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Physical Quantities & Measurement

Q) A block of 30cm, 25cm & 2 cm as. Find its density if mass is 7.5kg.

Sol. Volume = $30cm \times 25cm \times 2cm = 1500cm^3$

Mass = $7.5kg = 7500g$.

Density = $\frac{\text{Mass}}{\text{Volume}} = \frac{7500\,g}{1500\,cm^3} = 5\,g\,cm^{-3}$

$= 5000kg\,m^{-3}$.

Q) Density of Ag = $10300\ kgm^{-3}$. A block of Ag displaces 200ml of water. Find mass of silver block.

Sol. Density of Ag = $10300\ kgm^{-3} = 10.3\,g\,cm^{-3} = \frac{10.3\,g}{ml}$

Let the mass of Ag be = X grams.

Volume of Ag = 200 ml.

Now, $\frac{x}{200} = \frac{10.3\,g}{1ml}$ ~~$\Rightarrow x = 2 \times 10.3\,g = 2kg$~~.

$\Rightarrow x = 10.3 \times 200\,g = 2060\,g = 2.06\,kg$.

Q) A piece of iron when immersed in water taken in Eureka can displaced 25ml of water. Its mass is 195gm. Find the density of iron in kgm^{-3}.

Sol. Mass of iron = 195 g = 195×10^{-3} kg.
Volume of iron = Amount of water displaced
= 25 ml = 25 cm^3 = 25×10^{-6} m^3
So density of iron = $\frac{\text{Mass of iron}}{\text{Volume of iron}} = \frac{195 \times 10^{-3}}{25 \times 10^{-6}}$ kgm^{-3}

$= \frac{195}{25} \times \frac{10^3}{1000}$ kgm^{-3} = 7.8×10^3 kgm^{-3}.

NOTE :- 1 g/cc = [redacted] kgm^{-3}.
because ⇒ $1g = 10^{-3}$ kg and $1cm^3 = 10^{-6}$ m^3
* Density of water = $1gcm^{-3}$ = 1000 $kg\,m^{-3}$

(Q) Density of air 1.28 g/l. Express it in
a) gcm^{-3}.
Sol. Mass = 1.28 g ; Volume = 1 l = 1000 cm^3
∴ Density of air = 1.28×10^{-3} $g\,cm^{-3}$.
b) $kg\,m^{-3}$
Sol. Mass = 1.28 g = 1.28×10^{-3} kg.
Volume = 1 l = 10^{-3} m^3.
∴ Density of air = $1.28 \times 10^{-3} \times 10^{3} \times$ kgm^{-3}
= 1.28 $kg\,m^{-3}$

Q) Mass of density 51.5 g when empty, 76.5 g when filled with water & 71.85 g when filled with oil. Find.

a) Capacity of density bottle:

Mass of water = $(76.5 - 51.5)\ g = 25g$.

∴ Volume of water = Volume of density bottle

$= 25\ cm^3$. (as ρ of water = $1\ g\ cm^{-3}$)

(b) Density of oil :-

$$\frac{(71.85 - 51.5)g}{25\ cm^3} = \frac{20.35g}{25\ cm^3} =$$

$= 0.814\ g\ cm^{-3}$. $= 814\ kg\ m^{-3}$

Q) Mass of $10cm^3$ silver is 103g. Find

a) Density of silver =

$10.3\ g\ cm^{-3} = 10300\ kg\ m^{-3}$

b) Relative density of silver = 10.3

Home assignment

Numerical

4. Density of alcohol = $600\ kg\ m^{-3} = 0.6\ g\ cm^{-3}$.

6. Mass of wood = 150 g = 0.15 kg

Volume " " = $200\ cm^3 = 2 \times 10^{-4}\ m^3$

∴ Density of wood = $0.75\ g\ cm^{-3} = 750\ kg\ m^{-3}$

8. Density = $\frac{72}{42-24}\ g\ cm^{-3} = 4\ g\ cm^{-3}$

B·5. In general, when a fluid is heated, its intermolecular spaces increase. So, the volume increases. As density is inversely proportional to volume, density decreases.

9. Density bottle is a specially designed bottle with a fixed volume (generally 50ml). It is used to find relative density. It is first filled completely with water. Then the mass of the dry bottle is subtracted. As we now know the mass of water, we calculate the volume of bottle. Then another liquid is poured in and its mass is measured. As we now have density of water & the liquid, we can calculate Relative density.

Home assignment

1. Mass of water = 65g - 35g = 30g
∴ volume = $30 cm^3$
Mass of alcohol = (59 - 35)g = 24g
∴ Density of alcohol = $\frac{24}{30} g cm^{-3} = 0.8 g cm^{-3}$
∴ R.D of u = 0.8

B 12 ~~00~~ 9. Mass per unit volume of a substance is called density. Ratio of density of a substance & water is called relative density. It has no units.

B13. Relative density of aluminium is 2:7 means that

$$\frac{\text{Density of Aluminium}}{\text{Density of water}} = \frac{2}{7}.$$

Numerical 9. Mass of water = $(41.8 - 21.8)g = 20g$.

∴ Volume of bottle = $20g$.

Mass of liquid = $(40.6 - 21.8)g = 18.8g$

∴ Density of liquid = $0.94\ g cm^{-3}$

∴ R.D of liquid = 0.94

10. Mass of water = 28 g

∴ Volume of bottle = $28 cm^{-3}$

Mass of brine = 32g.

∴ Density of brine = $\frac{32}{28} g cm^{-3} \approx 1.14 g cm^{-3}$

∴ R.D of brine = 1.14

Buoyant force

- Whenever a body is immersed partially/fully in a liquid, it experiences upward force i.e the buoyant force or upthrust. The tendency of the liquid to apply upthrust on the body is called buoyancy.
- As a result of this, the weight of the blck decreases. Eg:- If a spring balance is placed

below the body, the reading will be less. This is apparent weight.

- Let W_B = True Weight of body
W_L = Buoyant force by the liquid, then,

$W_A = W_B - W_L$, $\Rightarrow W_L = W_B - W_A$

where W_A = Apparent weight

Buoyant force = Loss in weight = Upthrust

* Apparent weight is the weight of a solid in a liquid.

Factors of buoyant force

- Buoyant force depends on volume i.e volume of fluid displaced i.e the volume of immersed solid
- It also depends on the density of the liquid.

* Higher the volume of water displaced, higher the loss in weight, i.e higher the buoyancy
* Higher the density of liquid, higher the buoyant force.

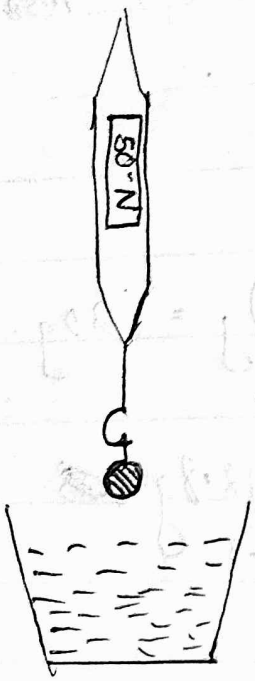
Archimedes Principle

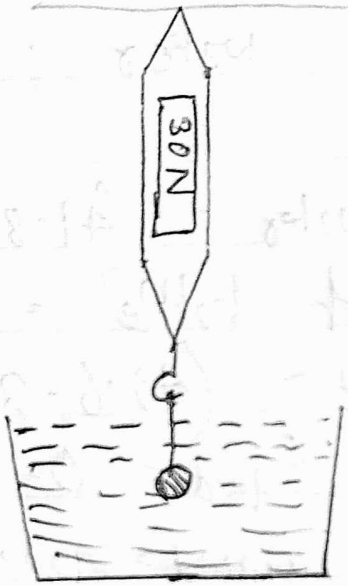
Loss in weight = Weight of fluid displaced
= Upthrust = Buoyant force

Buoyant force = $V\rho g$

where = V = volume of immersed part of solid
= amount of liquid displaced

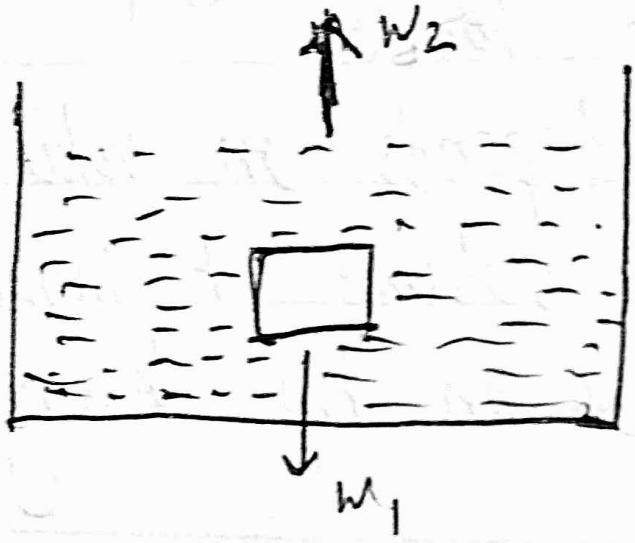
ρ = density of liquid in which solid is immersed.



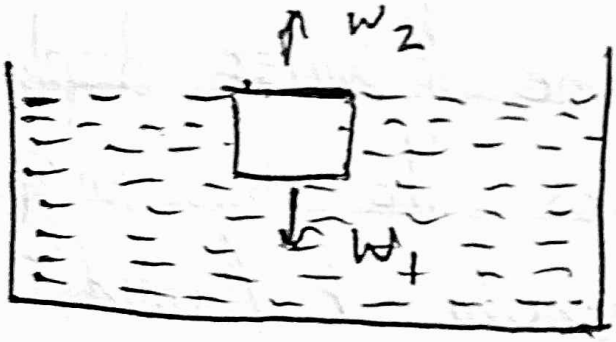


∴ Buoyant force
= 20 N

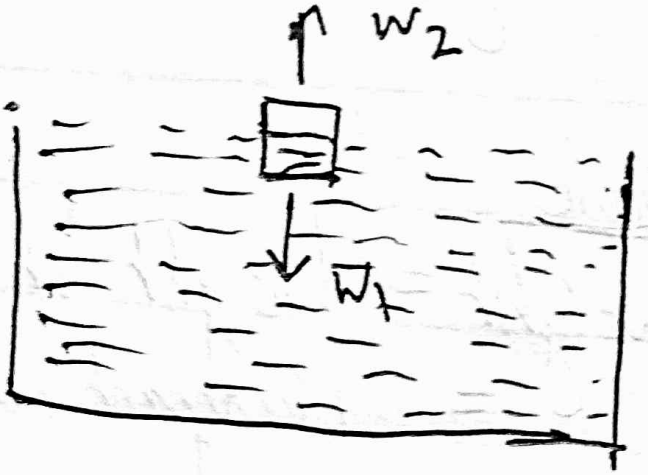
Case 1.



Case 2.



Case 3.



Principle of Floatation :-

★ A solid floats in liquid when true weight of a body is equal to the buoyant force.

★ Eg :- In the previous example,

True wt - Apparent wt = Loss in wt

$\Rightarrow$ 5kgf - 3kgf = 2kgf.

But if Apparent wt = 0,

then,

loss in wt = Buoyant force = True wt (= Floats)

Case I° $W_1 > W_2$, then the body will sink down

Case 2: $W_1 = W_2$, then, the body will float (but just the upper surface of the body will touch the upper surface of water.)

Here, apparent weight is 0.

Case 3: $W_1 < W_2$ then, the body will float (but some part of the solid is also above the liquid.)

Here also apparent weight is 0.

Difference between 2nd & 3rd case

- For 2nd case,

Weight of body = Upthrust

$Mg = mg$ (M = body's mass & m = mass of fluid displaced)

$V_{solid} \times \rho_{solid} \times g = V_{liquid\ displaced} \times \rho_{liquid} \times g$

As, $g = g$ & $V_{solid} = V_{liquid\ displaced}$,

$$\boxed{\rho_{solid} = \rho_{liquid}}$$

- For 3rd case,

$Mg = mg$

$V_{solid} \times \rho_{solid} \times g = V_{liquid\ displaced} \times \rho_{liquid} \times g$

Here, $g = g$, but $V_{solid} > V_{liquid\ displaced}$

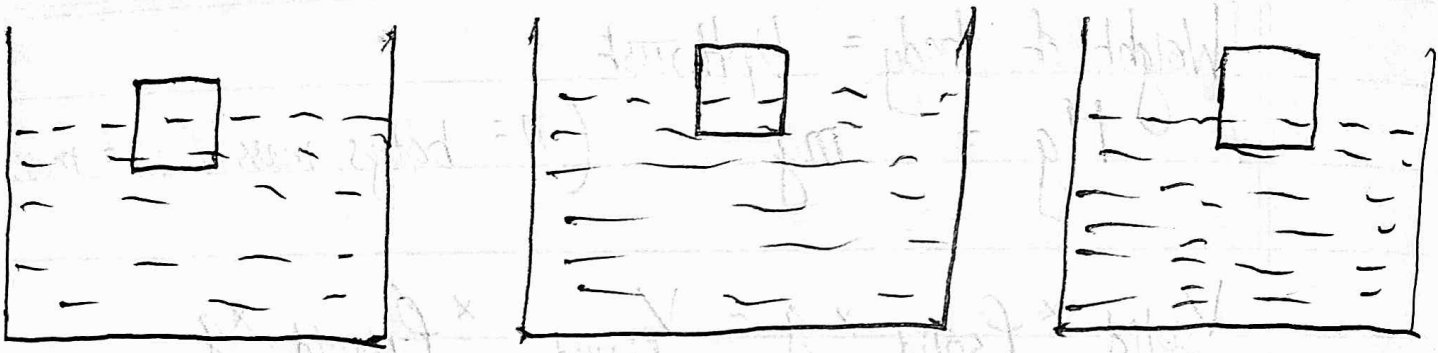
$\therefore$ $$\boxed{\rho_{solid} < \rho_{liquid}}$$

★ Similarly for first case,

$V_{solid} = V_{liquid\ displace}$ and,

$M > m$ then, $\boxed{\rho_{solid} > \rho_{liquid}}$

(as $Mg > mg$)


A
B
C

Q) $\rho_{water} = 1 g/cc$; $\rho_{iron} = 7.8 g/cc$, $\rho_{mercury} = 13.6 g/cc$

i) Will Fe float on H_2O? Sink

ii) Will Fe float/sink on Hg? Float

Q) In the diagram given, the same body is placed in 3 liquids A, B, C.

i) Which liquid has highest buoyant force? Upthrust is same

ii) Which liquid has highest density? C

iii) " " " least " ? A

Sol: Let V_A, V_B, V_C be liquid displaced by solid, & ρ_A, ρ_B, ρ_C are densities of these liquids, then, in each case, body is floating, so,

$$Mg = V_A \rho_A g = V_B \rho_B g = V_C \rho_C g.$$

As g = constant, & $V_A > V_B > V_C$,

$$\rho_A < \rho_B < \rho_C$$

B.14. If ρ_B is the density of body & ρ_l is the density of liquid, then,

the body will float if $\rho_B \leq \rho_l$

& the body will sink if $\rho_B > \rho_l$.

B·10· The density of a body w·r·t· water is called the relative density.

B·11· Relative density has no units.

B·17· Law of floatation states that a body will float over a liquid only if its density is less than equal to the density of the liquid.

or

Law of floatation states that a body will float over a liquid only when the apparent wt is zero. (ie when the buoyant force is more than equal to weight of the body.)

Floatation of Ship

An iron ship is hollowed (i.e it is filled with air inside it. Due to this, the average density of the ship is less than that of sea water.
On the other hand, nail of sinks as there is no hollow space. So, its density is greater than water.

Q) Relative density of ice w·r·t sea water is 0·9. What % of it will submerge inside water.
a) 45 %. b) 90 %. c) 60 %. d) 50 %.

Let the density of sea water be x, then, Let the required volume of submerged solid is V, then,

$$\frac{0.9x \times V \times g}{x \times V \times g} \times 100\% = 90\%.$$

a) Density of water at 4°C is $1 g cm^{-3}$. In MKS, it'll be,
(d) $10^3 kgm^{-3}$.

Icebergs :- Density of ice = $0.9 g cm^{-3}$ and density of sea water = $1.02 g cm^{-3}$. So, True weight of ice berg = Water displaced by Iceberg (As Apparent weight = 0).

True weight of ice berg = Total Volume of ice $\times \rho_{ice} \times g$

$= V \times 0.9 \times g$

Weight lost = Water displaced $\times \rho_{sea} \times g = V' \times 1.02 \times g$

$$\therefore \frac{V}{V'} = \frac{0.9 \times g}{1.02 \times g} = 88\%$$

$\therefore$ 88% of the iceberg is submerged. Only 12% is above water.

Q) When a body floats in water, $\frac{1}{3}^{rd}$ volume remains outside

Water. When it floats in another liquid, $3/4^{th}$ is outside. The density of the liquid is (b) $\frac{8}{3}$ g/cc.

Sol: $V \times \rho_{solid} \times g = \frac{2}{3} V \times \rho \times 1 \times g$

$\therefore \rho_{solid} = \frac{2}{3}$ g/cc. Now,

$V \times \frac{2}{3} \times g = \frac{1}{4} V \times \rho_{liquid} \times g \Rightarrow \rho_{liquid} = \frac{8}{3}$ g/cc

Exercize Questions

A. I. a) False b) False c) True d) True e) False f) False g) True h) False i) True j) True

2. a) 1000 b) Volume c) kgm^{-3} d) 1000 e) 1000 f) more g) less h) greater i) same j) zero

3. a) kgm^{-3} → (iv) Density ; b) No unit → i) Relative density c) Relative Density → v) Density bottle ; d) Iron → ii) Sinks in alcohol e) Wood → iii) Floats on water

4 a) → ii) ; b) → ii) ; c) → iii) 48 g ; d) → (ii) ; e) → (ii) ; f) → (iii) ; g) → (iii) ; h) → (i)

B. 2. S.I unit of density = kgm^{-3}. and $1 kgm^{-3} = \frac{1}{1000} g\,cm^{-3}$

3. It means that mass of $1cm^{-3}$ volume of brass is 8.4g

4. Cork, Water, Iron, Brass, Mercury

6. When liquid is heated its volume increases so, its density decreases.

7. Aim :- To determine density of a coin
Apparatus :- Measuring Cylinder, A coin, a thread, water
Procedure :-
A thread is tied to the coin and the coin is dipped in the Measuring cylinder. The rise in level of water is noted from which the volume of the displaced water is noted. After this, the mass of coin is measured using physical balance.
Conclusion :-
The value of mass is divided by volume to obtain desity.

8. Aim :- To determine density of a liquid
Apparatus :- Density bottle of volume 50ml, the required liquid.
Procedure :-
The density bottle is completely filled with the liquid, and its mass is measured (let it be M_1). Then the density bottle is rinsed and dried in the Sun. Now the mass of the empty bottle is measured (let it be M_2).
Conclusion :-

Mass of liquid = $M_1 - M_2$. Volume = 50ml.
The mass is divided by the volume to obtain density.

15. The density of cork is less than that of water so it floats. While iron nail has a higher density, so it sinks.

16. a) Float b) Sink c) Sink d) Float

20. For a floating body, Weight = Buoyant force

21. Ice has a lower density w.r.t water. So, it floats on water.

22. In an iron ship a lot of empty space is present inside it, so its average density becomes less than that of water. So it floats on water. A needle doesn't have empty space, so, it sinks.

23. Sea water has greater density than river water. So, it offers a greater drag than that of pure water, so it is difficult to swim in sea water.

24. Majority of the icebergs is present inside the waters hence they are not completely visible to ships. So, many of them collide with iceberg.

25. The apparent weight of stone in water is less than that of the true weight of stone. So, it is easy to lift it under water.

26. A submarine is a large vehicle which can move under water like a ship. It can be made to sink & rise inside the water by changing the amount of water present in the tanks of the submarine.

27. Hydrogen has the least density w.r.t. the atmosphere, so, it rises upwards.

C.1. a) 0.00128 g/cc b) 1.28 kgm^{-3}

2. Volume = 350m^3, Density = 1.11 kgm^{-3}
Mass = 11.1 × 35 kg = 388.5 kg

5. Density = $\frac{438.6}{86.2}$ = 5.1 gcm^{-3} = 5100 kgcm^{-3}

7. Density of wood = 0.8 gcm^{-3} = 800 kgm^{-3}.
Mass " " = 6000 kg
∴ Volume = 7.5m^3.

11. a) 45ml b) $\frac{35}{45}$ g/cc = $\frac{5}{7}$ gcm^{-3}

c) Relative density = $\frac{5}{7}$.