Chapter = 6

Gravitational

Q1.State and explain Newton law of gravitational

NEWTON LAW OF GRAVITATIONAL

STATEMENT

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

EXPLANATION

Consider two bodies of masses m_1 and m_2. The distance between their centers is r.

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

$$F \alpha m_1 m_2$$

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

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

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 constant of proportionality known as “Universal gravitational constant”.

The value of ‘G’ in S.I unit is $6.673 \times 10^{-11}\ Nm^2kg^{-2}$

Q2. Differentiate between G and g

G	g
It is universal gravitational constant	It is acceleration due to gravity which determines the gravitational force acting per unit mass.
It has same value everywhere in the universe	It has different values at different places

Its value is 6.673×10^{-11} Nm^2kg^{-2}	It near earth's surface has value $10ms^{-2}$ or 10 Nkg^{-1}

Q3. Give characteristics of Gravitational Force

CHARACTERISTICS OF GRAVITATIONAL FORCE

Gravitational force has 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 center of the objects.

vii) Hence it follows the "Inverse Square Law".

Q4. Define Gravitational Field.

GRAVITATIONAL FIELD

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

Q5. List gravity at different planets.

Planet	Value of g in ms^{-2}
Earth	10
Moon	1.62
Venus	8.87
Mars	3.77
Jupiter	25.95
Sun	274

Mercury	3.59
Saturn	11.08
Uranus	10.67
Neptune	14.07

Q6. Different between Natural and artificial satellite

NATURAL SATELLITE	**ARTIFICIAL SATELLITE**
The planet which revolves around another planet naturally is called "Natural Satellite".	The object which are sent into space by scientists to revolve around the Earth or other planets are called "Artificial Satellite".
E.g Moon is a natural satellite because it revolves around the Earth naturally.	E.g. Sputnik-1, Explorer-1 are amongst the artificial satellites.

Q7. Define orbital velocity

ORBITAL VELOCITY

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

Q8. List where artificial satellite is being used

USES OF ARTIFICIAL SATELLITES

Artificial satellites are used for different purposes like

For communication.

For making star maps.

For making maps of planetary surfaces.

For collecting information about weather.

For taking pictures of planets, etc.

Q9. List the orbits where artificial satellite been launched

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

1. Low- Earth orbit.
2. Medium- Earth orbit.
3. Geostationary orbit.
4. Elliptic orbit

Q10. Derive relation for mass of earth with the help of newton law of gravitational formula. Also calculate the mathematical value of mass of earth

MASS OF THE EARTH

Consider a body of mass 'm' placed on the surface of the earth. Let the mass of the earth is 'M_e' and radius of earth is 'R_e' .

ACCORDING TO NEWTON LAW OF GRAVITATIONAL

Gravitational force of attraction between earth and body is

$$F = \frac{GmM_e}{Re^2}$$

We know that the force of attraction of the earth on a body is equal to weight the weight of body.

i.e

$$F = W = mg$$

$$mg = \frac{GmM_e}{Re^2}$$

$$g = \frac{GM_e}{Re^2}$$

$$\frac{Re^2 g}{G} = Me$$

$$Me = \frac{Re^2 g}{G}$$

Since,

$g = 9.8\ m/s^2$

$R_e = 6.4 \times 10^6\ m$

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

on solving these values, we get

$$M_e = \frac{9.8 \times (6.4 \times 10^6)^2}{6.67 \times 10^{-11}}$$

$$M_e = 6 \times 10^{24} \text{ kg}$$

Q11. Derive $V^2 = \frac{GM}{R+h}$

DERIVATION

Let us consider the motion of a satellite which is revolving around the Earth

m → Mass of the satellite.

M → Mass of Earth.

R → Radius of Earth

h → Height(altitude) of satellite from the surface of Earth.

r = R + h → Radius of orbit.

Then, as we already discussed:

Centripetal force = Gravitational force

$$F_C = F_G$$

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

$$F_G = \frac{GMm}{r^2}$$

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

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

Since, r = R + h

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

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

Q12. Derive $T = 2\pi\sqrt{\frac{r^3}{GM}}$

DERIVATION

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

$$T = \frac{2\pi r}{V}$$

The velocity of satellite is given by

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

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

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

Chapter = 06

Numerical problems

Numerical # 1

Determine the gravitational force of attraction between two spherical bodies of masses 500kg and 800kg. Distance between their centers is 2 meters.

Data

m_1 = 500 kg

m_2 = 800 kg

r = 2 m

G = 6.67 x 10^{-7} Nm^2/Kg^2

F = ?

Solution

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

$$F = \frac{6.67 \times 10^{-7} \times 500 \times 800}{2^2}$$

$$F = \frac{2704000 \times 10^{-7}}{4}$$

F = 676000 x 10^{-7}N

Numerical # 2

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

Data

m = 65kg

g = 10 N/kg

W = ?

Solution

W = mg

W = 65 x 10

W = 650 N

Numerical # 3

Calculate the acceleration due to gravity on a planet that has mass two times to the mass of Earth and radius 1.5 times to 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?

Data

m_p = 2 of earth mass = $2m_e$

R_p = 1.5 of earth radius = 1.5R_e

g = 10 ms^{-2}

g_p = ?

Solution

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

$$g_p = \frac{Gm_p}{R_p^2}$$

$$g_p = \frac{G2m_e}{(1.5R_e)^2}$$

$$g_p = \frac{2Gm_e}{2.25{R_e}^2}$$

g_p = 0.8 g

g_p = 0.8 x 10

g_p = 8 ms^{-2}

Numerical # 4

Calculate the speed of a satellite which orbits the Earth at an altitude of 1000 kilometers above Earth's surface?

Data

h = 1000 km = 1000x1000 = 1000000m = 1 x 10^6 m

G = 6.67 x 10^{-7} Nm^2/Kg^2

M = 6 x 10^{24} kg

R = 6.4 x 10^6 m

Solution

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

$$V = \sqrt{\frac{6.67\times10^{-7}6\times10^{6}}{6.4\times10^{6}+1\times10^{6}}}$$

$$V = \sqrt{\frac{40.02\times10^{-7+6}}{7.4\times10^{6}}}$$

$$V = \sqrt{\frac{40.02\times10^{-1}}{7.4\times10^{6}}}$$

$$V = \sqrt{5.408 \times 10^{-1-6}}$$

$$V = \sqrt{5.408 \times 10^{-7}}$$

$$V = \sqrt{54.08 \times 10^{-8}}$$

V = 7.35 x 10^{-4} m/s

Numerical # 5

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.

Data

m_1 = 60 kg

m_2 = 70 kg

r = 50 m

G = 6.67 x 10^{-7} Nm^2/Kg^2

F = ?

Solution

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

$$F = \frac{6.67 \times 10^{-7} \times 60 \times 70}{50^2}$$

$$F = \frac{28014 \times 10^{-7}}{2500}$$

$F = 11.2056 \times 10^{-7}$ N

Numerical # 6

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

Data

W = 450N

m = ?

$g = 10ms^{-2}$

Solution

W = mg

450 = m x 10

$$m = \frac{450}{10}$$

m = 45kg

Numerical # 7

Weight of Naveera is 700N on the Earth's surface. What will be Naveera's weight at the surface of Moon? ($g_m = 1.62ms^{-2}$)

Data

$W_e = 700N$

$g_m = 1.62ms^{-2}$

$g_e = 10ms^{-2}$

$W_m = ?$

Solution

$W_e = mg_e$

700 = m 10

$$m = \frac{700}{10}$$

m = 70 kg

$W_m = mg_m$

$W_m = 70 \times 1.62$

$W_m = 113.4$ N

Numerical # 8

A planet has mass four times of Earth and 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.

Data

m_p = 4 of earth mass = $4m_e$

R_p = 2 of earth radius = $2R_e$

g = 10 ms^{-2}

g_p = ?

Solution

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

$$g_p = \frac{Gm_p}{R_p^2}$$

$$g_p = \frac{G \times 4m_e}{(2R_e)^2}$$

$$g_p = \frac{4Gm_e}{4{R_e}^2}$$

$g_p = 1 \times g$

$g_p = 1 \times 10$

$g_p = 10\ ms^{-2}$

Numerical # 9

Calculate the speed of a satellite which orbits the Earth at an altitude of 400 kilometers above Earth's surface.

Data

h = 400 km = 400x1000 = 400000m = 1×10^5 m

G = 6.67×10^{-7} Nm^2/Kg^2

M = 6×10^{24} kg

R = 6.4×10^6 m

Solution

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

$$V = \sqrt{\frac{6.67\times10^{-7}6\times10^{6}}{6.4\times10^{6}+4\times10^{5}}}$$

$$V = \sqrt{\frac{6.67\times10^{-7}6\times10^{6}}{6.4\times10^{6}+0.4\times10^{6}}}$$

$$V = \sqrt{\frac{40.02\times10^{-7+6}}{6.8\times10^{6}}}$$

$$V = \sqrt{\frac{40.02\times10^{-1}}{6.8\times10^{6}}}$$

$$V = \sqrt{5.88 \times 10^{-1-6}}$$

$$V = \sqrt{5.88 \times 10^{-7}}$$

$$V = \sqrt{58.8 \times 10^{-8}}$$

$V = 7.66 \times 10^{-4}$ m/s