Exercise-5(A)

1. **What do you understand by the term upthrust of a fluid? Describe an experiment to show its existence.**
   Solution:
   Upthrust 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:

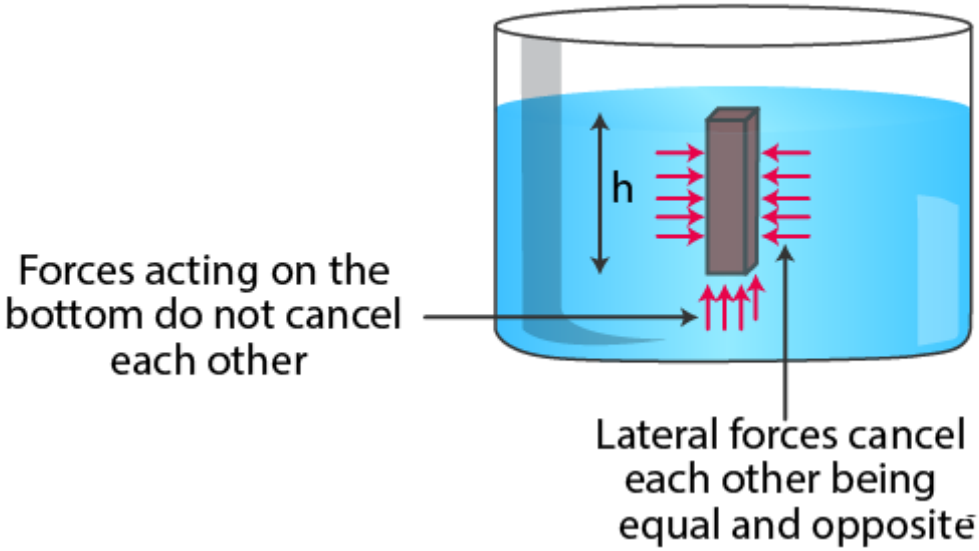
   When an empty can, with its mouth sealed with an airtight stopper is placed in a tub filled with water, it floats with a significantly larger portion of it above the water surface while only a small portion of it is present below the water surface.
   If we try to push the can we feel an upward force 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.

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

3. **What is meant by the term buoyancy?**
   Solution:
   Buoyancy is the property of liquid to exert an upward force on a body immersed in it.

4. **Define upthrust and state its S.I. unit.**
   Solution:
   Upthrust is also known as buoyant force. It is the upward force acting on a body when it is partially or fully immersed in a liquid.
   The S.I. unit of upthrust is Newton (N), since it is a force.

5. **What is the cause of upthrust? At which point it can be considered to act?**
   Solution:
   Liquid exerts pressure at all points and in all directions when contained in a vessel, this pressure on a liquid is the same in all directions and increases with depth inside the liquid.
   Upthrust is caused because of a difference in the pressures due to liquid on the two faces of a body (upper and lower) causing a net upward force known as upthrust. The thrust acting on the sides of the walls of the body get neutralized as they are equal in magnitude and opposite in directions.
   The upthrust is considered to act at the center of buoyancy i.e., the center of gravity of the displaced fluid.



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

7. **A piece of wood if left under water, comes to the surface. Explain the reason.**
   Solution:
   A piece of wood that is left under water comes to the surface as the upthrust on the block as a result of its submerged part is equivalent to its own weight.

8. **Describe an experiment to show that a body immersed in a liquid appears lighter than it really is.**
   Solution:
   The experiment explained below demonstrates that a body immersed in a liquid appears lighter than it actually is:
   Lifting of a bucket full of water from a well:
   - Tie a long rope to an empty bucket
   - When the bucket is immersed in the well, with one end of rope in hand and pulling the bucket when it is deep inside water, it is observed that it is easy to fetch the bucket as long as the bucket is in the water.
   - Once it is out of the water surface, drawing the bucket becomes difficult comparatively. It would require more force to be lifted.

   Hence the experiment clearly demonstrates that the water bucket appears lighter when it is immersed in water than its actual weight.

9. **Will a body weigh more in air or in vaccum when weighed with a spring balance? Give a reason for your answer.**
   Solution:
   A body weighs more in vaccum comparatively as there is no upthrust acting on the body in the absence of air.

10. **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.**
    Solution:
    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.

11. **A body dipped into a liquid experiences an upthrust. State two factors on which upthrust on the body depends.**
    Solution:
    The two factors on which upthrust on the body depends is:
    - Density of the liquid in which the body is submerged
    - Volume of the body immersed in the liquid

12. **How is the upthrust related to the volume of the body submerged in a liquid?**
    Solution:
    Upthrust acting on a body is greater if the volume of the body submerged in the liquid is larger.

13. **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 vaccum?**
    Solution:
    The feathers fall much after the stone falls because of air friction. The observation will be different in vaccum 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.

14. **A body experiences an upthrust F_1 in river water and F_2 in sea water when dipped up to the same level. Which is more F_1 or F_2? Give reason.**
    Solution:
    The body experiences more upthrust in sea water than the upthrust in river water, i.e., $F_2 > F_1$.
    It is because sea water is denser than river water.

15. **A small block of wood is held completely immersed in (i) water, (ii) glycerine and then released. In each case, what do you observe? Explain the difference in your observation in the two cases.**
    Solution:
    Volume of a block of wood immersed in glycerine is much smaller in comparison to the volume of the block that is immersed in water.

The density of glycerine is much more than that of water. Therefore, glycerine applies upthrust on the block of wood that is more than water which causes it to float in glycerine with low volume.

16. A body of volume V and density ρ is kept completely immersed in a liquid of density ρ_L. If g id the acceleration due to gravity, write expressions for the following:

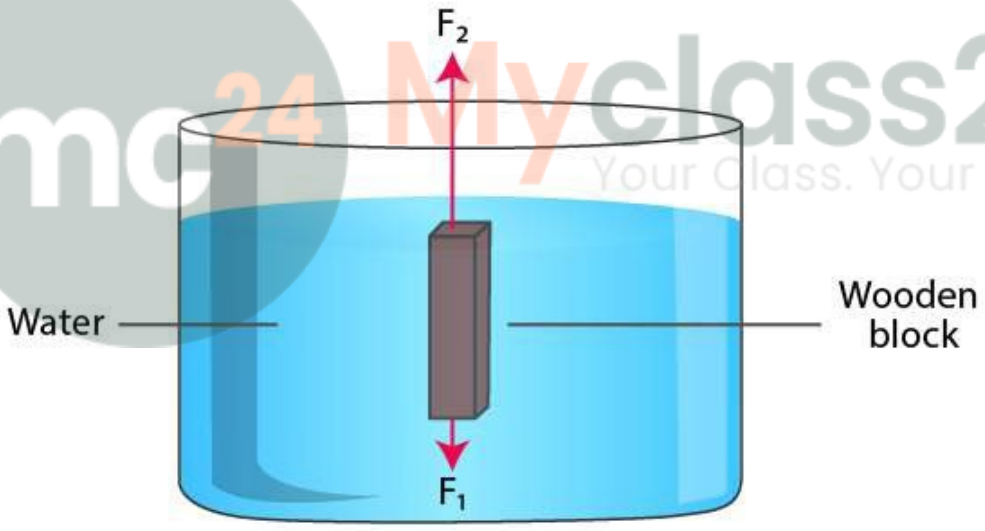
(i) The weight of the body
(ii) The upthrust on the body
(iii) The apparent weight of the body in liquid
(iv) The loss in weight of the body.

Solution:

(i) The weight of the body – V ρ g
(ii) The upthrust on the body – V ρ_L g
(iii) The apparent weight of the body in liquid – V(ρ - ρ_L)g
(iv) The loss in weight of the body - V ρ_L g

17. A body held completely immersed inside a liquid experiences two forces: (i) F_1, the force due to gravity and (ii) F_2, the buoyant force. Draw a diagram showing the direction of these forces acting on the body and state the conditions when the body will float or sink.

Solution:



The body floats if F_1 is lesser than F_2 or if both are equal. The body sinks if F_1 is greater than F_2.

18. Complete the following sentences:

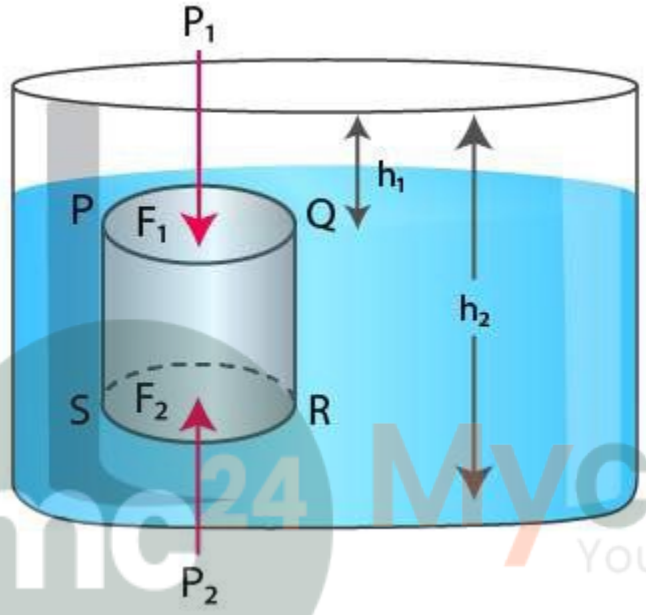
(a) Two balls, one of iron and the other of aluminum experience the same upthrust when dipped completely in water if _____
(b) An empty tin container with its mouth closed has an average density equal to that of a liquid. The container is taken 2m below the surface of that liquid and is left there. Then the container will _____
(c) A piece of wood is held under water. The upthrust on it will be _____the weight of the wood piece.

Solution:

(a) Both have equal volumes
(b) Remain at the same position
(c) More than

19. Prove that the loss in weight of a body when immersed wholly or partially in a liquid is equal to the buoyant force (or upthrust) and this loss is because of the difference in pressure exerted by liquid on the upper and lower surfaces of the submerged part of the body.

Solution:



Consider a cylindrical body PQRS of cross-sectional area A submerged in a liquid having density ρ as observed in the figure. Let the upper surface of the body PQ be at a depth h_1 while the lower surface of the body RS be at a depth h_2 below the surface of the liquid.

The pressure on the upper surface PQ at depth h_1 is:

$P_1 = h_1 \rho g$

The downward thrust on the surface PQ is given by

F_1 = pressure x area = $h_1 \rho g A$ ----- (i)

At depth h_2, the pressure on the lower surface RS

$P_2 = h_2 \rho g$

Upward thrust on the lower surface RS

F_2 = pressure x area = $h_2 \rho g A$ ---- (ii)

As the liquid pressure is the same at all points at the same depth, the horizontal thrust at various points on the vertical sides of the body get balanced.

From the equations (i) and (ii), we can deduce that $F_2 > F_1$ as $h_2 > h_1$ and hence the body will experience a net upward force.

The resultant upward thrust on the body

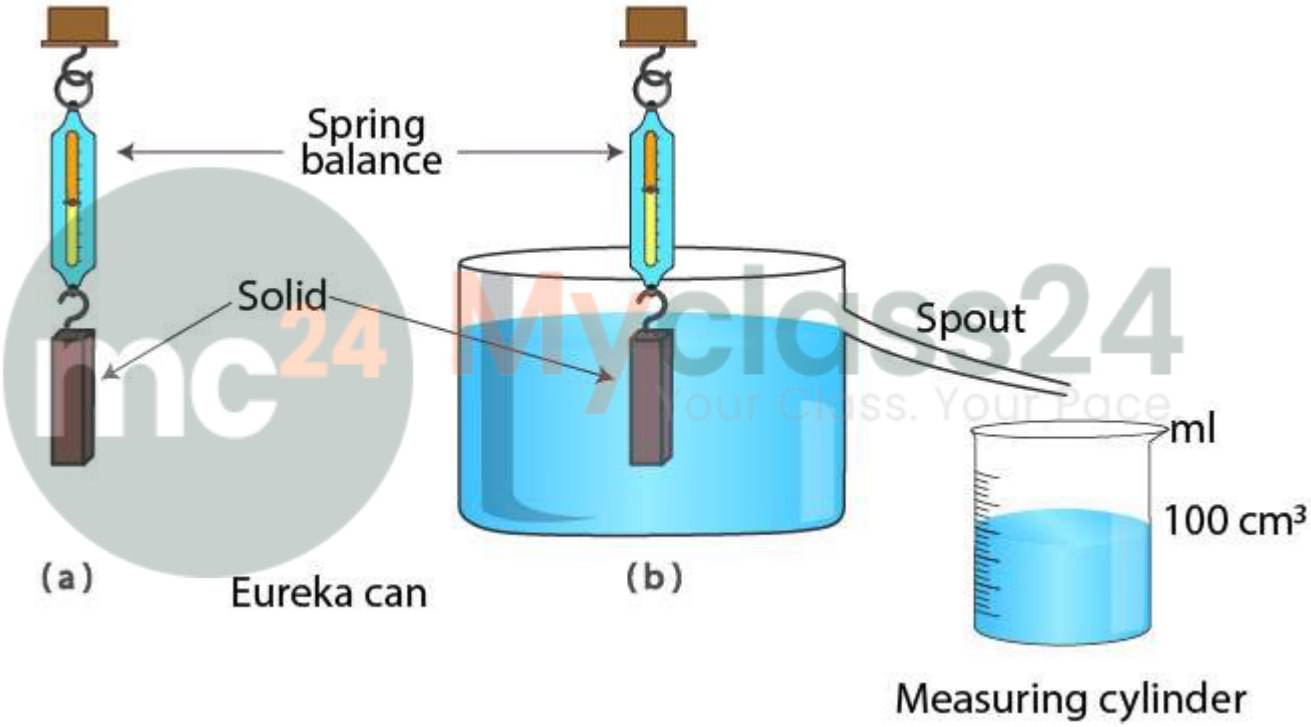
$F_B = F_2 - F_1$

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

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

But, we know that $A(h_2 - h_1)$ is the volume(V) of the liquid submerged in the liquid.
∴Upthrust $F_B = V \rho g$
$V \rho g$ = Volume of liquid displaced x density of liquid x acceleration due to gravity
= mass of liquid displaced x acceleration due to gravity
= weight of the liquid displaced by the submerged part of the body
Hence,
Upthrust = weight of the liquid displaced by the submerged part of the body -- (iii)

Take a solid now and suspend it by a thin thread from the hook of a spring balance, make note of its weight.
Fill a eureka can with water till its spout. Set up a measuring cylinder below the spout of the eureka can as observed in the diagram. Gently, submerge the solid in water and collect the dispersed water in the measuring cylinder.



Make note of the weight of the solid and the volume of the water that is assembled in the measuring cylinder once the water stops dripping through the spout.
It is clear from the diagram that the volume of the water displaced is equivalent to the difference of weight in air to the weight in water, i.e.,
Weight in air – weight in water = volume of water
Loss in the weight = volume of the water displaced x density of water [density of water = $1 gcm^{-3}$]
Loss in weight = weight of water displaced --- (iv)

From equations (iii) and (iv)
Loss in weight = upthrust
Hence proved.

20. A sphere of iron and another of wood of the same radius are held under water. Compare the upthrust on the two spheres.
[Hint: Both have equal volume inside water.]
Solution:
Volume of both the spheres inside water are the same as the spheres have the same radii. Therefore, the upthrust by water acting on both the spheres remains the same.
The upthrust acting on both the spheres is in the ratio 1:1

21. 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 reason to your answer.
Solution:
Between sphere of iron and sphere of wood, the sphere of iron would sink.
Explanation: density of water is lesser than the density of iron hence the weight of the sphere of iron would be more than the upthrust caused by water resulting in the iron sphere to sink.
Density of water is more than the density of wood hence the weight of the sphere of wood shall not sink but float with a volume immersed in water that is balanced by the upthrust due to water.

22. How does the density of material of a body determine whether it will float or sink in water?
Solution:
If a body has a density which is greater than that of a liquid, it will sink in it but if a body has average density that is equal to or lesser than that of the liquid, the body shall float on it.

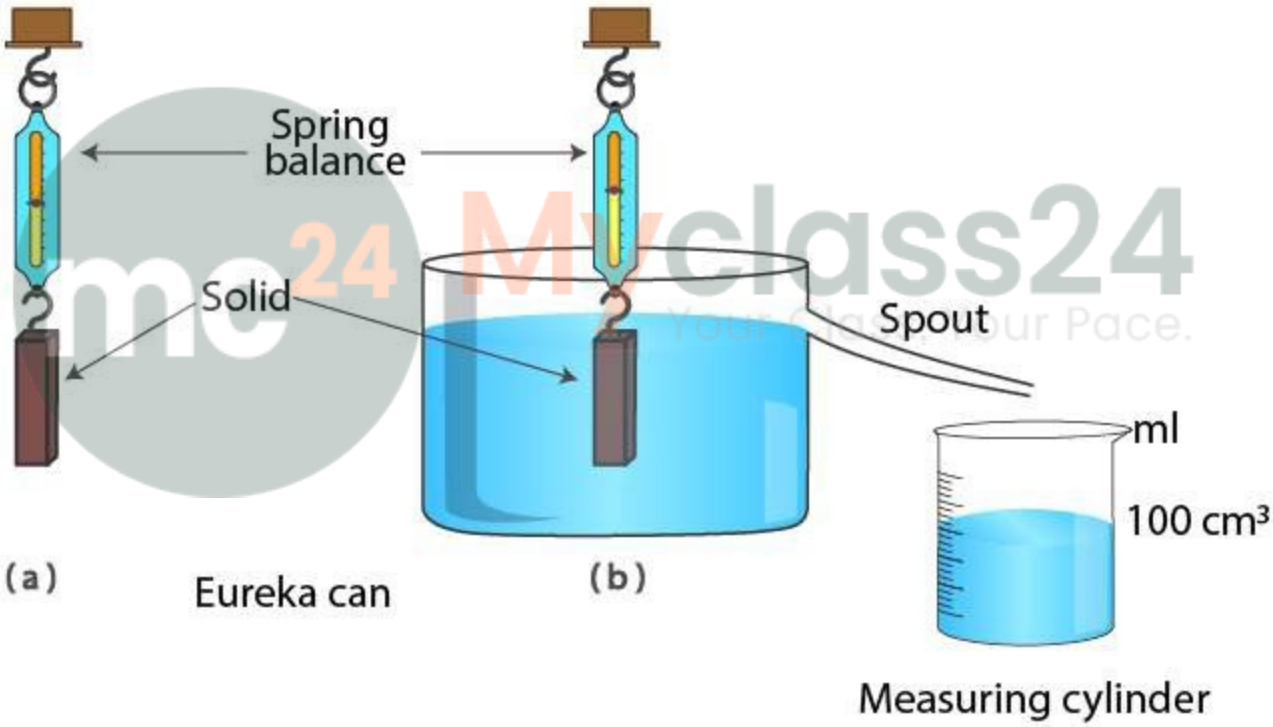
23. A body of density ρ is immersed in a liquid of density ρ_L. State condition when the body will (i) float, (ii) sink, in liquid.
Solution:
(i) The body will float when its density is lesser than or equal to the density of the liquid it is immersed in, that is to say, $\rho \leq \rho_L$
(ii) The body will sink in the liquid when the density of the body is greater than the density of the liquid it is immersed in, that is to say, $\rho > \rho_L$

24. It is easier to lift a heavy stone under water than in air. Explain.
Solution:
It is because in water, the stone experiences an upward buoyant force that balances the true weight of the stone which is acting in the opposite direction (weight acts downwards). Therefore, as a result of the upthrust, the heavy stone seems to be lighter because of the apparent loss of weight of the stone, making it easier to lift.

25. State Archimedes' principle.
Solution:
Archimedes' principle states that when a body is immersed partially or completely in a liquid, it experiences an upthrust which is equal to the weight of the liquid displaced by it.

26. Describe an experiment to verify Archimedes' principle.
Solution:
Experiment to verify Archimedes' principle:
- Suspend a solid by a thin thread from the hook of a spring balance. Make note of its weight

- Fill a eureka can with water up till its spout. Set up a measuring cylinder below the spout of the eureka as observed in the diagram. Gently, submerge the solid in water and collect the dispersed water in the measuring cylinder.
- Make note of the weight of the solid and the volume of the water that is assembled in the measuring cylinder once the water stops dripping through the spout.
- It is clear from the diagram that the volume of the water displaced is equivalent to the difference of weight in air to the weight in water, i.e.,
  Weight in air – weight in water = volume of water
  - ⇨ 300gf – 200gf =100gf
  - ⇨ Volume of water displaced is equal to the volume of solid which is equivalent to $100cm^3$
  - ⇨ As we know that the density of water is $1gcm^{-3}$
  - ⇨ Hence the weight of the water displaced is equivalent to the loss in weight or the upthrust =100gf



- ⇨ Hence the Archimedes' principle is verified.

Multiple Choice type:

1. **A body will experience minimum upthrust when it is completely immersed in:**
   (a) Turpentine
   (b) Water
   (c) Glycerine
   (d) Mercury
   Solution:
   (a) Turpentine

Lesser the density of the liquid, lesser the upthrust experienced by a body. Amongst these, turpentine has the least density.

2. **The S.I. unit of upthrust is:**
   (a) Pa
   (b) N
   (c) kg
   (d) kg m^{-3}
   Solution:
   (b) N
   Since, upthrust is a force, its S.I. unit is Newton (N)

3. **A body of density ρ sinks in a liquid of density ρ_L. The densities ρ and ρ_L are related as:**
   (a) $\rho = \rho_L$
   (b) $\rho < \rho_L$
   (c) $\rho > \rho_L$
   (d) nothing can be said
   Solution:
   (c) $\rho > \rho_L$
   Bodies of density greater than that of liquid, sink in it, while bodies of average density equal to or smaller than that of liquid, float on it.

Numericals:

1. **A body of volume 100cm^3 weighs 5kgf in air. It is completely immersed in a liquid of density 1.8 x 10^3 kg m^{-3}, find: (i) the upthrust due to liquid and (ii) the weight of the body in liquid.**
   Solution:
   Given:
   Weight of the body in air = 5kgf
   Volume of the body =100cm^3
   Density of the liquid = 1.8 x 10^3 kgm^{-3}
   (i) Upthrust due to liquid = volume of the solid x density of fluid x acceleration due to gravity
   = 100 x 10^{-1} x 1.8 x 10^{-2} x g
   = 0.18kgf
   (ii) weight of the body in liquid = weight of the body in air – upthrust
   = 5kgf – 0.18 kgf
   = 4.82 kgf

2. **A body weighs 450 gf in air and 310 gf when completely immersed in water. Find:**
   (i) The volume of the body,
   (ii) The loss in weight of the body, and
   (iii) The upthrust on the body.
   State the assumption made in part (i).
   Solution:
   Given: weight of the body in air=450kgf

Weight of the body in water =310kgf
Assumption: density of water = 1gcm^{-3}

(i) To find the volume of the body
Volume of the body = density of water x loss in weight
= 1 x (difference in the body weight)
= 1 x (450-310)
= 140 cm^3

(ii) To find the loss in weight of the body
Loss in weight = weight of the body in air – weight of the body in water
= 450 – 310
= 140 gf

(iii) To find the upthrust on the body
Upthrust = loss in weight = 140gf
Assumption made is density of water is 1g cm^{-3}

3. You are provided with a hollow iron ball A of volume 15cm^3 and mass 12g and a solid iron ball B of mass 12g. Both are placed on the surface of water contained in a large tub. (a) Find upthrust on each ball. (b) Which ball will sink? Give reason for your answer.(Density of iron = 8.0 gcm^{-3})

Solution:
Mass of ball A = 12g
Mass of ball B = 12g
Density of iron = 8gcm^3
Volume of the hollow iron ball A = 15cm^3
Volume of the hollow iron ball B = Mass/density = 12/8 = 1.5cm^{-3}

(a) To find the upthrust on ball A and B
Upthrust on ball A = volume of iron ball A x density of water x g
= 15 x 1 x g = 15gf
Upthrust on ball B = volume of iron ball B x density of water x g
= 1.5 x 1 x g = 1.5gf

(b) Hollow iron ball B will sink
Upthrust on ball B is 1.5gf which is less than its weight 12gf, while upthrust on ball A will be 15gf if it is fully submerged, which is greater than its weight 12gf, so it will float with its submerged part for which the upthrust becomes equal to its weight which is 12gf.

4. A solid of density 5000kgm^{-3} weighs 0.5kgf in air. It is completely immersed in water of density 1000 kg m^{-3}. Calculate the apparent weight of the solid in water.

Solution:
Given:
Weight of the solid = 0.5kgf
Density of the solid = 5000 kgm^{-3}
Density of water = 1000 kgm^{-3}
Upthrust = volume of the solid x density of water x g
= (0.5/5000) x 1000 x g
= 0.1kgf
We know that, apparent weight = true weight – upthrust

= 0.5-0.1 = 0.4 kgf

5. **Two spheres A and B, each of volume 100cm^3 are placed on water (density =1.0g cm^{-3}). The sphere A is made of wood of density 0.3g cm^{-3} and the sphere B is made of iron of density 8.9g cm^{-3}.**
   (a) Find: (i) the weight of each sphere, and (ii) the upthrust on each sphere.
   (b) Which sphere will float? Give reason.
   Solution:
   Given:
   Density of water = 1gcm^{-3}
   Density of sphere A = 0.3 gcm^{-3}
   Density of sphere B = 8.9 gcm^{-3}
   Volume of sphere A & B = 100 cm^3
   (a) (i)To find the weight of sphere A and B
   Weight of sphere A = density of sphere A x volume of sphere x g
   = 0.3 x 100 x g = 30gf
   Weight of sphere B = density of sphere B x volume of sphere x g
   = 8.9 x 100 x g = 890gf
   (ii) To find upthrust on each sphere
   Upthrust on sphere A = volume of sphere A x density of water x g
   = 100 x 1 x g = 100gf
   Upthrust on sphere B = volume of sphere B x density of water x g
   = 100 x 1 x g = 100 gf
   Upthrust acting on both the spheres is the same as the volume of spheres A and B inside water is the same
   (b) Sphere A will float as the density of wood is lesser than that of water.
   If a body has a density which is greater than that of a liquid, it will sink in it but if a body has average density that is equal to or lesser than that of the liquid, the body shall float on it.

6. **The mass of a block made of a certain material is 13.5kg and its volume is 15 x 10^{-3} m^3.**
   (a) Calculate upthrust on the block if it is held fully immersed in water
   (b) Will the block float or sink in water when released? Give reason for your answer
   (c) What will be the upthrust on block while floating? Take density of water = 1000 kg m^{-3}.
   Solution:
   Given:
   Mass of the block = 13.5kg
   Volume of the block = 15 x 10^{-3} m^3
   Density of water = 1000 kg m^{-3}
   (a) To find the upthrust on the block
   Upthrust on the block = volume of the block x density of water x g
   = 15 x 10^{-3} x 1000 x g = 15 kgf
   (b) The block will float on water as the upthrust on it is more than its weight when immersed completely in water
   (if mass is 13.5kg, weight = 13.5kgf)
   (c) When the block is floating, the upthrust is equivalent to its weight = 13.5kgf

7. A piece of brass weighs 175gf in air and 150 gf when fully immersed in water. The density of water is 1.0gcm^{-3}. (i) What is the volume of the brass piece? (ii) Why does the brass piece weigh less in water?

Solution:

Given:

Weight of brass piece in air = 175gf

Weight of the brass piece in water = 150gf

Density of water = 1.0gcm^{-3}

(i) To find the volume of the brass piece

We know that volume of a body is the loss in weight of the body

∴ Volume = loss in weight = 175 – 150 = 25 cm^3

(ii) The brass piece weighs lesser in water due to upthrust.

8. A metal cube of edge 5cm and density 9.0 gcm^{-3} is suspended by a thread so as to be completely immersed in a liquid of density 1.2 gcm^{-3}. Find the tension in thread. (Take g = 10 m/s^2)

[Hint: Tension in thread = apparent weight of the cube in liquid]

Solution:

Given:

Density of metal cube = 9.0 gcm^{-3}

Density of liquid = 1.2 gcm^{-3}

Side of the cube = 5cm

⇨ Volume of the cube = 5 x 5 x 5 = 125cm^3

To find weight of the cube:

Mass of the cube = volume of the cube x density of the cube

= 125 x 9 = 1125 g

∴ Weight of the cube = 1125 gf

Weight of the cube acts downwards

Upthrust acting on the cube = weight of the liquid moved

= volume of the cube x density of the liquid x g

= 125 x 1.2 x g = 150gf

Upthrust on the cube acts in the upward direction

Tension in thread = total force acting in the downward direction

= weight of the cube acting downwards – upthrust acting on the cube

= 1125 – 150 = 975gf or 9.75N

9. A block of wood is floating on water with its dimensions 50cm x 50 cm x 50 cm inside water. Calculate the buoyant force acting on the block. Take g = 9.8N kg^{-1}.

Solution:

Given:

Volume of the block = 50cm x 50cm x 50cm = 125000cm^3

Expressing volume in m^3 => 0.125 m^3

g = 9.8N kg^{-1} or 9.8m/s^2

We know that buoyant force = V ρ g

⇨ 0.125 x 1000 x 9.8 = 1225N

10. A block of mass 3.5kg displaces 1000cm^3 of water when fully immersed inside it. Calculate: (i) the volume of body, (ii) the upthrust on body and (iii) the apparent weight of body in water.

Solution:

Given:

Mass of block = 3.5kg => weight of the body = 3.5kgf

Volume of the water displaced when completely immersed in water = 1000cm^3

(i) To find the volume of the body when completely immersed in liquid is equivalent to the volume of the water displaced

Volume of the block = 1000 cm^3 or 0.001m^3

(ii) Upthrust acting on the body = volume of the body x density of water x g

= 0.001 x 1000 x g = 1 kgf

(iii) The apparent weight of body in water= true weight – upthrust

=3.5-1 = 2.5kgf