

# 1

## Gravitation



### Points to Remember :

- Gravitation was discovered by **Sir Isaac Newton**.
- Gravitational Force is an universal force which is not only on any two bodies on the surface of the Earth but also on any two celestial objects.
- Gravitation force is an attractive force.
- Every object in the universe attracts every other object with a force, which is **directly proportional** to the **product of their masses** and **inversely proportional to the square of the distance between their centres**  $F = \frac{G m_1 m_2}{d^2}$ .
- If two objects are **spherical**, the force between them is along the straight line joining their centres and the segment joining their centres is considered the distance between them.
- Out of the two objects, if mass of one of the objects is **doubled**, then according to law, the gravitational force between the two objects gets doubled. If the distance between the two objects is doubled, the gravitational force between them becomes **one fourth**.
- Value of G is  $6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$
- The **centripetal force** is centre-seeking or the force which is acting towards the centre.
- The **centripetal force** between the Sun and the planet Earth is responsible for the revolution of the Earth. It is **inversely proportional** to the square of the distance between them.
- The force that the Earth exerts on any object at or around the surface of the Earth is called the **Earth's gravitational force**. According to Newton's second law, the acceleration is produced in the body due to **applied force**.
- The acceleration produced by the Earth's gravitational force is called **acceleration due to gravity** or **gravitational acceleration**. It is denoted by  $g = \frac{GM}{R^2}$ .
- The acceleration due to gravity depends on **mass of the Earth (M)** and **radius of the Earth (R)** for an object on the surface or **height (h)** at which the object is placed from the surface of the Earth. It does not depend upon the mass of the falling object. Thus, acceleration due to gravity is same for all freely falling objects.
- The unit of 'g' in SI system is  $\text{m/s}^2$ . The mass of Earth is  $6 \times 10^{24} \text{ kg}$  and its **radius** is  $6.4 \times 10^6 \text{ m}$ .
- The Earth **does not have** perfectly spherical shape. It is slightly **flattened** at the **poles** and **bulged** at the **equator**. Therefore, the radius of the Earth at the poles is less than that at the equator.
- The value of 'g' is **maximum** at **poles** and it is  $9.83 \text{ m/s}^2$  or  $983 \text{ cm/s}^2$ .
- The value of 'g' is **minimum** at the **equator** and it is  $9.78 \text{ m/s}^2$  or  $978 \text{ cm/s}^2$ .
- As altitude increases, value of g decreases.
- As depth increases, value of g decreases.
- The gravitational acceleration is considered  $9.77 \text{ m/s}^2$  for all the practical purposes.
- The acceleration on the Moon is  $\frac{1}{6}$  of that on the surface of the Earth.
- When a body falls towards the Earth under the influence of the Earth's gravity alone, its motion is called '**free fall**'.
- In 'free fall', body comes to the surface of the Earth with **uniform acceleration**. Initial velocity may be **zero** but it increases at every time interval, due to acceleration due to gravity.
- The mass of an object is the quantity of matter contained in it. The **SI** unit of mass is **(kg)** and **CGS** unit is **gram (g)**.

- From Newton's first law, we know that mass is the measure of **inertia** of a body.
- Mass is a **scalar quantity** and it does not change from place to place on the surface of the Earth and even it does not change on the different planets.
- The weight of the body is defined as the force with which the Earth attracts it towards its centre  **$W = mg$** .
- Since the weight is a '**force**', its **SI** unit is **newton** and **CGS** unit is **dyne**. ( $1\text{N} = 10^5 \text{ dyne}$ )
- Weight is a **vector** quantity. It changes from place to place on the surface of the Earth and even changes with the planet.
- Since the value of '**g**' is **not** same everywhere, the weight of a body keeps on changing with place.
- The weight of an object on the Moon is  $\frac{1}{6}$  th of that on the Earth. We can write it as,  **$w_m = m \times g_m$** .
- **Spring balance** is used for measuring weight and **two scale balance** is used to compare masses.
- **Johannes Kepler (1571 – 1630)** was a German **astronomer** and a **Mathematician**.
- **Kepler's first law:** The orbit of a planet is an ellipse with the sun at one of the foci.
- **Kepler's second law:** The straight line joining a planet and the Sun sweeps equal area in equal time.
- **Kepler's third law:** The square of time period of revolution around the sun is directly proportional to cube of the mean distance of a planet from the sun.
- A body can have energy because of its shape or position or configuration. This is known as **potential energy**.
- The gravitational potential energy at the height (**h**) from the ground is  $\frac{-GMm}{R+h}$ .
- **Escape velocity** is that initial velocity of an object by which it overcomes the Earth's gravitational attraction.
- Escape velocity ( $v_{\text{esc}}$ ) can be calculated by the law of conservation of energy and is equal to  $v_{\text{esc}} = \sqrt{2gR}$ .

### MASTER KEY QUESTION SET - 1

#### Q.1. (A) 1. Fill in the blanks:

- (1) Gravitation was discovered by .....
- (2) Every object in the universe attracts every other object with ..... force.
- (3)  $F \propto \frac{m_1 m_2}{d^2}$  means  $F =$  .....
- (4) If the distance between the two object is doubled, then the gravitational force between them will be ..... times.
- (5) If mass increases, force .....
- (6) If mass triples, value of  $G$  .....
- (7) If Earth attracts a body with a force of 10 N, then the body attracts the Earth with ..... N.
- (8) S.I, unit of  $G$  is .....
- (9) Places on Earth exactly  $90^\circ$  to the direction of the moon experiences .....
- (10) ..... is a constant known as universal gravitational constant.
- (11) The Earth's gravitational force is always in the direction of the ..... of the Earth.
- (12) The Earth's gravitational acceleration is denoted by letter .....
- (13) The relation between  $g$  and  $G$  is .....
- (14) The value of acceleration due to gravity at poles is .....  $\text{m/s}^2$ .
- (15) The value of acceleration due to gravity at the equator is .....  $\text{cm/s}^2$ .
- (16) If altitude increases, value of  $g$  .....
- (17) When a spaceship is two Earth radii distance from the centre of Earth, its  $g$  is .....
- (18) During free fall, the object comes vertically downward with uniform .....
- (19) Mass is also a measure of ..... of an object.
- (20) The mass of the Earth is ..... kg.
- (21) The radius of the Earth is ..... m.
- (22) Value of  $g$  at centre of Earth is .....
- (23) The SI unit of weight is .....
- (24) The gravitational force acting on any object on the Earth is called it's .....
- (25) The weight of an object on the Earth is ..... times its weight on the Moon.
- (26) The weight of an object is maximum at ..... of the Earth.
- (27) The orbit of a planet is an ..... with the Sun at one of the foci.

- (28) The energy possessed because of position or configuration is called .....
- (29)  $v_{\text{esc}} = \dots\dots\dots$
- (30) Gravitational waves are detected by .....
- (31) During ascent ..... is zero and during descent ..... is zero.
- (32) Formula for centripetal force is .....

**Ans.** (1) Isaac Newton (2) gravitational (3)  $\frac{Gm_1m_2}{d^2}$   
 (4)  $\frac{1}{4}$  (5) increases (6) remains constant (7) 10  
 (8)  $\text{Nm}^2/\text{kg}^2$  (9) low tide (10) G (11) centre (12) 'g'  
 (13)  $g = \frac{GM}{R^2}$  (14) 9.83 (15) 978 (16) decreases  
 (17)  $\frac{1}{4}^{\text{th}}$  (18) acceleration (19) inertia  
 (20)  $6 \times 10^{24}$  (21)  $6.4 \times 10^6$  (22) Zero (23) newton (N)  
 (24) weight (25) six (26) poles (27) ellipse  
 (28) potential energy (29)  $\sqrt{2gR}$  (30) LIGO  
 (31) v, u (32)  $F = \frac{mv^2}{r}$

**Q.1. (A) 2. Find the odd word out:**

- (1) Acceleration, mass, force, weight
- (2) Change in value of 'g' at surface, change in value of 'g' at height, change in value of 'g' at depth, change in value of 'g' on thickness
- (3) Light, sound, heat, laws of planetary motion
- (4) Mass, potential energy, radius, weight
- (5)  $9.83 \text{ m/s}^2$ ,  $9.8 \text{ m/s}^2$ ,  $980 \text{ cm/s}^2$ ,  $9.77 \text{ m/s}^2$
- (6) Weight, Thrust, Force, Pressure
- (7) Newton's first law, Newton's law of gravity, Newton's third law, Newton's second law
- (8) Newton, Ohm, Kepler, Galileo
- (9)  $983 \text{ cm/s}^2$ ,  $977 \text{ cm/s}^2$ ,  $980 \text{ cm/s}^2$ ,  $9.83 \text{ m/s}^2$
- (10)  $9.83 \text{ m/s}^2$ ,  $98.3 \text{ m/s}^2$ ,  $983 \text{ m/s}$ ,  $98.03 \text{ m}^2\text{s}$

**Ans.** (1) Mass - It is scalar, while others are vectors.  
 (2) Change in value of 'g' on thickness. Others are related factors to the value of 'g'. (3) Law of planetary motion. Others are related to Newton. (4) Weight. It is vector, while others are scalars. (5)  $980 \text{ cm/s}^2$ . Others are values of g in MKS. (6) Pressure. Others are vectors. (7) Newton's law of gravity. Other are related to law of motion. (8) Ohm. Others are concerned with laws of gravity. (9)  $9.83 \text{ m/s}^2$ . Others are in CGS system. (10)  $9.83 \text{ m/s}^2$ . Others are not values of 'g'.

**Q.1. (A) 3. Complete the analogy:**

- (1)  $6 \times 10^{24} \text{ kg}$  : Mass of the Earth : :  $6.4 \times 10^6 \text{ m}$  : .....
- (2) Orbit of the space shuttle :  $8.7 \text{ m/s}^2$  : : Communication satellite : .....
- (3) Mass : Scalar quantity : : Weight : .....
- (4) At poles :  $9.83 \text{ m/s}^2$  : : At equator : .....
- (5) Shape of the Earth at equator : Bulged : : Shape of the Earth at poles : .....
- (6) Kinetic energy :  $\frac{1}{2} mv^2$  : : Potential energy : .....
- (7) Force :  $ma$  : : Gravitational force : .....
- (8) Force : Vector : : Weight : .....

**Ans.** (1) Radius of the Earth (2)  $0.225 \text{ m/s}^2$  (3) Vector  
 (4)  $9.78 \text{ m/s}^2$  (5) Flattened  
 (6)  $\frac{-GMm}{R+h}$  (7)  $\frac{Gm_1m_2}{d^2}$  (8) Vector

**Q.1. (A) 4. Answer the following in one sentence:**

**\*(1) What do you know about gravitational force?**  
 (Can you recall; Textbook Page no. 1)

**Ans.** Every object in the universe attracts every other object with a force. This force is called gravitational force.

**\*(2) Will the direction of the gravitational force change as we go inside the earth?** (Think about it; Textbook Page no. 9)

**Ans.** The direction of earths gravitational force is towards the center of earth so it will not change.

**\*(3) What would happen if there were no gravity?**  
 (Think about it; Textbook Page no. 8)

**Ans.** If gravitational force of the Earth would not have existed, then all the object would have floated in the air. Life would be unstable.

**\*(4) What would happen if the value of G was twice as large?** (Think about it; Textbook Page no. 8)

**Ans.** If the value of 'G' is doubled, then the gravitational force (F) also will get doubled.

**\*(5) What types of forces are we familiar with?**  
 (Can you recall; Textbook Page no. 1)

**Ans.** Types of forces are:

- (i) Gravitational force
- (ii) Electro-magnetic force
- (iii) Nuclear force
- (iv) Balanced force
- (v) Unbalanced force

**\* (6) What is the value of 'g' at the centre of the Earth?**

**Ans.** At the centre of the Earth the value of 'g' is zero.

**\* (7) Will the mass and weight of an object on the earth be same as their values on Mars? Why?**

**Ans.** (i) Mass of an object will be same on earth and mars.  
(ii) Since value of g on earth and mars is different, weight of the objects will be different.

**Q.1. (A) 5. With the information in three columns, match up and complete the chart:**

I	II	III
(1) Mass	(a) $m/s^2$	(i) Zero at the centre
(2) Weight	(b) kg	(ii) Measure of Inertia
(3) Acceleration due to gravity	(c) $Nm^2/kg^2$	(iii) Same in the entire universe
(4) Gravitational constant	(d) N	(iv) Depends on height

**Ans.** (1-b-ii), (2-d-iv), (3-a-i), (4-c-iii),

**(2) Match the columns:**

Column A	Column B
(1) Mass	(a) m/s
(2) Weight	(b) $m/s^2$
(3) Acceleration	(c) kg
(4) Velocity	(d) N

**Ans.** (1 - c), (2 - d), (3 - b), (4 - a)

**(3) Complete the chart:**

F (N)	$m_1$ (kg)	$m_2$ (kg)	d (m)
(1) .....	500	84	02
(2) $30 \times 10^{27}$	$15 \times 10^5$	.....	03
(3) $16 \times 10^9$	.....	17	34
(4) $250 \times 10^{-7}$	45	47	.....

**Ans.** (1)  $7 \times 10^{-7}$  (2)  $2.69 \times 10^{33}kg$  (3)  $1.63 \times 10^{22}kg$   
(4)  $7.5 \times 10^{-2}m$

**Q.1. (A) 6. State whether True or False:**

- Force = mass  $\times$  velocity
- 'G' is called gravitational acceleration.
- Acceleration is a scalar quantity.
- Gravitational force at the Moon is double than the Earth's gravitational force.
- $1 N = 1 kg \times 1 m/s^2$ .

(6)  $1 \text{ dyne} = 10^5 \text{ N}$ .

(7) The force towards the centre of the circular orbit is called centripetal force.

(8) The gravitational acceleration does not become zero at the centre of the Earth.

(9) At poles, the acceleration due to gravity is  $9.77 m/s^2$ .

(10) 'g' is called universal constant.

(11) Mass is a scalar quantity.

(12) Beyond the surface of the Earth,  $g \propto \frac{1}{(R+h)^2}$ .

(13) Weight is a vector quantity.

(14) The mass of the Earth is  $6.4 \times 10^6 kg$ .

(15) At the height of 'h' from the ground, the gravitational potential energy is  $\frac{-GMm}{R+h}$ .

**Ans.** (1) False (2) False (3) False (4) False (5) True  
(6) True (7) True (8) False (9) False (10) False  
(11) True (12) True (13) True (14) False (15) True

**Q.1. (B) Complete the following statements by selecting the proper alternative from the given:**

(1) The gravitational force of attraction between two objects is given by .....

(a)  $F \propto \frac{m_1 m_2}{d^2}$  (b)  $F \propto \frac{d^2}{m_1 m_2}$

(c)  $F \propto \frac{m_1 m_2}{\sqrt{d^2}}$  (d)  $F \propto \frac{m_1 m_2}{d^3}$

(2) If the distance between two bodies becomes half, the gravitational force between them becomes .....

- (a) half (b) one fourth  
(c) 4 times (d) 2 times

(3) If the distance between two objects increases 5 times, the gravitational force becomes ..... times.

- (a) 5 (b) 15 (c)  $\frac{1}{25}$  (d) 25

(4) The gravitational force on the surface of the Moon is ..... times than that on the surface of the Earth.

- (a) five (b) one fifth  
(c) one sixth (d) six

(5) The gravitational force causes .....

- (a) Tides (b) Circular motion of moon  
(c) None of these (d) Both a and b

- (6) The Earth attracts moon with a force of  $10^{20}$ N. The moon attracts Earth with a force of .....
- (a) less than  $10^{20}$  N (b)  $10^{20}$  N  
(c) greater than  $10^{20}$  N (d)  $10^{-20}$  N
- (7) The SI unit of gravitational constant is .....
- (a)  $\text{Nm}^2 / \text{kg}^2$  (b)  $\text{Nkg}^2 / \text{m}^2$   
(c)  $\text{m/s}^2$  (d)  $\text{N cm}^2 / \text{g}^2$
- (8) Acceleration is a ..... quantity.
- (a) scalar (b) fundamental  
(c) unit (d) vector
- (9) The value of acceleration due to gravity at the height 'h' from the ground is .....
- (a)  $g = \frac{GM}{R+h}$  (b)  $g = \frac{GM}{\sqrt{R+h}}$   
(c)  $g = \frac{GM}{(R+h)^2}$  (d)  $g = GM (R+h)^2$
- (10) The value of 'g' is maximum at poles and it is .....
- (a)  $9.72 \text{ m/s}$  (b)  $9.83 \text{ m/s}^2$   
(c)  $9.83 \text{ m/s}$  (d)  $9.72 \text{ m/s}^2$
- (11) The value of 'g' due to Earth is zero at .....
- (a) Centre of Earth (b) Poles  
(c) Infinite distance (d) Both a and c
- (12) When an object is thrown upward, the force of gravity .....
- (a) Is opposite to the direction of motion (b) Is in the same direction as that of motion  
(c) becomes zero at higher point (d) Increase as it rise up
- (13) The value of 'g' at the depth from the ground goes on .....
- (a) increasing (b) fluctuating  
(c) decreasing (d) varying
- (14) As the height of the object from the surface of the Earth increases, value of 'g' becomes .....
- (a) more (b) less  
(c) equal (d) can't say
- (15) The mass of objects ..... at any surface on the Earth.
- (a) remains constant (b) is non-uniform  
(c) changes (d) increases
- (16) According to Newton's first law, if mass is more, then the inertia of the body is .....
- (a) less (b) very less  
(c) more (d) can't say
- (17) The mass of the Earth is ..... kg.
- (a)  $6 \times 10^6$  (b)  $6 \times 10^{24}$   
(c)  $6.4 \times 10^6$  (d)  $6.4 \times 10^{24}$
- (18) The radius of the Earth is ..... m .
- (a)  $6.4 \times 10^6$  (b)  $4.6 \times 10^6$   
(c)  $4.6 \times 10^{-6}$  (d)  $6 \times 10^{24}$
- (19) The weight of body gradually decreases from .....
- (a) equator to poles (b) poles to equator  
(c) pole to pole (d) height to surface
- (20) A body of mass 1 kg is attracted by the Earth with a force which is equal to .....
- (a) 9.8 N (b)  $6.67 \times 10^{-11}$   
(c) 1 N (d) 9.8 m/s
- (21) The gravitational potential energy at the height of 'h' from the ground is .....
- (a)  $\frac{-GMm}{R+h}$  (b)  $\frac{-GMm_1}{R^2+h}$   
(c)  $\frac{GMm_1}{R^2+h^2}$  (d)  $\frac{GMm}{R^2+h}$
- (22) The orbit of a planet is an ellipse with the Sun at one of the .....
- (a) foci (b) centre (c) middle (d) surface
- (23) The straight line joining the planet and the Sun sweeps equal ..... in equal interval of time.
- (a) volume (b) angle  
(c) density (d) area
- (24) The square of time period of revolution around the Sun is ..... to the cube of the mean distance of the planet from the Sun.
- (a) inversely proportional  
(b) directly proportional  
(c) not proportional  
(d) depend
- (25) The periodic time of a planet is 'T' and the mean distance of the planet from the Sun is 'r', then according to Kepler's third law .....
- (a)  $T^2 \propto r^3$  (b)  $T \propto r^3$  (c)  $T^2 \propto r$  (d)  $T^3 \propto r^2$

- Ans.** (1)  $F \propto \frac{m_1 m_2}{d^2}$  (2) 4 times (3)  $\frac{1}{25}$  (4) one sixth  
 (5) both a and b (6)  $10^{20}$  N (7)  $\text{Nm}^2/\text{kg}^2$  (8) vector  
 (9)  $g = \frac{GM}{(R+h)^2}$  (10)  $9.83 \text{ m/s}^2$  (11) Both a and c  
 (12) Is opposite to the direction of motion (13) decreasing  
 (14) less (15) remains constant (16) more (17)  $6 \times 10^{24}$   
 (18)  $6.4 \times 10^6$  (19) poles to equator (20)  $9.8 \text{ N}$  (21)  $\frac{GMm}{R+h}$   
 (22) foci (23) area (24) directly proportional (25)  $T^2 \propto r^3$

### Q.2.1. Solve the following:

**Type: A**

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

$$F = ma$$

$$v = u + at$$

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

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

- \*(1)** Mahendra and Virat are sitting at a distance of 1 metre from each other. Their masses are 75 kg and 80 kg respectively. What is the gravitational force between them?

**Ans. Given:**  $r = 1 \text{ m}$

$$m_1 = 75 \text{ kg}$$

$$m_2 = 80 \text{ kg}$$

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

**To find:** Force (F) = ?

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

**Solution:**

$$F = \frac{6.67 \times 10^{-11} \times 75 \times 80}{1^2}$$

$$F = 6.67 \times 10^{-11} \times (6 \times 10^3)$$

$$= 40.02 \times 10^{-8}$$

$$= 4.002 \times 10^{-7} \text{ N}$$

**The gravitational force between Mahendra and Virat is  $4.002 \times 10^{-7} \text{ N}$**

- \*(2)** The mass of the Earth and Moon are  $6 \times 10^{24}$  kg and  $7.4 \times 10^{22}$  kg respectively. The distance between them is  $3.84 \times 10^5$  km. Calculate the gravitational force of attraction between the two?  $G = 6.7 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$ .

**Ans. Given:**  $m_1 = 6 \times 10^{24} \text{ kg}$

$$m_2 = 7.4 \times 10^{22} \text{ kg}$$

$$r = 3.84 \times 10^5 \text{ km}$$

$$r = 3.84 \times 10^8 \text{ m}$$

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

**To find:**  $F = ?$

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

**Solution:**

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

$$= \frac{297.48 \times 10^{-11} \times 10^{24} \times 10^{22}}{14.74 \times 10^{16}}$$

$$\approx \frac{300 \times 10^{19}}{15}$$

$$= 20 \times 10^{19}$$

$$F = 2 \times 10^{20} \text{ N}$$

**The gravitational force of attraction between Earth and Moon is  $2 \times 10^{20} \text{ N}$**

- \*(3)** The mass of the Earth is  $6 \times 10^{24}$  kg. The distance between the Earth and the Sun is  $1.5 \times 10^{11}$  m. If the gravitational force between the two is  $3.5 \times 10^{22}$  N, what is the mass of the sun?  $G = 6.7 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$ .

**Ans. Given:**  $m_1 = 6 \times 10^{24} \text{ kg}$

$$r = 1.5 \times 10^{11} \text{ m}$$

$$F = 3.5 \times 10^{22} \text{ N}$$

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

**To find:**  $m_2 = ?$

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

$$\text{Solution: } \frac{Fr^2}{Gm_1} = m_2$$

$$m_2 = \frac{3.5 \times 10^{22} \times (1.5 \times 10^{11})^2}{6.7 \times 10^{-11} \times 6 \times 10^{24}}$$

$$= \frac{7.875}{40.2} \times 10^{31}$$

$$= \frac{7.875}{40} \times 10^{31}$$

$$= 0.196 \times 10^{31} \text{ kg}$$

$$= 1.96 \times 10^{30} \text{ kg}$$

**The mass of the Sun is  $1.96 \times 10^{30} \text{ kg}$**

- \*(4)** In the previous example, assuming that the bench on which Mahendra is sitting is frictionless, starting with zero velocity. What will be Mahendra's velocity after 1s and how will it change with time? Mass of Mahendra (75 kg) and force ( $4.002 \times 10^{-7} \text{ N}$ ).

**Ans. Given:** Initial velocity (u) = 0 m/s

$$\text{Time (t)} = 1 \text{ s}$$

$$\text{Force (F)} = 4.002 \times 10^{-7} \text{ N}$$

$$\text{mass (m)} = 75 \text{ kg}$$

**To find:** Final velocity ( $v$ ) = ?

**Formulae:**  $v = u + at$ ,  $a = \frac{F}{m}$

**Solution:**  $a = \frac{4002 \times 10^{-7}}{75}$

$a = 0.0534 \times 10^{-7} \text{ m/s}^2$

$a = 5.34 \times 10^{-9} \text{ m/s}^2$

$v = u + at$

$= 0 + 5.34 \times 10^{-9} \times 1$

$= 5.34 \times 10^{-9} \text{ m/s}$

Velocity will increase with time

**As distance decreases, force increases thereby increasing acceleration.**

**\*(5) Assuming that acceleration remains constant ( $5.34 \times 10^{-9} \text{ m/s}^2$ ), How long will Mahendra take to move 1 cm towards Virat if he starts from rest? (Use your brain power; Textbook Page no. 6)**

**Ans. Given:** Acceleration ( $a$ ) =  $5.34 \times 10^{-9} \text{ m/s}^2$   
 $\approx 5 \times 10^{-9} \text{ m/s}^2$

Displacement ( $s$ ) = 1 cm =  $\frac{1}{100}$  m

Initial velocity ( $u$ ) = 0 m/s

**To find:** time ( $t$ ) = ?

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

**Solution:**  $\frac{1}{100} = 0 \times t + \frac{1}{2} \times 5 \times 10^{-9} \times t^2$

$\frac{1}{100} = 2.5 \times 10^{-9} \times t^2$

$\frac{1}{100 \times 2.5 \times 10^{-9}} = t^2$

$\frac{1 \times 10^9}{250} = t^2$

$\frac{1000 \times 10^6}{250} = t^2$

$4 \times 10^6 = t^2$

$t = \sqrt{4 \times 10^6} \text{ s}$

$t = 2 \times 10^3 \text{ s}$

**Mahendra will take  $2 \times 10^3$  s to move towards Virat.**

**(6) A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20s. Find its acceleration. Also find the force acting on it if its mass is 7000 kg.**

**Ans. Given:** Initial velocity ( $u$ ) =  $0 \text{ ms}^{-1}$   
 Distance travelled ( $s$ ) = 400 m  
 Time ( $t$ ) = 20 s  
 Mass of truck ( $m$ ) = 7000kg

**To find:** Acceleration ( $a$ ) = ?

Force ( $F$ ) = ?

**Formulae:** (i)  $s = ut + \frac{1}{2} at^2$  (ii)  $F = ma$

**Solution:** (i)  $s = ut + \frac{1}{2} at^2$

$400 = 0 \times 20 + \frac{1}{2} a \times 20 \times 20$

$400 \times 2 = 400a$

$\therefore a = \frac{400 \times 2}{400} = 2 \text{ ms}^{-2}$

(ii)  $F = ma$

$\therefore F = 7000 \times 2$

$\therefore F = 14000 \text{ N}$

**The truck moves with an acceleration of  $2 \text{ ms}^{-2}$  and the force acting on it is 14000N**

**(7) Karan and Arjun are two friends of mass  $m_1$  and  $m_2$  respectively, separated by a distance  $d$ .**

**What would happen to the force between them if**

**(i) Mass of Arjun is doubled.**

**(ii) Mass of both Karan and Arjun is doubled.**

**(iii) Distance between them is doubled.**

**(iv) Value of  $G$  doubled.**

**Ans.** (i) If ' $m_2$ ' is doubled.

$2F = \frac{G m_1 (2m_2)}{d^2}$

Force becomes double.

(ii) If ' $m_1$ ' and ' $m_2$ ' is doubled.

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

Force becomes 4 times.

(iii) If ' $d$ ' is doubled.

$\frac{1}{4} F = \frac{G m_1 m_2}{(2d)^2}$

Force becomes one fourth.

(iv) If 'G' is doubled.

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

Force is doubled.

### NUMERICALS FOR PRACTICE

- (1) Two boys sitting very close to each other at a distance of 0.5 m from each other. If the mass of one boy is 40 kg and other is 50 kg, find the gravitational force between them.  $(5.336 \times 10^{-7} \text{ N})$
- (2) If the force of gravitation between the Earth and an object of mass 'm' is  $9 \times 10^7 \text{ N}$ , find the mass of an object if the mass of the Earth is  $6 \times 10^{24} \text{ kg}$  and its radius is  $6.4 \times 10^6 \text{ m}$ .  $(9.2 \times 10^6 \text{ kg})$
- (3) If two objects of mass 500kg and 84kg respectively are at a distance of 2m apart from each other. Find gravitational force between them?  $(7 \times 10^{-7} \text{ N})$
- (4) If two objects of 45 kg and 47 kg respectively are attracted towards each other by a gravitational force of  $250 \times 10^{-7} \text{ N}$ , find the distance between their centres.  $(7 \times 10^{-7} \text{ N})$

#### Type: B

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

$$W = F = mg$$

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

Note:

$$\text{For Earth } g = 9.77 \text{ m/s}^2$$

$$\text{For Moon } g_m = 1.63 \text{ m/s}^2$$

$$v = u + at$$

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

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

- \* (1) Calculate the gravitational force due to the Earth on Mahendra, if mass of Earth is  $6 \times 10^{24} \text{ kg}$ , Radius is  $6.4 \times 10^6 \text{ m}$ ,  $g = 9.77 \text{ m/s}^2$  and mass of Mahendra is 75 kg.

**Ans. Given:** Mass of Earth (M) =  $6 \times 10^{24} \text{ kg}$   
 Radius of Earth (R) =  $6.4 \times 10^6 \text{ m}$   
 Mass of object (m) = 75 kg  
 Gravitational acceleration (g) =  $9.77 \text{ m/s}^2$

**To find:** Force (F) = ?

$$\text{Formula: } F = \frac{GMm}{R^2}$$

**Solution:**

$$F = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 75}{(6.4 \times 10^6)^2}$$

$$= \frac{9.77 \times 75}{1} = 732.75 \text{ N}$$

$$F \approx 733 \text{ N}$$

**The gravitational force is 733 N**

- \* (2) Starting from rest, due to the gravitational force of the Earth i.e. 733 N, What is the speed of Mahendra after 1 second? If his mass is 75 kg.

**Ans. Given:** Initial velocity (u) = 0 m/s  
 Force (F) = 733 N  
 Mass (m) = 75 kg  
 Time (t) = 1 s

**To find:** Final velocity (v) = ?

$$\text{Formulae: } v = u + at, a = \frac{F}{M}$$

**Solution:**

$$a = \frac{733}{75}$$

$$\therefore a = 9.77 \text{ m/s}^2$$

$$v = u + at$$

$$= 0 + 9.77 \times 1$$

$$= 9.77 \text{ m/s}$$

**The speed of Mahendra after 1 second is 9.77 m/s**

- \* (3) If a person weighs 750 N on Earth, how much would be his weight on the Moon given that Moon's mass is  $\frac{1}{81}$  of that of the Earth and its radius is  $\frac{1}{3.7}$  of that of Earth.

**Ans. Given:** Weight on Earth ( $W_E$ ) = 750 N

$$M_m = \frac{1}{81} M_E \quad \therefore \left( \frac{M_m}{M_E} \right) = \frac{1}{81}$$

$$R_m = \frac{1}{3.7} R_E \quad \therefore \left( \frac{R_m}{R_E} \right) = \frac{1}{3.7}$$

**To find:** Weight on Moon ( $W_m$ ) = ?

$$\text{Formula: } W = F = \frac{GMm}{R^2}$$

**Solution:**

For Earth

For Moon

$$W_E = \frac{G M_E m}{R_E^2} \dots (i) \quad W_m = \frac{G M_m m}{R_m^2} \dots (ii)$$

Dividing equation. (ii) by (i)

$$\frac{W_m}{W_E} = \frac{G M_m m}{R_m^2} \div \frac{G M_E m}{R_E^2}$$

$$\frac{W_m}{W_E} = \frac{M_m}{R_m^2} \times \frac{R_E^2}{M_E}$$



$$= \frac{M_m}{M_E} \times \left[ \frac{R_E}{R_m} \right]^2$$

$$\frac{W_m}{W_E} = \frac{1}{81} \times (3.7)^2$$

$$\frac{W_m}{750} = \frac{13.69}{81}$$

$$W_m = 13.69 \times \frac{750}{81} \approx 126.8 \text{ N}$$

**The weight on the Moon is 126.8 N**

**\* (4) The radius of the planet A is half the radius of planet B. If the mass of A is  $M_A$ . What must be the mass of B so that the value of g on B is half that of its value on A?**

**Ans. Given:**  $R_A = \frac{1}{2} R_B \quad \therefore \frac{R_A}{R_B} = \frac{1}{2}$

$$g_B = \frac{1}{2} g_A \quad \therefore \frac{g_B}{g_A} = \frac{1}{2}$$

**To find:** Mass of planet B,  $M_B = ?$

**Formula:**  $g = \frac{GM}{R^2}$

**Solution:** For planet A

$$g_A = \frac{GM_A}{R_A^2} \dots\dots\dots(i)$$

$$g_B = \frac{GM_B}{R_B^2} \dots\dots\dots(ii)$$

Dividing equation. (ii) by (i)

$$\frac{g_B}{g_A} = \frac{GM_B}{R_B^2} \div \frac{GM_A}{R_A^2}$$

$$\frac{1}{2} = \frac{GM_B}{R_B^2} \times \frac{R_A^2}{GM_A}$$

$$\frac{1}{2} = \frac{M_B}{M_A} \times \left[ \frac{R_A}{R_B} \right]^2$$

$$\frac{1}{2} = \frac{M_B}{M_A} \times \frac{1}{4}$$

$$\frac{1}{2} \times 4 = \frac{M_B}{M_A} \quad \therefore 2M_A = M_B$$

$$M_B = 2M_A$$

**The mass of B is twice mass of A**

**\* (5) The mass and weight of an object on Earth is 5 kg and 49 N respectively. What will be their values on the Moon? Assume that the acceleration due to gravity on the Moon is  $\frac{1}{6}$  th of that on the Earth.**

**Ans. Given:**  $m_e = 5 \text{ kg}$   
 $W_e = 49 \text{ N}$   
 $g_m = \frac{1}{6} g_e = \frac{1}{6} \times 9.8 = 1.633 \text{ m/s}^2$

**To find:** Mass on Moon  $m_m = ?$   
 Weight on Moon  $W_m = ?$

**Formula:**  $W = F = mg$

**Solution:** Mass remains same :  $m_m = 5 \text{ kg}$

$$W_m = m_m \times g_m$$

$$= 5 \times 1.633$$

$$W_m = 8.17 \text{ N}$$

**Mass on Moon is 5 kg and weight is 8.17 N**

**\* (6) Suppose you are standing on a tall ladder. If your distance from the centre of the Earth is  $2R$ , what will be your weight? (Use your brain power; Textbook Page no. 10)**

**Ans. Given:**  $R_1 = 2R$

**To find:**  $W_1 = ?$

**Formula:**  $W = F = \frac{GMm}{R^2}$

**Solution:**  $W = \frac{GMm}{R^2} \dots\dots(i)$

$$W_1 = \frac{GMm}{(2R)^2}$$

$$= \frac{GMm}{4R^2} \dots\dots(ii)$$

$$W_1 = \frac{1}{4} \times \left[ \frac{GMm}{R^2} \right]$$

$$W_1 = \frac{1}{4} W$$

**Weight will be one fourth the original weight**

**\* (7) What would be the value of g on the surface of the earth if its mass was twice as large and its radius half of what it is now? (Can you tell?; Textbook Page no. 8)**

**Ans. Given:**  $M' = 2M$

$$R' = \frac{R}{2}$$

**To find:**  $g' = ?$

**Formula:**  $g = \frac{GM}{R^2}$

**Solution:**  $g' = \frac{GM'}{R'^2}$

$$= \frac{G \times 2M}{\left(\frac{R}{2}\right)^2} = \frac{G \times 2M}{\frac{R^2}{4}} = \frac{4 \times 2 \times GM}{R^2}$$

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

$$g' = 8g$$

The value of g will become 8 times.

**NUMERICALS FOR PRACTICE**

- (1) Find the weight of a man whose mass is 50 kg. (490 N)
- (2) Find the gravitational force between man of mass 60 kg and the Earth. (586 N)
- (3) A stone of mass 2 kg is falling from a certain height. Find the force of attraction between the Earth and the stone. Also, find the acceleration. (19.6 N, 9.8 m/s<sup>2</sup>)
- (4) The planet in space with mass twice as that of the Earth and a radius thrice as that of the Earth. If the weight of a book is 90 N on the Earth, what would be the weight on that planet? (20 N)
- (5) Calculate the value of 'g' on the Moon, if its mass is  $7.4 \times 10^{22}$  kg and radius is 1740 km. (1.63 m/s<sup>2</sup>)
- (6) If the weight of a body on the surface of the Moon is 100 N, what is its mass? (61.34 kg)
- (7) If the acceleration due to gravity on the surface of the Earth is 9.8 m/s<sup>2</sup>, what will be the acceleration due to gravity on the surface of the planet whose mass and radius both are two times the corresponding quantities for the Earth. (4.9 m/s<sup>2</sup>)

Type: C

$$v_{esc} = \sqrt{2gR}$$

$$\frac{T^2}{R^3} = K$$

\* (1) Calculate the escape velocity on the surface of the Moon given the mass and radius of the Moon to be  $7.34 \times 10^{22}$  kg and  $1.74 \times 10^6$  m respectively.

**Ans. Given:** Mass (M) =  $7.34 \times 10^{22}$  kg  
 Radius (R) =  $1.74 \times 10^6$  m  
 Gravitational acceleration on Moon ( $g_m$ )  
 $= \frac{1}{6} g_e = \frac{9.8}{6}$  m/s<sup>2</sup>

**To find:**  $v_{esc} = ?$

**Formula:**  $v_{esc} = \sqrt{2g_m R}$

**Solution:**  $v_{esc} = \sqrt{2 \times 1.63 \times 1.74 \times 10^6}$   
 $= \sqrt{5.67 \times 10^6}$   
 $= 2.38 \times 10^3$  m/s  
 $v_{esc} = 2.38$  km/s

The escape velocity on Moon is 2.37 km/s

\* (2) Let the period of revolution of a planet at a distance R from a star be T. Prove that if it was at a distance of 2R from the star, its period of revolution will be  $\sqrt{8}$  T.

**Ans. Given:** Distance from Sun = R  
 Time of Rotation = T  
 New distance = 2R

**To find:** New time  $T_N = ?$

**Formula:**  $\frac{T^2}{R^3} = k$

**Solution:** Case (i)

$$\frac{T^2}{R^3} = k \dots\dots\dots(i)$$

Case (ii)

$$\frac{T_N^2}{(2R)^3} = k \text{ OR } \frac{T_N^2}{8R^3} = k \dots\dots\dots(ii)$$

From (i) and (ii)

$$\frac{T_N^2}{8R^3} = \frac{T^2}{R^3}$$

$$T_N^2 = 8T^2$$

$$T_N = \sqrt{8T^2}$$

$$T_N = \sqrt{8} T$$

**NUMERICALS FOR PRACTICE**

- (1) The escape velocity for mass is 5.02 km/s. If its radius is 3390 km, What is the value of g on its surface. (g = 3.71 m/s<sup>2</sup>)
- (2) A planet orbits the Sun in a time T at a distance of R from it. Another planet orbits the Sun in a time of 8T. What is its distance R' from the Sun. (R' = 4R)

**Type: D**      **Downward/Dropped/Falling**  
 $g$  (positive) = 10 m/s<sup>2</sup>  
 $v = u + gt$   
 $s = ut + \frac{1}{2} gt^2$       **Upward/Thrown up**  
 $g$  (negative) = -10 m/s<sup>2</sup>  
 $v^2 = u^2 + 2gs$

\* (1) An object takes 5s to reach the ground from a

height of 5m on a planet. What is the value of  $g$  on the planet?

**Ans. Given:** Displacement ( $s$ ) = 5 m

Time ( $t$ ) = 5 s

Initial velocity ( $u$ ) = 0 m/s

**To find:** Gravitational acceleration ( $g$ ) = ?

**Formula:**  $s = ut + \frac{1}{2}gt^2$

**Solution:**  $5 = 0 + \frac{1}{2} \times g \times 5^2$

$$5 = g \times \frac{25}{2}$$

$$\frac{5 \times 2}{25} = g$$

$$g = \frac{2}{5}$$

$$g = 0.4 \text{ m/s}^2$$

**Value of  $g$  on planet is  $0.4 \text{ m/s}^2$**

**\*(2) A ball falls off a table and reaches the ground in 1 s. Assuming  $g = 10 \text{ m/s}^2$ , calculate its speed on reaching the ground and the height of the table.**

**Ans. Given:** Time ( $t$ ) = 1 s

Gravitational acceleration ( $g$ ) =  $10 \text{ m/s}^2$

Initial velocity ( $u$ ) = 0

**To find:** Final velocity ( $v$ ) = ?

Displacement ( $s$ ) = ?

**Formulae:**  $v = u + gt$ ,  $s = ut + \frac{1}{2}gt^2$

**Solution:**  $v = u + gt$

$$= 0 + 10 \times 1$$

$$v = 10 \text{ m/s}$$

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

$$s = 5 \text{ m}$$

**Speed on reaching ground is  $10 \text{ m/s}$  and height of the table is  $5 \text{ m}$ .**

**\*(3) An iron ball of mass of 3 kg is released from height of 125m and falls freely to the ground. Assuming that the value of  $g$  is  $10 \text{ m/s}^2$ , calculate (i) time taken by the ball to reach the ground (ii) velocity of the ball on reaching the ground (iii) the height of the ball at half the time it takes to reach the ground.**

**Ans. Given:** Mass ( $m$ ) = 3 kg

Displacement ( $s$ ) = 125 m

$$g = 10 \text{ m/s}^2$$

Initial velocity ( $u$ ) = 0 m/s

**To find:** Time ( $t$ ) = ?

Final velocity ( $v$ ) = ?

Height ( $h_{t/2}$ ) = ?

**Formulae:**  $s = ut + \frac{1}{2}gt^2$ ,  $v = u + gt$

**Solution:** Case (i)

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

$$125 = 0 \times t + \frac{1}{2} \times 10 \times t^2$$

$$125 = 5t^2$$

$$\frac{125}{5} = t^2$$

$$t^2 = 25$$

$$t = 5 \text{ s}$$

Case (ii)

$$v = u + gt$$

$$= 0 + 10 \times 5$$

$$v = 50 \text{ m/s}$$

Case (iii)

$$\text{time} = \frac{t}{2} = \frac{5}{2} \text{ s}$$

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

$$= 0 + \frac{1}{2} \times 10 \times \frac{25}{4}$$

$$= \frac{125}{4} = 31.25 \text{ m}$$

But  $h = 125 - s$

$$= 125 - 31.25$$

$$= 93.75 \text{ m}$$

**(i) Time taken by the ball to reach the ground is 5s.**

**(ii) Velocity of ball on reaching ground is  $50 \text{ m/s}$ .**

**(iii) Height of ball at half time is  $93.75 \text{ m}$ .**

**\*(4) A tennis ball is thrown up and reaches a height of 4.05 m before coming down. What was its initial velocity? How much total time will it take to come down? Assume  $g = 10 \text{ m/s}^2$**

**Ans. Given:** Displacement ( $s$ ) = 4.05 m

$$g = -10 \text{ m/s}^2$$

$$\text{Final velocity (v)} = 0 \text{ m/s}$$

**To find:** Initial velocity (u) = ?

$$t_{\text{total}} (t) = ?$$

**Formulae:**  $v^2 = u^2 + 2gs$ ,  $u + gt$

$$t_{\text{total}} = 2 \times t$$

**Solution:**  $v^2 = u^2 + 2gs$

$$0^2 = u^2 + 2 \times (-10) \times 4.05$$

$$0 = u^2 - 81$$

$$u^2 = 81$$

$$u = 9 \text{ m/s}$$

$$v = u + gt$$

$$0 = 9 + (-10) \times t$$

$$10t = 9$$

$$t = 0.9 \text{ s}$$

Time of ascent = Time of descent

$$t_{\text{total}} = 2t$$

$$= 2 \times 0.9$$

$$= 1.8 \text{ s}$$

The initial velocity was 9 m/s and total time taken to come down, is 1.8 s.

**\*(5)** An object thrown vertically upwards reaches a height of 500 m. What was its initial velocity? How long will the object take to come back to the Earth? Assume  $g = 10 \text{ m/s}^2$ .

**Ans. Given:** Displacement (s) = 500 m  
Gravitational acceleration (g) =  $-10 \text{ m/s}^2$   
Final velocity (v) = 0 m/s

**To find:** Initial velocity (u) = ?

$$T_{\text{total}} (t) = ?$$

**Formulae:**  $v^2 = u^2 + 2gs$ ,  $T_{\text{total}} = 2t$

$$v = u + gt$$

**Solution:**  $v^2 = u^2 + 2gs$

$$0 = u^2 - 10000$$

$$10000 = u^2$$

$$u = 100 \text{ m/s}$$

$$v = u + gt$$

$$0 = 100 + (-10) \times t$$

$$10t = 100$$

$$t = 10\text{s}$$

Time of ascent = Time of descent

$$\therefore T_{\text{total}} = 2 \times 10$$

$$\therefore T_{\text{total}} = 20\text{s}$$

Initial velocity was 100 m/s and time taken to come back to Earth is 20s.

**(6)** Find a formula for.

Maximum height attained by object

**Ans. Solution:** From 3<sup>rd</sup> equation of motion

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

$$v = 0, a = -g$$

$$\therefore 0^2 = u^2 + 2(-g)s$$

$$2gs = u^2$$

$$s = \frac{u^2}{2g}$$

**\*(7)** A stone thrown vertically upwards with initial velocity  $u$  reaches a height 'h' before coming down. Show that the time taken to go up is same as the time taken to come down.

**Ans.** Time of Ascent = Time of Descent

During Ascent

$$v = u + at$$

$$v = 0, a = -g, t = t_1$$

$$0 = u - gt_1$$

$$gt_1 = u$$

$$t_1 = \frac{u}{g} \dots\dots\dots(i)$$

During Descent

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

$$u = 0, a = g, t = t_2$$

$$s = \frac{1}{2} gt_2^2 \quad \text{or} \quad s = \frac{gt_2^2}{2} \dots\dots\dots(ii)$$

We know, the formula for max height attained is

$$s = \frac{u^2}{2g} \dots\dots\dots(iii)$$

From (ii) and (iii),

$$\therefore \frac{u^2}{2g} = \frac{gt_2^2}{2}, \quad \frac{u^2}{g^2} = t_2^2$$

$$t_2 = \frac{u}{g} \dots\dots\dots(iv)$$

From (i) and (iv)

$$t_1 = t_2$$

### NUMERICALS FOR PRACTICE

- (1) A ball thrown up vertically returns to the thrower after 6s. Find the velocity with which it was thrown up. *(29.4 m/s)*
- (2) A boy drops a coin from the top of a building which is 49m high. Find the velocity with which the coin strikes the ground. *(v = 31 m/s)*
- (3) A ball is thrown vertically upwards with velocity of 49 m/s. Calculate (i) Maximum height to which it rises (ii) total time (t) it takes to return to the surface of Earth. *(s = 122.5 m, t = 10 s)*
- (4) A stone is thrown vertically upwards with initial velocity of 40 m/s. Taking  $g = 10 \text{ m/s}^2$  find the maximum and total distance covered by stone. *(s = 160 m, distance = 0)*

#### Q.2.2. Define/write the laws:

(1) Force

**Ans.** The force is that physical quantity which changes or tends to change the state of rest or of uniform motion in a straight line.

(2) Newton's universal law of gravitation

**Ans.** According to the Newton's universal law of gravitation, every object in the universe attracts every other object with a force, which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

(3) Universal constant of gravitation (G)

**Ans.** Universal constant of gravitation is the force of attraction between two unit masses placed at unit distance apart from each other.

(4) Centre of mass

**Ans.** It is the point inside or outside the object at which the total mass of the object can be assumed to be concentrated..

(5) Gravitational acceleration (g)

**Ans.** The gravitational force due to earth on a body results in its acceleration. This is called acceleration due to gravity.

\* (6) Free fall

**Ans.** When a body falls towards the Earth under the influence of the Earth's gravity alone, its motion is called a 'free fall'.

(7) Mass (m)

**Ans.** The mass of an object is the quantity of matter

contained in it. The mass is the measure of the inertia of a body.

(8) Weight (W)

**Ans.** The weight of a body is defined as the force with which the Earth attracts the object.

\* (9) Centripetal force

**Ans.** The force that acts on any object moving along a circle, directed towards the centre of the circle is called centripetal force.

(10) Uniform circular motion

**Ans.** When an object moves in a circular path with uniform speed, its motion is uniform circular motion.

(11) Potential energy

**Ans.** A body can have energy because of its shape or position or configuration. This is known as potential energy.

(12) Escape velocity

**Ans.** The minimum initial velocity needed by an object projected upwards to overcome Earth's gravitational force and not fall back on Earth is called escape velocity.

#### Q.2.3. Write short notes:

(1) Earth's gravitational force

**Ans.**

- (i) The Earth attracts all the objects at or around the surface of the Earth.
- (ii) The attraction is towards the centre of the Earth. Hence, the gravitational force of the Earth acts towards the centre of the Earth.
- (iii) Due to this force, all objects fall vertically downwards on the earth.

(2) Earth's gravitational acceleration

**Ans.**

- (i) The Earth applies a force of gravitation on any object at or around its surface.
- (ii) The uniform acceleration produced in a freely falling body due to the gravitational force of the Earth is called gravitational acceleration or acceleration due to gravity.
- (iii) Gravitational acceleration is denoted by 'g' and is a vector quantity. Its SI unit is  $\text{m/s}^2$ .

(3) Variation in the value of g.

**Ans.** The value of g varies based on the following

- (a) Along the surface of the earth.
  - The earth is not perfectly spherical.

- It is bulged at the equator and flattened at the poles.
- The radius is highest at the equator and least at poles.
- Value of  $g$  is highest at poles ( $9.832 \text{ m/s}^2$ )
- Value of  $g$  is least at equator ( $9.78 \text{ m/s}^2$ )

**(b) Change with height.**

- As height increases, value of  $g$  decreases.
- The change is negligible for height smaller than the radius of the earth.

**(c) Change with depth.**

- As depth increases, value of  $g$  decreases.
- This is because, as we go inside the earth, the mass under consideration decreases.
- Hence value of  $g$  decreases.

**Q.2.4. Complete the following table:**

Place	Altitude from the Earth's surface (km)	$g$ ( $\text{m/s}^2$ )
(i) Surface of Earth	0	.....
(ii) Mount Everest	8.8	.....
(iii) Altitude attained by Man-made balloon	36.6	.....
(iv) Orbit of space shuttle	400	.....
(v) Communication satellite	35700	.....

**Ans.** (i) 9.83 (ii) 9.8 (iii) 9.77 (iv) 8.7 (v) 0.225

**Q.2.5. Distinguish between:****(1) Gravitational constant and Gravitational acceleration.****Ans.**

Gravitational constant (G)	Gravitational acceleration (g)
(i) Gravitational constant is the force of attraction between two unit masses placed at unit distance apart from each other.	(i) The uniform acceleration produced in a freely falling body due to the gravitation force of the Earth is called gravitational acceleration.

(ii) It has SI unit  $\text{Nm}^2/\text{kg}^2$ , while CGS unit is  $\text{dyne.cm}^2/\text{g}^2$ .

(iii) It is always denoted by 'G'.

(iv) Its S.I. value is  $6.673 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$ , while in CGS, it is  $6.673 \times 10^{-8} \text{ dyne cm}^2/\text{g}^2$ .

(v) Its value is fixed and does not change with conditions, hence called universal constant.

(ii) It has SI unit  $\text{m/s}^2$ , while CGS unit is  $\text{cm/s}^2$ .

(iii) It is always denoted by 'g'.

(iv) Its S.I. value is  $9.77 \text{ m/s}^2$ , while in CGS, it is  $977 \text{ cm/s}^2$ .

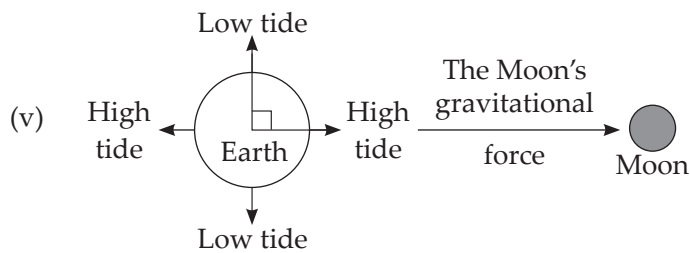
(v) The value of 'g' depends on various factors like altitude, depth, shape etc.

**\* (2) Weight and Mass****Ans.**

Mass (m)	Weight (W)
(i) Mass is the amount of matter present in the object.	(i) Weight is the force with which the Earth attracts the object.
(ii) Mass does not change with place.	(ii) $W = mg$ . As $g$ changes, $W$ also changes.
(iii) SI unit is kg. CGS unit is gram (g).	(iii) SI unit is newton. CGS unit is dyne.
(iv) Mass is a scalar quantity.	(iv) Weight is a vector quantity.

**Q.2.6. Give scientific reasons:****(1) High and low tides are regular phenomena.****Ans.**

- The sea level on the Earth is directly influenced by the gravitational force of the moon.
- Due to the gravitational force, the water on the Earth towards the direction of the Moon experiences pull, hence there occurs high tide.
- At the same time, the place which is at right angles or at  $90^\circ$ , the water level gets reduced and experience low tide.
- This situation occurs two times a day on regular basis, water level rises two times a day and reduces two times a day.



(2) **In the spacecraft, travellers and objects appear floating.**

**Ans.**

- (i) Though the spacecraft is taken to a huge height from the Earth, the value of acceleration due to gravity does not become zero.
  - (ii) The weightlessness is because the spacecraft is in a state of free fall.
  - (iii) Any object in a state of free fall will feel weightlessness.
- (3) **Weight of an object changes from place to place on the surface of the Earth.**

**Ans.**

- (i) The shape of the Earth is not exactly spherical. It is flattened at poles, while bulged at equator.
- (ii) Weight is the Earth's gravitational force acting on the object, which is generally  $W = mg$ .
- (iii) Mass of the object remains the same but value of 'g' keeps on changing from place to place.
- (iv) The value of 'g' is maximum at poles and it is  $9.83 \text{ m/s}^2$  while it is the least at equator i.e.  $9.78 \text{ m/s}^2$ .
- (v) Due to this the weight of an object changes from place to place on the surface of the Earth.
- (vi) It is maximum at poles but gets reduced at equator.

**Q.3.1. Explain the following:**

- (1) **Explain the terms:**  
 (a) Free fall, (b) Acceleration due to gravity,  
 (c) Escape velocity (d) Centripetal force  
 (e) Potential energy

**Ans.**

- \*(a) Free fall:**  
 When a body falls towards the Earth under the influence of the Earth's gravity alone, its motion is called free fall.
- \*(b) Acceleration due to gravity:**  
 The gravitational force due to earth on a body results in its acceleration. This is called acceleration due to gravity.

**\*(c) Escape velocity:**  
 The minimum initial velocity needed by an object projected upwards to overcome Earth's gravitational force and not fall back on Earth is called escape velocity.

**\*(d) Centripetal force:**  
 The force that acts on any object moving along a circle, directed towards the centre of the circle is called centripetal force.

**(e) Potential energy:**  
 The energy possessed due to position or configuration is called potential energy.

(2) **Define: The Universal law of gravitation and derive mathematically.**

**Ans. The Universal law of gravitation:** Every object in the universe attracts any other object with the force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

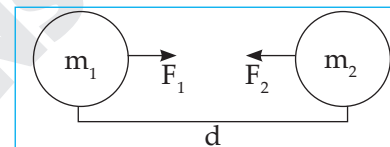


Fig 1.1

Let  $m_1$  and  $m_2$  are the masses of two objects, the distance between their centres be 'd'.

The gravitational attraction between the two will be given by,

$$F \propto \frac{m_1 m_2}{d^2}$$

$$\therefore F = \frac{Gm_1 m_2}{d^2} \quad (G \text{ is constant})$$

G is called gravitational constant; it is also known as Universal constant of gravitation.

**\*(3) Write Newton's three laws of motion.**  
 (Can you recall; Textbook Page no. 1)

**Ans.**

- (i) **Newton's first law of motion :** Every inanimate object continues to be in a state of rest or of uniform motion in a straight line unless it is acted upon by an external unbalanced force.
- (ii) **Newton's second law of motion :** The rate of change of momentum is directly proportional to the applied force and it takes place in the direction of force.
- (iii) **Newton's third law of motion :** To every action there is always instantaneous, equal and opposite reaction.

**\* (4) Write the effects of force acting on an object?***(Can you recall; Textbook Page no. 1)***Ans.** The applied force can:

- (i) change the state of rest.
- (ii) change the motion of an object
- (iii) change the direction of motion
- (iv) change both motion and direction of motion simultaneously
- (v) change the shape of the object temporarily.

**(5) Define: Acceleration due to gravity and derive mathematically.****Ans.** The gravitational force due to the Earth on an object results in its acceleration. It is called acceleration due to gravity.

We know,

$$F = \frac{GMm}{R^2} \dots\dots(i)$$

$$F = mg \dots\dots(ii)$$

From (i) and (ii)

$$mg = \frac{GMm}{R^2}$$

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

For Earth,  $g = 9.77 \text{ m/s}^2$ **\* (6) The value of 'g' at the centre of the Earth is zero. Explain?****Ans.** As we gradually go towards the centre of the Earth, the mass of Earth under consideration goes on decreasing.

We know,

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

At the centre of the Earth, the mass of earth under consideration is zero, Hence  $g$  at the centre of the earth becomes zero.**\* (7) Write the three laws given by Kepler. How did they help Newton to arrive at the inverse square law of gravity?****Ans.** Kepler's laws:

- (i) **Kepler's first law :** The orbit of a planet is an ellipse with the Sun at one of the foci.
- (ii) **Kepler's second law :** The line joining the planet and the Sun sweeps equal areas in equal intervals of time.
- (iii) **Kepler's third law:** The square of its period of revolution around the Sun is directly proportional to the cube of the mean distance of a planet from the Sun.

(i) If a planet revolves around the Sun in a circular orbit, then the centripetal force exerted on it by the Sun is  $F = \frac{mv^2}{r}$ where,  $m$  - mass of the planet  
 $v$  - velocity and  
 $r$  - radius of the circle.(ii) Distance travelled in one revolution by the planet = Circumference  
 $= 2\pi r$ Time period of revolution =  $(T)$ 

$$\therefore \text{speed} = \frac{\text{distance}}{\text{time}}$$

$$v = \frac{2\pi r}{T} \dots(i)$$

$$\therefore F = \frac{mv^2}{r}$$

$$\therefore F = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r} \dots[\text{from(i)}]$$

$$\therefore F = \frac{4m\pi^2 r}{T^2}$$

$$\therefore F = \frac{4m\pi^2 r}{T^2} \times \frac{r^2}{r^2}$$

$$\therefore F = \frac{4m\pi^2 r^3}{r^2 T^2} \dots \left[ \frac{T^2}{r^3} = k \text{ or } \frac{r^3}{T^2} = \frac{1}{k} \right] \dots(ii)$$

$$\therefore F = \frac{4m\pi^2}{kr^2} \dots[\text{from(ii)}]$$

[but  $\frac{4m\pi^2}{k}$  is constant]

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

This is how Newton proved inverse square law of gravity.

**(8) Define: Kepler's third law and derive mathematically to obtain constant.****Ans. Kepler's third law:** The square of its period of revolution around the Sun is directly proportional to the cube of the mean distance of a planet from the Sun.If ' $T$ ' is a periodic time and the average distance of a planet from the Sun is ' $r$ ', then,

$$T^2 \propto r^3$$

$$\therefore T^2 = kr^3 \dots k \text{ is constant, } k \neq 0$$

$$\therefore k = \frac{T^2}{r^3}$$



(9) If the value of  $g$  suddenly becomes twice its value, it will become two times more difficult to pull a heavy object along the floor. Why?

Ans.

- (i) If the value of  $g$  becomes double, the force with which the earth pulls the object i.e weight of object becomes double.
- (ii) As weight increases, frictional force also increases while pulling the object
- (iii) Hence, it will become two times more difficult to pull a heavy object along the floor.

(10) Explain centripetal force with suitable example.

Ans. The force on an object revolving in a circular path towards the centre is called centripetal force.

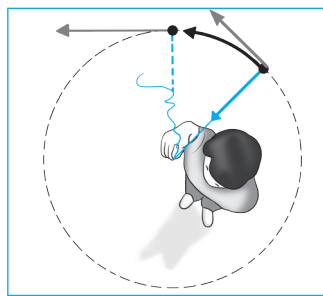


Fig 1.2

e.g. A stone tied to the string moves in a circular path and its velocity is tangential.

(11) Define: Escape velocity and derive mathematically.

Ans. The velocity required to overcome the Earth's gravitational force to move into the space is called escape velocity.

On surface of Earth

A  $K.E. = \frac{1}{2} mv_{esc}^2$   
 B  $P.E. = -\frac{GMm}{R}$   
 C  $T.E. = P.E. + K.E.$   
 $E_1 = \frac{1}{2} mv_{esc}^2 - \frac{GMm}{R}$

At infinity

A  $K.E. = 0$   
 B  $P.E. = -\frac{GMm}{\infty} = 0$   
 C  $T.E. = P.E. + K.E.$   
 $= 0 + 0 = 0$

According to law of conservation of energy.

$$E_1 = E_2$$

$$\frac{1}{2} mv_{esc}^2 - \frac{GMm}{R} = 0$$

$$\frac{1}{2} mv_{esc}^2 = \frac{GMm}{R}$$

$$v_{esc}^2 = \frac{2GM}{R}$$

$$v_{esc} = \sqrt{\frac{2GM}{R} \times R}$$

$$v_{esc} = \sqrt{\frac{2GM \times R}{R^2}} \dots \left[ g = \frac{GM}{R^2} \right]$$

$$v_{esc} = \sqrt{2gR}$$

For Earth,  $v_{esc} = 11.2 \text{ km/s}$ .

**Q.3.2. Open Ended Question:**

\* (1) According to Newton's law of gravity, every object attracts any other object means if the Earth attracts an apple towards it, then an apple also attracts the Earth with the same force, then why an apple falls down but the Earth does not move towards the apple?

Ans. Yes, the apple also attracts the Earth with equal force but the mass of the apple is much less as compared to that of Earth.

We know,  $F = ma$  or  $a = \frac{F}{M}$

Hence, greater the mass, lesser the acceleration. Therefore, due to greater mass, the Earth's acceleration is almost zero.

\* (2) Is there a gravitational force between two objects kept on a table or between you and your friend sitting next to you? If yes, why don't the two move towards each other? (Use your brain power; Textbook Page no. 5)

Ans. Yes, there is a force of attraction between the two objects as well as me and my friend.

We know,

$$F \propto m_1 m_2$$

Since the mass of me and my friend is very less as compared to the Earth, the force is also very less. Hence, we don't move towards each other.

\* (3) Will your weight remain constant as you go above the surface of the earth? (Use your brain power; Textbook Page no. 10)

Ans.

- (i) Weight of a body depends on acceleration due to gravity.
- (ii) As we go above the surface of the earth height increases and hence acceleration decreases.
- (iii) As acceleration due to gravity decreases consequently weight decreases.

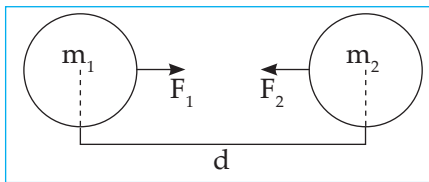
**\* (4)** According to Newton's law of gravitation, earth's gravitational force is higher on an object of larger mass. Why doesn't that object fall down with higher velocity as compared to an object with lower mass? (Use your brain power; Textbook Page no. 12)

**Ans.**

- (i) The acceleration due to gravity ( $g$ ) on an object only depends on mass ( $M$ ) and radius ( $R$ ) of the earth i.e.  $g = \frac{GM}{R^2}$ .
- (ii) It does not depend on mass ( $m$ ) of the object.
- (iii) The acceleration produced at a given point is the same for all objects.
- (iv) Hence, object of larger mass does not fall down with higher velocity as compared to an object with lower mass.

**Q.3.3. Figure based Question:**

**\* (1)** Observe the figure and answer the following questions: (Textbook Page no. 4)



(i) What are the masses of the objects shown?

**Ans.** The masses are  $m_1$  and  $m_2$ .

(ii) What is the distance between their centres?

**Ans.** The distance between their centres is ' $d$ '.

(iii) Write gravitational force between them.

**Ans.** The gravitational force between them would be,

$$F \propto \frac{m_1 m_2}{d^2}$$

$$\therefore F = \frac{Gm_1 m_2}{d^2} \dots \text{(G is constant of gravitation)}$$

(iv) Why gravitation constant is called universal constant?

**Ans.** The value of gravitational constant does not depend upon the nature and size of the bodies. It also does not depend upon the nature of the medium between two bodies; hence it is called universal constant.

(v) What will happen to gravitational force if mass of one of the objects is doubled?

**Ans.** If the mass of one of the objects is doubled, then the gravitational force between them also gets doubled.

(vi) What is the value of universal constant in SI?

**Ans.** In SI system, the value of ' $G$ ' is  $6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$ .

**\* (2)** Observe the following diagram and answer the questions:

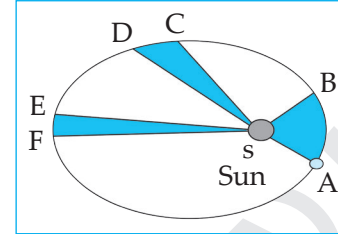


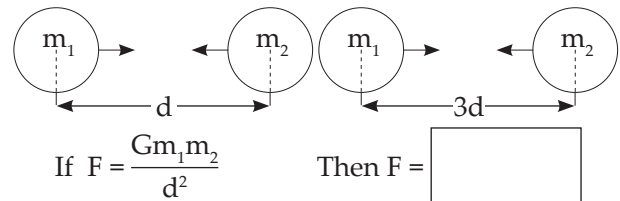
Fig 1.3: The orbit of a planet moving around the Sun.

In a given figure, area ESF is equal to ASB, then what can you say about EF? (Use your brain power; Textbook Page no. 4)

**Ans.**

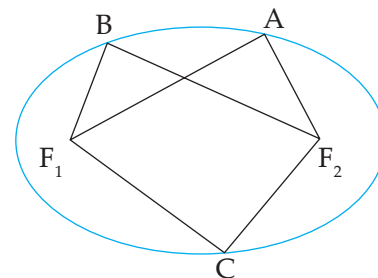
- (i) Distance EF is lesser than AB. Hence, speed will be lesser at EF and greater at AB
- (ii) Therefore, in an elliptical orbit, speed is not constant.

(3)



**Ans.**  $\frac{Gm_1 m_2}{9d^2}$

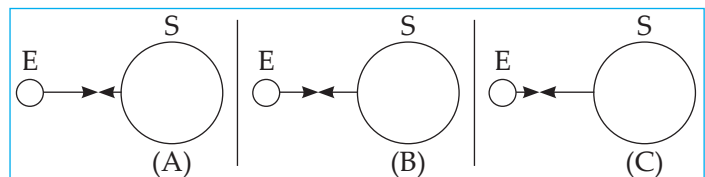
(4)



$$AF_1 + AF_2 = \boxed{\phantom{000}} = \boxed{\phantom{000}}$$

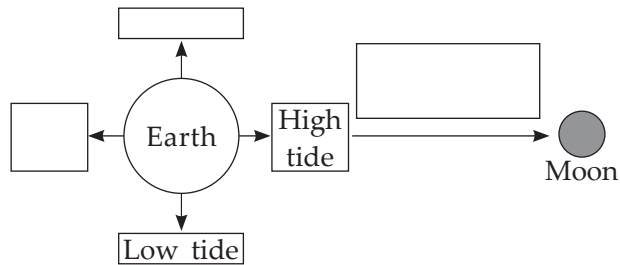
**Ans.**  $BF_1 + BF_2$ ;  $CF_1 + CF_2$

(5) Which of the following best represent force between Sun and Earth.

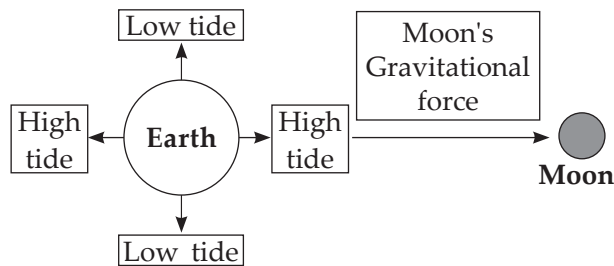


**Ans.** B. Force is equally exerted by 2 bodies.

### Q.3.4. Complete the flow chart:



Ans.



### Q.4.1. Paragraph based Questions:

(1) Read the paragraph and answer the following questions:

- (1) You must be knowing about the high and low tides that occur regularly in the sea. The level of sea water at any given location along sea shore increases and decreases twice a day at regular intervals. High and low tides occur at different times at different places. The level of water in the sea changes because of the gravitational force exerted by the moon. Water directly under the moon gets pulled towards the moon and the level of water there goes up causing high tide at that place. At two places on the earth at  $90^\circ$  from the place of high tide, the level of water is minimum and low tides occur there.

(i) How many times does the sea level at the coast change?

Ans. Sea level at the coast increases and decreases two times a day. Two high tides and two low tides.

(ii) How does sea level get changed?

Ans. The sea-level at the coastal region gets changed two times a day due to gravitational attraction of the Moon.

(iii) Where is high tide and low tide caused?

Ans. Due to gravitational attraction of the Moon, the water mass swells towards the direction of the Moon causing high-tide. The water mass shrinks at  $90^\circ$  from this place which causes low tide.

(2) The centre of mass of an object is the point inside or outside the object at which the total mass of the object can be assumed to be concentrated. The centre of mass of a spherical object having uniform density is at its geometrical centre. The centre of mass of any object having uniform density is at its centroid.

(i) Where can the total mass of an object be assumed to be concentrated?

Ans. As the centre of mass.

(ii) Where is the centre of mass located for an object of uniform density?

Ans. As its centroid.

(iii) Where is the centre of mass located for a spherical object?

Ans. As its geometrical centre.

(iv) What was the basis of Kepler's laws?

Ans. Kepler's laws were based on the motion of the planets.

(3) **Gravitational waves:**

Waves are created on the surface of water when we drop a stone into it. Similarly you must have seen the waves generated on a string when both its ends are held in hand and it is shaken. Light is also a type of wave called the electromagnetic wave. Gamma rays, X-rays, ultraviolet rays, infrared rays, microwave and radio waves are all different types of electromagnetic waves. Astronomical objects emit these waves and we receive them using our instruments. All our knowledge about the universe has been obtained through these waves.

Gravitational waves are a very different type of waves. They have been called the waves on the fabric of space-time. Einstein predicted their existence in 1916. These waves are very weak and it is very difficult to detect them. Scientists have constructed extremely sensitive instruments to detect the gravitational waves emitted by astronomical sources. Among these, LIGO (Laser Interferometric Gravitational Wave Observatory) is the prominent one. Exactly after hundred years of their prediction, scientists detected these waves coming from an astronomical source. Indian scientists have contributed significantly in this discovery. This discovery has opened a new path to obtain information about the Universe.

(i) What are the different types of electro magnetic waves?

**Ans.** Gamma rays, X-rays, Ultraviolet rays, infrared rays, microwave and radio waves.

(ii) What are the waves on the fabric of space - time called?

**Ans.** They are called gravitational waves.

(iii) Is it easy to detect Gravitational waves?

**Ans.** No, these waves are very weak and it is very difficult to detect them.

(iv) What is the device, used to detect Gravitational waves?

**Ans.** LIGO (Laser Interferometric Gravitational waves Observatory) is used to detect Gravitational waves.

(4) **Weightlessness in space:**

Space travellers as well as objects in the spacecraft appear to be floating. Why does this happen? Though the spacecraft is at a height from the surface of the earth, the value of  $g$  there is not zero. In the space station the value of  $g$  is only 11% less than its value on the surface of the earth. Thus, the height of a spacecraft is not the reason for their weightlessness.

Their weightlessness is caused by their being in the state of free fall. Though the spacecraft is not falling on the earth because of its velocity along the orbit, the only force acting on it is the gravitational force of the earth and therefore it is in a free fall. As the velocity of free fall does not depend on the properties of an object, the velocity of free fall is the same for the spacecraft, the travelers and the objects in the craft. Thus, if a traveller releases an object from her hand, it will remain stationary with respect to her and will appear to be weightless.

(i) Is the value of  $g$  zero in the space station?

**Ans.** No, the value of  $g$  is only 11% less than its value on the surface of Earth.

(ii) Why is weightlessness caused in a spacecraft?

**Ans.** The weightlessness is caused by them being in a state of free fall.

(iii) Why doesn't the spacecraft fall towards the Earth?

**Ans.** The spacecraft does not fall towards Earth because of its velocity along the orbit.

(iv) If a traveller releases an object from her hand in the spacecraft, what will happen?

**Ans.** The object will remain stationary with respect to her, because, the velocity of free fall is the same for the spacecraft, traveller and objects in the craft.

#### Q.4.2. Activity based Questions:

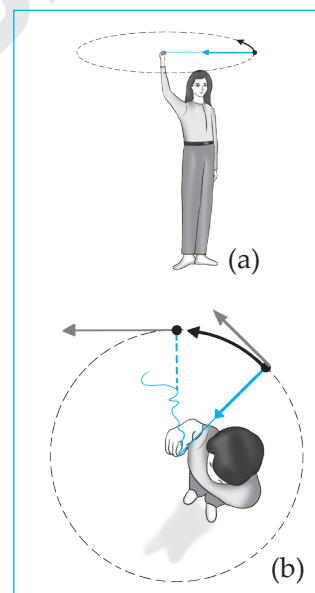
(1) Read the following paragraph carefully and answer the following:

(1) Tie a stone to one end of a string. Take the other end in your hand and rotate the string so that the stone moves along a circle.

As long as we are holding the string, we are pulling the stone towards us i.e. towards the centre of the circle

and are applying a force towards it. The force stops acting if we release the string.

In this case, the stone will fly off along a straight line which is the tangent to the circle at the position of the stone when the string is released, because that is the direction of its velocity at that instant of time. You may



recall a similar activity in which a 5 rupee coin kept on a rotating circular disk flies off the disk along the tangent to the disk. Thus, a force acts on any object moving along a circle and it is directed towards the centre of the circle. This is called the Centripetal force.

(i) The impressed force on the stone is in which direction?

**Ans.** On the stone, the force is directed towards the centre of the circle.

(ii) What happens if the string is released?

**Ans.** The stone will fly off in a straight line along the tangent to the circle.

(iii) What is centripetal force?

**Ans.** The force exerted towards the centre of the circle on an object moving along a circular path is called centripetal force. It is a centre seeking force.

- (2) Take a small stone. Hold it in your hand.

We know that the force of gravity due to the earth acts on each and every object. When we were holding the stone in our hand, the stone was experiencing this force, but it was balanced by a force that we were applying on it in the opposite direction. As a result, the stone remained at rest. Once we release the stone from our hands, the only force that acts on it is the gravitational force of the earth and the stone falls down under its influence. Whenever an object moves under the influence of the force of gravity alone, it is said to be falling freely. Thus the released stone is in a free fall. In free fall, the initial velocity of the object is zero and goes on increasing due to the acceleration due to gravity of the earth. During free fall, the frictional force due to air opposes the motion of the object and a buoyant force also acts on the object. Thus, true free fall is possible only in vacuum. For a freely falling object, the velocity on reaching the earth and the time taken for it can be calculated by using Newton's equations of motion. For free fall, the initial velocity  $u = 0$  and the acceleration  $a = g$ . Thus we can write the equations as

For calculating the motion of an object thrown upwards, acceleration is negative, i.e. in a direction opposite to the velocity and is taken to be  $-g$ . The magnitude of  $g$  is the same but the velocity of the object decreases because of this -ve acceleration.

$$(i) \quad v = gt$$

$$(ii) \quad s = \frac{1}{2} gt^2$$

$$(iii) \quad v^2 = 2gs$$

The moon and the artificial satellites are moving only under the influence of the gravitational field of the earth. Thus they are in free fall.

*(Try this; Textbook Page no. 11)*

- (i) **Which force acts on the stone when held in the hand?**

**Ans.** Gravitational force in downward direction and reaction force of hand in upward direction.

- (ii) **Which force acts on the stone in free fall after you release it?**

**Ans.** Only gravitational force acts on it when it is released.

- (iii) **What is free fall?**

**Ans.** When an object falls towards the Earth under the influence of the Earth's gravity alone it is called free fall.

- (iv) **What is the initial velocity and what is the effect of gravitational acceleration on the object in free fall?**

**Ans.** In free fall, the initial velocity of an object is zero and as the time progresses, velocity increases due to uniform gravitational acceleration.

- (v) **Write kinematic equations used in free fall?**

**Ans.** The kinematic equations are,  $v = gt$ ,  $s = \frac{1}{2} gt^2$  and  $v^2 = 2gs$



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### ASSIGNMENT - 1

**Time : 1 Hr.**

**Marks : 20**

**Q.1. (A)**

(3)

- (1) Fill in the blanks:
- (i) Value of  $g$  at centre of Earth is .....
- (ii) Mass is also a measure of ..... of an object.
- (2) Complete the analogy:
- (i) At poles :  $9.83 \text{ m/s}^2$  : : At equator : .....

**Q.1. (B) Complete the following statements by selecting the proper alternative from the given:**

(2)

- (1) The gravitational force of attraction between two objects is given by .....
- (a)  $F \propto \frac{m_1 m_2}{d^2}$     (b)  $F \propto \frac{d^2}{m_1 m_2}$     (c)  $F \propto \frac{m_1 m_2}{\sqrt{d^2}}$     (d)  $F \propto \frac{m_1 m_2}{d^3}$
- (2) The gravitational force on the surface of the Moon is ..... times than that on the surface of the Earth.
- (a) five                      (b) one fifth                      (c) one sixth                      (d) six

**Q.2. Answer the following: (any 2)**

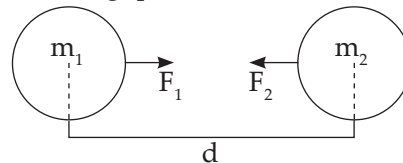
(4)

- (1) Mahendra and Virat are sitting at a distance of 1 metre from each other. Their masses are 75 kg and 80 kg respectively. What is the gravitational force between them?
- (2) Define: (i) Centre of mass                      (ii) Free fall
- (3) Distinguish between: Weight and Mass

**Q.3. Answer the following: (any 2)**

(6)

- (1) If a person weighs 750 N on Earth, how much would be his weight on the Moon given that Moon's mass is  $\frac{1}{81}$  of that of the Earth and its radius is  $\frac{1}{3.7}$  of that of Earth.
- (2) Define: The Universal law of gravitation and derive mathematically.
- (3) Observe the figure and answer the following questions:



- (i) Write gravitational force between them.
- (ii) What will happen to gravitational force if mass of one of the objects is doubled?
- (iii) What is the value of universal constant in SI system?

**Q.4. Answer the following: (any 1)**

(5)

- (1) Write the three laws given by Kepler. How did they help Newton to arrive at the inverse square law of gravity?
- (2) Define: Escape velocity and derive mathematically.

