GRAVITATION

SYNOPSIS - 1

Gravitation and gravity:

The earth attracts (or pulls) all the objects towards its centre. The force with which the earth pulls the objects towards it is called the gravitational force of earth or gravity (of earth). It is due to the gravitational force of earth that all the objects fall towards the earth when released from a height.

The gravitational force of earth (or gravity of earth) is responsible for holding the atmosphere above the earth; for the rain falling to the earth and for the flow of water in the rivers. It is also the gravitational force of earth and for the flow of water in the rivers. It is also the gravitational force of earth(or gravity of earth)which keeps us firmly on the ground.

Gravitation:

Every body in this universe attracts every other body with a force known as 'force of gravitation'. Gravitation is the force of attraction between any two bodies in the universe. The attraction between the sun and the earth, the attraction between a table and a chair lying in a room, the attraction between the earth and a satellite revolving around it, etc.; are all examples of gravitation.

Gravity:

Gravity is a special case of gravitation. Gravity is the attraction between the earth and any object lying on or near its surface. A body thrown up falls back on the surface of the earth due to earth's force of gravity.

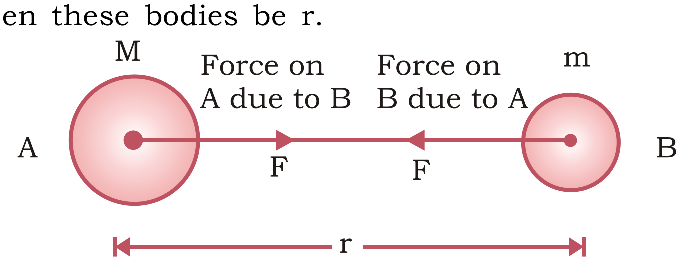
Universal law of gravitation or Newton's law of gravitation:

The law states that everybody in this 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 centres.

Note:- The force acts along the line joining centres of the two bodies.

Relation between gravitational force between two bodies and the distance between them.

Consider two bodies A and B having masses M and m respectively. Let the distance between these bodies be r.



If F is the force with which the two bodies attract each other, then according to the law of gravitation

$F \propto Mm$ ....(1) and $F \propto \frac{1}{r^2}$ ....(2)

Combining eqns. (1) and (2), we get

$$F \propto \frac{Mm}{r^2} \text{ or } F = G\frac{Mm}{r^2} \quad .....(3)$$

where G is constant and is known as universal gravitational constant.

Eqn (3) gives the magnitude of gravitational force between two interacting bodies of masses M and m separated by distance 'r'.

Definition of universal gravitational constant (G):

We know, $F = \frac{Mm}{r^2}$ or $G = \frac{Fr^2}{Mm}$

If M = 1 unit, m = 1 unit and r = 1 unit, then G = F

Thus, universal gravitational constant (G) is defined as the force of attraction between two bodies of unit masses separated by a unit distance.

Units of universal gravitational constant (G):

We know, $F = \frac{GMm}{r^2}$ or $G = \frac{Fr^2}{Mm}$

$$\therefore \quad G = \frac{\text{unit of force} \times (\text{unit of distance})^2}{\text{unit of mass} \times \text{unit of mass}}$$

Since S.I. unit of force is newton (N).

S.I. unit of distance is metre (m), S.I. unit of mass is kilogram (kg).

$\therefore$ S.I. unit of $G = \frac{Nm^2}{kg^2}$ or $Nm^2\ kg^{-2}$

Numerical value of gravitational constant G:

Henry Cavendish first determined the value of G experimentally in the year 1778, by using a sensitive balance.

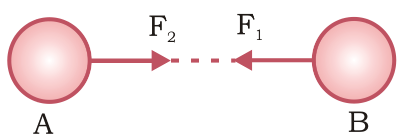
The numerical value of G is experimentally found to be $6.67 \times 10^{-11} Nm^2 Kg^{-2}$.

Newton's law of gravitation is known as universal law of gravitation:

This is because the law of gravitation holds good for any pair of bodies in the universe, whether the bodies are big or small, or whether they are celestial or terrestrial.

Characteristics of Gravitational force:

1. Gravitational force between two bodies or objects does not need any contact between them. It means, gravitational force is **action at a distance**.
2. Gravitational force between two bodies varies inversely proportional to the square of the distance between them, Hence, gravitational force is an **inverse square force.**
3. The gravitational forces between two bodies or objects from an action reaction pair. If object A attracts object B with a force F_1 and the object B attracts object A with a force F_2, then $F_1 = -F_2$



Free fall:

The falling of a body (or object) from a height towards the earth under the gravitational force of earth (with no other forces acting on it) is called free fall.

Note:-

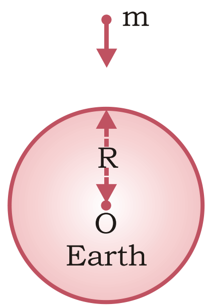
1) The acceleration of an object falling freely towards the earth does not depend on the mass of the object. Hence it is same for bodies of any mass
2) A freely falling body has acceleration equal to acceleration due to gravity (g).
3) The acceleration produced in the freely falling bodies is the same for all the bodies and its does not depend on the mass of the falling body.

Acceleration due to gravity:

The acceleration with which a body falls towards the earth due to earth's gravitational pull is known as acceleration due to gravity. It is denoted by 'g'.

Expression for the acceleration due to gravity (Relation between G and g)

Consider a body of mass m near the surface of the earth



The force acting on the body is the gravitational force of the earth. The magnitude of the gravitational force acting on the body due to the earth is given by

$$F = \frac{GMm}{R^2} \qquad \dots(1)$$

where, M = mass of the earth, R = radius of the earth

[Here, height of the body from the surface of the earth is neglected as compared to the radius of the earth because R = 6400 km is very large.]

This gravitational force (F) produces acceleration equal to 'g' in the body of mass m. So according to Newton's second law of motion,

$$F = mg \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_}(2)$$

Equating equations(1) and (2) $mg = \frac{GMm}{R^2}$ or $g = \frac{GM}{R^2}$ __________(3)

which is the expression for the acceleration due to gravity.

WORK SHEET - 1

Single Answer Type

1. The relation between g(acceleration due to gravity) and G(gravitational constant)

   1) $g = \frac{GM}{R^2}$ 2) $g = \frac{GM}{R}$ 3) $g = \frac{G}{R^2 M}$ 4) $g = \frac{G}{R^2}$

2. If F_1 is the force of attractionm for the bodies at separation $r_1$and F_2 is the force fpr the separation r_2, then

   1) $F_1 r_1^2 = F_2 r_2$ 2) $F_1 r_1 = F_2 r_2^2$ 3) $F_1 r_1^2 = F_2 r_2^2$ 4) $F_1 r_1 = F_2 r_2$

3. Force of gravitation can be between

   1) moon and the earth 2) sun and the earth
   3) moon and the sun 4) all of these

4. If 'F' is the force with which the two bodies attract each other which are at a distance 'r' then according to the law of gravitation

   1) $F \propto \frac{1}{r^3}$ 2) $F \propto \frac{1}{r}$ 3) $F \propto \frac{1}{r^2}$ 4) $F \propto r$

5. Every body in this universe attracts every other body with a force known as

   1) force of gravitation 2) electrostatic force 3) magnetic force 4) All of these

6. Choose the correct statement:

   1) The direction of acceleration due to gravity is always towards the centre.
   2) The aceeleration has the same value in magnitude whether the particle falls downwards or moves at some angle with the vertical
   3) The direction of acceleration due to gravity is always away from the centre.
   4) The aceeleration has the different value in magnitude whether the particle falls downwards or moves at some angle with the vertical

Multi Answer Type

7. Choose the correct statements

   1) Gravitational force on a particle due to number of particles is the vector sum of all the forces due to individual particles
   2) Gravitational force obeys inverse square law
   3) Gravitational force between any two bodies is always attractaive type only
   4) Gravitational force acts along line joining the two interacting particles

8. Choose the correct statements:
Universal law of gravitation states that
1) Everybody in this universe attracts every other body with a force which is directly proportional to the product of their masses
2) Inversely proportional to the square of the distance between their centres.
3) Everybody in this universe attracts every other body with a force which is inversely proportional to the product of their masses
4) Directly proportional to the square of the distance between their centres.

Reasoning Answer Type

9. *Statement I :* The force of attraction between two objects is called the force of gravitation
Statement II : The magnitude of gravitational force and its direction is given by the universal law of gravitation which was formulated by Newton.
1) Both Statements are true, Statement - II is the correct explanation of Statement-I
2) Both Statements are true, Statement - II is not correct explanation of Statement - I.
3) Statement - I is true, Statement - II is false.
4) Statement - I is false, Statement - II is true.

Comprehension Type

Universal law of gravitation states that everybody in this universe attracts every other body with a force which is directly proportional to the product of their masses inversely proportional to the square of the distance between their centres.

10. Universal law of gravitation is given by the formula
1) $F = G\frac{Mm}{r^2}$ 2) $F = G\frac{M}{r^2}$ 3) $F = G\frac{Mm}{r^3}$ 4) $F = G\frac{Mm}{r}$

11. In universal law of gravitation the constant G is
1) Independent of the nature of the particles
2) Independent of space where they are kept
3) Independent of time at which the force is considered
4) All of these

12. The unit of G is
1) $\frac{Nm^2}{kg^2}$ 2) $\frac{Nm}{kg^2}$ 3) $\frac{Nm^2}{kg}$ 4) $\frac{Nm^2}{g^2}$

Matrix Matching Type

13. **Column-I** | **Column-II**

Column-I	Column-II
a) Gravitational force	1) attractive force
b) Scalar	2) $Nm^2\ kg^{-2}$
c) unit of gravitational constant	3) 6.67×10^{-11}
d) numerical value of gravitational constant	4) dyne $cm^2\ g^{-2}$
	5) gravtitational constant

Integer Answer Type

14. The weight of a body of mass 5 kg is _________ N

Subjective Answer Type

15. The gravitational force between two protens kept at a separation of 1 femtometre (1 femtometre = 10^{-15} m). The mass of a proton is 1.67×10^{-27} kg (approximately)

1) 1.86×10^{-32} N 2) 1.86×10^{-34} N 3) 1.86×10^{-33} N 4) 1.86×10^{-35} N

SYNOPSIS - 2

Factors on which the acceleration due to gravity depends:

Acceleration due to gravity is

i) directly proportional to the mass of the earth and

ii) inversely proportional to the radius of the earth.

The value of acceleration due to gravity (g) on the earth:

We know, $g = \frac{GM}{R^2}$

Now, $G = 6.673 \times 10^{-11}\ Nm^2kg^{-2}$,$M = 5.98 \times 10^{24}$ kg (Mass of earth)

$R = 6.4 \times 10^6$ m (Radius of earth)

Substituting these values in equation (1), we get

$$g = \frac{6.673 \times 10^{-11} Nm^2kg^{-2} \times 5.98 \times 10^{24} kg}{\left(6.4 \times 10^6 m\right)^2}$$ $= 9.8\ Nkg^{-1} = 9.8\ kgms^{-2}kg^{-1} = 9.8\ ms^{-2}$

Value of 'g' on the surface of the moon:

We know, $g_{moon} = \frac{GM_m}{R_m^2}$ ....(1)

M_m (mass of the moon) = 7.4×10^{22} kg, R_m (radius of the moon) = 1.75×10^6 m

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

Then, from eqn. (1) $g_{moon} = \dfrac{6.673\times10^{-11}Nm^2kg^{-2}\times7.4\times10^{22}kg}{\left(1.75\times10^6 m\right)^2}$ = 1.6 ms^{-2}

Now, $\dfrac{g_{moon}}{g_{earth}} = \dfrac{1.7ms^{-2}}{9.8ms^{-2}} = \dfrac{1}{6}$ or $g_{moon} = \dfrac{1}{6} g_{earth}$

Thus, acceleration due to gravity on the surface of moon is $\dfrac{1}{6}$ the times the acceleration due to gravity on the surface of the earth.

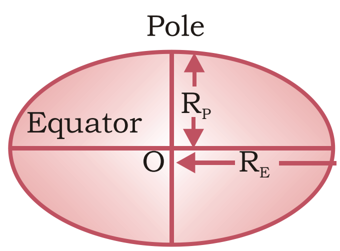
Variation in the value of 'g':

1. **Variation in the value of 'g' with the shape of the earth ;**

The acceleration due to gravity 'g' on the surface of the earth is given by

$G = \dfrac{GM}{R^2}$ ________________(1)

This expression for 'g' is calculated by considering the earth as a spherical body. In fact, the earth is not spherical in shape but it is egg shaped as shown in figure



Therefore, the radius of the earth (R) is not constant throughout. Hence, the value of 'g' is different at different points on the earth.

The equatorial radius (R_E) of the earth is about 21 km longer than its polar radius (R_p).

Now from equation (1)value of 'g' at equator is given by $g_e = \dfrac{GM}{R_p^2}$

__________(2)

Value of 'g' at pole is given by $g_p = \dfrac{GM}{R_p^2}$ _____________(3)

Dividing equation (3) by equation (2), we get $\dfrac{g_p}{g_E} = \left(\dfrac{R_E}{R_p}\right)^2$

Since $R_E > R_P \therefore g_p > g_E$

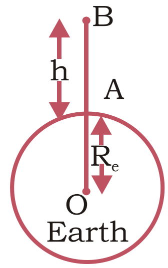
Thus, value of 'g' is more at equator than at poles.

2. ***Variation in the value of 'g' with the altitude (or height) above the surface of the earth.***

We know, acceleration due to gravity on the surface of the earth is given by

$$g = \frac{GM}{R^2} \qquad ...(1)$$

Now, let a body be at a height h above the surface of the earth.



The distance of the body from the centre of the earth = (R + h).
Therefore, acceleration due to gravity at height 'h' is given by

$$g_h = \frac{GM}{(R-h)^2} \qquad ...(2)$$

Dividing (2) by (1) we get $\frac{gh}{g} = \frac{GM}{(R+h)^2} \times \frac{R^2}{GM} = \frac{R^2}{(R+h)^2}$

or $$\frac{gh}{g} = \left(\frac{R}{R+h}\right)^2 \qquad ...(3)$$

Since (R + h) > R $\therefore \frac{gh}{g} < 1$ or gh < g

This shows that the value of 'g' decreases as we go higher and higher.
Thus, value of 'g' decreases with the height from the surface of the earth.

3. **Variation in the value of 'g' with depth below the surface of the earth.**
The value of 'g' decreases with depth below the surface of the earth.
The value of 'g' at depth d below the surface of the earth is given by

$$g_d = \left(1 - \frac{d}{R}\right)g \qquad g_d = g\left(\frac{R-d}{R}\right)$$

This shows that the value of 'g' decreases as we go deep into the crest of the earth.
Note:-At the centre of the earth, depth, d = R
$\therefore$ g (at centre of he earth) = 0
Thus, value of 'g' at the centre of the earth is zero.

4. ***Effect of latitude (Effect of rotation of the earth about its own axis).*** Due to the rotational motion of the earth about its own axis, the value of g at a place increases with the increase in latitude of the place. Hence due to rotation of the earth, the weight of a body is maximum at the poles and minimum at the equator. In fact rotation has no effect on the value of g at the poles.
Gravity meters:sensitive instrument used to measure small changes in

the value of g at a given location are called gravity meters.

WORK SHEET - 2

Single Answer Type

1. Acceleration due to gravity on the surface of moon is

1) $\frac{1}{4}$ the times the acceleration due to gravity on the surface of the earth.

2) $\frac{1}{16}$ the times the acceleration due to gravity on the surface of the earth.

3) $\frac{1}{2}$ the times the acceleration due to gravity on the surface of the earth.

4) $\frac{1}{6}$ the times the acceleration due to gravity on the surface of the earth.

2. Value of 'g' is

1) more at equator than at poles 2) less at equator than at poles
3) equal at equator and poles 4) more at poles than at equator

3. The correct relation between 'g' (acceleration due to gravity) and 'G'(universal gravitational constant) is

1) $g = \frac{GM}{R^2}$ 2) $g = \frac{GM}{R}$ 3) $g = \frac{G}{R^2}$ 4) $g = \frac{GM}{2R^3}$

4. Find the value of acceleration due to gravity at a height of 12,800 km from the surface of the earth.Earth radius = 6,400 km

1)1.7 m/s^2 2)1.09 m/s^2 3)2.09 m/s^2 4)4.09 m/s^2

5. Density of earth in terms of 'g' is acceleration due to gravity,M is mass of the earth,R is radius of earth

1) $\frac{3g}{4\pi RG}$ 2) $\frac{3G}{4\pi Rg}$ 3) $\frac{4G}{3\pi Rg}$ 4) $\frac{4G}{3Rg}$

6. The mass of a body on the surface of the earth is 70 kg. What willbe its (i) mass and (ii) weight at an altidue of 100 km? Radius of the earth is 6371 km.

1) 70 kg, 664.46 N 2) 70 kg, 66.446 N
3) 70 kg, 6.6446 N 4) 70 kg, 6644.6 N

Multi Answer Type

7. Choose the correct statements:

1) The equitorial radius of earth is greater than polar radius
2) acceleration due to gravity is minimum at the poles than at the equator
3) acceleration due to gravity decreases with increase in the value of h

4) As the g decreases with height the weight of an object also decreases

8. Choose the correct statements :

1) The weight of the body on the moon is about one-sixth of its weight on the earth

2) Rotation also affects effective value of g

3) At the centre of earth g is zero

4) If one goes above the earth surface or goes into deep mine, the value of g changes

9. Acceleration due to gravity is

1) directly proportional to the mass of the earth

2) inversely proportional to the radius of the earth

3) directly proportional to the radius of the earth

4) inversely proportional to the mass of the earth

Reasoning Answer Type

10. *Statement I :* Sensitive instrument used to measure small changes in the value of 'g' at a given location are called gravity meters.

Statement II : The value of 'g' is different at different points on the earth.

1) Both Statements are true, Statement - II is the correct explanation of Statement-I

2) Both Statements are true, Statement - II is not correct explanation of Statement - I.

3) Statement - I is true, Statement - II is false.

4) Statement - I is false, Statement - II is true.

Comprehension Type

The value of g varies with depth below the surface of the earth,the altitude (or height) above the surface of the earth,with the shape of the earth.

11. Acceleration due to gravity at height 'h' is given by the relation(all the terms have their usual meanings)R is radius of the earth.

1) $g_h = \frac{GM}{(R-h)}$ 2) $g_h = \frac{GM}{(R+h)^2}$ 3) $g_h = \frac{2G}{(R-h)^2}$ 4) $g_h = \frac{GM}{(R-h)^2}$

12. Variation in the value of 'g' with depth(d) below the surface of the earth is given by(all the terms have their usual meanings)R is radius of the earth.

1) $g_d = \left(1-\frac{d}{R}\right)g$ 2) $g_d = \left(1-\frac{R}{d}\right)g$ 3) $g_d = \left(1+\frac{R}{d}\right)g$

4) $g_d = \left(g-\frac{d}{R}\right)$

13. Choose the correct relations :

1)Value of 'g' decreases with the height from the surface of the earth

2)The value of 'g' decreases with depth below the surface of the earth.

3)Value of 'g' is less at equator than at poles

4)Both(1)& (2)

Integer Answer Type

14. The value of G is ________$\times 10^{-14}$

Subjective Answer Type

15. Density of earth is 5.488 $\times 10^{3}$ kgm^{-3}. Assume earth to be a hemogeneous sp[here. Find the value g on the surface of the earth. Use the known values of R and G

1) 8.9 ms^{-2} 2) 9.8 ms^{-2} 3) 8.9 ms^{-1} 4) 9.8 ms^{-1}

SYNOPSIS - 3

KEPLERS LAWS

1. The law of orbits: Every planet moves in an elliptical orbit around the sun, the sun being at one of the foci.
2. The law of area: the radius vector drawn from the sun t o a planet, sweeps out equal areas in equal intervals of time i.e., the areal velocity of radius is a constant.
3. The harmonic law: The square of the period of revolution of a planet around the sun is proportional to the cube of the semi- major axis of the ellipse. $T^2 \propto R^3$

WORK SHEET - 3

Single Answer Type

1. The period of revolution of a certain planet in an orbit of radius R is T. Its period of revolution in an orbit of radius 4R will be

1) 2T 2) T 3) 4T 4) 8T

2. An earth satellite S has an orbit radius which is 4 times that of a communication satellite C. The period of revolution of S is

1) 4 days 2) 8 days 3) 16 days 4) 32 days

3. Planets moves around the sun in______orbits

1)triangular 2) perfect circular 3)elliptical 4) can't say

Multi Answer Type

4. Choose the correct statements:

1) Every planet moves in an elliptical orbit around the sun, the sun being at one of the foci.

2) The areal velocity of radius vector drawn from the sun to a planet is constant.

3) Area swept by the radius vector drawn from the sun to a planet is equal in equal intervals of time

4) The areal velocity of radius vector drawn from the sun to a planet changes.

5. **Choose the correct statements :**

1) Areal velocity is area swept per unit time

2) If T_1 and T_2 be the periods of any two planets around the sun and R_1 and R_2 are their radii then $\frac{T_1^2}{T_2^2}=\frac{R_1^3}{R_2^3}$

3) If T_1 and T_2 be the periods of any two planets around the sun and R_1 and R_2 are their radii then $\frac{T_1^2}{T_2^2}=\frac{R_2^3}{R_1^3}$

4) The force of attraction between sun and the planet provide necessary centripetal force

Reasoning Answer Type

6. *Statement I :* The square of the period of revolution of a planet around the sun is proportional to the cube of the semi- major axis of the ellipse

Statement II : The square of the period of revolution of a planet around the sun is proportional to the square of the semi- major axis of the ellipse

1) Both Statements are true, Statement - II is the correct explanation of Statement-I

2) Both Statements are true, Statement - II is not correct explanation of Statement - I.

3) Statement - I is true, Statement - II is false.

4) Statement - I is false, Statement - II is true.

Integer Answer Type

7. The period of revolution of a certain planet in an orbit of radius R is T. Its period of revolution in an orbit of radius 4R will be__________×T

Comprehension Type

The square of the period of revolution of a planet around the sun is proportional to the cube of the semi- major axis of the ellipse. $T^2 \propto R^3$

8. The distance of the ftwo planets from the sun are 10^{13} m and 10^{12} m respectively. Find tht ratio of the time periods and speeds of the two plantes.

1) $\frac{1}{\sqrt{10}}$ 2) $\frac{2}{\sqrt{10}}$ 3) $\frac{3}{\sqrt{10}}$ 4) $\frac{4}{\sqrt{10}}$

9. The earth completes one revolution around the sun in one year. If the distance between them becomes double, the new period of revolution will be

1) 1/2 year 2) $2\sqrt{2}$ 3) 4 years 4) 8 years

10. If the radius of earth's orbit is made 1/4 th, then duration of year will become

1) 8 times 2) 4 times 3) 1/8 times 4) 1/4 times

11. The roataion period of an earth satellite close to the surface of earth is 83 minutes. The period of satellite in an orbit at a distance of three times earth radius from its surface will be

1) 83 min 2) $83 \times \sqrt{83}$ min 3) 664 min 4) 249 min

WORK SHEET – 1 (KEY)				
1) 1	2) 3	3) 4	4) 3	5) 1
6) 1,2	7) 1,2,3,4	8) 1,2	9) 2	10) 1
11) 4	12) 1	13) 1,5,(2,4),3	14) 49.0	15) 2

15. The gravitational force is

$$F = \frac{Gm_1m_2}{r^2} = \frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)\times\left(1.67\times10^{-27}kg\right)^2}{\left(10^{-15}m\right)^2} = 1.86\times10^{-34}N.$$

WORK SHEET – 2 (KEY)				
1) 4	2) 1	3) 1	4) 2	5) 1
6) 1	7) 1,3,4	8) 1,2,3,4	9) 1,2	10) 2
11) 4	12) 1	13) 4	14) 667	

6. Mass m = 70 kg Weight on the surface of the earth = mg = 70 × 9.8 = 686 N
The mass of the body at the altidue of 100 km is also the same as that on the surface of the earth i.e., 70 kg
Weight of the body at a height h is mg`

$$h = 100 \times 10^3 \text{ m} = 10^5 \text{ m}$$

Weight = $mg' = mg\left(1-\frac{2h}{R}\right) = 70\times9.8\left(1-\frac{2\times10^5}{6371\times10^3}\right) = 664.46N$

15.

$$g = 4\pi RGD/3 = 4\times3.14\times6371\times10^3\times6.67\times10^{-11}\times5.488\times10^3/3 = 9.8ms^{-2}$$

WORK SHEET – 3 (KEY)

1) 4	2) 2	3) 3	4) 1,2,3	5) 1,2,4
6) 3	7) 8	8) 3	9) 1	10) 2

1. According to Kepler's law of planetary motion, $T^2 \propto R^3$

$$\therefore \quad \left(\frac{T_2}{T_1}\right)^2 = \left(\frac{R_2}{R_1}\right)^3 \text{ or } \left(\frac{T_2}{T_1}\right)^2 = \left(\frac{4R}{R}\right)^3$$

$$\therefore \quad \frac{T_2}{T_1} = \sqrt{64} = 8 \text{ or } T_2 = 8T_1 \text{ or } T_2 = 8T$$

2. According to Kepler's law of planetary motion

$$\left(\frac{T_s}{T_c}\right)^2 = \left(\frac{R_s}{R_c}\right)^3 \therefore T_s = T_c \times \left(\frac{R_s}{R_c}\right)^{3/2} = 1 \times (4)^{3/2} = 8\,\text{days}$$

The time period T_c of a communication is 1 day.

8. According to Kepler's third law

$$\frac{T^2}{r^3} = \text{Constant}$$

$$\therefore \quad \frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3} \quad \text{or} \quad \frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2}$$

Here $r_1 = 10^{13}$ m; r2 $= 10^{12}$ m

$$\therefore \quad \frac{T_1^2}{T_2^2} = \left(\frac{10^{13}}{10^{12}}\right)^{3/2} = 10\sqrt{10}$$

$$v_1 = \frac{2\pi r_1}{T_1} \quad \text{and} \quad v_2 = \frac{2\pi r_2}{T_2}$$

$$\therefore \quad \frac{v_1}{v_2} = \frac{r_1}{r_2} \times \frac{T_2}{T_1} = \frac{10^{13}}{10^{12}} \times \frac{1}{10\sqrt{10}} = \frac{1}{\sqrt{10}}$$

9. $\left(\frac{T_2}{T_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^2 \quad \therefore \quad T_2 = T_1\left(\frac{r_2}{r_1}\right)^{3/2} = 1(2)^{3/2} = 2\sqrt{2}$ years

10. $\left(\frac{T_2}{T_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^3 \quad \therefore T_2 = T_1\left(\frac{r_2}{r_1}\right)^{3/2} = T_1\left(\frac{1}{4}\right)^{3/2} = \frac{T_1}{8}$