GRAVITY CLASSES

"Come Gravity Feel Success"

11th & 12th BOARD
(NEET & JEE)

5th - 10th (All Subject)

NOTES
PHYSICS

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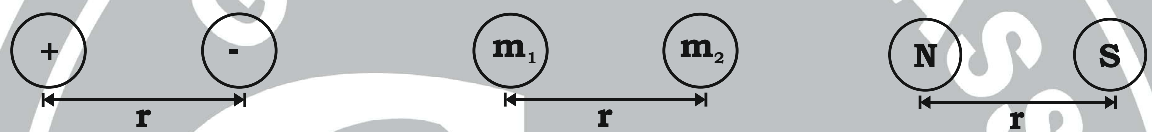
GRAVITATION

Universal Law of Gravitation:-

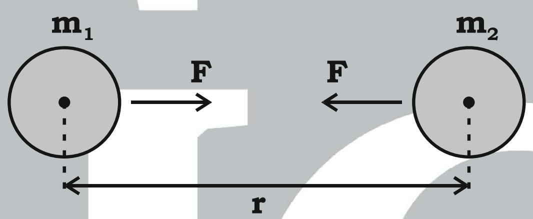
→ It states that "Every body in the universe attracts every other body with a **force** which is **directly** proportional to the **product** of their **masses** and **inversely** proportional to the **square of the distance** between them".

or

→ Force is independent of medium (air, water, oil etc.) "Gravitational Force is a **Non-Contact Force**".
→ Valid for point masses.
→ Significance heavy bodies.
→ It is always **Attractive** in Nature.
→ Depends **directly** on the **masses** and **inversely** on the **square** of the **distance**.
→ **Inverse square law** (applicable to charges, masses, magnetic poles).



(Electrostatic Force) (Gravitational Force) (Magnetic Force)



$F \propto m_1 \times m_2$

$F \propto \frac{1}{r^2}$

$F \propto \frac{m_1.m_2}{r^2}$

$$\boxed{F = \frac{G\,m_1.m_2}{r^2}}$$

Where, '**Cavendish**' gives this value.

G = Universal Gravitational Constant (UGC)

$= 6.67 \times 10^{-11}\ Nm^2/kg^2$

or

$= 6.7 \times 10^{-11}\ Nm^2/kg^2$

m_1 & m_2 = Mass of object one and second resp.

r = Distance between two mass object.

F = Force

Finding **SI unit** of 'G'.

$$F = \frac{G m_1.m_2}{r^2}$$

$$N = \frac{G \times kg \times kg}{m^2}$$

$$Nm^2 = G \times kg^2$$

$$\boxed{\frac{\mathbf{Nm^2}}{\mathbf{kg^2}} = \mathbf{G}}$$ (**G**→Units of G)

Q. Two masses of 1 kg each are separated by a distance of 1m. Find the force between them.

Sol. Given, m_1 = 1 kg, m_2 = 1 kg, r = 1 m, G = 6.7×10^{-11}

We known,

$$F = \frac{G.m_1.m_2}{r^2} \Rightarrow \frac{6.7 \times 10^{-11} \times 1 \times 1}{1^2} \Rightarrow \boxed{\mathbf{F = 6.7 \times 10^{-11} N}}$$

Q. The mass of the earth is 6×10^{24} kg and that of the moon is 7.4×10^{22} kg. If the distance between the earth and the moon is 3.84×10^5 km. Calculate the force exerted by the earth on the moon.

Sol. Mass of earth = 6×10^{24} kg

Mass of moon = 7.4×10^{22} kg

Distance = 3.84×10^5 **km** ⇒ $3.84 \times 10^5 \times 10^3$ **m**

We know,

$$F = \frac{G.m_1.m_2}{r^2}$$

$$= \frac{(6.7 \times 10^{-11}) \times (6 \times 10^{24}) \times (7.4 \times 10^{22})}{(3.84 \times 10^8)^2}$$

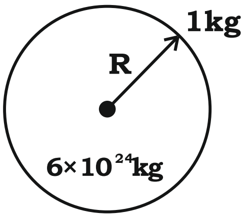
$$= \left(\frac{6.7 \times 6 \times 7.4}{3.84 \times 3.84}\right) \times \frac{(10^{-11} \times 10^{46})}{10^{16}}$$

$$= \left(\frac{297.48}{14.748}\right) \times (10^{-27} \times 10^{46})$$

$$\boxed{\mathbf{F = 20.18 \times 10^{19} N}}$$

Q. What is the magnitude of the gravitational force between the earth and a 1 kg object on its surface ? (Mass of the earth is 6×10^{24} kg and radius of the earth 6.4×10^6 m).

Sol.



Neglect body mass to earth because its too small as compare to Earth.

$$F = \frac{Gm_1.m_2}{r^2}$$

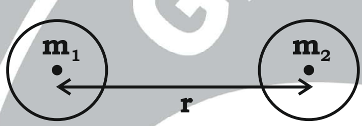
$$= \frac{(6.7\times10^{-11})\times(1)\times(6\times10^{24})}{(6.4\times10^{6})^2}$$

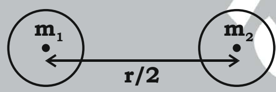
$$= \left(\frac{6.7\times1\times6}{6.4\times6.4}\right)\times\left(\frac{10^{-11}\times10^{24}}{10^{12}}\right)$$

$= 0.98 \times 10$

F = 9.8N

Q. How does the force of gravitation between two objects change when the distance between them is reduced to half ?





Sol. $F = \frac{Gm_1.m_2}{r^2}$ **.....(i)**

$$F' = \frac{Gm_1.m_2}{\left(\frac{r}{2}\right)^2}$$

$$= \frac{Gm_1.m_2}{\left(\frac{r^2}{4}\right)}$$

$$= \frac{4Gm_1.m_2}{r^2} \quad .....(ii)$$

Dividing eq (ii) by eq (i)

$$\frac{F'}{F} = \frac{4Gm_1.m_2}{r^2} \div \frac{Gm_1.m_2}{r^2}$$

$$\frac{F'}{F} = 4 \quad \Rightarrow \boxed{F' = 4F}$$

✳ After reducing the distance **2 half** of the previous value the **Force** becomes the **4 times**.

Acceleration due to Gravity (g):-

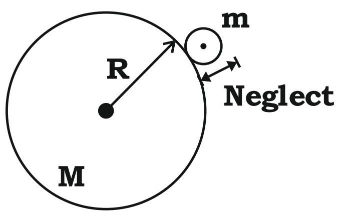
→ "Acceleration due to gravity is the acceleration gained by an object due to gravitational force".

→ Denoted by **'g'**.

→ Its **SI unit** is **m/s^2**.

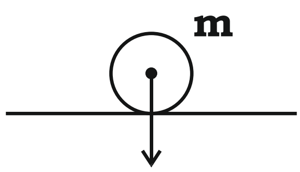
→ It has both **magnitude** and **direction**.

Deriving the formula of 'g'



$$F = \frac{Gm_1.m_2}{r^2}$$

$$F = \frac{GM.m}{R^2} \quad \textbf{...(i)}$$



$$F = ma$$

$$F = mg \quad \textbf{...(ii)} \quad [F \rightarrow \text{Gravitation Force}]$$

Equating eq (i) and eq (ii)

$$\cancel{m}g = \frac{GM\cancel{m}}{R^2}$$

'g' does not depend on m (small object) the person to person, Elephant, Pen, Table etc.

$$\boxed{\mathbf{g = \frac{GM}{R^2}}}$$

$\mathbf{g \propto M \rightarrow}$ **Bigger Mass**

i.e. $\mathbf{g \propto \frac{1}{R^2}}$

Q. Find the acceleration due to gravity of planet of mass half as that of earth and radius twice as that of earth.

Sol. Given m = M/2

$$g = \frac{GM}{R^2} \quad \textbf{...(i)}$$

R = 2R

$$g' = \frac{G\frac{M}{2}}{(2R)^2}$$

$$g' = \frac{GM}{2(4R^2)}$$

$$g' = \frac{GM}{8R^2} \quad \textbf{....(ii)}$$

Dividing eq (ii) by eq (i)

$$\frac{g'}{g} = \frac{GM}{8R^2} \div \frac{GM}{R^2}$$

$$= \frac{\cancel{GM}}{8\cancel{R^2}} \times \frac{\cancel{R^2}}{\cancel{GM}}$$

$$\frac{g'}{g} = \frac{1}{8}$$

$$\boxed{\mathbf{g' = \frac{g}{8}}}$$

Note:- This show that the planet has gravity **8 times** less than the earth.

Q. Gravitational force acts on all objects in proportion to their masses why then a heavy object does not fall faster than a light object ?

Sol. 'g' is acting upon both the object with same value i.e. **9.8 m/s²**.

Proof,

$$g = \frac{Gm}{R^2}$$

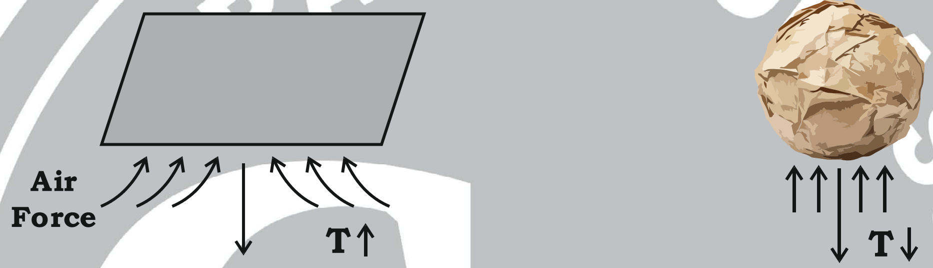
$$= \frac{6.7 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^{6})^2}$$

$$= \frac{6.7 \times 6}{6.4 \times 6.4} \times \frac{10^{-11} \times 10^{24}}{10^{16}}$$

$$\boxed{g_e = 9.8\,m/s^2}$$

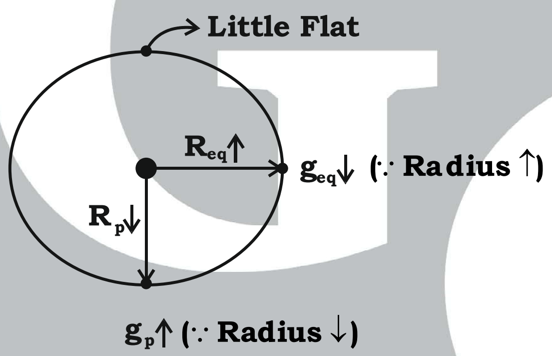
Q. Why will a sheet of paper fall slower than one that is crumpled in a ball?

Sol.



Variation in 'g'

Earth



Where, R_p = Radius through **Pole**.

R_{eq} = Radius through **Equator**.

$$\boxed{g_{eq}\downarrow = \frac{GM}{R_{eq}^2 \uparrow}} \qquad \boxed{g_p\uparrow = \frac{GM}{R_p^2 \downarrow}}$$

Note:- On **equator** position gravitation **force exert more** and **lesser on** the **Pole**.

Difference between 'G' and 'g'	
G	**g**
→ Universal Gravitational **Constant** (UGC)	→ Acceleration due to Gravity.
→ Value **6.7 × 10^{-11}** constant	→ Its values **varies** from place to place.
→ Nm^2/kg^2	→ m/s^2 [Earth **9.8** m/s^2]

Q. What happens to the force between two objects, if

(i) The mass of one object is doubled ?

(ii) The distance between the object is doubled and tripled ?

(iii) The masses of both objects are double ?

Sol. $\boxed{\text{Force} = \dfrac{G\,m_1.m_2}{r^2}}$ .....(i)

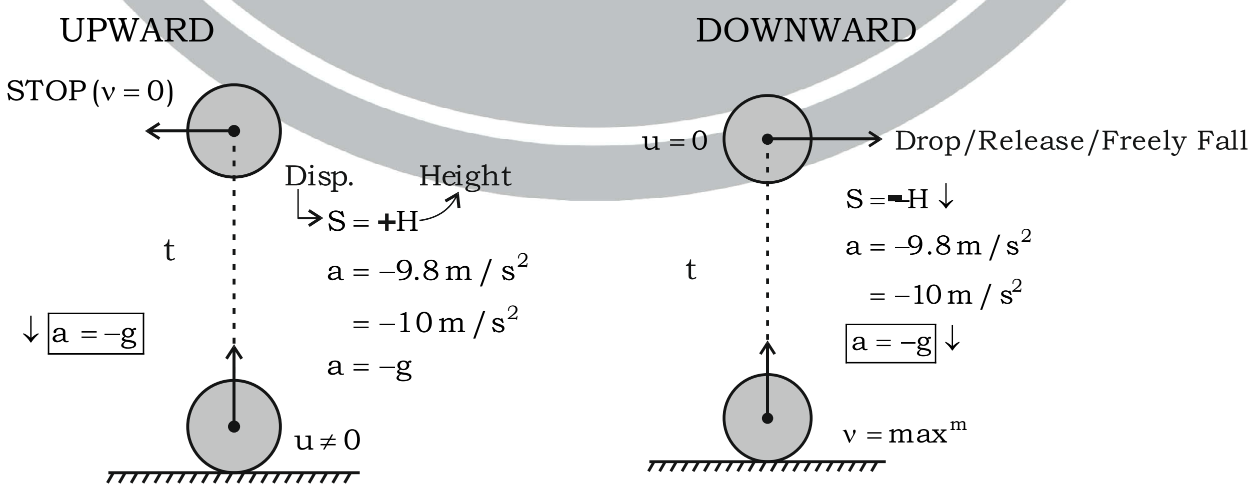
(i) Any one **mass doubled**, so **2M**.

$$F' = \frac{G(2m_1).m_2}{r^2} \quad .....(ii)$$

Dividing eq (ii) by eq (i) $\dfrac{F'}{F} = \dfrac{\frac{G(2m_1).m_2}{r^2}}{\frac{Gm_1.m_2}{r^2}}$	(ii) $F' = \dfrac{Gm_1.m_2}{(2r)^2}$ ..(ii) Dividing eq (ii) by eq(i)	$F' = \dfrac{Gm_1.m_2}{(3r)^2}$ ..(ii) Dividing eq (ii) by eq (i)	(iii) $F' = \dfrac{G.(2m_1)(2m_2)}{r^2}$ $F' = \dfrac{4Gm_1.m_2}{r^2}$ ..(ii)
$\dfrac{F'}{F} = \dfrac{\frac{G(2M_1).M_2}{r^2}}{\frac{Gm_1.m_2}{r^2}}$	$\dfrac{F'}{F} = \dfrac{\frac{Gm_1.m_2}{4r^2}}{\frac{Gm_1.m_2}{r^2}}$	$\dfrac{F'}{F} = \dfrac{\frac{Gm_1.m_2}{9r^2}}{\frac{Gm_1.m_2}{r^2}}$	Dividing eq (ii) by eq (i) $\dfrac{F'}{F} = \dfrac{\frac{4Gm_1.m_2}{r^2}}{\frac{Gm_1.m_2}{r^2}}$
$\dfrac{F'}{F} = \dfrac{2}{1}$	$\dfrac{F'}{F} = \dfrac{1}{4}$	$\dfrac{F'}{F} = \dfrac{1}{9}$	$\dfrac{F'}{F} = \dfrac{4}{1}$
$\boxed{F' = 2F}$	$\boxed{F' = \dfrac{F}{4}}$	$\boxed{F' = \dfrac{F}{9}}$	$\boxed{F' = 4F}$
Force become **twice** of its previous value.	Force become **4 times lesser** than previous one fourth	Force **9 times lesser** one ninth	Force become **4 times** of its previous value

Free Fall : The Concept:-

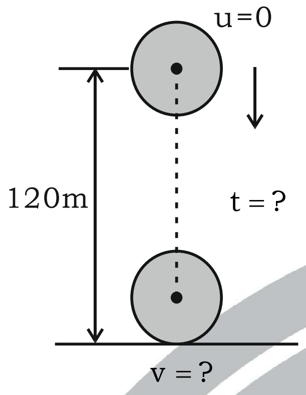
→ "It is a situation where the body experience only gravitational force and no other force should be taken into consideration.



Q. A ball is dropped from a building 120m tall, find :-

(i) Time of Fall.

(ii) Velocity, when it touches the ground.



Sol. Given, (i) u = 0, S = -120m, a = -10 m/s^2 or -9.8 m/s^2, t = ?, v = ?

From motion eq. we known

$$S = ut + \frac{1}{2}at^2$$

$$-120 = 0 \times t + \frac{1}{2} \times (-10) \times t^2$$

$$t = \sqrt{24}$$

$$\boxed{t = 2\sqrt{6}\,S}$$

(ii) Again from motion eq.

$$V = u + at$$

$$= 0 + (-10) \times 2\sqrt{6}$$

$$\boxed{V = -20\sqrt{6}\,m/s}$$

Note:- -ve sign shows that the ball is falling downward direction.

Q. An object is projected upwards with a velocity of 25 m/s. Find :-

(i) Maximum height achieved.

(ii) Time taken by the object to reach the ground again.

Sol. Given, u = 25 m/s, v = 0 m/s, a = -g = -10 m/s^2, s = ?, t = ?

(i) 3rd equation of motion	(ii) Time taken (t)
We know, this is the equation to find **distance**	This is the equation to find **displacement**.
$2as = v^2 - u^2$	$S = ut + \frac{1}{2}at^2$
$2 \times (-10)S = 0^2 - (25)^2$	$0 = 25(T) + \frac{1}{2} \times (-10)(T)^2$
$-20S = -625$	∵ Displacement (S) = 0 [Final-Initial Position]
$S = \frac{-625}{-20}$	T = Total time = (upward + downward)
$H = \boxed{S = 31.25m}$	$0 = 25T + \frac{1}{2} \times (-10)(T)^2$
	$\boxed{T = 5s}$

Mass	Weight
(i) **Actual content** present in a body.	(i) It is the **force exerted** by the body on earth.
(ii) Mass is always **constant**.	(ii) Weight is **variable** (change from place to place). **W = mg** or $F = m \times a$
(iii) Mass is **never zero** or **negative**.	(iii) Weight **can be** +, - or zero(0)
(iv) SI unit = Kilogram **(kg)**	(iv) SI unit – Newton **(N)**

Q. An object has mass 36 kg. Find its
(i) Weight on Earth.
(ii) Weight on Moon.

Sol. (i) Mass of object = 36 kg.

Weight of Earth $= m.g_{earth}$

$= 36 \times 9.8$

$= 36 \times 10 =$ **360 N**

As we know,

$$g_{moon} = \frac{g_{earth}}{6}$$

(ii) So, weight $= m \times g_{moon}$

$= 36 \times \frac{g_{earth}}{6}$

$= 36 \times \frac{10}{6}$

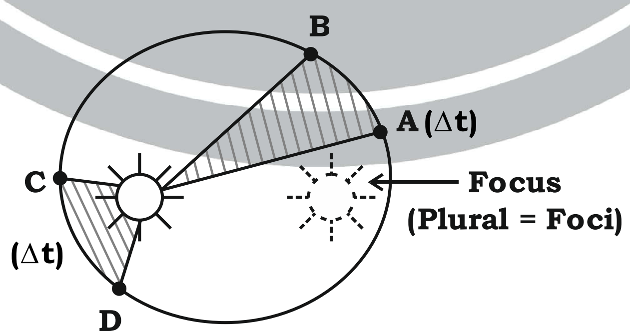
= **60 N**

- **Johannes Kepler's Law of Planetary Motion:-** (Tycho Brahe, Notes on Diary, 9yr)

(1) Kepler's 1st Law : Law of Orbits.

→ The orbit of a planet is an ellipse with the sun at one of the **foci**.

(2) Kepler's 2nd Law : (Law of Areas)



→ The line joining the planet and the sun sweep equal areas in equal interval of times.

(3) Kepler's 3rd Law : (Law of Periods)

→ The cube of the mean distance of a planet from the sun is proportional to the square of its orbital period T or $\boxed{T^2 \propto r^3}$.

Q. The weight of an object at the center of the earth of radius R, is

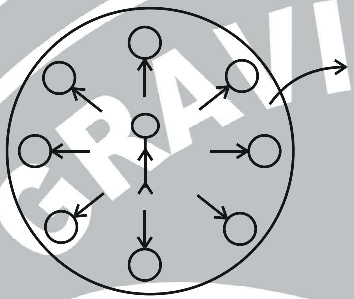
Option (a) Zero

(b) Infinite

(c) R times the weight at the surface of the earth.

(d) $\frac{1}{R^2}$ times the weight at the surface of the earth.

Because,

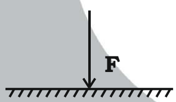


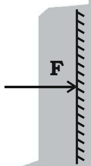
$F_{net} = 0$
Weight = 0
g = 0

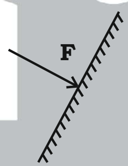
FLUID

- **Thrust:-** It is the **force acting perpendicularly** on a surface. ex.- Helicopter left upward, Board pin/ Paper pin.

→ **S.I.** unit is **Newton (N)**.







- **Pressure:-** It is defined as **thrust** acting on per unit **Area**.

$$\text{Pressure} = \frac{\text{Thrust (Force) } F_\perp}{\text{Area}}$$

$$\boxed{P = \frac{F_\perp}{A}}$$

Note:- $P = \frac{F_\perp}{A}$ (Area of contact)

→ **S.I.** unit is **Pascal (Pa)**.

Example of Pressure:-

(i) **Jumping** on **sofa** or sleeping on bed.

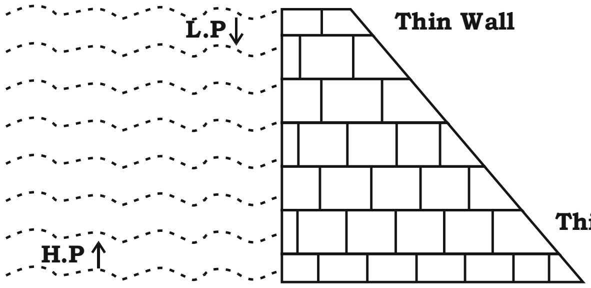
(ii) Circus hitting a **hammer** on **chest**.

(iii) Sitting on series of **pointed nail**.

(iv) Sandal **heel** and **foot of elephant**.

(v) **Knife** one side is **sharp** and another is **blunt**.

(iv)

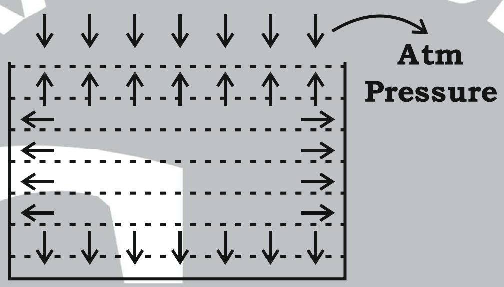


✳ Pressure in Fluid

● **Fluid:-** Any substance which can **flow due to** its **internal forces** is called fluid.

Gases and **Liquids** are considered as **fluids** whereas solids are rigid.

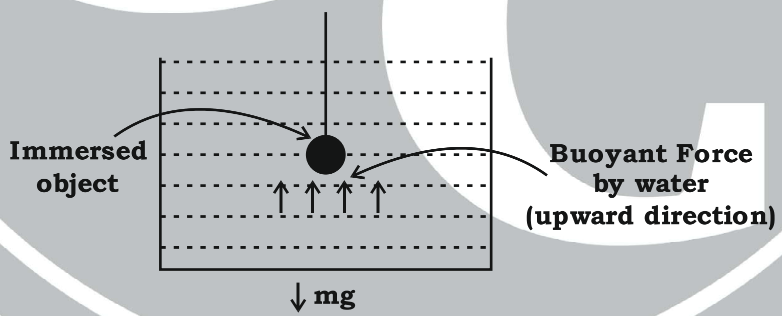
→ Fluid has a property that it exerts equal pressure on the wall of its container.



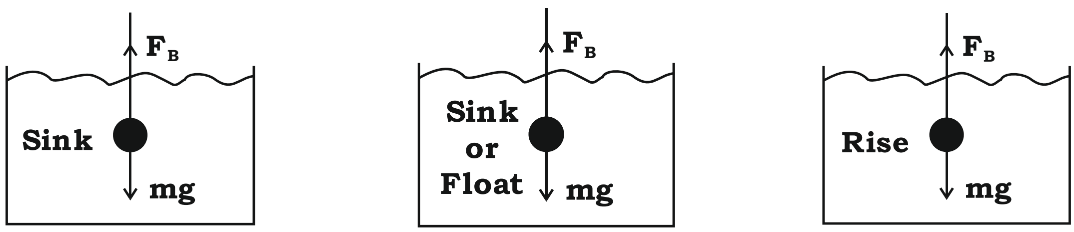
Liquid in Container

✳ BUOYANT FORCE :- Floating Principle

● **Buoyancy:-** It is the principle by which the **fluid exerts** a force in **upward direction** on the solid **object immersed** into the fluid. This upward force is called **Byoyant force** which is also known as **Upthrust**.

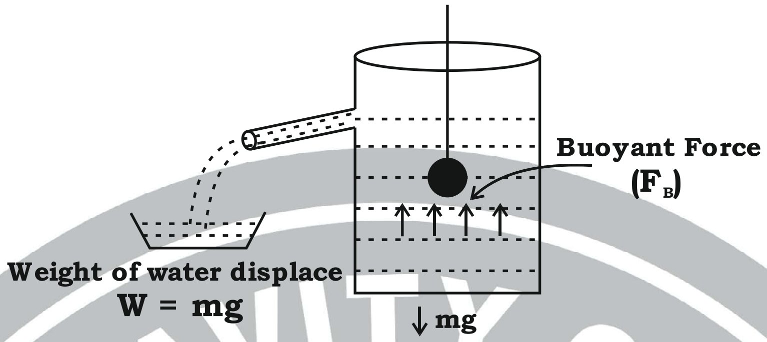


Case-I	Case-II	Case-III
$mg > F_B$ Sink (Stone)	$mg = F_B$ Float	$mg < F_B$ [Rise] (Mug, Fish, Submarine)



✳ Archimedes Principle

- **Statement:-** Archimede's principle states that, "when an object is wholly or **partially immersed** in a fluid an **upward force** called **buoyant force** acts on it, which is numerically equal to the **weight of the liquid** displaced by the **object**".



Buoyant Force = Weight of water displaced

We can conclude:-

(i) $V_{object} = V_{displaced\ liq.}$

(ii) $F_{buoyant} = W_{displaced\ liq.}$

- **Application:-**

(i) **Hydrometer:-** To find relative density that whether it will sink or hot.
(ii) **Lactometer:-** To find purity of milk.
(iii) Manufacturing of **ships.**
(iv) Boats and **Submarines**.

✳ Relative Density:-

- **Defination:-** Relative density of a substance is defined as the **ratio of density** of the substance **to the density of water** (at **4°C**, ↑maximum), it is **also** called **Specific Gravity**.

→ Through this Relative Density index we get the idea, whether the object will float on water or not.

$$\text{Relative Density}_{substance} = \frac{\text{Density}_{substance}}{\text{Density}_{water(4^\circ C)}}$$

$$\boxed{R.D_{sub.} = \frac{D_{sub.}}{D_{water}}}$$

✳ If R.D. is greater than 1 it will sink.

$\boxed{R.D > 1}$ **(SINK)**

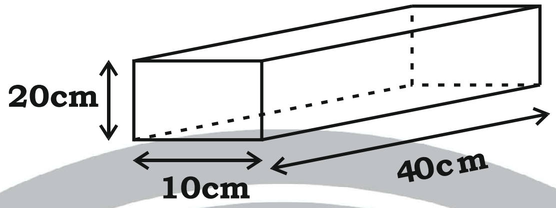
✳ If R.D. is equal to 1, it will float.

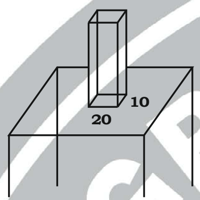
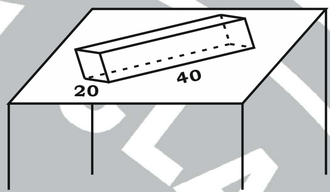
$\boxed{R.D = 1}$ **(FLOAT)**

$\boxed{0 < R.D < 1}$ **(RISE)**

Q. A block of block wood is kept on a tabletop. The mass of wooden block is 5 kg and its dimensions are 40 cm × 20 cm × 10 cm. Find the pressure exerted by the wooden block on the table top if it is made to lie on the table top with its sides of dimension.

Sol. (a) 20 cm × 10 cm (b) 40 cm × 20 cm



(a) 	(b) 
Area = l × b	Area = l × b
$= 20 \times 10\ \text{cm}^2$	$= 40 \times 20\ \text{cm}^2$
$= 200\ \text{cm}^2$	$= 800\ \text{cm}^2$
$= \frac{200}{10000}\ \text{m}^2$	$= \frac{800}{10000}\ \text{m}^2$
$\boxed{\mathbf{A = 0.02\ m^2}}$	$\boxed{\mathbf{A = 0.08\ m^2}}$
$P = \frac{F}{A}$	$P = \frac{F}{A}$
$= \frac{mg}{A}$	$= \frac{mg}{A}$
$= \frac{5 \times 10}{0.02}$	$= \frac{5 \times 10}{0.08}$
$\boxed{\mathbf{P = 2500\ Pa}}$	$\boxed{\mathbf{P = 625\ Pa}}$