, which refers to the angle of the rotary wing in relation to the oncoming wind.

- Stabilizer -- The stabilizer bar sits above and across the main rotor blade. Its weight and rotation dampen unwanted vibrations in the main rotor, helping to stabilize the craft in all flight conditions. Arthur Young, the gent who designed the Bell 47 helicopter, is credited with inventing the stabilizer bar.
- Rotor mast -- Also known as the rotor shaft, the mast connects the transmission to the rotor assembly. The mast rotates the upper swash plate and the blades.
- Transmission -- Just as it does in a motor vehicle, a helicopter's transmission transmits power from the engine to the main and tail rotors. The transmission's main gearbox steps down the speed of the main rotor so it doesn't rotate as rapidly as the engine shaft. A second gearbox does the same for the tail rotor, although the tail rotor, being much smaller, can rotate faster than the main rotor.
- Engine -- The engine generates power for the aircraft. Early helicopters relied on reciprocating gasoline engines, but modern helicopters use gas turbine engines like those found in commercial airliners.

4. Explain with neat sketches, the high lift devices.

In aircraft design and aerospace engineering, a high-lift device is a component or mechanism on an aircraft's wing that increases the amount of lift produced by the wing. The device may be a fixed component, or a movable mechanism which is deployed when required. Common movable high-lift devices include wing flaps and slats. Fixed devices include leading edge root extensions and boundary layer control systems, which are less commonly used.

There are many different types of flaps depending on the size, speed, and complexity of the aircraft they are to be used on, as well as the era in which the aircraft was designed. Plain flaps, slotted flaps, and Fowler flaps are the most common trailing edge flaps. Flaps used on the leading edge of the wings of many jet airliners are Krueger flaps, slats, and slots (Notice that slots are not explicitly flaps, but more precisely boundary layer control devices).

The plain flap is the simplest flap and it is used in light . The basic idea is to design the airfoil so that the trailing edge can rotate around an axis. The angle of that deflexion is the flap deflexion δf . The effect is an increase in the camber of the airfoil, resulting in an increase in the coefficient of lift.

Another kind of trailing edge high-lift device is the slotted flap. The only difference with the plain flap is that it includes a slot which allows the extrados and intrados to be communicated. By this mean, the flap deflexion is higher without the boundary layer dropping off.

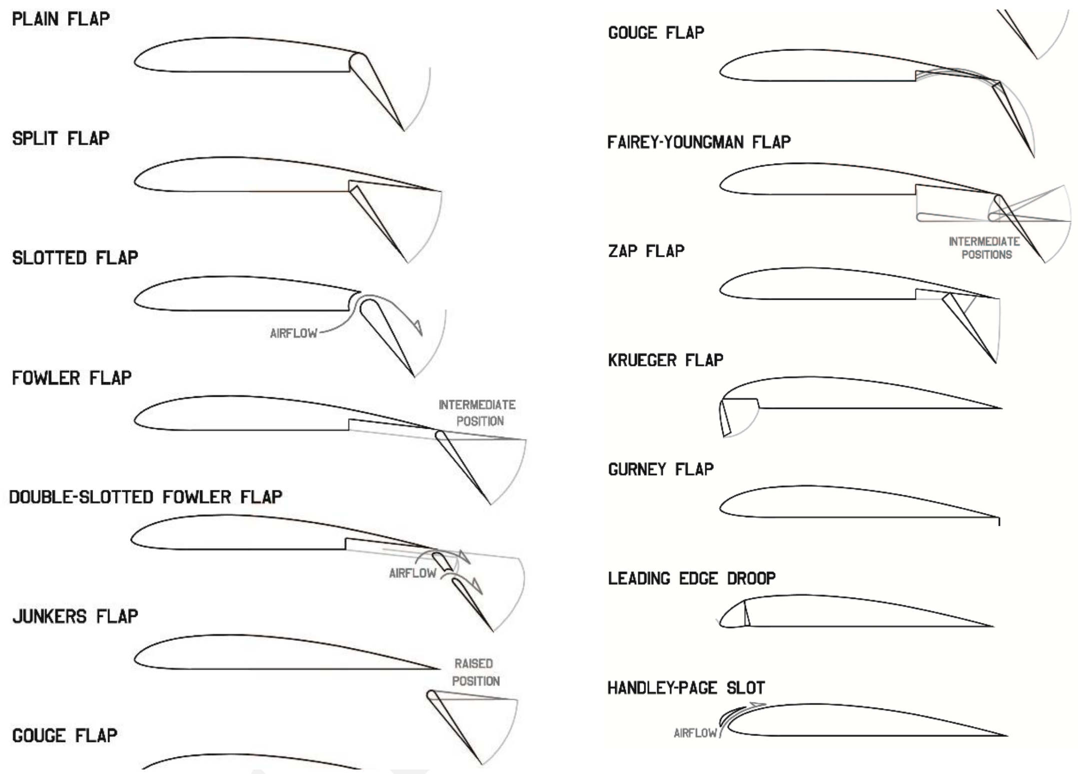
The last basic trailing edge high-lift device is the flap Fowler. This kind of flap combines the increase of camber with the increase in the chord of the airfoil (and therefore the wet surface). This fact increases also the slope of the lift curve. Combining the different types, there exist double and triple slotted Fowler flaps, combining also the control of the boundary layer. The Fairey-Youngman, Gouge, and Junkers flaps combine some of the exposed properties.

The last trailing edge high-lift device is the split flap (also refereed to as intrados flap). This flap provides, for the same increase of lift coefficient, more drag but with less torque.

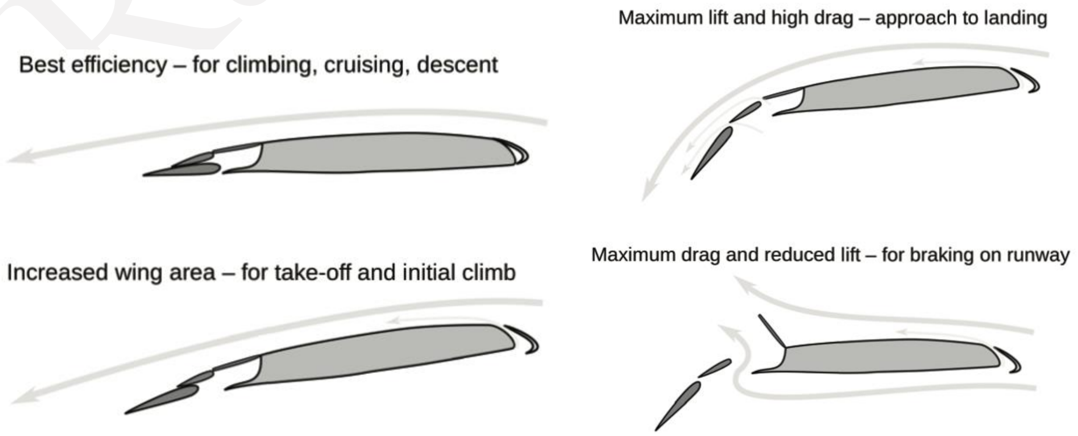
The most important leading edge high devices are: slot, the leading edge drop flap, and the flap Krueger.

The slot is a slot in the leading edge. It avoid the dropping off of the boundary layer by communicating extrados and intrados. The leading edge drop has the same philosophy as the plain flap, but applied in the leading edge instead of the trailing edge. The Kruger flaps works modifying the camber of the airfoil but also acting in the control of the boundary layer.

Types of high-lift devices:

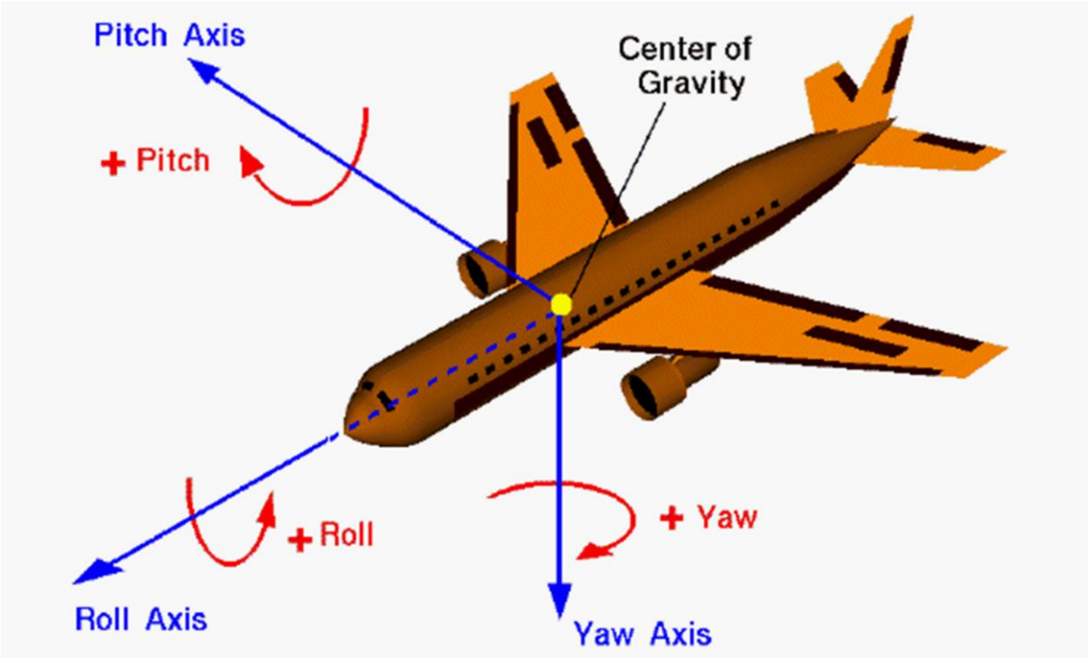


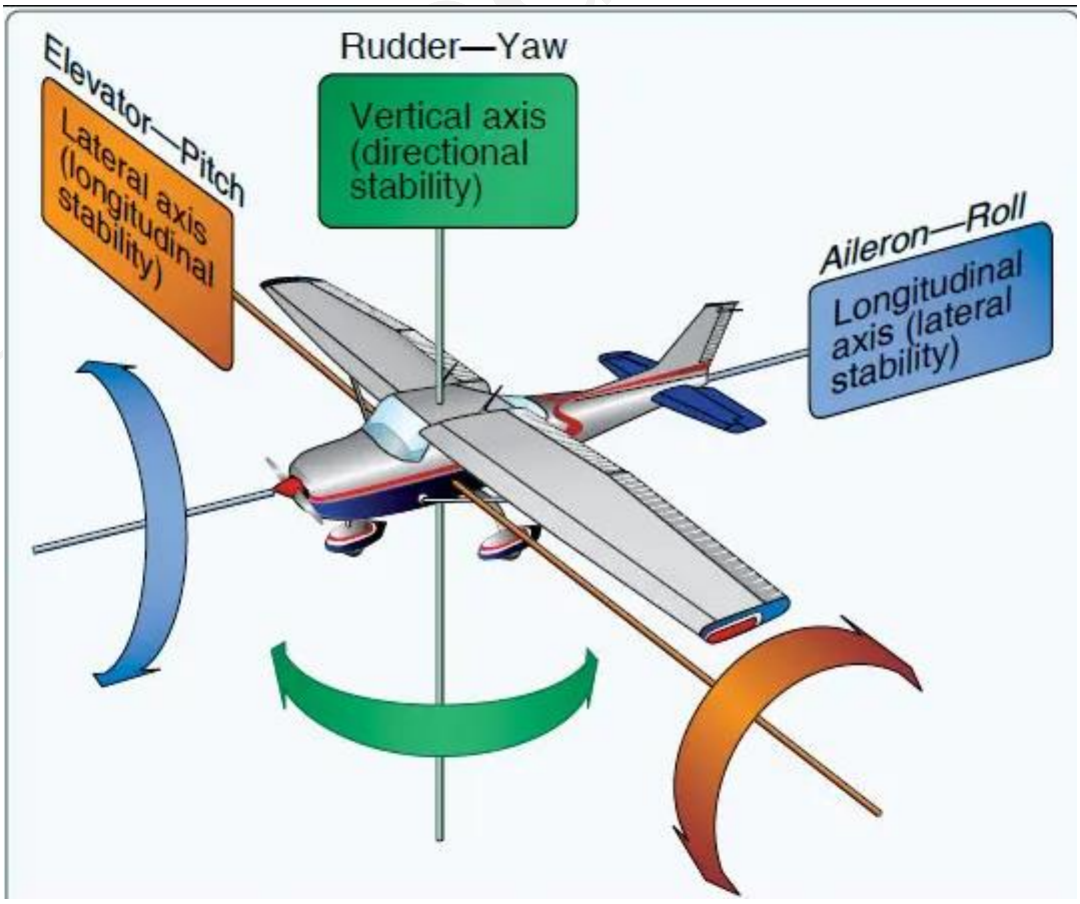
Effects of high lift devices in airfoil flow, showing configurations for normal, take-off, landing, and braking:



5. Write a short on Aircraft Axes system with relevant figures.
Or
Explain with neat diagram showing CG, lateral axis, vertical axis and longitudinal axis with reference airplane

Aircraft Axis System





In flight, any aircraft will rotate about its center of gravity, a point which is the average location of the mass of the aircraft. We can define a three dimensional coordinate system through the center of gravity with each axis of this coordinate system perpendicular to the other two axes. We can then define the orientation of the aircraft by the amount of rotation of the parts of the aircraft along these principal axes.

- The **yaw axis** is defined to be perpendicular to the plane of the wings with its origin at the center of gravity and directed towards the bottom of the aircraft. A yaw motion is a movement of the nose of the aircraft from side to side.
- The **pitch axis** is perpendicular to the yaw axis and is parallel to the plane of the wings with its origin at the center of gravity and directed towards the right wing tip. A pitch motion is an up or down movement of the nose of the aircraft.
- The **roll axis** is perpendicular to the other two axes with its origin at the center of gravity, and is directed towards the nose of the aircraft. A rolling motion is an up and down movement of the wing tips of the aircraft.

In flight, the control surfaces of an aircraft produce aerodynamic forces. These forces are applied at the center of pressure of the control surfaces which are some distance from the aircraft cg and produce torques (or moments) about the principal axes. The torques cause the aircraft to rotate. The elevators produce a pitching moment, the rudder produces a yawing moment, and the ailerons produce a rolling moment. The ability to vary the amount of the force and the moment allows the pilot to maneuver or to trim the aircraft.

6. Summarize the major stepping stones to controlled, heavier than air and powered flight with a human pilot.

19th And 20th Century Efforts:

1891 Otto Lilienthal: German engineer, Otto Lilienthal, studied aerodynamics and worked to design a glider that would fly. He was the first person to design a glider that could fly a person and was able to fly long distances. He was fascinated by the idea of flight. Based on his studies of birds and how they fly, he wrote a book on aerodynamics that was published in 1889 and this text was used by the Wright Brothers as the basis for their designs. After more than 2500 flights, he was killed when he lost control because of a sudden strong wind and crashed into the ground.

1891 Samuel P. Langley: Samuel Langley was an astronomer, who realized that power was needed to help man fly. He built a model of a plane, which he called an aerodrome that included a steam-powered engine. In 1891, his model flew for 3/4s of a mile before running out of fuel. Langley received a $50,000 grant to build a full sized aerodrome. It was too heavy to fly and it crashed. He was very disappointed. He gave up trying to fly. His major contributions to flight involved attempts at adding a power plant to a glider. He was also well known as the director of the Smithsonian Institute in Washington, DC.

1894 Octave Chanute: Octave Chanute published Progress in Flying Machines in 1894. It gathered and analyzed all the technical knowledge that he could find about aviation accomplishments. It included all of the world's aviation pioneers. The Wright Brothers used this book as a basis for much of their experiments. Chanute was also in contact with the Wright Brothers and often commented on their technical progress.

Orville and Wilbur Wright: Orville and Wilbur Wright were very deliberate in their quest for flight. First, they read about all the early developments of flight. They decided to make "a small contribution" to the study of flight control by twisting their wings in flight. Then they began to test their ideas with a kite. They learned about how the wind would help with the flight and how it could affect the surfaces once up in the air. The next step was to test the shapes of gliders much like George Cayley did when he was testing the many different shapes that would fly. They spent three years testing and learning about how gliders could be controlled at Kitty Hawk, North Carolina. The early engine that they designed generated almost 12 horsepower. That's the same power as two hand-propelled lawn mower engines. The "Flyer" lifted from level ground to the north of Big Kill Devil Hill, North Carolina, at 10:35 a.m., on December 17, 1903. Orville piloted the plane which weighed about six hundred pounds. The first heavier-than-air flight traveled one hundred twenty feet in twelve seconds. The two brothers took turns flying that day with the fourth and last flight covering 850 feet in 59 seconds. But the Flyer was unstable and very hard to control. The brothers returned to Dayton, Ohio, where they worked for two more years perfecting their design. Finally, on October 5, 1905, Wilbur piloted the Flyer III for 39 minutes and about 24 miles of circles around Huffman Prairie. He flew the first practical airplane until it ran out of gas.

7. Derive and describe the hydrostatic equation and also state the relation between geopotential and geometric altitudes.

Hydrostatic Equation

Consider the small stationary fluid element of air shown in Fig. 3.3. We take for convenience an element with rectangular faces, where the top and bottom faces have sides of unit length and the side faces have an infinitesimally small height dh_G.

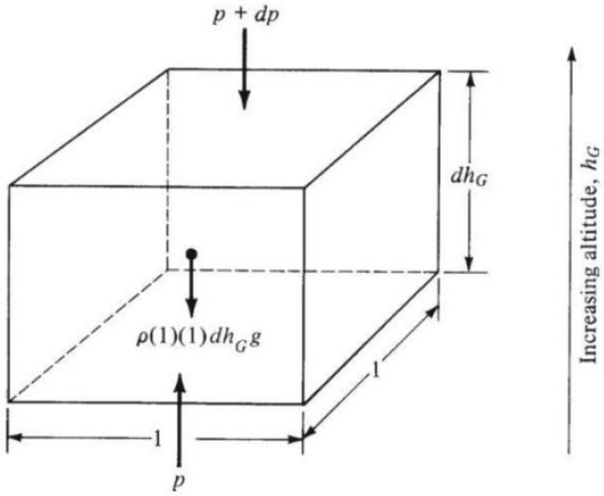


Figure 3.3 Force diagram for the hydrostatic equation.

On the bottom face, the pressure p is felt, which gives rise to an upward force of (p x 1 x 1) exerted on the fluid element.

The top face is slightly higher in altitude (by the distance dh_G); and because pressure varies with altitude, the pressure on the top face will differ slightly from that on the bottom face by the infinitesimally small value dp.

Hence, on the top face the pressure p + dp is felt. It gives rise to a downward force of (p + dp)(1)(1) on the fluid element.

Moreover, the volume of the fluid element is (1)(1) $dh_G = dh_G$; and because ρ is the mass per unit volume, the mass of the fluid element is simply P(l)(1) $dh_G = \rho\ dh_G$.

If the local acceleration of gravity is g, then the weight of the fluid element is ($g\rho dh_G$), as shown in Fig. 3.3.

The three forces shown in Fig. 3.3-pressure forces on the top and bottom, and the weight-must balance because the fluid element is not moving. Hence

$$p = p + dp + \rho g\, dh_G$$

.... (3)

Thus $$dp = -\rho g\, dh_G$$

Equation (3) is the hydrostatic equation and applies to any fluid of density ρ.

Strictly speaking, Eq. (3) is a differential equation; that is, it relates an infinitesimally small change in pressure dp to a corresponding infinitesimally small change in altitude dh_G, where in the language of differential calculus, dp and dh_G are differentials. Also note that g is a variable in Eq. (3); g depends on h_a as given by Eq. (2).

To be made useful, Eq. (3) should be integrated to give what we want: the variation of pressure with altitude p = p (h_G). To simplify the integration, we make the assumption that g is constant throughout the atmosphere, equal to its value at sea level g_o.

Hence we can write Eq. (3) as:

$$dp = -\rho g_0\, dh \quad \dots (4)$$

For the practical mind, geopotential altitude is a "fictitious" altitude, defined by Eq. (4) and that is physically compatible with the assumption of g = const =g_o.

Relation between Geopotential and Geometric altitudes

The variation of p with geometric altitude p = p(h_a). The variation of p with geopotential altitude p = p(h). We need to relate h to h_a, So dividing Eq. (4) by (3), we obtain

$$1 = \frac{g_0}{g}\frac{dh}{dh_G}$$

$$dh = \frac{g}{g_0} dh_G \quad \dots. (5)$$

We substitute Eq. (1) into (5):

$$dh = \frac{r^2}{(r+h_G)^2} dh_G \quad \dots. (6)$$

By convention, we set both h and h_G equal to zero at sea level. Now consider a given point in the atmosphere. This point is at a certain geometric altitude h_G, and associated with it is a certain value of h (different from h_G). Integrating Eq. (6) between sea level and the given point, we have

$$\int_0^h dh = \int_0^{h_G} \frac{r^2}{(r+h_G)^2} dh_G = r^2 \int_0^{h_G} \frac{dh_G}{(r+h_G)^2}$$

$$h = r^2\left(\frac{-1}{r+h_G}\right)_0^{h_G} = r^2\left(\frac{-1}{r+h_G}+\frac{1}{r}\right) = r^2\left(\frac{-r+r+h_G}{(r+h_G)r}\right)$$

$$\boxed{h = \frac{r}{r+h_G}h_G} \qquad \text{.... (7)}$$

Where h is geopotential altitude and h_G is geometric altitude. This is the desired relation between the two altitudes. When we obtain relations such as p= p(h), we can use Eq. (7) to subsequently relate p to h_G.

8. Describe about primary and secondary control surfaces with suitable diagrams.

Aircraft Control Surfaces

The directional control of a fixed-wing aircraft takes place around the lateral, longitudinal, and vertical axes by means of flight control surfaces designed to create movement about these axes. These control devices are hinged or movable surfaces through which the attitude of an aircraft is controlled during takeoff, flight, and landing. They are usually divided into three major groups: 1) primary or main flight control surfaces and 2) secondary and 3) auxiliary control surfaces.

Primary Flight Control Surfaces:

- The primary flight control surfaces on a fixed-wing aircraft include: ailerons, elevators, and the rudder.
- The ailerons are attached to the trailing edge of both wings and when moved, rotate the aircraft around the longitudinal axis.
- The elevator is attached to the trailing edge of the horizontal stabilizer. When it is moved, it alters aircraft pitch, which is the attitude about the horizontal or lateral axis.
- The rudder is hinged to the trailing edge of the vertical stabilizer. When the rudder changes position, the aircraft rotates about the vertical axis (yaw).

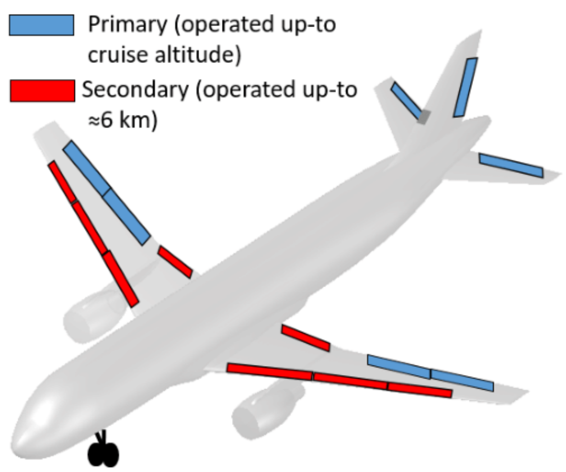
Secondary Control Surfaces:

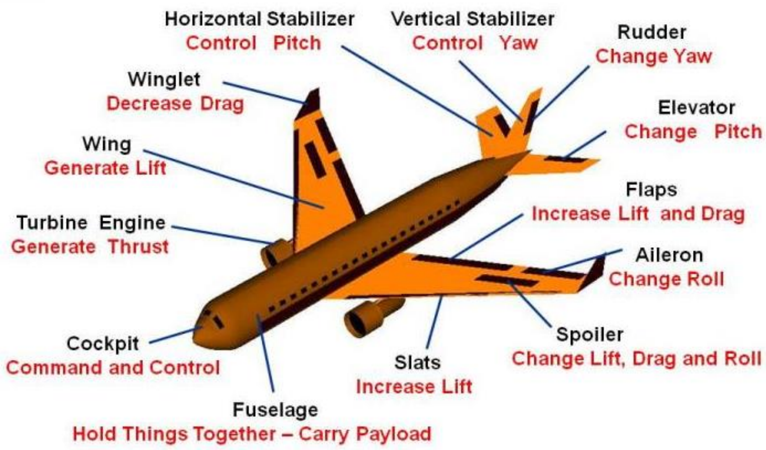
- Trim tabs are small surfaces connected to the trailing edge of a larger control surface on an aircraft, used to control the trim of the controls, i.e. to counteract hydro- or aerodynamic forces and stabilize the aircraft in a particular desired attitude without the need for the operator to constantly apply a control force. This is done by adjusting the angle of the tab relative to the larger surface.

- A servo tab is a small hinged device installed on an aircraft control surface to assist the movement of the control surfaces.

Auxiliary Control Surfaces:

- Flaps and control surfaces and these are hinged surfaces, usually at the trailing edge (the back edge) of the wings and tail that can be rotated up or down. The function of a flap is to increase the lift force on the airplane;
- Some aircraft are designed with flaps at the leading edge (Slats) of the wings as well as at the trailing edge. Slats are used at takeoff and landing to produce additional force.
- The spoilers are also used during landing to slow the plane down and to counteract the flaps when the aircraft is on the ground. The next time you fly on an airplane, notice how the wing shape changes during takeoff and landing.





9. With suitable diagrams explain wing structures

Wing Structure/Construction

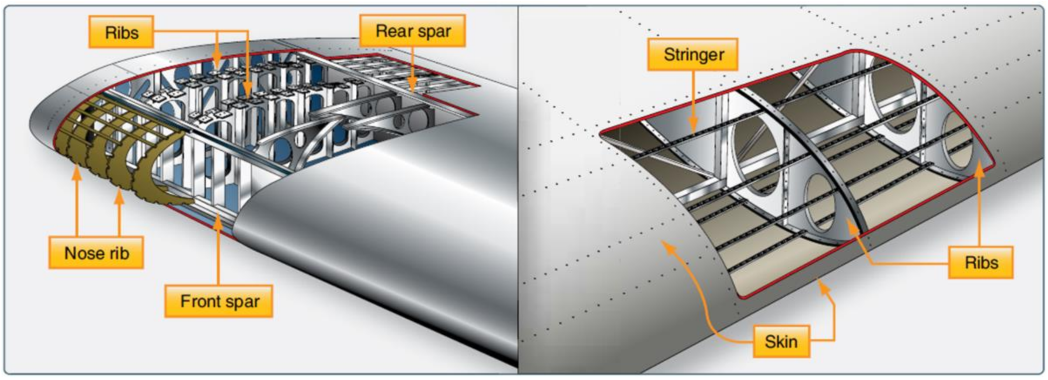
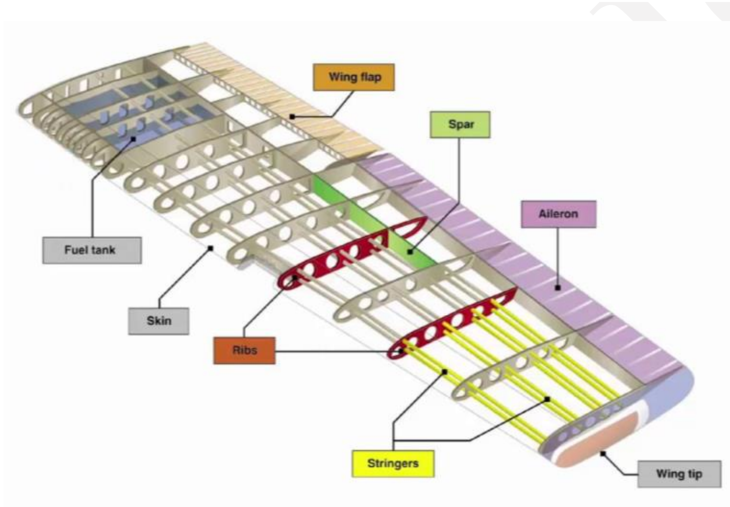


Figure 1-23. *Wing structure nomenclature.*

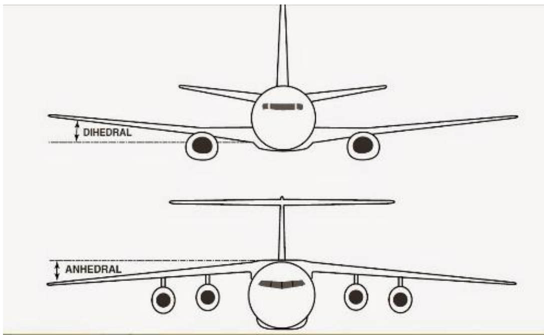


The wing is the principal structural unit of the airplane. It has several functions beyond that of providing lift. For a wing to produce "lift", it must be oriented at a suitable angle of attack relative to the flow of air past the wing. In aerodynamics, angle of attack (AOA) specifies the angle between the chord line of the wing of a fixed-wing aircraft and the vector representing the relative motion between the aircraft and the atmosphere.

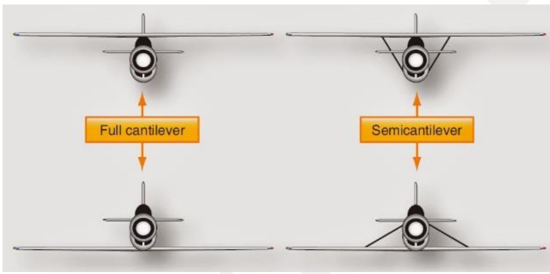
On larger airplanes the engines are mounted in nacelles either attached to the wing or mounted in the wing. The nacelles also provide a housing for the landing gear when it is retracted. The space within the wing is usually used for fuel storage.

The main geometrical features of a wing are its span; the area of the wing; its dihedral angle; its sweepback angle; and the wing section.

Dihedral angle is the upward angle of an aircraft's wing, from the wing root to the wing tip. The amount of dihedral determines the amount of inherent stability along the roll axis. Although an increase of dihedral will increase inherent stability, it will also decrease lift, and increase drag.



The design of the wing depends on the size, weight, and use of the airplane. Generally, there are two kinds of wing design: cantilever and semi-cantilever. The semi-cantilever usually has one, or perhaps two, supporting wires or struts attached to each wing and the fuselage.



As far as the internal structure is concerned, there are three general types of conventional wings: monospar, two-spar, and multispar. Stringers are longitudinal members which are attached to the upper and lower skin to make it stiff. They are used in the design of a wing with stressed skin. Ribs are the basic elements of the wing structure which give the wing section its shape and also transmit the air loads from the skin to the spars.

Many of the control functions are provided by special devices built into the wing. Most obvious are the ailerons and landing flaps.

Flaps are high lift devices. There are many different types of flaps used, with the specific choice depending on the size, speed and complexity of the aircraft on which they are to be used, as well as the era in which the aircraft was designed. Plain flaps, slotted flaps, and Fowler flaps are the most common. Krueger flaps are positioned on the leading edge of the wings and are used on many jet airliners.

The leading edge is the part of the wing that first contacts the air. The leading edge may be equipped with e.g. leading edge extensions, leading edge slats, leading edge slots, vortex generators.

The trailing edge of an aerodynamic surface such as a wing is its rear edge, where the airflow separated by the leading edge rejoins. Essential control surfaces are attached here to redirect the air flow and exert a controlling force by changing its momentum. Such control surfaces include ailerons on the wings for roll control, elevators on the tailplane controlling pitch and the rudder on the fin controlling yaw. Elevators and ailerons may be combined as elevons on tailless aircraft.

Other surfaces and equipment that may be attached to the trailing edge of an aircraft's wing or on its control surfaces include: trim tabs, servo tabs, anti-servo tabs, and flaps.

10. Define the following: Aeronautical Engineering, Aircraft, Airplane, Aerospace Engineering, Aerodynes.
Or
Define aeronautics, aircraft and airplane

Aeronautical Engineering: The branch of engineering concerned with the design, production, and maintenance of aircraft.

Aircraft: An aircraft is a vehicle or machine that is able to fly by gaining support from the air. It counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil, or in a few cases the downward thrust from jet engines.

Airplane: A powered flying vehicle with fixed wings and a weight greater than that of the air it displaces; an aeroplane.

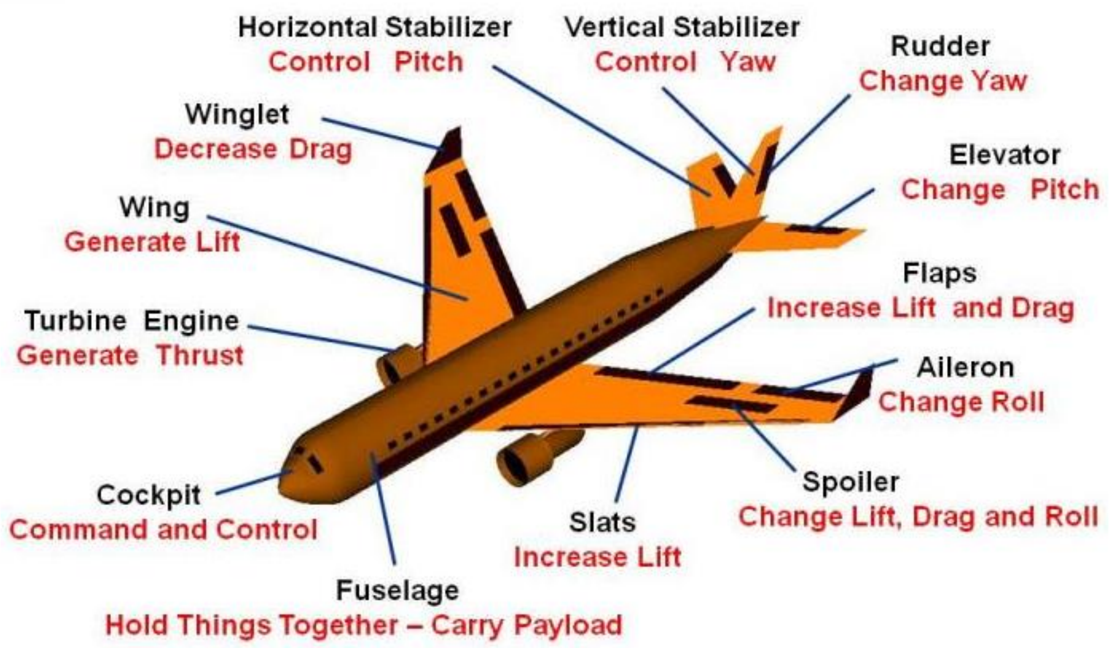
Aerospace Engineering: Aerospace engineering is the primary field of engineering concerned with the development of aircraft and spacecraft. It has two major and overlapping branches: aeronautical engineering and astronautical engineering.

Aerodynes: A heavier-than-air aircraft (such as an airplane, helicopter, or glider) — compare aerostat.

11. Describe the functions of: Winglet, Spoilers, Stabilizers, Cockpit.

Basic components of aircraft

- The **fuselage** is the center body, where most of the usable volume of the airplane is found. The fuselage carries people, baggage, other payload, instruments, fuel, and anything else that the airplane designer puts there.
- The **wings** are the main lift-producing components of the airplanes; the left and right wings are identified as you would see them from inside the airplane, facing forward. The internal volume of the wings can be used for such items as fuel tanks and storage of the main landing gear (the wheels and supporting struts) after the gear is retracted.



- The **horizontal and vertical stabilizers** are located and sized so as to provide the necessary stability for the airplane in flight. Sometimes these surfaces are called the horizontal and vertical tails, or fins.
- When the engines are mounted from the wings, they are usually housed in a type of shroud called a **nacelle**.
- **Flaps** and control surfaces and these are hinged surfaces, usually at the trailing edge (the back edge) of the wings and tail that can be rotated up or down. The function of a flap is to increase the lift force on the airplane;

- Some aircraft are designed with flaps at the leading edge **(Slats)** of the wings as well as at the trailing edge. Slats are used at takeoff and landing to produce additional force.
- The **ailerons** are control surfaces that control the rolling motion of the airplane around the fuselage. For example, when the left aileron is deflected downward and the right aileron is deflected upward, lift is increased on the left wing and decreased on the right wing, causing the airplane to roll to the right.
- The **elevators** are control surfaces that control the nose up-and-down pitching motion; when the elevator is deflected downward, the lift on the tail is increased, pulling the tail up and the nose of the airplane down.
- The **rudder** is a control surface that can turn the nose of the airplane to the right or left (called yawing).

12. List the description of several aspects of an aircraft configuration.

Wing Configuration

Wings are airfoils that, when moved rapidly through the air, create lift. They are built in many shapes and sizes. Wing design can vary to provide certain desirable flight characteristics. Control at various operating speeds, the amount of lift generated, balance, and stability all change as the shape of the wing is altered. Both the leading edge and the trailing edge of the wing may be straight or curved, or one edge may be straight and the other curved. One or both edges may be tapered so that the wing is narrower at the tip than at the root where it joins the fuselage. The wing tip may be square, rounded, or even pointed. Below figure shows a number of typical wing leading and trailing edge shapes.

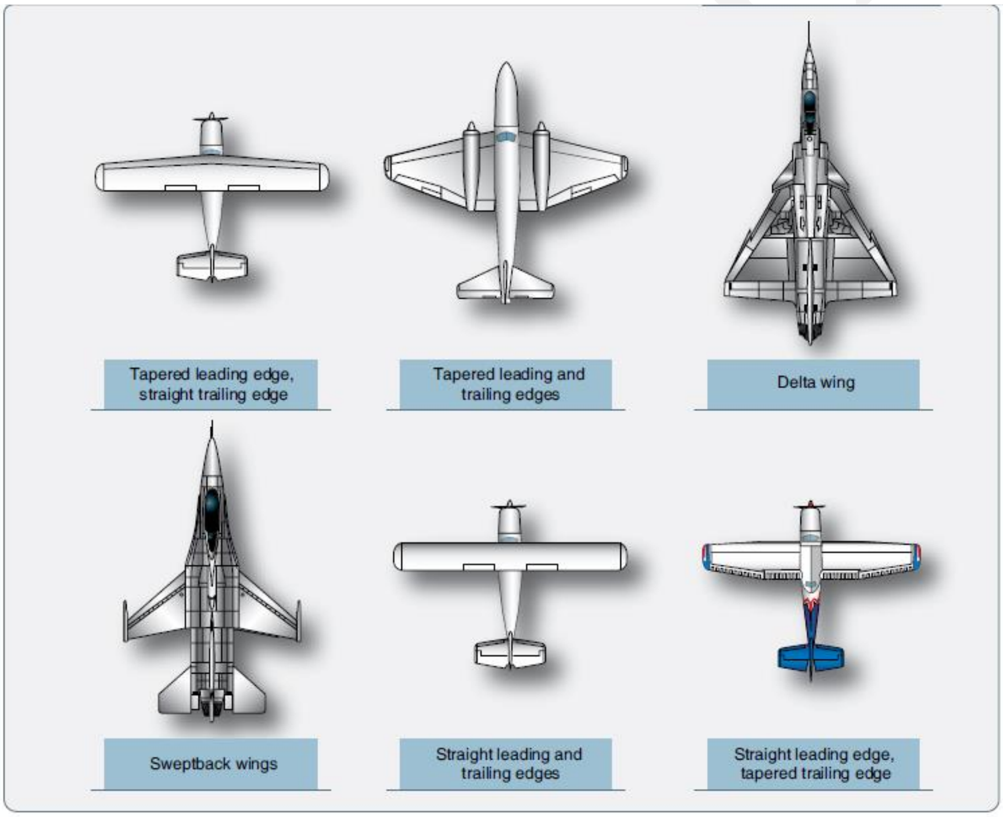


Figure 1-19. *Various wing design shapes yield different performance.*

The wings of an aircraft can be attached to the fuselage at the top, mid-fuselage, or at the bottom. They may extend perpendicular to the horizontal plain of the fuselage or can angle up or down slightly. This angle is known as the wing dihedral. The dihedral angle affects the lateral stability of the aircraft. Below figure shows some common wing attach points and dihedral angle.

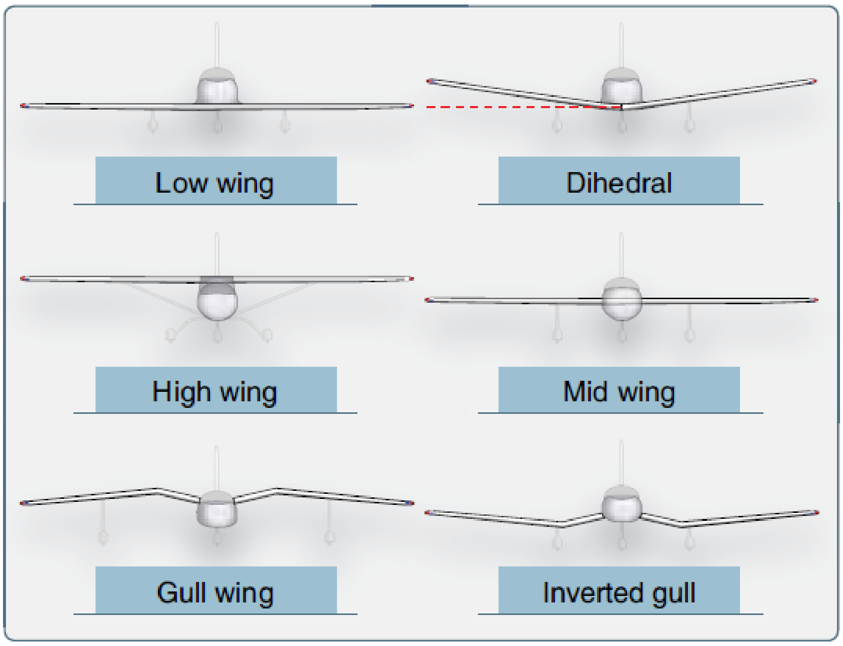
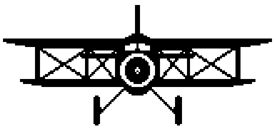


Figure 1-20. *Wing attach points and wing dihedrals.*

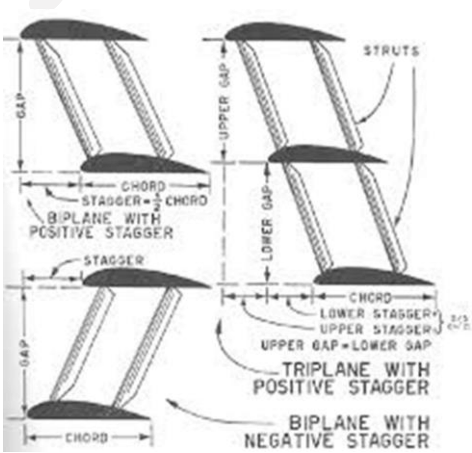
Biplane:



BIPLANE

In a biplane aircraft, as two wings are placed one above the other. Both provide part of the lift, although they are not able to produce twice as much lift as a single wing of similar size and shape because the upper and the lower are working on nearly the same portion of the atmosphere and thus interfere with each other's behavior.

Stagger:

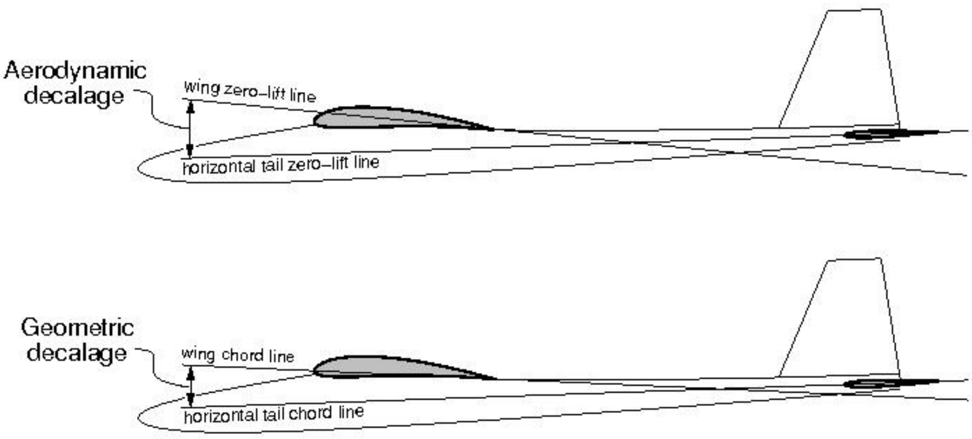


- Stagger is the horizontal positioning of a biplane, triplane, or multiplane's wings in relation to one another.

- An aircraft is said to have positive stagger, or simply stagger, when the upper wing is positioned forward of the lower (bottom).
- An aeroplane is said to have negative stagger in unusual cases where the upper wing is positioned behind the lower wing.
- An aircraft with the wings positioned directly above each other is said to have unstaggered wings.

Decalage:

- Decalage on a fixed-wing aircraft is the angle difference between the upper and lower wings of a biplane, i.e. the acute angle contained between the chords of the wings in question.
- The decalage is said to be positive when the upper wing has a higher angle of incidence than the lower wing, and negative when its angle of incidence is lower. Positive decalage results in greater lift from the upper wing than the lower wing, the difference increasing with the amount of decalage.
- Decalage angle can also refer to the difference in angle of the chord line of the wing and the chord line of the horizontal stabilizer.



Monoplane:

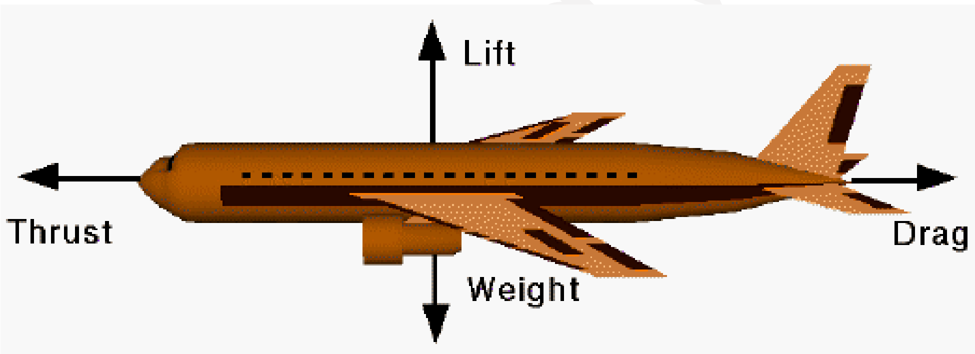
A monoplane is a fixed-wing aircraft with one main set of wing surfaces, in contrast to a biplane or triplane. Since the late 1930s it has been the most common form for a fixed-wing aircraft.

13. Explain wit neat sketch, the aircraft motions.

Aircraft Motion

By simplified motion we mean that some of the four forces acting on the aircraft are balanced by other forces and that we are looking at only one force and one direction at a time. In reality, this simplified motion doesn't occur because all of the forces are interrelated to the aircraft's speed, altitude, orientation, etc. But looking at the forces ideally and individually does give us some insight and is much easier to understand.

In an ideal situation, an airplane could sustain a constant speed and level flight in which the weight would be balanced by the lift, and the drag would be balanced by the thrust. The closest example of this condition is a cruising airliner. While the weight decreases due to fuel burned, the change is very small relative to the total aircraft weight. In this situation, the aircraft will maintain a constant cruise velocity as described by Newton's first law of motion.



Flight Condition	Effect
Lift > Weight	Plane Rises
Weight > Lift	Plane Falls
Drag > Thrust	Plane Slows
Thrust > Drag	Plane Accelerates

If the forces become unbalanced, the aircraft will move in the direction of the greater force. We can compute the acceleration which the aircraft will experience from Newton's second law of motion

$$F = m * a$$

Where a is the acceleration, m is the mass of the aircraft, and F is the net force acting on the aircraft. The net force is the difference between the opposing forces; lift minus weight, or thrust minus drag. With this information, we can solve for the resulting motion of the aircraft.

If the weight is decreased while the lift is held constant, the airplane will rise:

Lift > Weight - Aircraft Rises

If the lift is decreased while the weight is constant, the plane will fall:

Weight > Lift - Aircraft Falls

Similarly, increasing the thrust while the drag is constant will cause the plane to accelerate:

Thrust > Drag - Aircraft Accelerates

And increasing the drag at a constant thrust will cause the plane to slow down:

Drag > Thrust - Aircraft Slows

14. Why we are discussing these altitudes and their dependencies?

Need for ISA and agency prescribing it:

The properties of earth's atmosphere like pressure, temperature and density vary not only with height above the earth's surface but also with the location on earth, from day to day and even during the day. The performance of an airplane is dependent on the physical properties of the earth's atmosphere. Hence, for the purpose of comparing (a) the performance of different airplanes and (b) the performance of the same airplane measured in flight tests on different days, a set of values for atmospheric properties have been agreed upon, which represent average conditions prevailing for most of the year, in Europe and North America.

Though the agreed values do not represent the actual conditions anywhere at any given time, they are useful as a reference. This set of values called the International Standard Atmosphere (ISA) is prescribed by ICAO (International Civil Aviation Organization). It is defined by the pressure and temperature at mean sea level, and the variation of temperature with altitude up to 32 km. With these values being prescribed, it is possible to find the required physical characteristics (pressure, temperature, density etc) at any chosen altitude.

Features of ISA:

The main features of the ISA are the standard sea level values and the variation of temperature with altitude. The air is assumed as dry perfect gas. The standard sea level conditions are as follows:

- Temperature (T_0) = 288.15 K = 15^0 C
- Pressure (P_0) = 101325 N/m^2 = 760 mm of Hg
- Rate of change of temperature:

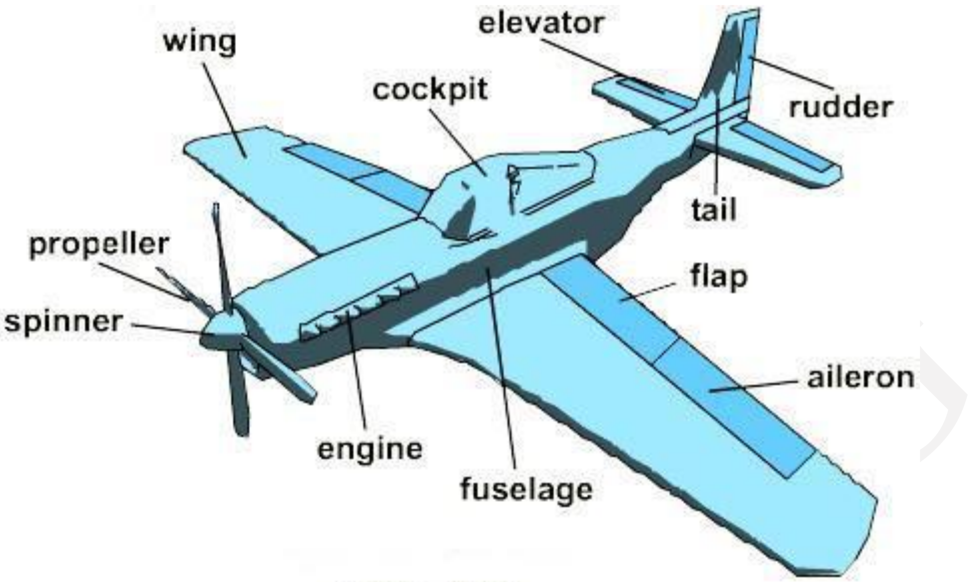
  = - 6.5 K/km up to 11 km

  = 0 K/km from 11 to 20 km

  = 1 K/km from 20 to 32 km

The region of ISA from 0 to 11 km is referred to as troposphere. That between 11 to 20 km is the lower stratosphere and between 20 to 32 km is the middle stratosphere.

15. Describe the major components of a piston engine airplane with neat diagrams.



Fuselage - The body of the airplane. The wings, tail, and engine are attached to the fuselage.

Wing - I'm sure you know what a wing is. It's the horizontal airfoil that produces lift. The ailerons and flaps are hinged to the wing.

Ailerons - hinged surfaces on the outside of the wing that swing up and down. While the right aileron hinges up, the left aileron hinges down. And vice versa. These surfaces control the roll of the airplane.

Tail - The rear section of the plane that consists of a horizontal stabilizer and a vertical stabilizer. The elevator hinges to the horizontal stabilizer. The rudder hinges to the vertical stabilizer.

Elevator - hinged surfaces on the horizontal part of the tail that swings up and down. These surfaces control the pitch of the airplane.

Rudder - hinged surface on the vertical part of the tail that swings left and right. This surface controls the yaw of the airplane.

Flaps - hinged surfaces on the wing just inside the ailerons. The flaps hinge down to increase lift on take off and landing.

Engine - Provides the power to turn the propeller to produce thrust for sustaining flight.

Propeller - A turning blade or twisted airfoil that produces thrust when powered by the engine.

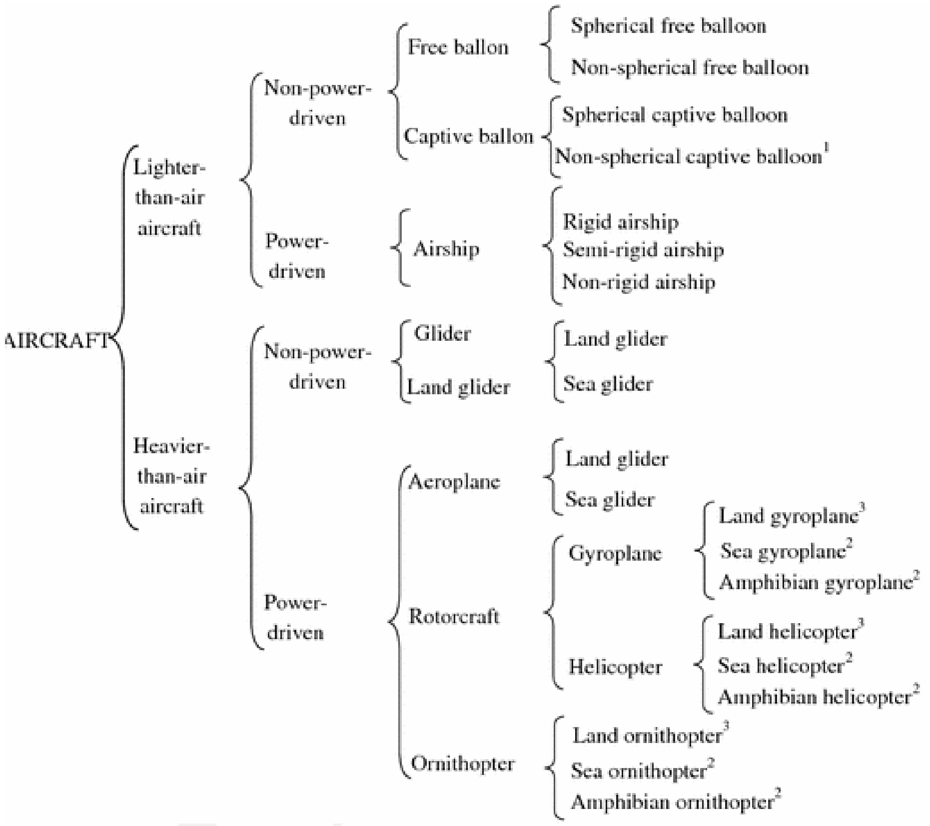
Spinner - The nose cone that covers the hub of the propeller. Helps smooth the airflow over the engine. Is where you place the electric starter on an RC airplane.

Cockpit - where the pilot sits while flying the plane. Houses all the controls and instrumentation.

Additional Topics:

1.1 Classification of Aircrafts

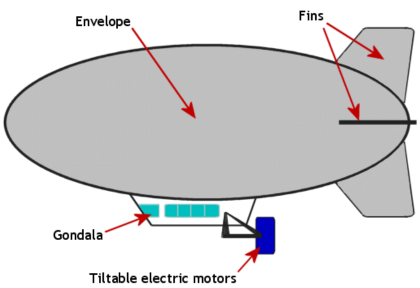
An aircraft is a machine that is able to fly by gaining support from the air. It counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil, or in a few cases the downward thrust from jet engines.



Lighter than air aircraft (Aerostats):

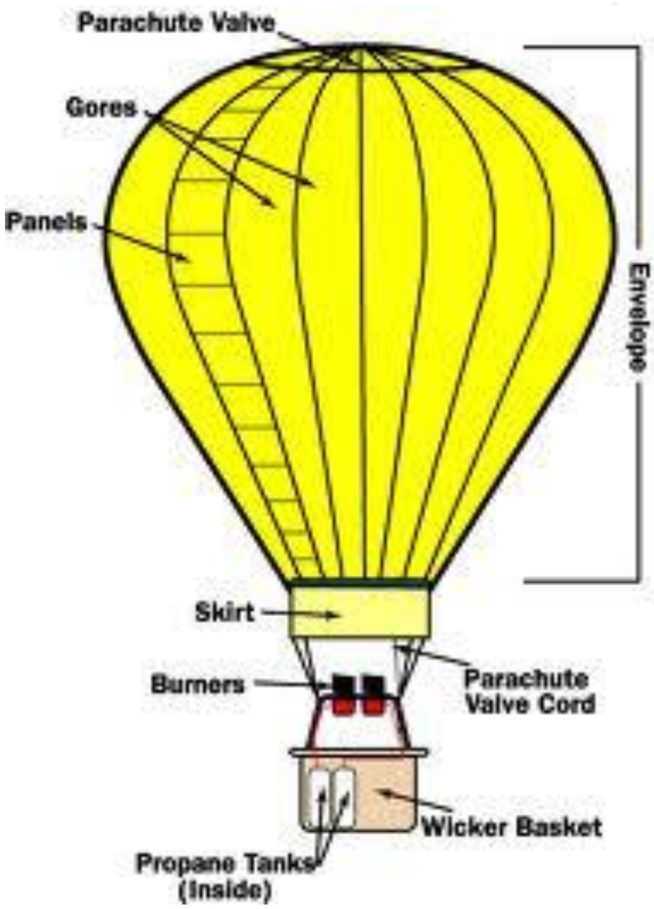
- The first flying object.
- Density is very less compare to the density of air.
- It easily float on the air.
- They are airships, free balloons and captive balloons.

Airship:



- An airship or dirigible balloon is a type of aerostat or lighter-than-air aircraft that can navigate through the air under its own power. Aerostats gain their lift from large gas bags filled with a lifting gas that is less dense than the surrounding air.
- Non-rigid airships, often called "blimps", rely on internal pressure to maintain the shape of the airship.
- Semi-rigid airships maintain the envelope shape by internal pressure, but have some form of supporting structure, such as a fixed keel, attached to it.
- Rigid airships have an outer structural framework which maintains the shape and carries all structural loads, while the lifting gas is contained in one or more internal gas bags or cells.
- It is used for transportation in earlier days(19 century)
- Now a days it is used for advertisement, surveillance, sight-seeing, research.

Balloon:



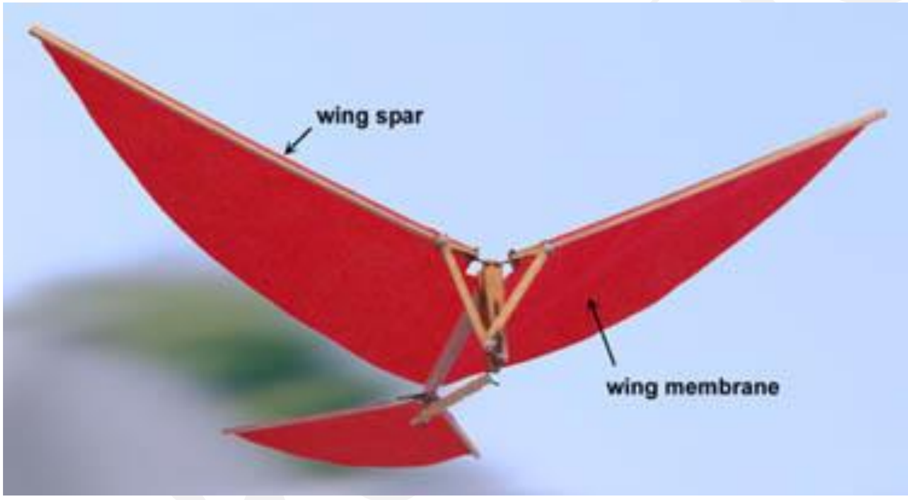
- A balloon is a kind of aircraft that stays in the sky by floating.
- A balloon has no engine and has no way to change its direction of movement (except up and down). A balloon travels by moving with the wind.

- The bottom of the balloon is called the "basket" where people can sit or stand. The top of a balloon is a big cloth bag called the "envelope".
- A **captive balloon** is an aircraft which does not fly free, but is held like a kite by a rope from the "pilot" or mooring. The rope or line is not only used for holding the aircraft, but it also allows steering the balloon.
- There are three kinds of balloon aircraft:
  - **Hot air** balloons stay in the sky by making the air inside the envelope hot. Making the air hot makes the air spread out (have lower density). Hot air balloons are the most common kind of balloon aircraft.
  - **Gas balloons** are not hot. Gas balloons have gas of low density in their envelopes. Examples of the gas used in gas balloons are heliumand hydrogen.
  - **Rozière balloons** are like both hot air balloons and gas balloons.
- **How the Balloon Works:**
  - The basis of how the balloon works is that warmer air rises in cooler air. This is because hot air is lighter than cool air as it has less mass per unit of volume.
  - The actual balloon (called an envelope) has to be so large as it takes such a large amount of heated air to lift it off the ground.
  - Increasing the air temperature inside the envelope makes it lighter than the surrounding (ambient) air.
  - The balloon floats because of the buoyant force exerted on it. The amount of lift (or buoyancy) provided by a hot air balloon depends primarily upon the difference between the temperature of the air inside the envelope and the temperature of the air outside the envelope.
  - For most envelopes made of nylon fabric, the maximum internal temperature is limited to approximately 120 °C
  - The burner uses propane gas to heat up the air in the envelope to move the balloon off the ground and into the air.
  - The pilot must keep firing the burner at regular intervals throughout the flight to ensure that the balloon continues to be stable.
  - Naturally, the hot air will not escape from the hole at the very bottom of the envelope as firstly, hot air rises and secondly, the buoyancy keeps it moving up.

Heavier than air aircrafts (Aerodynes):

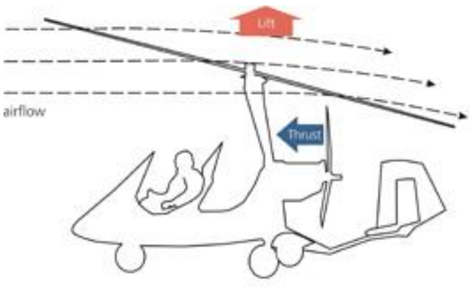
Ornithopter:

- An ornithopter (from Greek ornithos "bird" and pteron "wing") is an aircraft that flies by flapping its wings.
- Designers seek to imitate the flapping-wing flight of birds, bats, and insects. Though machines may differ in form, they are usually built on the same scale as these flying creatures.
- Manned ornithopters have also been built, and some have been successful.
- The machines are of two general types: those with engines, and those powered by the muscles of the pilot.

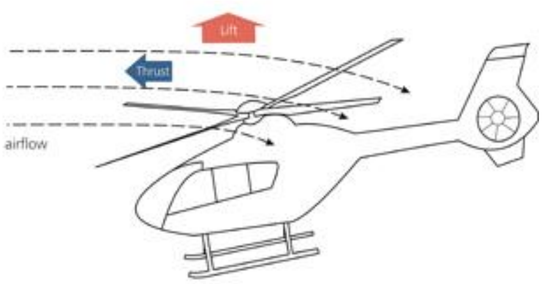


Rotorcraft:

- A **helicopter** is a type of rotorcraft in which lift and thrust are supplied by rotors. This allows the helicopter to take off and land vertically, to hover, and to fly forward, backward, and laterally.
- An **autogyro** also known as a **gyroplane** or gyrocopter, is a type of rotorcraft that uses an unpowered rotor in free autorotation to develop lift. Forward thrust is provided independently, typically by an engine-driven propeller.



Gyrocopter in autorotation



Helicopter in horizontal flight

Airplane:

An airplane or aeroplane (informally plane) is a powered, fixed-wing aircraft that is propelled forward by thrust from a jet engine, propeller.

Glider, Kite:

A glider is a heavier-than-air aircraft that is supported in flight by the dynamic reaction of the air against its lifting surfaces, and whose free flight does not depend on an engine.


Hang Glider


Sailplane


Toy Glider


Space Shuttle