NCERT Solution For Class 11 Physics Chapter 6 Work Energy and Power

Que.1. 1 The sign of work done by a force on a body is important to understand. State carefully if the following quantities are positive or negative:

(a) work done by a man in lifting a bucket out of a well by means of a rope tied to the bucket.
(b) work done by the gravitational force in the above case,
(c) work done by friction on a body sliding down an inclined plane,
(d) work done by an applied force on a body moving on a rough horizontal plane with uniform velocity,
(e) work done by the resistive force of air on a vibrating pendulum in bringing it to rest

Ans.

(a) It is clear that the direction of both the force and the displacement are the same and thus the work done on it is positive.

(b) It can be noted that the displacement of the object is in an upward direction whereas, the force due to gravity is in a downward direction. Hence, the work done is negative.

(c) It can be observed that the direction of motion of the object is opposite to the direction of the frictional force. So, the work done is negative.

(d) The object which is moving in a rough horizontal plane faces the frictional force which is opposite to the direction of the motion. To maintain a uniform velocity, a uniform force is applied on the object. So, the motion of the object and the applied force are in the same direction. Thus, the work done is positive.

(e) It is noted that the direction of the bob and the resistive force of air which is acting on it are in opposite directions. Thus, the work done is negative.

Que.2. A body has a mass of 3 kg which when applied with a force of 8 N moves from rest with a coefficient of kinetic friction = 0.2. Find the following:

(a) When a force is applied for 10 s, what is the work done?

(b) The work done by the friction in 10 s.

(c) When a net force acts on the body for 10 s, what is the work done?

(d) In the time interval of 10 s, the change in the kinetic energy.

Ans. Given: Mass m = 3 kg

Force F = 8 N

Kinetic friction coefficient μ = 0.2

Initial velocity , u = 0

t = 10 s

According to the Newton's law of motion:

$a' = \frac{F}{m} = \frac{8}{3}$ = 2.6 m/s^2

Friction force = μmg

= 0.2 x 3 x -9.8 = -5.88 N

Acceleration due to friction:

$a" = \frac{-5.88}{3}$ = -1.96 m/s^2

The total acceleration of the body = $a' + a"$

= 2.6 + (-1.96) = 0.64 m/s^2

According to the equation of the motion

s = ut + $\frac{1}{2}$ at^2

= 0 + $\frac{1}{2}$ x 0.64 x $(10)^2$

= 32 m

(a). W_a = F x s = 8 x 32 = 256 J

(b). W_t = F x s = -5.88 x 32 = -188 J

Net force = 8 + (-5.88) = 2.12 N

(c). W_{net} = 2.12 x 32 = 68 J

(d) Final velocity v = u + at

= 0 + 0.64 x 10 = 6.4 m/s

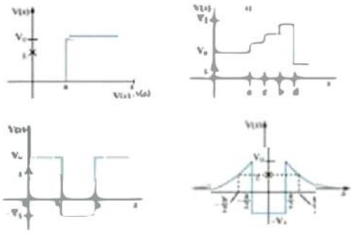
Change in kinetic energy = $\frac{1}{2}$ mv^2 - $\frac{1}{2}$ mu^2

= $\frac{1}{2}$ x 2 $(v^2 - u^2)$

= $6.4^2 - 0^2$

= 41 J

Que.3. Given in Fig. 6.11 are examples of some potential energy functions in one dimension. The total energy of the particle is indicated by a cross on the ordinate axis. In each case, specify the regions, if any, in which the particle cannot be found for the given energy. Also, indicate the minimum total energy the particle must have in each case. Think of simple physical contexts for which these potential energy shapes are relevant.



Ans. (a) x > a

The relation which gives the total energy:

E = P.E + K.E

K.E. = E − P.E

K.E of the body is a positive quantity and the region where K.E is negative, the particles does not exist.

For x > a, the potential energy V_0 is greater than the total energy E. Hence, the particle does not exist here. The minimum total energy is zero.

(b) All regions

The total energy in all regions is less than the kinetic energy. So the particles do not exist here.

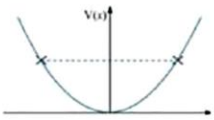
(c) x < b and x > a; $=V_1$

K.E is positive in the region between x > a and x < b. $-V_1$ is the minimum potential energy. K.E = E − $(-V_1)$ = E + V_1. For the K.E to be positive, total energy must be greater than $-V_1$.

(d) $\frac{-b}{2}$ < x < $\frac{a}{2}$; $\frac{a}{2}$ < x < $\frac{b}{2}$; $-V_1$

For the given condition, potential energy is greater. So in this region, the particles does not exist. $-V_1$ is the minimum potential energy. K.E = E + V_1. For the K.E to be positive, total energy must be greater than $-V_1$. The particle must have a minimum total K.E of $-V_1$.

Que.4. The potential energy function for a particle executing linear simple harmonic motion is given by $V(x) = kx^2/2$, where k is the force constant of the oscillator. For k = 0.5 N m-1, the graph of V(x) versus x is shown in Fig. 6.12. Show that a particle of total energy 1 J moving under this potential must 'turn back' when it reaches x = ± 2 m.



Ans. Particle energy E = 1 J

K = 0.5 N m^{-1}

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

Based on law of conservation of energy:

E = V + K

$1 = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$

Velocity becomes zero when it turns back

$1 = \frac{1}{2}kx^2$

$\frac{1}{2} \times 0.5x^2 = 1$

$X^2 = 4$

$X = \pm 2$

Thus, on reaching x = ± 2 m, the particle turns back.

Que.5. Answer the following:

(a) The casing of a rocket in flight burns up due to friction. At whose expense is the heat energy required for burning obtained? The rocket or the atmosphere?

Ans. When the casing burns up due to the friction, the rocket's mass gets reduced.

As per the law of conservation of energy:

Total energy = kinetic energy + potential energy

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

There will be a drop in total energy due to the reduction in the mass of the rocket. Hence, the energy which is needed for the burning of the casing is obtained from the rocket.

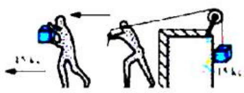
(b) Comets move around the sun in highly elliptical orbits. The gravitational force on the comet due to the sun is not normal to the comet's velocity in general. Yet the work done by the gravitational force over every complete orbit of the comet is zero. Why?

Ans. The force due to gravity is a conservative force. The work done on a closed path by the conservative force is zero. Hence, for every complete orbit of the comet, the work done by the gravitational force is zero.

(c) An artificial satellite orbiting the earth in very thin atmosphere loses its energy gradually due to dissipation against atmospheric resistance, however small. Why then does its speed increase progressively as it comes closer and closer to the earth ?

Ans. The potential energy of the satellite revolving the Earth decreases as it approaches the Earth and since the system's total energy should remain constant, the kinetic energy increases. Thus, the satellite's velocity increases. In spite of this, the total energy of the system is reduced by a fraction due to the atmospheric friction.

(d) In Fig. 6.13(i) the man walks 2 m carrying a mass of 15 kg on his hands. In Fig. 6.13(ii), he walks the same distance pulling the rope behind him. The rope goes over a pulley, and a mass of 15 kg hangs at its other end. In which case is the work done greater?



Ans.

Scenario I:

m = 20 kg

Displacement of the object, s = 4 m

W = Fs cos θ θ = It is the angle between the force and displacement

Fs = mgscos θ

W = mgs cos θ = 20 x 4 x 9.8 cos 90

= 0 (cos 90 = 0)

Scenario II.

Mass = 20 kg

S = 4 m

The applied force direction is same as the direction of the displacement.

$\theta = 0°$

$\cos 0° = 1$

$W = Fs \cos \theta$

$= mgs \theta$

$= 20 \times 4 \times 9.8 \times \cos 0°$

= 784 J

Thus, the work done is more in the second scenario.

Que.6. Underline the correct alternative :

(a) When a conservative force does positive work on a body, the potential energy of the body increases/decreases/remains unaltered.

Ans. Decreases

When a body is displaced in the direction of the force, positive work is done on the body by the conservative force due to which the body moves to the center of force. Thus the separation between the two decreases and the potential energy of the body decreases.

(b) Work done by a body against friction always results in a loss of its kinetic/potential energy.

Ans. Kinetic energy

Velocity of the body is reduced when the work done is in the direction opposite to that of friction. Thus, the kinetic energy decreases.

(c) The rate of change of total momentum of a many-particle system is proportional to the external force/sum of the internal forces on the system

Ans. External force

Change in momentum cannot be produced by internal forces, irrespective of their directions. Thus, the change in total momentum is proportional to the external force on the system.

(d) In an inelastic collision of two bodies, the quantities which do not change after the collision are the total kinetic energy/total linear momentum/total energy of the system of two bodies

Ans. Total linear momentum

Irrespective of elastic collision or an inelastic collision, the total linear momentum remains the same

Que.7. State if each of the following statements is true or false. Give reasons for your answer

(a) In an elastic collision of two bodies, the momentum and energy of each body is conserved.

Ans. False

The momentum and the energy of both the bodies are conserved and not individually.

(b) Total energy of a system is always conserved, no matter what internal and external forces on the body are present.

Ans. False.

The external forces on the system can do work on the body and are able to change the energy of the system.

(c) Work done in the motion of a body over a closed loop is zero for every force in nature.

Ans. False.

The work done by the conservative force on the moving body in a closed loop is zero.

(d) In an inelastic collision, the final kinetic energy is always less than the initial kinetic energy of the system.

Ans. True

The final kinetic energy is always lesser than the initial kinetic energy as there will be always a loss of energy in the form of heat, light, etc.

Que.8. Answer carefully, with reasons :

(a) In an elastic collision of two billiard balls, is the total kinetic energy conserved during the short time of collision of the balls (i.e. when they are in contact)?

Ans. The initial and the final kinetic energy is equal in an elastic collision. When the two balls collide, there is no conservation of kinetic energy. It gets converted into potential energy

(b) Is the total linear momentum conserved during the short time of an elastic collision of two balls?

Ans. The total linear momentum of the system is conserved in an elastic collision.

(c) What are the answers to (a) and (b) for an inelastic collision?

Ans. There will be a loss of kinetic energy in an inelastic collision. The K.E after the collision is always less than the K.E before the collision.

The total linear momentum of the system is conserved in an inelastic collision also.

(d) If the potential energy of two billiard balls depends only on the separation distance between their centres, is the collision elastic or inelastic? (Note, we are talking here of potential energy corresponding to the force during a collision, not gravitational potential energy).

Ans. It is an elastic collision as the forces involved are conservative forces. It depends on the distance between the centres of the billiard balls.

Que.9. A body is initially at rest. It undergoes one-dimensional motion with constant acceleration. The power delivered to it at time t is proportional to

(i) $t^{\frac{1}{2}}$

(ii) $t^{\frac{3}{2}}$

(iii) t^2

(iv) t

Ans. body mass = m

Acceleration = a

According to Newton's second law of motion:

F = ma (constant)

We know that a = $\frac{dv}{dt}$ = constant

dv = dt x constant

On integrating

$v = \alpha t \rightarrow 1$

Where, α is also a constant

$v \propto t \rightarrow 2$

The relation of power is given by:

P = F.v

From equation 1 & 2

$P \propto t$

Thus, from the above, we conclude that power is proportional to time.

Que.10. 0 A body is moving unidirectionally under the influence of a source of constant power. Its displacement in time t is proportional to

(i) $t^{\frac{1}{2}}$

(ii) $t^{\frac{3}{2}}$

(iii) t^2

(iv) t

Ans. We know that the power is given by:

P = Fv

= mav = mv $\frac{dv}{dt}$

= k (constant)

vdv = $\frac{k}{m}$ dt

On integration:

$\frac{v^2}{2}$ = $\frac{k}{m}dt$

v = $\sqrt{\frac{2kt}{m}}$

To get the displacement:

v = $\frac{dx}{dt}$ = $\sqrt{\frac{2k}{m}}$ $t^{\frac{1}{2}}$

dx = k' $t^{\frac{1}{2}}$ dt

where k' = $\sqrt{\frac{2k}{3}}$

x = $\frac{2}{3}$ k' $t^{\frac{3}{2}}$

Hence, from the above equation it is shown that x $\propto$ $t^{\frac{3}{2}}$

Que.11. A body constrained to move along the z-axis of a coordinate system is subject to a constant force F given by F = -$\hat{i}$ + 2$\hat{j}$ + 3$\hat{k}$ N

Unit vectors are $\hat{i}$, $\hat{j}$, $\hat{z}$ which are along the x, y and z axis of the system. If a body is moved to a distance of 6m along the z-axis, find the work done.

Ans. F = -$\hat{i}$ +2$\hat{j}$ + 3$\hat{k}$ N

Displacement s = 6 $\hat{k}$ m

Work done, W = F.s

= (-$\hat{i}$ + 2$\hat{j}$ + 3$\hat{k}$) (4$\hat{k}$)

= 0 + 0 - 6 x 4

= 24 J

Thus, the work done on the body is 24 J

Que.12. An electron and a proton are detected in a cosmic ray experiment, the first with kinetic energy 10 keV, and the second with 100 keV. Which is faster, the electron or the proton ? Obtain the ratio of their speeds. (electron mass = 9.11×10-31 kg, proton mass = 1.67×10−27 kg, 1 eV = 1.60 ×10−19 J)

Ans. Electron mass, m_e = 9.11 x 10^{-31} kg

Proton mass, m_p = 1.67 x 10^{-27} kg

Electron's kinetic energy

E_{ke} = 20 keV = 20 x 10^3 eV

= 20 x 10^3 x 1.60 x 10^{-19}

= 3.2 x 10^{-15} J

Proton's kinetic energy,

E_{kp} = 200 kev = 2 x 10^5 eV

= 3.2 x 10^{-14} J

To find the velocity of electron v_e, the kinetic energy is used.

$E_{ke} = \frac{1}{2} m v_e^2$

$V_e = \sqrt{\frac{2 \times E_{ke}}{m}}$

$= \sqrt{\frac{2 \times 3.2 \times 10^{-15}}{9.11 \times 10^{-31}}}$

= 8.38 x 10^7 m/s

To find the velocity of proton v_p, the kinetic energy is used.

$E_{kp} = \frac{1}{2} m v_p^2$

$v_p = \sqrt{\frac{2 \times E_{kp}}{m}}$

$v_p = \sqrt{\frac{2 \times 3.2 \times 10^{-15}}{1.67 \times 10^{-27}}}$

= 6.19 x 10^6 m/s

Thus, electron moves faster when compared with proton.

The speed ratios are:

$\frac{v_e}{v_p} = \frac{8.38 \times 10^7}{6.19 \times 10^6} = \frac{13.53}{1}$

Que.13. From a height of 1000 m above the ground, a water drop of 4 mm falls. Till the half way, the speed decreases due to the air resistance and after the half mark, it attains its maximum speed and moves in a constant speed after it. Give the work done by the gravity in the first and the last phase of the journey. If the speed of the drop on reaching the ground is 20 m s^{-1}, find the work done by the resistive force for the entire journey.

Ans. Radius of the water drop, r = 4 mm = 4 x 10^{-3} m

Volume $V = \frac{4}{3} \pi r^3$

$= \frac{4}{3}$ x 3.14 x (4 x 10^{-3} $)^3$ m^{-3}

Density of water, ρ = 10^3 kg m^{-3}

Mass m = ρV

m = $\frac{4}{3}$ x 3.14 x (4 x 10^{-3} $)^3$ x 10^3 kg

Force due to gravity, F = mg

F = $\frac{4}{3}$ x 3.14 x (4 x 10^{-3} $)^3$ x 10^3 x 9.8 N

The work done on the water drop by the force of gravity in the first half of the journey:

W_1 = Fs

$= \frac{4}{3}$ x 3.14 x (4 x 10^{-3}) x 10^3 x 9.8 x 500

= 1.31 J

The work done on the water drop by the force of gravity in the second half of the journey:

W_2 = 1.31 J

According to the law of conservation of energy, the total energy of the water drop remains the same if there is no resistive force.

Therefore, the total energy at the top:

E_T = mgh + 0

$\frac{4}{3}$ x 3.14 x $(4 \times 10^{-3})^3$ x 10^3 x 9.8 x 1000 x 10^{-5}

= 2.62 J

The drop reaches the ground at a velocity of 20 m/s.

Total energy at the ground:

$E_G = \frac{1}{2} mv^2 + 0$

$= \frac{1}{2} \times \frac{4}{3} \times 3.14 \times (4 \times 10^{-3})^3 \times 10^3 \times 9.8 \times (20)^2$

= 0.525 J

Resistive force = $E_G - E_T = -2.095$ J

Que.14. A molecule with a speed of 300 m s^{-1} hits the wall of the container at an angle 40° with the normal and rebounds with the same speed. During the collision is the momentum conserved? Is it an elastic or an inelastic collision?

Ans. The collision is an elastic collision.

Whether the collision is an elastic or an inelastic collision, the momentum gets conserved. The molecule travels at a speed of 300 m/s and strikes the wall and rebounds with the same speed. Thus, the wall's rebound velocity is zero. During the collision, the total kinetic energy gets conserved.

Que.15. A water pump takes 20 minutes to pump water to fill a tank of volume 40 m^3. If the efficiency of pump is 40 % and the tank is at a height 50 m, how much electric power is needed for the pump?

Ans. Tank volume V = 40 m^3

Operation time, t = 20 min = 20 x 60 = 1200 s

Height of the tank, h = 50 m

Efficiency, η = 40 %

Water density, $\rho = 10^3$ kg/m^3

Mass of water, m = $\rho V = 40 \times 10^3$ kg

Output power, $P_0 = \frac{Work\ done}{Time\ taken}\ \frac{mgh}{t}$

$\frac{40 \times 10^3 \times 9.8 \times 50}{1200}$

= 16.333×10^3 W

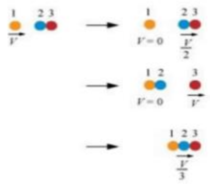
To find input power:

$\eta = \frac{P_0}{P_i}$ = 40 %

$P_i = \frac{16.333}{40} \times 100 \times 10^3$

= 40.8 KW

Que.16. On a frictionless table, two ball bearing which are identical are in contact with each other and they are hit by an another ball of same mass head-on with the initial speed V. Which of the following are correct, if the collision is an elastic collision.



Ans. In each case, the total momentum before and after collision is same. So, the kinetic energy should be conserved before and after collision.

Before collision:

Kinetic energy = $\frac{1}{2}mV^2 + \frac{1}{2}(2m)0$

$\frac{1}{2}mV^2$

Scenario I:

After collision, the kinetic energy = $\frac{1}{2}m \times 0 + \frac{1}{2}(2m) \times \frac{V^2}{4}$

$= \frac{1}{4}mV^2$

Thus, the K.E is not conserved.

Scenario II:

Kinetic energy after collision = $\frac{1}{2}(2m) \times 0 + \frac{1}{2}mV^2$

The kinetic energy is conserved in this case

Scenario III:

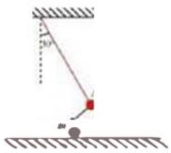
Kinetic energy after collision = $\frac{1}{2}(3m)\frac{V^2}{9}$

The kinetic energy is not conserved in this case.

Hence, the scenario II is the correct answer.

Que.17. A ball A which is at an angle 30° to the vertical is released and it hits a ball B of same mass which is at rest.

Does the ball A rises after collision? The collision is an elastic collision.



Ans. In an elastic collision when the ball A hits the ball B which is stationary, the ball B Acquires the velocity of the ball A while the ball A comes to rest immediately after collision. There is transfer of momentum to the moving body from the stationary body. Thus, the ball A comes to rest after collision and ball B moves with velocity of ball A.

Que.18. From a horizontal position, the bob of the pendulum is released. The pendulum's length is 2.5 m. At what speed does the bob arrive at the lowest point? 10 % of the initial energy is dissipated due to the air resistance.

Ans. Length, l = 2.5 m

Mass = m

Energy dissipated due to air resistance = 10 %

The total energy of the system remains constant due to the law of conservation of energy.

At horizontal position:

Potential energy $E_p = mgl$

Kinetic energy $E_k = 0$

Total energy = mgl

At the lowest point:

Potential energy, E_p = mgl

Kinetic energy, $E_k = \frac{1}{2} mv^2$

Total energy $E_x = \frac{1}{2} mv^2$

10% energy is dissipated when the bob moves from the horizontal position. The total energy at the lowest point is 90 % of the energy at the horizontal point.

$\frac{1}{2} mv^2 = \frac{90}{100} \times mgl$

$v = \sqrt{\frac{2 \times 90 \times 2.5 \times 9.8}{100}}$

= 6.64 m/s

Que.19. A sandbag of 30 kg is carried by a trolley of mass 250 Kg which moves at a speed of 24 km/h on a frictionless track. The sand starts to leak through a holes at a rate of 0.06 kg s^{-1}. After the sand bag gets empty, find the speed of the trolley.

Ans. The trolley with a sand bag on it moves with the speed of 24 km/h. The external force is zero on the system. There is no velocity change even when the sand starts leaking from the bag as there are no external force produced on the system due to the leaking action. Hence, the speed remains same.

Que.20. A body travels in a straight line whose velocity and mass of v = $ax^{\frac{3}{2}}$ and 0.6 kg where a = 5 $m^{-\frac{1}{2}}$ s^{-1}. Find the work done when it is displaced from x = 0 to x = 2 m.

Ans. Mass = 0.6 kg

v = a $x^{\frac{3}{2}}$ where a = 5 $m^{\frac{-1}{2}}$ s^{-1}

Initial velocity u = 0

Final velocity v = $10\sqrt{2}$ m/s

Work done W = $\frac{1}{2} m (v^2 - u^2)$

= $\frac{1}{2} \times 0.5 \times \{(10\sqrt{2})^2 - (0)^2\}$

= $\frac{1}{2} \times 0.5 \times 10 \times 10 \times 2$

= 50 J.

Que.21. The windmill sweeps a circle of area A with their blades. If the velocity of the wind is perpendicular to the circle, find the air passing through it in time t and also the kinetic energy of the air. 25 % of the wind energy is converted into electrical energy and v = 36 km/h, A = 30 m^2 and the density of the air is 1.2 kg m^{-3}. What is the electrical power produced?

Area = A

Velocity = V

Density = ρ

(a) Volume of the wind through the windmill per sec = Av

Mass = ρAv

Mass m through the windmill in time t = ρAvt

(b) kinetic energy = $\frac{1}{2}mv^2$

= $\frac{1}{2}(\rho Avt)v^2 = \frac{1}{2}\rho Av^3t$

(c) Area = 30 m^2

Velocity = 36 km/h

Density of air ρ = 1.2 kg m^{-3}

Electric energy = 25 % of wind energy

= $\frac{25}{100}$ x kinetic energy

= $\frac{1}{8}\rho Av^3t$

Power = $\frac{Electric\ energy}{Time}$

= $\frac{1}{8}\frac{\rho Av^3t}{t} = \frac{1}{8}\rho Av^3$

= $\frac{1}{8}$ x 1.2 x 30 x 10^3

= 4.5 x 10^3 W =4.5 kW

Que.22. A person who wants to lose weight lifts a mass of 20 kg to a height of 0.6 m a thousand times. Each time she lower the mass, the potential energy lost is dissipated. (a) What is the work done against gravitational force? The fat supplies 3.8 x 10^7 J of energy which is converted with an efficiency of 20 % into mechanical energy. How much fat is used up?

Ans. Mass m = 20 kg

Height h = 0.6 m

No. of times weight lifted n = 1000

Work done against gravitational force = n(mgh)

= 1000 x 20 x 9.8 x 0.6 = 117.6 KJ

Energy equivalent to 1 Kg of fat = 3.8 x 10^7 J

Efficiency = 20 %

Mechanical energy = $\frac{20}{100}$ x 3.8 x 10^7 J

= $\frac{1}{5}$ x 3.8 x 10^7 J

Mass of fat lost = $\frac{1}{\frac{1}{5}\times 3.8\times 10^7}\times 117.6\times 10^3$

=1.5 x 10^{-2} kg

Que.23. 10 KW of power is used by a family.

(a) On the horizontal surface, the average solar energy generated is 300 W per square meter. If the electrical energy conversion is 25%, then to supply 10 KW, how large should the area be?

(b) Compare the typical house with this area?

Ans. Power P = 10 x 10^3 W

Solar energy = 300W

Conversion efficiency = 25%

Area required = A

10 $\times$ 10^3 = 25 % $\times$ (A $\times$ 300)

$= \quad - \frac{25}{100} \times A \times 300$

$A = \frac{10 \times 10^3}{75} = 133\ m^2$

This area is almost equal to the roof having dimensions 11 m x 11 m.

Que.24. A bullet travels at a speed of 80 m s^{-1} whose mass is 0.018 kg and strikes the piece of wood whose mass is 0.6 kg and comes to rest instantly. By means of a thin wire, the block is suspended from the ceiling. How high does the block rise and also find the heat produced.

Ans. Bullet mass = 0.018 Kg

Initial bullet speed, u_b = 80 m/s

Mass of wood, M = 0.6 Kg

Initial speed of wood u_B = 0

Final speed = v

According to law of conservation of momentum:

$Mu_b + Mu_B = (m + M)v$

$0.018 \times 80 + 0.6 \times 0 = (0.018 + 0.6)v$

$v = \frac{1.44}{0.618} = 2.33$ m/s

System mass m' = 0.618 kg

System velocity = 2.33 m/s

Height = h

According to law of conservation of energy

Potential energy at highest point = kinetic energy at lowest point

m'gh = $\frac{1}{2}$ m'v^2

h = $\frac{1}{2}$ ($\frac{v^2}{g}$)

= $\frac{1}{2}$ x $\frac{2.33^2}{9.8}$

h= 0.276 m

Heat produced = kinetic energy of the bullet – system

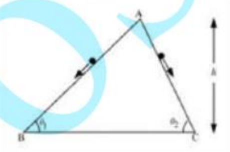
= $\frac{1}{2}$ mu^2 – $\frac{1}{2}$ m'v^2

= $\frac{1}{2}$ x 0.018 x 80^2 – $\frac{1}{2}$ x 0.618 x 2.33^2

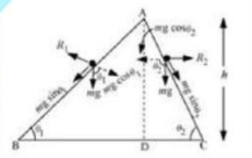
= 57.6 – 1.67

= 55.93 J

Que.25. Two stones are allowed to slide down from point A without any friction as shown. Does the stones reach down at the same time and is the speed remains same till they reach there? $\theta_1 = 30^\circ$, $\theta_2 = 60^\circ$ ***and height = 10 m. Find the speed and the time taken by the stones.***



Ans:



The potential energy at point A is same as the initial height (h) is same

According to law of conservation of energy, at point B and C, the kinetic energy will be same for the stones.

$\frac{1}{2}$ m v_1^2 = $\frac{1}{2}$ m v_2^2

$v_1 = v_2 = v$

m = mass of each stone

v = Speed of each stone at B and C

They reach at the same speed v.

For stone I:

Net force on the stone:

$F_{net} = ma_1 = mg \sin\theta_1$

a_1 g sinθ_1

Stone II:

$a_2 = g \sin\theta_2$ $\theta_2 > \theta_1$

sin θ_2 > sin θ_1

$a_2 > a_1$

Time can be found using motion equation

v = u + at

$t_1 = \frac{v}{a}$ (u = 0)

For stone I:

$t_1 = \frac{v}{a_1}$

For stone II

$t_2 = \frac{v}{a_2}$

$a_2 > a_1$

$t_2 < t_1$

So, the stone moving in a steep plane reaches first.

By law of conservation of energy:

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

v = $\sqrt{2gh}$

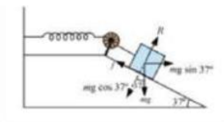
= $\sqrt{2 \times 9.8 \times 10}$

= $\sqrt{196}$ = 14 m/s

$t_1 = \frac{v}{a_1} = \frac{v}{g\ sin\theta_1} = \frac{14}{9.8 \times sin30} = \frac{14}{9.8 \times \frac{1}{2}}$ = 2.86 s

$t_2 = \frac{v}{a_2} = \frac{v}{g\ sin\theta_2} = \frac{14}{9.8 \times sin30} = \frac{14}{9.8 \times \frac{\sqrt{3}}{2}}$ = 1.65 s.

Que.26. A spring is attached to a 1 kg block which is inclined on a rough surface having a spring constant of 100 N m^{-1}. The block moves 10 cm with the string in the unstretched position before coming to rest. Find the coefficient of friction between the block and the incline.



Ans. Mass m = 1 Kg

Spring constant, k = 100 N m^{-1}

Displacement = 0.1 m

At equilibrium:

R = mg cos 37°

f = μ R = mg sin 37°

coefficient of friction = μ

Net force = mg sin 37° − f

= mg(sin 37° – μ cos 37°

Work done is equal to potential energy at equilibrium.

mg(sin 37° – μ cos 37°)x = $\frac{1}{2}$ kx^2

1 x 9.8 (sin 37° – μ cos 37°) = $\frac{1}{2}$ x 100 x 0.1

0.602 – μ x 0.799 = 0.510

$\mu = \frac{0.092}{0.799}$ = 0.115

Que.27. An elevator is moving down with an uniform speed of 8 m s^{-1} and a bolt of mass 0.4 kg falls from the ceiling. It hits the elevator's floor and does not rebound. The length of the elevator is 3 m. Find the heat produced during the impact. What will be the answer if the elevator is stationary?

Ans. Mass m = 0.4 kg

Speed of the elevator = 8 m/s

Height h = 3 m

The potential energy gets converted into heat energy as the relative velocity is zero.

Heat produced = loss of potential energy

= mgh = 0.4 x 9.8 x 3

= 11.76 J

Even if the elevator is stationary, the heat produced is still the same.

Que.28. On a frictionless track, a trolley moves with a speed of 36 km/h with a mass of 200 Kg. A child whose mass is 20 kg runs on the trolley with a speed of 4 m s^1 from one end to other which is 20 m. The speed is relative to the trolley in the direction opposite to its motion. Find the final speed of the trolley and the distance the trolley moved from the time the child began to run.

Ans. Mass m = 200 Kg

Speed v = 36 km/h = 10 m/s

Mass of boy = 20 Kg

Initial momentum = (M + m)v

= (200 +20) x 10

= 2200 kg m/s

v' is final velocity of the trolley

Final velocity of boy = M v' +m(v' – 4)

= 200 v' + 20 v' – 80

= 220 v' – 80

According to law of conservation of energy:

Initial momentum = final momentum

2200 = 220 v' – 80

$v' = \frac{2280}{220}$ = 10.36 m/s

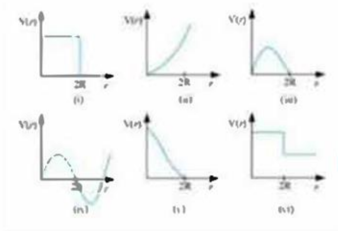
Length l = 20 m/s

v'' = 4 m/s

t = $\frac{20}{4}$ = 5 s

Distance moved by the trolley = v'' x t = 10.36 x 5 = 51.8 m

Que.29. Which of the following does not describe the elastic collision of two billiard balls? Distance between the centers of the balls is r.

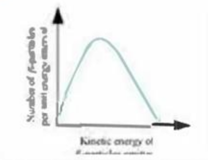


Ans. (i), (ii), (iii), (iv) and (vi).

The potential energy of two masses in a system is inversely proportional to the distance between them. The potential energy of the system of two balls will decrease as they get closer to each other. When the balls touch each other, the potential energy becomes zero, i.e. at r = 2R. The potential energy curve in (i), (ii), (iii), (iv) and (vi) do not satisfy these conditions. So, there is no elastic collision.

Que.30. The decay of free neutrons at rest: $n \rightarrow p + e^-$

Show that the two body decay must give an electron of fixed energy and therefore, can't account for continuous energy distribution in β-decay of a neutron or a nucleus.



Ans. The decay process of free neutron at rest:

$n \rightarrow p + e^-$

From Einstein's mass energy relation

Electron energy = Δmc^2

Δm = mass defect = mass of neutron − (mass of proton and electron)

c = Speed of light

The presence of neutrino on the LHS of decay explains the continuous energy distribution.