1 Gravitation

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) $F \alpha \frac{m_1m_2}{d^2}$ means F = ...

(4) If the distance between the two objects 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° 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 .... m/s^2.

(15) The value of acceleration due to gravity at the equator is .... 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 becomes ....

(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 the centre of the 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 .... on the surface 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_{esc} = ...

(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) Nm^2/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) $\frac{1}{4}^{th}$ (18) acceleration (19) inertia (20) 6×10^{24} (21) 6.4×10^6 (22) Zero (23) newton (N) (24) weight (25) six (26) poles (27) ellipse (28) potential energy (29) $\sqrt{2gR}$ (30) LIGO (31) Final velocity (v), Initial velocity (u) (32) $F = \frac{mv^2}{r}$*

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

(1) Acceleration, mass, force, weight

Ans. Mass - It is scalar, while others are vectors.

(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

Ans. Change in value of 'g' on thickness. Others are related factors to the value of 'g'.

*(3) Light, sound, heat, laws of planetary motion

Ans. Law of planetary motion. Others are related to Newton.

(4) Mass, potential energy, radius, weight

Ans. Weight. It is vector, while others are scalars.

(5) 9.83 m/s^2, 9.8 m/s^2, 980 cm/s^2, 9.77 m/s^2

Ans. 980 cm/s^2. Others are values of g in MKS.

(6) Weight, Thrust, Force, Pressure

Ans. Pressure. Others are vectors.

(7) Newton's first law, Newton's law of gravity, Newton's third law, Newton's second law

Ans. Newton's law of gravity. Other are related to law of motion.

(8) Newton, Ohm, Kepler, Galileo

Ans. Ohm. Others are concerned with laws of gravity.

(9) 983 m/s^2, 977 m/s^2, 980 m/s^2, 9.83 m/s^2

Ans. 9.83 m/s^2. Others are in CGS system.

(10) 9.83 m/s^2, 98.3 m/s^2, 983 m/s, 98.03 m^2s

Ans. 9.83 m/s^2. Others are not values of 'g'.

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

(1) 6×10^{24} kg : Mass of the Earth : : 6.4×10^{6} m : ....

Ans. Radius of the Earth - Mass is measured in kg and distance is measured in metres.

(2) Height of a weather satellite : 8.7 m/s^2 : : Height of Communication satellite : ....

Ans. 0.225 m/s^2 - The value of 'g' changes with the change in the height of the satellites.

(3) Mass : Scalar quantity : : Weight : ....

Ans. Vector quantity - Weight being a force is a vector quantity and its direction is towards the centre of the earth.

(4) At poles : 9.83 m/s^2 : : At equator : ....

Ans. 9.78 m/s^2 - Earth's radius is the largest at the equator and the smallest at the poles.

(5) Shape of the Earth at equator : Bulged : : Shape of the Earth at poles : ....

Ans. Flattened - The shape of the Earth is not exactly spherical. Due to its rotation, the earth bulges at the equator and is flattened at the poles.

(6) Kinetic energy : $\frac{1}{2}mv^2$: : Gravitational Potential energy : ....

Ans. $\frac{-GMm}{R+h}$ - For small distances, i.e. heights, the potential energy is less than zero, i.e. it is negative.

(7) Force : ma : : Gravitational force : ....

Ans. $\frac{Gm_1m_2}{d^2}$ - Mathematically, the gravitational force of attraction between two bodies is given by $\frac{Gm_1m_2}{d^2}$

(8) Force : Vector : : Weight : ....

Ans. Vector - Weight is also a force and its direction is towards the centre of the earth. Weight = m × g

Q.1. (A) 4. With the information in three columns, match up and complete the chart:

*(1)

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)	30×10^{27}	15×10^{5}	....	03
(3)	16×10^{9}	....	17	34
(4)	250×10^{-7}	45	47	....

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

Q.1. (A) 5. State whether the following statements are True or False. Correct the false statement.

(1) Force = mass × velocity

(2) 'G' is called gravitational acceleration.

(3) Acceleration is a scalar quantity.

(4) Gravitational force at the Moon is double than the Earth's gravitational force.

(5) 1 N = 1 kg × 1 m/s^2.

(6) 1 dyne = 10^5 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 the 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, $g \alpha \frac{1}{(R+h)^2}$.

(13) Weight is a vector quantity.

(14) The mass of the Earth is 6.4×10^6 kg.

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

Ans. *(1) False. Force = mass × acceleration (2) False. 'G' is called Universal gravitational constant (3) False. Acceleration is a vector quantity (4) False. Gravitational force at the moon is $\frac{1}{6}^{th}$ of* *the Earth's gravitational force (5) True (6) True (7) True (8) False. The gravitational acceleration becomes zero at the centre of the Earth (9) False. The acceleration due to gravity is 9.83 m/s^2 at the poles (10) False. 'g' is called acceleration due to gravity (11) True (12) True (13) True (14) False. Mass of the earth is 6 × 10^{24} kg (15) True.*

Q.1. (B) Choose and write the correct option:

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

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

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

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

(a) half (b) one forth

(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) Nm^2 / kg^2 (b) Nkg^2 / m^2

(c) m/s^2 (d) $N\ cm^2 / g^2$

(8) 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) $g = GM\ (R + h)^2$

(9) The value of 'g' is maximum at poles and it is ________ .

(a) 9.72 m/s (b) 9.83 m/s^2

(c) 9.83 m/s (d) 9.72 m/s^2

(10) The value of 'g' on Earth is zero at ________ .

(a) Centre of Earth (b) Poles

(c) Infinite distance (d) Both a and c

(11) 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

(12) The value of 'g' ________ as the depth from surface increases.

(a) increases (b) fluctuates

(c) decreases (d) varies

(13) 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

(14) The mass of objects ________ at any place on the surface on the Earth.

(a) remains constant (b) is non-uniform

(c) changes (d) increases

(15) 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

(16) The weight of body gradually decreases from ________ .

(a) equator to poles (b) poles to equator

(c) pole to pole (d) height to surface

(17) A body of mass 1 kg is attracted by the Earth with a force which is equal to ________ .

(a) 9.8 N (b) 6.67×10^{-11}

(c) 1 N (d) 9.8 m/s

(18) 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) $\frac{GMm}{R^2 + h}$

(19) The orbit of a planet is an ellipse with the Sun at one of the ....

(a) foci (b) centre (c) middle (d) surface

(20) The straight line joining the planet and the Sun sweeps equal .... in equal interval of time.

(a) volume (b) angle
(c) density (d) area

(21) The square of time period of revolution around the Sun is directly proportional to the .... of the planet from the Sun.

(a) mean distance
(b) square of the distance
(c) cube to the distance
(d) cube of the mean distance

(22) Which of the following is not an example of free fall?

(a) Moon revolving around the Earth
(b) Earth revolving around the Sun
(c) Parachute jumping
(d) Artificial satellites revolving around the Earth

(23) The centre of mass of an object having uniform density is at its ....

(a) centre (b) Geometrical centre
(c) centroid (d) Circumference

Ans. *(1) (a) F α $\frac{m_1m_2}{d^2}$ (2) (c) 4 times (3) (c) $\frac{1}{25}$ (4) (c) one sixth (5) (d) both a and b (6) (b) 10^{20} N (7) (a) Nm^2/kg^2 (8) (c) $g = \frac{GM}{(R+h)^2}$ (9) (b) 9.83 m/s^2 (10) (d) Both a and c (11) (a) Is opposite to the direction of motion (12) (c) decreases (13) (b) less (14) (a) remains constant (15) (c) more (16) (b) poles to equator (17) (a) 9.8 N (18) (a) $\frac{-GMm}{R+h}$ (19) (a) foci (20) (d) area (21) (d) cube of the mean distance (22) (c) Parachute jumping (23) centroid*

Q.2.1. Solve the following:

Type: A	
$F = \frac{Gm_1m_2}{r^2}$	$v = u + at$
$F = ma$	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$

***(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 m
$m_1 = 75$ kg
$m_2 = 80$ kg
$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$

To find: Force (F) = ?

Formula: $F = \frac{Gm_1m_2}{r^2}$

Solution:

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

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

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

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

The gravitational force between Mahendra and Virat is 4.002 × 10^{-7} N

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

Ans. Given: $m_1 = 6 \times 10^{24}$ kg
$m_2 = 7.4 \times 10^{22}$ kg
$r = 3.84 \times 10^5$ km $= 3.84 \times 10^8$ m
$G = 6.7 \times 10^{-11}\ Nm^2/kg^2$

To find: F = ?

Formula: $F = \frac{Gm_1m_2}{r^2}$

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

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

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

$= 20 \times 10^{19}$

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

The gravitational force of attraction between Earth and Moon is 2 × 10^{20} N

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

Ans. Given: $m_1 = 6 \times 10^{24}$ kg
$r = 1.5 \times 10^{11}$ m
$F = 3.5 \times 10^{22}$ N
$G = 6.7 \times 10^{-11}\ Nm^2/kg^2$

To find: m_2 = ?

Formula: $F = \frac{Gm_1m_2}{r^2}$

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

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

$= \frac{7.875 \times 10^{44}}{40.2 \times 10^{13}}$

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

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

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

The mass of the Sun is 1.96×10^{30} 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 (4.002×10^{-7} N).**

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

Time (t) = 1 s

Force (F) = 4.002×10^{-7} N

mass (m) = 75 kg

To find: Final velocity (v) = ?

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

Solution: $a = \frac{4.002 \times 10^{-7}}{75}$

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

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

v = u + at

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

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

Velocity will increase with time

As distance decreases, force increases thereby increasing acceleration. Hence velocity increases

***(5) Assuming that acceleration remains constant (5.34×10^{-9} m/s²), 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) = 5.34×10^{-9} m/s^2

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

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

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

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

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

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

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

$t = 2 \times 10^3$ s

Mahendra will take 2×10^3 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 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) $s = ut + \frac{1}{2}at^2$

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

$400 = \frac{400\,a}{2}$

$\therefore a = \frac{400 \times 2}{400} = 2$ m/s^2

(ii) F = ma

$\therefore$ F = 7000 × 2

$\therefore$ F = 14000N

The truck moves with an acceleration of 2 m/s² 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. The force between Karan and Arjun is

$$F = \frac{G\, m_1\, m_2}{d^2} \quad ...(i)$$

(i) If 'm_2' is doubled.

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

$F^1 = 2F$ ...[from(i)]

Force becomes double.

(ii) If 'm_1' and 'm_2' are doubled.

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

$F^1 = 4F$ ...[from(i)]

Force becomes 4 times.

(iii) If 'd' is doubled.

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

$F^1 = \frac{1}{4} F$ ...[from(i)]

Force becomes one forth.

(iv) If 'G' is doubled.

$F^1 = \frac{2G\, m_1 m_2}{d^2} = 2F$ ...[from(i)]

Force is doubled.

NUMERICALS FOR PRACTICE

(1) **Two boys are 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.** ***(5.336×10^{-7} N)***

(2) If the force of gravitation between the Earth and an object of mass 'm' is 9×10^7 N, find the mass of an object if the mass of the Earth is 6×10^{24} kg and its radius is 6.4×10^6 m. ***(9.2×10^6 kg)***

(3) If two objects of masses 500kg and 84kg respectively are at a distance of 2m apart from each other. Find gravitational force between them? ***(7×10^{-7} N)***

(4) If two objects of 45 kg and 47 kg respectively are attracted towards each other by a gravitational force of 250×10^{-7} N, find the distance between their centres. ***(7×10^{-7} N)***

Type: B

$g = \frac{GM}{R^2}$	$v = u + at$
$W = F = mg$	$s = ut + \frac{1}{2}at^2$
$W = F = \frac{GM\,m}{R^2}$	$v^2 = u^2 + 2as$

Note:

For Earth g = 9.77 m/s²

For Moon g_m = 1.63 m/s²

***(1) Calculate the gravitational force due to the Earth on Mahendra, if mass of Earth is 6×10^{24} kg, Radius is 6.4×10^6 m, g = 9.77 m/s² and mass of Mahendra is 75 kg.**

Ans. Given: Mass of Earth (M) = 6×10^{24} kg

Radius of Earth (R) = 6.4×10^6 m

Mass of object (m) = 75 kg

Gravitational acceleration (g) = 9.77 m/s²

To find: Force (F) = ?

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

Solution:

$$F = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 75}{40.96 \times 10^{12}}$$

$$= \frac{9.77 \times 75}{1}$$

= 732.75 N

$F \approx 733$ 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)= ?

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

Solution:

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

$\therefore$ a = 9.77 m/s²

$v = u + at$

$= 0 + 9.77 \times 1$

= 9.77 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 $(W_m) = ?$

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

Solution:

For Earth

$$W_E = \frac{G\,M_E\,m}{R_E^2} \quad \text{...(i)}$$

For Moon

$$W_m = \frac{G\,M_m\,m}{R_m^2} \quad \text{...(ii)}$$

Dividing equation (ii) by (i),

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

$$\frac{W_M}{W_E} = \frac{G\,M_m\,m}{R_m^2} \times \frac{R_E^2}{G\,M_E\,m}$$

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

$$\frac{W_m}{750} = \frac{1}{81} \times (3.7)^2 \quad \text{. . . from 'given'}$$

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

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

$$W_m = 126.8 \text{ N}$$

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

$$g_A = \frac{GM_A}{R_A^2} \quad \text{. . . (i)}$$

$$g_B = \frac{GM_B}{R_B^2} \quad \text{. . . (ii)}$$

Dividing equation (ii) by (i),

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

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

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

$$\frac{1}{2} = \frac{M_B}{M_A} \times \frac{1}{4} \quad \text{. . . from 'given'}$$

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

$$M_B = 2M_A$$

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:

$m_e = 5$ kg

$W_e = 49$ 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 : $m_m = 5$ 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: $W = \frac{GMm}{R^2} \ldots (i)$

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

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

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

$W_1 = \frac{1}{4} W$ ...[from(i)]

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

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

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

$g' = 8\,g$

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/s²)***

(4) **The planet in space has 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 7.4×10^{22} kg and radius is 1740 km.** ***(1.63 m/s²)***

(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/s², 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/s²)***

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 7.34×10^{22} kg and 1.74×10^6 m respectively.**

Ans. **Given:** Mass (M) = 7.34×10^{22} kg

Radius (R) = 1.74×10^6 m

Gravitational acceleration on Moon(g_m)

$= \frac{1}{6} g_e = \frac{9.8}{6}$ m/s² = 1.63 m/s²

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)

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

Case (ii)

$\frac{T_N^2}{(2R)^3} = k$ OR $\frac{T_N^2}{8R^3} = k$ . . . (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. ***($g = 3.71\ m/s^2$)***

(2) A planet orbits the Sun in 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/s²
$v = u + gt$	
$s = ut + \frac{1}{2}gt^2$	Upward/Thrown up g (negative) = -10 m/s²
$v^2 = u^2 + 2gs$	

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

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

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

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

$g = 0.4\ m/s^2$

Value of g on the planet is 0.4 m/s²

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

Ans. Given: Time (t) = 1 s
Gravitational acceleration (g) = 10 m/s²
Initial velocity (u) = 0 m/s

To find: Final velocity (v) = ?
Displacement (s) = ?

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

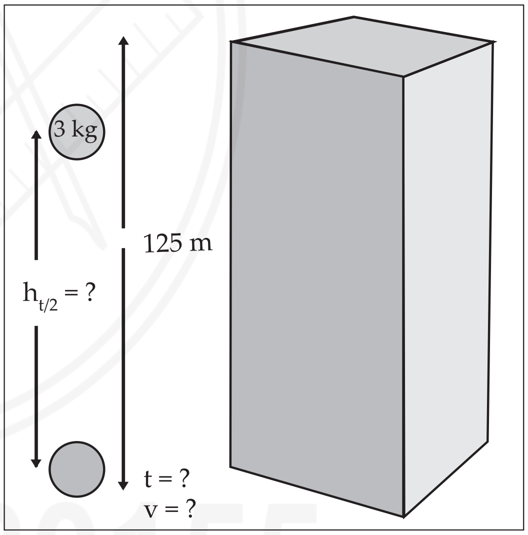
Solution: $v = u + gt$
$= 0 + 10 \times 1$
$v = 10\ m/s$

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

$s = 5\ m$

Speed on reaching ground is 10 m/s and height of the table is 5 m.

***(3) An iron ball of mass of 3 kg is released from height of 125 m and falls freely to the ground. Assuming that the value of g is 10 m/s², 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.**



(Diagram is only for reference)

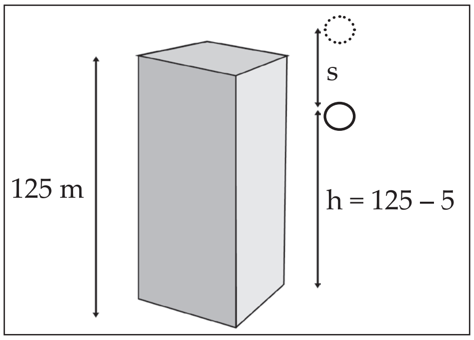
Ans. Given: Mass (m) = 3 kg
Displacement (s) = 125 m
g = 10 m/s²
Initial velocity (u) = 0 m/s

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)

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



(Diagram is only for reference)

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

$125 = 5t^2$

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

$t^2 = 25$

$t = 5$ s ...(i)

Case (ii)

$v = u + gt$

$= 0 + 10 \times 5$

$v = 50$ m/s...(ii)

Case (iii)

Half time $= \frac{t}{2} = \frac{5}{2}$ ...(from (i))

$= 2.5$s

Height of the ball at 2.5s = s

∴ Using Newton's second equation,

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

$s = 0 + \frac{1}{2} \times 10 \times (2.5)^2$

$s = 31.25$ m

∴ Height of the ball at half time

$= 125 - 31.25$

$= 93.75$ m

(i) Time taken by the ball to reach the ground is 5s.
(ii) Velocity of ball on reaching ground is 50 m/s.
(iii) Height of ball at half time is 93.75 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 m/s²**

Ans. Given: Displacement (s) = 4.05 m

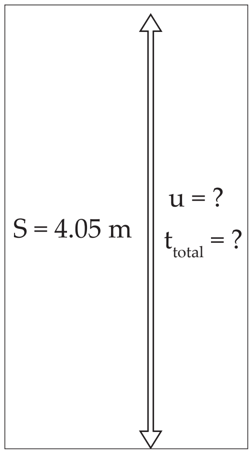
$g = -10$ m/s^2

Final velocity (v) = 0 m/s

To find:

Initial velocity (u) = ?

t_{total} = ?



(Diagram is only for reference)

Formulae:

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

$t_{total} = 2 \times t$

∴ v, g and s are given,
to find u,
we use 2nd equation

Solution:

(a) $v^2 = u^2 + 2gs$

$0^2 = u^2 + 2\times(-10)\times4.05$

$0 = u^2 - 81$

$u^2 = 81$

$u = 9$ m/s ...(i)

∴ we have v, u and g to find t.
we use 1st equation

(b) $v = u + gt$

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

$10\,t = 9$

$t = 0.9$ s

Time of ascent = Time of descent

$t_{total} = 2t$

$= 2 \times 0.9$

$= 1.8$ 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 m/s².**

Ans. Given: Displacement (s)= 500 m

Gravitational acceleration (g) = -10 m/s^2

Final velocity (v) = 0 m/s

To find: Initial velocity (u) = ?

t_{total} = ?

Formulae: $v^2 = u^2 + 2gs$, $t_{total} = 2t$

$v = u + gt$

∴ v, g and s is given,
to find u, we use 3rd equation

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

$0 = u^2 - 10000$

$10000 = u^2$

$u = 100$ m/s

Since, we have v, u and g to find t, we use 1st equation.

$v = u + gt$

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

$10\,t = 100$

$t = 10s$

Time of ascent = Time of descent

$\therefore\ t_{total} = 2 \times 10$

$\therefore\ t_{total} = 20s$

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 3rd equation of motion

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

$v = 0,\ a = -g$

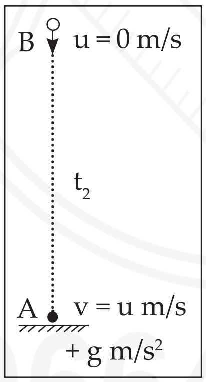
$\therefore\ 0^2 = u^2 + 2(-g)s$

$2gs = u^2$

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

***(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. **When object is thrown up.** (During Ascent)



Initial velocity = u m/s

Final velocity = 0 m/s

Acceleration = $-g\ m/s^2$

Time taken to go up = t_1

According to 1st eq. of motion

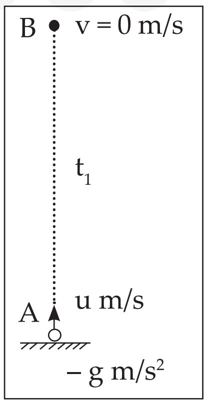
$v = u + gt$

$0 = u - gt_1$

$gt_1 = u$

$t_1 = \dfrac{u}{g}$ (s) . . . (i)

When object falls down. (During Descent)



(Diagram is only for reference)

Initial velocity = 0 m/s

Final velocity (v) = u m/s

Acceleration = $g\ m/s^2$

Time taken to go down = t_2

According to 1st eq. of motion

$v = u + gt$

$u = 0 + gt_2$

$t_2 = \dfrac{u}{g}$ (s) . . . (ii)

From (i) and (ii),

$t_1 = t_2$

NUMERICALS FOR PRACTICE

(1) A ball thrown up vertically returns to the person 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 m/s² find the maximum height and total distance covered by stone. ***(h = 80 m, d = 160 m)***

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) OR Acceleration due to gravity**

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. 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 Earths gravitational force and not fall back on Earth is called escape velocity.

Q.2.3. Answer the following in one or two sentences:

***(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 earth's 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?** *(Think about it; Textbook Page no. 9)*

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) The mass of the object will remain same but its weight will differ on Mars.

(ii) Since mass of an object is the amount of matter present in the body, its value remains the same on Earth and Mars.

(iii) Weight is the force with which the Earth attracts the object. It is given as W = mg. As g changes, weight (W) also changes.

Q.2.4. Write short notes:

(1) Earth's gravitational force

Ans.

(i) The Earth attracts all the objects towards 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 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, due to its rotation.
- The radius is highest at the equator and least at the poles.
- Value of g is highest at poles(9.832 m/s^2)

- Value of g is least at equator (9.78 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.2.5. Complete the following table:

Place	Altitude from the Earth's surface (km)	g (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.2.6. 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 gravitational force of the Earth is called gravitational acceleration.
(ii) It has SI unit Nm^2/kg^2, while CGS unit is dyne.cm^2/g^2.	(ii) It has SI unit m/s^2, while CGS unit is cm/s^2.
(iii) It is always denoted by 'G'.	(iii) It is always denoted by 'g'.
(iv) Its S.I. value is 6.673×10^{-11} Nm^2/kg^2, while in CGS, it is 6.673×10^{-8} dyne cm^2/g^2.	(iv) Its S.I. value is 9.77 m/s^2, while in CGS, it is 977 cm/s^2.
(v) Its value is fixed and does not change with conditions, hence it is called universal constant.	(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) Weight(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.2.7. Give scientific reasons:

(1) High and low tides are regular phenomena.

Ans.

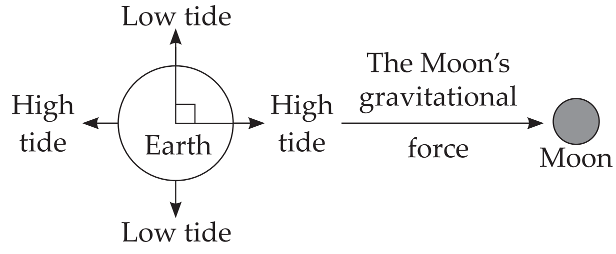
(i) The sea level on the Earth is directly influenced by the gravitational force of the moon.

(ii) Due to the gravitational force, the water on the Earth experiences pull towards the direction of the Moon, hence there occurs high tide.

(iii) At the same time, the place which is at right angles or at 90°, the water level gets reduced and experiences low tide.

(iv) This situation occurs two times a day on regular basis, water level rises two times in a day and reduces two times in a day.

(v)



(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 weight lessness.

(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 i.e. 9.83 m/s^2 while it is the least at equator i.e. 9.78 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 Earths 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 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.

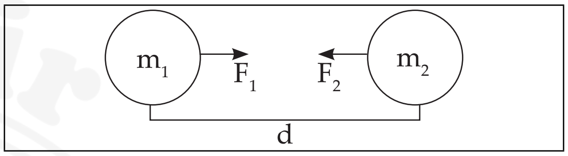


Fig 1.1 Gravitational force between two objects.

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

The gravitational attraction between the two will be given by,

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

$$\therefore \quad F = \frac{G m_1 m_2}{d^2} \qquad \text{(G is constant)}$$

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

***(3) What are Newton's 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) What are 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 the speed of a moving object

(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,

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

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

From (i) and (ii),

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

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

For Earth, $g = 9.77\ m/s^2$

***(6) The value of 'g' at the centre of the Earth is zero. Explain?**

Ans. The acceleration due to gravity is given as

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

At the centre of the Earth, the mass under consideration is zero.

i.e. M = O

$$\therefore\ g = 0$$

Hence, acceleration due to gravity, at the centre of the earth, is zero.

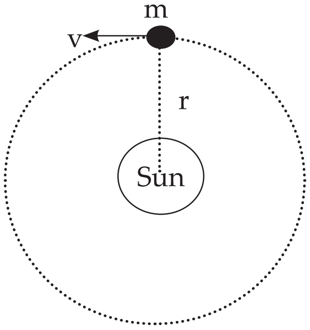
***(7) Write the three laws given by Kepler. How did they help Newton to arrive at the inverse square law of gravity?**

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.



Centripetal force $F = \frac{mv^2}{r}$ ...(i)

Distance travelled by planet in one revolution = Circumference of orbit = $2\pi r$

Time period of revolution = (T)

$$\therefore \text{ speed of planet } v = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{T} \quad \ldots(ii)$$

Substituting eq. (ii) in (i)

$$\therefore F = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{m4\pi^2 r^2}{rT^2}$$

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

Multiplying numerator and denominator with 'r^2'.

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

$$\therefore F = \frac{4m\pi^2 \mathbf{r^3}}{r^2\mathbf{T^2}} \quad \ldots(iii)$$

According to Kepler's 3rd law

$$\frac{T^2}{r^3} = k \text{ or } \frac{\mathbf{r^3}}{\mathbf{T^2}} = \frac{\mathbf{1}}{\mathbf{k}} \quad \ldots(iv)$$

Substituting (iv) in (iii)

$$F = \frac{4m\pi^2 \mathbf{r^3}}{r^2\mathbf{T^2}} \times \frac{1}{k} = \frac{4m\pi^2}{r^2 k} \quad \ldots(v)$$

Rearranging eq. (v)

$$F = \frac{4m\pi^2}{k} \times \frac{1}{r^2}$$

Since $\frac{4m\pi^2}{k}$ = constant.

$$\therefore F = \text{constant} \times \frac{1}{r^2}$$

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

(8) State 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,

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

$\therefore \quad T^2 = kr^3 \qquad$ ... k is constant, $k \neq 0$

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

***(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.

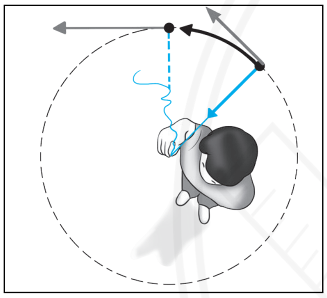


Fig 1.2 Centripetal force

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 $\qquad K.E. = \dfrac{1}{2} mv_{esc}^2$

B $\qquad P.E. = -\dfrac{GMm}{R}$

C $\qquad T.E. = P.E. + K.E.$

$$E_1 = \frac{1}{2} mv_{esc}^2 - \frac{GMm}{R}$$

At infinity

A $\qquad K.E. = 0$

B $\qquad P.E. = -\dfrac{GMm}{\infty} = 0 \qquad \because R + h = \infty$

C $\qquad T.E. = P.E. + K.E.$

$\qquad\qquad = 0 + 0 = 0$

According to the law of conservation of energy,

$E_1 = E_2$

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

$\dfrac{1}{2} \cancel{m}v_{esc}^2 = \dfrac{GM\cancel{m}}{R}$

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

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

$v_{esc} = \sqrt{\dfrac{2GM \times R}{R^2}} \quad ... \left[g = \dfrac{GM}{R^2}\right]$

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

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

Q.3.2. Open Ended Question:

***(1) According to Newton's law of gravitation, every object attracts every 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?** *(Use your brain power; Textbook Page no. 7)*

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

We know, $F = ma \qquad$ or $\quad a = \dfrac{F}{m}$

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. $W = m \times g$

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

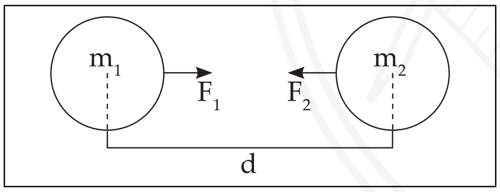
(ii) It does not depend on mass (m) of the object.

(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. Application based Questions / Questions based on figures:

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



(i) The force of Gravitation between two bodies having irregular shape is taken to be the distance between their

(a) centre of mass **(b) centre of the body**

(c) Edge of the body

Ans. (a) centre of mass

(ii) If the distance between the two bodies is tripled, how will the Gravitational force between them change?

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

If the distance is tripled,

$F' = G\frac{m_1 m_2}{(3d)^2} = G\frac{m_1 m_2}{9d} = \frac{1}{9}F$

The gravitational force between them becomes $\frac{1}{9}$ th the initial force.

(iii) The mass of m_2 was reduced to 50% and the force exerted by m_1 on m_2 was found to be 20 N, what will be the force exerted by m_2 on m_1?

Ans. The force exerted by m_2 on m_1 is 20 N.

(iv) Why gravitational 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 6.67×10^{-11} Nm^2/kg^2.

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

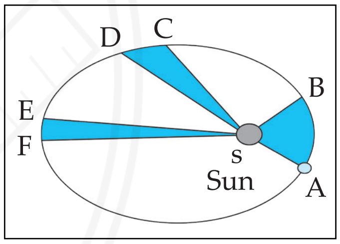


Fig 1.3: The orbit of a planet moving around the Sun.

(a) 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.

(b) If x, y and z are the speeds of revolution of the planet from A to B, C to D and E to F, then which of the following relation is true?

(a) $x > y > z$ (b) $x < y < z$ (c) $x < y > z$ (d) $x > y < z$

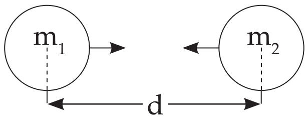
Ans. (a) $x > y > z$

(c) Correct and rewrite Kepler's third law.

The period of revolution of a planet around the sun is directly proportional to the cube of the distance of the planet from the sun.

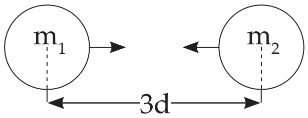
Ans. The square of the period of revolution of a planet around the sun is directly proportional to the cube of the mean distance of the planet from the Sun.

(3) If two objects are at a distance of d from each others



Then $F = \frac{Gm_1m_2}{d^2}$

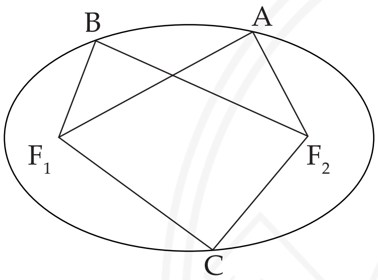
If the distance between two bodies is 3d



Then F = [ ]

Ans. $\frac{Gm_1m_2}{9d^2}$

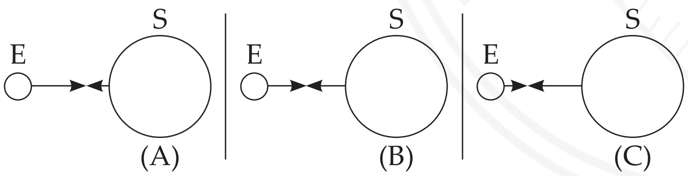
(4)



$AF_1 + AF_2 =$ [ ] = [ ]

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.

(6) An elephant and a matchbox fall from a height of 200m. If they are in a state of free fall, which of them will reach the ground first and why?

Ans. Both will reach the ground at the same time. Since they are in a state of free fall, there is no resistive force acting on them and the only force acting is the force of gravity. The acceleration due to gravity is same for all the bodies irrespective of the mass of the body.

(7) Complete the following for an object of mass *'m'*

On Earth's surface	**At infinity**
(A) $KE = \frac{1}{2}mv^2$	(A) KE = ...
(B) PE = ...	(B) PE = 0

Ans.

On Earth's surface	**At infinity**
(A) $KE = \frac{1}{2}mv^2$	(A) KE = **0**
(B) $PE = -\frac{\mathbf{GMm}}{\mathbf{R}}$	(B) PE = 0

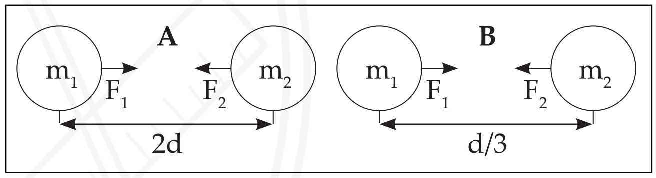
(8) An artificial satellite is shifted from LEO to HEO, how will the value of 'g' vary?

Ans. If an artifical satellite is shifted from LEO to HEO, the value of 'g' decreases. This is because as the satellite is shifted from LEO to HEO, its distance from earth's surface increases. Because $g \alpha \frac{1}{r^2}$, as distance increases the value of g will decreases.

(9) How will the value of 'g' change if a person travels from Delhi to Moscow?

Ans. From Delhi to Moscow, the value of g will increase. As Delhi lies close to equator and Moscow is close to pole, the value of g from equator to pole goes on increasing.

(10)



In which of the two cases, A or B, is the force exerted stronger?

Ans. $F = G\frac{m_1m_2}{d^2}$

Case A : $F_1 = G\frac{m_1m_2}{4d^2} = \frac{1}{4}F$

Case B : $F_2 = G\frac{m_1m_2}{\frac{d^2}{9}} = 9F$

The force exerted is maximum in case B.

(11) If a traveler in a spacecraft orbiting the Earth releases an object from his hand, it remains stationary and appears to be in a state of weightlessness. Does this mean there is no force of gravity acting on the object?

Ans.

(i) No, there is a force of gravity acting on the body. Though the spacecraft is at a height from the surface of the earth, the value of g there is not zero, but only 11% less than its value on the surface of the earth.

(ii) Thus, the weightlessness is not caused by the height of the satellite but by being in a 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 state of free fall.

(iii) As the velocity of free fall does not depend on the properties of an object, it is the same for the spacecraft, the travellers and the objects in the craft.

(iv) Thus, if a traveller releases an object from his hand, it will remain stationary with respect to him and will appear to be weightless.

(12) (i) Will the velocity of a stone thrown vertically upwards remain constant or will it change with time? How will it change?

(ii) Why doesn't the stone move up all the time? Why does it fall down after reaching a certain height?

(iii) What does its maximum height depend on?

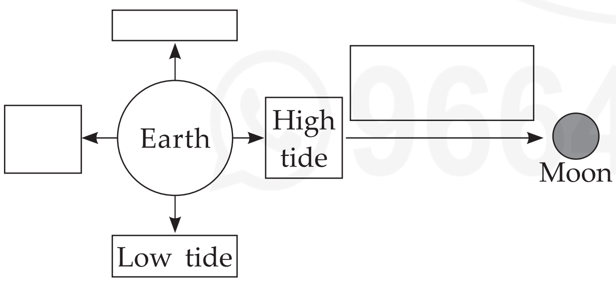
Ans.

(i) The velocity of the stone thrown vertically upward will not remain constant. It will decrease with time till it becomes zero.

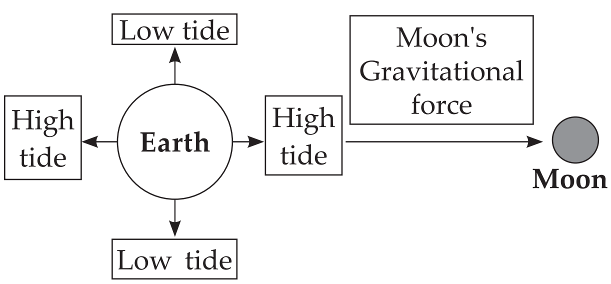
(ii) When the stone is thrown vertically upwards, the gravitational force tries to pull it down and reduces its velocity. Due to this constant downward pull, the velocity becomes zero after a while. The pull continues to be exerted and the stone starts moving vertically downward towards the centre of the earth under its influence.

(iii) The maximum height the stone can achieve depends on the initial velocity with which the stone is thrown vertically upwards.

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° 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° 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. At the centre of the mass of object.

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

Ans. At its centroid.

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

Ans. At 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. Insteine 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 state. 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 travellers 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 the 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 the 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 on it 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 disc flies off the disc along the tangent to the disc. 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.

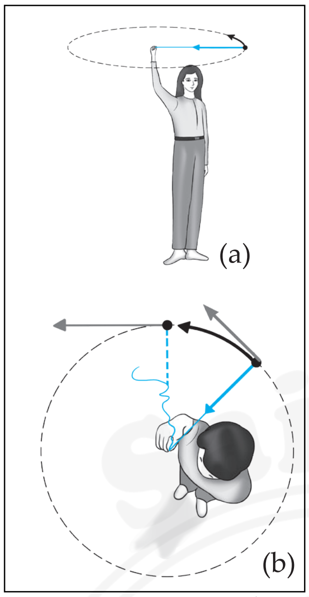


Fig 1.4: A stone tied to a string, moving along a circular path and its velocity in tangential direction

(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 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

$v = gt;\ s = \frac{1}{2}gt^2;\ v^2 = 2gs$

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 due to -ve acceleration.

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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