Up thrust in Fluids, Archimedes' Principle and Floatation

1. **What is Up thrust or Buoyant Force? What is its SI Unit?**
   Ans. The upward force exerted on a body by the fluid in which it is submerged, is called Up-thrust or Buoyant Force.
   It is denoted by F_B.
   Its S.I. unit is 'newton' or kgf.

2. **What do you understand by the term up thrust of a fluid? Describe an experiment to show its existence.**
   Ans. Up thrust is an upward force that acts on a body when it is partially or fully immersed in a fluid.
   Following is an experiment that demonstrate the existence of upthrust:
   When an empty can, with its mouth sealed with an airtight stopper is placed in a tub filled with water, it floats with a significantly larger portion of it above the water surface while only a small portion of it is present below the water surface. If we try to push the can we feel an upward force opposing the push making it difficult to push further. In order to push it further, more force is required till it is fully immersed. Even when it is fully immersed, a constant force is still required in order for it to remain static in the same position. That is the maximum thrust on the can. At this position, if the can is released, it bounces back to the water surface and floats again.

3. **What is called Buoyancy?**
   Ans. The property of liquid to exert an upward force on a body immersed in it, is called Buoyancy.

4. **In what direction and at what point does the buoyant force on a body due to a liquid, act?**
   Ans. The buoyant force on a body due to a liquid act in the upward direction at the center of buoyancy.

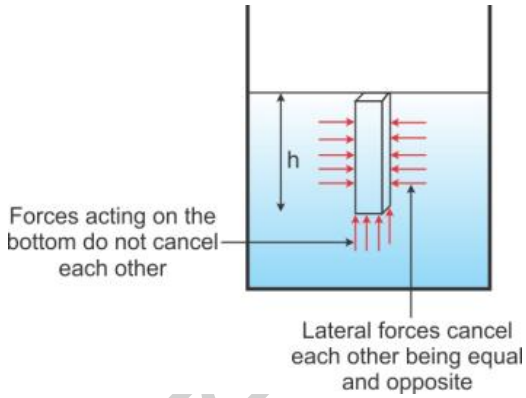
5. **Why we do not feel the property of buoyancy of Air?**
   Ans. Like liquid, gases also have the property of buoyancy, i.e. a body immersed in gas also experiences an up-thrust. All objects including ourselves, are also acted upon by a buoyant force due to air, but we do not feel it because it is negligible small as compared to our own weight.

6. **What are the properties of Up thrust?**
   Ans. The up-thrust has the following three characteristic properties:
   a. Larger the volume of body submerged in a fluid, greater is the up-thrust.
   b. For some volume, inside the fluid more the density of fluid, greater is the up-thrust.
   c. The up-thrust acts on the body in upward direction at the center of buoyancy i.e. the center of gravity of the displaced fluid.

7. **Why is a force needed to keep a block of wood inside water?**
   An upward force, an up-thrust is required to keep a block of wood in water as the up-thrust due to water on the block when it is completely submerged is much more than its weight.

8. **A piece of wood if left under water, comes to the surface. Explain the reason.**
   Ans. A piece of wood that is left under water comes to the surface as the up-thrust on the block as a result of its submerged part is equivalent to its own weight.

9. **What is the cause of up-thrust? At which point can it be considered to act?**
   Ans. A liquid contained in a vessel exerts pressure at all points and in all directions. The pressure at a point in a liquid is the same in all directions - upwards, downwards and sideways. It increases with the depth inside the liquid.
   When a body is immersed in a liquid, the thrusts acting on the side walls of the body are neutralized as they are equal in magnitude and opposite in direction. However, the magnitudes of pressure on the upper and lower faces are not equal. The difference in pressure on the upper and lower faces cause a net upward force (= pressure x area) or up-thrust on the body. It acts at the center of buoyancy.



10. **Will a body weigh more in air or in vacuum when weighed with a spring balance? Give a reason for your answer.**
    Ans. A body weighs more in vacuum comparatively as there is no up-thrust acting on the body in the absence of air.

11. **A metal solid cylinder tied to a thread is hanging from the hook of a spring balance. The cylinder is gradually immersed into water contained in a jar. What changes do you expect in the readings of spring balance? Explain your answer.**
    Ans. It is observed that the readings on the spring balance decrease. When the metal solid cylinder is immersed in the water jar, it is acted upon by an upward force which is in the opposite direction to the weight of the cylinder which is why the cylinder appears to be lighter.

12. **A body dipped into a liquid experience an up thrust. State two factors on which up-thrust on the body depends.**
    Ans. The two factors on which up-thrust on the body depends is:
    - Density of the liquid in which the body is submerged
    - Volume of the body immersed in the liquid

13. **How is the up-thrust related to the volume of the body submerged in a liquid?**
    Ans. Up-thrust acting on a body is greater if the volume of the body submerged in the liquid is larger.

14. **A bunch of feathers and a stone of the same mass are released simultaneously in air. Which will fall faster and why? How will your observation be different if they are released simultaneously in vacuum?**
    Ans. The feathers fall much after the stone falls because of air friction. The observation will be different in vacuum as there is no friction in air because of absence of air. As a result of which the acceleration due to gravity acting on both bodies will be the same and hence the feathers and the stone will fall at the same time without any delay.

15. Proof that Up thrust is equal to the weight of displaced liquid.

Ans. When a body is immersed in a liquid, up thrust on it due to liquid is equal to the weight of the liquid displaced by the submerged part of the body.

Consider a cylinder body PQRS of cross-sectional area A immersed in a liquid of density ρ. Let the upper surface PQ of body be at a depth h_1 while its lower surface RS be at a depth h_2 below the free surface of liquid.

At depth h_1 pressure om the upper surface PQ

$P_1 = h_1 \rho g$

Dowuward thrust on the upper surface PQ is

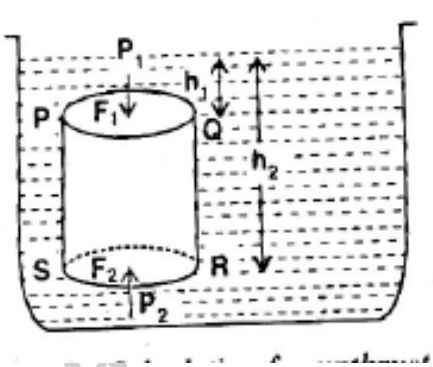
F_1 = pressure × area = $h_1 \rho g A$ ..... (i)

At depth h_2 pressure on the lower surface RS

$P_2 = h_2 \rho g$

Upward thrst on the lower surface RS is

$F_2 = h_2 \rho g A$ ..... (ii)



The horizondal thrust at various points on the vertical sides of body get balanced because liquid pressure in same at all points at the same depth.

From the above eqs. (i) and (ii)

$F_2 > F_1$ because $h_2 > h_1$

Therefore the body will experience a net upward force.

Resultant upward thrust on the body

$F_B = F_2 - F_1$

$= h_2 \rho g A - h_1 \rho g A$

$= A (h_2 - h_1) \rho g$

But $A (h_2 - h_1) = V$, the volume of the body submerged in liquid

So **Upthrust $F_B = V \rho g$**

F_B = Volume of liquid displaced × density of liquid × acceleration due to gravity.

= mass of liquid displaced × acceleration due to gravity.

Upthrust F_B = Weight of the diaplaced by the submerged part of the body

16. Which factors are affected the upthrust?

Ans. The following two factors are affected the upthrust

a. Volume of the body submerged in liquid and
b. Density of the liquid in which the body is submerged.

17. A sphere of iron and another sphere of wood of the same radius are held under water. Compare the up-thrust on the two spheres.

Ans. Since the spheres have the same radius, both will have an equal volume inside water, and hence, the up-thrust acted by water on both the spheres will be the same.

Hence, the required ratio of up-thrust acting on two spheres is 1:1.

18. A sphere of iron and another of wood, both of same radius are placed on the surface of water. State which of the two will sink? Give a reason for your answer.

Ans. Sphere of iron will sink.

Density of iron is more than the density of water, so the weight of iron sphere will be more than the up-thrust due to water in it; thus, it causes the iron sphere to sink.

Density of wood is less than the density of water, so the weight of sphere of wood shall be less than the up-thrust due to water in it. So, the sphere of wood will float with a volume submerged inside water which is balanced by the up-thrust due to water.

19. It is easier to lift a heavy stone under water than in air. Explain.

Ans. It is easier to lift a heavy stone under water than in air because in water, it experiences an upward buoyant force which balances the actual weight of the stone acting downwards. Thus, due to up-thrust there is an apparent loss in the weight of the heavy stone, which makes it lighter in water, and hence easy to lift.

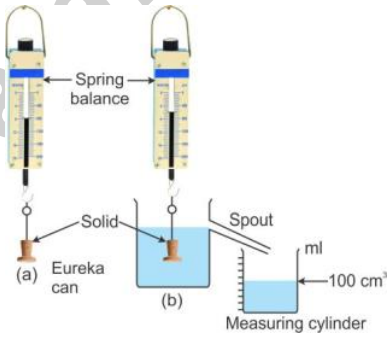
20. State the Archimedes' principle.

Ans. Archimedes' principle states that when a body is immersed partially or completely in a liquid, it experiences an up-thrust, which is equal to the weight of liquid displaced by it.

21. Describe an experiment to verify the Archimedes' principle.

Ans. Let us take a solid and suspend it by a thin thread from the hook of a spring balance and note its weight (Fig a).

Then take a eureka can and fill it with water up to its spout. Arrange a measuring cylinder below the spout of the eureka can as shown. Immerse the solid gently in water. The water displaced by the solid gets collected in the measuring cylinder. When water stops dripping through the spout, note the weight of the solid and volume of water collected in the measuring cylinder.



From diagram, it is clear that

Loss in weight (Weight in air − weight in water)

= 300 gf − 200 gf = 100 gf

Volume of water displaced = Volume of solid = 100 cm3

Because density of water = 1 gcm-3

Weight of water displaced = 100 gf = Up-thrust or loss in weight

This verifies Archimedes' principle.

22. Define the term density.

Ans. The density of a substance is its mass per unit volume.

So **Density=** $\frac{\text{Mass of the substance}}{\text{Volume of the substance}}$

- It is Scaler Quantity
- It is denoted by ρ
- If the mass of the substance is M and its volume is V then Density ρ= M/V
- The unit of Density is Kgm^{-3} (SI) $gmcm^{-3}$ (CGS)

23. What is the relation between SI and CGS unit of Density

Ans. SI unit of Density is $\frac{kg}{m^3} = \frac{1000gm}{100cm^3} = \frac{1}{1000} gcm^{-3}$

$$1\ kgm^{-3} = 10^{-3}\ gcm^{-3}$$

24. What is the relation between Density and Relative Density?

Ans. In CGS System the density of water in 4^0C is 1 gcm^{-3}. So

So Relative Density= $\frac{\text{Density of Substance}}{1}$

Relative Density= Numerical Value of Density

In SI System the density of water in 4^0C is 1000 kgm^{-3}. So

So Relative Density= $\frac{\text{Density of Substance}}{1000\ kg/m\hat{}3}$

Relative Density= Numerical Value of Density

25. The density of iron is 7800 kg m^{-3}. What do you understand by this statement?

Ans. The statement conveys that the mass of 1m-3 of iron is 7800kg.

26. Write the density of water at 4℃ in S.I. unit.

Ans. The density of water at 4℃ in S.I. unit is 1000 kg m^{-3}.

27. How are the (i) mass, (ii) volume, and (iii) density of a metallic piece affected, if at all, with increase in temperature?

Ans. With an increase in the temperature, the parameters are affected in the following ways:

(i) Mass – mass is unchanged with an increase in temperature

(ii) Volume – with an increase in the temperature, the volume increases

(iii) Density – with an increase in the temperature, the density of the metallic piece affected decreases. 7. Water is heated from 0℃ to 10℃. How does the density of water change with temperature? Solution: When water is heated from 0℃, the density of water increases up to 4℃ and then decreases beyond 4℃.

28. What do you understand by the term relative density of a substance?

Ans. The relative density of a substance is the ratio of density of that substance to the density of water at 4^0C.

So Relative Density = $\frac{\text{Density of Substance}}{\text{Density of water}}$

29. What is the unit of relative density?

Ans. Relative density is the ratio of two similar quantities; thus, it has no unit.

30. How can we differentiate between density and relative density of a substance.

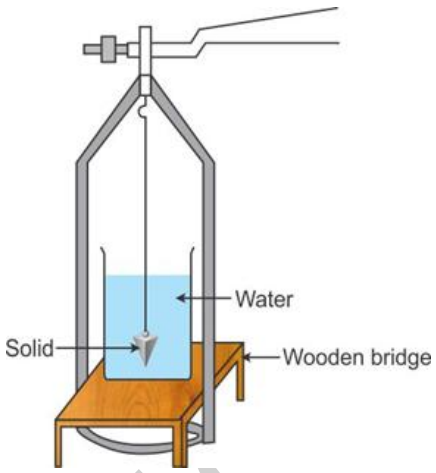
Ans.

Density	Relative Density
Density of a substance is the ratio of its mass to its volume	R.D. of a substance is the ratio of density of that substance to the density of water at 4^0C.
It is expressed by gcm^{-3} or kgm^{-3}	It has no limit

31. With the use of Archimedes' principle, state how you will find relative density of a solid denser than water. How will you modify your experiments if the solid is soluble in water?

Ans. (i) With the help of a physical balance, find the weight, W1 of the given solid.

(ii) Immerse the solid completely in a beaker filled with water such that it does not touch the walls and bottom of beaker, and find the weight W2 of solid in water.



Observations:

Loss in weight of solid when immersed in water = $(W_1 - W_2)$.gf

R.D. = Weight of solid in air/Loss of weight of solid in water

R.D. = $W_1/(W_1 - W_2)$.

If the solid is soluble in water, then instead of water, take a liquid in which the solid is insoluble and it sinks in the liquid.

Then, R.D. = (Weight of solid in air/Loss of weight of solid in liquid) x R.D. of the liquid

32. A body weighs W gf in air and W1 gf when it is completely immersed in water. Find: (i) Volume of the body, (ii) Up-thrust on the body and (iii) Relative density of the material of the body.

Ans. (i) Volume of the body = $(W - W_1)\text{cm}^3$

(ii) Upthrust on the body = $(W - W_1)\text{gf}$

(iii) R.D. of the material of body = $\dfrac{W}{W - W_1}$

33. Describe an experiment, using Archimedes principle, to find relative density of a liquid.

Ans. Relative density is the ratio of weight of a given volume of liquid to the weight of the same volume of water.

Using Archimedes principle, we can perform an experiment which measures the weight of a liquid displaced by a body and weight of water displaced by the same body.

Weight of liquid displaced by a body is given by the difference of weight of a body in air and weight of a body in liquid.

Weight of the water displaced by the body can be found by knowing the difference of the weight of the body in air and the weight of the body in water.

Therefore, using Archimedes principle, the relative density can be calculated using the formula:

$$\text{RD of Liquid} = \frac{W_1 - W_2}{W_1 - W_3}$$

34. What happen when a body is immerged in a liquid?

Ans. When a body is immersed in a liquid the following two forces act on it

a. The weight W of body acting vertically downwards, through the centre of gravity G of the body. This force has a tendency to sink the body
b. The Upthrust F_B of the liquid acting vertically upwards, through the centre of buoyancy B i.e. th Centre of Gravirty of the displaced Liquid.
The upthrust is equal to the magnitude of the weight of the liquiddisplaced. This force has a tendency to make the body float.

Fig. 5.9 shows the two forces W and F_B acting on a body floating on a liquid.

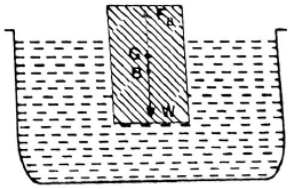


Fig. 5.9 Two forces acting on a floating body

In magnitude,

W = volume of body × density of body × g ..(5.16)

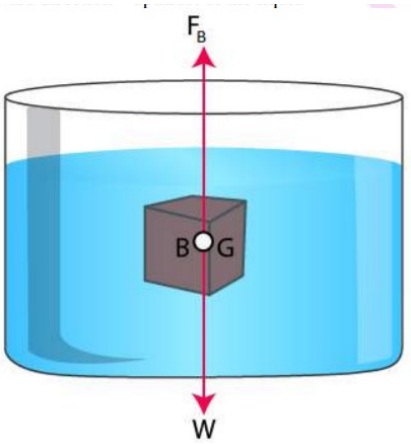
and F_B = volume of submerged part of body × density of liquid × g ..(5.17)

35. State the Principle of Floatation.

Ans. According to the principle of floatation, the weight of a floating body is equal to the weight of the liquid displaced by its submerged part.

36. A body is held immersed in a liquid. (i) Name the two forces acting on body and draw a diagram to show these forces. (ii) State how do the magnitudes of two forces mentioned in part (i) determine whether the body will float or sink in liquid when it is released. (iii) What is the net force on body if it (a) sinks, (b) floats?

Ans. (i) The two forces that act on the body are:
Downward direction – weight of the body Upward direction – up-thrust of the liquid



(ii) Magnitude of the forces acting on the body can determine whether the body will sink or float. The body will sink if the weight of the body is greater than the up-thrust acting on it whereas the body will float if the weight of the body is equivalent to or lesser than the up-thrust acting on it.
(iv)(a) The net force acting on the body when it sinks are the weight of the body itself.
(b) The net force acting on the body when it floats is the up-thrust due to the liquid.

37. How does the density of a substance determine whether a solid piece of that substance will float or sink in a given liquid?

Ans. The body will float if its density is less than or equal to the density of the liquid. $\rho_S \leq \rho_L$

The body will sink if its density is greater than the density of the liquid $\rho_S > \rho_L$

38. Explain why an iron nail floats on mercury, but it sinks in water.
Ans. Density of iron is less than the density of mercury; hence, an iron nail floats in mercury and density of iron is more than the density of water; hence, an iron nail sinks in water.

39. A body floats in a liquid with a part of it submerged inside liquid. Is the weight of floating body greater than, equal to or less than up-thrust?
Ans. If the body is floating on the liquid, the weight of the floating body is equal to the up-thrust.

40. A homogenous block floats on water (a) partly immersed (b) completely immersed. In each case state the position of centre of buoyancy B with respect to the centre of gravity G of the block.
Ans. (a) Partly immersed - centre of buoyancy B will lie vertically below centre of gravity, G.
(b) Completely immersed - centre of buoyancy B will coincide with centre of gravity, G.

41. A balloon filled with helium gas floats in a big closed jar which is connected to an evacuating pump. What will be your observation, if air from jar is pumped out? Explain your answer.
Ans. The balloon will sink. The density of air in the jar decreases as the air is pumped out from the jar. Hence the up-thrust on the balloon decreases. The balloon sinks as the weight of the balloon surpasses the up-thrust acting on it.

42. A block of wood is so loaded that it just floats in water at room temperature. What change will occur in the state of floatation, if (a) Some salt is added to water, (b) Water is heated?
Ans. (a) It floats with some part outside water. The density of water increases when salt is added to water, so the up-thrust on the block of wood increases and therefore, the block rises up till the weight of salty water displaced by the submerged part of the block becomes equal to the weight of the block. (b) It sinks. The density of water decreases on heating, hence the up-thrust on the block decreases and the weight of the block exceeds the up-thrust as a result of which it sinks.

43. A body of volume V and density ρS, floats with volume v inside a liquid of density ρL. Show that $v/V = \rho S / \rho L$.
Ans. To prove: v V = ρS ρL
Consider: V to be the volume of the body having density ρS 'v' to be the volume of the body when immersed in a liquid having density ρL
The weight of the body can be given by:
W = volume of the body x density of the body x g = V ρS g
Up-thrust or the weight of the liquid displaced by the body is given by:
FB = volume of the liquid displaced x density of the body x g = v ρL g
We know that for floatation,
FB = W
Or, V ρS g = v ρL g
Or. V/V = ρS /ρL **Proved.**

44. What is centre of buoyancy? State its position for a floating body with respect to the centre of gravity of body.

Ans. Centre of buoyancy is the point through which the resultant of the buoyancy forces acts on an immersed body. It coincides with the centre of gravity of the liquid that is displaced if the body is fully immersed.

In case of a floating body, the centre of buoyancy is at the centre of gravity of the immersed part of a floating body in the liquid, and lies vertically below the centre of gravity of the whole body.

45. Why is floating ice less submerged in brine than in water?

Ans. Floating ice is less submerged in brine than in water because the density of brine is more than the density of water.

46. A man first swims in sea water and then in river water.

(i) Compare the weights of sea water and river water displaced by him.

(ii) Where does he find it easier to swim and why?

Ans. (i) The weight of the water displaced is equal to the weight of the man in both cases, when he swims in sea water and in river water, hence the comparison yields 1:1.

(ii)The man will find it easier to swim to swim in sea water as the density of sea water is more than that of the river water. Therefore, his weight is balanced in sea water with lesser part of his immersed inside it.

47. An iron nail sinks in water while an iron ship floats on water. Explain the reason.

Ans. It is because the density of iron is more than the density of water. Hence the weight of the nail is comparatively greater than the up-thrust that acts on water. Ships are made of iron yet they do not sink as ships are hollow and the empty space in it contains air making the average density lesser than that of water. Consequently, even with a smaller portion of ship immersed in water, the weight of water displaced by the immersed part of the ship becomes equivalent to the net weight of the ship causing it to floats.

48. What can you say about the average density of a ship floating on water in relation to the density of water?

Ans. The relation is that the average density of a ship floating on water is lesser than the density of water.

49. A piece of ice floating in a glass of water melts, but the level of water in glass does not change. Give reason.

Ans. Ice contracts by the volume equivalent to the volume of ice pieces over the surface of water when floating pieces of ice melts into water. Consequently, the water level remains unchanged when floating ice melts on it.

50. **A loaded cargo ship sails from sea water to river water. State and explain your observation.**

Solution: The observation is as follows: The cargo ship dips into water as it advances from sea water to river water. Explanation: Density of sea water is more than that of river water. Consequently, as per the law of floatation, in order to balance the weight of the ship, more volume of water is required for the river water having lower density to displace it.

51. Explain the following:

(a) Icebergs floating in sea are dangerous for ships.

(b) An egg sinks in fresh water, but floats in a strong salt solution

(c) A toy balloon filled with hydrogen rises to the ceiling, but if filled with carbon dioxide sinks to the floor

(d) As a ship in harbour is being unloaded, it slowly rises higher in water

(e) A balloon filled with hydrogen rises to a certain height and then stops rising further.

(f) A ship submerges more as it sails from sea water to river water.

Ans.(a) Icebergs being lighter than water, float on it with almost 90% of it submerged in water and merely some part appearing outside the surface of water. As the portion of iceberg in water surface is dependent on the density of sea water, it becomes challenging for the helmsman to estimate the size of the iceberg. Thus, an iceberg can be very dangerous for a ship as it may collide with the ship and cause damage.

(b) As the density of strong salt solution is denser than fresh water, it exerts more up-thrust on the egg that balances the weight of the egg hence the egg sinks in fresh water but floats on a strong salt solution.

(c) Density of carbon dioxide is much more than the density of hydrogen, hence when a balloon is filled with hydrogen, the weight of the air displaced by an inflated balloon or the up-thrust tends to become greater than the weight of the gas balloon that is filled causing it to rise. But when the balloon is filled with carbon dioxide, the balloon weighs more than the up-thrust offered by air causing it to sink to the floor.

(d) The weight of the ship decreases as it is unloaded at the harbour because of which less water is displaced causing the hull of the ship to rise in water until the weight of the water displaced balances the weight of the unloaded ship

(e) The density of air decreases as the altitude decreases. Hence, as the balloon eventually goes up in the air, the weight of the air displaced decreases. The balloon keeps rising until the up-thrust surpasses its own weight and stops rising once the up-thrust is equivalent to its weight.

(f) Density of sea water is more than that of river water. Consequently, as per the law of floatation, in order to balance the weight of the ship, more volume of water is required for the river water having lower density to displace it.