Date: 24/9/2021

Q1. State the universal law of gravitation.

Q2. Write the formula to find the magnitude of the gravitational force between the Earth and an object on the surface of the Earth.

Q3. Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster that a light object?

Q4. What do we call the gravitational force between the Earth and an object?

Q5. What do you mean by free fall?

Q6. What do you mean by acceleration due to gravity?

Q7. Amit buys few grams of gold at the poles as per the instruction of 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 bought? If not, why?

Q8. What do you mean by buoyancy?

Q9. In what direction does the buoyant force on an object immersed in a liquid act?

Q10. Why does a block of plastic released under water come up to the surface of water?

Q11. How does the force of gravitation between two objects change when the distance between them is reduced to half?

Q12. What is the magnitude of the gravitational force between the Earth and a 1 kg object on its surface? (Mass of the Earth 6×10^{24} kg and radius of the Earth is 6.4×10^{6} m)

Q13. 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.

Q14. What is the acceleration of free fall?

Q15. What is the importance of universal law of gravitation?

Q16. If the Moon attracts the Earth, why does the Earth not move towards the Moon?

Q17. 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?

Q18. 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?

Q19. You find your mass to be 42 kg on a weighing machine. Is your mass more or less than 42 kg?

Q20. 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?

Q21. Why does an object float or sink when placed on the surface of water?

Q22. Why is it difficult to hold a school bag is made of thin and strong string?

Q23. Why will a sheet of paper fall slower than one that is crumpled into a ball?

Q24. Gravitational force on the surface of the Moon is only $\frac{1}{6}$th as strong as gravitational force on the Earth. What is the weight in newtons of a 10 kg object on the Moon and on the Earth?

Q25. A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground.

Q26. What are the differences between the mass of an object and its weight?

Q27. Why is the weight of an object on the Moon $\frac{1}{6}$th its weight on the Earth?

Q28. 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?

Q29. What happens to the force between two objects, if

(a) the mass of one object is doubled?

(b) the distance between the objects is doubled and tripled?

(c) the masses of both objects are doubled?

Q30. A ball is thrown vertically upwards with a velocity of 49 m/s. Calculate

(a) the miximum height to which it rises,

(b) the total time it takes to return to the surface of the Earth.

Q31. A stone is thrown vertically upward 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?

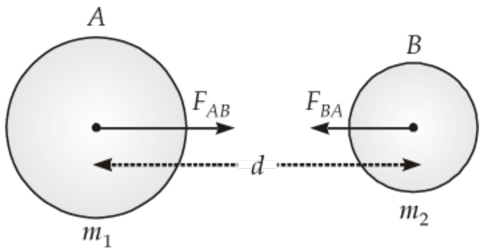
Q32. A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet. (take g = 10 m/s^2)

Q33. A ball thrown up vertically returns to the thrower after 6 s. Find: (a) the velocity with which it was thrown up, (b) the maximum height it reaches, and (c) its position after 4 s.

Date: 24/9/2021

S1. According to universal law of gravitation, force of gravitation between two objects is directly proportional to the product of their masses and inversely propertional to the square of the distance between them.

If A and B be two objects of masses m_1 and m_2 respectively and d be the distance between their centres, then gravitational force between them



$$F \propto \frac{m_1 m_2}{d^2} \quad \text{or} \quad F = \frac{G m_1 m_2}{d^2}$$

where G is the universal constant of gravitation having a value $6.673 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$.

S2. Consider an object of mass 'm' placed on the surface of Earth of mass 'M', then distance between the object and the centre of Earth will be equal to radius of Earth 'R'. Hence, the gravitational force between the Earth and the given object will be given by

$$F = \frac{GMm}{R^2},$$

where G is the universal constant of gravitation.

S3. Although gravitational force due to Earth is directly proportional to mass of the object, but acceleration of object = $\frac{\text{Force}}{\text{Mass}}$. As a result, acceleration due to gravity is same on all objects, be a heavy object or a light object and all objects fall at the same rate.

S4. The gravitational force bnetween the Earth and an object is called force due to gravity.

S5. Whenever an object falls towards the Earth under the force of gravity alone and no other force is present, the motion of the object is said to be "*Free fall*".

S6. The acceleration of free fall is the acceleration due to gravity. Alternatively the acceleration of an object due to the gravitational force of Earth acting on it is known as the acceleration due to gravity.

S7. The friend will not agree with the weight of gold. Weight $W = mg$ and value of g at equator is less than that at poles. Hence, weight of gold at equator will be less than its weight at the poles.

S8. Buoyancy means upward thrust acting on a body when it is completely or partly immersed in a fluid (either a liquid or a gas).

S9. If an object is immersed in a liquid then the buoyant force due to liquid acts on the object in vertically upward direction.

S10. As density of plastic is less than the density of water, plastic block will float on water. Hence if a plastic block is once immersed in water and then released, it will come on the surface of water and will float.

S11. The force of gravitation between two objects, separated by a distance r,

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

If distance between two objects is reduced to half *i.e.*, $r = \frac{r}{2}$ then the new force will be:

$$F' = \frac{Gm_1 m_2}{\left(\frac{r}{2}\right)^2} = \frac{4Gm_1 m_2}{r^2} = 4\,\text{F}$$

Thus, the new force will be 4 times the magnitude of original force of gravitation.

S12. Here, Mass of Earth $M = 6 \times 10^{24}$ kg, Mass of object m = 1 kg

Distance of the object from centre of Earth = $R = 6.4 \times 10^6$ m

$\therefore$ Magnitude of gravitational force $F = \frac{GMm}{R^2} = \frac{6.673 \times 10^{-11} \times 6 \times 10^{24} \times 1}{(6.4 \times 10^6)^2}$

$= 9.77 \text{ N} \simeq 9.8 \text{ N}.$

S13. Here mass of the Earth $M_E = 6 \times 10^{24}$ kg, mass of the Sun $M_S = 2 \times 10^{30}$ kg and average distance between them $d = 1.5 \times 10^{11}$ m

$\therefore$ Gravitational force between Sun and Earth

$$F = \frac{GM_S M_E}{d^2} = \frac{6.673 \times 10^{-11} \times 2 \times 10^{30} \times 6 \times 10^{24}}{(1.5 \times 10^{11})^2}$$

$= 3.56 \times 10^{22}$ N.

S14. The acceleration experienced by a freely falling body due to the force of gravity is called the acceleration of free fall. It is represented by the symbol g and its mean value of surface of Earth is 9.8 m s^{-2}.

S15. The universal law of gravitation successfully explained several phenomena. Some such phenomena are:

(a) the force which binds us to the Earth.

(b) motion of Moon around the Earth.

(c) motion of planets around the Sun.

(d) Occurence of sea tides due to attraction of Moon and of Sun.

S16. Definitely the Earth should move towards the Moon and actually Earth is moving towards the Moon. However, as mass of Earth is nearly 81 times of Moon, the motion of Earth is $\frac{1}{81}$ th towards Moon as compared to motion of Moon towards Earth. So, the motion of Earth is not commonly observed.

S17. Force of gravitational attraction between two objects is directly proportional to the product of their masses. On account of this reason force with which Earth attracts the Moon = force with which Moon attracts the Earth = $\frac{GM_E M_M}{(d_{EM})^2}$.

Where M_E = mass of Earth, M_M = mass of Moon and d_{EM} = distance between Earth and Moon.

S18. In reality bag of cotton is heavier.

Upward thrust of buoyancy due to air acting on an object is equal to weight of air displaced by the object. As volume of bag of cotton is more than that of an iron bar, it will displace more air and hence force of buoyancy on it is more. So, truly speaking correct weight of cotton bag is more than that of iron bar.

S19. On weighing machine we are actually measuring weight and considering this as a measure of mass. As the weighing is being done in air, there is a force of buoyancy due to air also.

Hence, Weight of 42 kg = True weight – Force of buoyancy.

So, it is clear that true weight must be more than 42 kg. Hence, mass of said body is more than 42 kg.

S20. In present problem density of water $\rho_w = 1\ \text{g cm}^{-3}$

Mass of substance $m = 50$ g

Volume of substance $V = 20\ \text{cm}^3$

$\therefore$ Density of substance $\rho = \frac{m}{V} = \frac{50\ \text{g}}{20\ \text{cm}^3} = 2.5\ \text{vm}^{-3}$

As the density of the substance is greater than that of water, the given substance will sink in water.

S21. An object floats on the surface of water if its density is less than water or if its relative density is less than one. For such an object the upward thrust due to water will be greater than its weight and so the object floats.

An object sinks if its density is more than water or if its relative density is more than one. For such an object the upward thrust due to water will be less than its weight and so the object sinks.

S22. If the strap of the school bag is made of a thin and strong string, then pressure on hand (or shoulder) of the student will be much more, for a given thrust pressure is inversely proportional to the surface area. So, it wil be difficult for the student to hold his school bag having a strip made of a thin and strong string.

S23. When a sheet of paper and a crumpled ball of paper fall freely under gravity, the air resistance and the upward thrust due to buoyancy of air is greater on the sheet due to its large surface area than that on crumpled paper ball. Consequently, the sheet of paper falls slowly.

S24. Here, mass of given object $m = 10$ kg.

Value of acceleration due to gravity on Earth $g_E = 9.8\ \text{m s}^{-2}$

$\therefore$ Weight of object on Earth $W_E = mg_E = 10 \times 9.8 = 98$ N

As value of acceleration due to gravity on Moon is $\frac{1}{6}$th of its value on Earth,

hence, $g_m = \frac{1}{6} g_E = \frac{9.8}{6} = 1.63\ \text{m s}^{-2}$

$\therefore$ Weight of given object on Moon $W_m = mg_m = 10 \times 1.63 = 16.3$ N.

S25. Here initial velocity of stone $u = 0$, distance covered by the stone before reaching the ground $h = 19.6$ m and acceleration of freely falling stone $a = +g = +9.8\ \text{m s}^{-2}$ (because motion is in downward direction).

If v be the velocity of stone just before touching the ground, then

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

$$\therefore \quad v^2 - (0)^2 = 2 \times 9.8 \times 19.6$$

$$\Rightarrow \quad v = \sqrt{2 \times 9.8 \times 19.6} = 19.6\ \text{m s}^{-1}.$$

S26. Difference between the mass and weight.

Mass (m)	Weight (W)
1. It is a measure of inertia of an object.	1. It is the force acting on the object due to gravity. Hence weight $W = mg$.
2. Its SI unit is kg.	2. Its SI unit is a newton.
3. Mass of an object is constant and does not change from place to place. Moreover, mass of no object can ever be zero.	3. Weight of an object changes from place to place and may even be zero.
4. Mass has only magnitude *i.e.*, it is a scalar.	4. Weight has both magnitude and direction *i.e.*, it is a vector.

S27. Weight of an object of mass m is given by $W = mg$. Mass of an object never changes but value of g on Moon is $\frac{1}{6}$th of its value on Earth *i.e.*, $g_m = \frac{g_E}{6}$.

$\therefore$ Weight of object on Moon $W_m = m \cdot g_m = \frac{g_E}{6} = \frac{W_E}{6}$.

S28. Here, Mass of sealed packet $m = 500$ g

Volume of sealed packet $V = 350 \text{ cm}^3$

$$\text{Density of sealed packet } \rho = \frac{m}{V} = \frac{500 \text{ g}}{350 \text{ cm}^3} = 1.43 \text{ g cm}^{-3}$$

and Density of water $\rho_w = 1 \text{ g cm}^{-3}$

As density of sealed packet is more than that of water, the sealed packet will sink in water.

$\therefore$ Volume of sealed packet immersed in water = $V = 350 \text{ cm}^3$

$\therefore$ Weight of water displaced by the packet = $V\rho_w = 350 \times 1 = 350$ g.

S29. Force between two objects of masses m_1 and m_2 and separated by a distance d is

$$F = \frac{Gm_1 m_2}{d^2}$$

(a) It the mass of one object (say 1st) is doubled then $m_1 = 2m_1$

$$\therefore \quad \text{Froce } F' = \frac{Gm_1' m_2}{d^2} = \frac{G \cdot (2m_1)(m_2)}{d^2} = 2F$$

(b) If distance between the objects is doubled, then

$$F' = \frac{Gm_1 m_2}{(2d)^2} = \frac{Gm_1 m_2}{4d^2} = \frac{F}{4}$$

Similarly, if distance is tripled, then $F' = \frac{F}{9}$

(c) If the masses of both objects are doubled, then

$$F' = \frac{G(2m_1) \cdot (2m_2)}{d^2} = \frac{4Gm_1 m_2}{d^2} = 4F.$$

S30. Here initial velocity of ball in vertically upward direction $u = 49 \text{ m s}^{-2}$.

Acceleration of ball a = acceleration due to gravity in downward direction = $-g = -9.8 \text{ m s}^{-2}$.

(a) The ball rises to a maximum height h where final velocity of ball $v = 0$

Applying the relation $v^2 - u^2 = 2as$, we have

$$(0)^2 - (49)^2 = 2 \times (-9.8) \times h$$

$$\Rightarrow \quad h = \frac{49 \times 49}{2 \times 9.8} = 122.5 \text{ m}$$

(b) If t_1 be the time taken by the ball to reach the maximum height, then from the relation $v = u + at$, we have

$$0 = 49 + (-9.8) \times t_1 \quad \text{or} \quad 49 = 9.8 t_1$$

$$\therefore \quad t_1 = \frac{49}{9.8} = 5 \text{ s}$$

The ball will now fall back on Earth and time of descent t_2 = time of ascent $t_1 = 5 \text{ s}$.

$\therefore$ The ball will return on Earth surface after a total time

$$t = t_1 + t_2 = 5 + 5 = 10 \text{ s}.$$

S31. Here, vertically upward initial velocity $u = 40 \text{ m s}^{-1}$ and $g = 10 \text{ m s}^{-2}$.

Let stone reaches a maximum height h, where final velocity $v = 0$.

Taking g to be – ve for upward motion, we have

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

$$\therefore \quad (0)^2 - (40)^2 = -2 \times 10 \times h$$

$$\Rightarrow \quad h = \frac{40 \times 40}{2 \times 10} = 80 \text{ m}$$

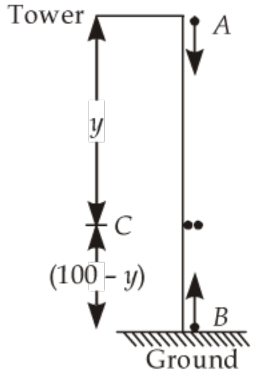
As the stone falls back from this height to ground, hence total distance covered by the stone

$$= 80 + 80 = 160 \text{ m}$$

As initial and final positions of stone are at the same point, hence net displacement of the stone = 0.

S32. Let a stone A is allowed to fall from top of a tower of height $h = 100\,\text{m}$. Its initial velocity $u_1 = 0$ and acceleration $a_1 = +g = +10\,\text{m s}^{-2}$.

Another stone B is projected vertically upwards from the ground with an initial velocity $u_2 = 25\,\text{m s}^{-1}$ and for it acceleration $a_2 = -g = -10\,\text{m s}^{-2}$.



Let the two stones meet at a point C at a distance y below A or a distance $(100 - y)$ above B after a time t.

Then for stone A, $$y = u_1 t + \frac{1}{2} a_1 t^2 = 0 \times t + \frac{1}{2} \times 10 \times t^2$$

or $$y = 5t^2 \qquad \text{... (i)}$$

and for stone B, $$(100 - y) = u_2 t + \frac{1}{2} a_2 t^2 = 25t + \frac{1}{2} \times (-10) \times t^2 = 25t - 5t^2$$

or $$100 - y = 25t - 5t^2 \qquad \text{... (ii)}$$

Adding Eq. (i) and (ii), we get

$$100 = 25t$$

$$\Rightarrow \qquad t = \frac{100}{25} = 4\,\text{s}$$

Substituting value of t in Eq. (i), we get

$$y = 5 \times (4)^2 = 80\,\text{m}$$

Thus, the two stones will meet 4 s after projection at a point 80 m below the top of tower (or 20 m above the ground).

S33. Let the ball was thrown vertically upwards with an initial velocity u. As ball returns to the thrower after 6 s, it takes $\frac{6}{2} = 3\,\text{s}$ to reach the highest point h where its velocity $v = 0$.

(a) Using the relation $v = u + at$, we have

$$0 = u + (-9.8) \times 3 \qquad [\because \text{ acceleration } a = -g = -9.8\,\text{m s}^{-2} \text{ for upward motion}]$$

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

(b) Maximum height reached h can be calculated by using the relation

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

$$\therefore \qquad (0)^2 - (29.4)^2 = 2 \times (-9.8) \times h$$

$$\Rightarrow \qquad h = \frac{29.4 \times 29.4}{2 \times 9.8} = 44.1\,\text{m}$$

(c) Let after 4 s from start the ball be at a height h from ground. Out of 4 s, ball takes 3 s to reach the maximum height and in remaining 1 s falls downward covering a distance

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

$\therefore$ Height of ball from the ground

$$h' = h - s = 44.1 - 4.9 = 39.2\,\text{m}.$$