# SHORT QUESTIONS

**4.1 A person holds a bag of groceries while standing still, taking to a friend. A car is stationery with its engine running. From the stand point of work, how are these two situations similar?**

**Ans.** In both the situations there is no work done because both the bodies have zero displacement i.e.,

$$W = \vec{F} \cdot \vec{d}$$

$$= Fd\cos\theta \qquad \text{But} \qquad d = 0$$

$$W = F(0)\cos\theta$$

$$W = 0$$

Hence no work is done in both the cases.

**4.2 Calculate the work done in kilo joules in lifting a mass of 10 kg (at a steady velocity) through a vertical height of 10m.**

**Ans.** ***Data***

Mass = m = 10 kg

Vertical height = h = 10 m

***To Find***

Work done in KJ = ?

***Solution***

By formula:

$$\text{Work done} = W = mgh$$

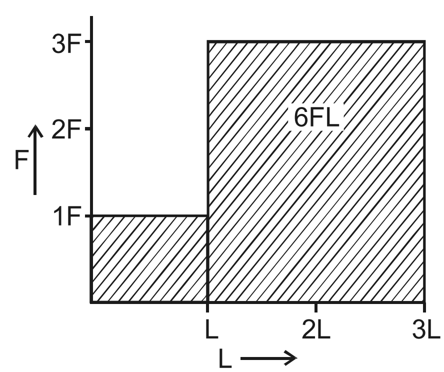
$$= 10 \times 10 \times 9.8$$

$$= 980\text{ J} = \frac{980}{1000}\text{ KJ}$$

Work done = 0.98 KJ

**4.3 A force F acts through a distance L. The force is then increased to 3 F, and then acts through a further distance of 2L. Draw the work diagram to scale.**

**Ans.** Work diagram is a force distance graph as shown in figure. A force F acts through a distance L then work done is FL. If the force is increased to 3F through a distance 2L then




$$\text{Work done} = 3F \cdot 2L$$

$$= 6FL$$

Hence the total:

$$\text{Work done} = FL + 6FL$$

$$= 7FL$$

**4.4 In which case is more work done? When a 50 kg bag of books is lifted through 30 cm, or when a 50 kg create is pushed through 2m across the floor with a force of 50 N?**

**Ans.** In 1st case when m = 50 kg

h = 50 cm = 0.5 m

Work done in this case is:

$$\text{Work done} = W_1 = mgh$$
$$= 50 \times 0.5 \times 9.8$$
$$W_1 = 245 \text{ J}$$

In 2nd case:

m = 50 kg

d = 2 m

F = 50 N

Work done in this case is:

$$W_2 = F \cdot d$$
$$= 50 \times 2$$
$$W_2 = 100 \text{ J}$$

It is clear that more work is done in 1st case.

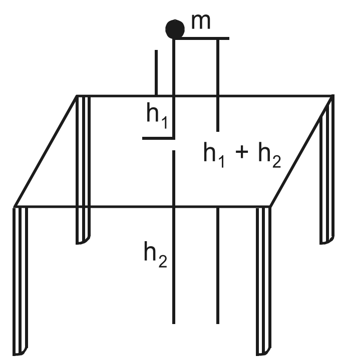
**4.5 An object has 1 J of potential energy. Explain what does it mean?**

**Ans.** As $1\text{ J} = 1\text{ N} \times 1\text{ m}$

When one Newton force is applied on a body in lifting it through a height of one metre. Then work done is stored in a body as P.E which is 1 Joule i.e., the body has the ability of doing 1 Joule of work.

**4.6 A ball of mass m is held at a height $h_1$ above a table. The table top is at a height $h_2$ above the floor. One student says that the ball has potential energy $mgh_1$ but another says that it is mg ($h_1 + h_2$). Who is correct?**

**Ans.** The ball is at a height $h_1$ with respect to the table and the table is at height $h_2$ with respect to the ground, so the ball is at a height of $h_1 + h_2$ from the ground. Therefore the potential energy stored in the ball with respect to the top is $mgh_1$ and with respect to ground is $mg(h_1 + h_2)$. Hence both the students are correct because one student is telling with respect to the top and other is telling with respect to the ground.




**4.7 When a rocket re-enters the atmosphere, its nose cone becomes very hot. Where does this heat energy come from?**

**Ans.** When the rocket re-enters into the atmosphere then a part of its kinetic energy is used to do work against friction with air and dust particles present in atmosphere which will be appear in the form of heat therefore due to this reason nose cone of rocket become very hot.

**4.8 What sort of energy is in the following:**

**(a) Compressed spring**

**(b) Water in a high dam**

**(c) A moving car**

**Ans.** (a) A compressed spring has elastic potential energy.

(b) A water in a high dam has gravitational potential energy.

(c) A moving car has kinetic energy.

**4.9 A girl drops a cup from a certain height, which breaks into pieces. What energy changes are involved?**

**Ans.** At a certain height, a cup has gravitational potential energy. When it is dropped its gravitational potential energy decreases and kinetic energy increases. Just before striking the floor, kinetic energy is maximum. On striking, kinetic energy is changed into sound energy, heat energy and energy to break the cup if air friction is ignored. If air friction is present then some part of K.E is also used to overcome this friction.

**4.10 A boy uses a catapult to throw a stone which accidentally smashes a green house window. List the possible energy changes.**

**Ans.** Elastic potential energy stored in catapult, which is transferred to the stone as its kinetic energy. When the stone strikes the green house window, its kinetic energy changes into sound, heat and energy to break the glass window.

# PROBLEMS WITH SOLUTIONS

## PROBLEM 4.1

**A man pushes a lawn mower with a 40 N force directed at an angle of 20° downward from the horizontal. Find the work done by the man as he cuts a strip of grass 20m long.**

### *Data*

Force exerted = F = 40 N

Angle = $\theta$ = 20°

Length of strip of grass = d = 20 m

### *To Find*

Work done = W = ?

## SOLUTION

By formula

$$W = \vec{F} \cdot \vec{d}$$

$$\boxed{W = Fd\cos\theta}$$

$$W = (40)(20)\cos 20°$$

$$= 751.7\ J$$

$$= 7.5 \times 10^2\ J$$

### *Result*

Work done = W = $7.5 \times 10^2$ J

## PROBLEM 4.2

**A rain drop (m = $3.35 \times 10^{-5}$kg) falls vertically at a constant speed under the influence of the forces of gravity and friction. In falling through 100 m, how much work is done by.**

**(a) Gravity and (b) Friction**

### *Data*

Mass of raindrop = m = $3.35 \times 10^{-5}$ kg

Height = h = 100 m

### *To Find*

(a) Work done by gravity = W = ?

(b) Work done by friction = W = ?

**SOLUTION**

(a) As we know that work done by gravity is

$$W = \vec{F} . \vec{d}$$

$$= Fd \cos 0°$$

$$= Fd (1)$$

$$W = mgh$$

Putting values

$$W = 3.35 \times 10^{-5} \times 9.8 \times 100$$

$$W = 0.0328 \text{ J}$$

(b) Now work done by friction is

$$W = \vec{F} . \vec{d}$$

$$= Fd \cos 180°$$

$$= Fd (–`1)$$

$$= –mgh$$

Putting values

$$W = –3.35 \times 10^{-5} \times 9.8 \times 100$$

$$= –0.0328 \text{ J}$$

### *Result*

(a) Work done by gravity = W = 0.0328 J

(b) Work done by friction = W = –0.0328 J

**PROBLEM 4.3**

**Ten bricks, each 6.0 cm thick and mass 1.5 kg, lie flat on a table. How much work is required to stack them one on the top of another?**

### *Data*

Number of bricks = 10

Mass of each brick = m = 1.5 kg

Height of each brick = h = 6 cm

= 0.06 m

### *To Find*

Work done by placing one on the top = W = ?

**SOLUTION**

Now the total work done placing one brick on the top of another is

$$W = mgh + 1\ mgh + 2\ mgh + 3\ mgh + 4\ mgh + 5\ mgh + 6\ mgh + 7\ mgh + 8\ mgh + 9\ mgh$$

$$= (1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9)mgh$$

$$= 45\ mgh$$

$$= 45 \times 1.5 \times 9.8 \times 0.06$$

$$= 39.69\ J$$

$$W = 40\ J$$

### *Result*

Work done by placing one on the top of another = W = 40 J

**PROBLEM 4.4**

**A car mass 800 kg traveling at 54 kmh$^{-1}$ is brought to rest in 60 meters. Find the average retarding force on the car. What has happened to original kinetic energy?**

### *Data*

Mass of car = m = 800 kg

Initial velocity of car = $v_i$ = 54 km/hr

$$= \frac{54 \times 1000}{3600}$$

$$= 15\ m/s$$

Distance = d = 60 m

Final velocity of car = $v_f$ = 0

### *To Find*

Average force = F = ?

**SOLUTION**

By formula

$$F \times d = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$F \times 60 = \frac{1}{2}m(0^2 - 15^2)$$

$$60F = \frac{1}{2} \times 800(-15^2)$$

$$= 400 \times -225$$

$$60F = 400 \times -225$$

$$60F = -90000$$

$$F = \frac{-90000}{60}$$

$$F = -1500\ \text{N} \quad \text{(negative shows force is retarding)}$$

### *Result*

Average force = F = 1500 N

***Note:*** Original K.E. energy has been used in doing work against the friction between tyre and road.

## *PROBLEM 4.5*

**A 1000 kg automobile at the top of an incline 10 metre high and 100m long is released and rolls down the hill. What is its speed at the incline if the average retarding force due to friction is 480 N?**

### *Data*

Mass of automobile = m = 1000 kg

Height of inclined plane = h = 10 m

Length of plane = S = 100 m

Retarding force = f = 480 N

### *To Find*

Speed of automobile = v = ?

## *SOLUTION*

As Loss of P.E = Gain in K.E + Work done against friction

$$mgh = \frac{1}{2} mv^2 + fS$$

$$\frac{1}{2} mv = mgh - fS$$

$$\frac{1}{2} \times 1000\ v^2 = 1000 \times 9.8 \times 10 - 480 \times 100$$

$$500\ v^2 = 98000 - 48000$$

$$v^2 = 50,000$$

$$v^2 = \frac{50,000}{500}$$

$$v^2 = 100$$

$$v = 10\ ms^{-1}$$

### *Result*

Speed of automobile = v = 10 m/s

**PROBLEM 4.6**

**100 $m^3$ of water is pumped from a reservoir into a tank, 10 m higher than the reservoir, in 20 minutes. If density of water 1000 kg $m^{-3}$, find.**

**(a) The increase in P.E.**

**(b) The power delivered by the pump.**

### *Data*

Volume of water = V = 100 $m^3$

Height of tank = h = 10 m

Time taken = t = 20 min.

= $20 \times 60$

= 1200 sec.

### *To Find*

(a) Increase in P.E. = ?

(b) Power delivered by pump = P = ?

**SOLUTION**

(a) For increase in P.E.

$$\boxed{P.E = mgh}$$

But Mass = Volume × Density

= $100 \times 1000$

m = $10^5$ kg

So P.E = $10^5 \times 9.8 \times 10$

P.E = $9.8 \times 10^6$ J

(b) For power delivered by pump

$$\text{Power} = \frac{P.E}{\text{Time}}$$

$$= \frac{9.8 \times 10^6}{1200}$$

$$P = 8.16 \times 10^{-3+6}$$

$$= 8.16 \times 10^3 \text{ watt}$$

$$= 8.2 \text{ k watt}$$

### *Result*

(a) Increase in P.E = $9.8 \times 10^6$ J

(b) Power delivered = P = 8.2 k watt

## PROBLEM 4.7

**A force (thrust) of 400 N is required to overcome road friction and air resistance in propelling an automobile at 80 kmh$^{-1}$. What power (kW) must the engine develop?**

### *Data*

Force required = F = 400 N

Velocity of automobile = v = 80 km/h

$$= \frac{80 \times 1000}{3600}$$

= 22.22 m/s

### *To Find*

Power = P = ?

## SOLUTION

As we know that

$$P = \vec{F} \cdot \vec{v}$$

$$= Fv \cos\theta \qquad \text{But} \qquad \theta = 0°$$

$$P = Fv \cos 0°$$

$$P = Fv$$

$$= (400)(82.22)$$

$$= 8888 \text{ watt}$$

$$= 8.88 \text{ k watt}$$

$$= 8.9 \text{ k watt}$$

### *Result*

Power = P = 8.9 k watt

## PROBLEM 4.8

**How large a force is required to accelerate an electron (m = 9.1 × 10$^{-31}$kg) from rest to a speed of 2.0 × 10$^{7}$ ms$^{-1}$ through a distance of 5.0 cm?**

### *Data*

Mass of electron = m = $9.1 \times 10^{-31}$ kg

Initial velocity = $v_i$ = 0

Final velocity = $v_f$ = $2 \times 10^{7}$ m/s

Distance = d = 5 cm = 0.05 m

### *To Find*

Force required = F = ?

**SOLUTION**

According to work energy principle

$$Fd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$Fd = \frac{1}{2}mv_f^2 \qquad \text{Since} \quad v_i = 0$$

$$F \times 0.05 = \frac{1}{2} \times 9.1 \times 10^{-31} (2 \times 10^7)^2$$

$$0.05\,F = 18.2 \times 10^{-31+14}$$

$$0.05\,F = 18.2 \times 10^{-17}$$

$$F = \frac{18.2 \times 10^{-17}}{0.05}$$

$$F = 364 \times 10^{-17}$$

$$F = 3.64 \times 10^{-15}\ N$$

### Result

Force required $= F = 3.64 \times 10^{-15}$ N

**PROBLEM 4.9**

**A diver weighing 750 N dives from a board 10 m above the surface of a pool of water. Use the conservation of mechanical energy to find his speed at a point 5.0 m above the water surface, neglecting air friction.**

### Data

Weight of diver $= W = 750$ N

Height of board $= h_1 = 10$ m

Height of point from water $= h_2 = 5$ m

### To Find

Speed of diver $= v = ?$

**SOLUTION**

As we know that

$$\text{Gain in K.E} = \text{Loss of P.E}$$

$$\frac{1}{2}mv^2 = mgh$$

$$\sqrt{v^2} = \sqrt{2gh}$$

$$v = \sqrt{2g(h_1 - h_2)}$$

$$v = \sqrt{2 \times 9.8 \times 5} \qquad \text{Since} \quad h = h_1 - h_2$$

$$v = 9.89 \text{ m/s}$$

$$v = 9.9 \text{ m/s}$$

### *Result*

Speed of diver = v = 9.9 m/s

### *PROBLEM 4.10*

**A child starts from ret at the top of a slide of height 4.0m, (a) what is his speed at the bottom if the slide is frictionless? (b) if he reaches the bottom, with a speed of 6 $ms^{-1}$, what percentage of his total energy at the top of the slide is lost as a result of friction?**

### *Data*

Height of slide = h = 4 m

### *To Find*

(a) Speed at bottom = v = ?

(b) % of total energy lost = ?

If v′ = 6 m/s

### *SOLUTION*

(a) As we know that

Gain in K.E = Loss of P.E

$$\frac{1}{2} mv^2 = mgh$$

$$v^2 = 2gh$$

$$v = \sqrt{2gh}$$

$$= \sqrt{2 \times 9.8 \times 4}$$

$$= \sqrt{78.4}$$

$$= 8.8 \text{ m/s}$$

K.E when the child is moving with 8.8 m/s

$$K.E = \frac{1}{2} mv^2$$

$$= \frac{1}{2} m (8.8)^2$$

$$K.E = 38.72 \text{ mJ}$$

(b) K.E when the child is moving with 6 m/s

$$K.E' = \frac{1}{2} mv'^2$$

$$= \frac{1}{2} m (6)^2$$

$$K.E' = 18 \text{ mJ}$$

Loss of energy $= K.E - K.E'$

$= 38.72 \text{ m} - 18 \text{ m}$

$= 20.72 \text{ mJ}$

% loss of energy $= \frac{20.72 \text{ m}}{38.72 \text{ m}} \times 100$

$= 53.5\%$

$= 54\%$

## *Result*

(a) Speed of child at bottom = v = 8.8 m/s

(b) % loss of energy = 54%