Exercise -3(E)

1. **State Newton's law of gravitation.**
   Solution:
   Newton's law of gravitation states that – The force of attraction acting between two bodies is (i) directly proportional to the product of their masses and (ii) inversely proportional to the square of the distance between them. The force acts along the line joining the two particles.

2. **State whether the gravitational force between two masses is attractive or repulsive?**
   Solution:
   The gravitational force between two masses is always attractive.

3. **Write an expression for the gravitational force of attraction between two bodies of masses m_1 and m_2 separated by a distance r.**
   Solution:
   The gravitational force 'F' between two bodies having masses m_1 and m_2, separated by a distance r is given by:

   $$F = G\frac{m1\,m2}{r^2}$$

   where G is the constant of proportionality known as the gravitational constant.

4. **How does the gravitational force of attraction between two masses depend on the distance between them?**
   Solution:
   The gravitational force of attraction between two masses is inversely proportional to the square of the distance between the masses.

5. **How is the gravitational force between two masses affected if the separation between them is doubled?**
   Solution:
   The gravitational force reduces to one-fourth if the distance between two masses is doubled.

6. **Define gravitational constant G.**
   Solution:
   The gravitational constant G can be defined as the force of attraction between two masses having unit mass separated by a unit distance.

7. **Write the numerical value of gravitational constant G with its S.I unit.**
   Solution:
   The numerical value of gravitational constant G is 6.67×10^{-11} Nm^2kg^{-2}
   The S.I unit of G is Nm^2kg^{-2}

8. **What is the importance of the law of gravitation?**
   Solution:
   Newton used the law of gravitation to explain:

- the motion of planets around the sun
- the motion of the moon(satellite) around the earth
- the motion of a freely falling body.

9. What do you understand by the term force due to gravity?

Solution:

As per the law of gravitation, the earth attracts each object around it, towards its center. The force with which the earth attracts a body is called the force due to gravity.

10. Write an expression for the force due to gravity on a body of mass m and explain the meaning of the symbols used in it.

Solution:

The force due to gravity 'F' acting on a body of mass placed on the earth's surface having mass 'm' and radius 'r' is equivalent to the force of attraction between the body and the earth.

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

11. Define the term acceleration due to gravity? Write its S.I. unit.

Solution:

Acceleration due to gravity can be defined as the rate at which the velocity of a freely falling body increases. The S.I. unit of acceleration due to gravity is m/s^2.

12. Write down the average value of g on the earth's surface.

Solution:

The average value of g on the surface of the earth is 9.8 m/s^2.

13. How is the acceleration due to gravity on the surface of the earth related to its mass and radius?

Solution:

The acceleration due to gravity 'g' on the surface of earth, where mass is 'm' and radius is 'r'.

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

14. How are g and G related?

Solution:

The universal gravitational constant (G) and the acceleration due to gravity (g) are directly proportional to each other.

15. A body falls freely under gravity from rest and reaches the ground in time t. Write an expression for the height fallen by the body.

Solution:

Given: acceleration due to gravity='g', initial velocity, u=0, time=t.

Let 'h' be the height fallen by the body

$h = ut + ½ gt^2$

u = 0 m/s, therefore the equation becomes;

$h = ½ gt^2$

16. A body is thrown vertically upwards with an initial velocity u. Write an expression for the maximum height attained by the body.

Solution:

There will be retardation when a body is thrown vertically upwards having an initial velocity 'u' to reach a height 'h'. The final velocity 'v' at the highest point is 0m/s

We know from the equation of motion that,

$v^2 = u^2 - 2gh$

$h_{max} = \frac{u^2}{2g}$

17. Define the terms mass and weight.

Solution:

Mass: mass of a body is the quantity of matter it contains. It is a scalar quantity.

Weight: Weight of a body is the force with which the earth attracts it. It is the force of gravity on it. Weight is a vector quantity.

18. Distinguish between mass and weight.

Solution:

Mass	Weight
It is the quantity of matter it contains	It is the force with which earth attracts a body
Mass is a scalar quantity	Weight is a vector quantity
Mass of a body is always constant	Weight of a body varies from place to place
S.I. unit of mass is kg	S.I. unit of weight is newton

19. State the S.I. units of (a) mass and (b) weight.

Solution:

The S.I. unit of mass is kilogram and symbol is kg

The S.I. unit of weight is newton and symbol is N

20. The value of g at the center of the earth is zero. What will be the weight of a body of mass m kg at the center of the earth?

Solution:

Weight of a body of mass m kg

W =mg

At the center of the earth, acceleration due to gravity 'g' = 0, substituting this value,

W = 0

21. Which of the following quantity does not change by change of place of a body: mass or weight?

Solution:

Mass of a body is constant and does not change whereas weight varies from place to place.

22. Explain the meaning of the following statement '1kgf=9.8N'.

Solution:

The gravitational unit of force in M.K.S system is kilogram force (kgf)

One kilogram force is the force due to gravity on a mass of 1kg.
1kg = force due to gravity on a mass of 1kg
= mass of 1kg x acceleration due to gravity g m/s^2
= g newton
Since the average value of g is 9.8 m/s^2,
1kgf = 9.8 newton or 9.8N

Multiple choice type:

1. **The gravitational force between two bodies is:**
   (a) Always repulsive
   (b) Always attractive
   (c) Attractive only at large distances
   (d) Repulsive only at large distances
   Solution:
   (c) Always attractive
   Gravitational force between two masses is always attractive

2. **The value of G is**
   (a) 9.8N m^2 kg^{-2}
   (b) 6.7 x 10^{-11} Nm^2kg^{-2}
   (c) 6.7 x 10^{-11} ms^{-2}
   (d) 6.7 Nkg^{-1}
   Solution:
   (b) 6.7 x 10^{-11} Nm^2kg^{-2}
   Universal gravitational constant is represented as 'G'

3. **The force of attraction between two masses each of 1kg kept at a separation of 1m is:**
   (a) 9.8N
   (b) 6.7N
   (c) 980N
   (d) 6.7 x 10^{-11} N
   Solution:
   (d) 6.7 x 10^{-11} N
   The force of attraction is the gravitational force between two bodies.

4. **A body is projected vertically upward with an initial velocity u. If acceleration due to gravity is g, the time for which it remains in air, is:**
   (a) u/g
   (b) ug
   (c) 2u/g
   (d) u/2g
   Solution:
   (c) 2u/g
   Time taken 't'= u/g, time taken to travel upwards and remain in air is 2t= 2u/g

5. **An object falling freely from rest reaches ground in 2s. if acceleration due to gravity is 9.8 m/s^2, the velocity of the object on reaching the ground will be:**
   (a) 9.8m/s
   (b) 4.9 m/s
   (c)19.6m/s
   (d) Zero
   Solution:
   (c) 19.6 m/s
   Value of g=9.8m/s^2, t=2s, v=?
   Velocity of the object = g x t
   = 9.8m/s x 2s = 19.6 m/s

Numericals:

1. **The force of attraction between two bodies at a certain separation is 10N. What will be the force of attraction between them if the separation is reduced to half?**
   Solution:
   Given: F=10N;
   $F = G\frac{Mm}{R^2}$
   Let the new distance be R1 acting between two bodies with force F1, then:
   $R1 = R/2$
   $F1 = G\frac{Mm}{\left(\frac{R}{2}\right)^2} = 4G\frac{Mm}{(R)^2}$
   $F1 = 4\ F$
   $= 4 \times 10$
   $F1 = 40N$

2. **Write the approximate weight of a body of mass 5kg. What assumption have you made?**
   Solution:
   Given: mass = 5kg,
   Assumption made is value of acceleration due to gravity is 10m/s^2
   Weight = mg
   = 5 x 10 = 50N

3. **Calculate the weight of a body of mass 10kg in (a) kgf and (b) newton. Take g=9.8m/s^2**
   Solution:
   Given: mass =10kg
   (i) Weight of the body in kgf = 10 x 1 kgf = 10kgf
   (ii) Weight of the body in newton = 10 x 9.8 = 98N

4. **State the magnitude and direction of the force of gravity acting on a body of mass 5kg. Take g=9.8m/s^2**
   Solution:

Given: m=5kg, g=9.8m/s^2, F=?
If F is the force of gravity,
F=mg
= 5 x 9.8
= 49N
The force of gravity =49N acting vertically downwards.

5. The weight of a body is 2.0N. What is the mass of the body? (g=10 m/s^2)
Solution:
Given: w=2N, g=10m/s^2;
Let 'm' be the mass of the body,
We know that, W=mg
⇨ m = W/g = 2/9.8 = 0.2kg

6. The weight of a body on earth is 98N where the acceleration due to gravity is 9.8ms^{-2}. What will be its (a) mass and (b) weight on moon where the acceleration due to gravity is 1.6m/s^2?
Solution:
Given: weight=98N, g=9.8m/s^2
If 'm' is the mass of the body,
m = W/g
= 98/9.8 = 10kg
Mass remains constant
(a) Mass on the moon is the same as the mass on earth = 10kg
(b) If weight on the moon is W1,
W1 = mass x g on earth = 10 x 1.6 = 16N

7. A man weighs 600N on earth. What would be his approximate weight on moon? Give reason for your answer?
Solution:
Given: weight of man on earth = 600N
Weight of the man on moon = 1/6 weight of man on earth;
It is because the acceleration due to gravity on the moon is 1/6th of earth,
w=mg
∴ Weight of the man on the moon = 600/6 = 100N

8. What is the (a) force of gravity and (b) weight of a block of mass 10.5kg? Take g=10 m/s^2
Solution:
Given: m=10.5kg, G=10m/s^2
(a) Force of gravity, F=mg
= 10.5 x 10 = 105N
(b) Weight of a block mass, w=mg
w = 10.5 x 10 = 105N

9. A ball is released from a height and it reaches the ground in 3s. If g=9.8m/s^2, find:
(a) The height from which the ball was released,
(b) The velocity with which the ball will strike the ground.

Solution:

Given: t=3s, g = 9.8m/s^2, initial velocity u=0m/s

Assume 's' to be the height the ball is released;

(a)We know from the equation of motion;

$S = ut + ½ at^2$

$= 0 + ½ (9.8) (3)^2$

$= 44.1m$

(b) Assume 'v' to be the velocity with which the ball strikes the ground,

We know from the equation of motion,

$v^2 – u^2 = 2gs$

$v^2 – 0^2 = 2 (9.8)(44.1)$

$v^2 = 864.36$

$v = 29.4$ m/s

10. What force, in newton, your muscles need to apply to hold a mass of 5kg in your hand? State the assumption.

Solution:

Given: m=5kg,

$F=mg$

$= (5) (9.8)$

$= 49N$

The value of acceleration due to gravity assumed is 9.8m/s^2

11. A ball is thrown vertically upwards. It goes to a height 20m and then returns to the ground. Taking acceleration due to gravity g to be 10m/s^2, find:

(a) The initial velocity of the ball

(b) The final velocity of the ball on reaching the ground and

(c) The total time of journey of the ball.

Solution:

Given: maximum height, s= 20m, g=10m/s^2

(a) If 'u' is the initial velocity, velocity is zero at the highest point

We know that $v^2 – u^2 = 2gs$

$0 - u^2 = 2 (10)(20)$

$u^2 = - 400$m/s

$u = 20$ m/s

Here, the negative sign indicates that the motion is against gravity.

(b) If v1 is the final velocity of the ball when it strikes the ground,

Velocity at the maximum height reached is zero which is equivalent to the initial velocity for the journey of the ball towards the ground.

Distance covered, s=20m;

We know from the equation of motion;

$v^2 – u^2 = 2gs$

$v^2 – 0 = 2(10)(20)$ m/s

$v^2 = 400$ m/s or $v = 20$ m/s

(c) Time for which the ball stays in air, t=2u/g

t=2 (20)/10

= 4s

12. A body is dropped from the top of a tower. It acquires a velocity 20m/s on reaching the ground. Calculate the height of the tower. (Take g=10m/s^2)

Solution:

Given: u=0m/s, v=20 m/s, g=10m/s^2;

Assume 'h' to be the height of the tower

We know from the equation of motion;

$v^2 - u^2 = 2gs$

$(20)^2 - 0 = 2\,(10)(h)$

h=400/20 => 20m

13. A ball is thrown vertically upwards. It returns 6s later. Calculate: (i) the greatest height reached by the ball, and (ii) the initial velocity of the ball. (Take g=10m/s^2)

Solution:

Given: time=6s, g=10 m/s^2;

(i) To calculate the greatest height reached by the ball.

Assume 'h' to be the greatest height reached. Ascent

Time for the rise of the ball = 6/2 =3s

Initial velocity for the rise is zero

As per the equation of motion;

$h=ut + ½\ gt^2$

$= 0(3) + ½\ (10)(3)^2$

$= 0 + 45$

⇨ 45m

(ii) To calculate the initial velocity of the ball

Assume u1 to be the initial velocity

We know from the equation of motion

$v^2 - u^2 = 2gh$

⇨ $v^2 - 0 = 2(10)(45)$

⇨ v = 30m/s

14. A pebble is thrown vertically upwards with a speed of 20m/s. How high will it be after 2s? (Take g=10m/s^2)

Solution:

Given: initial velocity u = 20 m/s, t=2s, g=10m/s^2

The greatest height reached by the pebble can be obtained by the equation of motion

$H=ut + ½\ gt^2$

$=0(2) + ½\ (10)(2)^2$

= 20m

15. (a) How long will a stone take a fall to the ground from the top of a building 80m high and (b) what will be the velocity of the stone on reaching the ground? (Take g=10 m/s^2)

Solution:

Given: height=80m, g=10 m/s^2;

(a)From the equation of motion;

$H=ut + ½ gt^2$

⇨ $80 = 0(t) + ½ (10)t^2$

⇨ $160 = 10t^2$

⇨ $t=4s$

(b) To find the velocity of the stone, assume 'v' to be the velocity

From the equation of motion;

$v^2 – u^2 = 2gh$

$v^2 – 0 = 2(10)(80)$

$v^2 = 1600$

$v = 40m/s$

16. A body falls from the top of a building and reaches the ground 2.5s later. How high is the building? (Take $g=9.8m/s^2$)

Solution:

Given: $g=9.8m/s^2$, $t=2.5s$

Assume 'h' to be the height of the building

We know from the equation of motion,

$H=ut + ½ gt^2$

⇨ $H= ½ gt^2$

⇨ $H=1/2 (9.8)(2.5)^2$

⇨ $30.6m$

17. A ball is thrown vertically upwards with an initial velocity of 49m/s. Calculate: (i) the maximum height attained, (ii) the time taken by it before it reaches the ground again. (Take $g=9.8m/s^2$)

Solution:

Given: initial velocity $u=49m/s$, $g=9.8m/s^2$

(i) Assume 'h' to be the height, velocity = 0m/s at the greatest height

We know from the equation of motion,

$v^2 – u^2 = 2gh$

⇨ $0-(49)^2 = 2(-9.8)(h)$

⇨ $h=(49)^2/19.6$

⇨ $h=122.5m$

(ii) Time taken before the ball reaches the ground is given by $t=2u/g$

$t=2(49)/9.8$

$= 10s$

18. A stone is dropped freely from the top of a tower and it reaches the ground in 4s. Taking $g=10m/s^2$, calculate the height of the tower.

Solution:

Given: initial velocity $u=0m/s$, $t=4s$, $g=10\ m/s^2$

Assume 'h' to be the height of the tower.

From the equation of motion,

$H=ut + ½ at^2$

$= 0 + ½ (10)(4)^2$

$= 80m$

19. A pebble is dropped freely in a well from its top. It takes 20s for the pebble to reach the water surface in the well. Taking g=10m/s^2 and speed of sound=330m/s, find: (i) the depth of water surface, and (ii) the time when echo is heard after the pebble is dropped.

Solution:

Given: t=20s, g=10m/s^2

(i) Assume 'h' to be the depth of the well,

We know from the equation of motion,

$H=ut + ½ gt^2$

$= 0 + ½ (10)(20)^2$

= 2000m

(ii) To find the time when the echo is heard after the pebble is dropped

Given: speed of sound = 330 m/s

Time taken = depth/speed

= 2000/330

=6.1s

For the pebble to reach the water surface, it takes 20s,

Hence the total time taken when the echo is heard after the pebble is dropped

= 20 + 6.1 = 21.6s

20. A ball is thrown vertically upwards from the top of a tower with an initial velocity of 19.6m/s. the ball reaches the ground after 5s. Calculate: (i) the height of the tower, (ii) the velocity of ball on reaching the ground. Take g=9.8m/s^2

Solution:

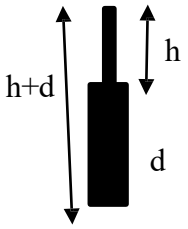
Given:

Initial velocity=19.6m/s, t=5s;

Velocity at the highest point is zero

(i) To calculate the height of the tower

Assume'd' to be height of the tower and 'h' to be the distance from the top of the tower to the maximum height as shown in the figure



We know from the equation of motion,

$v^2 – u^2 = 2gh$

⇨ $0 – (19.6)^2 = 2(9.8)(h)$

⇨ h=19.6m

(ii)

Let t1 be the time taken by the ball to reach the greatest point from the top of the tower

To calculate the time for which the ball remains in air;

We know the from the equation of motion,

v=u-gt

$0 = 19.6 – (9.8)(t1)$

$t1 = 2s$

Assume motion for (h+d) part;

Time taken for the ball to reach from the highest point of the tower to the ground is

$t-t1 = 5-2 = 3s$

From the equation of motion,

$s = ut+ ½ gt^2$

's' here is the distance from the top of the tower to the highest point, i.e., h+d

⇨ $h+d = 0 + ½ (9.8)(3)^2$

⇨ $d+19.6 = 44.1m$

⇨ $d=24.5m$

⇨ The height of the tower is 24.5m

(iii) Assume 'v' be the velocity of the ball when it strikes the ground

We know from the relation;

$v = u +gt$

$v = 0 + (9.8)(3)$

$= 29.4m/s$