UNIT 6 Gravitation

Section A Multiple Choice Questions (M.C.Qs)

Tick mark (✓) the correct answer:

01. *The motion of a falling ball towards Earth is due to the__________.*
(a) weightlessness (b) gravitational force
(c) acceleration due to gravity (d) Both 'a' and 'b'

02. *Newton's law of gravitational holds between every two objects on the ________.*
(a) Earth (b) Jupiter (c) Moon (d) Universe

03. *Numerical value of G is____________.*
(a) $G = 6.673 \times 10^{-11}\ Nm^2kg^{-2}$ (b) $G = 6.673 \times 10^{11}\ Nm^2kg^{-2}$
(c) $G = 6.763 \times 10^{-11}\ Nm^2kg^{-2}$ (d) $G = 6.763 \times 10^{11}\ Nm^2kg^{-2}$

04. *Gravitational field of Earth is directed__________.*
(a) towards the Earth (b) towards the Sun (c) towards the Moon (d) away from the Earth

05. *__________ was the first scientist who gave the concept of gravitation.*
(a) Einstein (b) Newton (c) Faraday (d) Maxwell

06. *According to Newton's law of universal gravitation, force ∝ __________.*
(a) m_1m_2 (b) $\frac{1}{r^2}$ (c) r^2 (d) Both (a) & (b)

07. *Gravitational force is always__________.*
(a) repulsive (b) attractive (c) both (d) None of these

08. *Numerical value of __________ remains constant everywhere.*
(a) g (b) G (c) F (d) W

09. *Gravitation force is __________of the medium between the objects.*
(a) dependent (b) independent (c) Both 'a' and 'b' (d) None of these

10. *Near Earth's surface g = __________.*
(a) $10\ ms^{-2}$ (b) $1.6\ ms^{-1}$ (c) Both (a) and (b) (d) None of these

11. *Newton's law of gravitation is consistent with Newton's ________law of motion.*
(a) 1st (b) 2nd (c) 3rd (d) All of them

12. *Spring balance is used to measure ____________.*
(a) mass (b) weight (c) elasticity (d) density

13. *Your weight as measured on Earth will be ________ on the Moon.*
(a) increased (b) decreased (c) remains the same (d) None of these

14. *Mass of the Earth is __________.*
(a) 6.0×10^{23} kg (b) 6.0×10^{24} kg (a) 6.0×10^{25} kg (b) 6.0×10^{26} kg

15. *__________ is a natural satellite.*
(a) Earth (b) Jupiter (c) Moon (d) Mars

16. *A communication satellite completes its one revolution around the Earth in ________ hours*
(a) 6 (b) 12 (c) 18 (d) 24

17. *The velocity of a satellite is ________ of its mass.*
(a) independent (b) dependent (c) equal (d) double

18. *________ are used to put satellites into orbits.*
(a) Helicopters (b) Aeroplanes (c) Rockets (d) None of these

19. *The critical velocity V_c = ________.*
(a) gR (b) $\frac{g}{R}$ (c) $\sqrt{gR}$ (d) $\sqrt{\frac{g}{R}}$

20. *According to Newton's law of universal gravitation, force is inversely proportional to ________.*
(a) m_1m_2 (b) $\frac{1}{r^2}$ (c) r^2 (d) Both (a) & (b)

21. *According to Newton's law of universal gravitation, force ∝ to ________.*
(a) m_1m_2 (b) $\frac{1}{m_1m_2}$ (c) r^2 (d) Both (a) & (c)

22. *It changes the path of the Moon around the Earth.*
(a) centripetal force (b) centrifugal force
(c) pull of the gravity (d) turning effect of the force

23. *It determines the gravitational force acting per unit mass:*
(a) G (b) g (c) τ (d) None of these

24. *Gravitational force is always present between two objects because of their:*
(a) volumes . (b) shapes (c) density (d) masses

25. *Gravitation force follows the:*
(a) direct square law (b) inverse square law (c) direct law (d) inverse law

26. *In 1798, he completed the 1st experiment that demonstrated Newton's Law of universal gravitation.*
(a) Einstein (b) Cavendish (c) Faraday (d) Maxwell

27. *Earth's field force is a:*
(a) non-contact force (b) contact force (c) Both 'a' & 'b' (d) None of these

28. *Weight is measure in:*
(a) kg (b) kg-m (c) kg/m (d) N

29. *Ocean tides are caused by the:*
(a) gravity of the earth (b) gravity of the sun
(c) gravity of the moon (d) Both "b" & "c"

30. *The first artificial satellite, Sputnik-1, was sent into space by:*
(a) USA (b) USSR (c) UK (d) China

31. *The gravitational pull of the Earth on the satellite provides the ________ needed to keep a satellite in orbit around some planet.*
(a) centripetal force (b) centrifugal force (c) gravity (d) force of attraction

32. *The height of a geostationary satellite is about ________ km from the surface of the Earth.*
(a) 32,000 (b) 35,600 (c) 40,800 (d) 42,300

33. *The time required for a satellite or complete one revolution around the Earth in its orbit is called its:*
(a) period (b) rotational period (c) time period (d) revolving time

34. *Expression for the mass of the Earth is:*
(a) $\frac{gR_E^2}{G}$ (b) $\frac{gG}{R_E^2}$ (c) $\frac{gG}{R_E}$ (d) $\frac{gR_E}{G}$

35. *The velocity that a satellite must possess when orbiting around the Earth in an orbit of radius (r = R + h) is:*

(a) $\sqrt{\frac{R+h}{GM}}$ (b) $\sqrt{\frac{M(R+h)}{G}}$ (c) $\sqrt{\frac{G(R+h)}{M}}$ (d) $\sqrt{\frac{GM}{R+h}}$

36. *The expression for the time period of a satellite orbiting around the Earth is:*

(a) $2\pi\sqrt{\frac{r}{GM}}$ (b) $2\pi\sqrt{\frac{r^2}{GM}}$ (c) $2\pi\sqrt{\frac{r^2}{GM}}$ (d) $2\pi\sqrt{\frac{r^2}{GM^2}}$

37. *Sun's gravitational attraction to the Earth is ______ times greater than that of the moon to the Earth.*

(a) 100 (b) 156 (c) 177 (d) 189

38. *The constant horizontal velocity required to put the satellite into a stable circular orbit around the Earth is called:*

(a) orbital velocity (b) critical velocity
(c) centripetal velocity (d) centrifugal velocity

39. *Expression for critical velocity is:*

(a) $\sqrt{gR}$ (b) $\sqrt{gM_E}$ (c) $\sqrt{g(R+h)}$ (d) $\sqrt{gGR}$

Answers

1.	(b)	2.	(d)	3.	(a)	4.	(a)	5.	(b)	6.	(d)	7.	(b)
8.	(b)	9.	(b)	10.	(a)	11.	(c)	12.	(b)	13.	(b)	14.	(b)
15.	(c)	16.	(d)	17.	(a)	18.	(c)	19.	(c)	20.	(c)	21.	(a)
22.	(c)	23.	(b)	24.	(d)	25.	(b)	26.	(b)	27.	(a)	28.	(d)
29.	(d)	30.	(b)	31.	(a)	32.	(d)	33.	(c)	34.	(a)	35.	(d)
36.	(c)	37.	(c)	38.	(b)	39.	(a)						

Section B & C Short & Detailed Answer Questions

Introduction

Why a leaf which drops from a tree always falls on the Earth? Why a ball which is thrown upward comes back to Earth? Which force keeps objects around us at their place? Why a body has weight? Which force is responsible for the motion of an artificial satellite around the Earth?

After studying this unit we will be able to find the answers to such questions and other similar questions.

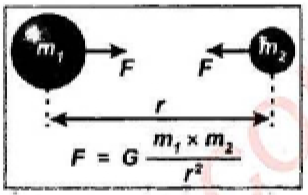
Among famous stories in the history of science one comes from 1666. One day Isaac Newton was sitting in his mother's garden where he witnessed an apple falling from a tree. The scenario helped him to explore the idea of gravity. Newton successfully discovered the cause of falling bodies. He further revealed that gravity makes the planets revolve around the sun and it also causes the moon and satellite to orbit around the earth in a specific fashion.

Q.1 State Newton's Law of Gravitation. Derive the equation, $F = G\frac{m_1m_2}{r^2}$

Ans: ***Newton's Law of Gravitation:*** Newton's law of universal gravitation states that:

Every body in the universe attracts every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

Derivation of Newton's Law of Gravitation: To understand this law, we consider two bodies of masses m_1 and m_2. The distance between their centres is r.



According to the statement force of attraction between two bodies is directly proportional to the product of their masses. Therefore,

$$F \propto m_1 m_2 \quad \text{------------------- (i)}$$

The gravitational force of attraction is inversely proportional to the square of the distance between the centres of the masses of the bodies. Therefore

$$F \propto \frac{1}{r^2} \quad \text{------------------- (ii)}$$

Combining equation (i) and equation (ii):

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

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

where 'G' is the constant of proportionality known as "universal gravitational constant". The value of 'G' in the SI unit is $6.673 \times 10^{-11} Nm^2kg^{-2}$. This is a very small value. 'G' remains constant everywhere.

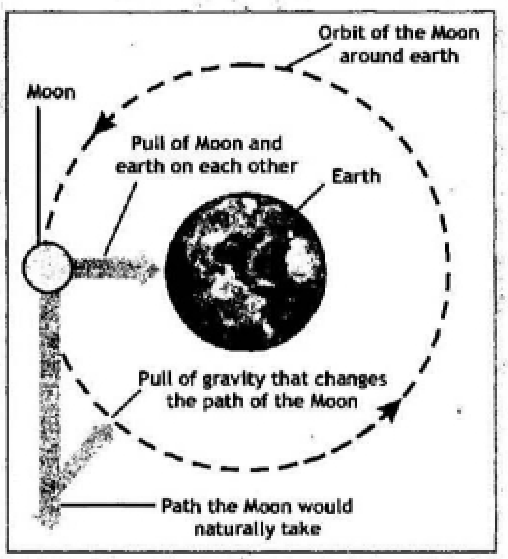
We do not feel the gravitational force of attraction between objects around us due to the very small value of 'G'. But it exists everywhere in the universe.

More Information:

Sir Isaac Newton's was one of the greatest scientists in the world. He made fundamental contributions not only the several branches of Physics (like optics and mechanics) but also to Astronomy and Mathematics. He formulated the laws of motion and the law of universal gravitation.

Q.2 *What changes the path of the moon around the earth?*

Ans: The pull of gravity changes the path of the Moon around the Earth.



Q.3 What are the characteristics / key points of gravitational force?

Ans: ***Characteristics / Key Points of Gravitational Force:*** Gravitational force has the following characteristics:

(i) It is always present between every two objects because of their masses.
(ii) It exists everywhere in the universe.
(iii) It forms an action–reaction pair.
(iv) It is independent of the medium between the objects.
(v) It is directly proportional to the product of the masses of objects.
(vi) It is inversely proportional to the square of the distance between the centres of the objects.
(vii) Hence it follows the "Inverse Square Law".

Weblinks

Web links for moment of force.
- https://www.youtube.com/watch?v=Ym6nlwvQZnE
- https://www.youtube.com/watch?v=2PSjARmmL7M

Q.4 Is Newton's law of gravitation consistent with Newton's third law of motion?

Ans: ***Law of Gravitation and Newton's Third Law of Motion:*** According to Newton's law of gravitation, every two objects attract each other with equal force but in opposite directions. As shown in the given figure.

From the figure:

m_1 = mass of body A m_2 = mass of body B
F_{12} = force with which body A attracts body B
F_{21} = force with which body B attracts body A

Then according to this law,

$$F_{12} = -F_{21}$$

More Information:

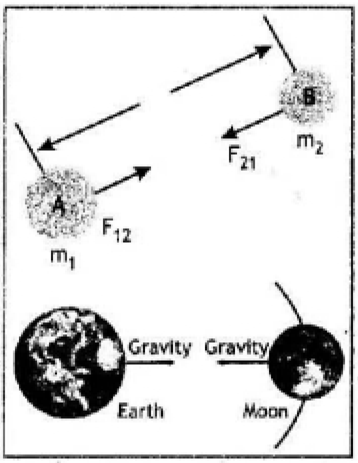
"G" is also known as the Newtonian constant of gravitation or the Cavendish gravitational constant.

This shows that the two forces are equal in magnitude but opposite in direction. Now, if F_{12} is considered as "Action Force" and F_{21} as "Reaction Force". Then by using the above equation, it is concluded that "Action equals to reaction but in opposite direction".

Recall that, above statement is in accordance with Newton's third law of motion which states that "To every action, there is always an equal and opposite reaction".

Hence, Newton's law of gravitation is consistent with Newton's third law of motion.

For example, according to Newton's law of universal gravitation, the Earth pulls the Moon with its gravity and the Moon pulls the Earth with its gravity. Therefore they form an action-reaction pair, which is in accordance with Newton's third law of motion.



More Information:

Henry Cavendish in 1798 completed the 1st experiment that demonstrated Newton's Law of universal gravitation. This happens more than a century after Newton had announced the law of universal gravitation.

Activity

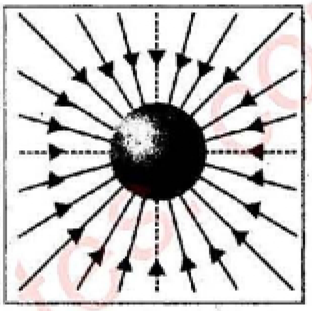
Measure the masses of your copy and pen and then calculate the gravitational force of attraction between them.

Q.5 Define gravitational field. Describe the Earth's gravitational field.

Ans: ***Gravitational Field:*** Gravitational field can be described as:

"A gravitational field is a region in which a mass experiences a force due to gravitational attraction".

Earth's Gravitational Field: The earth has an attractive gravitational field around it. Any object near the Earth experience this force which is due to Earth's gravity. This field is directed towards the centre of the Earth.



This field is the strongest near the surface of the Earth and, gets weaker as we move farther and farther away from the Earth. This force is called the "Field Force" because it acts on all objects whether they are in contact with Earth's surface or not. So, it is a non-contact force. For example, it acts on an aeroplane either it is standing on Earth's surface or flying in the sky.

Gravitational Field Strength: A body of mass one kilogram (1kg) on Earth experiences a force of about ten Newton (10N) due to Earth's gravitational field. This force determines the gravitational field strength which is defined as Gravitational field strength 'g' is the gravitational force acting per unit mass.

The gravitational field strength 'g' is approximately 10 Newton per kilogram $10Nkg^{-1}$.

The gravitational field strength 'g' is different at different planets. For example, the gravitational field strength 'g' on the surface of the Moon is approximately 1.6 Newton per Kilogram $1.6Nkg^{-1}$.

Acceleration due to gravity 'g' at different planets is shown in the following table.

Planet	*Value of g (ms^{-2})*
Earth	10
Moon	1.62
Venus	8.87
Mars	3.77
Jupiter	25.95
Mercury	3.59
Saturn	11.08
Uranus	10.67
Neptune	14.07

Point to Ponder

Does the whole solar system works in a push and pull network?

Gravity keeps things together. It is a force that attracts matter towards it. Anything with mass creates gravity, but the amount of gravity is proportional to the amount of mass. Therefore, Jupiter has a stronger gravitational pull than Mercury. Distance also affects the strength of the gravitational force. Therefore, the Earth has a stronger pull on us than Jupiter does, even though Jupiter is as big as over 1,300 Earths. While we are familiar with gravity's impact on us and Earth, this force also has many effects on the entire solar system, too.

Creates Orbit: One of the most noticeable effects of gravity in the solar system is the orbit of the planets. The sun could hold 1.3 million Earths so its mass has a strong gravitational pull. When a planet tries to go past the sun at a high rate of speed, gravity grabs the planet and pulls it towards the sun. Likewise, the planet's gravity is trying to pull the sun towards it but can't because of the vast difference in mass. The planet keeps moving but is always caught up in the push–pull forces caused by the interaction of these gravitational forces. As a result, the planet begins orbiting the sun. The same phenomenon causes the moon to orbit around the Earth except for the Earth's gravitational force, not the sun's that keeps it moving around us.

Tidal Heating: Just as the moon orbits the Earth, other planets have moons of their own. The push-pull relationship between the gravitational forces of the planets and their moons causes an effect known as tidal bulges. On Earth, we see these bulges as high and low tides because they occur over oceans. But on planets or moons without water, tidal bulges can occur over land. In some cases, the bulge created by gravity will be pulled back and forth because the orbit varies in its distance from the primary source of gravity. The pulling causes friction and is known as tidal heating. On Io, one of Jupiter's moons, the tidal heating has caused volcanic activity. This heating may also be responsible for volcanic activity on Saturn's Enceladus and liquid water underground on Jupiter's Europa.

Creating Stars: Giant molecular clouds made up of gas and dust slowly collapse because of the inward pull of their gravity. When these clouds collapse, they form lots of smaller areas of gas and dust that will eventually collapse as well. When these fragments collapse, they form stars. Because the fragments from the original GMC stay in the same general area, their collapse causes stars to form clusters.

Formation of Planets: When a star is born, all of the dust and gas not needed in its formation ends up trapped in the orbit of the star. The dust particles have more mass than the gas so they can begin to concentrate in certain areas where they come in contact with other dust grains. These grains are pulled together by their own gravitational forces and kept in orbit by the gravity of the star. As the collection of grains becomes bigger, other forces also begin to act upon it until a planet forms over a very long period of time.

Causes Destruction: Because many things in the solar system are held together thanks to the gravitational pull among its components, strong external gravitational forces could pull those components apart thus destroying the object. This happens with moons sometimes. For example, Neptune's Triton is being pulled closer and closer to the planet as it orbits. When the moon gets too close, perhaps in 100 million to 1 billion years, the planet's gravity will pull the moon apart. This effect might also explain the origin of the debris that makes up the rings found around all of the large planets: Jupiter, Saturn, and Uranus.

Q.6 ***What will be the effect on the gravitational pull between two objects if the medium between them is changed?***

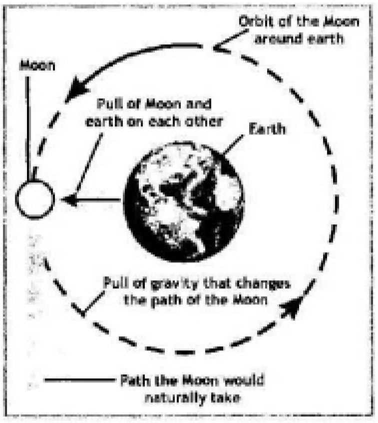
Ans: The gravitational force present between the two masses will always remain the same no matter whether the masses are in air, vacuum, water, or separated by some hindrance. Because, the gravitational force is not dependent on the intervening medium. Therefore, there will be no effect on the gravitational pull between two objects if the medium between them is changed.

Q.7 ***Which force causes the moon to move in orbit around the earth?***

Ans: When an object moves in a circle at a constant speed, its direction constantly changes. A change in direction causes a change in velocity. This is because velocity is a vector quantity - it has an associated direction as well as a magnitude. A change in velocity results in acceleration, so an object moving in a circle is accelerating even though its speed may be constant.

An object will only accelerate if a resultant force acts on it. For an object moving in a circle, this resultant force is the centripetal force that acts towards the middle of the circle.

The gravitational attraction provides the centripetal force needed to keep planets in orbit around the Sun and all types of satellites in orbit around the Earth. The Earth's gravity keeps the Moon orbiting us. It keeps changing the direction of the Moon's velocity. This means gravity makes the Moon accelerate all the time, even though its speed remains constant.



Q.8 *Define weight. What instrument is used to measure the weight of an object?*

Ans: We know that all the objects which are thrown upward in the air fall back to the ground. The force applied by the Earth's gravitational field pulls the object downward. Weight is another name for Earth's gravitational force on objects. Therefore weight can be defined as:

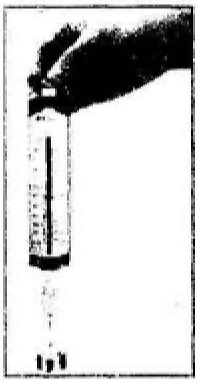
The weight of an object is the measurement of the gravitational force acting on the object.

Weight "W" of an object of mass 'm', in a gravitational field of strength 'g' is given by the relation:

$$W = mg$$

Like other forces weight is also measured in Newton's (N).

Instrument Used to Measure Weight: Spring balance is used to measure the weight of an object.



An object of mass 1kg has a weight of 9.8N near the surface of Earth. The objects with larger masses may have larger weights. Our weight varies slightly from place to place, because Earth's gravitational field strength varies at different places. The weight of the object changes as it moves away from the Earth. The weight of the object is different on different planets. For example, we will have less weight at Moon because Moon's gravitational field is weaker than Earth.

Activity

The teacher should encourage and facilitate the students in the class to measure their masses and then calculate their weights on Earth, Moon and Mars.

More Information:

'Gravity' is taken from the Latin word 'gravitas' means 'weight'.

Q.9 *What is the actual value of 'g' near the surface of Earth?*

Ans: Near Earth's surface, gravitational acceleration is approximately 9.81 m/s^2, which means that ignoring the effects of air resistance, the speed of an object falling freely will increase by about 9.81 metres per second second.

Q.10 *If you go on a diet and lose weight, will you also lose mass? Explain.*

Ans: Let us imagine a surface that just barely surrounds our body as if we shrink-wrapped a body in plastic. By the law of conservation of mass, the only way our body can lose any amount of mass is for that amount of mass to pass out through the surface. So we just have to consider what bodily functions cause that to happen:

(i) Exhaling (ii) Sweating

(iii) Excretion (in the non-technical sense of, roughly, things we do in the bathroom)

Any dead skin cells, strands of hair, etc. that fail off we would also count.

As a bonus, the "shrink-wrap view" also makes it easy to identify how we gain mass, by looking for all processes that cause matter to be drawn in through the invisible surface:

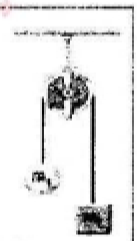
(i) Eating and drinking - solids and liquids through the oesophagus and gastrointestinal tract

(ii) Inhaling–gas through the trachea and lungs

The thing is, when most people talk about losing weight, they're referring to a long–term average loss of mass, which means that the processes in the first list have to remove more mass over some extended period of time than the ones in the second list bring in. This requires some of the pre–existing mass in our body to be converted into the waste forms that we can dispose of through excretion, exhaling and sweating. This pre–existing mass generally tends to be body fat. The other answers do a pretty good job filling in the details of how the fat gets converted to waste products.

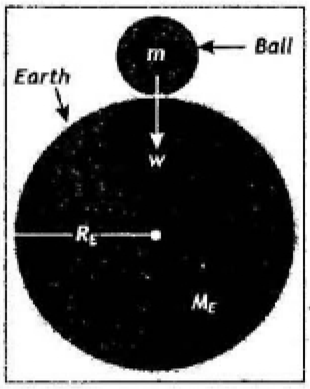
More Information:

British scientist George Atwood (1746-1807) used two masses suspended from a fixed pulley, to study the motion and measure the value of 'g'. This is named as "Atwood Machine".



Q.11 By using Newton's Law of Gravitation, find the mass of the earth.

Ans: ***Mass of the Earth:*** Mass of Earth cannot be measured directly by placing it on any weighing scale. But it can be measured by an indirect method. This method utilizes Newton's law of universal gravitation. Let us consider, the following figure, in which a small ball is placed on the surface of the Earth.



m = Mass of the ball $\quad M_E$ = Mass of the Earth

G = Universal gravitational constant

R_E = Radius of the earth; which is also the distance between the ball and centre of the earth.

Then according to Newton's law of universal gravitation, the gravitational force F of the Earth acts on the ball is:

$$F = G\frac{mM_E}{R_E^2} \quad \text{-------------------------(i)}$$

whereas the force with which the Earth attracts the ball towards its centre is equal to the weight of the ball. Therefore

$$F = W = mg \quad \text{------------------------(ii)}$$

Comparing equation (i) and (ii); we get

$$mg = G\frac{mM_E}{R_E^2}$$

Re–arranged of above equations gives

$$M_E = \frac{gR_E^2}{G} \quad \text{-------------------------(iii)}$$

Numerical values of the constants at right hand side of equation (iii) are:

$g = 10\ Nkg^{-1}$ $\quad$ RE $= 6.38 \times 10^6$ m $\quad$ $G = 6.673 \times 10^{-11}\ Nm^2kg^{-2}$

Substituting these values in equation (iii), we get:

$$M_E = \frac{(10\ \text{Nkg}^{-1})\ (6.38 \times 10^6\ \text{m})^2}{6.673 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}} = 6.0 \times 10^{24}\ \text{kg}$$

Thus, mass of Earth is 6.0×10^{24} kg.

Activity

Calculate the mass of the Earth if acceleration due to gravity, $g = 9.8\ \text{ms}^{-2}$.

More Information:

- Ocean tides are caused by the gravity of the Moon.
- The Earth has 9.3 times more mass than Mars.

Q.12 What are satellites? Define its types.

Ans: ***Satellite:*** A satellite is an object that revolves around a planet.
Satellites are of two types:

(i) Natural satellites (ii) Artificial satellites

Natural Satellites: The planet which revolves around another planet naturally is called a "Natural Satellite".

Example: Moon is a natural satellite because it revolves around the Earth naturally.

Artificial Satellite: The objects which are sent into space by scientists to revolve around the Earth or other planets are called "Artificial Satellites".

Examples: Sputnik–1 and Explorer–1 are amongst the artificial satellites.

Q.13 What are the uses of artificial satellites?
OR Write down any four uses of an artificial satellite.

Ans: ***Uses of Artificial Satellites:*** Artificial satellites are used for different purposes like:

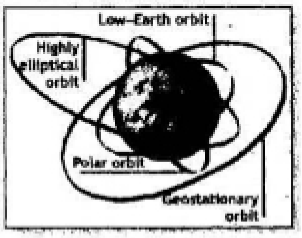
(i) for communication. (ii) for making star maps.
(iii) for making maps of planetary surfaces. (iv) for collecting weather information.
(v) for taking pictures of planets, etc.

Artificial satellites carry instruments, passengers or both to perform different experiments in space. Rockets are used to put satellites into orbits in space.

Q.14 What do you know about the orbits of artificial satellites?

Ans: ***Orbits of Artificial Satellites:*** Artificial satellites have been launched into different orbits around the Earth. There are different types of orbits like:

(i) For communication. (ii) Low–Earth orbit.
(iii) Medium–Earth orbit. (iv) Geostationary orbit.
(v) Elliptic orbit.



These orbits are characterized based on different parameters like their distance from the Earth, their time period around the Earth etc.

Q.15 *Describe communication satellites.*
OR What is a geostationary orbit?

Ans: **Communication Satellites:** An artificial satellite that completes its one revolution around the Earth in 24 hours is used for communication purposes. As Earth also completes its one rotation about its axis in 24 hours, therefore the above satellite appears to be stationary with respect to Earth. Its orbit is therefore called "Geostationary orbit". As it is used for communication purposes, therefore it is known as a "Communication Satellite".The height of a geostationary satellite is about 42,300km from the surface of the Earth. Its velocity with respect to Earth is zero.

More Information:
The first artificial satellite was Sputnik-1 which was sent into space by Soviet Union (Russia) on 4th October 1957.

Interesting Information

Mass and radius of different objects

Planet / Star	Mass (Kg)	Radius (m)
Sun	1.99×10^{30}	6.96×10^{8}
Moon	7.35×10^{22}	1.74×10^{6}
Mercury	3.30×10^{23}	2.44×10^{6}
Venus	4.87×10^{24}	6.05×10^{6}
Earth	5.97×10^{24}	6.38×10^{6}
Mars	6.42×10^{23}	3.40×10^{6}
Jupiter	1.90×10^{27}	6.91×10^{7}
Saturn	5.68×10^{26}	6.03×10^{7}
Uranus	8.68×10^{25}	2.56×10^{7}
Neptune	1.02×10^{26}	2.48×10^{7}

Q.16 *Define orbit.*

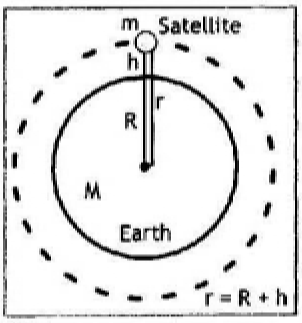
Ans: **Orbit:** The curved path along which a natural or artificial satellite revolves around a planet is called an "orbit".

Q.17 *Derive an expression for the velocity that a satellite must possess when orbiting around the Earth and an expression for the time period of a satellite orbiting around the Earth.*

Ans: ***Expression for the velocity that a satellite must possess when orbiting around the Earth:***

Newton's law of gravitation has an important role in the motion of a satellite in its orbit because the gravitational pull of the Earth on the satellite provides the centripetal force needed to keep a satellite in orbit around some planet.

Let us consider the motion of a satellite that is revolving around the Earth. In the given figure:



m = mass of the satellite $\quad M$ = mass of the Earth
R = radius of the earth $\quad r = R + h$ is radius of orbit
h = height (altitude of satellite from the surface of the Earth)

We know that: Centripetal force = Gravitational force or $F_C = F_G$ ---------------------------------(i)

$\therefore$ $F_C = \frac{mv^2}{r}$ and $F_G = \frac{GmM}{r^2}$

Substituting the value of F_C and F_G in equation (i):

$$\frac{mv^2}{r} = \frac{GmM}{r^2}$$

$$v^2 = \frac{GM}{r} \quad [\because \ r = R + h]$$

$$v^2 = \frac{GM}{R + h}$$

$$v = \sqrt{\frac{GM}{R + h}} \quad \text{---------------------------------(ii)}$$

This gives the velocity that a satellite must possess when orbiting around Earth in an orbit of radius (r=R+h).

This shows that the speed of the satellite is independent of its mass. Hence every satellite whether it is very massive (large) or very light (small) has the same speed in the orbit.

Expression for the time period of a satellite orbiting around the Earth:

The time required for a satellite or complete one revolution around the Earth in its orbit is called its times period "T". The time period of a satellite can be calculated as:

$$\therefore \quad T = \frac{2\pi r}{v} \quad \text{---------------------------------(iii)}$$

The velocity of satellite is given by equation (ii) as:

$$v = \sqrt{\frac{GM}{R + h}}$$

Substituting it in equation (iii):

$$\therefore \quad T = \frac{2\pi r}{\sqrt{\frac{GM}{R + h}}} \quad [\because \ r = R + h]$$

$$\therefore \quad T = 2\pi r \sqrt{\frac{r}{GM}}$$

$$\therefore \quad T = 2\pi \sqrt{\frac{r^3}{GM}}$$

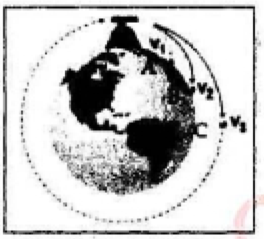
The above equation gives the expression for the time period of a satellite orbiting around the Earth. Thus, Newton's law of gravitation helps to describe the motion of a satellite in an orbit around the Earth.

Weblinks

How Satellite is launched into an orbit:
https://www.youtube.com/watch?v=8t2eyEDy7p4

Q.18 *Describe the motion of an artificial satellite around the earth.*

Ans: ***Motion of Artificial Satellite around the Earth:*** The satellites are put into their orbits around the Earth by rockets. When a satellite is put into orbit, its speed is selected carefully and correctly. If speed is not chosen correctly then the satellite may fall back to Earth or its path may



take it further into orbit. During the motion of a satellite in the orbit, the gravitation pull of the Earth on it is always directed towards the centre of the Earth.

Newton used the following example to explain how gravity makes orbiting possible.

Let us imagine a cannonball launched from a high mountain. The given figure shows three paths the ball can follow.

Path A	*Path B*	*Path C*
The cannonball is launched at a slow speed.	The cannonball is launched at a medium speed.	The cannonball is launched at a high speed.
The cannonball will fall back to Earth.	The cannonball will fall back to Earth.	The cannonball will not fall back to Earth instead it orbits around the Earth.

The above example shows that, for an artificial satellite to orbit the Earth and to retrace its path it requires a certain orbital velocity.

Q.19 *Define orbital velocity. Derive an expression for the orbital velocity of an artificial satellite.*

Ans: ***Orbital Velocity:*** The orbital velocity is defined as:

The velocity required to keep the satellite into its orbit is called "Orbital Velocity".

It is also defined as:

The constant horizontal velocity is required to put the satellite into a stable circular orbit around the Earth.

It is also known as orbital speed or proper speed.

> **More Information:**
> Tides in the ocean resulting from the gravitational attraction of the sun and the moon. Sun's gravitational attraction to the Earth is 177 times greater than that of the moon to the Earth.

Expression for the orbital velocity of an artificial satellite:

The gravitational pull of Earth on a satellite provides the necessary centripetal force for orbital motion. Since this force is equal to the weight of the satellite,

$W_s = mg$, therefore

$F_c = W_s$ ------------------------------ (i)

and $W_s = mg_h$

where,

m = Mass of the satellite and

g_h = Acceleration due to gravity at height 'h' from the surface of Earth.

The centripetal force 'F_C' on the satellite is:

$$F_C = \frac{mv^2}{r}$$

Substituting the values of F_C and 'W_S' in equation (i):

$$\frac{mv^2}{r} = mg_h$$

$$\frac{v^2}{r} = g_h$$

$\therefore$ $v^2 = g_h r$

$\therefore$ $v = \sqrt{g_h r}$

We know that $r = R + h$,

$\therefore$ $v = \sqrt{gh\,(R + h)}$ ------------------------------ (ii)

If the satellite is orbiting very close to the surface of the Earth then: $h << R$

In this case orbital radius may be considered equal to radius of Earth.

Therefore, $R + h = R$

also $g_h = g$

and $v = v_c$

where, v_c = critical velocity and g = acceleration due to gravity on the surface of the earth

In terms of above factors equation (ii) becomes:

$$v_c = \sqrt{gR} \quad \text{------------------------ (iii)}$$

This is known as "Critical velocity".

If $g = 10\ ms^{-2}$ and $R = 6.38 \times 10^6\ m$

then equation (iii) becomes:

$$v_c = \sqrt{gR} = \sqrt{(10\ ms^{-2})(6.38 \times 10^6\ m)}$$

$$v_c = 7.99 \times 10^3\ ms^{-1}$$

or $$v_c = 8.0\ kms^{-1}$$

It should be noted that as the satellite gets closer to the Earth, the gravitational pull of the Earth on it get stronger. So, the satellite to stay in an orbit closer to Earth needs to travel faster as compare to those satellites in the farther orbits.

Q.20 *How would the value of g and G be affected, if the mass of the earth becomes four times?*

Ans: (i) As $g = \frac{GM_e}{R_e^2}$

It means that "g" is directly proportional to the mass of the earth if the mass of the earth decrease, the value of "g" will also decreases. If the mass of the earth increases the value of "g" will also increases. If the mass of the earth becomes four times the value of "g", g will also become four times. It means "g" will increase four times.

(ii) "G" is a gravitational constant it remains the same through out the universe.

If the mass of the earth becomes four times the value of "G", G will not change. It will remain the same as it is a constant. Its value is $6.67 \times 10^{-11} Nm^2/Kg^2$.

Q.21 *Define field force.*

Ans: ***Field Force:*** In physics, a force field is a vector field that describes a non-contact force acting on a particle at various positions in space.

Q.22 *If you step on a scale and it gives a reading of 55kg, is that a measure of your weight. If not then which physical quantity it shows?*

Ans: The terms "balance" and "scale" are often used interchangeably, and most of us would have a bit of trouble nailing down the characteristics of each.

There are technical and practical differences between the two, including exactly what is being measured and the types of applications they are used for. Although the terms "balance" and "scale" are used interchangeably, technically they measure different things.

Balances Measure Mass: Balances are instruments that measure mass (basically the amount of matter in something). A true balance measures mass directly by comparing the unknown mass to a known mass, a process that is not affected by changes in gravity. A balance of this sort will give the same reading irrespective of location because gravity will act on both sides of the balance equally.

Scales Measure Weight: Scales measure weight, which is the force acting on a mass that is equal to the object's mass times its acceleration due to gravity. A scale can't measure mass directly, because the weighing mechanism and the weight of any given object are dependent on local gravity. On the Earth, gravitational acceleration can vary by as much as 0.5%, changing with distance from the Earth's core, as well as the latitudinal way.

From a practical viewpoint, once a scale has been calibrated at its location, gravity is assumed or ignored. Therefore, weights are reported in mass units like kilograms, even though weight is a measurement of force using the newton. This also allows for the use of the terms "weight" to refer to both weight and mass, and "weigh" can be the process of determining either.

Q.23 ***If "M_E" is the mass of Earth, "R_E" radius of Earth, "G" is universal gravitational constant, then find the acceleration due to gravity "g":***
(i) on the surface of the Earth, (ii) at the center of the Earth.

Ans: (i) We consider a body of mass m on the earth's surface. The gravitational force of attraction between the body and the earth are equal to the weight of the body.

$$F = W = \frac{GmM_E}{R_E^2}$$

$$mg = \frac{GmM_E}{R_E^2}$$

$$g = \frac{GM_E}{R_E^2}$$

We know that

Mass of the Earth $= M_E = 6.0 \times 10^{24}$ kg

Radius of the Earth $= R_E = 6.38 \times 10^6$ m

Universal gravitational constant $= G = 6.673 \times 10^{-11}\ Nm^2kg^{-2}$

Therefore,

$$g = \frac{GM_E}{R_E^2}$$

$$g = \frac{(6.673 \times 10^{-11})(6 \times 10^{24})}{(6.38 \times 10^6)^2}$$

$$g = 9.8\ ms^{-2}$$

(ii) At the center of the Earth, the force due to any portion of the Earth at the centre will be cancelled due to the portion opposite to it. Thus, the gravitational force at the centre on any body will be 0. Since, from Newton's law, we know F = mg. Since the mass m of an object can never be 0. Therefore, when F = 0, then g has to be 0. Thus the value of g is zero at the centre of the Earth.

We have a relation, $$g = \frac{GM_E}{R_E^2}$$

$$g = \frac{GM_E}{R_E^2} \times \frac{V}{V}$$, where V is volume

We know that density $\rho = \frac{M}{V} = \frac{\text{Mass}}{\text{Volume}}$

Therefore, $$g = \frac{G\rho}{R_E^2} \times V$$

We know that volume of a sphere, $V = \frac{4}{3}\pi r^3$, therefore

$$g = \frac{G\rho}{R_E^2} \times \frac{4}{3}\pi(R_E)^3$$

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

At the center of the Earth, $R_E = 0$, therefore,

$$g = G\rho \times \frac{4}{3} \pi(0)$$

$$g = 0$$

Q.24 *Evaluate the acceleration due to gravity in terms of the mass of Earth "M_E", the radius of Earth "R_E" and universal gravitational constant "G":*
(i) at a distance, twice the Earth's radius.
(ii) at a distance, one half the Earth's radius.

Ans: If mass of the Earth $= M_E$, radius of the Earth $= R_E$ and universal gravitational constant $= G$

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

(i) In this case, Distance $= R' = 2R_E$
Therefore, the above equation becomes

$$g = \frac{GM_E}{(2R_E)^2}$$

$$\boxed{g = \frac{GM_E}{4R_E}}$$

(ii) In this case, Distance $= R' = \frac{R_E}{2}$
Therefore, the above equation becomes

$$g = \frac{GM_E}{\left(\frac{R_E}{2}\right)^2} = \frac{GM_E}{\frac{R_E^2}{4}}$$

$$\boxed{g = \frac{4GM_E}{R_E^2}}$$

Scientific Reasons

01. ***Why don't we feel the gravitational force of attraction between objects around us?***

Ans: We do not feel the gravitational force of attraction between objects around us due to the very small value of 'G'. But it exists everywhere in the universe.
Gravitational force is a weak force unless large masses are involved. The masses of humans are quite small and thus the magnitude of gravitational force is also very small and negligible as compared to that shown by the Earth. Thus, gravitational force exists between two people sitting close by but it is negligible and cannot be felt.

02. ***Why weight of an object is different on different planets?***

Ans: An object's weight is dependent on its mass and how strongly gravity pulls on it. In other words, our weight is a measure of the pull of gravity between us and the body (planet) we are standing on. Every object in the universe with mass attracts every other object with mass. The strength of gravity depends on how far away one object is from another. That's why the same object weighs different amounts on different planets. Our weight is different on other planets due to gravity so the higher the gravity higher our weight.

03. ***Why do the two satellites of different masses have the same speed in the same orbit?***

Ans: We know that

$$v = \sqrt{\frac{GM}{R+h}}$$

This gives the velocity that a satellite must possess when orbiting around the Earth in an orbit of radius (r=R+h).
This shows that the speed of the satellite is independent of its mass. Hence every satellite whether it is very massive (large) or very light (small) has the same speed in the orbit.
Hence, the two satellites of different masses have the same speed in the same orbit.

04. ***Why Weight of an object does not remain the same everywhere on the Earth?***

Ans: The weight of a body is the gravitational force on it. Thus, weight is dependent on gravitational acceleration, g or gravity. Hence, the weight of a body will change from one place to another place because the value of g is different in different places.
Gravity is often assumed to be the same everywhere on Earth, but it varies because the planet is not perfectly spherical or uniformly dense. Earth's gravity is weaker at the equator due to centrifugal forces produced by the planet's rotation. It's also weaker at higher altitudes, further from the planet's centre. Therefore, the weight of an object does not remain the same everywhere on the Earth.

05. ***Why the unit of weight is Newton? Explain.***

Ans: The weight of an object is the force of gravity on the object and may be defined as the mass times the acceleration of gravity, $w = mg$. Since the weight is a force, its SI unit is the newton.

06. ***Your weight decreases as you go up at high altitudes, without dieting. Explain with reason.***

Ans: If we move up to higher altitudes, the distance between us and the earth increases. Since the gravitational force is inversely proportional to distance multiplied by itself, the gravitational force exerted on our body decreases and so we weigh less.

Differences

01. ***Differentiate between "G' and "g".***

Ans: ***Difference between "G" and "g":***

G	g
It is a universal gravitational constant.	It is the acceleration due to gravity that determines the gravitational force acting per unit mass.
It has the same value everywhere in the universe.	It has different values at different places.
It has value $6.673 \times 10^{-11}\ Nm^2 kg^{-2}$.	Near the earth's surface, it has a value of $10 ms^{-2}$ or $10 Nkg^{-1}$.

02. ***What is the difference between natural and artificial satellites?***

Ans: ***Difference between Natural and Artificial Satellite***

Natural Satellite	Artificial Satellite
The planet which revolves around another planet naturally is called "Natural Satellite".	The objects which are sent into space by scientists to revolve around the Earth or other planets are called "Artificial Satellites".
e.g. Moon is a natural satellite because it revolves around the Earth naturally.	e.g. Sputnik–1 and Explorer–1 are amongst the artificial satellites.

Section D Numerical

Worked Examples of the Textbook

01. ***Determine the gravitational force of attraction between two spherical bodies of masses 500kg and 800kg. The distance between their centres is 2 meters.***

Solution: Step 1: Write the known quantities and point out quantities to be found.

$m_1 = 500\text{ kg}$ $\quad m_2 = 800\text{ kg}$ $\quad r = 2\text{ m}$

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

Step 2: Write the formula and rearrange if necessary.

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

Step 3: Put the value in the formula and calculate.

$$F = \frac{(6.67 \times 10^{-11}\text{Nm}^2\text{kg}^{-2})(500\text{kg})(800\text{kg})}{(2\text{m})^2} = 6.67 \times 10^{-6}\text{ N}$$

Hence, the gravitational force of attraction between the bodies is 6.67×10^{-6} N.

02. ***Calculate the weight of Rumaisa, who has a mass of 65kg standing on the ground. The strength of the gravitational field on Rumaisa is 10 Newton per kilogram?***

Solution: Step 1: Write down known quantities and quantities to be found.

$m = 65\text{ kg}$ $\quad g = 10\text{ Nkg}^{-1}$ $\quad W = ?$

Step 2: Write down the formula and rearrange if necessary.

$W = mg$

Step 3: Put the value in the formula and calculate.

$W = (65\text{ kg})(10\text{ Nkg}^{-1}) = 650\text{ N}$

Hence, the weight of Rumaisa is 650N Newton.

03. ***Calculate the acceleration due to gravity on a planet that has mass two times the mass of Earth and radius 1.5 times the radius of Earth. If the acceleration due to gravity on the surface of Earth is 10ms^{-2}, calculate acceleration due to gravity on the planet.***

Solution: Step 1: Write down known quantities and quantities to be found.

Mass of the planet $= M_p = 2M_E$

Mass of the Earth $= M_E = 6.0 \times 10^{24}$ kg

Radius of the planet $= R_p = 1.5R_E$

Radius of the Earth $= R_E = 6.38 \times 10^6$ m

Universal gravitational constant $= G = 6.673 \times 10^{-11}\text{ Nm}^2\text{kg}^{-2}$

Acceleration due to gravity on the Earth $= g_E = 10\text{ ms}^{-2}$

Acceleration due to gravity on the planet $= g_p = ?$

Step 2: Write down the formula and rearrange if necessary.

We know that

$$M_E = \frac{g_E R_E^2}{G}$$

Therefore $$g_E = \frac{GM_E}{R_E^2}$$

For the Planet:

$$g_P = \frac{GM_P}{R_P^2}$$

Step 3: Put the value in the formula and calculate.

$$g_p = \frac{(6.673 \times 10^{-11} Nm^2 kg^{-2})2(6.0 \times 10^{24} kg)}{(1.5 \times 6.638 \times 10^6 m)^2} = 8.74\ ms^{-2}$$

Hence, acceleration due to gravity on the planet is $8.74\ ms^{-2}$

04. ***Calculate the speed of a satellite that orbits the Earth at an altitude of 1000 kilometres above Earth's surface.***

Solution: *Step 1:* Write down known quantities and quantities to be found.

$M_{Earth} = M = 6.0 \times 10^{24}$ kg $\quad R_{Earth} = R = 6.38 \times 10^6$ m

$h = 1000$ km $= 1000 \times 10^3$ m $= 1 \times 10^6$ m

$G = 6.673 \times 10^{-11} Nm^2kg^{-2} \quad v = ?$

Step 2: Write down the formula and rearrange if necessary.

$$v = \sqrt{\frac{GM}{R+h}}$$

Step 3: Put the value in formula and calculate.

$$g_p = \sqrt{\frac{(6.673 \times 10^{-11} Nm^2 kg^{-2})(6.0 \times 10^{24} kg)}{6.38 \times 10^6 m + 1 \times 10^6 m}} = 7.36 \times 10^3\ ms^{-1}$$

Hence, the orbital speed of the satellite is $7.36 \times 10^3\ ms^{-1}$.

Solved Numerical

01. ***Determine the gravitational force of attraction between Urwa and Ayesha standing at a distance of 50m apart. The mass of Urwa is 60kg and that of Ayesha is 70kg.***

Solution: *Data:* Mass of Urwa = m_1 = 60 kg $\quad$ Mass of Ayesha = m_2 = 70 kg

Distance between Urwa and Ayesha = r = 50 m

Gravitational force = F = ? $\quad G = 6.673 \times 10^{-11}Nm^2kg^{-2}$

Working Formula: $F = G\frac{m_1m_2}{r^2}$

Calculation: $F = \frac{(6.673 \times 10^{-11})(60)(70)}{(50)^2} = \frac{(6.673 \times 10^{-11})(4200)}{2500}$

$F = \boxed{1.121064 \times 10^{-10} N}$ Ans.

02. ***Weight of Rani is 450N at the surface of the Earth. Find her mass.***

Solution: *Data:* Weight of Rani = W = 450 N

Acceleration due to gravity = g = 10 ms^{-2}

Mass of Rani = m = ?

Working Formula: W = mg

Calculation: 450 = m(10)

$m = \frac{450}{10} = \boxed{45\ kg}$ Ans.

03. ***Weight of Naveera is 700N on the Earth's surface. What will be Naveera's weight at the surface of the Moon?***

Solution: *Data:* Naveera's weight on the Earth's surface = W_e = 700 N

Acceleration due to gravity on the surface of the Earth = g_e = 10 Nkg^{-1}

Acceleration due to gravity on the surface of the Earth = g_m = 1.6Nkg^{-1}

Naveera's weight at the surface of the moon = W_m = ?

Working Formula: $W = mg$

Calculation: To calculate Naveera's weight at the surface of the Moon, we need to know her mass. To calculate her mass, we apply the formula, $W = mg$

$$W_e = mg_e$$
$$700 = m(10)$$
$$m = \frac{700}{10} = 70 \text{ kg}$$

Now, to find her weight at the surface of the moon,

$$W_m = mg_m$$
$$W_m = (70)(1.6) = \boxed{112 \text{ N}} \quad \text{Ans.}$$

04. ***A planet has mass four times of the Earth and a radius two times that of the Earth. If the value of "g" on the surface of Earth is $10ms^{-2}$, calculate acceleration due to gravity on the planet.***

Solution: Data: Mass of the planet = $M = 4M_e$ Radius of the planet = $r = 2R_e$
Acceleration due to gravity on the surface of the Earth = $g = 10 \text{ ms}^{-2}$
Acceleration due to gravity on the planet = $g' = ?$

Working Formula:

$$g' = \frac{GM}{r^2}$$

Calculation:

$$g' = \frac{G(4M_e)}{(2R_e)^2} = \frac{4GM_e}{4R_e^2} = \frac{GM_E}{R_e^2}$$

$$\boxed{g' = g} \quad \text{Ans.}$$

05. ***Calculate the speed of a satellite that orbits the Earth at an altitude of 400 kilometres above the Earth's surface.***

Solution: Data: $M_{Earth} = M = 6.0 \times 10^{24}$ kg $R_{Earth} = R = 6.38 \times 10^6$ m
$h = 400 \text{ km} = 400 \times 10^3 \text{ m} = 4 \times 10^5 \text{ m}$
$G = 6.673 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2}$ $v = ?$

Working Formula: $v = \sqrt{\frac{GM}{(R+h)}}$

Calculation:

$$v = \sqrt{\frac{(6.673 \times 10^{-11}\text{Nm}^2\text{kg}^{-2})(6.0 \times 10^{24}\text{kg})}{6.38 \times 10^6 \text{ m} + 4 \times 10^5 \text{ m}}}$$

$$v = \sqrt{\frac{4.0038 \times 10^{14}}{6780000}} = 59,053,097.34513 \text{ ms}^{-1}$$

Hence, the orbital speed of the satellite is $5.905 \times 10^7 \text{ ms}^{-1}$.

06. ***The strength of gravity on the Moon is $1.6Nkg^{-1}$. If an astronaut's mass is 80kg on Earth, what would it be on the Moon?***

Solution: Data: $g = 1.6 \text{ Nkg}^{-1}$ $m = 80$ kg $W = ?$

Working Formula: $W = mg$

Calculation: $W = (80)(1.6) = \boxed{128 \text{ N}}$ Ans.

07. ***What will be the value of acceleration due to gravity on the surface of the earth if its radius reduces to half?***

Solution: Data: The radius of the earth decrease to half , therefore

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

Working Formula: We know that

$$M_E = \frac{gR_E^2}{G}$$

Therefore $g = \frac{GM_E}{R_E^2}$

Now, with the reduced radius

$$g' = \frac{GM_E}{R'^2}$$

$$g' = \frac{GM_E}{R'^2} = \frac{GM_E}{\left(\frac{R_E}{2}\right)^2} = \frac{GM_E}{\frac{R_E^2}{4}} = \frac{4GM_E}{R_E^2}$$

$$g' = 4g$$

$$g' = 4(9.8) = \boxed{39.2\ ms^{-2}} \quad \text{Ans.}$$

(08.) ***What will be acceleration due to gravity on the surface of earth if its mass reduces by 25%?***

Solution: Data: The mass of the earth decrease by 25% , remaining 75% of

$$M' = \frac{75}{100} M_E$$

Working Formula: We know that

$$M_E = \frac{gR_E^2}{G}$$

Therefore $g = \frac{GM_E}{R_E^2}$

Now, with the reduced mass

$$g' = \frac{GM'}{R_E^2}$$

$$g' = \frac{GM'}{R_E^2} = \frac{G\left(\frac{75}{100} M_E\right)}{R_E^2} = \frac{GM_E}{R_E^2}\left(\frac{75}{100}\right)$$

$$g' = \left(\frac{75}{100}\right) g = 0.75g$$

$$g' = 0.75(9.8) = \boxed{7.35\ ms^{-2}} \quad \text{Ans.}$$

(09.) ***What will be the mass of a planet whose radius is 20% of the radius of earth?***

Solution: Radius of the planet $= R = \frac{20}{100} R_E$

Mass of the planet $= M = ?$

We know that

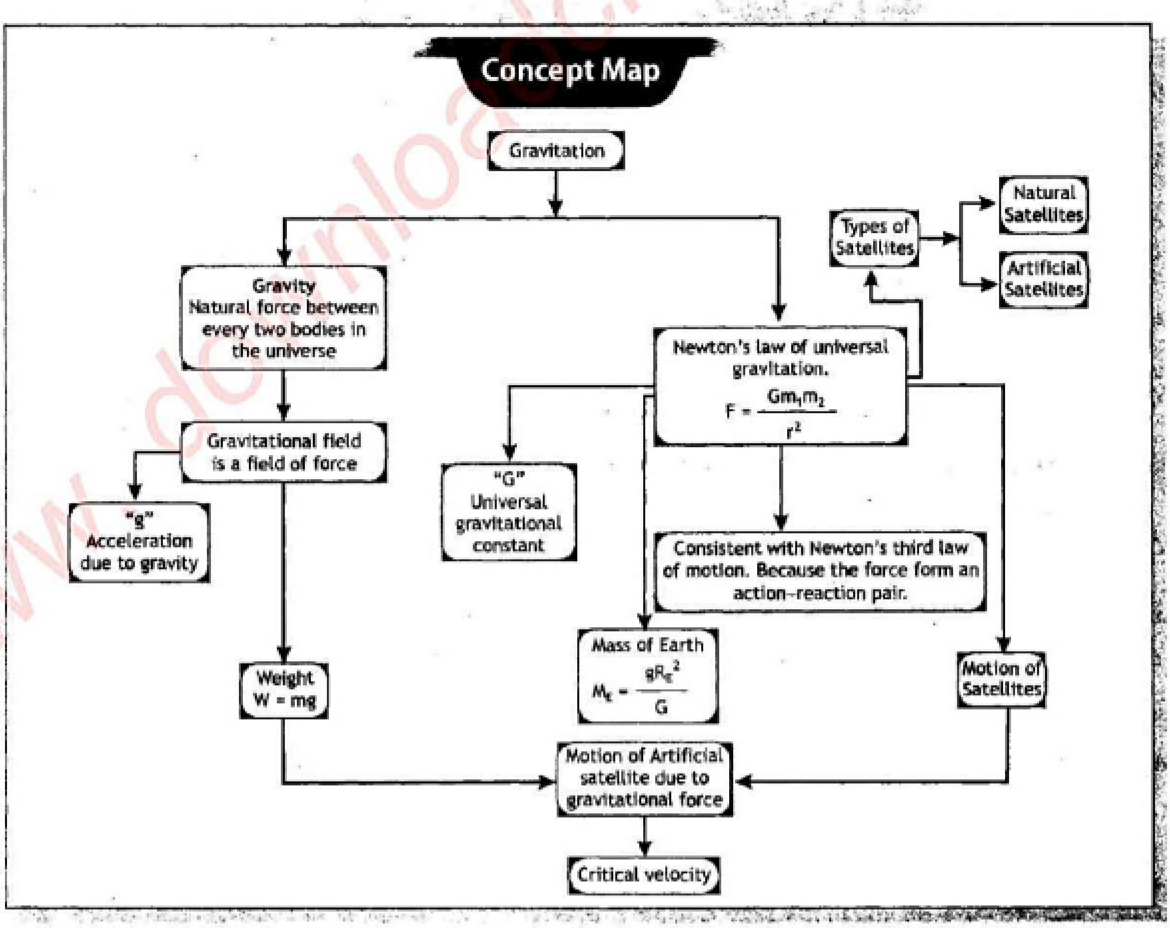
$$M = \frac{gR^2}{G}$$

Therefore

$$M = \frac{g\left(\frac{20}{100} R_E\right)^2}{G} = \frac{400gR_E^2}{10000G} = \boxed{\frac{gR_E^2}{25G}}$$

Summary

- The gravitational force (pull) of the Earth is known as gravity.
- Every body in the universe attracts every other body with a gravitational force of magnitude
$$F = G\frac{m_1m_2}{r^2}$$
- Gravitational force forms an action–reaction pair. Newton's law of gravitation is consistent with Newton's third law of motion.
- "G" has constant value throughout the universe.
- "g" has different values at different places.
- A gravitational field is a region in which a mass is attracted due to gravitational attraction.
- The weight of an object is the gravitational pull of Earth acting on it. Mathematically, W = mg.
- The mass of Earth is 6.0×10^{24}kg.
- A satellite is an object that revolves around a planet.
- A natural satellite is a planet that revolves around another planet naturally like the Moon is the natural satellite of Earth.
- An artificial satellite is an object which is sent to space to revolve around a planet, like Sputnik–1. Meteosat are artificial satellites of the Earth.
- Critical velocity is the constant horizontal velocity needed to put a satellite into a stable circular orbit around the Earth.



End of Unit Questions Solution

SECTION – A: MULTIPLE CHOICE QUESTIONS

Tick Mark (✓) the correct answer:

See "Multiple Choice Questions (M.C.Qs)" – (1) to (19)

SECTION – B: STRUCTURED QUESTIONS

Newton's Law of gravitation

01. (a) ***Why we do not feel the gravitational force of attraction from the objects around us?***
(b) ***Define Gravitational field with an example.***

Ans: (a) See "Scientific Reasons" – Q.1
(b) See "Short & Detailed Answer Questions" – Q.5

02. (a) ***Write down any three characteristics of Gravitational force.***
(b) ***Define gravitational field strength.***

Ans: (a) See "Short & Detailed Answer Questions" – Q.3
(b) See "Short & Detailed Answer Questions" – Q.5

03. (a) ***State & explain Newton's law of gravitation?***
(b) ***Define 'field force'.***

Ans: (a) See "Short & Detailed Answer Questions" – Q.1
(b) See "Short & Detailed Answer Questions" – Q.21

04. ***Determine the gravitational force of attraction between Urwa and Ayesha standing at a distance of 50m apart. The mass of Urwa is 60kg and that of Ayesha is 70kg.***

Ans: See 'Solved Numerical' – Q.1

Weight

05. (a) ***Why Weight of an object does not remain the same everywhere on the Earth?***
(b) ***Why the unit of weight is Newton? Explain.***

Ans: (a) See "Scientific Reasons" – Q.4
(b) See "Scientific Reasons" – Q.5

06. (a) ***Define Weight and write down its equation.***
(b) ***Weight of Rani is 450N at the surface of Earth. Find her mass?***

Ans: (a) See "Short & Detailed Answer Questions" – Q.8
(b) See 'Solved Numerical' – Q.2

07. ***Weight of Naveera is 700N on the Earth's surface. What will be Naveera's weight at the surface of the Moon?***

Ans: See 'Solved Numerical' – Q.3

08. (a) ***Your weight decreases as you go up at high altitudes, without dieting. Explain.***
(b) ***If you step on a scale and it gives a reading of 55kg, is that a measure of your weight. If not then which physical quantity it shows?***

Ans: (a) See "Scientific Reasons" – Q.6
(b) See "Short & Detailed Answer Questions" – Q.22

Mass of Earth

09. ***Calculate the mass of Earth by using Newton's law of gravitation.***

Ans: See "Short & Detailed Answer Questions" – Q.11

10. ***If "M_E" is the mass of Earth, "R_E" radius of Earth, "G" is universal gravitational constant, then find the acceleration due to gravity "g":***
(i) on the surface of Earth, (ii) at the center of Earth.

Ans: See "Short & Detailed Answer Questions" – Q.23

11. ***A planet has mass four times of Earth and a radius two times that of Earth. If the value of "g" on the surface of Earth is $10ms^{-2}$, calculate acceleration due to gravity on the planet.***

Ans: See "Solved Numerical" – Q.4

12. ***Evaluate the acceleration due to gravity in terms of the mass of Earth "M_E", the radius of Earth "R_E" and universal gravitational constant "G":***
(i) at a distance, twice the Earth's radius.
(ii) at a distance, one half the Earth's radius.

Ans: See "Short & Detailed Answer Questions" – Q.24

Artificial Satellite

13. ***(a) Calculate the speed of a satellite that orbits the Earth at an altitude of 400 kilometres above Earth's surface.***
(b) Write the name of any one natural satellite.

Ans: (a) See "Solved Numerical" – Q.5
(b) Earth's Natural Satellite – The Moon

14. ***(a) Write down the names of four different types of orbit.***
(b) Define the terms:
(i) Critical Velocity (ii) Communication Satellite

Ans: (a) See "Short & Detailed Answer Questions" - Q 14
(b) (i) See "Short & Detailed Answer Questions" – Q.19
(ii) See "Short & Detailed Answer Questions" – Q.15.

15. ***Derive the expression for the motion of a satellite.***

$$v = \sqrt{\frac{GM}{R + h}}$$

Ans: See "Short & Detailed Answer Questions" – Q.17

16. ***(a) Differentiate between the natural satellite and artificial satellite.***
(b) Name the parameters based on which orbits are characterized.

Ans: (a) See "Differences" - Q 2
(b) See "Short & Detailed Answer Questions" – Q.14 (last paragraph)