Gravitation
NCERT Exemplar Problems

Multiple Choice Questions

1. Two objects of different masses falling freely near the surface of moon would

   (a) have same velocities at any instant

   (b) have different accelerations

   (c) experience forces of same magnitude

   (d) undergo a change in their inertia

2. The value of acceleration due to gravity

   (a) is same on equator and poles

   (b) is least on poles

   (c) is least on equator

   (d) increases from pole to equator

3. The gravitational force between two objects is F. If masses of both objects are halved without changing distance between them, then the gravitational force would become

   (a) $\frac{F}{4}$

   (b) $\frac{F}{2}$

   (c) F

   (d) $2F$

4. A boy is whirling a stone tied with a string in an horizontal circular path. If the string breaks, the stone

   (a) will continue to move in the circular path

   (b) will move along a straight line towards the centre of the circular path

   (c) will move along a straight line tangential to the circular path

   (d) will move along a straight line perpendicular to the circular path away from the boy

5. An object is put one by one in three liquids having different densities. The object floats with $\frac{1}{9}$, $\frac{2}{11}$ and $\frac{3}{7}$ parts of their volumes outside the liquid surface in liquids of densities d_1, d_2 and d_3 respectively. Which of the following statement is correct?

(a) $d_1 > d_2 > d_3$

(b) $d_1 > d_2 < d_3$

(c) $d_1 < d_2 > d_3$

(d) $d_1 < d_2 > d_3$

6. In the relation $F = G\frac{Mm}{d^2}$, the quantity G

   (a) depends on the value of g at the place of observation

   (b) is used only when the earth is one of the two masses

   (c) is greatest at the surface of the earth

   (d) is universal constant of nature

7. Law of gravitation gives the gravitational force between

   (a) the earth and a point mass only

   (b) the earth and Sun only

   (c) any two bodies having some mass

   (d) two charged bodies only

8. The value of quantity G in the law of gravitation

   (a) depends on mass of earth only

   (b) depends on radius of earth only

   (c) depends on both mass and radius of earth

   (d) is independent of mass and radius of the earth

9. Two particles are placed at some distance. If the mass of each of the two particles is doubled, keeping the distance between them unchanged, the value of gravitational force between them will be

   (a) $\frac{1}{4}$ times

   (b) 4 times

   (c) $\frac{1}{2}$ times

   (d) unchanged

10. The atmosphere is held to the earth by

    (a) gravity

    (b) wind

    (c) clouds

(d) earth's magnetic field

11. The force of attraction between two unit point masses separated by a unit distance is called

    (a) gravitational potential

    (b) acceleration due to gravity

    (c) gravitational field

    (d) universal gravitational constant

12. The weight of an object at the centre of the earth of radius R is

    (a) zero

    (b) infinite

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

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

13. An object weighs 10 N in air. When immersed fully in water, it weighs only 8 N. The weight of the liquid displaced by the object will be

    (a) 2 N

    (b) 8 N

    (c) 10 N

    (d) 12 N

14. A girl stands on a box having 60 cm length, 40 cm breadth and 20 cm width in three ways. In which of the following cases, pressure exerted by the brick will be

15. Why is the earth not a perfect sphere?

    (a) maximum when length and breadth form the base

    (b) maximum when breadth and width form the base

    (c) maximum when width and length form the base

    (d) the same in all the above three cases

16. An apple falls from a tree because of gravitational attraction between the earth and apple. If F_1 is the magnitude of force exerted by the earth on the apple and F_2 is the magnitude of force exerted by apple on earth, then

    (a) F_1 is very much greater than F_2

    (b) F_2 is very much greater than F_1

    (c) F_1 is only a little greater than F_2

(d) F_1 and F_2 are equal

Short Answer Questions

What is the source of centripetal force that a planet requires to revolve around the Sun? On what factors does that force depend?

On the earth, a stone is thrown from a height in a direction parallel to the earth's surface while another stone is simultaneously dropped from the same height. Which stone would reach the ground first and why?

Suppose gravity of earth suddenly becomes zero, then in which direction will the moon begin to move if no other celestial body affects it?

Identical packets are dropped from two aeroplanes, one above the equator and the other above the north pole, both at height h. Assuming all conditions are identical, will those packets take same time to reach the surface of earth. Justify your answer.

The weight of any person on the moon is about $\frac{1}{6}$ times that on the earth. He can lift a mass of 15 kg on the earth. What will be the maximum mass, which can be lifted by the same force applied by the person on the moon?

Calculate the average density of the earth in terms of g, G and R.

The earth is acted upon by gravitation of Sun, even though it does not fall into the Sun. Why?

Long Answer Questions

How does the weight of an object vary with respect to mass and radius of the earth. In a hypothetical case, if the diameter of the earth becomes half of its present value and its mass becomes four times of its present value, then how would the weight of any object on the surface of the earth be affected?

How does the force of attraction between the two bodies depend upon their masses and distance between them? A student thought that two bricks tied together would fall faster than a single one under the action of gravity. Do you agree with his hypothesis or not? Comment.

Two objects of masses m_1 and m_2 having the same size are dropped simultaneously from heights h_1 and h_2 respectively. Find out the ratio of time they would take in reaching the ground. Will this ratio remain the same if (i) one of the objects is hollow and the other one is solid and (ii) both of them are hollow, size remaining the same in each case. Give reason.

(a) A cube of side 5 *cm* is immersed in water and then in saturated salt solution. In which case will it experience a greater buoyant force. If each side of the cube is reduced to 4 *cm* and then immersed in water, what will be the effect on the buoyant force experienced by the cube as compared to the first case for water. Give reason for each case.

(b) A ball weighing 4 *kg* of density 4000 $kg\ m^{-3}$ is completely immersed in water of density $10^3\ kg\ m^{-3}$. Find the force of buoyancy on it. (Given $g = 10\ m\ s^{-2}$).

(c) maximum when width and length form the base

(d) the same in all the above three cases

Multiple Choice Answers

1. (a) have same velocities at any instant.

   Gravitational force acts on all objects in proportion to their masses, but to move any object we need to overcome inertia which is also proportional to the mass. Hence, the mass term cancels out and we see all objects, heavy or light, fall at the same rate under the influence of gravity given that no other forces such as air drag is affecting them.

2. (c) is least on equator.

   Acceleration due to gravity is not constant on earth (as earth is not a perfect sphere), the force experienced by a body is also not a constant, it changes with loacation. The distance from the centre of the earth to the surface is lowest at the poles and is highest at the equator. As g is inversely proportional to square of the distance, its value is least at the equator.

3. (a) $\frac{F}{4}$

   The universal law of gravitation says that the force of gravitation between two objects of mass M and m respectively, separated by a distance r is:

   (a) Directly proportional to the product of their masses, and

   $$F \propto Mm$$

   (b) Inversely proportional to the square of the distance between them.

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

   If masses of both objects are halved without changing distance between them, then the gravitational force would become

   $$F' \propto \frac{M}{2} \times \frac{m}{2} = \frac{Mm}{4}$$

4. (c) will move along a straight line tangential to the circular path.

   During circular motion, there is always a force which is pushing the stone towards the centre. This is called the centripetal force. If the string breaks, it will set off in a straight line which is the tangent to the circle of revolution. This happens because the force applied is suddenly removed, and there is no force to bend the stone towards the centre.

5. (d) $d_1 < d_2 < d_3$

   The buoyant force is directly proportional to the volume of fluid displaced. Hence, if more volume of the object is outside the liquid surface, it means that the object is experiencing more upward force and that liquid has a higher density. With that in mind, we can guess the fractional value for the given volumes, $\frac{1}{9}$ should be close to 0.1 (as $\frac{1}{10}$ is 0.1) but slightly greater, $\frac{2}{11}$ should be close to 0.2 (as $\frac{2}{10}$ is 0.2) but slightly lower and $\frac{3}{7}$ should be close to 0.5 (as $\frac{3}{6}$ is 0.5) but slightly lower. It can, now, be easily deduced that $d_1 < d_2 < d_3 d$.

6. (d) is universal constant of nature.

   To remove the proportionality from the universal law of gravitation, a constant is introduced, which is universal in nature. It's called the "Universal Gravitational Constant", G, whose SI Units is $N\,m^2\,kg^{-2}$. The value of G is $6.673 \times 10^{-11} Nm^2 kg^{-2}$.

7. (c) any two bodies having some mass

   According to universal law of gravitation, every object in the universe attracts every other object with a force proportional to the product of their mass.

8. (d) is independent of mass and radius of the earth.

   In the law of gravitation, G is universal in nature and is regarded as one of the fundamental constants present in nature, its value does not depend on mass or radius of the earth or anything for that matter.

9. (b) 4 times

   The universal law of gravitation says that the force of gravitation between two objects of mass M and m respectively, separated by a distance r is:

   (a) Directly proportional to the product of their masses, and

   $$F \propto Mm$$

   (b) Inversely proportional to the square of the distance between them.

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

   If masses of both objects are doubled without changing distance between them, then the gravitational force would become

   $$F' \propto 2M \times 2m = 4Mm$$

10. (a) gravity

    The atmosphere on earth is a massive cluster of gases held together by the force of gravity.

11. (d) universal gravitational constant

    According to universal law of gravitation,

$$F = G\frac{Mm}{d^2}$$

    If we subtitute $M = m = 1$ and $d = 1$. We get,

$$F = G\frac{1 \times 1}{1^2}$$
$$= G$$

12. (a) zero

    One might think that at the centre of the earth, the force of gravitation will be infinite as $r = 0$. But that is wrong. If we carefully think about ourselves being at the centre of the earth, we can feel the same amount of matter present all around us. If we look up, we see some amount of matter, this is exactly equal to the amount of matter if we look down. This means that the force exerted on us by the matter above us is exactly equal to the force exerted by the matter present below us. Hence, these two cancels each other. If we carry this argument for all directions, we can see that no force is actually acting on us.

13. (a) 2 *N*

    As the buoyant force always acts opposite to gravity, when an object is immersed in liquid, the difference in weight is the exact buoyant force experienced by the object. In this case the difference in weights is $10 - 8 = 2$ *N*.

14. (b) maximum when breadth and width form the base.

    Pressure is inversely proportional to area,

$$Pressure = \frac{Thrust}{Area}$$

    This means that lower the area, more the pressure. Out of the three areas 60×40 cm^2 (length-breadth), 40×20 cm^2 (breadth-width) and 60×20 cm^2 (length-width), the lowest is breadth-width and in this case the pressure exerted will be maximum.

15. (d) F_1 and F_2 are equal

    The earth attracts the apple with a force that is equal to the force with which the apple attracts the earth. The only difference is that these two forces acts in opposite direction as virtue of Newton's third law of motion.

Short Answers

16. A force that keeps an object such as planets in a circular motion by pulling it towards the centre is known as centripetal force. Tis is the Gravitational force. This force depends on the product of the masses of the planet and sun and the distance between them.

17. Both stones will take the same time to reach the ground because the two stones fall from the same height.

18. The moon will begin to move in a straight line in the direction in which it was moving at that instant because the circular motion of moon is due to centripetal force provided by the gravitational force of earth.

19. The value of 'g' at the equator of the earth is less than that at poles. Therefore, the packet falls slowly at equator in comparison to the poles. Thus, the packet will remain in air for longer time interval, when it is dropped at the equator.

20. As the acceleration due to gravity on moon is six time less as that on the earth, it is reasonable to say that a person can lift six times more massive objects. If a person on earth can lift a mass of 15 kg on earth, the same person can lift $15 \times 6 = 90$ kg on the moon with the same amount of force.

21. Density of an object is given by,

$$Density = \frac{Mass}{Volume}$$

    Mass of earth, M, can be calculated in terms of g, G and R as follows,

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

    By consdering the earth to be a perfect sphere, volume of the earth is given as,

$$V = \frac{4}{3}\pi R^3$$

Therefore, density of earth is given by,

$$\text{Density} = \frac{gR^2}{G \times \frac{4}{3}\pi R^3}$$
$$= \frac{3g}{4\pi GR}$$

22. The gravitational force is responsible for providing the necessary centripetal force. “Falling” is actually a misnomer here, all objects under the influence of gravitational force tend to be pulled with a force that is acting towards the centre of mass of each object. That is known as the centripetal force.

Long Answers

23. Weight of an object is directly proportional to g which is directly proportional to the mass of the earth and inversely proportional to the square of the radius of the earth. i.e., Weight of a body $\propto \frac{M}{R^2}$
Using this we can find the original weight of the body,

$$W_o = mg = m\,G\,\frac{M}{R^2}$$

In the hypothetical case,
The new mass $M' = 4M$
The new radius, $R' = \frac{R}{2}$
This changes the weight of the body as follows,

$$W' = m\,G\,\frac{M'}{R'^2}$$
$$= m\,G\,\frac{4M}{(\frac{R}{4})^2}$$
$$= 16\,m\,G\,\frac{M}{R^2}$$
$$= 16 \times W_o$$

The weight will become 16 times.

24. This hypothesis is not correct. Gravitational force acts on all objects in proportion to their masses, but to move any object we need to overcome inertia which is also proportional to the mass. Hence, the mass term cancels out and we see all objects, heavy or light, fall at the same rate under the influence of gravity given that no other forces such as air drag is affecting them. The two bricks, like a single body, fall with the

same speed to reach the ground at the same time in case of free-fall. This is because acceleration due to gravity is independent of the mass of the falling body.

25. When an object is dropped from a height, the initial velocity, $u = 0\ m\ s^{-1}$
We know that,

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

For both objects we can write,

$$h_1 = \frac{1}{2}gt_1^2$$
$$h_2 = \frac{1}{2}gt_2^2$$

Taking the ratio of the above gives,

$$\frac{h_1}{h_2} = \frac{t_1^2}{t_2^2}$$
$$\implies \frac{t_1}{t_2} = \sqrt{\frac{h_1}{h_2}}$$

Ratio will not change in either case because acceleration remains the same. In case of free-fall acceleration does not depend upon mass and size (when ignoring air resistance).

26. (a) i The cube will experience a greater buoyant force in the saturated salt solution because the density of the salt solution is greater than that of water.
ii The smaller cube will experience lesser buoyant force as its volume is lesser than the initial cube.

(b) According to Archimedes' principle,

$$\begin{aligned}\text{Buoyant force} &= \text{weight of the liquid displaced}\\ &= \text{density of water} \times \text{volume of water displaced} \times g\\ &= 1000 \times \frac{4}{1000} \times 10\\ &= 10\ N\end{aligned}$$