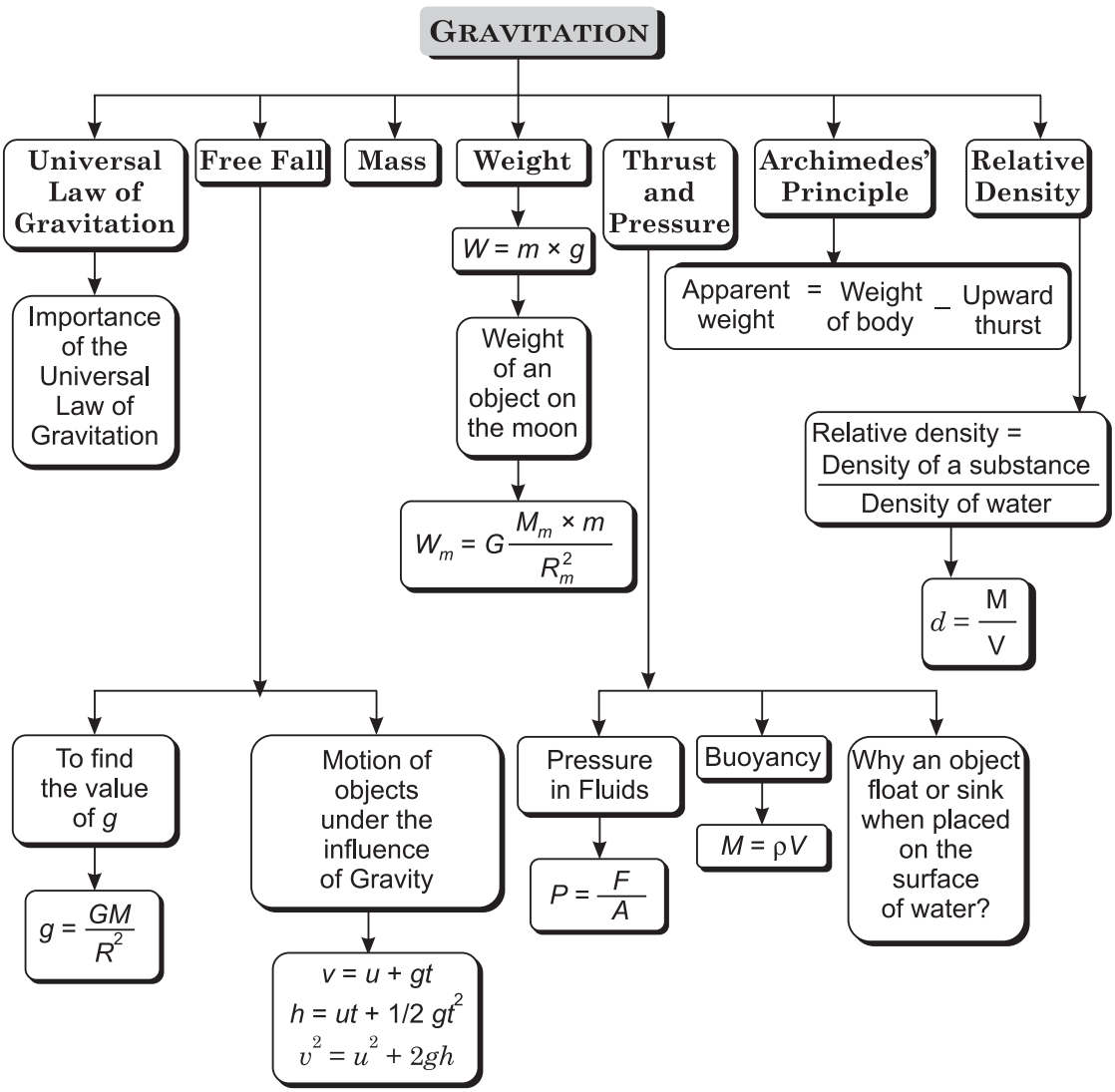
10 Gravitation

Topics Covered

10.1 Gravitation, Law of Gravitation, Motion of Objects under Gravitational Force of the Earth
10.2 Thrust, Pressure, Buoyancy, Archimedes' Principle, Relative Density

CHAPTER MAP



QUICK REVISION NOTES

Gravitation is the force of attraction between any two particles or objects in the Universe.

- The force of attraction between any two objects in this universe is directly proportional to their masses and inversely proportional to the square of the distance between them.
- Gravitational force is the weakest force in nature.

Gravitation force due to earth is called gravity.

- $\boxed{F = \frac{G \times m_1 \times m_2}{d^2}}$, where 'F' is force between the two bodies of mass m_1 and m_2 separated by a distance d, 'G' is universal gravitational constant, 'd' is distance between the two bodies.
- Value of G = 6.67×10^{-11} N m^2/kg^2
- 'g' on earth's surface = 9.8 m s^{-2}, Mass of earth = 6×10^{24} kg
  'R' (radius of earth) = 6.37×10^6 m

  $F = ma$ (Newton's second Law)
- $\boxed{g = \frac{GMe}{R^2}}$ 'g' is acceleration of an object falling freely towards the earth, which further depends upon the mass of the earth (M_e) and radius of earth. **It does not depend upon the mass of the object,** i.e. stones of 500 g and 150 g will reach the earth at the same time if falling freely from the same height, 'R' is the radius of earth. When object is on or near the surface after time t on earth then d = R.

  The three equations of motion for free fall.
- **Case I:** When an object is falling freely towards the earth with an initial velocity (u) and after time t its final velocity become (v) after travelling height h
  then $v = u + gt$
  where 'g' is acceleration due to gravity

  Height covered in 't' seconds, $h = ut + \frac{1}{2}gt^2$

  Similarly $v^2 = u^2 + 2gh$
- **Case II:** When an object is falling from the rest position, it means that initial velocity (u) = 0,

  $\therefore$ $v = gt$

  $h = \frac{1}{2}gt^2$

  $v^2 = 2gh$
- **Case III:** When an object is thrown vertically upwards with initial velocity 'u', the gravitational acceleration will be negative ($-g$), then

  $v = u - gt$

  $h = ut - \frac{1}{2}gt^2$

  $v^2 = u^2 - 2gh$

Mass of a body is the quantity of matter contained in it. It is a scalar quantity, i.e. it has only magnitude and no direction.

- It remains constant and does not change from place to place.
- Mass of the body cannot be equal to zero.
- It is measured by physical or chemical balance. Its SI unit is kg.

Weight: The force with which an object is attracted towards the centre of the earth.

$$F = m \times a$$

In case of earth a = g

$$F = mg$$

$$W = mg$$

- Weight is Force and its SI unit is newton (N).
- It changes from place to place because value of '*g*' changes.
- At the centre of earth '*g*' = 0; therefore weight of any body at the centre of earth is zero.

kg/wt is the gravitational unit of force.

Relation between 1 kg weight and newton

$$W = m \times g$$

If $m = 1$ kg, $g = 9.8$ m s^{-2}

$$W = 1 \times 9.8 \text{ kg m s}^{-1} = 9.8 \text{ N}$$

$$\boxed{1 \text{ kg Wt} = 9.8 \text{ N}}$$

1 kg Wt is the gravitational force which acts on an object of 1 kg mass. Value of *g* vary from place to place on earth surface. *g* is maximum at poles and minimum at equator. *g* decreases with altitude

$$g = \frac{GM}{(R+h)^2}$$

where *h* is the height of an object from the surfaces of earth. *g* decreases with depth also, at centre of earth *g* = 0. Due to this the weight of a body is not constant.

- The weight of an object on the moon is about $\frac{1}{6}$ the of the weight on earth.

Thrust: The force acting on an object perpendicular to the surface of the object is called thrust.

Pressure: It is defined as force (effect of thrust) per unit area.

$$P = \frac{F}{a}$$

- SI unit of pressure is N m^{-2} or Pascal (Pa).
- Pressure depends upon (*i*) Force applied, (*ii*) Area of surface over which force acts. Fluid is a substance which can flow. Liquids and gases are called fluids. Fluids also exert pressure on the base and walls of the container in which they are enclosed.
- **Buoyancy** is the property of any fluid due to which it exerts an upward force when the body is immersed partially or fully in a fluid.

$$U = mg$$

$$U = V \times \rho \times g \quad \boxed{\because \quad \rho = \frac{m}{V} \quad \Rightarrow \quad m = \rho \times V}$$

where ρ is density of fluid.

- It acts in the upward direction and depends upon the density of the fluid (liquid).
- If the weight of an object > Buoyant force, the **object sinks**.
- If the weight of an object ≤ Buoyant force, the **object floats.**

That is why, all pin sinks and boat/ship floats on the surface of sea water.

Density of a body is defined as the mass per unit volume.

$$\text{Density } (d) = \frac{\text{Mass (M)}}{\text{Volume (V)}}$$

Its SI unit is kg m^{-3}.

Archimedes' Principle: 'When a body is fully or partially immersed in a fluid, it experiences an upward force that is equal to the weight of fluid displaced by it.

Applications:

(*i*) It is used to determine the relative density of substances.

(*ii*) It is used in designing of ships and submarines.

(*iii*) Hydrometers and lactometers are manufactured on this principle.

$$\textbf{Relative density} = \frac{\text{Density of substance}}{\text{Density of water}}$$

- It is a ratio, hence it does not have any unit.

1. Gravitation, Law of Gravitation, Motion of Objects under Gravitational Force of the Earth

Gravitational Force

The force of attraction acting between the objects in this universe is called the gravitational force.

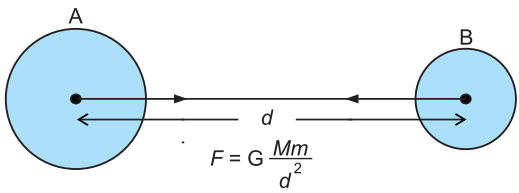
Universal Law of Gravitation

The force of attraction between two bodies is directly proportional to the product of the masses of the two bodies and is inversely proportional to the square of the distance between them.

$$F \propto M \times m$$

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

$$F \propto \frac{M \times m}{d^2}$$



$\boxed{F = G\frac{M \times m}{d^2}}$ Where 'M' and 'm' are the masses of objects A and B, F is gravitational force, 'G' is the universal gravitational constant and 'd' is distance between the bodies.

$$\boxed{G = \frac{F \times d^2}{M \times m}}$$

$G = 6.673 \times 10^{-11}$ N m^2 kg^{-2}.

This law is considered universal law because it is applicable to all the objects in the universe.

Importance: It explains

- the force that binds all objects us to the earth.
- the motion of moon around the earth.
- the motion of planets around the sun.
- formation tides due to the moon and Sun.
- presence of atmosphere around the earth. Force on an object of mass m due to acceleration due to gravity.

Free Fall

$$\boxed{F = mg} \qquad (i)$$

where 'm' is mass of the object, 'g' is acceleration due to gravity, F is gravitational force between mass of earth and mass of the object.

$$F = \frac{G.M \times m}{d^2} \qquad \ldots(ii)$$

$\therefore$ From Eq. (*i*) and (*ii*)

$$mg = \frac{G.M \times m}{d^2}$$

$\boxed{g = G\frac{M}{d^2}}$ where 'M' is mass of the earth and '*d*' is the distance between the object and the earth.

If the object is on or near the surface of earth, then $d = R$, where 'R' is the radius of Earth.

$$\boxed{g = \frac{G.M}{R^2}}$$

The earth is not a perfect sphere. The radius of earth increases from the poles to the equator, therefore the value of '*g*' decreases from pole to the equator. We take '*g*' as a constant at the surface of the earth.

$$g = \frac{6.7\times10^{-11}\ \text{N m}^2\text{kg}^{-2} \times 6\times10^{24}\,\text{kg}}{(6.4\times10^{6}\,\text{m})^2}$$

$$g = 9.8\ \text{ms}^{-2}$$

Motion of Objects Under the Influence of Gravitation Pull

$$v = u + gt$$

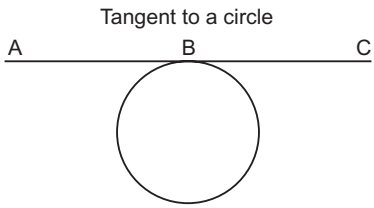
$$h = ut + \frac{1}{2}gt^2$$

$$v^2 = u^2 + 2gh$$

'*g*' is +ve when object is falling towards the earth, '*g*' is –ve if object is thrown upwards against the gravitational force.

Centripetal Force

The force that causes the acceleration and keeps the body moving along the circular path and is acting along the radius towards the centre of the circular path is called centripetal force (centre seeking). The motion of moon around the earth is due to centripetal force which is provided by the force of attraction of the earth.



- If this force is not present, the stone will fly off along a straight line tangent to the circular path as shown in diagram.

Tangent to the circle: A straight line that the meets the circle at one and only one point is called tangent to the circle, e.g. ABC is tangent to the circle.

- Apple falls on the earth due to gravitational pull of earth. Apple does not attract earth because its mass is very small as compared to the earth.
- Earth attracts the moon but Earth does not move towards the moon because mass of Moon is less as compared to Earth.

Exercise 10.1

I. Very Short Answer Type Questions (1 Mark)

1. Write the formula to find the magnitude of the gravitational force between the earth and an object on the surface of earth. [*NCERT*]
2. What do you mean by free fall? [*NCERT*]
3. What do you mean by acceleration due to gravity? [*NCERT*]
4. How does the force of gravitation between two objects changes when the distance between them is reduced to half ?

5. Is the value of 'G' constant at all the places?
6. What is the weight of an object of mass 1 kg?
7. What is the value of gravitational acceleration acting on a free falling object? [*NCERT*]
8. What is value 'G' and also write its unit?
9. Mass of an object is 10 kg. What is its weight on Earth? [*NCERT*]
10. Why is the weight of an object on the moon is $\frac{1}{6}$ th of its weight on earth? [*NCERT*]
11. You find your mass to be 42 kg on a weighing machine. Is your mass greater or less than 42 kg?
12. What do we call the gravitational force between the earth and an object on its surface?
13. A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity.

II. Short Answer Type Questions–I (2 Marks)

14. 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. ($G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}). [*NCERT*]
15. An object is thrown vertically upwards and rises to a height of 10 m. Calculate (*i*) the velocity with which the object was thrown upwards and (*ii*) the time taken by the object to reach the highest point. [*NCERT*]
16. 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 is 6.4×10^6 m). [*NCERT*]
17. The weight of a body on the surface of earth is 10 kg. What will be its weight when it is taken at the centre of earth?
18. A ball is thrown up with a speed of 5 m s^{-1}. How high will it go before it begins to fall? ($g = 9.8$ m s^{-2})
19. What is height of a building if the stone dropped from the roof take 10 seconds to reach the ground? ($g = 9.8$ m s^{-2})
20. Explain how weight of an object on the moon will be $\frac{1}{6}$ th to that on the earth.
21. An object weighs 10 N when measured on the surface of the earth. What will be its weight when measured on surface of moon? [*NCERT*]
22. Gravitational force acts on all the objects in proportion to their masses. Why then, a heavy object does not fall faster than a lighter object?
23. The earth and the moon are attracted to each other by gravitational force. Does the earth attract the moon with a force that is greater or smaller or the same as the force with which the moon attracts the earth? Why? [*NCERT*]
24. If the moon attracts the earth, why does the earth not move towards the moon? [*NCERT*]
25. What is the importance of universal law of gravitation? [*NCERT*]
26. Amit buys few grams of gold at the pole as per the instruction by one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold he bought? If not, why? [Hint: The value of g is greater at the poles than at the equator.] [*NCERT*] [*CBSE* 2012]
27. A ball is thrown vertically upwards with a velocity of 49 m/s.
    Calculate
    (*i*) the maximum height to which it rises.
    (*ii*) the total time it take to return to the surface of the earth. [*CBSE* 2011]
28. Calculate the force of gravitation between the earth and the sun, given that the mass of the earth = 6×10^{24} kg and of the sun = 2×10^{30} kg. The average distance between the two is 1.5×10^{11} m. [*NCERT*] [*CBSE* 2016]

29. A force of 20 N acts upon a body whose weight is 9.8 N. What is the mass of a body and how much is its acceleration? [*DOE*]

30. A man weighs 1200 N on earth. What is his mass? ($g = 10\ m\ s^{-2}$). If he was taken to the moon, his weight will be 200 N. What is his mass on the moon? What is the acceleration due to gravity on moon? (Take $g = 10\ ms^{-2}$) [*DOE*]

31. An object was thrown vertically upwards and reaches a height of 78.4 m. Calculate the velocity at which the object was thrown? ($g = 9.8\ m/s^2$)

32. A ball is released from a height of 1 metre. What time will it take to reach the surface of the earth?

33. Mona weighs 750 N on earth:

(*i*) On planet Mars, the force of gravity is 38% of that on Earth. How much will Mona weigh on Mars?

(*ii*) What will be Mona's mass on Earth? ($g = 10\ m\ s^{-2}$) [*CBSE* 2016]

34. Consider two bodies A and B. The body 'B' is heavier than body 'A'. Which of the bodies is attracted with a greater force by earth? Which of the two will fall with greater acceleration? Explain. [*DOE*]

III. Short Answer Type Questions–II (3 Marks)

35. A car falls off a ledge and drops to the ground in 0.5 s. Let $g = 10\ m\ s^{-2}$ (for simplifying the calculations).

(*i*) What is its speed on striking the ground?

(*ii*) What is its average speed during: its fall, i.e. during 0.5 s?

(*iii*) How high is the ledge from the ground? [*NCERT*]

36. Give six differences between mass and weight. [*NCERT*]

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

(*i*) the mass of one of the object is doubled.

(*ii*) the distance between the objects is doubled and tripled respectively.

(*iii*) the masses of both the objects are doubled. [*NCERT*] [*CBSE* 2011]

38. A stone is thrown vertically upwards with an initial velocity of 40 m/s. Taking $g = 10\ m/s^2$, find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone? [*NCERT*]

39. A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet. [*NCERT*] **[HOTS]**

40. A person throws a ball vertically up returns to him after 6 seconds. Find.

(*a*) the velocity with which it was thrown up.

(*b*) the maximum height it reaches.

(*c*) its position after 4 s. **[HOTS]**

Answers 10.1

1. $\boxed{F = \dfrac{G.M \times m}{R^2}}$ where 'M' is mass of earth,

'*m*' is mass of object and 'R' is radius of earth.

2. When an object falls alone towards the earth freely only under the force of gravity, we say that object is in free fall.

3. The acceleration which is gained by an object due to the gravitational force of earth, is called acceleration due to gravity. Its SI unit is ms^{-2}.

4. $F \propto \frac{1}{d^2} \quad \Rightarrow \quad F \propto \frac{1}{\left(\frac{1}{2}\right)^2}$

The force of gravitation will become 4 times.

5. Yes, value of 'G' is constant at all the places.

6. $W = mg$

$W = 1 \text{ kg} \times 9.8 \text{ m s}^{-2} = 9.8 \text{ N}$

7. $g = 9.8 \text{ m s}^{-2}$

8. $G = 6.673 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

9. $W = mg = 10 \text{ kg} \times 9.8 \text{ ms}^{-2} = 98$ newton (N).

10. It is because gravitational pull of moon is $\frac{1}{6}$th of that of earth. The value of 'g' is $\frac{1}{6}$th of the value of 'g' on earth.

11. In a fact, a weighing machine is a short of spring balance which measures the weight (not mass) of a body. Whey we stand on the weighing machine, our weight acts vertically downwards. But the buoyancy due to air acts on the body upwards. Therefore as a result of this our apparent weight is lesser than true weight. The weighing machine measure the apparent weight. The true weight must be greater than 42 kg.

12. Gravitational force between earth and an object is called gravity. It is measured as weight of the object.

13. $u = 0, \quad h = 19.6 \text{ m}, \quad v = ?, \quad g = 9.8 \text{ m s}^{-2}$

$v^2 - u^2 = 2gh$

$v^2 - 0 = 2 \times 19.6 \times 9.8$

$v^2 = (19.6)^2$

$\therefore \quad v = 19.6 \text{ ms}^{-1}$

14. $M = 6 \times 10^{24} \text{ kg}, \quad m = 7.4 \times 10^{22} \text{ kg}, \quad d = 3.84 \times 10^5 \text{ km}$

$G = 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

$d = 3.84 \times 10^5 \times 10^3 \text{ m} \quad \Rightarrow \quad d = 3.84 \times 10^8 \text{ m}$

$$\text{Now, } F = \frac{G.M \times m}{d^2}$$

$$= \frac{6.7 \times 10^{11} \times 6 \times 10^{24} \times 7.4 \times 10^{24}}{(3.84 \times 10^8)^2} \Rightarrow 2.01 \times 10^{20} \text{ N}$$

Thus force exerted by the earth on the moon is 2.01×10^{20} N.

15. (*i*) $s = 10 \text{ m}, \quad g = -9.8 \text{ m s}^{-2}$ (upward direction), $\quad v = 0, \quad u = ?$

$v^2 = u^2 + 2gs$

$0 = u^2 + 2 \times -9.8 \times 10$

$u^2 = 196 \quad \Rightarrow \quad u = \sqrt{196} \quad \Rightarrow \quad u = 14 \text{ m s}^{-1}$

(*ii*) $v = u + gt$

$0 = 14 - 9.8 \times t \quad \Rightarrow \quad t = \frac{14}{9.8} = 1.43$ seconds.

16. $F = \frac{G.M \times m}{R^2}$

$$F = \frac{6.673\times10^{-11}\times6\times10^{24}\times1\,kg}{(6.4\times10^{6}\,m)^2} = \frac{40.038\times10^{13}}{40.96\times10^{12}} = 0.977\times10 = \textbf{9.77 Newtons}$$

17. **Weight:** $W = mg$

$W = 10 \times 0 \Rightarrow 0$ [$\because$ g = 0 at centre of earth]

18. $v^2 - u^2 = 2gh$

$0 - (5)^2 = 2 \times -9.8 \times h$ [$g = -9.8\ m\ s^{-2}$ $\because$ ball is going upward]

$-25 = -19.6 \times h$; $\quad h = \frac{25}{19.6} = \frac{250}{196} = 1.27$ m

19. $h = ?$ $\quad g = 9.8\ m\ s^{-2}$, $\quad t = 10$ s, $\quad u = 0$

$$h = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2}\times9.8\times10\times10 = \frac{980}{2} = 490\ m$$

20. Let W_m and W_e be the weight of an object on moon and on earth, respectively.

$$F = W_m = \frac{G.M_m\times m}{R_m^2} = \frac{7.36\times10^{22}\times G\times m}{(1.74\times10^{6})^2} = 2.431\times10^{10}\ G\times m$$

$$F = W_e = \frac{G.M_e\times m}{R_e^2} = G\times\frac{5.98\times10^{24}}{(6.37\times10^{6})^2}\times m = 1.474\times10^{11}\ G\times m$$

$$\Rightarrow \quad \frac{W_m}{W_e} = \frac{2.431\times10^{10}}{1.474\times10^{11}} = \frac{1}{6}$$

$\therefore$ Weight of an object on the moon = $\frac{1}{6}$ × weight of the object on the earth.

21. Weight of the object on the moon

$= \frac{1}{6}$ × its weight on the earth = $\frac{1}{6}\times10\ N = 1.67\ N$ $\left[\because\ g_{moon} = \frac{1}{6}\,g_{earth}\right]$

22. $g = \frac{GM}{R^2}$

The value of '*g*' depends upon the mass of earth (M) and radius of the earth and not on the mass of the body, therefore both objects will reach the earth's surface at the same time.

23. $\boxed{F = G\frac{M_e\times M_m}{d^2}}$

The value of 'F' is same for the earth as well as for the moon. Both the bodies will attract each other with the same force. This force is called the gravitational force.

24. It is because mass of the earth is greater than the mass of moon, therefore earth does not move towards the moon.

25. *Importance:* It explains

- the force that binds all objects with the earth.
- the motion of moon around the earth.
- the motion of planets around the sun.
- the formation of tides due to the moon and the sun.

26. $W = mg$

The value of '*g*' is greater at the poles than the equator, therefore weight will be more at poles than the equator, therefore his friend will not agree.

27. (*i*) $u = 49 \text{ m s}^{-1}$, $v = 0$, $h = ?$

$v^2 - u^2 = 2gh$

$0 - (49 \times 49) = 2 \times -9.8 \times h$ [$\because$ g = –9.8 m s^{-2} for upward direction]

$h = \frac{49 \times 490}{2 \times 98} = \frac{490}{4} = 122.5 \text{ m}$

(*ii*) $u = 49 \text{ m s}^{-1}$, $v = 0$, g = –9.8 m s^{-2}[For upward direction]

$v = u + gt$; $0 = 49 - 9.8 \times t$

$t = \frac{49}{9.8} = 5$ seconds

Total time = 5 + 5 = 10 seconds

28. $F = G\frac{M_s \times m_e}{d^2} = \frac{6.67 \times 10^{-10} \times 2 \times 10^{30} \times 6 \times 10^{24}}{(1.5 \times 10^{11})^2} = 3.56 \times 10^{22} \text{ N}$

29. W = mg

$9.8 = m \times 9.8 \Rightarrow m = 1 \text{ kg}$

$F = ma \Rightarrow 20 \text{ N} = 1 \text{ kg} \times a \Rightarrow a = 20 \text{ m s}^{-2}$

30. W = 1200 N

$W = mg \Rightarrow 1200 = m \times 10 \Rightarrow m = 120 \text{ kg}$

Mass on moon = mass on earth = 120 kg [$\because$ mass does not change]

$W_2 = mg_2 \Rightarrow 200 \text{ N} = 120 \times g_2$

At moon, $g_2 = \frac{200}{120} = \frac{5}{3} = 1.66 \text{ m s}^{-2}$

31. $u = ?$, $v = 0$, g = 9.8 ms^{-2}, $h = 78.4$ m

$v^2 - u^2 = 2gh$

$0 - u^2 = 2 \times (-9.8) \times 78.4 \Rightarrow u^2 = 1536.64 \Rightarrow u = 39.2 \text{ m s}^{-1}$

[$\because$ g = –9.8 ms^{-2} for upward movement]

32. $h = 1$ m, $t = ?$, $v = 0$

$v^2 = u^2 + 2gh$

$0 = u^2 + 2 \times 9.8 \times 1 \text{ m}$

$u^2 = -2 \times 9.8 = -19.6$

u = –4.42 ms^{-1}

$v = u + gt$

$0 = -4.42 + 9.8 \times t$

$\Rightarrow t = \frac{4.42}{9.8} = 0.45$ s

33. (*i*) Weight on Mars = $750 \times \frac{38}{100} = 285$ N

(*ii*) W = mg

750 N = $m \times 10$

$m = 75$ kg on Earth

34. Both will be attracted by the same force by Earth because it depends upon the mass of the earth and not on the mass of body. Both will have same acceleration.

35. (*i*) $t = 0.5$ s, g = 10 m s^{-2}, $v = ?$

Initial velocity, $u = 0$

$v = u + gt = 0 + 10 \times 0.5$

$v = 5 \text{ m s}^{-1}$

(*ii*) Average speed $= \frac{u+v}{2} = \frac{0+5}{2} = 2.5 \text{ m s}^{-1}$

(*iii*) $S = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2} \times 10 \times (0.5)^2 = 0 + \frac{1}{2} \times 10 \times \frac{1}{2} \times \frac{1}{2} = 0 + \frac{5}{4} = 1.25 \text{ m}$

36.

Mass	Weight
It is a quantity of matter contained in a substance.	It is the force by which earth attracts the body towards it.
Its SI unit is kg.	Its SI unit is (N)newton.
It remains constant.	It changes from place to place with change in the value of '*g*'
Mass is a measure of inertia.	Weight is a force, vertically acting downward.
It has only magnitude.	It has magnitude as well as direction.
Mass is measured with the help of a beam balances.	Weight is measured by a spring balances.

37. (*i*) The force of attraction will become double.

(*ii*) The force of attraction will become $\frac{1}{4}$ and $\frac{1}{9}$, respectively.

(*iii*) The force of attraction will become four times.

$\therefore \quad F \propto \frac{M \times m}{d^2}$

38. $u = 40 \text{ m s}^{-1}$, $g = 10 \text{ m/s}^2$, $h = ?$, $v = 0$

$v^2 - u^2 = 2gh$

$0 - (40 \times 40) = 2 \times -10 \text{ m s}^{-2} \times h$ [$g = -10 \text{ m s}^{-2}$ for upward direction]

$$h = \frac{40 \times 40}{20} = 80 \text{ m}$$

Net displacement = 0 [$\because$ After reaching 80 m, it falls down to the earth]

Distance covered = 80 *m* + 80 *m* = 160 m

39. $h = 100$ m

(*i*) Distance covered by stone downwards

$$s_1 = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2} \times 10 \times t^2 = 5t^2$$

(*ii*) Distance covered by stone upwards

$$s_2 = ut + \frac{1}{2}gt^2$$

$$s_2 = 25 \times t + \frac{1}{2}(-10) \times t^2 = 25t + (-5t^2)$$

$s_1 + s_2 = 100$ m

$5t^2 + 25t - 5t^2 = 100 \Rightarrow 25t = 100 = 4$ seconds

$s_1 = 5 \times 4^2 = 100 - 80 = 20$ m

Two stones will meet after 4 second when falling stone reaches 80 *m* from the top of tower.

40. $t = 6$ seconds

(*a*) total time = 6 second

Time for upward journey = $\frac{6}{2}$ = 3 second

$v = u + gt$

$0 = u + -9.8 \times 3 \Rightarrow u = 29.4 \text{ m s}^{-1}$

(*b*) $s = ut + \frac{1}{2}gt^2 = 29.4 \times 3 + \frac{1}{2} \times -9.8 \times (3)^2$

$= 88.2 - \frac{9.8 \times 9}{2} = 88.2 - \frac{88.2}{2}$

$= 88.2 - 44.1 = 44.1$ m

(*c*) In 3 seconds, it will reach 44.1 m,

$\therefore t = 1$ seconds, $u = 0$

$s = ut + \frac{1}{2}gt^2 = 0 + \frac{1}{2} \times 9.8 \times (1)^2 = 4.9$ m

So, it will reach 4.9 *m* from the top.

2. Thrust, Pressure Buoyancy, Archimedes' Principle, Relative Density

Thrust

The force acting on an object perpendicular to the surface is called thrust. The effect of thrust depends upon the area on which it acts, e.g. the effect of thrust is larger while standing on sand than while lying. The thrust per unit area is called pressure.

$$\text{Pressure} = \frac{\text{Thrust}}{\text{Area}} \qquad \boxed{\text{Thrust} = W = mg}$$

SI unit of pressure is Nm^{-2} or Pascals (Pa).

Pressure

It is defined as a perpendicular force acting per unit area. Its SI unit is Pascals.

Pressure, $P = \frac{F}{A}$ where 'A' is area, 'F' is force.

(*a*) Pascal: When a force of 1N acts perpendicularly on an area of 1 m^2, the pressure is equal to 1 Pascal.

(*b*) Pressure and Area: Smaller the area, greater will be the pressure. Force acting on a smaller area will produce more pressure than the same force acting on a larger area, e.g. if you stand on sand, your feet will go deep into it due to smaller area as your body will exert more force.

If you lay down on the same sand, your body will not go deep as the area is more, force exerted on sand will be less, so the pressure will be less.

- Walking on pointed heels becomes difficult because area is smaller whole body weight is acting on a small area, hence a greater pressure is produced.
- When a nail is hit with a hammer due to its small area more pressure is produced and it goes into the wall easily.
- A knife has sharp and thin edges. When force acts on sharp edges, it produces more pressure.

- For the same force, increasing the area reduces the pressure. Snow shoes, skating equipments have large surface areas so as pressure is reduced which makes walk or skate easily.
- JCB (Excavators) have caterpiller tracks which have larger surface areas so as to reduce the pressure on the soft earth area for movement.

(*c*) Force and Pressure: For the same area, pressure can be increased by increasing the force and vice-versa, e.g. A heavy man on a pair of skis will leave deeper impressions on the snow than a boy wearing the same skis with lesser weight.

(*d*) Atmospheric Pressure: The pressure exerted by the weight of the air in our atmosphere is called atmospheric pressure.

(*e*) Pressure of Fluids: Liquids also exert pressure. Water pressure can be felt when one dives deep into water. Fluids exert pressure due to its weight and they also exert pressure on the base and walls of the container in which they are enclosed.

- Pressure exerted by a confined mass of fluids is exerted equally in all the directions.

Buoyancy

The property of any fluid due to which it exerts an upward force on an object when it is immersed partially or wholly into a fluid (liquid) is called the force of buoyancy or buoyancy.

- It acts in upward direction and depends upon density of fluid.
- If the gravitational pull on an object is more than upward thrust, it will sink and if upward thrust is equal or more than gravitation pull, it will float. Upward thrust is directly proportional to density.

$$\boxed{U = mg}$$

Where 'm' is mass, 'g' is acceleration due to gravity

$$\boxed{U = V \times \rho \times g}$$ Where 'ρ' is density of fluid (liquid)

$$\boxed{\rho = \frac{m}{V} \Rightarrow m = \rho V}$$

- **Density:** It is defined as mass per unit volume, the density of cork is less than the density of water.
- The upward thrust of water is greater than the weight of the cork, so it floats.
- The density of iron nail is more than density of water, therefore it sinks because upward thrust of water is less than the weight of a nail.

Archimedes Principle

When a body is immersed partially or completely in a fluid (liquid or gas) it experiences an upthrust or buoyant force which is equal to the weight of the fluid displaced by the body.

- The weight of the body decreases due to buoyant force acting in the body, when immersed in a fluid.

Upthrust (Buoyant force) = Weight of fluid displaced by body

= Weight of body in air – Weight of body in the fluid.

Apparant weight = Weight of body – Upward thrust

Application:

(*i*) Ships and submarines are designed on the basis of Archimedes' principle.

(*ii*) Hydrometer are used to measure the density of liquids and lactometers are used to measure the purity of milk, both are based on Archimedes Principle.

Relative Density

The relative density of a substance is the ratio of density of a substance to the density of water.

- It does not have any unit because it is the ratio of similar quantities.

$$\text{Relative density} = \frac{\text{Density of substance}}{\text{Density of water}} = \frac{\text{Weight of a substance in Air}}{\text{Loss in weight of a substance in water}}$$

$$= \frac{\text{Mass of a substance of any volume}}{\text{Mass of water of same volume}}$$

Exercise 10.2

I. Very Short Answer Type Questions (1 Mark)

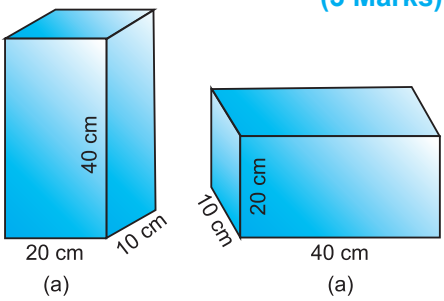
1. Relative density of gold is 19.3. The density of water is 10^3 kg m^{-3}. What is the density of gold in kg/m^3? [*DOE*]
2. Mass of 0.025 m^3 of aluminium is 67 kg. Calculate the density of aluminium.
3. Why is it difficult to hold a school bag having a narrow straps.? [*NCERT*]
4. What do you mean by force of buoyancy? [*NCERT*]
5. Why does an object float or sink when placed on the surface of water? [*NCERT*]
6. In which direction does the buoyant force on an object immersed in a liquid act? [*NCERT*]

II. Short Answer Type Questions–I (2 Marks)

7. State two factors on which the Buoyant force will depend. [*DOE*]
8. You have a bag of cotton and an iron bar, each indicating a mass of 100 kg when measured on a weighing machine. In reality, one is heavier than other. Can you say which one is heavier and why? [*NCERT*]
9. Density of aluminium is 2700 kg m^{-3}. What is its relative density? Density of water = 1000 kg m^{-3}. Define relative density. [*DOE*]
10. Why does a block of plastic released under water comes up to the surface of water? [*NCERT*] [*CBSE* 2011]
11. The volume of 50 g of a substance is 20 cm^3. If the density of water is 1 g cm^{-3}, will the substance float or sink? [*NCERT*] [*CBSE* 2011, 12]
12. A solid weighs 80 g in air and 64 g in water. Calculate the relation for density of solid when it is kept in water, state if the object would float or sink?
13. A solid weighs 75 g in air and 55.6 g in water. Find the relative density of the solid. Also state if the object will float or sink when it is immersed in water. [*CBSE* 2014]
14. Give the mathematical formula that relates thrust and pressure. Define 1 Pascal. Calculate the thrust and pressure exerted by a wooden block exerting a force of 500 N on the surface of a table if the surface area of contact is 2.5 m^2. **[HOTS]**

III. Short Answer Type Questions–II (3 Marks)

15. A block of wood is kept on a table top. The mass of a 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 dimensions
(*a*) 20 cm × 10 cm (*b*) 40 cm × 20 cm [*NCERT*]



16. The volume of a 500 g sealed packet is 350 cm^3. Will the packet float or sink in water if the density of water is 1 g cm^{-3}? What will be the mass of the water displaced by this packet? [*NCERT*]

17. Differentiate between density and relative density. What is the density of silver, given that its relative density is 10.3? [*CBSE* 2015, 2016]

18. (*a*) A metal rod sinks but a ship made up of the same metal does not sink, why?
(*b*) Why does the block of the same metal feel different weight, when they are completely immersed in different liquids? [*CBSE* 2015]

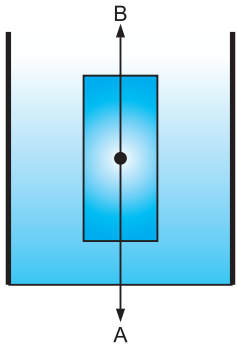
19. (*a*) Name and state the principle which is used to check the purity of milk by lactometer
(*b*) Explain two of its applications. [*CBSE* 2016]

IV. Long Answer Type Questions (5 Marks)

20. Differentiate between thrust and pressure (give two points). What do you understand by 1 Pascal and 1 Newton? How will the pressure change when the area of contact is doubled? [*CBSE* 2014]

21. (*a*) A body floats in kerosene of density 0.8×10^3 kg/m^3 upto certain distance. If the same body is immersed in water of density 1.0×10^3 kg/m^3, will it sink more or less? Give reason for your answer.
(*b*) If a fresh egg is put into beaker filled with water, it sinks. On dissolving a lot of salt in water, the egg begins to rise and then floats, Why? [*CBSE* 2016]

22. (*a*) On which principle lactometer and hydrometer are based upon?
(*b*) A bucket of water is easily lifted as long as it is in water. Why?
(*c*) Following forces act on body immersed in a liquid as shown in the figure.
(*i*) Name the forces acting on the body.
(*ii*) What happens when mass of A is greater than B.
[*CBSE* 2015]



Answers 10.2

1. Relative Density of Gold = 19.3
Density of water = 1000 kg/m^3 = 10^3 kg m^{-3}
Density of gold = Relative density of gold × density of water
or $\rho = 19.3 \times 10^3$ kg/m^3

2. Mass of Al = 67 kg
Volume of Al = 0.025 m^3

$$\text{Density of Al} = \frac{M}{V} = \frac{67\,\text{kg}}{0.025\,\text{m}^3} = 2680 \text{ kg/m}^3$$

3. The area under a narrow strap will be small, therefore large pressure will be exerted by the strap on our shoulder.
That is why a bag with narrow strap is caused. It is difficult to hold

4. The upward force experienced by an object when it is immersed into a liquid (fluid) is called the force of buoyancy.

5. When an upward thrust is equal or more than the gravitational force acting downward as the body will float.
When upward thrust is less than the gravitational force acting downwards on the body, it will sink.

6. It acts in upward direction.

7. (*i*) Density of liquid in which body is immersed.
(*ii*) Volume of body immersed in a liquid.

8. Iron bar is heavier than cotton. It is because iron bar experiences less upward thrust than cotton bag.

9. Relative density is defined as the ratio of density of a given substances to the density of water.

$$\text{Relative density of Al} = \frac{\text{Density of 'Al' in air}}{\text{Density of water}} = \frac{2700\,\text{kg m}^{-3}}{1000\,\text{kg m}^{-3}} = 2.7$$

10. The upward thrust (Buoyant force) acting on a block of plastic in the upward direction is greater than the force in downward direction.

11. $\text{Density} = \frac{M}{V} = \frac{50\,\text{g}}{20\,\text{cm}^3} = 2.5\ \text{g cm}^{-3}$

Since density of a substance is greater than density of water, therefore it will sink.

12. $\text{Relative density} = \frac{\text{Weight of solid in air}}{\text{Loss of weight of solid water}} = \frac{80}{80-64} = 5$

It will sink because its relative density is greater than water.

13. Relative density

$$= \frac{\text{Weight of substance in air}}{\text{Loss of weight of substance in water}}$$

$$= \frac{75}{77-55.6} = \frac{75}{19.4} = 3.86$$

It will sink because its relative density is greater than water.

14. Thrust acting per unit surface area is called pressure.

$$P = \frac{F}{A} = \frac{\text{Thurst}}{\text{Area}}$$

1 Pascal is the pressure exerted by 1 Newton force on 1 m^2 area.

Thrust, $F = 500$ N

$$\text{Pressure} = \frac{F}{A} = \frac{500\,\text{N}}{2.5\,\text{m}^2} = 200\ \text{N m}^{-2} = 200\ \text{Pa}$$

15. Mass of wooden block = 5 kg

(*a*) Area of side wooden block (20 cm × 10 cm)

$$= \frac{20}{100}\text{m} \times \frac{10}{100}\text{m} = 2 \times 10^{-2}\ \text{m}^2$$

$$F = m \times g = 5\ \text{kg} \times 9.8\ \text{m s}^{-2} = 49\ \text{N}$$

$$\text{Pressure} = \frac{F}{A} = \frac{49\text{N}}{2 \times 10^{-2}\ \text{m}^2} = 2450\ \text{N m}^{-2} = 2450\ \text{Pa}$$

(*b*) When wooden block lies on its side by dimension 40 cm × 20 cm, it exerts the same thrust i.e., 49 N.

$$\text{Area} = \frac{40\text{ m}}{100} \times \frac{20\text{ m}}{100} = 8 \times 10^{-2}\text{ m}^2$$

$$\text{Pressure} = \frac{F}{A} = \frac{49\text{ N}}{8 \times 10^{-2}\text{ m}^2} = \frac{4900}{8}\text{ Nm}^{-2} = 612.5\text{ N m}^{-2} = 612.5\text{ Pa}$$

16. $$d = \frac{M}{V} = \frac{500\text{ g}}{350\text{ cm}^3} = \frac{10}{7} = 1.43\text{ g cm}^{-3}$$

It will sink because its density is greater than water.

Mass of water displaced

= Volume of packet × Density of water

= 350 cm^3 × 1 g cm^{-3} = 350 g

17. Density is defined as the mass per unit volume of a substance.

Relative density is the ratio of density of substance to the density of water.

Relative density of Ag:

$$= \frac{\text{Density of Ag}}{\text{Density of water}}$$

$$10.3 = \frac{\text{Density of Ag}}{1000\text{ kg m}^{-3}}$$

Density of silver = 10.3×10^3 g m^{-3}

18. (*a*) In an iron rod. Its density is greater than water i.e. upward thrust is less. Its weight is more than the weight of water displaced by it, so it sinks.

In ships upward thrust is greaters, so it floats. Iron ship is hollow, filled with air, so its average density of ship is less than density of water. So weight of water displaced is more than the weight of ship so ship floats.

(*b*) The upward thrust depends upon the density of liquid, therefore weight of same metal block will be different in different liquids.

In the liquid having higher density, there will be more apparent weight loss and vice-versa.

19. **Archimedes Principle:** It states 'When a body is fully or partially immersed in a liquid, it experiences an upward thrust equal to the weight of fluid displaced by the body.

(*a*) **Applications:**

(*i*) Ships float on water because it displaces water equal to its own weight because it average density is less than water.

(*ii*) Icebergs displaces more weight of sea water than their own weight, hence the iceberg will float on sea water.

20.

Thrust	Pressure
It is the net force applied in a particular direction.	It is the measure of force per unit area of an object.
Its S.I. unit is Newton.	Its S.I unit is Pascal (Pa) or N/m^2.

1 Pascal is the pressure exerted by 1 Newton force on an area of 1 m^2.

1 Newton is the force exerted on 1 kg mass of a body which produces an acceleration of 1 m s^{-2}.

When area of contact is doubled, pressure will be reduced to half $\left(\because P \propto \frac{1}{\text{Area}}\right)$.

21. (*a*) A body will float more and sink less because density of water is greater than kerosene, therefore water will exert more upward thrust than kerosene due to higher density.
(*b*) Fresh egg sinks in water because upward thrust by water is less than buoyant force. In salt water, it floats because density of salt solution is more, so it exerts more upward thrust.

22. (*a*) Archimedes Principle
(*b*) It is because weight of a bucket will be less as long as it is in water due to upward thrust.
(*c*) (*i*) Thrust acting upwards. Weight of the body act downwards.
(*ii*) Since A is greater than B, therefore the body will sink.

Value Based Questions

1. In a village Ramesh mix water in the milk whereas Rajesh sells pure milk. Both of them sell milk to a shopkeeper in the market. Ram suggests the shopkeeper to purchase a lactometer to check the purity of milk. Shopkeeper followed to his advice and stopped taking milk from Ramesh.
(*i*) What values are associated with Rajesh and Ram?
(*ii*) On which principle lactometer is based?
(*iii*) Which will have higher density: pure milk or milk mixed with water?

2. Renu is having a school bag with narrow straps. She feels lot of pain on her shoulders. Her father gave her another school bag with wider straps. She feels comfortable now.
(*i*) What values are associated with Renu's father?
(*ii*) Which bag exerts more pressure, having thin strips or wide strips? Why?

3. Shruti and Kriti were performing the experiment to find the pressure exerted by a cuboid kept on sand with its different faces. Shruti shared her thoughts with Kriti and told her that since the teacher had explained about pressure and area, therefore she could guess the results.
(*i*) How can you relate the pressure applied by an object with its area?
(*ii*) What could be the observations of Shruti and Kriti?
(*iii*) Which qualities of Shruti do you observe?[*CBSE* 2015]

Answers

1. (*i*) Rajesh is an honest person. Ram has knowledge of science and is a helpful person.
(*ii*) Archimedes Principle
(*iii*) Density of pure milk will be more.

2. (*i*) He is concerned about the comforts of his daughter.
(*ii*) Bag with thinner strips exerts more pressure, because of less area. This is because pressure is inversely proportional to the area.

3. (*i*) Pressure is inversely proportional to the area.
(*ii*) The side with less area will exert more pressure and will go deep into the sand.
(*iii*) Shruti is a helpful person. She shares her knowledge with her friend.

Practical Bases Questions

Experiment 1: *To determination of the density of solid (denser than water) by using a spring balance and a measuring cylinder.*

Q1. While determining the density of a metal block using a spring balance and measuring cylinder, write the steps in proper sequence. (Experimental Skills)

Ans. (*i*) Weigh the metal block in air with the help of a spring balance, after checking zero error if any.

(*ii*) Note the water level in the measuring cylinder.

(*iii*) Immerse the metal block centrally in water without touching the sides and at centre of the bottom of the cylinder.

(*iv*) Note the water level in the measuring cylinder having a metal block dipped in it.

(*v*) Once again measure the weight of block in water using the spring balance.

Q2. Give two precautions while taking reading of the measuring cylinder.

(Experimental Skills)

Ans. (*i*) Read lower meniscus of water.

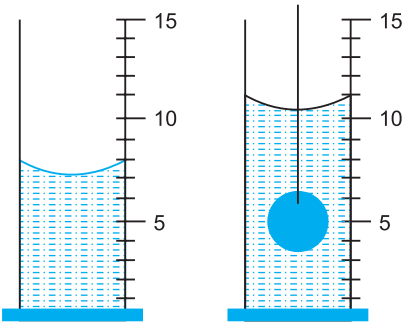
(*ii*) Keep your eye in the level of meniscus.

Q3. Give two precautions while taking reading from a spring balance. (Experimental Skills)

Ans. (*i*) Record a positive or negative zero error in the spring balloons.

(*ii*) Pointer must be at rest while taking final reading and adjust the zero error if any.

Q4. The level of water in a measuring cylinder before and after a solid of mass 4 g is fully immersed in it is shown in the diagram as follows. The density of the solid is: (Numerical Skills) [*CBSE* 2012]



Ans. Initial reading = 7 ml

Find reading = 11 ml

Volume of water displaced = 11 – 7 = 4 ml

Volume of sphere = 4 ml

$$d = \frac{M}{V} = \frac{4\,g}{4\,ml} = 1\ g\ ml^{-1} = 1\ g\ cm^{-3}$$

Q5. The density of a solid sphere is 7.01 g/mL. The volume of water displaced by a solid is 8 mL. What will be the density of the solid? (Numerical Skills)

Ans. $D = \frac{M}{V} \Rightarrow M = D \times V = 7.01 \times 8 = 56.08\ g$

Mass of solid = 56.08 g

∴ Volume of water displaced = Volume of sphere

Q6. The mass of a solid sphere is 3 kg. What will be the reading of a spring balance calibrated in Newtons on weighing that solid? ($g = 9.8\ ms^{-1}$) (Numerical Skills)

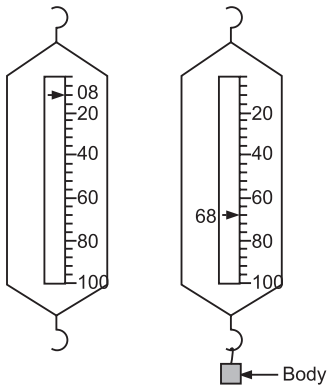
Ans.
$$\text{Mass} = \frac{\text{Weight}}{\text{Gravity}}$$

$$\text{Weight} = \text{Mass} \times \text{Gravity} = 3\ kg \times 9.8\ ms^{-1}$$

∴ Weight of solid sphere = 3 × 9.8 = 29.4 Newton

Q7. In an experiment of measuring the weight of a given body, the two positions of the pointer in the spring balance used, before and after attaching the body to it are as shown. The weight of the body is:

(Conceptual Skills)



Ans. Zero error = 8 gram weight

Final reading = 68 gram weight

∴ Weight of the body = Final reading – Zero error

= 68 g wt – 8 g wt = 60 g

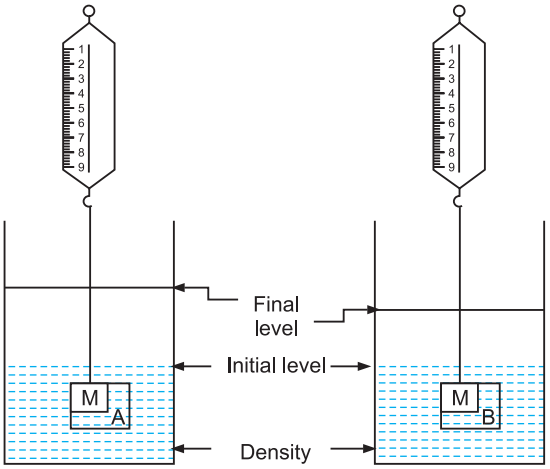
Q8. State Archimedes principle. (Conceptual Skills) [*CBSE* 2014]

Ans. It states that when an object is partially or completely immersed in a liquid, it experience or upthrust which is equal to the weight of the liquid displaced by it.

Q9. Two spheres 'A' and 'B' of some material having mass 'm' and '3m', respectively are taken to find the density of a material. What will be ratio of their density? (Reasoning Skills)

Ans. Their density will be same because the material used is same. Density does not depends upon the mass. It is the ratio of mass per unit volume. It depends upon the nature of the material.

Q10. If U_1 and U_2 are the upthrust exerted by the liquid on M_A and M_B then,



what is the relationship between U_1 and U_2? Give reason. (Observation Skills)

Ans. $U_1 > U_2$

Reason: It is because upward thrust is directly proportional to the volume which is proportional to the mass for same density.

Experiment 2: *To establish the relation between the loss in weight of a solid when fully immersed in: (a) tap water, (b) strong salty water, with the weight of water displaced by it by taking at least two different solids.*

Q1. The mass of body is 10 kg at a place where g is 9.8 m s^{-2}. What will be its weight in air and water? (Numerical Skills)

Ans. W = mg = 10 kg × 9.8 m s^{-2} = 98 Newton. The weight in water will be less than 98 N.

Q2. A spring balance calibrated in Newtons reads 19.6 N. Calculate its mass in grams. (Numerical Skills) [*CBSE* 2016]

Ans.
$$W = mg$$
$$19.6\ N = m \times 9.8\ ms^{-2}$$
$$m = 2\ kg = 2000\ g$$

Q3. While doing an experiment on establishing the relationship between the loss in weight of a solid when in tap water, with the weight of water displaced by it, a student record the following observations:

Weight of solid in air = W_1

Apparent weight of solid when fully immersed in tap water = W_2

Weight of water displaced by the solid = W_3

What is the relationship between W_1, W_2 and W_3? Give reason.

(Numerical and Reasoning Skills)

Ans. $W_1 = W_2 + W_3$

Weight of water displaced = Loss in weight.

Q4. Mass of an object in air is 30 kg. What will be its mass in water? Why?

(Conceptual Skills)

Ans. The mass of the object in water will be less than 30 kg because Bouyant force will be acting on the body, so there will be an apparent loss in weight.

Q5. In an experiment when an object in immersed in water, what does the volume of displaced water indicate? While taking the reading of level of water in measuring cylinder, what should be the position of the eye? (Conceptual Skills) [*CBSE* 2014]

Ans. Volume of water displaced = Buoyant force = Lost of weight of the object in liquid.

The eye level should be at the same level of water in measuring cylinder.

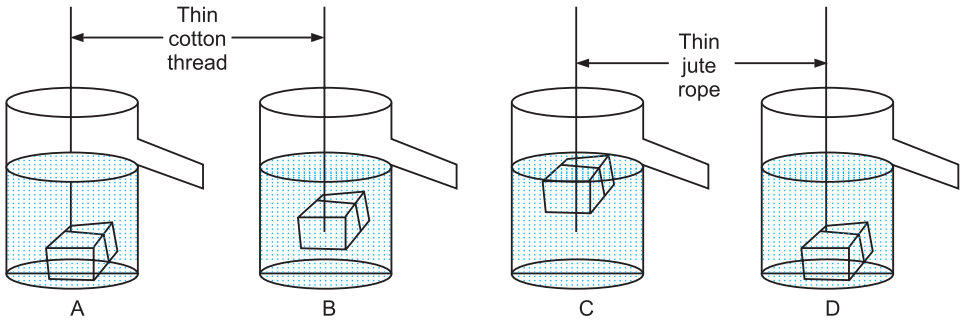
Q6. Name the two factors which affects Buoyant force. (Conceptual Skills)

Ans. (*i*) Density of liquid (*ii*) Value of '*g*' (gravity)

Q7. Why is it easier to swim in sea than in lake or river water? (Reasoning Skills)

Ans. Loss of weight will be more in sea water than lake or river water due to more buoyant force, that is why it is easier to swim in sea water because the density of salty water from sea is more than than the density of lake or river water.

Q8. In an experiment to establish the relation between loss in weight of an immersed solid with the weight of water displaced by it, which of the following represents the correct set up and why? (Observation Skills)



Ans. 'B' represents the correct set up. Thin cotton thread is better than jute rope.

Reason: The body should be completely immersed in liquid and it should not touch the bottom of the container.

Q9. If a body is fully immersed in a salty solution and tap water, in which of them will more apparent loss in weight takes place? Why? (Observational Skills) [*CBSE* 2011]

Ans. There will be more loss in weight in salty water than tap water because density of salty water is more than that of tap water which will exert more buoyant force than tap water.

Q10. A given solid is weighed in air using a spring balance. It is then weighed separately by immersing it fully first in vessel containing tap water and then in water containing salt solution. What would be the readings of the spring balance in these solutions and why?

(Observational Skills) [*CBSE* 2010]

Ans. The reading of spring balance will be more in air than in tap water and it is minimum in salt solution because buoyant force exerted by the salt water is maximum which leads to more apparent loss of weight.

Q11. From the given table of densities of different substances, infer whether the given object would float or sink in the given solution? (Inference Skills) [*CBSE* 2016]

Material	Density g/cm^3
Gasoline	0.7
Gold	19.3
Lead	11.3
Mercury	13.6
Paraffin (wax)	0.87
Platinum	21.4

Now answer:

(*i*) Will a bar of gold sink in mercury?

(*ii*) Will a piece of platinum float on gasoline?

(*iii*) Will a block of paraffin sink in gasoline?

(*iv*) Will a piece of platinum sink in mercury?

Ans.

(*i*) Yes, a bar of gold has density 19.3 g cm^{-3} and mercury has 13.5 g cm^{-3}. Therefore gold bar sink in mercury due to it has **higher density than mercury**.

(*ii*) No, platinum piece will not float on gasoline because it has higher density than gasoline.

(*iii*) Yes, because the density of wax is higher than that of Gasoline.

(iv) Yes, platinum will sink in mercury due to its higher density than mercury.

COMMON ERRORS

Errors	Corrections
• When a body is going vertically upward, *'g'* is taken as +ve by the students.	☞ *'g'* is –ve when body goes upward and +ve when it comes downward.
• Children calculate the mass of objects wrongly at moon.	☞ Mass remains the same everywhere. Weight of the body depends upon *'g'* and hence changes on moon.
• Children do not write formula in numerical problem.	☞ Mass of planet $= \frac{1}{2}$ × Mass of earth Radius of planet = 2 × Radius of earth
• Children do not know how to convert density in SI units if relative density is given.	☞ The density of water should be taken as 10^3 kg m^{-3} and not as 1 g cm^{-3} to get density in SI units, i.e. kg m^{-3}.

IMPORTANT FORMULAE

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

G = Gravitation constant

= 6.67×10^{-11} N m^2/kg^2, m_1 and m_2 are the masses of the objects separated by a distance r.

2. $\boxed{P = \frac{F}{A} = \frac{\text{Thrust}}{\text{Area}}}$

For freely falling bodies, $a = +g\downarrow$; $a = -g\uparrow$

(*i*) $v = u \pm gt$ (*ii*) $v^2 = u^2 \pm 2gh$ (*iii*) $h = ut \pm \frac{1}{2} gt^2$

3. $\boxed{1\,\text{kg Wt} = 9.8 \text{ Newton}}$ $\because$ W = mg = 1 kg × 9.8 m s^{-2} = 9.8 N (newton)

Upthrust, U = Volume immersed × Density of fluid × *g*

Apparent weight= Weight – Upthrust = $V\rho_b g - V\rho_a g$

where 'ρ_b', 'ρ_l' are densities of body and liquid,

V and V_1 are the volume of the body and the liquid in which it is immersed.

4. $\boxed{\text{S.I. unit of density is kg m}^{-3}}$ $\boxed{D = \frac{M}{V} = \frac{\text{Mass}}{\text{Volume}}}$

$$\text{Relative density} = \frac{\text{Density of substance}}{\text{Density of water}}$$

When W > U; the body sinks

When W < U, the body floats outside

When W = U, The body floats with its top surface on the surface of liquid

$$\text{Relative Density} = \frac{\text{Mass of substance}}{\text{Mass of equal volume of water}}$$

$$= \frac{\text{Weight of substance}}{\text{Weight of equal volume of water}}$$

$$= \frac{\text{Weight of substance in air } (W_S)}{\text{Loss of weight in water (U)}}$$

$U = mg = V \times \rho \times g$ [where 'U' is upthrust, 'ρ' is density of fluid, 'g' is acceleration due to gravity, 'V' is volume of object in fluid]

IMPORTANT NUMERICAL PROBLEMS

1. A bag of cotton weighs 10 kg and occupies a volume of 2 m^3. Find its density. Express it in CGS units also.

Sol. $$d = \frac{M}{V} = \frac{10 \text{ kg}}{2 m^3} = 5 \text{ kg m}^{-3}$$

$$d = \frac{M}{V} = \frac{10 \times 1000 \text{ g}}{2 \times (100 \text{ cm})^3} = \frac{10^4}{2 \times 10^6} = 0.5 \times 10^{-2} = 5 \times 10^{-3} \text{ g cm}^{-3}$$

2. The volume of 500 g sealed packet is 300 cm^3. Will this packet sink or float in water if density of water is 1 g cm^{-3}? What will be the mass of the water displaced by the packet?

Sol. Volume of bag = 300 cm^3

Density of water = 1 g cm^{-3}

$$\text{Relative density} = \frac{\text{Mass of packet}}{\text{Mass of water displaced}} = \frac{500}{300} = 1.66$$

Since relative density of a packet is more than the density of water, so it will sink.

Mass of the water displaced = $\frac{\text{Mass of packet}}{\text{Relative density}} = \frac{500}{5/3} = 300\ \text{cm}^3$

3. A solid exerts a pressure of 20 Pa on the surface area of 2 m^2. Find its weight.

Sol. $P = \frac{W}{A} \Rightarrow 20\ \text{Pa} = \frac{W}{2\,\text{m}^2} \Rightarrow W = 40$ Newton

4. Which will exert more pressure : 100 kg mass on 10 m^2 or 50 kg mass on 4 m^2? Give reason. ($g = 9.8\ ms^{-2}$)

Sol. $P = \frac{W}{A} = \frac{mg}{A} = \frac{100\ \text{kg} \times 9.8}{10\,\text{m}^2} = 98$ Pa

$P = \frac{W}{A} = \frac{mg}{A} = \frac{50\ \text{kg} \times 9.8}{4\,\text{m}^2} = \frac{490}{4} = 122.5$ Pa

$\therefore$ Pressure on 50 kg mass will be more, because it has less surface area.

5. The weight of an object on the earth's surface is 100 N. Find its

(*i*) mass on the earth

(*ii*) mass and weight on the moon. (Given 'g' on earth is 10 m s^{-2}, 'g' on earth = 1.67 m s^{-2})

Sol. (*i*) $W = mg \Rightarrow 100\ \text{N} = m \times 10\ \text{m s}^{-1}$, $m = 10$ kg

(*ii*) Mass on moon = 10 kg

$W = mg = 10\ \text{kg} \times 1.67 = 16.7$ Newton

6. A body is thrown up with a velocity of 40 m s^{-1}. How long does it take to reach the highest point? After how much time will the body come back to the ground.

Sol. $u = 40\ \text{m s}^{-1}$ $v = 0$ $g = 10\ \text{m s}^{-2}$

$V = u - gt$

$0 = 40 - 10 \times t \Rightarrow t = \frac{40}{10} = 4$ seconds

Time take to come back = 4 + 4 = 8 seconds.

7. Calculate the gravitational force of attraction between the earth and the moon

$M_e = 6 \times 10^{24}$ kg, $M_n = 7.4 \times 10^{22}$ kg, Mean distance = 3.8×10^8 m,

$G = 6.66 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2$

Sol.
$$F = \frac{9 \times m_1 \times m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 7.4 \times 10^{22}}{(3.6 \times 10^8)^2}$$
$$= \frac{6.67 \times 6 \times 7.4}{3.6 \times 3.6} \times 10^{-11+24+22-16}$$
$$= \frac{296.148}{14.44} \times 10^{19} = 20.5 \times 10^{19}\ \text{N} = 2.05 \times 10^{20}\ \text{N}$$

8. Estimate the gravitational force between two protons with mass 1.6×10^{-27} kg each separated by a distance of 1A° [1A° = 10^{-10} m], $G = 6.67 \times 10^{-11}\ \text{N m}^2/\text{kg}^2$

Sol.
$$F = \frac{9 \times m_1 \times m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 1.67 \times 10^{-27}\ \text{kg} \times 1.67 \times 10^{-23}\ \text{kg}}{(10^{-10}\,\text{m})^2}$$
$$F = 18.60 \times 10^{-65+20} = 18.60 \times 10^{-45}\ \text{Newton} = 1.86 \times 10^{-44}\ \text{Newton}.$$

REVISION CHART

GRAVITATIONAL FORCE

The force of attraction between the objects in this universe is called gravitational force.

Mass

It is the measure of its inertia. The mass of an object is constant and it does not change from place to place.

Free Fall

When objects fall towards the earth under the gravitational force alone.

Weight

The force of attraction of the earth on an object is known as the weight of the object. It is denoted by *W*.

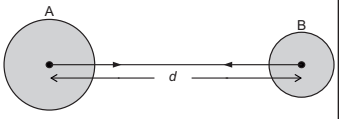
Relative Density

It is the ratio of the density of a substance to that of water.

Relative Density = $\frac{\text{Density of a substance}}{\text{Density of water}}$

Universal Law of Gravitation

The force of attraction between two objects is directly proportional to the product of the masses of two bodies and is inversely proportional to the square of the distance between them.



$$F = G\frac{M \times m}{d^2}$$

$G = 6.673 \times 10^{-11}\ N\ m^2\ kg^{-2}$

Thrust and Pressure

The thrust per unit area is called pressure.

Pressure = Thrust/Area

Archimedes' Principle

It states that when a body is immersed fully or partially in a fluid, it experiences an upward force that is equal to the weight of the fluid displaced by it.