EXAM DRILL

Gravitation

CHAPTER 10

ANSWERS

1. No, heavier objects and lighter objects have the same acceleration due to gravity (g).

2. As the gravity disappears, we shall be thrown out in space from the surface of Earth due to centrifugal force (equal and opposite to centripetal force).

3(i) Mass of Moon is less than that of Earth.

3(ii) The value of g on Moon is 1/6 times that of Earth.

3(iii) Because the size of Earth is grater than Moon.

3(iv) Weight on Earth = 60 kg

Weight on Moon = $\frac{1}{6} \times 60$ kg = 10 kg

4(i) $F = GM_1M_2/R^2$

4(ii) Newton is the unit of gravitational force denoted by (N).

4(iii) (c) : $F = \frac{GM_1M_2}{R^2}$

$= \frac{6.67 \times 10^{-11} \text{N m}^2\text{kg}^{-2} \times 0.5 \text{ kg} \times 0.5 \text{ kg}}{(1 \text{ m})^2}$

$= 1.67 \times 10^{-11}$ N.

4(iv)(d) : $F = \frac{GM_1M_2}{R^2} = \frac{6.67 \times 10^{-11} \text{N m}^2\text{kg}^{-2} \times 60 \text{ kg} \times 60 \text{ kg}}{(10 \text{ m})^2}$

$= 2.4 \times 10^{-9}$ N

5. **(a) :** Newton's law of gravitation can be verified in the laboratory.

OR

(d) : $g_m = \frac{1}{6} g_e$.

6. **(a) :** The clouds are held to the Earth by gravity, *i.e.*, gravitational pull of Earth on them.

7. **(c) :** Law of gravitation is universal. It gives the gravitational force between any two bodies having some mass.

OR

(c) : At the highest point, the vertical velocity is zero but the acceleration always acts on it due to gravity, which is in the downward direction.

8. **(c) :** It means 3.5 g glass is contained in 1 cm^3 volume.

9. **(d) :** The weightlessness situation arises when there is a free fall of the satellite under the effect of gravity.

10. **(c) :** The buoyant force acting on a body immersed in a liquid is given by

$F_B = Vdg$

where V is the volume and d is the density of the liquid displaced.

OR

(c) : Lactometer is used for determining the purity of a sample of milk.

11. **(b) :** Here, volume of the hall,

$V = 50 \text{ m} \times 15 \text{ m} \times 3.5 \text{ m} = 2625 \text{ m}^3$

Density of air, $d = 1.30$ kg/m^3

$\therefore$ Mass of air in the hall, $M = V \times d$

$= (2625 \text{ m}^3) \times (1.30 \text{ kg/m}^3) = 3412.5$ kg

12. **(b) :** Acceleration due to gravity changes more with depth than height.

13. **(c) :** velocity depends on the radius of the orbit. As the orbits are elliptical in shape and direction of planet changes in time but velocity does not it remain constant.

14. **(a) :** A person weights less in water than is air due to buoyancy acting on him in water is larger than the buoyancy acting on him in air.

15. Suppose Earth is a perfect sphere of radius R.

$\therefore$ Volume of Earth $= \frac{4}{3}\pi R^3$

If ρ is average density of Earth, then mass of Earth,

M = volume × density $\Rightarrow M = \frac{4}{3}\pi R^3 \times \rho$

From Newton's law of gravitation,

$$g = \frac{GM}{R^2} = \frac{G}{R^2}\left(\frac{4}{3}\pi R^3 \rho\right)$$

$$g = \frac{4\pi}{3} R \rho G$$

$$\rho = \frac{3g}{4\pi RG}.$$

16. It is known that value of acceleration due to gravity (g) at poles is higher than its value at equator, *i.e.*, $g_p > g_e$. Therefore, from given height, the packet dropped above the North pole will reach the Earth earlier than the packet dropped above the equator.

17. Let V be the volume and ρ is the density of the solid.

Weight of body = $V \rho g$

Volume of solid body inside water $= V - \frac{V}{4} = \frac{3V}{4}$

Weight of water displaced by the immersed portion of the solid

$= \frac{3V}{4} \times 10^3 \times g$

Using the principle of floatation, $V \rho g = \frac{3V}{4} \times 10^3 \times g$

or $\rho = \frac{3}{4} \times 10^3 = 750 \text{ kg m}^{-3}$

OR

Atmospheric pressure, $P = h \rho g$

$h = 0.76$ m

$\rho = 13.6 \text{ g/cc} = 13.6 \times 10^3 \text{ kg/m}^3$

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

Putting these values and solving we get,

$P = 0.76 \times 13.6 \times 10^3 \times 9.8$

$= 1.013 \times 10^5 \text{ N m}^{-2}$

18.

	Acceleration due to gravity (g)	Universal gravitational constant (G)
(i)	It is the acceleration acquired by a body due to the Earth's gravitational pull on it.	It is equal to the force of attraction between two masses of 1 kg each separated by a distance of 1 m.
(ii)	The value of 'g' is different at different places on the surface of the Earth. Its value varies from one celestial (heavenly) body to another.	'G' is a universal constant, *i.e.*, its value is the same everywhere in the universe. ($G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$)
(iii)	It is a vector quantity.	It is a scalar quantity.

19. $F_s = \frac{G M_e M_s}{R_s^2}$

$F_m = \frac{G M_e M_m}{R_m^2}$

$\frac{F_s}{F_m} = \frac{M_s R_m^2}{M_m R_s^2} = \frac{2 \times 10^{30} \times (3.84 \times 10^8)^2}{7.3 \times 10^{22} \times (1.50 \times 10^{11})^2} \simeq 180$ times

The force of the Sun is approximately 180 times more than that of the Moon.

OR

The acceleration due to the gravitational force exerted by the Moon is given by

$a = \frac{GM_m}{R_m^2}$,

where M_m is mass of the Moon and R_m is the radius of the Moon.

The corresponding value of the acceleration due to gravity at the Earth's surface is given by,

$g = \frac{GM_e}{R_e^2}$,

where M_e is mass of the earth of radius R_e.

Also, $\frac{a}{g} = \frac{GM_m}{R_m^2} \times \frac{R_e^2}{GM_e} = \frac{M_m}{M_e} \times \frac{R_e^2}{R_m^2}$

Substituting the respective values, we have

$\frac{a}{g} = \frac{7.3 \times 10^{22} \text{kg}}{6 \times 10^{24} \text{ kg}} \times \left(\frac{6400 \text{ km}}{1740 \text{ km}}\right)^2 \simeq 0.16$

or $a = 0.16 \times g = 0.16 \times 9.8 = 1.57 \text{ m s}^{-2}$

20. A ship has a larger volume as compared to the solid sheet of the same mass. Accordingly, a part of the ship displaces more water than the entire solid sheet and thus experiences more buoyant force and does not sink. One can argue like this also. The average density of an object = mass of the object/ volume of the object. Since, the volume of the ship is much more than that of the solid sheet of the same mass, average density of ship is less than that of water. Hence, the ship floats. The sheet sinks as its average density is more than water.

21. Velocity during ascent = 2 m/s

Height of the helicopter = 24 m

So, height from where the packet is dropped = 24 m

Initial velocity of the packet, $u = -2$ m/s

Final velocity of the packet, $v = ?$

Using the equation,

$v^2 - u^2 = 2as$

$v^2 - (-2 \text{ m/s})^2 = 2 \times 10 \text{ m/s}^2 \times 24 \text{ m} = 480 \text{ m}^2/\text{s}^2$

$v^2 = 480 \text{ m}^2/\text{s}^2 + 4 \text{ m}^2/\text{s}^2 = 484 \text{ m}^2/\text{s}^2$

This, gives, $v = \sqrt{484 \text{ m}^2/\text{s}^2} = 22$ m/s

Converting the units of velocity,

$$= v = \frac{22 \times 1\text{m}}{1\text{s}} = \frac{22 \times 10^{-3} \text{km}}{(1/60 \times 60)\text{ h}} = 79.2 \text{ km/h}$$

As final velocity (79.2 km/h) is greater than 72 km/h, so the packet would be damaged

22. The weight is equal to the force of gravity, therefore weight can be written as, Weight = Force due to gravity

$W = \frac{G \times M_m \times 60}{R_m^2}$

$= \frac{6.67 \times 10^{-11} \times 7.18 \times 10^{22} \times 60}{(1.738 \times 10^6)^2} \text{N} = 95.13 \text{ N}.$

This weight is about one-sixth of the weight of the same object would have on the Earth ($60 \times 9.8 = 588$ N), even its mass is same in both places.

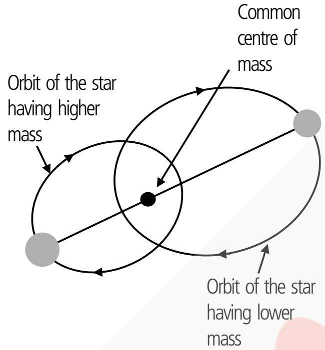
OR

Determination of the masses of planets and stars.

Knowing precise values of g, R, and G, it is possible to determine accurately the mass of any planet or star by using the relationship,

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

Estimating the masses of double stars : A double star is a system consisting of two stars orbiting round their common centre of mass. From the extent of irregularity in the motion of a star due to the gravitational pull by some other star bound to it, can be used for estimating their masses. Such a small irregularity in motion is called wobble.



Orbits of stars of a double-star system

Many planets outside our solar system have been detected in recent years by measuring the irregularity (called wobble) in the motion of stars.

23. Archimedes' Principle has many practical applications which is used in:

(i) designing ships and submarines. A ship is given such a shape that as it sinks into water, it displaces a large volume and soon the weight of the displaced water equals its own weight. The factor which makes it possible for a ship to float is its shapes. The density of the material of which a ship is built is greater than that of sea-water. A submarine is so built that it can float like an ordinary ship. It has two shells, one inside the other. The inner shell is much stronger than the outer shell. The space between the two shells is divided into chambers. When they are full of air, the submarine floats. When the chambers are filled with water, the submarine sinks. When it is required to rise to the surface, water is expelled from the chambers by means of pumps driven by compressed air. This lightens the submarine and it floats up.

(ii) determining the purity of a sample of milk by using an instrument, called lactometer.

(iii) determining the densities of liquids by using an instrument, called hydrometer.

(iv) checking the concentration density of sulphuric acid in acid batteries by using an instrument, called acid battery hydrometer.

24. (a) Liquid (R) has the highest density.

(b) Weight of the block

= Weight of the liquid displaced by the immersed portion of the block

= Mass of the liquid displaced $\times$ Acceleration due to gravity

= Volume of the liquid displaced $\times$ Density of the liquid $\times$ g

For a liquid of the highest density, volume of the liquid displaced should be the least. This is observed to be in (R).

25. Consider vessel containing the liquid of density d. Let us consider that the liquid is stationary. To calculate the pressure at the height h, consider the horizontal circular surface PQ of area A at depth h below the surface XY of the liquid.

Now, thrust exerted on the surface PQ

= Weight of the liquid column $PQRS$

= Volume of the column $PQRS$ $\times$ density x acceleration due to gravity

= (Area of the base $PQ \times$ depth h) $\times d$ x g.

$= Ahdg$

From the Formula,

Pressure= Thrust/Area.

$\Rightarrow$ Pressure $= Ahdg/A$

$\Rightarrow$ Pressure $= hdg$

OR

Buoyant force in liquids helps in making objects appear lighter. The objects appear to be less heavy when submerged in water than they are in air. The objects appear to be less heavy in water because the water exerts an upward force on them. Liquids and gases exhibit the property of buoyancy.

The buoyant force/upthrust has the following three characteristic properties:

(i) Larger the volume of body submerged in fluid, greater is the buoyant force.

(ii) More the density of fluid, greater is the buoyant force.

(iii) The buoyant force acts on the body in upward direction at the center of gravity of the displaced fluid which is called the center of buoyancy.

26. Archimedes' principle states that when a body is immersed partially or wholly in a liquid at rest, it experiences an upthrust which is equal to the weight of the liquid displaced. The apparent loss in weight of the body is equal to the upthrust on the body.

In essence, Archimedes' Principle states that :

(i) When a body is immersed either partially or fully in a liquid, it experiences an upthrust or buoyant force (F_B).

(ii) This upthrust (F_B) is equal to the weight (W_l) of the liquid displaced by the body, *i.e.*,

$$F_B = W_l = V d_l g$$

where d_l is ,the density of liquid in which the body is immersed and V is the volume of the liquid displaced.

Clearly, F_B depends upon :

(a) volume of the liquid displaced and

(b) density of the liquid.

(iii) The body appears to lose weight while in the liquid and this apparent loss in weight is equal to the upthrust or the weight of the liquid displaced by the body.

(iv) apparent weight of the body in the liquid = actual weight of the body in air – weight of the liquid displaced by the body.

27. Let, Mass of the earth (M_e) = 6×10^{24} kg

Mass of the body (m) = 1 kg

Radius of the earth, $r = 6.4 \times 10^6$ m

$$F = \frac{G M_e m}{r^2}$$

where F is gravitational force between the Earth and the body. Since the Earth has a very large radius, the distance between the centres of the Earth and the body is taken as the radius of the Earth.

Putting the values we get,

$$F = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 1}{(6.4 \times 10^6)^2} = 9.8 \text{ N}$$

This gravitational force is the force acting on the Earth due to the body and is equal to the force acting on the body due to the Earth. Though the forces are equal, they act in opposite directions on different bodies in accordance with the 3rd law of motion.

Acceleration of the body in the downward direction,

$$a_1 = \frac{F}{1 \text{kg}} = 9.8 \text{ m s}^{-2}$$

Distance travelled by the body,

$$S_1 = \frac{1}{2} g t^2 = \frac{1}{2} \times 9.8 \times 1 = 4.9 \text{ m} \quad \text{...(i)}$$

we have taken t = 1 s and the initial velocity, u = 0.

Acceleration of the Earth in the upward direction,

$$a_2 = \frac{F}{M_1} = \frac{9.8}{6 \times 10^{24}} = 1.63 \times 10^{-24} \text{ m s}^{-2}$$

Distance travelled by the Earth,

$$S_2 = \frac{1}{2} a_2 (1)^2 = \frac{1}{2} \times 1.63 \times 10^{-24} = 8.15 \times 10^{-25} \text{ m} \quad \text{...(ii)}$$

From eqns. (i) and (ii) we notice that the distance travelled by the Earth is negligibly small as compared to that travelled by the body under the same given conditions. This clearly explains our inability to notice the motion of the Earth.

OR

(a) Time of ascent = time of decent $= \frac{10}{2} = 5$ s

From, $v = u + at$

$0 = u - 9.8 \times 5 \Rightarrow u = 49$ m/s

This is the velocity with which it was thrown up.

(b) Maximum height $= \frac{u^2}{2g} = \frac{49 \times 49}{2 \times 9.8} = 122.5$ m

(c) From, $s = ut + \frac{1}{2} at^2$

$$x = 0 + \frac{1}{2} \times 9.8 \times (2)^2 = 19.6 \text{ m, from the top.}$$

Position of the ball after 7 s = 122.5 – 19.6 = 102.9 m above the ground.

28. **(a)** Initial velocity, u = 0 (dropped gently),

acceleration, a= 10 m/s^2

height, s =20 m; final velocity, v = ? and time taken, t = ?

Use third equation of motion :

$v^2 = u^2 + 2as$

$\Rightarrow v^2 = 0 + 2 \times 10 \times 20 \Rightarrow v^2 = 400$

$v = 20$ m/s

Using the second equation of motion, we get

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

$20 = 0 \times t + \frac{1}{2} \times 10 \times t^2$

$t^2 = 4$

$t = 2$ s

(b) On A, force = 1.5 N

area = 2 mm^2

1 mm = 1/1000 m = 0.001 m

1 mm^2 = 1 mm × 1 mm = 0.001 m × 0.001 m

= 0.000001 m^2 = 10^{-6} m^2

$P = 1.5 \text{ N}/(2 \times 10^{-6}) \text{ m}^2 = 7.5 \times 10^5$ Pa

On B, $P = 1.5 \text{ N}/(6 \times 10^{-6}) \text{ m}^2 = 2.5 \times 10^5$ Pa

29. When an object is placed in water (or any other liquid), the two forces acting on it are :

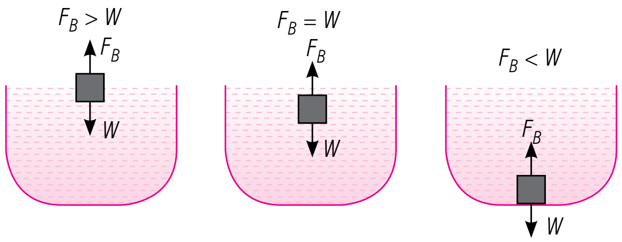
(i) Weight (W) of the object acting vertically downwards.

(ii) Buoyant force or upthrust F_B (or B) acting on the object vertically upwards.

The object will move in the direction of the force which is greater.

Depending upon the magnitudes of the two forces, the following three situations are possible.

(i) When $F_B > W$: Since the upward force is greater than the downward force, the body will float on the surface of the water or is partially immersed in liquid. Example: cork, wax etc.



(a) (b) (c)

(ii) When $F_B = W$: Since the downward and the upward forces are equal, the body will just float along the surface of the liquid. Example : wood, plastic mug filled with water, etc.

(iii) When $F_B < W$: Since the downward force is greater than the upward force, the body will sink. Example : iron nail, stone, etc.

An ice cube floats on water. This is because ice is lighter than water - density of ice is 0.92 g/mL and that of water is 1.0 g/mL at 0°C. As a result the ice cube sinks until the weight of the water displaced by the immersed portion of the ice cube becomes equal to weight of the ice cube.

A piece of solid iron sinks into water because it is heavier than water - the density of iron is 7.86 g/mL whereas that of water is 1.0 g/mL. The shape of the iron piece is such that the weight of the water displaced by it is less than the weight of the iron piece. As a result, iron piece sinks into the water.

OR

Relative density of any substance is the ratio of its density to that of water.

Mathematically,

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

Relative density is a pure number. It has no units.

We know,

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

So, we can write,

$$\text{Relative density of a substance} = \frac{\dfrac{\text{Mass of the substance}}{\text{Volume of the substance}}}{\dfrac{\text{Mass of water}}{\text{Volume of water}}}$$

If the volume of the water is the same as that of the substance,

$$\text{Relative density of a substance} = \frac{\dfrac{\text{Mass of the substance}}{\text{Volume of the substance}}}{\dfrac{\text{Mass of water}}{\text{Volume of water}}}$$

Relative density of a solid can be easily determined by Archimedes' principle.

30. **(a)** Mass of the football player $m = 80$ kg.

Acceleration due to gravity on the surface of the Earth $g = 9.8\ \text{m/s}^2$.

Weight in newtons is given by

Weight $= m \times g = 80\ \text{kg} \times 9.8\ \text{m/s}^2 = 784$ N.

Hence, the weight of the football player will be 784 N.

(b) (i) The Earth's radius is $r = 6.38 \times 10^6$ m and mass of Earth $M_e = 6 \times 10^{24}$ kg. On the Earth's surface, the weight is given by

$$W = G\frac{M_e m}{r^2}$$

$$= \frac{(6.67 \times 10^{-11}\,\text{N m}^2/\text{kg}^2)(6 \times 10^{24}\,\text{kg})(11600\,\text{kg})}{(6.38 \times 10^6\,\text{m})^2}$$

$= 1.14 \times 10^5$ N.

(ii) When the telescope is 598 km above the surface, its distance form the center of the Earth is

$r = 6.38 \times 10^6\ \text{m} + 598 \times 10^3\ \text{m} = 6.978 \times 10^6$ m.

Thus, the weight is

$$W = G\frac{M_e m}{r^2}$$

$$= \frac{(6.67 \times 10^{-11}\,\text{N m}^2/\text{kg}^2)(6 \times 10^{24}\,\text{kg})(11600\,\text{kg})}{(6.978 \times 10^6\,\text{m})^2}$$

$\approx 0.950 \times 10^5$N.

As expected, the weight is less in orbit.

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