Chapter

6

Work, Energy, Power and Collision

Introduction

The terms 'work', 'energy' and 'power' are frequently used in everyday language. A farmer clearing weeds in his field is said to be working hard. A woman carrying water from a well to her house is said to be working. In a drought affected region she may be required to carry it over large distances. If she can do so, she is said to have a large stamina or energy. Energy is thus the capacity to do work. The term power is usually associated with speed. In karate, a powerful punch is one delivered at great speed. In physics we shall define these terms very precisely. We shall find that there is a loose correlation between the physical definitions and the physiological pictures these terms generate in our minds.

Work is said to be done when a force applied on the body displaces the body through a certain distance in the direction of force.

Work Done by a Constant Force

Let a constant force $\vec{F}$ be applied on the body such that it makes an angle θ with the horizontal and body is displaced through a distance s

By resolving force $\vec{F}$ into two components :

(i) $F\cos\theta$ in the direction of displacement of the body.

(ii) $F\sin\theta$ in the perpendicular direction of displacement of the body.

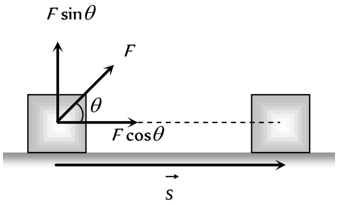


Fig. 6.1

Since body is being displaced in the direction of $F\cos\theta$, therefore work done by the force in displacing the body through a distance s is given by

$$W = (F\cos\theta)s = Fs\cos\theta$$

or $W = \vec{F}.\vec{s}$

Thus work done by a force is equal to the scalar (or dot product) of the force and the displacement of the body.

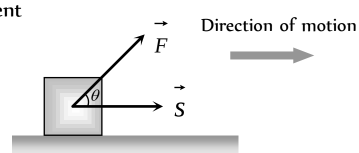
If a number of forces $\vec{F}_1, \vec{F}_2, \vec{F}_3 ......\vec{F}_n$ are acting on a body and it shifts from position vector $\vec{r}_1$ to position vector $\vec{r}_2$ then

$$W = (\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ... \vec{F}_n).(\vec{r}_2 - \vec{r}_1)$$

Nature of Work Done

Positive work

Positive work means that force (or its component) is parallel to displacement



$0^o \le \theta < 90^o$

Fig. 6.2

The positive work signifies that the external force favours the motion of the body.

Example: (i) When a person lifts a body from the ground, the work done by the (upward) lifting force is positive

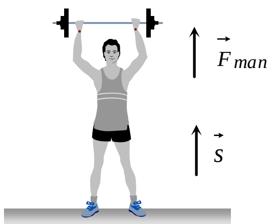


Fig. 6.3

(ii) When a lawn roller is pulled by applying a force along the handle at an acute angle, work done by the applied force is positive.

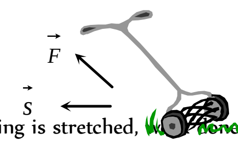


Fig. 6.4

(iii) When a spring is stretched, work done by the external (stretching) force is positive.

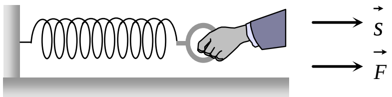
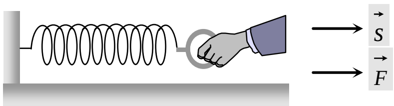


Fig. 6.5



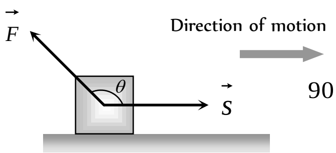
Maximum work : $W_{max} = Fs$

When $\cos\theta = \text{maximum} = 1$ *i.e.* $\theta = 0^o$

It means force does maximum work when angle between force and displacement is zero.

Negative work

Negative work means that force (or its component) is opposite to displacement *i.e.*



$90^o < \theta \le 180^o$

Fig. 6.6

The negative work signifies that the external force opposes the motion of the body.

Example: (i) When a person lifts a body from the ground, the work done by the (downward) force of gravity is negative.

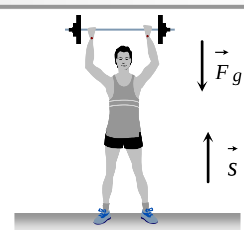


Fig. 6.7

(ii) When a body is moving over a rough surface, the work done by the frictional force is negative.

Minimum work : $W_{min} = -Fs$

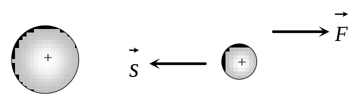


Fig. 6.8

When $\cos\theta = \text{minimum} = -1$ *i.e* $\theta = 180^o$

It means force does minimum [maximum negative] work when angle between force and displacement is 180°.

(iii) When a positive charge is moved towards another positive charge. The work done by electrostatic force between them is negative.

Zero work

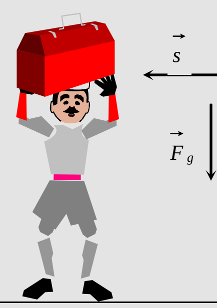
Under three condition, work done becomes zero $W = Fs\cos\theta = 0$

(1) **If the force is perpendicular to the displacement** $[\vec{F} \perp \vec{s}\,]$

Example: (i) When a coolie travels on a horizontal platform with a load on his head, work done against gravity by the coolie is zero.

(ii) When a body moves in a circle the work done by the centripetal force is always zero.

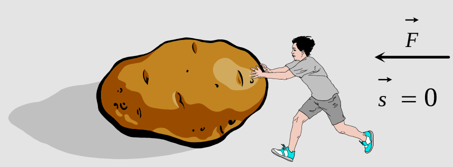
(iii) In case of motion of a charged particle in a magnetic field as force $[\vec{F} = q(\vec{v} \times \vec{B})]$ is always perpendicular to motion, work done by this force is always zero.



(2) **If there is no displacement** [s = 0]

Example: (i) When a person tries to displace a wall or heavy stone by applying a force and it does not move, then work done is zero.

(ii) A weight lifter does work in lifting the weight off the ground but does not work in holding it up.



(3) **If there is no force acting on the body** [F = 0]

Example: Motion of an isolated body in free space.

Work Done by a Variable Force

When the magnitude and direction of a force varies with position, the work done by such a force for an infinitesimal displacement is given by

$dW = \vec{F}.d\vec{s}$

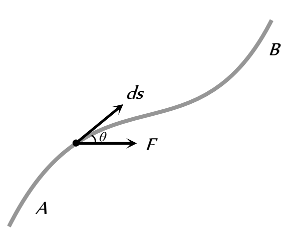


Fig. 6.9

The total work done in going from A to B as shown in the figure is

$$W = \int_A^B \vec{F}.d\vec{s} = \int_A^B (F\cos\theta)ds$$

In terms of rectangular component $\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$

$$d\vec{s} = dx\hat{i} + dy\hat{j} + dz\hat{k}$$

$$\therefore\ W = \int_A^B (F_x\hat{i} + F_y\hat{j} + F_z\hat{k}).(dx\hat{i} + dy\hat{j} + dz\hat{k})$$

or $$W = \int_{x_A}^{x_B} F_x dx + \int_{y_A}^{y_B} F_y dy + \int_{z_A}^{z_B} F_z dz$$

Dimension and Units of Work

Dimension : As work = Force × displacement

$$[W] = [MLT^{-2}] \times [L] = [ML^2T^{-2}]$$

Units : The units of work are of two types

Absolute units	Gravitational units
Joule [S.I.]: Work done is said to be one *Joule*, when 1 *Newton* force displaces the body through 1 *metre* in its own direction. From, $W = F.s$ 1 *Joule* = 1 *Newton* ×1 *m*	*kg-m* [S.I.]: 1 *kg-m* of work is done when a force of 1*kg-wt.* displaces the body through 1*m* in its own direction. From $W = F\,s$ 1 *kg-m* = 1 *kg-wt* × 1 *m* = 9.81 *N* × 1 *metre* = 9.81 *Joule*
erg [C.G.S.] : Work done is said to be one *erg* when 1 *dyne* force displaces the body through 1 *cm* in its own direction. From $W = F\,s$ $1\,erg = 1 dyne \times 1 cm$ **Relation between Joule and erg** 1 *Joule* = 1 *N* × 1 *m* = 10^5 *dyne* × 10^2 *cm* = 10^7 *dyne* × *cm* = 10^7 *erg*	*gm-cm* [C.G.S.] : 1 *gm-cm* of work is done when a force of 1*gm-wt* displaces the body through 1*cm* in its own direction. From $W = F\,s$ 1 *gm-cm* = 1*gm-wt* × 1*cm.* = 981 *dyne* × 1cm = 981 *erg*

Work Done Calculation by Force Displacement Graph

Let a body, whose initial position is x_i, is acted upon by a variable force (whose magnitude is changing continuously) and consequently the body acquires its final position x_f.

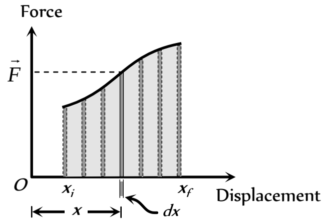


Fig. 6.10

Let F be the average value of variable force within the interval dx from position x to $(x + dx)$ *i.e.* for small displacement dx. The work done will be the area of the shaded strip of width dx. The work done on the body in displacing it from position x_i to x_f will be equal to the sum of areas of all the such strips

$$dW = \vec{F}\,dx$$

$$\therefore W = \int_{x_i}^{x_f} dW = \int_{x_i}^{x_f} F\,dx$$

$$\therefore W = \int_{x_i}^{x_f} (\text{Area of strip of width } dx)$$

$$\therefore W = \text{Area under curve between } x_i \text{ and } x_f$$

i.e. Area under force-displacement curve with proper algebraic sign represents work done by the force.

Work Done in Conservative and Non-conservative Field

(1) In conservative field, work done by the force (line integral of the force *i.e.* $\int \vec{F}.\vec{dl}$) is independent of the path followed between any two points.

$$\underset{\text{Path I}}{W_{A\to B}} = \underset{\text{Path II}}{W_{A\to B}} = \underset{\text{Path III}}{W_{A\to B}}$$

or $$\underset{\text{Path I}}{\int \vec{F}.\vec{dl}} = \underset{\text{Path II}}{\int \vec{F}.\vec{dl}} = \underset{\text{Path III}}{\int \vec{F}.\vec{dl}}$$

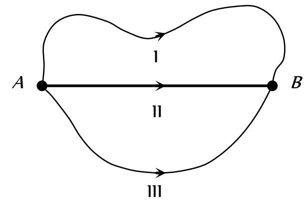


Fig. 6.11

(2) In conservative field work done by the force (line integral of the force *i.e.* $\int \vec{F}.\vec{dl}$) over a closed path/loop is zero.

$$W_{A\to B} + W_{B\to A} = 0$$

or $$\oint \vec{F}.\vec{dl} = 0$$

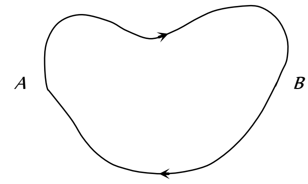


Fig. 6.12

Conservative force : The forces of these type of fields are known as conservative forces.

Example : Electrostatic forces, gravitational forces, elastic forces, magnetic forces *etc* and all the central forces are conservative in nature.

If a body of mass m lifted to height h from the ground level by different path as shown in the figure

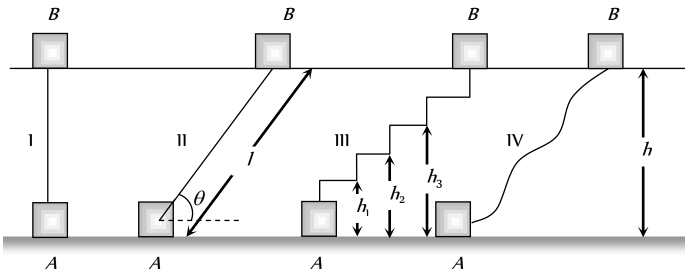


Fig. 6.13

Work done through different paths

$$W_I = F.s = mg \times h = mgh$$

$$W_{II} = F.s = mg\sin\theta \times l = mg\sin\theta \times \frac{h}{\sin\theta} = mgh$$

$$W_{III} = mgh_1 + 0 + mgh_2 + 0 + mgh_3 + 0 + mgh_4$$

$$= mg(h_1 + h_2 + h_3 + h_4) = mgh$$

$$W_{IV} = \int \vec{F}.\vec{ds} = mgh$$

It is clear that $W_I = W_{II} = W_{III} = W_{IV} = mgh$.

Further if the body is brought back to its initial position A, similar amount of work (energy) is released from the system, it means $W_{AB} = mgh$ and $W_{BA} = -mgh$.

Hence the net work done against gravity over a round trip is zero.

$$W_{Net} = W_{AB} + W_{BA} = mgh + (-mgh) = 0$$

i.e. the gravitational force is conservative in nature.

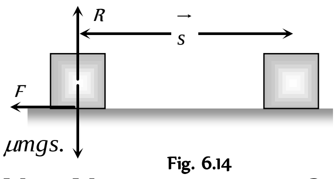
Non-conservative forces : A force is said to be non-conservative if work done by or against the force in moving a body from one position to another, depends on the path followed between these two positions and for complete cycle this work done can never be zero.

Example: Frictional force, Viscous force, Airdrag *etc.*

If a body is moved from position *A* to another position *B* on a rough table, work done against frictional force shall depend on the length of the path between *A* and *B* and not only on the position *A* and *B*.

$$W_{AB} = \mu mgs$$

Further if the body is brought back to its initial position *A*, work has to be done against the frictional force, which opposes the motion. Hence the net work done against the friction over a round trip is not zero.



$W_{BA} = \mu mgs.$

Fig. 6.14

$\therefore W_{Net} = W_{AB} + W_{BA} = \mu mgs + \mu mgs = 2\mu mgs \neq 0.$

i.e. the friction is a non-conservative force.

Work Depends on Frame of Reference

With change of frame of reference (inertial), force does not change while displacement may change. So the work done by a force will be different in different frames.

Examples : (1) If a porter with a suitcase on his head moves up a staircase, work done by the upward lifting force relative to him will be zero (as displacement relative to him is zero) while relative to a person on the ground will be *mgh*.

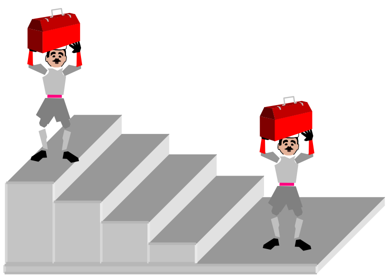


Fig. 6.15

(2) If a person is pushing a box inside a moving train, the work done in the frame of train will $\vec{F}.\vec{s}$ while in the frame of earth will be $\vec{F}.(\vec{s} + \vec{s}_0)$ where $\vec{s}_0$ is the displacement of the train relative to the ground.

Energy

The energy of a body is defined as its capacity for doing work.

(1) Since energy of a body is the total quantity of work done, therefore it is a scalar quantity.

(2) Dimension: $[ML^2T^{-2}]$ it is same as that of work or torque.

(3) Units : *Joule* [S.I.], *erg* [C.G.S.]

Practical units : *electron volt* (*eV*), Kilowatt hour (*KWh*), Calories (*cal*)

Relation between different units:

1 *Joule* = 10^7 *erg*

1 *eV* = 1.6×10^{-19} *Joule*

1 *kWh* = 3.6×10^6 *Joule*

1 *calorie* = 4.18 *Joule*

(4) Mass energy equivalence : Einstein's special theory of relativity shows that material particle itself is a form of energy.

The relation between the mass of a particle *m* and its equivalent energy is given as

$E = mc^2$ where *c* = velocity of light in vacuum.

If $m = 1\, amu = 1.67 \times 10^{-27}\, kg$

then $E = 931\, MeV = 1.5 \times 10^{-10}\, Joule$.

If $m = 1 kg$ then $E = 9 \times 10^{16}\, Joule$

Examples : (i) Annihilation of matter when an electron (e^-) and a positron (e^+) combine with each other, they annihilate or destroy each other. The masses of electron and positron are converted into energy. This energy is released in the form of γ -rays.

$$e^- + e^+ \rightarrow \gamma + \gamma$$

Each γ photon has energy = 0.51 *MeV*.

Here two γ photons are emitted instead of one γ photon to conserve the linear momentum.

(ii) Pair production : This process is the reverse of annihilation of matter. In this case, a photon (γ) having energy equal to 1.02 *MeV* interacts with a nucleus and give rise to electron (e^-) and positron (e^+). Thus energy is converted into matter.

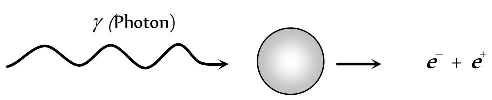


Fig. 6.16

(iii) Nuclear bomb : When the nucleus is split up due to mass defect (The difference in the mass of nucleons and the nucleus), energy is released in the form of γ -radiations and heat.

(5) Various forms of energy

(i) Mechanical energy (Kinetic and Potential)

(ii) Chemical energy

(iii) Electrical energy

(iv) Magnetic energy

(v) Nuclear energy

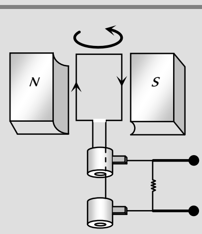
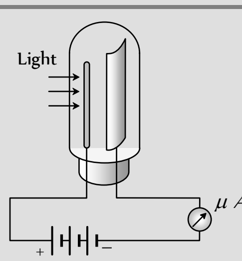
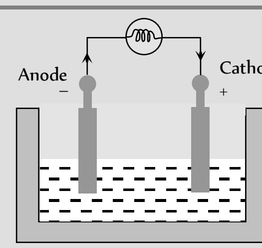
(vi) Sound energy

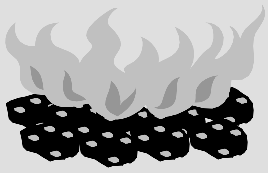
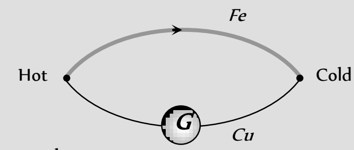
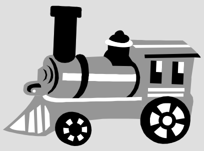
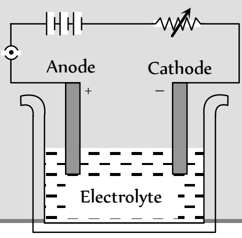
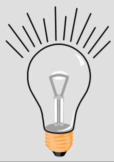
(vii) Light energy

(viii) Heat energy

(6) Transformation of energy : Conversion of energy from one form to another is possible through various devices and processes.

Table : 6.1 Various devices for energy conversion from one form to another

Mechanical → electrical	Light → Electrical	Chemical → electrical
Dynamo 	Photoelectric cell 	Primary cell 

Chemical → heat	Sound → Electrical	Heat → electrical
 Coal Burning	 Microphone	 Thermo-couple
Heat → Mechanical	**Electrical → Mechanical**	**Electrical → Heat**
 Engine	 Motor	 Heater
Electrical → Sound	**Electrical → Chemical**	**Electrical → Light**
 Speaker	 Voltameter	 Bulb

Kinetic Energy

The energy possessed by a body by virtue of its motion, is called kinetic energy.

Examples : (i) Flowing water possesses kinetic energy which is used to run the water mills.

(ii) Moving vehicle possesses kinetic energy.

(iii) Moving air (*i.e.* wind) possesses kinetic energy which is used to run wind mills.

(iv) The hammer possesses kinetic energy which is used to drive the nails in wood.

(v) A bullet fired from the gun has kinetic energy and due to this energy the bullet penetrates into a target.

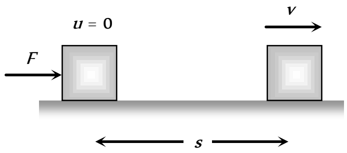


Fig. 6.17

(1) **Expression for kinetic energy :**

Let m = mass of the body,

u = Initial velocity of the body (= 0)

F = Force acting on the body,

a = Acceleration of the body,

s = Distance travelled by the body,

v = Final velocity of the body

From $v^2 = u^2 + 2as$

$$\Rightarrow v^2 = 0 + 2as \quad \therefore s = \frac{v^2}{2a}$$

Since the displacement of the body is in the direction of the applied force, then work done by the force is

$$W = F \times s = ma \times \frac{v^2}{2a}$$

$$\Rightarrow W = \frac{1}{2}mv^2$$

This work done appears as the kinetic energy of the body $KE = W = \frac{1}{2}mv^2$

(2) **Calculus method :** Let a body is initially at rest and force $\vec{F}$ is applied on the body to displace it through small displacement $d\vec{s}$ along its own direction then small work done

$$dW = \vec{F}.d\vec{s} = F\,ds$$

$$\Rightarrow \quad dW = m\,a\,ds \qquad [\text{As } F = ma]$$

$$\Rightarrow \quad dW = m\frac{dv}{dt}ds \qquad \left[\text{As } a = \frac{dv}{dt}\right]$$

$$\Rightarrow dW = mdv.\frac{ds}{dt}$$

$$\Rightarrow dW = m\,v\,dv \qquad ...(i)$$

$$\left[As\ \frac{ds}{dt}=v\right]$$

Therefore work done on the body in order to increase its velocity from zero to v is given by

$$W=\int_0^v mv\,dv=m\int_0^v v\,dv=m\left[\frac{v^2}{2}\right]_0^v=\frac{1}{2}mv^2$$

This work done appears as the kinetic energy of the body $KE=\frac{1}{2}mv^2$.

In vector form $KE=\frac{1}{2}m(\vec{v}.\vec{v})$

As m and $\vec{v}.\vec{v}$ are always positive, kinetic energy is always positive scalar *i.e.* kinetic energy can never be negative.

(3) **Kinetic energy depends on frame of reference :** The kinetic energy of a person of mass m, sitting in a train moving with speed v, is zero in the frame of train but $\frac{1}{2}mv^2$ in the frame of the earth.

(4) **Kinetic energy according to relativity :** As we know $E=\frac{1}{2}mv^2$.

But this formula is valid only for ($v << c$) If v is comparable to c (speed of light in free space = $3\times10^8\ m/s$) then according to Einstein theory of relativity

$$E=\frac{mc^2}{\sqrt{1-(v^2/c^2)}}-mc^2$$

(5) **Work-energy theorem:** From equation (i) $dW=mv\,dv$.

Work done on the body in order to increase its velocity from u to v is given by

$$W=\int_u^v mv\,dv=m\int_u^v v\,dv=m\left[\frac{v^2}{2}\right]_u^v$$

$$\Rightarrow W=\frac{1}{2}m[v^2-u^2]$$

Work done = change in kinetic energy

$W=\Delta E$

This is work energy theorem, it states that work done by a force acting on a body is equal to the change in the kinetic energy of the body.

This theorem is valid for a system in presence of all types of forces (external or internal, conservative or non-conservative).

If kinetic energy of the body increases, work is positive *i.e.* body moves in the direction of the force (or field) and if kinetic energy decreases, work will be negative and object will move opposite to the force (or field).

Examples : (i) In case of vertical motion of body under gravity when the body is projected up, force of gravity is opposite to motion and so kinetic energy of the body decreases and when it falls down, force of gravity is in the direction of motion so kinetic energy increases.

(ii) When a body moves on a rough horizontal surface, as force of friction acts opposite to motion, kinetic energy will decrease and the decrease in kinetic energy is equal to the work done against friction.

(6) **Relation of kinetic energy with linear momentum:** As we know

$$E=\frac{1}{2}mv^2=\frac{1}{2}\left[\frac{P}{v}\right]v^2 \qquad [\text{As } P=mv]$$

$$\therefore\ E=\frac{1}{2}Pv$$

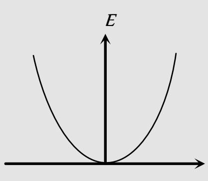
or $$E=\frac{P^2}{2m} \qquad \left[\text{As } v=\frac{P}{m}\right]$$

So we can say that kinetic energy $E=\frac{1}{2}mv^2=\frac{1}{2}Pv=\frac{p^2}{2m}$

and Momentum $P=\frac{2E}{v}=\sqrt{2mE}$

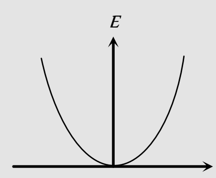
From above relation it is clear that a body can not have kinetic energy without having momentum and vice-versa.

(7) **Various graphs of kinetic energy**



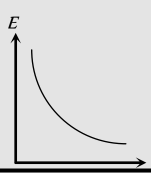
$E\propto v$

m = constant



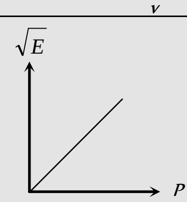
$E\propto P^2$

m = constant



$E\propto\frac{1}{m}$

P = constant



$P\propto\sqrt{E}$

m = constant

Stopping of Vehicle by Retarding Force

If a vehicle moves with initial velocity and due to some retarding force it stops after covering some distance after some time.

(1) **Stopping distance :** Let m = Mass of vehicle,

v = Velocity, P = Momentum, E = Kinetic energy

F = Stopping force, x = Stopping distance,

t = Stopping time

Then, in this process stopping force does work on the vehicle and destroy the motion.

By the work- energy theorem

$$W = \Delta K = \frac{1}{2}mv^2$$

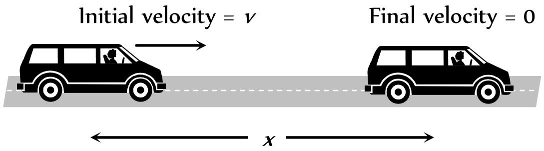


Fig. 6.18

$\Rightarrow$ Stopping force (F) × Distance (x) = Kinetic energy (E)

$\Rightarrow$ Stopping distance $(x) = \dfrac{\text{Kinetic energy } (E)}{\text{Stopping force } (F)}$

$$\Rightarrow x = \frac{mv^2}{2F} \quad ...(i)$$

(2) **Stopping time :** By the impulse-momentum theorem

$$F \times \Delta t = \Delta P \Rightarrow F \times t = P$$

$$\therefore t = \frac{P}{F}$$

$$\text{or } t = \frac{mv}{F} \quad ...(ii)$$

(3) **Comparison of stopping distance and time for two vehicles :** Two vehicles of masses m_1 and m_2 are moving with velocities v_1 and v_2 respectively. When they are stopped by the same retarding force (F).

The ratio of their stopping distances $\dfrac{x_1}{x_2} = \dfrac{E_1}{E_2} = \dfrac{m_1 v_1^2}{m_2 v_2^2}$

and the ratio of their stopping time $\dfrac{t_1}{t_2} = \dfrac{P_1}{P_2} = \dfrac{m_1 v_1}{m_2 v_2}$

(i) If vehicles possess same velocities

$v_1 = v_2$

$$\frac{x_1}{x_2} = \frac{m_1}{m_2} \;;\; \frac{t_1}{t_2} = \frac{m_1}{m_2}$$

(ii) If vehicle possess same kinetic momentum

$P_1 = P_2$

$$\frac{x_1}{x_2} = \frac{E_1}{E_2} = \left(\frac{P_1^2}{2m_1}\right)\left(\frac{2m_2}{P_2^2}\right) = \frac{m_2}{m_1}$$

$$\frac{t_1}{t_2} = \frac{P_1}{P_2} = 1$$

(iii) If vehicle possess same kinetic energy

$$\frac{x_1}{x_2} = \frac{E_1}{E_2} = 1$$

$$\frac{t_1}{t_2} = \frac{P_1}{P_2} = \frac{\sqrt{2m_1E_1}}{\sqrt{2m_2E_2}} = \sqrt{\frac{m_1}{m_2}}$$

Note : If vehicle is stopped by friction then

Stopping distance $x = \dfrac{\frac{1}{2}mv^2}{F} = \dfrac{\frac{1}{2}mv^2}{ma} = \dfrac{v^2}{2\mu g}$

[As $a = \mu g$]

Stopping time $t = \dfrac{mv}{F} = \dfrac{mv}{m\mu g} = \dfrac{v}{\mu g}$

Potential Energy

Potential energy is defined only for conservative forces. In the space occupied by conservative forces every point is associated with certain energy which is called the energy of position or potential energy. Potential energy generally are of three types : Elastic potential energy, Electric potential energy and Gravitational potential energy.

(1) **Change in potential energy :** Change in potential energy between any two points is defined in the terms of the work done by the associated conservative force in displacing the particle between these two points without any change in kinetic energy.

$$U_2 - U_1 = -\int_{r_1}^{r_2} \vec{F}.d\vec{r} = -W \quad ...(i)$$

We can define a unique value of potential energy only by assigning some arbitrary value to a fixed point called the reference point. Whenever and wherever possible, we take the reference point at infinity and assume potential energy to be zero there, *i.e.* if we take $r_1 = \infty$ and $r_2 = r$ then from equation (i)

$$U = -\int_{\infty}^{r} \vec{F}.d\vec{r} = -W$$

In case of conservative force (field) potential energy is equal to negative of work done by conservative force in shifting the body from reference position to given position.

This is why, in shifting a particle in a conservative field (say gravitational or electric), if the particle moves opposite to the field, work done by the field will be negative and so change in potential energy will be positive *i.e.* potential energy will increase. When the particle moves in the direction of field, work will be positive and change in potential energy will be negative *i.e.* potential energy will decrease.

(2) **Three dimensional formula for potential energy:** For only conservative fields $\vec{F}$ equals the negative gradient $(-\vec{\nabla})$ of the potential energy.

So $\vec{F} = -\vec{\nabla} U$ ($\vec{\nabla}$ read as Del operator or Nabla operator and $\vec{\nabla} = \frac{\partial}{\partial x}\hat{i} + \frac{\partial}{\partial y}\hat{j} + \frac{\partial}{\partial z}\hat{k}$)

$$\Rightarrow \vec{F} = -\left[\frac{\partial U}{\partial x}\hat{i} + \frac{\partial U}{\partial y}\hat{j} + \frac{\partial U}{\partial z}\hat{k}\right]$$

where,

$\dfrac{\partial U}{\partial x}$ = Partial derivative of U *w.r.t.* x (keeping y and z constant)

$\dfrac{\partial U}{\partial y}$ = Partial derivative of U *w.r.t.* y (keeping x and z constant)

$\dfrac{\partial U}{\partial z}$ = Partial derivative of U *w.r.t.* z (keeping x and y constant)

(3) **Potential energy curve :** A graph plotted between the potential energy of a particle and its displacement from the centre of force is called potential energy curve.

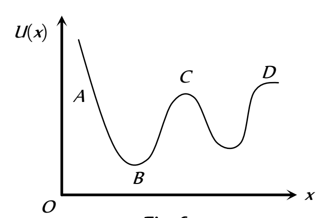


Fig. 6.19

Figure shows a graph of potential energy function $U(x)$ for one dimensional motion.

As we know that negative gradient of the potential energy gives force.

$$\therefore\ -\frac{dU}{dx} = F$$

(4) **Nature of force**

(i) Attractive force :

On increasing x, if U increases,

$\frac{dU}{dx} = \text{positive}$, then F is in negative direction

i.e. force is attractive in nature.

In graph this is represented in region BC.

(ii) Repulsive force :

On increasing x, if U decreases,

$\frac{dU}{dx} = \text{negative}$, then F is in positive direction

i.e. force is repulsive in nature.

In graph this is represented in region AB.

(iii) Zero force :

On increasing x, if U does not change,

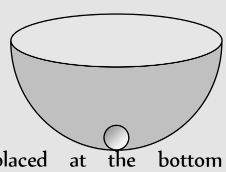
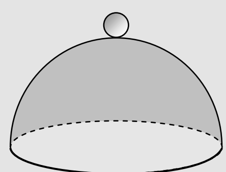
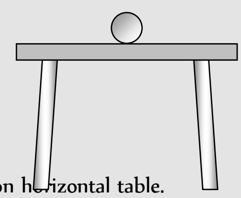
$\frac{dU}{dx} = 0$ then F is zero

i.e. no force works on the particle.

Point B, C and D represents the point of zero force or these points can be termed as position of equilibrium.

(5) **Types of equilibrium :** If net force acting on a particle is zero, it is said to be in equilibrium.

For equilibrium $\frac{dU}{dx} = 0$, but the equilibrium of particle can be of three types :

Stable	Unstable	Neutral
When a particle is displaced slightly from its present position, then a force acting on it brings it back to the initial position, it is said to be in stable equilibrium position.	When a particle is displaced slightly from its present position, then a force acting on it tries to displace the particle further away from the equilibrium position, it is said to be in unstable equilibrium.	When a particle is slightly displaced from its position then it does not experience any force acting on it and continues to be in equilibrium in the displaced position, it is said to be in neutral equilibrium.
Potential energy is minimum.	Potential energy is maximum.	Potential energy is constant.
$F = -\frac{dU}{dx} = 0$	$F = -\frac{dU}{dx} = 0$	$F = -\frac{dU}{dx} = 0$
$\frac{d^2U}{dx^2} = \text{positive}$ *i.e.* rate of change of $\frac{dU}{dx}$ is positive.	$\frac{d^2U}{dx^2} = \text{negative}$ *i.e.* rate of change of $\frac{dU}{dx}$ is negative.	$\frac{d^2U}{dx^2} = 0$ *i.e.* rate of change of $\frac{dU}{dx}$ is zero.
Example :  A marble placed at the bottom of a hemispherical bowl.	*Example* :  A marble balanced on top of a hemispherical bowl.	*Example* :  A marble placed on horizontal table.

Elastic Potential Energy

(1) **Restoring force and spring constant :** When a spring is stretched or compressed from its normal position ($x = 0$) by a small distance x, then a restoring force is produced in the spring to bring it to the normal position.

According to Hooke's law this restoring force is proportional to the displacement x and its direction is always opposite to the displacement.

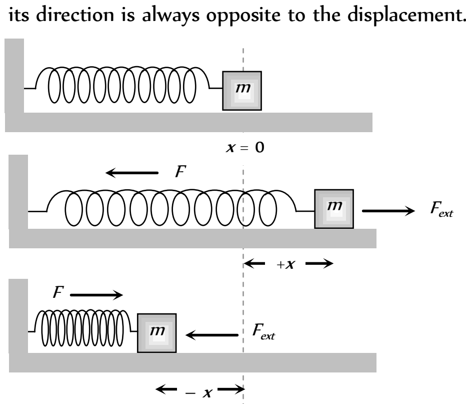


Fig. 6.20

i.e. $\vec{F} \propto -\vec{x}$

or $\vec{F} = -k\,\vec{x}$ ...(i)

where k is called spring constant.

If $x = 1$, $F = k$ (Numerically)

or $k = F$

Hence spring constant is numerically equal to force required to produce unit displacement (compression or extension) in the spring. If required force is more, then spring is said to be more stiff and vice-versa.

Actually k is a measure of the stiffness/softness of the spring.

Dimension : As $k = \frac{F}{x}$

$\therefore\ [k] = \frac{[F]}{[x]} = \frac{[MLT^{-2}]}{L} = [MT^{-2}]$

Units : S.I. unit *Newton/metre*, C.G.S unit *Dyne/cm*.

Note : ❑ Dimension of force constant is similar to surface tension.

(2) **Expression for elastic potential energy :** When a spring is stretched or compressed from its normal position ($x = 0$), work has to be done by external force against restoring force. $\vec{F}_{ext} = -\vec{F}_{restoring} = k\vec{x}$

Let the spring is further stretched through the distance dx, then work done

$$dW = \vec{F}_{ext}.d\vec{x} = F_{ext}.dx\cos 0^o = kx\,dx \quad [\text{As } \cos 0^o = 1]$$

Therefore total work done to stretch the spring through a distance x from its mean position is given by

$$W = \int_0^x dW = \int_0^x kx\,dx = k\left[\frac{x^2}{2}\right]_0^x = \frac{1}{2}kx^2$$

This work done is stored as the potential energy in the stretched spring.

$\therefore$ Elastic potential energy $U = \frac{1}{2}kx^2$

$$U = \frac{1}{2}Fx \qquad \left[\text{As } k = \frac{F}{x}\right]$$

$$U = \frac{F^2}{2k} \qquad \left[\text{As } x = \frac{F}{k}\right]$$

$\therefore$ Elastic potential energy $U = \frac{1}{2}kx^2 = \frac{1}{2}Fx = \frac{F^2}{2k}$

Note : ❑ If spring is stretched from initial position x_1 to final position x_2 then work done

= Increment in elastic potential energy

$= \frac{1}{2}k(x_2^2 - x_1^2)$

❑ Work done by the spring-force on the block in various situation are shown in the following table

Table : 6.2 Work done for spring

Initial state of the spring	Final state of the spring	Initial position (x_1)	Final position (x_2)	Work done (W)
Natural	Compressed	0	$-x$	$-1/2\ kx^2$
Natural	Elongated	0	x	$-1/2\ kx^2$
Elongated	Natural	x	0	$1/2\ kx^2$
Compressed	Natural	$-x$	0	$1/2\ kx^2$
Elongated	Compressed	x	$-x$	0
Compressed	Elongated	$-x$	x	0

(3) **Energy graph for a spring :** If the mass attached with spring performs simple harmonic motion about its mean position then its potential energy at any position (x) can be given by

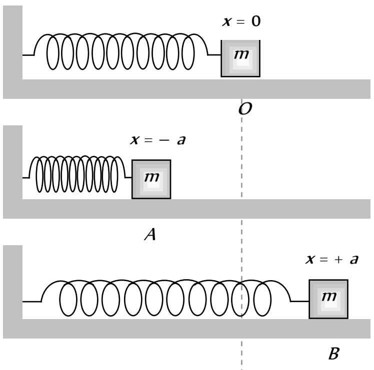


Fig. 6.21

$$U = \frac{1}{2}kx^2 \qquad ...(i)$$

So for the extreme position

$$U = \frac{1}{2}ka^2 \qquad [\text{As } x = \pm a \text{ for extreme}]$$

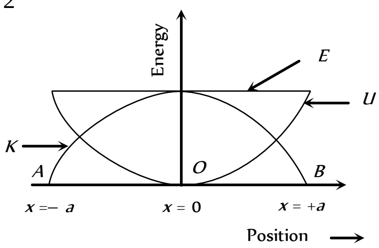


Fig. 6.22

This is maximum potential energy or the total energy of mass.

$\therefore$ Total energy $E = \frac{1}{2}ka^2$ ...(ii)

[Because velocity of mass is zero at extreme position]

$\therefore\ K = \frac{1}{2}mv^2 = 0$]

Now kinetic energy at any position

$$K = E - U = \frac{1}{2}ka^2 - \frac{1}{2}kx^2$$

$$K = \frac{1}{2}k(a^2 - x^2) \qquad ...(iii)$$

From the above formula we can check that

$$U_{max} = \frac{1}{2}ka^2 \qquad \text{[At extreme } x = \pm a]$$

and $$U_{min} = 0 \qquad \text{[At mean } x = 0]$$

$$K_{max} = \frac{1}{2}ka^2 \qquad \text{[At mean } x = 0]$$

and $$K_{min} = 0 \qquad \text{[At extreme } x = \pm a]$$

$$E = \frac{1}{2}ka^2 = \text{constant (at all positions)}$$

It means kinetic energy and potential energy changes parabolically *w.r.t.* position but total energy remain always constant irrespective to position of the mass

Electrical Potential Energy

It is the energy associated with state of separation between charged particles that interact via electric force. For two point charge q_1 and q_2, separated by distance *r*.

$$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r}$$

While for a point charge *q* at a point in an electric field where the potential is *V*

$U = qV$

As charge can be positive or negative, electric potential energy can be positive or negative.

Gravitational Potential Energy

It is the usual form of potential energy and this is the energy associated with the state of separation between two bodies that interact via gravitational force.

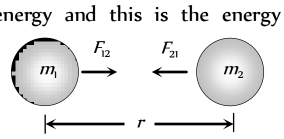


Fig. 6.23

For two particles of masses m_1 and m_2 separated by a distance *r*

Gravitational potential energy $U = -\frac{G m_1 m_2}{r}$

(1) If a body of mass *m* at height *h* relative to surface of earth then

Gravitational potential energy $U = \frac{mgh}{1 + \frac{h}{R}}$

Where *R* = radius of earth, *g* = acceleration due to gravity at the surface of the earth.

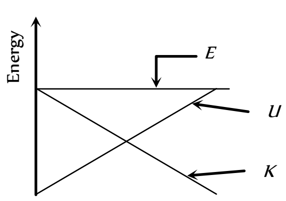
(2) If $h << R$ then above formula reduces to $U = mgh$.

(3) If *V* is the gravitational potential at a point, the potential energy of a particle of mass *m* at that point will be

$U = mV$

(4) Energy height graph : When a body projected vertically upward from the ground level with some initial velocity then it possess kinetic energy but its initial potential energy is zero.

As the body moves upward its potential energy increases due to increase in height but kinetic energy decreases (due to decrease in velocity). At maximum height its kinetic energy becomes zero and potential energy maximum but through out the complete motion, total energy remains constant as shown in the figure.



Work Done in Pulling the Chain Against Gravity

A chain of length *L* and mass *M* is held on a frictionless table with $(1/n)^{th}$ of its length hanging over the edge.

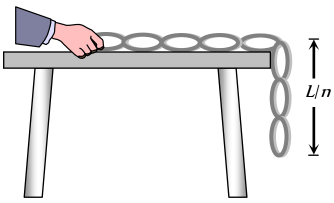


Fig. 6.25

Let $m = \frac{M}{L}$ = mass per unit length of the chain and *y* is the length of the chain hanging over the edge. So the mass of the chain of length *y* will be *ym* and the force acting on it due to gravity will be *mgy*.

The work done in pulling the *dy* length of the chain on the table.

$dW = F(-dy)$ [As *y* is decreasing]

i.e. $dW = mgy\,(-dy)$

So the work done in pulling the hanging portion on the table.

$$W = -\int_{L/n}^{0} mgy\,dy = -mg\left[\frac{y^2}{2}\right]_{L/n}^{0} = \frac{mg\,L^2}{2n^2}$$

$$\therefore \; W = \frac{MgL}{2n^2} \qquad \text{[As } m = M/L]$$

Alternative method :

If point mass *m* is pulled through a height *h* then work done $W = mgh$

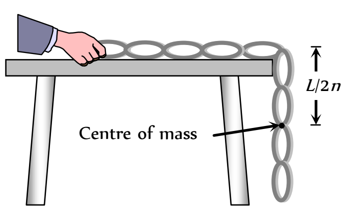


Fig. 6.26

Similarly for a chain we can consider its centre of mass at the middle point of the hanging part *i.e.* at a height of $L/(2n)$ from the lower end and mass of the hanging part of chain $= \frac{M}{n}$

So work done to raise the centre of mass of the chain on the table is given by

$$W = \frac{M}{n} \times g \times \frac{L}{2n} \qquad \text{[As } W = mgh]$$

or $$W = \frac{MgL}{2n^2}$$

Velocity of Chain While Leaving the Table

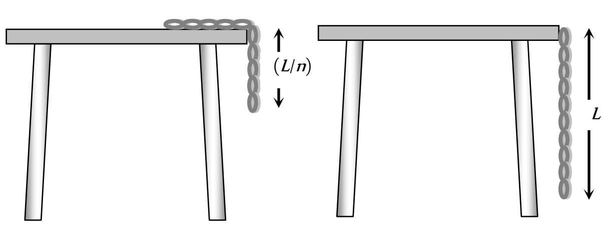


Fig. 6.27

Taking surface of table as a reference level (zero potential energy)

Potential energy of chain when $1/n$ length hanging from the edge $= \frac{-MgL}{2n^2}$

Potential energy of chain when it leaves the table $= -\frac{MgL}{2}$

Kinetic energy of chain = loss in potential energy

$$\Rightarrow \frac{1}{2}Mv^2 = \frac{MgL}{2} - \frac{MgL}{2n^2}$$

$$\Rightarrow \frac{1}{2}Mv^2 = \frac{MgL}{2}\left[1 - \frac{1}{n^2}\right]$$

$\therefore$ Velocity of chain $v = \sqrt{gL\left(1 - \frac{1}{n^2}\right)}$

Law of Conservation of Energy

(1) **Law of conservation of energy**

For a body or an isolated system by work-energy theorem we have

$K_2 - K_1 = \int \vec{F}.d\vec{r}$ ...(i)

But according to definition of potential energy in a conservative field

$U_2 - U_1 = -\int \vec{F}.d\vec{r}$ ...(ii)

So from equation (i) and (ii) we have

$$K_2 - K_1 = -(U_2 - U_1)$$

or $K_2 + U_2 = K_1 + U_1$

i.e. $K + U$ = constant.

For an isolated system or body in presence of conservative forces, the sum of kinetic and potential energies at any point remains constant throughout the motion. It does not depend upon time. This is known as the law of conservation of mechanical energy.

$$\Delta(K + U) = \Delta E = 0$$

[As E is constant in a conservative field]

$\therefore$ $\Delta K + \Delta U = 0$

i.e. if the kinetic energy of the body increases its potential energy will decrease by an equal amount and vice-versa.

(2) **Law of conservation of total energy :** If some non-conservative force like friction is also acting on the particle, the mechanical energy is no more constant. It changes by the amount equal to work done by the frictional force.

$$\Delta(K + U) = \Delta E = W_f$$

[where W_f is the work done against friction]

The lost energy is transformed into heat and the heat energy developed is exactly equal to loss in mechanical energy.

We can, therefore, write $\Delta E + Q = 0$

[where Q is the heat produced]

This shows that if the forces are conservative and non-conservative both, it is not the mechanical energy which is conserved, but it is the total energy, may be heat, light, sound or mechanical *etc.*, which is conserved.

In other words : "*Energy may be transformed from one kind to another but it cannot be created or destroyed. The total energy in an isolated system remain constant*". This is the law of conservation of energy.

Power

Power of a body is defined as the rate at which the body can do the work.

Average power $(P_{av.}) = \frac{\Delta W}{\Delta t} = \frac{W}{t}$

Instantaneous power $(P_{inst.}) = \frac{dW}{dt} = \frac{\vec{F}.d\vec{s}}{dt}$ [As $dW = \vec{F}.d\vec{s}$]

$P_{inst} = \vec{F}.\vec{v}$ [As $\vec{v} = \frac{d\vec{s}}{dt}$]

i.e. power is equal to the scalar product of force with velocity.

Important Points

(1) Dimension : $[P] = [F][v] = [MLT^{-2}][LT^{-1}]$

$\therefore$ $[P] = [ML^2T^{-3}]$

(2) Units : *Watt* or *Joule/sec* [S.I.]

Erg/sec [C.G.S.]

Practical units : *Kilowatt* (*KW*), *Mega watt* (*MW*) and Horse power (*hp*)

Relations between different units :

$1\,Watt = 1\,Joule/\sec = 10^7\,erg/\sec$

$1hp = 746\,Watt$

$1\,MW = 10^6\,Watt$

$1\,KW = 10^3\,Watt$

(3) If work done by the two bodies is same then power $\propto \frac{1}{\text{time}}$

i.e. the body which perform the given work in lesser time possess more power and vice-versa.

(4) As power = work/time, any unit of power multiplied by a unit of time gives unit of work (or energy) and not power, *i.e.* Kilowatt-hour or watt-day are units of work or energy.

$$1\,KWh = 10^3\frac{J}{sec} \times (60 \times 60 sec) = 3.6 \times 10^6\ Joule$$

(5) The slope of work time curve gives the instantaneous power. As $P = dW/dt = \tan\theta$

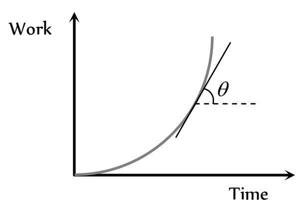


Fig. 6.28

(6) Area under power-time curve gives the work done as $P = \frac{dW}{dt}$

$\therefore$ $W = \int P\,dt$

$\therefore$ W = Area under P-t curve

Position and Velocity of an Automobile w.r.t Time

An automobile of mass m accelerates, starting from rest, while the engine supplies constant power P, its position and velocity changes *w.r.t* time.

(1) **Velocity :** As $Fv = P$ = constant

i.e. $m\frac{dv}{dt}v = P$ $\left[\text{As } F = \frac{mdv}{dt}\right]$

or $\int v\,dv = \int \frac{P}{m} dt$

By integrating both sides we get $\frac{v^2}{2} = \frac{P}{m} t + C_1$

As initially the body is at rest *i.e.* $v = 0$ at $t = 0$, so $C_1 = 0$

$\therefore \; v = \left(\frac{2Pt}{m}\right)^{1/2}$

(2) **Position :** From the above expression $v = \left(\frac{2Pt}{m}\right)^{1/2}$

or $\frac{ds}{dt} = \left(\frac{2Pt}{m}\right)^{1/2}$ $\qquad \left[\text{As}\, v = \frac{ds}{dt}\right]$

i.e. $\int ds = \int \left(\frac{2Pt}{m}\right)^{1/2} dt$

By integrating both sides we get

$$s = \left(\frac{2P}{m}\right)^{1/2} . \frac{2}{3} t^{3/2} + C_2$$

Now as at $t = 0$, $s = 0$, so $C_2 = 0$

$$s = \left(\frac{8P}{9m}\right)^{1/2} t^{3/2}$$

Collision

Collision is an isolated event in which a strong force acts between two or more bodies for a short time as a result of which the energy and momentum of the interacting particle change.

In collision particles may or may not come in real touch e.g. in collision between two billiard balls or a ball and bat, there is physical contact while in collision of alpha particle by a nucleus (*i.e.* Rutherford scattering experiment) there is no physical contact.

(1) **Stages of collision :** There are three distinct identifiable stages in collision, namely, before, during and after. In the before and after stage the interaction forces are zero. Between these two stages, the interaction forces are very large and often the dominating forces governing the motion of bodies. The magnitude of the interacting force is often unknown, therefore, Newton's second law cannot be used, the law of conservation of momentum is useful in relating the initial and final velocities.

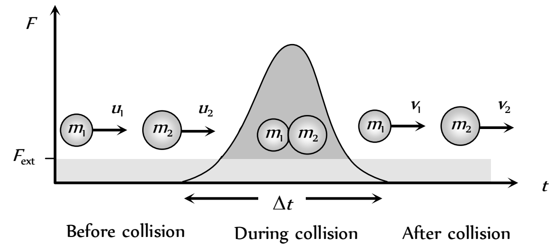


Fig. 6.29

(2) **Momentum and ene[illegible]n in collision**

(i) Momentum conservation : In a collision, the effect of external forces such as gravity or friction are not taken into account as due to small duration of collision (Δt) average impulsive force responsible for collision is much larger than external force acting on the system and since this impulsive force is 'Internal' therefore the total momentum of system always remains conserved.

(ii) Energy conservation : In a collision 'total energy' is also always conserved. Here total energy includes all forms of energy such as mechanical energy, internal energy, excitation energy, radiant energy or even mass energy.

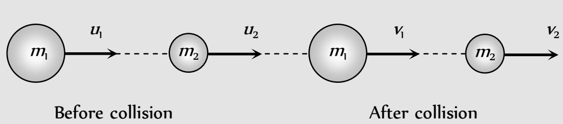
These laws are the fundamental laws of physics and applicable for any type of collision but this is not true for conservation of kinetic energy.

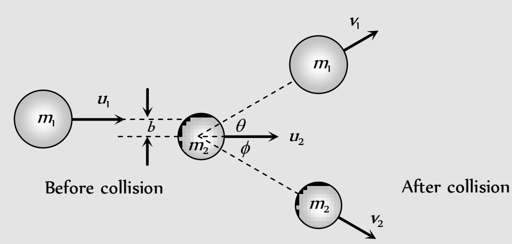
(3) **Types of collision :** (i) On the basis of conservation of kinetic energy.

Perfectly elastic collision	Inelastic collision	Perfectly inelastic collision
If in a collision, kinetic energy after collision is equal to kinetic energy before collision, the collision is said to be perfectly elastic.	If in a collision kinetic energy after collision is not equal to kinetic energy before collision, the collision is said to inelastic.	If in a collision two bodies stick together or move with same velocity after the collision, the collision is said to be perfectly inelastic.
Coefficient of restitution $e = 1$	Coefficient of restitution $0 < e < 1$	Coefficient of restitution $e = 0$
$(KE)_{final} = (KE)_{initial}$	Here kinetic energy appears in other forms. In some cases $(KE)_{final} < (KE)_{initial}$ such as when initial KE is converted into internal energy of the product (as heat, elastic or excitation) while in other cases $(KE)_{final} > (KE)_{initial}$ such as when internal energy stored in the colliding particles is released	The term 'perfectly inelastic' does not necessarily mean that all the initial kinetic energy is lost, it implies that the loss in kinetic energy is as large as it can be. (Consistent with momentum conservation).
Examples : (1) Collision between atomic particles (2) Bouncing of ball with same velocity after the collision with earth.	*Examples* : (1) Collision between two billiard balls. (2) Collision between two automobile on a road. In fact all majority of collision belong to this category.	*Example* : Collision between a bullet and a block of wood into which it is fired. When the bullet remains embedded in the block.

(ii) On the basis of the direction of colliding bodies

Head on or one dimensional collision	Oblique collision
In a collision if the motion of colliding particles before and after the collision is along the same line, the collision is said to be head on or one dimensional.	If two particle collision is 'glancing' *i.e.* such that their directions of motion after collision are not along the initial line of motion, the collision is called oblique. If in oblique collision the particles before and after collision are in same plane, the collision is called 2-dimensional otherwise 3-dimensional.
Impact parameter b is zero for this type of collision.	Impact parameter b lies between 0 and $(r_1 + r_2)$ *i.e.* $0 < b < (r_1 + r_2)$ where r_1 and r_2 are radii of colliding bodies.

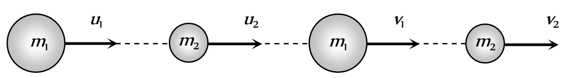




Example : collision of two gliders on an air track.	*Example* : Collision of billiard balls.

Perfectly elastic head on collision

Let two bodies of masses m_1 and m_2 moving with initial velocities u_1 and u_2 in the same direction and they collide such that after collision their final velocities are v_1 and v_2 respectively.



Before collision   After collision

Fig. 6.30

According to law of conservation of momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \quad \text{... (i)}$$

$$\Rightarrow m_1(u_1 - v_1) = m_2(v_2 - u_2) \quad \text{...(ii)}$$

According to law of conservation of kinetic energy

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \quad \text{...(iii)}$$

$$\Rightarrow m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2) \quad \text{...(iv)}$$

Dividing equation (iv) by equation (ii)

$$v_1 + u_1 = v_2 + u_2 \quad \text{...(v)}$$

$$\Rightarrow u_1 - u_2 = v_2 - v_1 \quad \text{...(vi)}$$

Relative velocity of separation is equal to relative velocity of approach.

Note : ❑ The ratio of relative velocity of separation and relative velocity of approach is defined as coefficient of restitution.

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

or $v_2 - v_1 = e(u_1 - u_2)$

❑ For perfectly elastic collision, $e = 1$

$\therefore v_2 - v_1 = u_1 - u_2$ [As shown in eq. (vi)]

❑ For perfectly inelastic collision, $e = 0$

$\therefore v_2 - v_1 = 0$ or $v_2 = v_1$

It means that two body stick together and move with same velocity.

❑ For inelastic collision, $0 < e < 1$

$\therefore v_2 - v_1 = e(u_1 - u_2)$

In short we can say that e is the degree of elasticity of collision and it is dimensionless quantity.

Further from equation (v) we get

$$v_2 = v_1 + u_1 - u_2$$

Substituting this value of v_2 in equation (i) and rearranging

we get, $$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2} \quad \text{...(vii)}$$

Similarly we get,

$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2} \quad \text{...(viii)}$$

(1) **Special cases of head on elastic collision**

(i) **If projectile and target are of same mass *i.e.* $m_1 = m_2$**

Since $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2}{m_1 + m_2}u_2$ and $v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2}$

Substituting $m_1 = m_2$ we get

$v_1 = u_2$ and $v_2 = u_1$

It means when two bodies of equal masses undergo head on elastic collision, their velocities get interchanged.

Example : Collision of two billiard balls

Before collision   After collision

Sub case : $u_2 = 0$ *i.e.* target is at rest

$v_1 = 0$ and $v_2 = u_1$

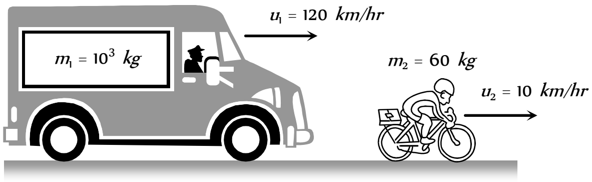
(ii) **If massive projectile collides with a light target *i.e.* $m_1 >> m_2$**

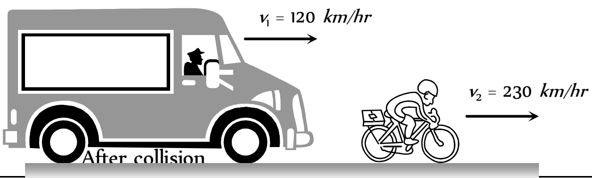
Since $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$ and $v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2}$

Substituting $m_2 = 0$, we get

$v_1 = u_1$ and $v_2 = 2u_1 - u_2$

Example : Collision of a truck with a cyclist





Sub case : $u_2 = 0$ i.e. target is at rest

$v_1 = u_1$ and $v_2 = 2u_1$

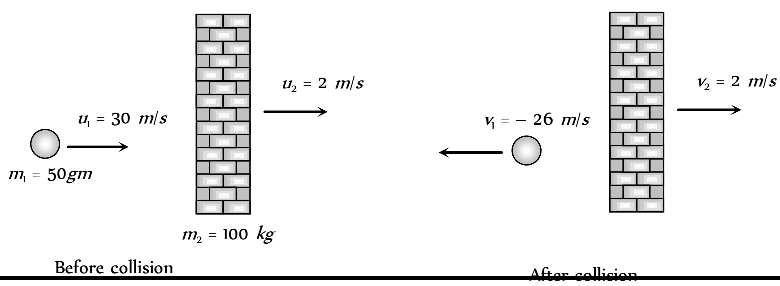
(iii) **If light projectile collides with a very heavy target *i.e.* $m_1 << m_2$**

Since $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$ and $v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2}$

Substituting $m_1 = 0$, we get

$v_1 = -u_1 + 2u_2$ and $v_2 = u_2$

Example : Collision of a ball with a massive wall.



Sub case : $u_2 = 0$ i.e. target is at rest

$v_1 = -u_1$ and $v_2 = 0$

i.e. the ball rebounds with same speed in opposite direction when it collide with stationary and very massive wall.

(2) **Kinetic energy transfer during head on elastic collision**

Kinetic energy of projectile before collision $K_i = \frac{1}{2}m_1u_1^2$

Kinetic energy of projectile after collision $K_f = \frac{1}{2}m_1v_1^2$

Kinetic energy transferred from projectile to target ΔK = decrease in kinetic energy in projectile

$$\Delta K = \frac{1}{2}m_1u_1^2 - \frac{1}{2}m_1v_1^2 = \frac{1}{2}m_1(u_1^2 - v_1^2)$$

Fractional decrease in kinetic energy

$$\frac{\Delta K}{K} = \frac{\frac{1}{2}m_1(u_1^2 - v_1^2)}{\frac{1}{2}m_1u_1^2} = 1 - \left(\frac{v_1}{u_1}\right)^2 \quad \text{...(i)}$$

We can substitute the value of v_1 from the equation

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$$

If the target is at rest *i.e.* $u_2 = 0$ then $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1$

From equation (i) $\frac{\Delta K}{K} = 1 - \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2$ ...(ii)

or $\frac{\Delta K}{K} = \frac{4m_1m_2}{(m_1 + m_2)^2}$ ...(iii)

or $\frac{\Delta K}{K} = \frac{4m_1m_2}{(m_1 - m_2)^2 + 4m_1m_2}$ ...(iv)

Note : ❑ Greater the difference in masses, lesser will be transfer of kinetic energy and vice versa

❑ Transfer of kinetic energy will be maximum when the difference in masses is minimum

i.e. $m_1 - m_2 = 0$ or $m_1 = m_2$ then

$$\frac{\Delta K}{K} = 1 = 100\%$$

So the transfer of kinetic energy in head on elastic collision (when target is at rest) is maximum when the masses of particles are equal i.e. mass ratio is 1 and the transfer of kinetic energy is 100%.

❑ If $m_2 = nm_1$ then from equation (iii) we get

$$\frac{\Delta K}{K} = \frac{4n}{(1+n)^2}$$

❑ Kinetic energy retained by the projectile

$$\left(\frac{\Delta K}{K}\right)_{\text{Retained}} = 1 - \text{kinetic energy transferred by projectile}$$

$$\Rightarrow \left(\frac{\Delta K}{K}\right)_{\text{Retained}} = 1 - \left[1 - \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2\right] = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2$$

(3) **Velocity, momentum and kinetic energy of stationary target after head on elastic collision**

(i) Velocity of target : We know

$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1 u_1}{m_1 + m_2}$$

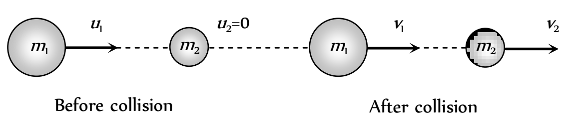


Fig. 6.31

$$\Rightarrow v_2 = \frac{2m_1 u_1}{m_1 + m_2}$$

$$= \frac{2u_1}{1 + m_2/m_1} \quad \text{As } u_2 = 0 \text{ and}$$

Assuming $\frac{m_2}{m_1} = n$

$$\therefore v_2 = \frac{2u_1}{1+n}$$

(ii) Momentum of target : $P_2 = m_2 v_2 = \frac{2nm_1 u_1}{1+n}$

$$\left[\text{As } m_2 = m_1 n \text{ and } v_2 = \frac{2u_1}{1+n}\right]$$

$$\therefore P_2 = \frac{2m_1 u_1}{1 + (1/n)}$$

(iii) Kinetic energy of target :

$$K_2 = \frac{1}{2}m_2 v_2^2 = \frac{1}{2}n m_1\left(\frac{2u_1}{1+n}\right)^2 = \frac{2m_1 u_1^2 n}{(1+n)^2}$$

$$= \frac{4(K_1)n}{(1-n)^2 + 4n} \qquad \left[\text{As } K_1 = \frac{1}{2}m_1 u_1^2\right]$$

(iv) Relation between masses for maximum velocity, momentum and kinetic energy

Velocity	$v_2 = \frac{2u_1}{1+n}$	For v_2 to be maximum n must be minimum *i.e.* $n = \frac{m_2}{m_1} \to 0 \therefore m_2 << m_1$	Target should be very light.
Momentum	$P_2 = \frac{2m_1 u_1}{(1 + 1/n)}$	For P_2 to be maximum, $(1/n)$ must be minimum or n must be maximum. *i.e.* $n = \frac{m_2}{m_1} \to \infty \therefore m_2 >> m_1$	Target should be massive.
Kinetic energy	$K_2 = \frac{4K_1 n}{(1-n)^2 + 4n}$	For K_2 to be maximum $(1-n)^2$ must be minimum. *i.e.* $1 - n = 0 \Rightarrow n = 1 = \frac{m_2}{m_1} \therefore m_2 = m_1$	Target and projectile should be of equal mass.

Perfectly Elastic Oblique Collision

Let two bodies moving as shown in figure.

By law of conservation of momentum

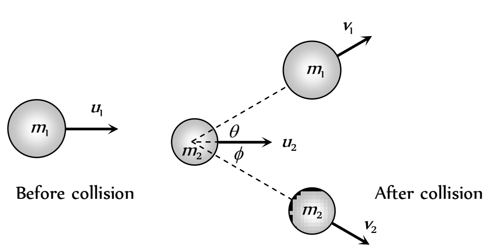


Fig. 6.32

Along x-axis, $m_1 u_1 + m_2 u_2 = m_1 v_1 \cos\theta + m_2 v_2 \cos\phi$ ....(i)

Along y-axis, $0 = m_1 v_1 \sin\theta - m_2 v_2 \sin\phi$ ....(ii)

By law of conservation of kinetic energy

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \quad ...(iii)$$

In case of oblique collision it becomes difficult to solve problem unless some experimental data is provided, as in these situations more unknown variables are involved than equations formed.

Special condition : If $m_1 = m_2$ and $u_2 = 0$ substituting these values in equation (i), (ii) and (iii) we get

$$u_1 = v_1 \cos\theta + v_2 \cos\phi \quad ...(iv)$$

$$0 = v_1 \sin\theta - v_2 \sin\phi \quad ...(v)$$

and $u_1^2 = v_1^2 + v_2^2$ ...(vi)

Squaring (iv) and (v) and adding we get

$$u_1^2 = v_1^2 + v_2^2 + 2v_1v_2\cos(\theta+\phi) \quad ...(vii)$$

Using (vi) and (vii) we get $\cos(\theta+\phi) = 0$

$\therefore\ \theta + \phi = \pi/2$

i.e. after perfectly elastic oblique collision of two bodies of equal masses (if the second body is at rest), the scattering angle $\theta+\phi$ would be 90^o.

Head on Inelastic Collision

(1) **Velocity after collision :** Let two bodies *A* and *B* collide inelastically and coefficient of restitution is *e*.

Where

$$e = \frac{v_2 - v_1}{u_1 - u_2} = \frac{\text{Relative velocity of separation}}{\text{Relative velocity of approach}}$$

$\Rightarrow v_2 - v_1 = e(u_1 - u_2)$

$\therefore\ v_2 - v_1 = e(u_1 - u_2)$ ...(i)

From the law of conservation of linear momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \quad ...(ii)$$

By solving (i) and (ii) we get

$$v_1 = \left(\frac{m_1 - em_2}{m_1 + m_2}\right)u_1 + \left(\frac{(1+e)m_2}{m_1+m_2}\right)u_2$$

Similarly $v_2 = \left[\frac{(1+e)m_1}{m_1+m_2}\right]u_1 + \left(\frac{m_2 - e\,m_1}{m_1+m_2}\right)u_2$

By substituting $e = 1$, we get the value of v_1 and v_2 for perfectly elastic head on collision.

(2) **Ratio of velocities after inelastic collision :** A sphere of mass *m* moving with velocity *u* hits inelastically with another stationary sphere of same mass.

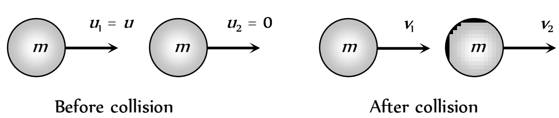


Fig. 6.33

$\therefore\ e = \frac{v_2 - v_1}{u_1 - u_2} = \frac{v_2 - v_1}{u - 0}$

$\Rightarrow\ v_2 - v_1 = eu$ ...(i)

By conservation of momentum :

Momentum before collision = Momentum after collision

$mu = mv_1 + mv_2$

$\Rightarrow v_1 + v_2 = u$ ...(ii)

Solving equation (i) and (ii) we get $v_1 = \frac{u}{2}(1-e)$

and $v_2 = \frac{u}{2}(1+e)$

$\therefore \frac{v_1}{v_2} = \frac{1-e}{1+e}$

(3) **Loss in kinetic energy**

Loss in K.E. (ΔK) = Total initial kinetic energy − Total final kinetic energy

$$= \left(\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2\right) - \left(\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2\right)$$

Substituting the value of v_1 and v_2 from the above expressions

$$\text{Loss } (\Delta K) = \frac{1}{2}\left(\frac{m_1m_2}{m_1+m_2}\right)(1-e^2)(u_1-u_2)^2$$

By substituting $e = 1$ we get $\Delta K = 0$ *i.e.* for perfectly elastic collision, loss of kinetic energy will be zero or kinetic energy remains same before and after the collision.

Rebounding of Ball After Collision With Ground

If a ball is dropped from a height *h* on a horizontal floor, then it strikes with the floor with a speed.

$v_0 = \sqrt{2gh_0}$ [From $v^2 = u^2 + 2gh$]

and it rebounds from the floor with a speed

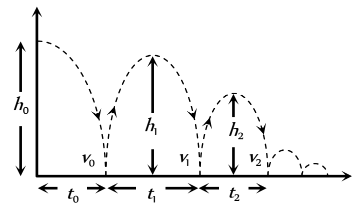


Fig. 6.34

$v_1 = e\,v_0 = e\sqrt{2gh_0}$

$$\left[\text{As } e = \frac{\text{velocity after collision}}{\text{velocity before collision}}\right]$$

(1) **First height of rebound :** $h_1 = \frac{v_1^2}{2g} = e^2h_0$

$\therefore$ h = eh

(2) **Height of the ball after *n* rebound :** Obviously, the velocity of ball after *n* rebound will be

$$v_n = e^n v_0$$

Therefore the height after n rebound will be

$$h_n = \frac{v_n^2}{2g} = e^{2n} h_0$$

$$\therefore\ h_n = e^{2n} h_0$$

(3) **Total distance travelled by the ball before it stops bouncing**

$$H = h_0 + 2h_1 + 2h_2 + 2h_3 + \ldots = h_0 + 2e^2 h_0 + 2e^4 h_0 + 2e^6 h_0 + \ldots$$

$$H = h_0[1 + 2e^2(1 + e^2 + e^4 + e^6 \ldots.)]$$

$$= h_0\left[1 + 2e^2\left(\frac{1}{1-e^2}\right)\right]$$

$$\left[\text{As } 1 + e^2 + e^4 + \ldots. = \frac{1}{1-e^2}\right]$$

$$\therefore\ H = h_0\left[\frac{1+e^2}{1-e^2}\right]$$

(4) **Total time taken by the ball to stop bouncing**

$$T = t_0 + 2t_1 + 2t_2 + 2t_3 + .. = \sqrt{\frac{2h_0}{g}} + 2\sqrt{\frac{2h_1}{g}} + 2\sqrt{\frac{2h_2}{g}} + ..$$

$$= \sqrt{\frac{2h_0}{g}}\ [1 + 2e + 2e^2 + \ldots\ldots] \quad [\text{As } h_1 = e^2 h_0\,;\ h_2 = e^4 h_0\,]$$

$$= \sqrt{\frac{2h_0}{g}}\ [1 + 2e(1 + e + e^2 + e^3 + \ldots\ldots)]$$

$$= \sqrt{\frac{2h_0}{g}}\left[1 + 2e\left(\frac{1}{1-e}\right)\right] = \sqrt{\frac{2h_0}{g}}\left(\frac{1+e}{1-e}\right)$$

$$\therefore\ T = \left(\frac{1+e}{1-e}\right)\sqrt{\frac{2h_0}{g}}$$

Perfectly Inelastic Collision

In such types of collisions, the bodies move independently before collision but after collision as a one single body.

(1) **When the colliding bodies are moving in the same direction**

By the law of conservation of momentum

$$m_1 u_1 + m_2 u_2 = (m_1 + m_2) v_{comb}$$

$$\Rightarrow\ v_{comb} = \frac{m_1 u_1 + m_2 u_2}{m_1 + m_2}$$

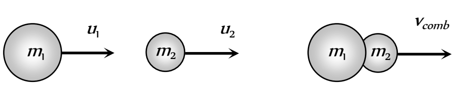


Fig. 6.35

Loss in kinetic energy

$$\Delta K = \left(\frac{1}{2}m_1 u_1^2 + \frac{1}{2}m_2 u_2^2\right) - \frac{1}{2}(m_1 + m_2)v_{comb}^2$$

$$\Delta K = \frac{1}{2}\left(\frac{m_1 m_2}{m_1 + m_2}\right)(u_1 - u_2)^2$$

[By substituting the value of v_{comb}]

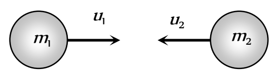
(2) **When the colliding bodies are moving in the opposite direction**

By the law of conservation of momentum

$$m_1 u_1 + m_2(-u_2) = (m_1 + m_2) v_{comb}$$

(Taking left to right as positive)

$$\therefore\ v_{comb} = \frac{m_1 u_1 - m_2 u_2}{m_1 + m_2}$$



Before collision

Fig. 3.36

when $m_1 u_1 > m_2 u_2$ then $v_{comb} > 0$ (positive)

i.e. the combined body will move along the direction of motion of mass m_1.

when $m_1 u_1 < m_2 u_2$ then $v_{comb} < 0$ (negative)

i.e. the combined body will move in a direction opposite to the motion of mass m_1.

(3) **Loss in kinetic energy**

ΔK = Initial kinetic energy – Final kinetic energy

$$= \left(\frac{1}{2}m_1 u_1^2 + \frac{1}{2}m_2 u_2^2\right) - \left(\frac{1}{2}(m_1 + m_2)v_{comb}^2\right)$$

$$= \frac{1}{2}\frac{m_1 m_2}{m_1 + m_2}(u_1 - u_2)^2$$

Collision Between Bullet and Vertically Suspended Block

A bullet of mass m is fired horizontally with velocity u in block of mass M suspended by vertical thread.

After the collision bullet gets embedded in block. Let the combined system raised upto height h and the string makes an angle θ with the vertical.

(1) **Velocity of system**

Let v be the velocity of the system (block + bullet) just after the collision.

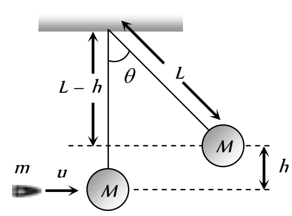


Fig. 3.37

$Momentum_{bullet} + Momentum_{block} = Momentum_{bullet\ and\ block}$

$$mu + 0 = (m + M)v$$

$$\therefore\ v = \frac{mu}{(m + M)} \qquad \ldots(i)$$

(2) **Velocity of bullet :** Due to energy which remains in the bullet-block system, just after the collision, the system (bullet + block) rises upto height h.

By the conservation of mechanical energy

$$\frac{1}{2}(m + M)v^2 = (m + M)gh \Rightarrow v = \sqrt{2gh}$$

Now substituting this value in the equation (i) we get

$$\sqrt{2gh} = \frac{mu}{m+M}$$

$$\therefore \quad u = \left[\frac{(m+M)\sqrt{2gh}}{m}\right]$$

(3) **Loss in kinetic energy :** We know that the formula for loss of kinetic energy in perfectly inelastic collision

$$\Delta K = \frac{1}{2}\frac{m_1 m_2}{m_1 + m_2}(u_1 - u_2)^2$$ (When the bodies are moving in same direction.)

$$\therefore \quad \Delta K = \frac{1}{2}\frac{mM}{m+M}u^2$$

[As $u_1 = u$, $u_2 = 0$, $m_1 = m$ and $m_2 = M$]

(4) **Angle of string from the vertical**

From the expression of velocity of bullet $u = \left[\frac{(m+M)\sqrt{2gh}}{m}\right]$ we can get $h = \frac{u^2}{2g}\left(\frac{m}{m+M}\right)^2$

From the figure $\cos\theta = \frac{L-h}{L} = 1 - \frac{h}{L} = 1 - \frac{u^2}{2gL}\left(\frac{m}{m+M}\right)^2$

or $\quad \theta = \cos^{-1}\left[1 - \frac{1}{2gL}\left(\frac{mu}{m+M}\right)^2\right]$

Tips & Tricks

✍ The area under the force-displacement graph is equal to the work done.

✍ Work done by gravitation or electric force does not depend on the path followed. It depends on the initial and final positions of the body. Such forces are called conservative. When a body returns to the starting point under the action of conservative force, the net work done is zero that is $\oint dW = 0$.

✍ Work done against friction depends on the path followed. Viscosity and friction are not conservative forces. For non conservative forces, the work done on a closed path is not zero. That is $\oint dW \neq 0$.

✍ Work done is path independent only for a conservative field.

✍ Work done depends on the frame of reference.

✍ Work done by a centripetal force is always zero.

✍ Energy is a promise of work to be done in future. It is the stored ability to do work.

✍ Energy of a body is equal to the work done by the body and it has nothing to do with the time taken to perform the work. On the other hand, the power of the body depends on the time in which the work is done.

✍ When work is done on a body, its kinetic or potential energy increases.

✍ When the work is done by the body, its potential or kinetic energy decreases.

✍ According to the work energy theorem, the work done is equal to the change in energy. That is $W = \Delta E$.

✍ Work energy theorem is particularly useful in calculation of minimum stopping force or minimum stopping distance. If a body is brought to a halt, the work done to do so is equal to the kinetic energy lost.

✍ Potential energy of a system increases when a conservative force does work on it.

✍ The kinetic energy of a body is always positive.

✍ When the momentum of a body increases by a factor *n*, then its kinetic energy is increased by factor *n*.

✍ If the speed of a vehicle is made *n* times, then its stopping distance becomes *n* times.

✍ The total energy (including mass energy) of the universe remains constant.

✍ One form of energy can be changed into other form according to the law of conservation of energy. That is amount of energy lost of one form should be equal to energy or energies produced of other forms.

✍ Kinetic energy can change into potential energy and vice versa. When a body falls, potential energy is converted into kinetic energy.

✍ Pendulum oscillates due to conversion of kinetic energy into potential energy and vice versa. Same is true for the oscillations of mass attached to the spring.

✍ Conservation laws can be used to describe the behaviour of a mechanical system even when the exact nature of the forces involved is not known.

✍ Although the exact nature of the nuclear forces is not known, yet we can solve problems regarding the nuclear forces with the help of the conservation laws.

✍ Violation of the laws of conservation indicates that the event cannot take place.

✍ The gravitational potential energy of a mass *m* at a height *h* above the surface of the earth (radius *R*) is given by $U = \frac{mgh}{1 + h/R}$. When $h \ll R$, we find $U = mgh$.

✍ Electrostatic energy in capacitor - $U = \frac{1}{2}CV^2$, where *C* is capacitance, *V* = potential difference between the plates.

✍ Electric potential energy of a test charge *q* at a place where electric potential is *V*, is given by : $U = qV$.

✍ Electric potential energy between two charges (*q* and *q*) separated by a distance *r* is given by $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$. Here ε_0 is permittivity of vacuum and $1/4\pi\varepsilon_0 = 9 \times 10^9\ Nm^2C^{-2}$.

✍ Magnetic energy stored in an inductor –

$U = \frac{1}{2}LI^2$, where *L* = inductance, *I* = current.

✍ Energy gained by a body of mass m, specific heat C, when its temperature changes by $\Delta\theta$ is given by : $Q = mC\Delta\theta$.

✍ The Potential energy associated with a spring of constant k when extended or compressed by distance x is given by $U = \frac{1}{2}kx^2$.

✍ Kinetic energy of a particle executing SHM is given by : $K = \frac{1}{2}m\omega^2(a^2 - y^2)$ where m = mass, ω = angular frequency, a= amplitude, y = displacement.

✍ Potential energy of a particle executing SHM is given by : $U = \frac{1}{2}m\omega^2 y^2$.

✍ Total energy of a particle executing SHM is given by : $E = K + U = \frac{1}{2}m\omega^2 a^2$.

✍ Energy density associated with a wave $= \frac{1}{2}\rho\omega^2 a^2$ where ρ =density of medium, ω = angular frequency, a = amplitude of the of the wave.

✍ Energy associated with a photon :

$E = h\nu = hc/\lambda$, where h = planck's constant, ν = frequency of the light wave, c = velocity of light, λ = wave length.

✍ Mass and energy are interconvertible. That is mass can be converted into energy and energy can be converted into mass.

✍ A mass m (in kg) is equivalent to energy (in J) which is equal to mc where c = speed of light.

✍ A stout spring has a large value of force constant, while for a delicate spring, the value of spring constant is low.

✍ The term energy is different from power. Whereas energy refers to the capacity to perform the work, power determines the rate of performing the work. Thus, in determining power, time taken to perform the work is significant but it is of no importance for measuring energy of a body.

✍ Collision is the phenomenon in which two bodies exert mutual force on each other.

✍ The collision generally occurs for very small interval of time.

✍ Physical contact between the colliding bodies is not essential for the collision.

✍ The mutual forces between the colliding bodies are action and reaction pair. In accordance with the Newton's third law of motion, they are equal and opposite to each other.

✍ The collision is said to be elastic when the kinetic energy is conserved.

✍ In the elastic collisions the forces involved are conservative.

✍ In the elastic collisions, the kinetic or mechanical energy is not converted into any other form of energy.

✍ Elastic collisions produce no sound or heat.

✍ There is no difference between the elastic and perfectly elastic collisions.

✍ In the elastic collisions, the relative velocity before collision is equal to the relative velocity after the collision. That is $\vec{u}_1 - \vec{u}_2 = \vec{v}_2 - \vec{v}_1$ where $\vec{u}_1$ and $\vec{u}_2$ are initial velocities and $\vec{v}_1$ and $\vec{v}_2$ are the velocities of the colliding bodies after the collision. This is called Newton's law of impact.

✍ The collision is said to be inelastic when the kinetic energy is not conserved.

✍ In the perfectly inelastic collision, the colliding bodies stick together. That is the relative velocity of the bodies after the collision is zero.

✍ In an elastic collision of two equal masses, their kinetic energies are exchanged.

✍ If a body of mass m moving with velocity v, collides elastically with a rigid wall, then the change in the momentum of the body is $2mv$.

✍ $e = \frac{\vec{v}_2 - \vec{v}_1}{\vec{u}_1 - \vec{u}_2}$ is called coefficient of restitution. Its value is 1 for elastic collisions. It is less than 1 for inelastic collisions and zero for perfectly inelastic collision.

✍ During collision, velocity of the colliding bodies changes.

✍ Linear momentum is conserved in all types of collisions.

✍ Perfectly elastic collision is a rare physical phenomenon.

✍ Collisions between two ivory or steel or glass balls are nearly elastic.

✍ The force of interaction in an inelastic collision is non-conservative in nature.

✍ In inelastic collision, the kinetic energy is converted into heat energy, sound energy, light energy etc.

✍ In head on collisions, the colliding bodies move along the same straight line before and after collision.

✍ Head on collisions are also called one dimensional collisions.

✍ In the oblique collisions the colliding bodies move at certain angles before and/or after the collisions.

✍ The oblique collisions are two dimensional collisions.

✍ When a heavy body collides head-on elastically with a lighter body, then the lighter body begins to move with a velocity nearly double the velocity of the heavier body.

✍ When a light body collides with a heavy body, the lighter body returns almost with the same speed.

✍ If a light and a heavy body have equal momenta, then lighter body has greater kinetic energy.

✍ Suppose, a body is dropped form a height h_0 and it strikes the ground with velocity v_0. After the (inelastic) collision let it rise to a height h_1. If v_1 be the velocity with which the body rebounds, then

$$e = \frac{v_1}{v_0} = \left[\frac{2gh_1}{2gh_0}\right]^{1/2} = \left[\frac{h_1}{h_0}\right]^{1/2}$$

✍ If after n collisions with the ground, the velocity is v_n and the height to which it rises be h_n then

$$e^n = \frac{v_n}{v_0} = \left[\frac{h_n}{h_0}\right]^{1/2}$$

✍ $P = \vec{F}.\vec{v} = Fv\cos\theta$ where $\vec{v}$ is the velocity of the body and θ is the angle between $\vec{F}$ and $\vec{v}$.

✍ Area under the $F-v$ graph is equal to the power dissipated.

✍ Power dissipated by a conservative force (gravitation, electric force etc.) does not depend on the path followed. It depends on the initial and final positions of the body. That is $\oint dP = 0$.

✍ Power dissipated against friction depends on the path followed. That is $\oint dP \neq 0$.

✍ Power is also measured in horse power (*hp*). It is the *fps* unit of power. 1 *hp* = 746 *W*.

✍ An engine pulls a train of mass *m* with constant velocity. If the rails are on a plane surface and there is no friction, the power dissipated by the engine is zero.

✍ In the above case if the coefficient of friction for the rail is μ, the power of the engine is $P = \mu mgv$.

✍ In the above case if the engine pulls on a smooth track on an inclined plane (inclination θ), then its power $P = (mg\sin\theta)v$.

✍ In the above case if the engine pulls upwards on a rough inclined plane having coefficient of friction μ, then power of the engine is

$P = (\mu\cos\theta + \sin\theta)mg\,v$.

✍ If the engine pulls down on the inclined plane then power of the engine is

$P = (\mu\cos\theta - \sin\theta)mg\,v$.

Ordinary Thinking

Objective Questions

Work Done by Constant Force

1. A body of mass m is moving in a circle of radius r with a constant speed v. The force on the body is $\frac{mv^2}{r}$ and is directed towards the centre. What is the work done by this force in moving the body over half the circumference of the circle

(a) $\frac{mv^2}{\pi r^2}$ (b) Zero

(c) $\frac{mv^2}{r^2}$ (d) $\frac{\pi r^2}{mv^2}$

2. If the unit of force and length each be increased by four times, then the unit of energy is increased by [CPMT 1987]

(a) 16 times (b) 8 times

(c) 2 times (d) 4 times

3. A man pushes a wall and fails to displace it. He does [CPMT 1992]

(a) Negative work

(b) Positive but not maximum work

(c) No work at all

(d) Maximum work

4. The same retarding force is applied to stop a train. The train stops after 80 *m*. If the speed is doubled, then the distance will be

(a) The same (b) Doubled

(c) Halved (d) Four times

5. A body moves a distance of 10 *m* along a straight line under the action of a force of 5 *N*. If the work done is 25 *joules*, the angle which the force makes with the direction of motion of the body is

[NCERT 1980; JIPMER 1997; CBSE PMT 1999; BHU 2000; RPMT 2000; Orissa JEE 2002]

(a) 0° (b) 30°

(c) 60° (d) 90°

6. You lift a heavy book from the floor of the room and keep it in the book-shelf having a height 2 *m*. In this process you take 5 seconds. The work done by you will depend upon [MP PET 1993]

(a) Mass of the book and time taken

(b) Weight of the book and height of the book-shelf

(c) Height of the book-shelf and time taken

(d) Mass of the book, height of the book-shelf and time taken

7. A body of mass *m kg* is lifted by a man to a height of one metre in 30 *sec*. Another man lifts the same mass to the same height in 60 *sec*. The work done by them are in the ratio

(a) $1:2$ (b) 1 : 1

(c) 2 : 1 (d) 4 : 1

8. A force $\mathbf{F} = (5\hat{\mathbf{i}} + 3\hat{\mathbf{j}})$ *newton* is applied over a particle which displaces it from its origin to the point $\mathbf{r} = (2\hat{\mathbf{i}} - 1\hat{\mathbf{j}})$ *metres*. The work done on the particle is

[MP PMT 1995; RPET 2003]

(a) – 7 *joules* (b) + 13 *joules*

(c) + 7 *joules* (d) + 11 *joules*

9. A force acts on a 30 *gm* particle in such a way that the position of the particle as a function of time is given by $x = 3t - 4t^2 + t^3$, where x is in *metres* and t is in seconds. The work done during the first 4 seconds is [NCERT 1977]

[CBSE PMT 1998]

(a) 5.28 *J* (b) 450 *mJ*

(c) 490 *mJ* (d) 530 *mJ*

10. A body of mass 10 *kg* is dropped to the ground from a height of 10 *metres*. The work done by the gravitational force is $(g = 9.8\, m/\sec^2)$ [SCRA 1994]

(a) – 490 *Joules* (b) + 490 *Joules*

(c) – 980 *Joules* (d) + 980 *Joules*

11. Which of the following is a scalar quantity [AFMC 1998]

(a) Displacement (b) Electric field

(c) Acceleration (d) Work

12. The work done in pulling up a block of wood weighing 2 *kN* for a length of 10*m* on a smooth plane inclined at an angle of 15° with the horizontal is [AFMC 1999; Pb PMT 2003]

(a) 4.36 *kJ* [CPMT 1984] (b) 5.17 *kJ*

(c) 8.91 *kJ* (d) 9.82 *kJ*

13. A force $\vec{F} = 5\hat{i} + 6\hat{j} - 4\hat{k}$ acting on a body, produces a displacement $\vec{s} = 6\vec{i} + 5\vec{k}$. Work done by the force is

[KCET 1999]

(a) 18 units (b) 15 units

(c) 12 units (d) 10 units

14. A force of 5 *N* acts on a 15 *kg* body initially at rest. The work done by the force during the first second of motion of the body is

(a) 5 *J* (b) $\frac{5}{6}J$

(c) 6 *J* (d) $75\,J$

15. A force of 5 *N*, making an angle θ with the horizontal, acting on an object displaces it by $0.4m$ along the horizontal direction. If the object gains kinetic energy of 1*J*, the horizontal component of the force is

[EAMCET (Engg.) 2000]

(a) 1.5 *N* [MP PMT 1993] (b) 2.5 *N*

(c) 3.5 *N* (d) 4.5 *N*

16. The work done against gravity in taking 10 *kg* mass at 1*m* height in 1*sec* will be [RPMT 2000]

(a) 49 *J* (b) 98 *J*

(c) 196 *J* (d) None of these

17. The energy which an e^- acquires when accelerated through a potential difference of 1 volt is called [UPSEAT 2000]
(a) 1 *Joule* (b) 1 *Electron volt*
(c) 1 *Erg* (d) 1 *Watt.*

18. A body of mass 6*kg* is under a force which causes displacement in it given by $S = \frac{t^2}{4}$ *metres* where t is time. The work done by the force in 2 seconds is [EAMCET 2001]
(a) 12 *J* (b) 9 *J*
(c) 6 *J* (d) 3 *J*

19. A body of mass 10*kg* at rest is acted upon simultaneously by two forces 4 *N* and 3*N* at right angles to each other. The kinetic energy of the body at the end of 10 *sec* is [Kerala (Engg.) 2001]
(a) 100 *J* (b) 300 *J*
(c) 50 *J* (d) 125 *J*

20. A cylinder of mass 10*kg* is sliding on a plane with an initial velocity of 10*m/s*. If coefficient of friction between surface and cylinder is 0.5, then before stopping it will describe [Pb. PMT 2001]
(a) 12.5 *m* (b) 5 *m*
(c) 7.5 *m* (d) 10 *m*

21. A force of $(3\hat{i} + 4\hat{j})$ *Newton* acts on a body and displaces it by $(3\hat{i} + 4\hat{j})m$. The work done by the force is [AIIMS 2001]
(a) 10 *J* (b) 12 *J*
(c) 16 *J* (d) 25 *J*

22. A 50*kg* man with 20*kg* load on his head climbs up 20 steps of 0.25*m* height each. The work done in climbing is [JIPMER 2002]
(a) 5 *J* (b) 350 *J*
(c) 100 *J* (d) 3430 *J*

23. A force $\vec{F} = 6\hat{i} + 2\hat{j} - 3\hat{k}$ acts on a particle and produces a displacement of $\vec{s} = 2\hat{i} - 3\hat{j} + x\hat{k}$. If the work done is zero, the value of x is [Kerala PMT 2002]
(a) – 2 (b) 1/2
(c) 6 (d) 2

24. A particle moves from position $\vec{r}_1 = 3\hat{i} + 2\hat{j} - 6\hat{k}$ to position $\vec{r}_2 = 14\hat{i} + 13\hat{j} + 9\hat{k}$ under the action of force $4\hat{i} + \hat{j} + 3\hat{k}\, N$. The work done will be [Pb. PMT 2002,03]
(a) 100 *J* (b) 50 *J*
(c) 200 *J* (d) 75 *J*

25. A force $(\vec{F}) = 3\hat{i} + c\hat{j} + 2\hat{k}$ acting on a particle causes a displacement: $(\vec{s}) = -4\hat{i} + 2\hat{j} + 3\hat{k}$ in its own direction. If the work done is $6\,J$, then the value of 'c' is [CBSE PMT 2002]
(a) 0 (b) 1
(c) 6 (d) 12

26. In an explosion a body breaks up into two pieces of unequal masses. In this [MP PET 2002]
(a) Both parts will have numerically equal momentum
(b) Lighter part will have more momentum
(c) Heavier part will have more momentum
(d) Both parts will have equal kinetic energy

27. Which of the following is a unit of energy [AFMC 2002]
(a) Unit (b) Watt
(c) Horse Power (d) None

28. If force and displacement of particle in direction of force are doubled. Work would be [AFMC 2002]
(a) Double (b) 4 times
(c) Half (d) $\frac{1}{4}$ times

29. A body of mass 5 *kg* is placed at the origin, and can move only on the x-axis. A force of 10 *N* is acting on it in a direction making an angle of 60^o with the x-axis and displaces it along the x-axis by 4 *metres*. The work done by the force is
(a) 2.5 *J* (b) 7.25 *J*
(c) 40 *J* (d) 20 *J*

30. A force $\vec{F} = (5\hat{i} + 4\hat{j})$ *N* acts on a body and produces a displacement $\vec{S} = (6\hat{i} - 5\hat{j} + 3\hat{k})\,m$. The work done will be [CPMT 2003]
(a) 10 *J* (b) 20 *J*
(c) 30 *J* (d) 40 *J*

31. A uniform chain of length 2*m* is kept on a table such that a length of 60*cm* hangs freely from the edge of the table. The total mass of the chain is 4*kg*. What is the work done in pulling the entire chain on the table [AIEEE 2004]
(a) 7.2 *J* (b) 3.6 *J*
(c) 120 *J* (d) 1200 *J*

32. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle, the motion of the particle takes place in a plane. It follows that
(a) Its velocity is constant
(b) Its acceleration is constant
(c) Its kinetic energy is constant
(d) It moves in a straight line

33. A ball of mass *m* moves with speed *v* and strikes a wall having infinite mass and it returns with same speed then the work done by the ball on the wall is [BCECE 2004]
(a) Zero (b) *mv J*
(c) *m/v.J* (d) *v/m J*

34. A force $\vec{F} = (5\hat{i} + 3\hat{j} + 2\hat{k})N$ is applied over a particle which displaces it from its origin to the point $\vec{r} = (2\hat{i} - \hat{j})m$. The work done on the particle in joules is [AIEEE 2004]
(a) – 7 (b) +7
(c) +10 (d) +13

35. The kinetic energy acquired by a body of mass *m* is travelling some distance *s*, starting from rest under the actions of a constant force, is directly proportional to [Pb. PET 2000]
(a) m^0 (b) m
(c) m^2 (d) $\sqrt{m}$

36. If a force $\vec{F} = 4\hat{i} + 5\hat{j}$ causes a displacement $\vec{s} = 3\hat{i} + 6\hat{k}$, work done is [Pb. PET 2002]
(a) 4×6 unit (b) 6×3 unit

(c) 5×6 unit (d) 4×3 unit

37. A man starts walking from a point on the surface of earth (assumed smooth) and reaches diagonally opposite point. What is the work done by him [DCE 2004]

(a) Zero (b) Positive

(c) Negative (d) Nothing can be said

38. It is easier to draw up a wooden block along an inclined plane than to haul it vertically, principally because [CPMT 1977; JIPMER 1997]

(a) The friction is reduced

(b) The mass becomes smaller

(c) Only a part of the weight has to be overcome

(d) 'g' becomes smaller

39. Two bodies of masses 1 *kg* and 5 *kg* are dropped gently from the top of a tower. At a point 20 *cm* from the ground, both the bodies will have the same [SCRA 1998]

(a) Momentum (b) Kinetic energy

(c) Velocity (d) Total energy

40. Due to a force of $(6\hat{i} + 2\hat{j})N$ the displacement of a body is $(3\hat{i} - \hat{j})m$, then the work done is [Orissa JEE 2005]

(a) 16 *J* (b) 12 *J*

(c) 8 *J* (d) Zero

41. A ball is released from the top of a tower. The ratio of work done by force of gravity in first, second and third second of the motion of the ball is [Kerala PET 2005]

(a) 1 : 2 : 3 (b) 1 : 4 : 9

(c) 1 : 3 : 5 (d) 1 : 5 : 3

Work Done by Variable Force

1. A particle moves under the effect of a force $F = Cx$ from $x = 0$ to $x = x_1$. The work done in the process is [CPMT 1982; DCE 2002;Orissa JEE 2005]

(a) Cx_1^2 (b) $\frac{1}{2}Cx_1^2$

(c) Cx_1 (d) Zero

2. A cord is used to lower vertically a block of mass M by a distance d with constant downward acceleration $\frac{g}{4}$. Work done by the cord on the block is [CPMT 1972]

(a) $Mg\frac{d}{4}$ (b) $3Mg\frac{d}{4}$

(c) $-3Mg\frac{d}{4}$ (d) Mgd

3. Two springs have their force constant as k_1 and $k_2 (k_1 > k_2)$. When they are stretched by the same force [EAMCET 1981]

(a) No work is done in case of both the springs

(b) Equal work is done in case of both the springs

(c) More work is done in case of second spring

(d) More work is done in case of first spring

4. A spring of force constant 10 *N/m* has an initial stretch 0.20 *m*. In changing the stretch to 0.25 *m*, the increase in potential energy is about [CPMT 1977]

(a) 0.1 *joule* (b) 0.2 *joule*

(c) 0.3 *joule* (d) 0.5 *joule*

5. The potential energy of a certain spring when stretched through a distance 'S' is 10 *joule*. The amount of work (in joule) that must be done on this spring to stretch it through an additional distance 'S' will be [MNR 1991; CPMT 2002; UPSEAT 2000; Pb. PET 2004]

(a) 30 (b) 40

(c) 10 (d) 20

6. Two springs of spring constants 1500 *N/m* and 3000 *N/m* respectively are stretched with the same force. They will have potential energy in the ratio [MP PMT/PET 1998; Pb. PMT 2002]

(a) 4 : 1 (b) 1 : 4

(c) 2 : 1 (d) 1 : 2

7. A spring 40 *mm* long is stretched by the application of a force. If 10 *N* force required to stretch the spring through 1 *mm*, then work done in stretching the spring through 40 *mm* is

(a) 84 *J* (b) 68 *J*

(c) 23 *J* (d) 8 *J*

8. A position dependent force $F = 7 - 2x + 3x^2$ *newton* acts on a small body of mass 2 *kg* and displaces it from $x = 0$ to $x = 5\,m$. The work done in *joules* is [CBSE PMT 1994]

(a) 70 (b) 270

(c) 35 (d) 135

9. A body of mass 3 *kg* is under a force, which causes a displacement in it is given by $S = \frac{t^3}{3}$ (in *m*). Find the work done by the force in first 2 seconds [BHU 1998]

(a) 2 *J* (b) 3.8 *J*

(c) 5.2 *J* (d) 24 *J*

10. The force constant of a wire is k and that of another wire is $2k$. When both the wires are stretched through same distance, then the work done [MH CET 2000]

(a) $W_2 = 2W_1^2$ (b) $W_2 = 2W_1$

(c) $W_2 = W_1$ (d) $W_2 = 0.5W_1$

11. A body of mass 0.1 *kg* moving with a velocity of 10 *m/s* hits a spring (fixed at the other end) of force constant 1000 *N/m* and comes to rest after compressing the spring. The compression of the spring is

(a) $0.01m$ (b) $0.1m$

(c) $0.2m$ (d) $0.5m$

12. When a 1.0*kg* mass hangs attached to a spring of length 50 *cm*, the spring stretches by 2 *cm*. The mass is pulled down until the length of the spring becomes 60 *cm*. What is the amount of elastic energy stored in the spring in this condition, if g = 10 *m/s*

(a) 1.5 *Joule* (b) 2.0 *Joule*

(c) 2.5 *Joule* (d) 3.0 *Joule*

13. A spring of force constant 800 *N/m* has an extension of 5*cm*. The work done in extending it from 5*cm* to 15 *cm* is [AIEEE 2002]

(a) 16 *J* (b) 8 *J*

(c) 32 *J* (d) 24 *J*

14. When a spring is stretched by 2 *cm*, it stores 100 *J* of energy. If it is stretched further by 2 *cm*, the stored energy will be increased by

(a) 100 *J* (b) 200 *J*
(c) 300 *J* (d) 400 *J*

15. A spring when stretched by 2 mm its potential energy becomes 4 J. If it is stretched by 10 mm, its potential energy is equal to

(a) 4 *J* (b) 54 *J*
(c) 415 *J* (d) None

16. A spring of spring constant 5×10^3 *N/m* is stretched initially by 5*cm* from the unstretched position. Then the work required to stretch it further by another $5cm$ is [AIEEE 2003]

(a) 6.25 *N-m* (b) 12.50 *N-m*
(c) 18.75 *N-m* (d) 25.00 *N-m*

17. A mass of 0.5*kg* moving with a speed of 1.5 *m/s* on a horizontal smooth surface, collides with a nearly weightless spring of force constant $k = 50\ N/m$. The maximum compression of the spring would be [CBSE PMT 2004]

(a) 0.15 *m* (b) 0.12 *m*
(c) 1.5 *m* (d) 0.5 *m*

18. A particle moves in a straight line with retardation proportional to its displacement. Its loss of kinetic energy for any displacement *x* is proportional to [AIEEE 2004]

(a) x^2 (b) e^x
(c) x (d) $\log_e x$

19. A spring with spring constant *k* when stretched through 1 *cm*, the potential energy is *U*. If it is stretched by 4 *cm*. The potential energy will be [Orissa PMT 2004]

(a) 4*U* (b) 8*U*
(c) 16 *U* (d) 2*U*

20. A spring with spring constant *k* is extended from $x = 0$ to $x = x_1$. The work done will be [Orissa PMT 2004]

(a) kx_1^2 (b) $\frac{1}{2}kx_1^2$
(c) $2kx_1^2$ (d) $2kx_1$

21. If a long spring is stretched by 0.02 *m*, its potential energy is *U*. If the spring is stretched by 0.1 *m*, then its potential energy will be [MP PMT 2002; CBSE PMT 2003; UPSEAT 2004]

(a) $\frac{U}{5}$ (b) U
(c) 5*U* (d) 25*U*

22. Natural length of a spring is 60 *cm*, and its spring constant is 4000 *N/m*. A mass of 20 *kg* is hung from it. The extension produced in the spring is, (Take $g = 9.8\ m/s^2$) [DCE 2004]

(a) 4.9 *cm* (b) 0.49 *cm*
(c) 9.4 *cm* (d) 0.94 *cm*

23. The spring extends by *x* on loading, then energy stored by the spring is :
(if *T* is the tension in spring and *k* is spring constant) [Pb. PMT 2003]

(a) $\frac{T^2}{2k}$ [Orissa JEE 2002] (b) $\frac{T^2}{2k^2}$
(c) $\frac{2k}{T^2}$ (d) $\frac{2T^2}{k}$

24. The potential energy of a body is given by, [BCECE 2003] $U = A - Bx^2$ (Where *x* is the displacement). The magnitude of force acting on the particle is [BHU 2002]

(a) Constant
(b) Proportional to *x*
(c) Proportional to x^2
(d) Inversely proportional to *x*

25. The potential energy between two atoms in a molecule is given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$; where *a* and *b* are positive constants and *x* is the distance between the atoms. The atom is in stable equilibrium when [CBSE PMT 1995]

(a) $x = \sqrt[6]{\frac{11a}{5b}}$ (b) $x = \sqrt[6]{\frac{a}{2b}}$
(c) $x = 0$ (d) $x = \sqrt[6]{\frac{2a}{b}}$

26. Which one of the following is not a conservative force [Kerala PMT 2005]

(a) Gravitational force
(b) Electrostatic force between two charges
(c) Magnetic force between two magnetic dipoles
(d) Frictional force

Conservation of Energy and Momentum

1. Two bodies of masses m_1 and m_2 have equal kinetic energies. If p_1 and p_2 are their respective momentum, then ratio $p_1 : p_2$ is equal to [MP PMT 1985; CPMT 1990]

(a) $m_1 : m_2$ (b) $m_2 : m_1$
(c) $\sqrt{m_1} : \sqrt{m_2}$ (d) $m_1^2 : m_2^2$

2. Work done in raising a box depends on

(a) How fast it is raised
(b) The strength of the man
(c) The height by which it is raised
(d) None of the above

3. A light and a heavy body have equal momenta. Which one has greater K.E [MP PMT 1985; CPMT 1985; Kerala PMT 2004]

(a) The light body (b) The heavy body
(c) The K.E. are equal (d) Data is incomplete

4. A body at rest may have

(a) Energy (b) Momentum
(c) Speed (d) Velocity

5. The kinetic energy possessed by a body of mass *m* moving with a velocity *v* is equal to $\frac{1}{2}mv^2$, provided

(a) The body moves with velocities comparable to that of light

(b) The body moves with velocities negligible compared to the speed of light

(c) The body moves with velocities greater than that of light

(d) None of the above statement is correcst

6. If the momentum of a body is increased n times, its kinetic energy increases

(a) n times (b) $2n$ times

(c) $\sqrt{n}$ times (d) n^2 times

7. When work is done on a body by an external force, its

(a) Only kinetic energy increases

(b) Only potential energy increases

(c) Both kinetic and potential energies may increase

(d) Sum of kinetic and potential energies remains constant

8. The bob of a simple pendulum (mass m and length l) dropped from a horizontal position strikes a block of the same mass elastically placed on a horizontal frictionless table. The K.E. of the block will be

(a) 2 mgl (b) $mgl/2$

(c) mgl (d) 0

9. From a stationary tank of mass 125000 *pound* a small shell of mass 25 *pound* is fired with a muzzle velocity of 1000 *ft/sec*. The tank recoils with a velocity of [NCERT 1973]

(a) 0.1 *ft/sec* (b) 0.2 *ft/sec*

(c) 0.4 *ft*/sec (d) 0.8 *ft/sec*

10. A bomb of 12 *kg* explodes into two pieces of masses 4 *kg* and 8 *kg*. The velocity of 8*kg* mass is 6 *m/sec*. The kinetic energy of the other mass is

[MNR 1985; CPMT 1991; Manipal MEE 1995; Pb. PET 2004]

(a) 48 *J* (b) 32 *J*

(c) 24 *J* (d) 288 *J*

11. A rifle bullet loses 1/20 of its velocity in passing through a plank. The least number of such planks required just to stop the bullet is[EAMCET 1987; AFMC 2004]

(a) 5 (b) 10

(c) 11 (d) 20

12. A body of mass 2 *kg* is thrown up vertically with K.E. of 490 joules. If the acceleration due to gravity is $9.8\, m/s^2$, then the height at which the K.E. of the body becomes half its original value is given by [EAMCET 1986]

(a) 50 *m* (b) 12.5 *m*

(c) 25 *m* (d) 10 *m*

13. Two masses of 1 *gm* and 4 *gm* are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta is

[AIIMS 1987; NCERT 1983; MP PMT 1993; IIT 1980; RPET 1996; CBSE PMT 1997; Orissa JEE 2003; KCET 1999; DCE 2004]

(a) 4 : 1 (b) $\sqrt{2}:1$

(c) 1 : 2 (d) 1 : 16

14. If the *K.E.* of a body is increased by 300%, its momentum will increase by [JIPMER 1978; AFMC 1993; RPET 1999; CBSE PMT 2002]

(a) 100% (b) 150%

(c) $\sqrt{300}\%$ (d) 175%

15. A light and a heavy body have equal kinetic energy. Which one has a greater momentum ?

[NCERT 1974; CPMT 1997; DPMT 2001]

(a) The light body

(b) The heavy body

(c) Both have equal momentum

(d) It is not possible to say anything without additional information

16. If the linear momentum is increased by 50%, the kinetic energy will increase by

[CPMT 1983; MP PMT 1994; MP PET 1996, 99; UPSEAT 2001]

(a) 50% (b) 100%

(c) 125% (d) 25%

17. A free body of mass 8 *kg* is travelling at 2 *meter* per second in a straight line. At a certain instant, the body splits into two equal parts due to internal explosion which releases 16 *joules* of energy. Neither part leaves the original line of motion finally

(a) Both parts continue to move in the same direction as that of the original body

(b) One part comes to rest and the other moves in the same direction as that of the original body

(c) One part comes to rest and the other moves in the direction opposite to that of the original body

(d) One part moves in the same direction and the other in the direction opposite to that of the original body

18. If the K.E. of a particle is doubled, then its momentum will

[EAMCET 1979; CPMT 2003: Kerala PMT 2005]

(a) Remain unchanged (b) Be doubled

(c) Be quadrupled (d) Increase $\sqrt{2}$ times

19. If the stone is thrown up vertically and return to ground, its potential energy is maximum [EAMCET 1979]

(a) During the upward journey

(b) At the maximum height

(c) During the return journey

(d) At the bottom

20. A body of mass 2 *kg* is projected vertically upwards with a velocity of $2\, m\, sec^{-1}$. The K.E. of the body just before striking the ground is [EAMCET 1980]

(a) 2 *J* (b) 1 *J*

(c) 4 *J* (d) 8 *J*

21. The energy stored in wound watch spring is

[EAMCET 1982]

(a) K.E. (b) P.E.

(c) Heat energy (d) Chemical energy

22. Two bodies of different masses m_1 and m_2 have equal momenta. Their kinetic energies E_1 and E_2 are in the ratio

[EAMCET 1990]

(a) $\sqrt{m_1}:\sqrt{m_2}$ (b) $m_1 : m_2$

(c) $m_2 : m_1$ (d) $m_1^2 : m_2^2$

23. A car travelling at a speed of 30 *km/hour* is brought to a halt in 8 *m* by applying brakes. If the same car is travelling at 60 *km/hour*, it can be brought to a halt with the same braking force in

(a) 8 *m* (b) 16 *m*

(c) 24 *m* (d) 32 *m*

24. Tripling the speed of the motor car multiplies the distance needed for stopping it by [NCERT 1978]

(a) 3 (b) 6

(c) 9 (d) Some other number

25. If the kinetic energy of a body increases by 0.1%, the percent increase of its momentum will be [MP PMT 1994]

(a) 0.05% (b) 0.1%

(c) 1.0% (d) 10%

26. If velocity of a body is twice of previous velocity, then kinetic energy will become [AFMC 1996]

(a) 2 times (b) $\frac{1}{2}$ times

(c) 4 times (d) 1 times

27. Two bodies *A* and *B* having masses in the ratio of 3 : 1 possess the same kinetic energy. The ratio of their linear momenta is then

(a) 3 : 1 (b) 9 : 1

(c) 1 : 1 (d) $\sqrt{3}:1$

28. In which case does the potential energy decrease [MP PET 1996]

(a) On compressing a spring

(b) On stretching a spring

(c) On moving a body against gravitational force

(d) On the rising of an air bubble in water

29. A sphere of mass *m*, moving with velocity *V*, enters a hanging bag of sand and stops. If the mass of the bag is *M* and it is raised by height *h*, then the velocity of the sphere was

(a) $\frac{M+m}{m}\sqrt{2gh}$ (b) $\frac{M}{m}\sqrt{2gh}$

(c) $\frac{m}{M+m}\sqrt{2gh}$ (d) $\frac{m}{M}\sqrt{2gh}$

30. Two bodies of masses m and $2m$ have same momentum. Their respective kinetic energies E_1 and E_2 are in the ratio [MP PET 1997; KCET 2004]

(a) 1 : 2 (b) 2 : 1

(c) $1:\sqrt{2}$ (d) 1 : 4

31. If a lighter body (mass M_1 and velocity V_1) and a heavier body (mass M_2 and velocity V_2) have the same kinetic energy, then

(a) $M_2V_2 < M_1V_1$ (b) $M_2V_2 = M_1V_1$

(c) $M_2V_1 = M_1V_2$ (d) $M_2V_2 > M_1V_1$

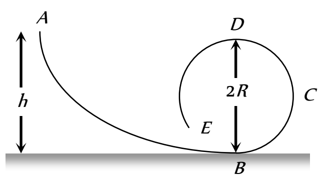
32. A frictionless track *ABCDE* ends in a circular loop of radius *R*. A body slides down the track from point *A* which is at a height *h* = 5 *cm*. Maximum value of *R* for the body to successfully complete the loop is [MP PMT/PET 1998]

(a) 5 *cm*

(b) $\frac{15}{4}$ *cm*

(c) $\frac{10}{3}$ *cm*

(d) 2 *cm*



33. The force constant of a weightless spring is 16 *N*/*m*. A body of mass 1.0 *kg* suspended from it is pulled down through 5 cm and then released. The maximum kinetic energy of the system (spring + body) will be [MP PET 1999; DPMT 2000]

(a) 2×10^{-2} *J* (b) 4×10^{-2} *J*

(c) 8×10^{-2} *J* (d) 16×10^{-2} *J*

34. Two bodies with kinetic energies in the ratio of 4 : 1 are moving with equal linear momentum. The ratio of their masses is

(a) 1 : 2 (b) 1 : 1

(c) 4 : 1 (d) 1 : 4

35. If the kinetic energy of a body becomes four times of its initial value, then new momentum will

[AIIMS 1998; AIIMS 2002; KCET 2000; J & K CET 2004]

(a) Becomes twice its initial value

[Haryana CEE 1996]

(b) Become three times its initial value

(c) Become four times its initial value

(d) Remains constant

36. A bullet is fired from a rifle. If the rifle recoils freely, then the kinetic energy of the rifle is

[AIIMS 1998; JIPMER 2001; UPSEAT 2000]

(a) Less than that of the bullet

(b) More than that of the bullet

(c) Same as that of the bullet

(d) Equal or less than that of the bullet [MP PET 1997]

37. If the water falls from a dam into a turbine wheel 19.6 *m* below, then the velocity of water at the turbine is $(g = 9.8\ m/s^2)$

(a) 9.8 *m*/*s* (b) 19.6 *m*/*s*

(c) 39.2 *m*/*s* (d) 98.0 *m*/*s*

38. Two bodies of masses 2*m* and *m* have their K.E. in the ratio 8 : 1, then their ratio of momenta is [EAMCET (Engg.) 1995]

(a) 1 : 1 (b) 2 : 1

(c) 4 : 1 (d) 8 : 1

39. A bomb of 12 *kg* divides in two parts whose ratio of masses is 1 : 3. If kinetic energy of smaller part is 216 *J*, then momentum of bigger part in *kg*-*m*/*sec* will be [MP PMT 1997] [RPET 1997]

(a) 36 (b) 72

(c) 108 (d) Data is incomplete

40. A 4 *kg* mass and a 1 *kg* mass are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta is[CBSE PMT 1993; Orissa JE

(a) 1 : 2 (b) 1 : 1

(c) 2 : 1 (d) 4 : 1

41. Two identical cylindrical vessels with their bases at same level each contains a liquid of density ρ. The height of the liquid in one vessel is h_1 and that in the other vessel is h_2. The area of either base is *A*. The work done by gravity in equalizing the levels when the two vessels are connected, is [SCRA 1996]

(a) $(h_1 - h_2)g\rho$ (b) $(h_1 - h_2)gA\rho$

(c) $\frac{1}{2}(h_1 - h_2)^2 gA\rho$ (d) $\frac{1}{4}(h_1 - h_2)^2 gA\rho$

42. If the increase in the kinetic energy of a body is 22%, then the increase in the momentum will be

[RPET 1996; DPMT 2000]

(a) 22% (b) 44%

(c) 10% (d) 300%

43. If a body of mass 200 *g* falls from a height 200 *m* and its total P.E. is converted into K.E. at the point of contact of the body with earth surface, then what is the decrease in P.E. of the body at the contact $(g = 10\, m/s^2)$ [AFMC 1997]

(a) 200 *J* (b) 400 *J*

(c) 600 *J* (d) 900 *J*

44. If momentum is increased by 20%, then K.E. increases by

[AFMC 1997; MP PMT 2004]

(a) 44% (b) 55%

(c) 66% (d) 77%

45. The kinetic energy of a body of mass 2 *kg* and momentum of 2 *Ns* is

(a) 1 *J* (b) 2 *J*

(c) 3 *J* (d) 4 *J*

46. The decrease in the potential energy of a ball of mass 20 *kg* which falls from a height of 50 *cm* is [AIIMS 1997]

(a) 968 *J* (b) 98 *J*

(c) 1980 *J* (d) None of these

47. An object of 1 *kg* mass has a momentum of 10 *kg m/sec* then the kinetic energy of the object will be [RPMT 1999]

(a) 100 *J* (b) 50 *J*

(c) 1000 *J* (d) 200 *J*

48. A ball is released from certain height. It loses 50% of its kinetic energy on striking the ground. It will attain a height again equal to

(a) One fourth the initial height

(b) Half the initial height

(c) Three fourth initial height

(d) None of these

49. A 0.5 *kg* ball is thrown up with an initial speed 14 *m/s* and reaches a maximum height of 8.0*m*. How much energy is dissipated by air drag acting on the ball during the ascent

[AMU (Med.) 2000]

(a) $19.6\, Joule$ (b) $4.9\, Joule$

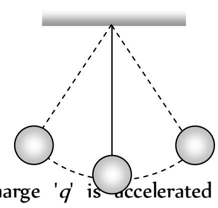
(c) $10\, Joule$ (d) $9.8\, Joule$

50. An ice cream has a marked value of 700 *kcal*. How many kilowatt-hour of energy will it deliver to the body as it is digested

(a) $0.81 kWh$ (b) $0.90 kWh$

(c) $1.11 kWh$ (d) $0.71 kWh$

51. What is the velocity of the bob of a simple pendulum at its mean position, if it is able to rise to vertical height of $10cm$ (Take $g = 9.8\, m/s^2$) [BHU 2000]



(a) 0.6 *m/s*

(b) 1.4 *m/s*

(c) 1.8 *m/s*

(d) 2.2 *m/s*

52. A particle of mass '*m*' and charge '*q*' is accelerated through a potential difference of 'V' volt. Its energy is [UPSEAT 2001]

(a) qV (b) mqV

(c) $\left(\frac{q}{m}\right)V$ (d) $\frac{q}{mV}$

53. A running man has half the kinetic energy of that of a boy of half of his mass. The man speeds up by 1*m/s* so as to have same *K.E.* as that of the boy. The original speed of the man will be

(a) $\sqrt{2}\, m/s$ (b) $(\sqrt{2} - 1) m/s$

(c) $\frac{1}{(\sqrt{2} - 1)} m/s$ (d) $\frac{1}{\sqrt{2}} m/s$

54. The mass of two substances are $4gm$ and $9gm$ respectively. If their kinetic energies are same, then the ratio of their momenta will be

(a) 4 : 9 (b) 9 : 4

(c) 3 : 2 (d) 2 : 3

55. If the momentum of a body is increased by 100%, then the percentage increase in the kinetic energy is

[AFMC 1998; DPMT 2000]

[BHU 1999; Pb. PMT 1999; CPMT 2000; CBSE PMT 2001; BCECE 2004]

(a) 150% (b) 200%

(c) 225% (d) 300%

56. If a body looses half of its velocity on penetrating 3 *cm* in a wooden block, then how much will it penetrate more before coming to rest

(a) 1 *cm* (b) 2 *cm*

(c) 3 *cm* (d) 4 *cm*

57. A bomb of mass 9*kg* explodes into 2 pieces of mass 3*kg* and 6*kg*. The velocity of mass 3*kg* is 1.6 *m/s*, the K.E. of mass 6*kg* is

(a) 3.84 *J* (b) 9.6 *J*

(c) 1.92 *J* (d) 2.92 *J*

58. Two masses of 1*kg* and 16*kg* are moving with equal K.E. The ratio of magnitude of the linear momentum is [RPMT 2000] [AIEEE 2002]

(a) 1 : 2 (b) 1 : 4

(c) $1 : \sqrt{2}$ (d) $\sqrt{2} : 1$

59. A machine which is 75 percent efficient, uses 12 joules of energy in lifting up a 1 *kg* mass through a certain distance. The mass is then allowed to fall through that distance. The velocity at the end of its fall is (in ms^{-1}) [Kerala PMT 2002]

(a) $\sqrt{24}$ (b) $\sqrt{32}$

(c) $\sqrt{18}$ (d) $\sqrt{9}$

60. Two bodies moving towards each other collide and move away in opposite directions. There is some rise in temperature of bodies because a part of the kinetic energy is converted into [AMU (Med.) 2000]

(a) Heat energy (b) Electrical energy

(c) Nuclear energy (d) Mechanical energy

61. A particle of mass m at rest is acted upon by a force *F* for a time *t*. Its Kinetic energy after an interval *t* is

[Kerala PET 2002]

(a) $\frac{F^2t^2}{m}$ (b) $\frac{F^2t^2}{2m}$

(c) $\frac{F^2t^2}{3m}$ (d) $\frac{Ft}{2m}$

62. The potential energy of a weight less spring compressed by a distance a is proportional to [MP PET 2003]

(a) a (b) a^2

(c) a^{-2} (d) a^0

63. Two identical blocks A and B, each of mass 'm' resting on smooth floor are connected by a light spring of natural length L and spring constant K, with the spring at its natural length. A third identical block 'C' (mass m) moving with a speed v along the line joining A and B collides with A. the maximum compression in the spring is [EAMCET 2003]

(a) $v\sqrt{\frac{m}{2k}}$ (b) $m\sqrt{\frac{v}{2k}}$

(c) $\sqrt{\frac{mv}{k}}$ (d) $\frac{mv}{2k}$

64. Two bodies of masses m and 4 m are moving with equal K.E. The ratio of their linear momentums is

[Orissa JEE 2003; AIIMS 1999]

(a) 4 : 1 (b) 1 : 1

(c) 1 : 2 (d) 1 : 4

65. A stationary particle explodes into two particles of a masses m and m which move in opposite directions with velocities v_1 and v_2. The ratio of their kinetic energies E_1 / E_2 is

[CBSE PMT 2003]

(a) m_1 / m_2 (b) 1

(c) $m_1 v_2 / m_2 v_1$ (d) m_2 / m_1

66. The kinetic energy of a body of mass 3 kg and momentum 2 Ns is

(a) 1 J (b) $\frac{2}{3} J$

(c) $\frac{3}{2} J$ (d) 4 J

67. A bomb of mass 3.0 Kg explodes in air into two pieces of masses 2.0 kg and 1.0 kg. The smaller mass goes at a speed of 80 m/s. The total energy imparted to the two fragments is

[AIIMS 2004]

(a) 1.07 kJ (b) 2.14 kJ

(c) 2.4 kJ (d) 4.8 kJ

68. A bullet moving with a speed of 100 ms^{-1} can just penetrate two planks of equal thickness. Then the number of such planks penetrated by the same bullet when the speed is doubled will be

(a) 4 (b) 8

(c) 6 (d) 10

69. A particle of mass m_1 is moving with a velocity v_1 and another particle of mass m_2 is moving with a velocity v_2. Both of them have the same momentum but their different kinetic energies are E_1 and E_2 respectively. If $m_1 > m_2$ then

(a) $E_1 < E_2$ (b) $\frac{E_1}{E_2} = \frac{m_1}{m_2}$

(c) $E_1 > E_2$ (d) $E_1 = E_2$

70. A ball of mass 2kg and another of mass 4kg are dropped together from a 60 $feet$ tall building. After a fall of 30 $feet$ each towards earth, their respective kinetic energies will be in the ratio of

(a) $\sqrt{2} : 1$ (b) $1 : 4$

(c) $1 : 2$ (d) $1 : \sqrt{2}$

71. Four particles given, have same momentum which has maximum kinetic energy [Orissa PMT 2004]

(a) Proton (b) Electron

(c) Deutron (d) α -particles

72. A body moving with velocity v has momentum and kinetic energy numerically equal. What is the value of v

[Pb. PMT 2002; J&K CET 2004]

(a) 2m/s (b) $\sqrt{2} m/s$

(c) 1m/s (d) 0.2 m/s

73. If a man increase his speed by 2 m/s, his K.E. is doubled, the original speed of the man is [Pb. PET 2002]

(a) $(1 + 2\sqrt{2})\, m/s$ (b) 4 m/s

(c) $(2 + 2\sqrt{2}) m/s$ (d) $(2 + \sqrt{2})\, m/s$

74. An object of mass 3m splits into three equal fragments. Two fragments have velocities $v\hat{j}$ and $v\hat{i}$. The velocity of the third fragment is [UPSEAT 2004]

(a) $v(\hat{j} - \hat{i})$ (b) $v(\hat{i} - \hat{j})$

(c) $-v(\hat{i} + \hat{j})$ (d) $\frac{v(\hat{i} + \hat{j})}{\sqrt{2}}$

[MP PET 2004]

75. A bomb is kept stationary at a point. It suddenly explodes into two fragments of masses 1 g and 3 g. The total K.E. of the fragments is $6.4 \times 10^4\ J$. What is the K.E. of the smaller fragment

(a) $2.5 \times 10^4\ J$ (b) $3.5 \times 10^4\ J$

(c) $4.8 \times 10^4\ J$ (d) $5.2 \times 10^4\ J$

76. Which among the following, is a form of energy [DCE 2004]

(a) Light (b) Pressure

(c) Momentum (d) Power

77. A body is moving with a velocity v, breaks up into two equal parts. One of the part retraces back with velocity v. Then the velocity of the other part is [DCE 2004]

(a) v in forward direction [KCET 2004] (b) 3v in forward direction

(c) v in backward direction (d) 3v in backward direction

78. If a shell fired from a cannon, explodes in mid air, then

[Pb. PET 2004]

(a) Its total kinetic energy increases

(b) Its total momentum increases

[CBSE PMT 2004]

(c) Its total momentum decreases

(d) None of these

79. A particle of mass m moving with velocity V_0 strikes a simple pendulum of mass m and sticks to it. The maximum height attained by the pendulum will be [RPET 2002]

(a) $h = \frac{V_0^2}{8g}$ [CBSE PMT 2004] (b) $\sqrt{V_0 g}$

(c) $2\sqrt{\frac{V_0}{g}}$ (d) $\frac{V_0^2}{4g}$

80. Masses of two substances are 1 *g* and 9 *g* respectively. If their kinetic energies are same, then the ratio of their momentum will be

(a) 1 : 9 (b) 9 : 1

(c) 3 : 1 (d) 1 : 3

81. A body of mass 5 *kg* is moving with a momentum of 10 *kg-m/s*. A force of 0.2 *N* acts on it in the direction of motion of the body for 10 *seconds*. The increase in its kinetic energy is [MP PET 1999]

(a) 2.8 *Joule* (b) 3.2 *Joule*

(c) 3.8 *Joule* (d) 4.4 *Joule*

82. If the momentum of a body increases by 0.01%, its kinetic energy will increase by [MP PET 2001]

(a) 0.01% (b) 0.02%

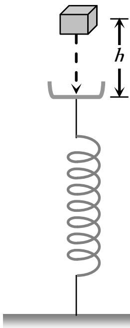
(c) 0.04% (d) 0.08%

83. 1 *a.m.u.* is equivalent to [UPSEAT 2001]

(a) 1.6×10^{-12} *Joule* (b) 1.6×10^{-19} *Joule*

(c) 1.5×10^{-10} *Joule* (d) 1.5×10^{-19} *Joule*

84. A block of mass *m* initially at rest is dropped from a height *h* on to a spring of force constant *k*. the maximum compression in the spring is *x* then [BCECE 2005]



(a) $mgh=\frac{1}{2}kx^2$

(b) $mg(h+x)=\frac{1}{2}kx^2$

(c) $mgh=\frac{1}{2}k(x+h)^2$

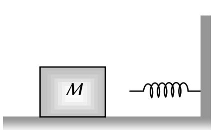
(d) $mg(h+x)=\frac{1}{2}k(x+h)^2$

85. A spherical ball of mass 20 *kg* is stationary at the top of a hill of height 100 *m*. It slides down a smooth surface to the ground, then climbs up another hill of height 30 *m* and finally slides down to a horizontal base at a height of 20 *m* above the ground. The velocity attained by the ball is [AIEEE 2005]

(a) 10 *m/s* (b) $10\sqrt{30}$ *m/s*

(c) 40 *m/s* (d) 20 *m/s*

86. The block of mass *M* moving on the frictionless horizontal surface collides with the spring of spring constant *K* and compresses it by length *L*. The maximum momentum of the block after collision is



(a) Zero

(b) $\frac{ML^2}{K}$

(c) $\sqrt{MK}\,L$

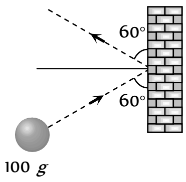
(d) $\frac{KL^2}{2M}$

87. A bomb of mass $30\,kg$ at rest explodes into two pieces of masses $18\,kg$ and $12\,kg$. The velocity of $18\,kg$ mass is $6\,ms^{-1}$. The kinetic energy of the other mass is [CBSE PMT 2005]

(a) 256 *J* (b) 486 *J*

(c) 524 *J* (d) 324 *J*

88. A mass [BHU 2004] of 100*g* strikes the wall with speed 5*m/s* at an angle as shown in figure and it rebounds with the same speed. If the contact time is 2×10^{-3} sec, what is the force applied on the mass by the wall [Orissa JEE 2005]



(a) $250\sqrt{3}$ *N* to right

(b) 250 *N* to right

(c) $250\sqrt{3}$ *N* to left

(d) 250 *N* to left

Power

1. If a force *F* is applied on a body and it moves with a velocity *v*, the power will be [CPMT 1985, 97; DCE 1999; UPSEAT 2004]

(a) $F\times v$ (b) F/v

(c) F/v^2 (d) $F\times v^2$

2. A body of mass *m* accelerates uniformly from rest to v_1 in time t_1. As a function of time *t*, the instantaneous power delivered to the body is [AIEEE 2004]

(a) $\frac{mv_1t}{t_1}$ (b) $\frac{mv_1^2t}{t_1}$

(c) $\frac{mv_1t^2}{t_1}$ (d) $\frac{mv_1^2t}{t_1^2}$

3. A man is riding on a cycle with velocity 7.2 *km/hr* up a hill having a slope 1 in 20. The total mass of the man and cycle is 100 *kg*. The power of the man is

(a) 200 *W* (b) 175 *W*

(c) 125 *W* (d) 98 *W*

4. A 12 *HP* motor has to be operated 8 *hours/day*. How much will it cost at the rate of 50 *paisa/kWh* in 10 days

(a) Rs. 350/- (b) Rs. 358/-

(c) Rs. 375/- (d) Rs. 397/-

5. A motor boat is travelling with a speed of 3.0 *m/sec*. If the force on it due to water flow is 500 *N*, the power of the boat is

(a) 150 *kW* (b) 15 *kW*

(c) 1.5 *kW* (d) 150 *W*

6. An electric motor exerts a force of 40 *N* on a cable and pulls it by a distance [AIEEE 2005] of 30 *m* in one minute. The power supplied by the motor (in *Watts*) is [EAMCET 1984]

(a) 20 (b) 200

(c) 2 (d) 10

7. An electric motor creates a tension of 4500 *newton* in a hoisting cable and reels it in at the rate of 2 *m/sec*. What is the power of electric motor [MNR 1984]

(a) 15 *kW* (b) 9 *kW*

(c) 225 *W* (d) 9000 *HP*

8. A weight lifter lifts 300 *kg* from the ground to a height of 2 *meter* in 3 *second*. The average power generated by him is [CPMT 1989; JIPMER 2001,02]

(a) 5880 *watt* (b) 4410 *watt*

(c) 2205 *watt* (d) 1960 *watt*

9. Power of a water pump is 2 kW. If $g = 10\, m/\sec^2$, the amount of water it can raise in one minute to a height of 10 m is

(a) 2000 *litre* (b) 1000 *litre*

(c) 100 *litre* (d) 1200 *litre*

10. An engine develops 10 kW of power. How much time will it take to lift a mass of 200 kg to a height of 40 m. $(g = 10\, m/\sec^2)$

(a) 4 *sec* (b) 5 *sec*

(c) 8 *sec* (d) 10 *sec*

11. A car of mass 'm' is driven with acceleration 'a' along a straight level road against a constant external resistive force 'R'. When the velocity of the car is 'V', the rate at which the engine of the car is doing work will be

[MP PMT/PET 1998; JIPMER 2000]

(a) RV (b) maV

(c) $(R + ma)V$ (d) $(ma - R)V$

12. The average power required to lift a 100 kg mass through a height of 50 *metres* in approximately 50 *seconds* would be

[SCRA 1994; MH CET 2000]

(a) 50 J/s (b) 5000 J/s

(c) 100 J/s (d) 980 J/s

13. From a waterfall, water is falling down at the rate of 100 kg/s on the blades of turbine. If the height of the fall is 100 m, then the power delivered to the turbine is approximately equal to[KCET 1994; BHU 1997; MP PET 2000]

(a) 100 kW (b) 10 kW

(c) 1 kW (d) 1000 kW

14. The power of a pump, which can pump 200kg of water to a height of 200m in 10*sec* is $(g = 10 m/s^2)$ [CBSE PMT 2000]

(a) 40 kW (b) 80 kW

(c) 400 kW (d) 960 kW

15. A 10 *H.P.* motor pumps out water from a well of depth 20m and fills a water tank of volume 22380 *litres* at a height of 10m from the ground. the running time of the motor to fill the empty water tank is $(g = 10 ms^{-2})$

[EAMCET (Engg.) 2000]

(a) 5 *minutes* (b) 10 *minutes*

(c) 15 *minutes* (d) 20 *minutes*

16. A car of mass 1250 kg is moving at 30m/s. Its engine delivers 30 kW while resistive force due to surface is 750N. What max acceleration can be given in the car

[RPET 2000]

(a) $\frac{1}{3} m/s^2$ (b) $\frac{1}{4} m/s^2$

(c) $\frac{1}{5} m/s^2$ (d) $\frac{1}{6} m/s^2$

17. A force applied by an engine of a train of mass $2.05 \times 10^6 kg$ changes its velocity from $5m/s$ to 25 m/s in 5 minutes. The power of the engine is [EAMCET 2001]

(a) $1.025 MW$ (b) $2.05 MW$

(c) $5 MW$ (d) $6 MW$

18. A truck of mass 30,000kg moves up an inclined plane of slope 1 in 100 at a speed of 30 *kmph*. The power of the truck is (given $g = 10 ms^{-1}$) [Kerala (Engg.) 2001]

(a) 25 kW (b) 10 kW

(c) 5 kW (d) 2.5 kW

19. A 60 kg man runs up a staircase in 12 seconds while a 50 kg man [CBSE PMT 1990; Kerala PMT 2004] runs up the same staircase in 11, seconds, the ratio of the rate of doing their work is [AMU (Engg.) 2001]

(a) 6 : 5 (b) 12 : 11

(c) 11 : 10 (d) 10 : 11

20. A pump [CPMT 1992] motor is used to deliver water at a certain rate from a given pipe. To obtain twice as much water from the same pipe in the same time, power of the motor has to be increased to

(a) 16 times (b) 4 times

(c) 8 times (d) 2 times

21. What average horsepower is developed by an 80 kg man while climbing in 10 s a flight of stairs that rises 6 m vertically

(a) 0.63 HP (b) 1.26 HP

(c) 1.8 HP (d) 2.1 HP

22. A car of mass 1000 kg accelerates uniformly from rest to a velocity of 54 km/hour in 5s. The average power of the engine during this period in watts is (neglect friction)

[Kerala PET 2002]

(a) 2000 W (b) 22500 W

(c) 5000 W (d) 2250 W

23. A quarter horse power motor runs at a speed of 600 *r.p.m.* Assuming 40% efficiency the work done by the motor in one rotation will be [Kerala PET 2002]

(a) 7.46 J (b) 7400 J

(c) 7.46 *ergs* (d) 74.6 J

24. An engine pumps up 100 kg of water through a height of 10 m in 5 s. Given that the efficiency of the engine is 60% . If $g = 10 ms^{-2}$, the power of the engine is [DPMT 2004]

(a) $3.3 kW$ (b) $0.33 kW$

(c) $0.033 kW$ (d) $33 kW$

25. A force of $2\hat{i} + 3\hat{j} + 4\hat{k}\ N$ acts on a body for 4 second, produces a displacement of $(3\hat{i} + 4\hat{j} + 5\hat{k}) m$. The power used is [Pb. PET 2001; CBSE PMT 2

(a) 9.5 W (b) 7.5 W

(c) 6.5 W (d) 4.5 W

26. The power of pump, which can pump 200 kg of water to a height of 50 m in 10 *sec*, will be [DPMT 2003]

(a) 10×10^3 *watt* (b) 20×10^3 *watt*

(c) 4×10^3 *watt* (d) 60×10^3 *watt*

27. From an automatic gun a man fires 360 bullet per minute with a speed of 360 *km/hour*. If each weighs 20 g, the power of the gun is

(a) $600 W$ (b) $300 W$

(c) $150 W$ (d) $75 W$

28. An engine pump is used to pump a liquid of density ρ continuously through a pipe of cross-sectional area A. If the speed of flow of the liquid in the pipe is v, then the rate at which kinetic energy is being imparted to the liquid is

(a) $\frac{1}{2} A\rho v^3$ (b) $\frac{1}{2} A\rho v^2$

(c) $\frac{1}{2} A\rho v$ (d) $A\rho v$

29. If the heart pushes 1 cc of blood in one second under pressure 20000 N/m^2 the power of heart is [J&K CET 2005]

(a) 0.02 W (b) 400 W

(c) 5×10^{-10} W (d) 0.2 W

30. A man does a given amount of work in 10 sec. Another man does the same amount of work in 20 sec. The ratio of the output power of first man to the second man is

[J&K CET 2005]

(a) 1 (b) 1/2

(c) 2/1 (d) None of these

Elastic and Inelastic Collision

1. The coefficient of restitution e for a perfectly elastic collision is

(a) 1 (b) 0

(c) ∞ (d) -1

2. The principle of conservation of linear momentum can be strictly applied during a collision between two particles provided the time of impact is

(a) Extremely small

(b) Moderately small

(c) Extremely large

(d) Depends on a particular case

3. A shell initially at rest explodes into two pieces of equal mass, then the two pieces will

[CPMT 1982; EAMCET 1988; Orissa PMT 2004]

(a) Be at rest

(b) Move with different velocities in different directions

(c) Move with the same velocity in opposite directions

(d) Move with the same velocity in same direction

4. A sphere of mass m moving with a constant velocity u hits another stationary sphere of the same mass. If e is the coefficient of restitution, then the ratio of the velocity of two spheres after collision will be [RPMT 1996; BHU 1997]

(a) $\frac{1-e}{1+e}$ (b) $\frac{1+e}{1-e}$

(c) $\frac{e+1}{e-1}$ (d) $\frac{e-1}{e+1}t^2$

5. Two solid rubber balls A and B having masses 200 and 400 gm respectively are moving in opposite directions with velocity of A equal to 0.3 m/s. After collision the two balls come to rest, then the velocity of B is [CPMT 1978, 86, 88]

(a) 0.15 m/sec (b) 1.5 m/sec

(c) $-$ 0.15 m/sec (d) None of the above

6. Two perfectly elastic particles P and Q of equal mass travelling along the line joining them with velocities 15 m/sec and 10 m/sec. After collision, their velocities respectively (in m/sec) will be

(a) 0, 25 (b) 5, 20

(c) 10, 15 (d) 20, 5

7. A cannon ball is fired with a velocity 200 m/sec at an angle of 60° with the horizontal. At the highest point of its flight it explodes into 3 equal fragments, one going vertically upwards with a velocity 100 m/sec, the second one falling vertically downwards with a velocity 100 m/sec. The third fragment will be moving with a velocity

[NCERT 1983; AFMC 1997]

(a) 100 m/s in the horizontal direction

(b) 300 m/s in the horizontal direction

(c) 300 m/s in a direction making an angle of 60° with the horizontal

(d) 200 m/s in a direction making an angle of 60° with the horizontal

8. A lead ball strikes a wall and falls down, a tennis ball having the same mass and velocity strikes the wall and bounces back. Check the correct statement

(a) The momentum of the lead ball is greater than that of the tennis ball

(b) The lead ball suffers a greater change in momentum compared with the tennis ball [CBSE PMT 1988]

(c) The tennis ball suffers a greater change in momentum as compared with the lead ball

(d) Both suffer an equal change in momentum

9. When two bodies collide elastically, then

[CPMT 1974; MP PMT 2001; RPET 2000; Kerala PET 2005]

(a) Kinetic energy of the system alone is conserved

(b) Only momentum is conserved

(c) Both energy and momentum are conserved

(d) Neither energy nor momentum is conserved

10. Two balls at same temperature collide. What is conserved

[NCERT 1974; CPMT 1983; DCE 2004]

(a) Temperature (b) Velocity

(c) Kinetic energy (d) Momentum

11. A body of mass 5 kg explodes at rest into three fragments with masses in the ratio 1 : 1 : 3. The fragments with equal masses fly in mutually perpendicular directions with speeds of 21 m/s. The velocity of the heaviest fragment will be

[CBSE PMT 1991]

(a) 11.5 m/s (b) 14.0 m/s

(c) 7.0 m/s (d) 9.89 m/s

12. A heavy steel ball of mass greater than 1 kg moving with a speed of $2\, m\, sec^{-1}$ collides head on with a stationary ping-pong ball of mass less than 0.1 gm. The collision is elastic. After the collision the ping-pong ball moves approximately with speed

(a) $2\, m\, sec^{-1}$ (b) $4\, m\, sec^{-1}$

(c) $2 \times 10^4\, m\, sec^{-1}$ (d) $2 \times 10^3\, m\, sec^{-1}$

13. A body of mass 'M' collides against a wall with a velocity v and retraces its path with the same speed. The change in momentum is (take initial direction of velocity as positive)

[EAMCET 1982]

(a) Zero (b) 2Mv

(c) Mv (d) $-$ 2 Mv

14. A gun fires a bullet of mass 50 gm with a velocity of $30\, m\, sec^{-1}$. [CPMT 1988; MP PMT 1994] Because of this the gun is pushed back with a velocity of $1\, m\, sec^{-1}$. The mass of the gun is

[EAMCET 1989; AIIMS 2001]

(a) 15 kg (b) 30 kg

(c) 1.5 kg (d) 20 kg

15. In an elastic collision of two particles the following is conserved[MP PET 1994; D

(a) Momentum of each particle

(b) Speed of each particle

(c) Kinetic energy of each particle

(d) Total kinetic energy of both the particles

16. A ^{238}U nucleus decays by emitting an alpha particle of speed $v\,ms^{-1}$. The recoil speed of the residual nucleus is (in ms^{-1}) [CBSE PMT 1995; AIEEE 2003]

(a) $-4v/234$ (b) $v/4$

(c) $-4v/238$ (d) $4v/238$

17. A smooth sphere of mass *M* moving with velocity *u* directly collides elastically with another sphere of mass *m* at rest. After collision their final velocities are *V* and *v* respectively. The value of *v* is

(a) $\frac{2uM}{m}$ (b) $\frac{2um}{M}$

(c) $\frac{2u}{1+\frac{m}{M}}$ (d) $\frac{2u}{1+\frac{M}{m}}$

18. A body of mass *m* having an initial velocity *v*, makes head on collision with a stationary body of mass *M*. After the collision, the body of mass *m* comes to rest and only the body having mass *M* moves. This will happen only when [MP PMT 1995]

(a) $m >> M$ (b) $m << M$

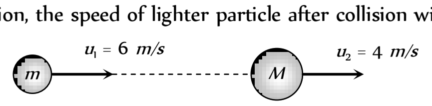
(c) $m = M$ (d) $m = \frac{1}{2}M$

19. A particle of mass *m* moving with a velocity $\vec{V}$ makes a head on elastic collision with another particle of same mass initially at rest. The velocity of the first particle after the collision will be [MP PMT 1997; MP PET 2001; UPSEAT 2001]

(a) $\vec{V}$ (b) $-\vec{V}$

(c) $-2\vec{V}$ (d) Zero

20. A particle of mass m moving with horizontal speed 6 *m/sec* as shown in figure. If $m << M$ then for one dimensional elastic collision, the speed of lighter particle after collision will be



(a) 2*m/sec* in original direction

(b) 2 *m/sec* opposite to the original direction

(c) 4 *m/sec* opposite to the original direction

(d) 4 *m/sec* in original direction

21. A shell of mass *m* moving with velocity *v* suddenly breaks into 2 pieces. The part having mass *m*/4 remains stationary. The velocity of the other shell will be [CPMT 1999]

(a) *v* (b) 2*v*

(c) $\frac{3}{4}v$ (d) $\frac{4}{3}v$

22. Two equal masses m_1 and m_2 moving along the same straight line with velocities + 3 *m/s* and – 5 *m/s* respectively collide elastically. Their velocities after the collision will be respectively [CBSE PMT 1994, 98; AIIMS 2000]

(a) + 4 *m/s* for both (b) – 3 *m/s* and +5 *m/s*

(c) – 4 *m/s* and + 4 *m/s* (d) – 5 *m/s* and + 3 *m/s*

23. A rubber ball is dropped from a height of 5 *m* on a planet where the acceleration due to gravity is not known. On bouncing, it rises to 1.8 *m*. The ball loses its velocity on bouncing by a factor of

(a) 16/25 (b) 2/5

(c) 3/5 (d) 9/25

24. A metal ball falls from a height of 32 *metre* on a steel plate. If the coefficient of restitution is 0.5, to what height will the ball rise after second bounce [EAMCET 1994]

(a) 2 *m* (b) 4 *m*

(c) 8 *m* (d) 16 *m*

25. At high altitude, a body explodes at rest into two equal fragments with one fragment receiving horizontal velocity of 10 *m/s*. Time taken by the two radius vectors connecting point of explosion to fragments to make 90° is [EAMCET (Engg.) 1995; DPMT 2000]

(a) 10 [MP PET 1995] (b) 4 *s*

(c) 2 *s* (d) 1 *s*

26. A ball of mass 10 *kg* is moving with a velocity of 10 *m/s*. It strikes another ball of mass 5 *kg* which is moving in the same direction with a velocity of 4 *m/s*. If the collision is elastic, their velocities after the collision will be, respectively [CMEET Bihar 1995]

(a) 6 *m/s*, 12 *m/s* (b) 12 *m/s*, 6 *m/s*

(c) 12 *m/s*, 10 *m/s* (d) 12 *m/s*, 25 *m/s*

27. A body of mass 2 *kg* collides with a wall with speed 100 *m/s* and rebounds with same speed. If the time of contact was 1/50 second, the force exerted on the wall is [CPMT 1993]

(a) 8 *N* (b) $2\times10^4\ N$

(c) 4 *N* (d) $10^4\ N$

28. A body falls on a surface of coefficient of restitution 0.6 from a height of 1 *m*. Then the body rebounds to a height of [CPMT 1993; Pb. PET 2001]

(a) 0.6 *m* (b) 0.4 *m*

(c) 1 *m* (d) 0.36 *m*

29. A ball is dropped from a height *h*. If the coefficient of restitution be *e*, then to what height will it rise after jumping twice from the ground [MP PMT 2003] [RPMT 1996; Pb. PET 2001]

(a) *eh*/2 (b) 2*eh*

(c) *eh* (d) e^4h

30. A ball of weight 0.1 *kg* coming with speed 30 *m/s* strikes with a bat and returns in opposite direction with speed 40 *m/s*, then the impulse is (Taking final velocity as positive) [AFMC 1997]

(a) $-0.1\times(40)-0.1\times(30)$ (b) $0.1\times(40)-0.1\times(-30)$

(c) $0.1\times(40)+0.1\times(-30)$ (d) $0.1\times(40)-0.1\times(20)$

31. A billiard ball moving with a speed of 5 *m/s* collides with an identical ball originally at rest. If the first ball stops after collision, then the second ball will move forward with a speed of

(a) $10\,ms^{-1}$ (b) $5\,ms^{-1}$

(c) $2.5\,ms^{-1}$ (d) $1.0\,ms^{-1}$

32. If two balls each of mass 0.06 *kg* moving in opposite directions with speed 4 *m/s* collide and rebound with the same speed, then the impulse imparted to each ball due to other is [CBSE PMT 1998]

(a) 0.48 *kg-m/s* (b) 0.24 *kg-m/s*

(c) 0.81 *kg-m*/*s* (d) Zero

33. A ball of mass *m* falls vertically to the ground from a height h_1 and rebound to a height h_2. The change in momentum of the ball on striking the ground is [AMU (Engg.) 1999]

(a) $mg(h_1 - h_2)$ (b) $m(\sqrt{2gh_1} + \sqrt{2gh_2})$

(c) $m\sqrt{2g(h_1 + h_2)}$ (d) $m\sqrt{2g}(h_1 + h_2)$

34. A body of mass 50 *kg* is projected vertically upwards with velocity of 100 *m*/*sec*. 5 seconds after this body breaks into 20 *kg* and 30 *kg*. If 20 *kg* piece travels upwards with 150 *m*/*sec*, then the velocity of other block will be [RPMT 1999]

(a) 15 *m*/*sec* downwards (b) 15 *m*/*sec* upwards

(c) 51 *m*/*sec* downwards (d) 51 *m*/*sec* upwards

35. A steel ball of radius 2 *cm* is at rest on a frictionless surface. Another ball of radius 4*cm* moving at a velocity of 81 *cm*/*sec* collides elastically with first ball. After collision the smaller ball moves with speed of [RPMT 1999]

(a) 81 *cm*/*sec* (b) 63 *cm*/*sec*

(c) 144 *cm*/*sec* (d) None of these

36. A space craft of mass *M* is moving with velocity *V* and suddenly explodes into two pieces. A part of it of mass *m* becomes at rest, then the velocity of other part will be

[RPMT 1999]

(a) $\frac{MV}{M-m}$ (b) $\frac{MV}{M+m}$

(c) $\frac{mV}{M-m}$ (d) $\frac{(M+m)V}{m}$

37. A ball hits a vertical wall horizontally at 10*m/s* bounces back at 10 *m/s* [JIPMER 1999]

(a) There is no acceleration because $10\frac{m}{s} - 10\frac{m}{s} = 0$

(b) There may be an acceleration because its initial direction is horizontal

(c) There is an acceleration because there is a momentum change

(d) Even though there is no change in momentum there is a change in direction. Hence it has an acceleration

38. A bullet of mass 50 *gram* is fired from a 5 *kg* gun with a velocity of 1*km/s*. the speed of recoil of the gun is

[JIPMER 1999]

(a) $5 m/s$ (b) $1 m/s$

(c) $0.5 m/s$ (d) $10 m/s$

39. A body falling from a height of 10m rebounds from hard floor. If it loses 20% energy in the impact, then coefficient of restitution is

(a) 0.89 (b) 0.56

(c) 0.23 (d) 0.18

40. A body of mass m_1 moving with a velocity 3 *ms*⁻¹ collides with another body at rest of mass m_2. After collision the velocities of the two bodies are 2 *ms*⁻¹ and 5*ms*⁻¹ respectively along the direction of motion of m_1. The ratio m_1/m_2 is

[EAMCET (Engg.) 2000]

(a) $\frac{5}{12}$ (b) 5

(c) $\frac{1}{5}$ (d) $\frac{12}{5}$

41. 100 *g* of a iron ball having velocity 10 *m*/*s* collides with a wall at an angle 30^o and rebounds with the same angle. If the period of contact between the ball and wall is 0.1 second, then the force experienced by the ball is

[DPMT 2000]

(a) 100*N* (b) 10 *N*

(c) 0.1 *N* (d) 1.0 *N*

42. Two bodies having same mass 40 *kg* are moving in opposite directions, one with a velocity of $10 m/s$ and the other with $7 m/s$. If they collide and move as one body, the velocity of the combination is [Pb. PMT 2000]

(a) $10 m/s$ (b) $7 m/s$

(c) $3 m/s$ (d) $1.5 m/s$

43. A body at rest breaks up into 3 parts. If 2 parts having equal masses fly off perpendicularly each after with a velocity of 12*m*/*s*, then the velocity of the third part which has 3 times mass of each part is

(a) $4\sqrt{2} m/s$ at an angle of 45^o from each body

(b) $24\sqrt{2} m/s$ at an angle of 135^o from each body

(c) $6\sqrt{2} m/s$ at 135^o from each body

(d) $4\sqrt{2} m/s$ at 135^o from each body

44. A particle falls from a height *h* upon a fixed horizontal plane and rebounds. If *e* is the coefficient of restitution, the total distance travelled before rebounding has stopped is

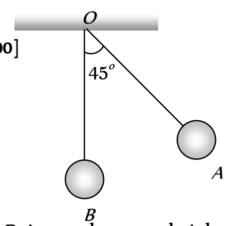
[EAMCET 2001]

(a) $h\left(\frac{1+e^2}{1-e^2}\right)$ (b) $h\left(\frac{1-e^2}{1+e^2}\right)$

(c) $\frac{h}{2}\left(\frac{1-e^2}{1+e^2}\right)$ (d) $\frac{h}{2}\left(\frac{1+e^2}{1-e^2}\right)$

45. The bob A of a simple pendulum is released when the string makes an angle of 45^o with the vertical. It hits another bob *B* of the same material and same mass kept at rest on the table. If the collision is elastic [Kerala (Engg.) 2001]

[AIIMS 2000]



(a) Both *A* and *B* rise to the same height

(b) Both *A* and *B* come to rest at *B*

(c) Both *A* and *B* move with the same velocity of *A*

(d) A comes to rest and B moves with the velocity of A

46. A big ball of mass M, moving with velocity u strikes a small ball of mass m, which is at rest. Finally small ball obtains velocity u and big ball v. Then what is the value of v [RPET 2001]

(a) $\frac{M-m}{M+m}u$ (b) $\frac{m}{M+m}u$

(c) $\frac{2m}{M+m}u$ (d) $\frac{M}{M+m}u$

47. A body of mass 5 kg moving with a velocity 10m/s collides with another body of the mass 20 kg at, rest and comes to rest. The velocity of the second body due to collision is [Pb. PMT 1999; KCET 2001]

(a) 2.5 m/s (b) 5 m/s

(c) 7.5 m/s (d) 10 m/s

48. A ball of mass m moving with velocity V, makes a head on elastic collision with a ball of the same mass moving with velocity $2V$ towards it. Taking direction of V as positive velocities of the two balls after collision are [MP PMT 2002]

(a) $-V$ and $2V$ (b) $2V$ and $-V$

(c) V and $-2V$ (d) $-2V$ and V

49. A body of mass M_1 collides elastically with another mass M_2 at rest. There is maximum transfer of energy when [Orissa JEE 2002; DCE 2001, 02]

(a) $M_1 > M_2$

(b) $M_1 < M_2$

(c) $M_1 = M_2$

(d) Same for all values of M_1 and M_2

50. A body of mass 2kg makes an elastic collision with another body at rest and continues to move in the original direction with one fourth of its original speed. The mass of the second body which collides with the first body is [Kerala PET 2002]

(a) 2 kg (b) 1.2 kg

(c) 3 kg (d) 1.5 kg

51. In the elastic collision of objects [RPET 2003]

(a) Only momentum remains constant

(b) Only K.E. remains constant

(c) Both remains constant

(d) None of these

52. Two particles having position vectors $\vec{r}_1 = (3\hat{i} + 5\hat{j})$ *metres* and $\vec{r}_2 = (-5\hat{i} - 3\hat{j})$ *metres* are moving with velocities $\vec{v}_1 = (4\hat{i} + 3\hat{j}) m/s$ and $\vec{v}_2 = (\alpha\hat{i} + 7\hat{j})$ m/s. If they collide after 2 seconds, the value of 'α' is [EAMCET 2003]

(a) 2 (b) 4

(c) 6 (d) 8

53. A neutron makes a head-on elastic collision with a stationary deuteron. The fractional energy loss of the neutron in the collision is

(a) 16/81 (b) 8/9

(c) 8/27 (d) 2/3

54. A body of mass m is at rest. Another body of same mass moving with velocity V makes head on elastic collision with the first body. After collision the first body starts to move with velocity

(a) V (b) $2V$

(c) Remain at rest (d) No predictable

55. A body of mass M moves with velocity v and collides elastically with a another body of mass m (M>>m) at rest then the velocity of body of mass m is [BCECE 2004]

(a) v (b) $2v$

(c) v/2 (d) Zero

56. Four smooth steel balls of equal mass at rest are free to move along a straight line without friction. The first ball is given a velocity of 0.4 m/s. It collides head on with the second elastically, the second one similarly with the third and so on. The velocity of the last ball is[UPSEAT 2

(a) $0.4 m/s$ (b) $0.2 m/s$

(c) $0.1 m/s$ (d) $0.05 m/s$

57. A space craft of mass 'M' and moving with velocity 'v' suddenly breaks in two pieces of same mass m. After the explosion one of the mass 'm' becomes stationary. What is the velocity of the other part of craft [DCE 2003]

(a) $\frac{Mv}{M-m}$ (b) v

(c) $\frac{Mv}{m}$ (d) $\frac{M-m}{m}v$

58. Two masses m_A and m_B moving with velocities v_A and v_B in opposite directions collide elastically. After that the masses m_A and m_B move with velocity v_B and v_A respectively. The ratio (m_A / m_B) is [RPMT 2003, AFMC 2002]

(a) 1 (b) $\frac{v_A - v_B}{v_A + v_B}$

(c) $(m_A + m_B)/m_A$ (d) v_A / v_B

59. A ball is allowed to fall from a height of 10 m. If there is 40% loss of energy due to impact, then after one impact ball will go up to

(a) 10 m (b) 8 m

(c) 4 m (d) 6 m

60. Which of the following statements is true [NCERT 1984]

(a) In elastic collisions, the momentum is conserved but not in inelastic collisions

(b) Both kinetic energy and momentum are conserved in elastic as well as inelastic collisions

(c) Total kinetic energy is not conserved but momentum is conserved in inelastic collisions

(d) Total kinetic energy is conserved in elastic collisions but momentum is not conserved in elastic collisions

61. A tennis ball dropped from a height of 2 m rebounds only 1.5 m after hitting the ground. What fraction of its energy is lost in the impact

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$

(c) $\frac{1}{3}$ (d) $\frac{1}{8}$

62. A body of mass m moving with velocity v makes a head-on collision with another body of mass 2 m which is initially at rest. The loss of kinetic energy of the colliding body (mass m) is [AIIMS 2003]

(a) $\frac{1}{2}$ of its initial kinetic energy

[Orissa PMT 2004]

(b) $\frac{1}{9}$ of its initial kinetic energy

(c) $\frac{8}{9}$ of its initial kinetic energy

(d) $\frac{1}{4}$ of its initial kinetic energy

63. The quantities remaining constant in a collision are

(a) Momentum, kinetic energy and temperature

(b) Momentum and kinetic energy but not temperature

(c) Momentum and temperature but not kinetic energy

(d) Momentum but neither kinetic energy nor temperature

64. An inelastic ball is dropped from a height of 100 *m*. Due to earth, 20% of its energy is lost. To what height the ball will rise

(a) 80 *m* (b) 40 *m*

(c) 60 *m* (d) 20 *m*

65. A ball is projected vertically down with an initial velocity from a height of 20 *m* onto a horizontal floor. During the impact it loses 50% of its energy and rebounds to the same height. The initial velocity of its projection is

[EAMCET (Engg.) 2000]

(a) $20\,ms^{-1}$ (b) $15\,ms^{-1}$

(c) $10\,ms^{-1}$ (d) $5\,ms^{-1}$

66. A tennis ball is released from height *h* above ground level. If the ball makes inelastic collision with the ground, to what height will it rise after third collision [RPET 2002]

(a) he^6 (b) e^2h

(c) e^3h (d) None of these

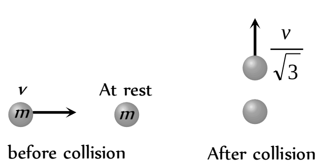
67. A mass '*m*' moves with a velocity '*v*' and collides inelastically with another identical mass. After collision the 1st mass moves with velocity $\frac{v}{\sqrt{3}}$ in a direction perpendicular to the initial direction of motion. Find the speed of the 2nd mass after collision

(a) $\frac{2}{\sqrt{3}}v$

(b) $\frac{v}{\sqrt{3}}$

(c) v

(d) $\sqrt{3}\,v$



68. A sphere collides with another sphere of identical mass. After collision, the two spheres move. The collision is inelastic. Then the angle between the directions of the two spheres is

(a) 90° (b) 0°

(c) 45° (d) Different from 90°

Perfectly Inelastic Collision

1. A particle of mass *m* moving eastward with a speed *v* collides with another particle of the same mass moving northward with the same speed *v*. The two particles coalesce on collision. The new particle of mass 2*m* will move in the north-easterly direction with a velocity [NCERT 1980; CPMT 1991; MP PET 1999; DPMT 1999, 2005]

(a) *v*/2 (b) 2*v*

(c) $v/\sqrt{2}$ (d) *v*

2. The coefficient of restitution *e* for a perfectly inelastic collision is

(a) 1 (b) 0

(c) ∞ (d) – 1

3. When two bodies stick together after collision, the collision is said to be [MP PET 1997]

(a) Partially elastic (b) Total elastic

(c) Total inelastic (d) None of the above

4. A bullet of mass *a* and velocity *b* is fired into a large block of mass *c*. The final velocity of the system is

[AFMC 1981, 94, 2000; NCERT 1971; MNR 1998]

(a) $\frac{c}{a+b}\cdot b$ [RPMT 1996] (b) $\frac{a}{a+c}\cdot b$

(c) $\frac{a+b}{c}.a$ (d) $\frac{a+c}{a}\cdot b$

5. A mass of 10 *gm* moving with a velocity of 100 *cm/s* strikes a pendulum bob of mass 10 *gm*. The two masses stick together. The maximum height reached by the system now is $(g = 10\,m/s^2)$

(a) Zero (b) 5 *cm*

(c) 2.5 *cm* (d) 1.25 *cm*

6. A completely inelastic collision is one in which the two colliding particles

(a) Are separated after collision

(b) Remain together after collision

(c) Split into small fragments flying in all directions

(d) None of the above

7. A bullet hits and gets embedded in a solid block resting on a horizontal frictionless table. What is conserved ?

[NCERT 1973; CPMT 1970; AFMC 1996; BHU 2001]

(a) Momentum and kinetic energy

(b) Kinetic energy alone

(c) Momentum alone [AIEEE 2005]

(d) Neither momentum nor kinetic energy

8. A body of mass 2 *kg* moving with a velocity of 3 *m/sec* collides head on with a body of mass 1 *kg* moving in opposite direction with a velocity of 4 *m/sec*. After collision, two bodies stick together and move with a common velocity which in *m/sec* is equal to

[NCERT 1984; MNR 1995, 98; UPSEAT 2000]

(a) 1/4 (b) 1/3

(c) 2/3 (d) 3/4

9. A body of mass *m* moving with a constant velocity *v* hits another body of the same mass moving with the same velocity *v* but in the opposite direction and sticks to it. The velocity of the compound body after collision is [KCET 1994]

[NCERT 1977; RPMT 1999]

(a) *v* (b) 2*v*

(c) Zero (d) *v*/2

10. In the above question, if another body is at rest, then velocity of the compound body after collision is

(a) *v*/2 (b) 2*v*

(c) *v* (d) Zero

11. A bag (mass *M*) hangs by a long thread and a bullet (mass *m*) comes horizontally with velocity *v* and gets caught in the bag. Then for the combined (bag + bullet) system

[CPMT 1989; Kerala PMT 2002]

(a) Momentum is $\frac{mvM}{M+m}$

(b) Kinetic energy is $\frac{mv^2}{2}$

(c) Momentum is $\frac{mv(M+m)}{M}$

(d) Kinetic energy is $\frac{m^2v^2}{2(M+m)}$

12. A 50 *g* bullet moving with velocity 10 *m/s* strikes a block of mass 950 *g* at rest and gets embedded in it. The loss in kinetic energy will be [MP PET 1994]

(a) 100% (b) 95%

(c) 5% (d) 50%

13. Two putty balls of equal mass moving with equal velocity in mutually perpendicular directions, stick together after collision. If the balls were initially moving with a velocity of $45\sqrt{2}\ ms^{-1}$ each, the velocity of their combined mass after collision is [Haryana CEE 1996; BVP 2003]

(a) $45\sqrt{2}\ ms^{-1}$ (b) $45\ ms^{-1}$

(c) $90\ ms^{-1}$ (d) $22.5\sqrt{2}\ ms^{-1}$

14. A particle of mass *m* moving with velocity *v* strikes a stationary particle of mass 2*m* and sticks to it. The speed of the system will be [MP PMT/PET 1998; AIIMS 1999; JIPMER 2001, 02]

(a) $v/2$ (b) $2v$

(c) $v/3$ (d) $3v$

15. A moving body of mass *m* and velocity 3 *km/h* collides with a rest body of mass 2*m* and sticks to it. Now the combined mass starts to move. What will be the combined velocity [CBSE PMT 1996; JIPMER 2001, 02]

(a) 3 *km/h* (b) 2 *km/h*

(c) 1 *km/h* (d) 4 *km/h*

16. If a skater of weight 3 *kg* has initial speed 32 *m/s* and second one of weight 4 *kg* has 5 *m/s*. After collision, they have speed (couple) 5 *m/s*. Then the loss in K.E. is [CPMT 1996]

(a) 48 *J* (b) 96 *J*

(c) Zero (d) None of these

17. A ball is dropped from height 10 *m*. Ball is embedded in sand 1 *m* and stops, then [AFMC 1996]

(a) Only momentum remains conserved

(b) Only kinetic energy remains conserved

(c) Both momentum and K.E. are conserved

(d) Neither K.E. nor momentum is conserved

18. A metal ball of mass 2 *kg* moving with a velocity of 36 *km/h* has an head on collision with a stationary ball of mass 3 *kg*. If after the collision, the two balls move together, the loss in kinetic energy due to collision is [CBSE PMT 1997; AIIMS 2001]

(a) 40 *J* (b) 60 *J*

(c) 100 *J* (d) 140 *J*

19. A body of mass 2*kg* is moving with velocity 10 *m/s* towards east. Another body of same mass and same velocity moving towards north collides with former and coalsces and moves towards north-east. Its velocity is [CPMT 1997; JIPMER 2000]

(a) 10 *m/s* (b) 5 *m/s*

(c) 2.5 *m/s* (d) $5\sqrt{2}\ m/s$

20. Which of the following is not a perfectly inelastic collision [BHU 1998; JIPMER 2001, 02; BHU 2005]

(a) Striking of two glass balls

(b) A bullet striking a bag of sand

(c) An electron captured by a proton

(d) A man jumping onto a moving cart

21. A mass of 20 *kg* moving with a speed of 10*m/s* collides with another stationary mass of $5kg$. As a result of the collision, the two masses stick together. The kinetic energy of the composite mass will be

(a) 600 *Joule* (b) 800 *Joule*

(c) 1000 *Joule* (d) 1200 *Joule*

22. A neutron having mass of $1.67\times10^{-27}\ kg$ and moving at $10^8\ m/s$ collides with a deutron at rest and sticks to it. If the mass of the deutron is $3.34\times10^{-27}\ kg$ then the speed of the combination is [CBSE PMT 2000]

(a) $2.56\times10^3\ m/s$ (b) $2.98\times10^5\ m/s$

(c) $3.33\times10^7\ m/s$ (d) $5.01\times10^9\ m/s$

23. The quantity that is not conserved in an inelastic collision is [Pb. PMT 2000]

(a) Momentum (b) Kinetic energy

(c) Total energy (d) All of these

24. A body of mass 40*kg* having velocity 4 *m/s* collides with another body of mass 60*kg* having velocity 2 *m/s*. If the collision is inelastic, then loss in kinetic energy will be [Pb. PMT 2001]

(a) 440 *J* (b) 392 *J*

(c) 48 *J* (d) 144 *J*

25. A body of mass m_1 is moving with a velocity V. It collides with another stationary body of mass m_2. They get embedded. At the point of collision, the velocity of the system

(a) Increases

(b) Decreases but does not become zero

(c) Remains same

(d) Become zero

26. A bullet of mass *m* moving with velocity *v* strikes a block of mass *M* at rest and gets embedded into it. The kinetic energy of the composite block will be [MP PET 2002]

(a) $\frac{1}{2}mv^2\times\frac{m}{(m+M)}$ (b) $\frac{1}{2}mv^2\times\frac{M}{(m+M)}$

(c) $\frac{1}{2}mv^2\times\frac{(M+m)}{M}$ (d) $\frac{1}{2}Mv^2\times\frac{m}{(m+M)}$

27. In an inelastic collision, what is conserved [DCE 2004]

(a) Kinetic energy (b) Momentum

(c) Both (a) and (b) (d) Neither (a) nor (b)

28. Two bodies of masses 0.1 *kg* and 0.4 *kg* move towards each other with the velocities 1 *m/s* and 0.1 *m/s* respectively, After collision they stick together. In 10 *sec* the combined mass travels

(a) 120 *m* (b) 0.12 *m*

(c) 12 *m* (d) 1.2 *m*

29. A body of mass 4 *kg* moving with velocity 12 *m/s* collides with another body of mass 6 *kg* at rest. If two bodies stick together after collision, then the loss of kinetic energy of system is

(a) Zero (b) 288 J

(c) 172.8 J (d) 144 J

30. Which of the following is not an example of perfectly inelastic collision [AFMC 2005]

(a) A bullet fired into a block if bullet gets embedded into block

(b) Capture of electrons by an atom

(c) A man jumping on to a moving boat

(d) A ball bearing striking another ball bearing

Critical Thinking

Objective Questions

1. A ball hits the floor and rebounds after inelastic collision. In this case [IIT 1986]

(a) The momentum of the ball just after the collision is the same as that just before the collision

(b) The mechanical energy of the ball remains the same in the collision

(c) The total momentum of the ball and the earth is conserved

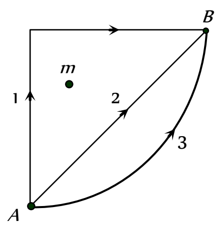
(d) The total energy of the ball and the earth is conserved

2. A uniform chain of length L and mass M is lying on a smooth table and one third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, the work required to pull the hanging part on to the table is [IIT 1985; MNR 1990; AIEEE 2002; MP PMT 1994, 97, 2000; JIPMER 2000]

(a) MgL (b) $MgL/3$

(c) $MgL/9$ (d) $MgL/18$

3. If W_1, W_2 and W_3 represent the work done in moving a particle from A to B along three different paths 1, 2 and 3 respectively (as shown) in the gravitational field of a point mass m, find the correct relation between W_1, W_2 and W_3



(a) $W_1 > W_2 > W_3$

(b) $W_1 = W_2 = W_3$

(c) $W_1 < W_2 < W_3$

(d) $W_2 > W_1 > W_3$

4. A particle of mass m is moving in a horizontal circle of radius r under a centripetal force equal to $-K/r^2$, where K is a constant. The total energy of the particle is [IIT 1977]

(a) $\frac{K}{2r}$ (b) $-\frac{K}{2r}$

(c) $-\frac{K}{r}$ (d) $\frac{K}{r}$

5. The displacement x of a particle moving in one dimension under the action of a constant force is related to the time t by the equation $t = \sqrt{x} + 3$, where x is in meters and t is in seconds. The work done by the force in the first 6 seconds is [IIT 1979]

(a) 9 J (b) 6 J

(c) 0 J (d) 3 J

[J&K CET 2005]

6. A force $\vec{F} = -K(y\hat{i} + x\hat{j})$ (where K is a positive constant) acts on a particle moving in the xy-plane. Starting from the origin, the particle is taken along the positive x-axis to the point $(a, 0)$ and then parallel to the y-axis to the point (a, a). The total work done by the force F on the particles is [IIT 1998]

(a) $-2Ka^2$ (b) $2Ka^2$

(c) $-Ka^2$ (d) Ka^2

7. If g is the acceleration due to gravity on the earth's surface, the gain in the potential energy of an object of mass m raised from the surface of earth to a height equal to the radius of the earth R, is

(a) $\frac{1}{2}mgR$ (b) $2\ mgR$

(c) mgR (d) $\frac{1}{4}mgR$

8. A lorry and a car moving with the same K.E. are brought to rest by applying the same retarding force, then [IIT 1973; MP PMT 2003]

(a) Lorry will come to rest in a shorter distance

(b) Car will come to rest in a shorter distance

(c) Both come to rest in a same distance

(d) None of the above

9. A particle free to move along the x-axis has potential energy given by $U(x) = k[1 - \exp(-x)^2]$ for $-\infty \le x \le +\infty$, where k is a positive constant of appropriate dimensions. Then [IIT-JEE 1999; UPSEAT 2003]

(a) At point away from the origin, the particle is in unstable equilibrium

(b) For any finite non-zero value of x, there is a force directed away from the origin

(c) If its total mechanical energy is $k/2$, it has its minimum kinetic energy at the origin

[IIT-JEE Screening 2003]

(d) For small displacements from x = 0, the motion is simple harmonic

10. The kinetic energy acquired by a mass m in travelling a certain distance d starting from rest under the action of a constant force is directly proportional to [CBSE PMT 1994]

(a) $\sqrt{m}$ (b) Independent of m

(c) $1/\sqrt{m}$ (d) m

11. An open knife edge of mass 'm' is dropped from a height 'h' on a wooden floor. If the blade penetrates upto the depth 'd' into the wood, the average resistance offered by the wood to the knife edge is [BHU 2002]

(a) mg (b) $mg\left(1 - \frac{h}{d}\right)$

(c) $mg\left(1 + \frac{h}{d}\right)$ (d) $mg\left(1 + \frac{h}{d}\right)^2$

12. Consider the following two statements

1. Linear momentum of a system of particles is zero

2. Kinetic energy of a system of particles is zero

Then [AIEEE 2003]

(a) 1 implies 2 and 2 implies 1

(b) 1 does not imply 2 and 2 does not imply 1

(c) 1 implies 2 but 2 does not imply 1

(d) 1 does not imply 2 but 2 implies 1

13. A body is moved along a straight line by a machine delivering constant power. The distance moved by the body in time t is proportional to

[IIT 1984; BHU 1984, 95; MP PET 1996; JIPMER 2000; AMU (Med.) 1999]

(a) $t^{1/2}$ (b) $t^{3/4}$

(c) $t^{3/2}$ (d) t^2

14. A shell is fired from a cannon with velocity v *m/sec* at an angle θ with the horizontal direction. At the highest point in its path it explodes into two pieces of equal mass. One of the pieces retraces its path to the cannon and the speed in *m/sec* of the other piece immediately after the explosion is

[IIT 1984; RPET 1999, 2001; UPSEAT 2002]

(a) $3v\cos\theta$ (b) $2v\cos\theta$

(c) $\frac{3}{2}v\cos\theta$ (d) $\frac{\sqrt{3}}{2}v\cos\theta$

15. A vessel at rest explodes into three pieces. Two pieces having equal masses fly off perpendicular to one another with the same velocity 30 *meter* per *second*. The third piece has three times mass of each of other piece. The magnitude and direction of the velocity of the third piece will be

[AMU (Engg.) 1999]

(a) $10\sqrt{2}\ m/second$ and 135° from either

(b) $10\sqrt{2}\ m/second$ and 45° from either

(c) $\frac{10}{\sqrt{2}}\ m/second$ and 135° from either

(d) $\frac{10}{\sqrt{2}}\ m/second$ and 45° from either

16. Two particles of masses m_1 and m_2 in projectile motion have velocities $\vec{v}_1$ and $\vec{v}_2$ respectively at time $t = 0$. They collide at time t_0. Their velocities become $\vec{v}_1{}'$ and $\vec{v}_2{}'$ at time $2t_0$ while still moving in air. The value of $|(m_1\vec{v}_1{}' + m_2\vec{v}_2{}') - (m_1\vec{v}_1 + m_2\vec{v}_2)|$ is

[IIT-JEE Screening 2001]

(a) Zero (b) $(m_1 + m_2)gt_0$

(c) $2(m_1 + m_2)gt_0$ (d) $\frac{1}{2}(m_1 + m_2)gt_0$

17. Consider elastic collision of a particle of mass m moving with a velocity u with another particle of the same mass at rest. After the collision the projectile and the struck particle move in directions making angles θ_1 and θ_2 respectively with the initial direction of motion. The sum of the angles. $\theta_1 + \theta_2$, is

(a) 45° (b) 90°

(c) 135° (d) 180°

18. A body of mass m moving with velocity v collides head on with another body of mass $2m$ which is initially at rest. The ratio of K.E. of colliding body before and after collision will be

(a) 1 : 1 (b) 2 : 1

(c) 4 : 1 (d) 9 : 1

19. A particle P moving with speed v undergoes a head -on elastic collision with another particle Q of identical mass but at rest. After the collision [Roorkee 2000]

(a) Both P and Q move forward with speed $\frac{v}{2}$

(b) Both P and Q move forward with speed $\frac{v}{\sqrt{2}}$

(c) P comes to rest and Q moves forward with speed v

(d) P and Q move in opposite directions with speed $\frac{v}{\sqrt{2}}$

20. A set of n identical cubical blocks lies at rest parallel to each other along a line on a smooth horizontal surface. The separation between the near surfaces of any two adjacent blocks is L. The block at one end is given a speed v towards the next one at time $t = 0$. All collisions are completely inelastic, then

(a) The last block starts moving at $t = \frac{(n-1)L}{v}$

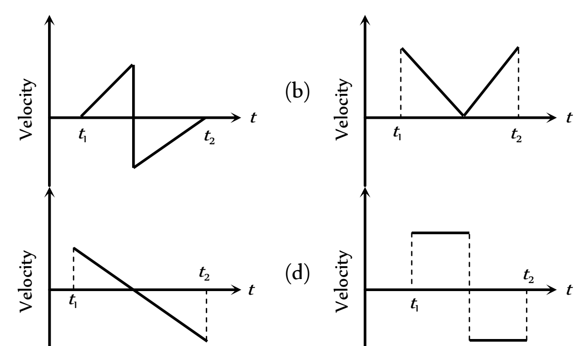
(b) The last block starts moving at $t = \frac{n(n-1)L}{2v}$

(c) The centre of mass of the system will have a final speed v

(d) The centre of mass of the system will have a final speed $\frac{v}{n}$

GQ Graphical Questions

1. A batsman hits a sixer and the ball touches the ground outside the cricket ground. Which of the following graph describes the variation of the cricket ball's vertical velocity v with time between the time t_1 as it hits the bat and time t when it touches the ground



2. The relationship between force and position is shown in the figure given (in one dimensional case). The work done by the force in displacing a body from $x = 1$ *cm* to $x = 5$ *cm* is

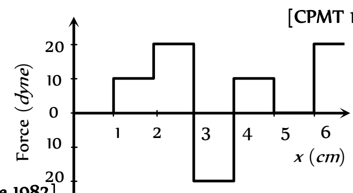
[UPSEAT 2004] [CPMT 1976]

(a) 20 *ergs*

(b) 60 *ergs*

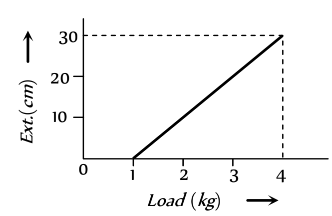
(c) 70 *ergs*

(d) 700 *ergs*



[Roorkee 1982]

3. The pointer reading v/s load graph for a spring balance is as given in the figure. The spring constant is



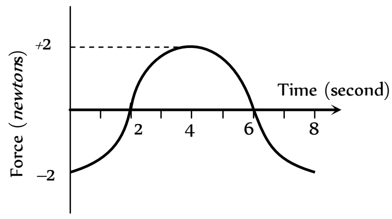
(a) 0.1 *kg/cm*

(b) 5 *kg/cm*

(c) 0.3 *kg/cm*

(d) 1 *kg/cm*

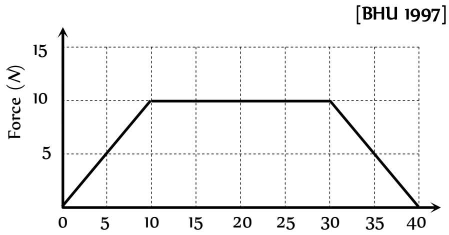
4. A force-time graph for a linear motion is shown in figure where the segments are circular. The linear momentum gained between zero and 8 *second* is [CPMT 1989]



(a) -2π *newton* $\times$ *second* (b) *Zero newton* $\times$ *second*

(c) $+4\pi$ *newton* $\times$ *second* (d) -6π *newton* $\times$ *second*

5. Adjacent figure shows the force-displacement graph of a moving body, the work done in displacing body from $x = 0$ to $x = 35\,m$ is equal to [BHU 1997]



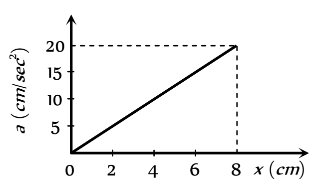
(a) 50 *J*

(b) 25 *J*

(c) 287.5 *J*

(d) 200 *J*

6. A 10*kg* mass moves along *x*-axis. Its acceleration as a function of its position is shown in the figure. What is the total work done on the mass by the force as the mass moves from $x = 0$ to $x = 8\,cm$



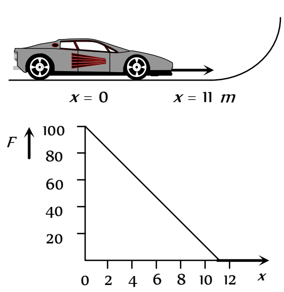
(a) 8×10^{-2} *joules*

(b) 16×10^{-2} *joules*

(c) 4×10^{-4} *joules*

(d) 1.6×10^{-3} *joules*

7. A toy car of mass 5 *kg* moves up a ramp under the influence of force *F* plotted against displacement *x*. The maximum height attained is given by



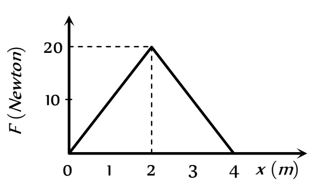
(a) $y_{max} = 20m$

(b) $y_{max} = 15m$

(c) $y_{max} = 11m$

(d) $y_{max} = 5m$

8. The graph between the resistive force *F* acting on a body and the distance covered by the body is shown in the figure. The mass of the body is 25 *kg* and initial velocity is 2 *m/s*. When the distance covered by the body is 4*m*, its kinetic energy would be



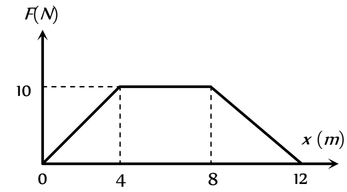
(a) 50 *J*

(b) 40 *J*

(c) 20 *J*

(d) 10 *J*

9. A particle of mass 0.1 *kg* is subjected to a force which varies with distance as shown in fig. If it starts its journey from rest at $x = 0$, its velocity at $x = 12\,m$ is [AIIMS 1995]



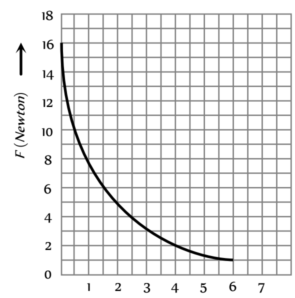
(a) 0 *m/s*

(b) $20\sqrt{2}\ m/s$

(c) $20\sqrt{3}\ m/s$

(d) $40\ m/s$

10. The relation between the displacement *X* of an object produced by the application of the variable force *F* is represented by a graph shown in the figure. If the object undergoes a displacement from $X = 0.5\,m$ to $X = 2.5\,m$ the work done will be approximately equal to [CPMT 1986]



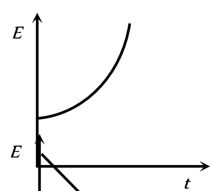
(a) 16 *J*

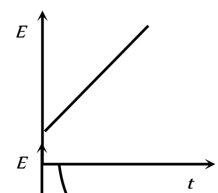
(b) 32 *J*

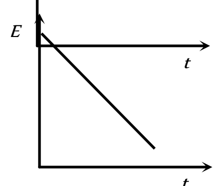
(c) 1.6 *J*

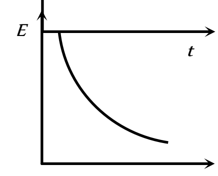
(d) 8 *J*

11. A particle is dropped from a height *h*. A constant horizontal velocity is given to the particle. Taking *g* to be constant every where, kinetic energy *E* of the particle *w. r. t.* time *t* is correctly shown in [AMU (Med.) 2000]

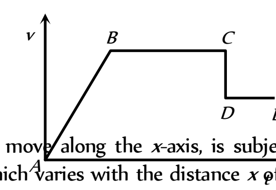
(a) 

(b) 

(c) 

(d) 

12. The adjoining diagram shows the velocity versus time plot for a particle. The work done by the force on the particle is positive from



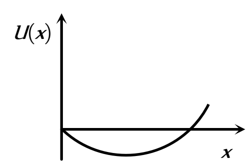
(a) *A* to *B*

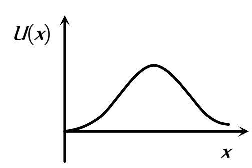
(b) *B* to *C*

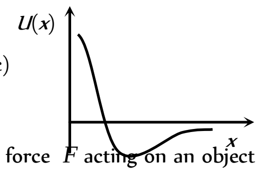
(c) *C* to *D*

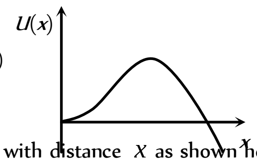
(d) *D* to *E*

13. A particle which is constrained to move along the *x*-axis, is subjected to a force in the same direction which varies with the distance *x* of the particle from the origin as $F(x) = -kx + ax^3$. Here *k* and *a* are positive constants. For $x \geq 0$, the functional from of the potential energy $U(x)$ of the particle is [IIT-JEE (Screening) 2002]

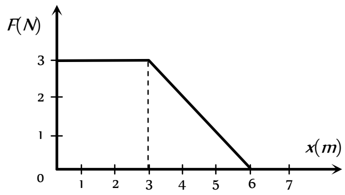
(a) 

(b) 

(c) 

(d) 

14. A force F acting on an object varies with distance x as shown here. The force is in *newton* and x in *metre*. The work done by the force in moving the object from $x = 0$ to $x = 6m$ is



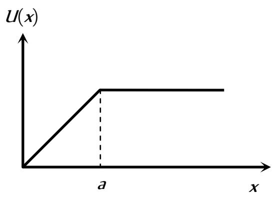
(a) 4.5 J

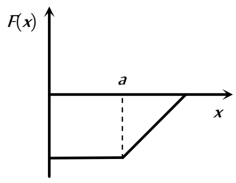
(b) 13.5 J

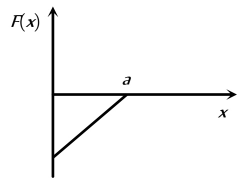
(c) 9.0 J

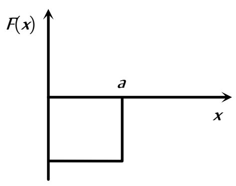
(d) 18.0 J

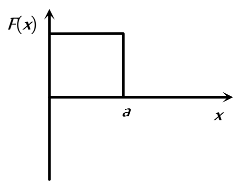
15. The potential energy of a system is represented in the first figure. the force acting on the system will be represented by



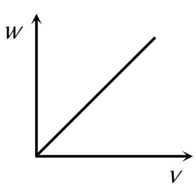
(a) 

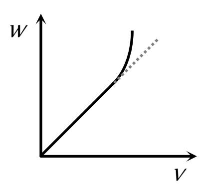
(b) 

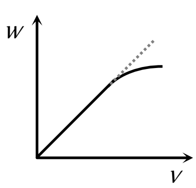
(c) 

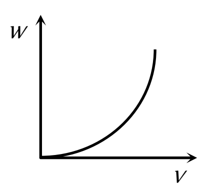
(d) 

16. A particle, initially at rest on a frictionless horizontal surface, is acted upon by a horizontal force which is constant in size and direction. A graph is plotted between the work done (W) on the particle, against the speed of the particle, (v). If there are no other horizontal forces acting on the particle the graph would look like

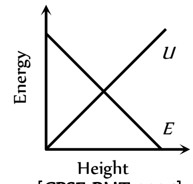
(a) 

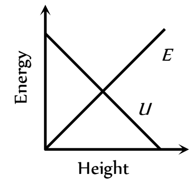
(b) 

(c) 

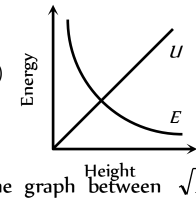
(d) 

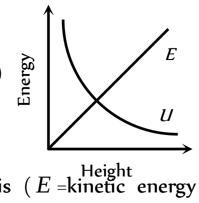
17. Which of the following graphs is correct between kinetic energy (E), potential energy (U) and height (h) from the ground of the particle

(a) 

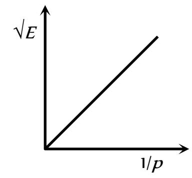
(b) 

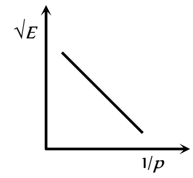
[CBSE PMT 2005]

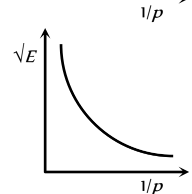
(c) 

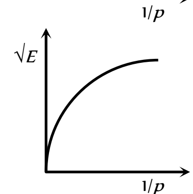
(d) 

18. The graph between $\sqrt{E}$ and $\frac{1}{p}$ is (E = kinetic energy and p = momentum)

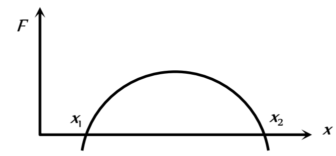
(a) 

(b) 

(c) 

(d) 

19. The force acting on a body moving along x-axis varies with the position of the particle as shown in the fig.



The body is in stable equilibrium at

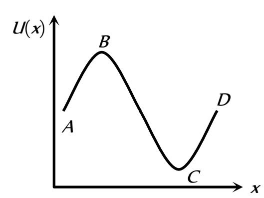
(a) $x = x_1$

(b) $x = x_2$

(c) both x_1 and x_2

(d) neither x_1 nor x_2

20. The potential energy of a particle varies with distance x as shown in the graph.



The force acting on the particle is zero at

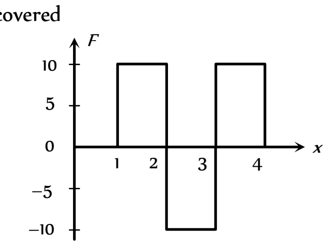
(a) C

(b) B

(c) B and C

(d) A and D

21. Figure shows the F-x graph. Where F is the force applied and x is the distance covered



by the body along a straight line path. Given that F is in *newton* and x in *metre*, what is the work done ?

(a) 10 J (b) 20 J

(c) 30 J (d) 40 J

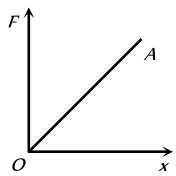
22. The force required to stretch a spring varies with the distance as shown in the figure. If the experiment is performed with the above spring of half length, the line OA will

(a) Shift towards F-axis

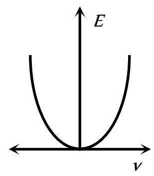
(b) Shift towards X-axis

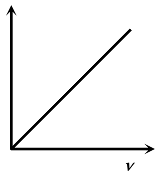
(c) Remain as it is

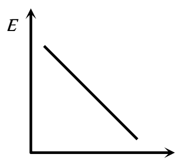
(d) Become double in length

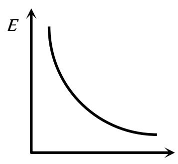


23. The graph between E and v is

(a) 

(b) 

(c) 

(d) 

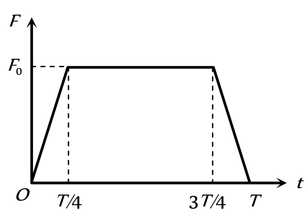
24. A particle of mass m moving with a velocity u makes an elastic one dimensional collision with a stationary particle of mass m establishing a contact with it for extremely small time T. Their force of contact increases from zero to F_0 linearly in time $\frac{T}{4}$, remains constant for a further time $\frac{T}{2}$ and decreases linearly from F_0 to zero in further time $\frac{T}{4}$ as shown. The magnitude possessed by F_0 is

(a) $\frac{mu}{T}$

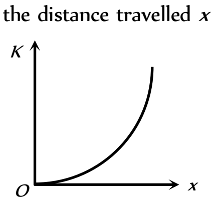
(b) $\frac{2mu}{T}$

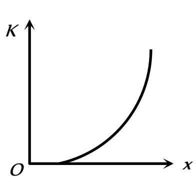
(c) $\frac{4mu}{3T}$

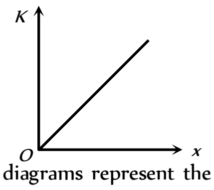
(d) $\frac{3mu}{4T}$

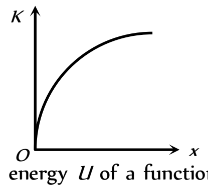


25. A body moves from rest with a constant acceleration. Which one of the following graphs represents the variation of its kinetic energy K with the distance travelled x ?

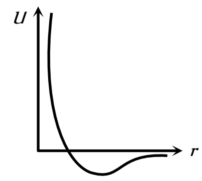
(a) 

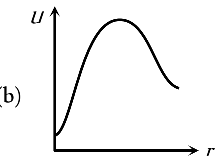
(b) 

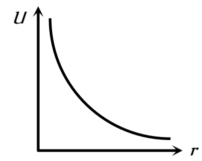
(c) 

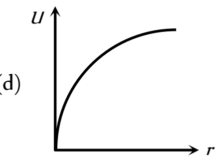
(d) 

26. The diagrams represent the potential energy U of a function of the inter-atomic distance r. Which diagram corresponds to stable molecules found in nature.

(a) 

(b) 

(c) 

(d) 

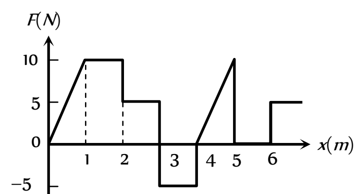
27. The relationship between the force F and position x of a body is as shown in figure. The work done in displacing the body from $x = 1$ m to $x = 5$ m will be [KCET 2005]

(a) 30 J

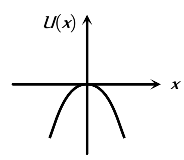
(b) 15 J

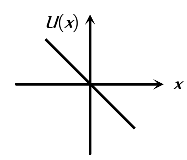
(c) 25 J

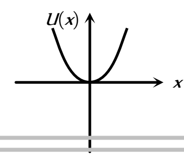
(d) 20 J

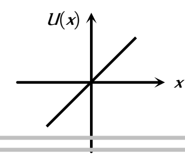


28. A particle is placed at the origin and a force $F = kx$ is acting on it (where k is positive constant). If $U(0) = 0$, the graph of $U(x)$ versus x will be (where U is the potential energy function)[IIT-JEE (Screening) 20

(a) 

(b) 

(c) 

(d) 

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If assertion is true but reason is false.

(d) If the assertion and reason both are false.

(e) If assertion is false but reason is true.

1. Assertion : A person working on a horizontal road with a load on his head does no work.

	Reason	:	No work is said to be done, if directions of force and displacement of load are perpendicular to each other.
2.	Assertion	:	The work done during a round trip is always zero.
	Reason	:	No force is required to move a body in its round trip.
3.	Assertion	:	Work done by friction on a body sliding down an inclined plane is positive.
	Reason	:	Work done is greater than zero, if angle between force and displacement is acute or both are in same direction.
4.	Assertion	:	When a gas is allowed to expand, work done by gas is positive.
	Reason	:	Force due to gaseous pressure and displacement (of piston) are in the same direction.
5.	Assertion	:	A light body and heavy body have same momentum. Then they also have same kinetic energy.
	Reason	:	Kinetic energy does not depend on mass of the body.
6.	Assertion	:	The instantaneous power of an agent is measured as the dot product of instantaneous velocity and the force acting on it at that instant.
	Reason	:	The unit of instantaneous power is watt.
7.	Assertion	:	The change in kinetic energy of a particle is equal to the work done on it by the net force.
	Reason	:	Change in kinetic energy of particle is equal to the work done only in case of a system of one particle.
8.	Assertion	:	A spring has potential energy, both when it is compressed or stretched.
	Reason	:	In compressing or stretching, work is done on the spring against the restoring force.
9.	Assertion	:	Comets move around the sun in elliptical orbits. The gravitational force on the comet due to sun is not normal to the comet's velocity but the work done by the gravitational force over every complete orbit of the comet is zero.
	Reason	:	Gravitational force is a non conservative force.
10.	Assertion	:	The rate of change of total momentum of a many particle system is proportional to the sum of the internal forces of the system.
	Reason	:	Internal forces can change the kinetic energy but not the momentum of the system.
11.	Assertion	:	Water at the foot of the water fall is always at different temperature from that at the top.
	Reason	:	The potential energy of water at the top is converted into heat energy during falling.
12.	Assertion	:	The power of a pump which raises 100 *kg* of water in 10*sec* to a height of 100 *m* is 10 *KW*.
	Reason	:	The practical unit of power is horse power.
13.	Assertion	:	According to law of conservation of mechanical energy change in potential energy is equal and opposite to the change in kinetic energy.
	Reason	:	Mechanical energy is not a conserved quantity.
14.	Assertion	:	When the force retards the motion of a body, the work done is zero.
	Reason	:	Work done depends on angle between force and displacement.
15.	Assertion	:	In an elastic collision of two bodies, the momentum and energy of each body is conserved.
	Reason	:	If two bodies stick to each other, after colliding, the collision is said to be perfectly elastic.
16.	Assertion	:	A body cannot have energy without having momentum but it can have momentum without having energy.
	Reason	:	Momentum and energy have same dimensions.
17.	Assertion	:	Power developed in circular motion is always zero.
	Reason	:	Work done in case of circular motion is zero.
18.	Assertion	:	A kinetic energy of a body is quadrupled, when its velocity is doubled.
	Reason	:	Kinetic energy is proportional to square of velocity.
19.	Assertion	:	A quick collision between two bodies is more violent than slow collision, even when initial and final velocities are identical.
	Reason	:	The rate of change of momentum determine that force is small or large.
20.	Assertion	:	Work done by or against gravitational force in moving a body from one point to another is independent of the actual path followed between the two points.
	Reason	:	Gravitational forces are conservative forces.
21.	Assertion	:	Wire through which current flows gets heated.
	Reason	:	When current is drawn from a cell, chemical energy is converted into heat energy.
22.	Assertion	:	Graph between potential energy of a spring versus the extension or compression of the spring is a straight line.
	Reason	:	Potential energy of a stretched or compressed spring, proportional to square of extension or compression.
23.	Assertion	:	Heavy water is used as moderator in nuclear reactor.
	Reason	:	Water cool down the fast neutron.
24.	Assertion	:	Mass and energy are not conserved separately, but are conserved as a single entity called mass-energy.
	Reason	:	Mass and energy conservation can be obtained by Einstein equation for energy.
25.	Assertion	:	If two protons are brought near one another, the potential energy of the system will increase.
	Reason	:	The charge on the proton is $+1.6\times10^{-19}\ C$.
26.	Assertion	:	In case of bullet fired from gun, the ratio of kinetic energy of gun and bullet is equal to ratio of mass of bullet and gun.
	Reason	:	In firing, momentum is conserved.
27.	Assertion	:	Power of machine gun is determined by both, the number of bullet fired per second and kinetic energy of bullets.
	Reason	:	Power of any machine is defined as work done (by it) per unit time.
28.	Assertion	:	A work done in moving a body over a closed loop is zero for every force in nature.
	Reason	:	Work done does not depend on nature of force.

29. Assertion : Mountain roads rarely go straight up the slope.

Reason : Slope of mountains are large therefore more chances of vehicle to slip from roads.

30. Assertion : Soft steel can be made red hot by continued hammering on it, but hard steel cannot.

Reason : Energy transfer in case of soft iron is large as in hard steel.

Answers

Work Done by Constant Force

1	b	2	a	3	c	4	d	5	c
6	b	7	b	8	c	9	a	10	d
11	d	12	b	13	d	14	b	15	b
16	b	17	b	18	d	19	d	20	d
21	d	22	d	23	d	24	a	25	c
26	a	27	d	28	b	29	d	30	a
31	b	32	c	33	a	34	b	35	a
36	d	37	a	38	c	39	c	40	a
41	c								

Work Done by Variable Force

1	b	2	c	3	c	4	a	5	a
6	c	7	d	8	d	9	d	10	b
11	b	12	c	13	b	14	c	15	d
16	c	17	a	18	a	19	c	20	b
21	d	22	a	23	a	24	b	25	d
26	d								

Conservation of Energy and Momentum

1	c	2	c	3	a	4	a	5	b
6	d	7	c	8	c	9	b	10	d
11	c	12	b	13	c	14	a	15	b
16	c	17	b	18	d	19	b	20	c
21	b	22	c	23	d	24	c	25	a
26	c	27	d	28	d	29	a	30	b
31	d	32	d	33	a	34	d	35	a
36	a	37	b	38	c	39	a	40	c
41	d	42	c	43	b	44	a	45	a
46	b	47	b	48	b	49	d	50	a
51	b	52	a	53	c	54	d	55	d
56	a	57	c	58	b	59	c	60	a
61	b	62	b	63	a	64	c	65	d
66	b	67	d	68	b	69	a	70	c
71	b	72	a	73	c	74	c	75	c
76	a	77	b	78	a	79	a	80	d
81	d	82	b	83	c	84	b	85	c
86	c	87	b	88	c				

Power

1	a	2	d	3	d	4	b	5	c
6	a	7	b	8	d	9	d	10	c
11	c	12	d	13	a	14	a	15	c
16	c	17	b	18	a	19	c	20	c
21	a	22	b	23	a	24	a	25	a
26	a	27	a	28	a	29	a	30	c

Elastic and Inelastic collision

1	a	2	a	3	c	4	a	5	c
6	c	7	b	8	c	9	c	10	d
11	d	12	b	13	d	14	c	15	d
16	a	17	c	18	c	19	d	20	a
21	d	22	d	23	b	24	a	25	c
26	a	27	b	28	d	29	d	30	b
31	b	32	a	33	b	34	a	35	c
36	a	37	c	38	d	39	a	40	b
41	b	42	d	43	d	44	a	45	d
46	a	47	a	48	d	49	c	50	b
51	c	52	d	53	b	54	a	55	b
56	a	57	a	58	a	59	d	60	c
61	a	62	c	63	d	64	a	65	a
66	a	67	a	68	d				

Perfectly Inelastic Collision

1	c	2	b	3	c	4	b	5	d
6	b	7	c	8	c	9	c	10	a
11	d	12	b	13	b	14	c	15	c
16	d	17	a	18	b	19	d	20	a
21	b	22	c	23	b	24	c	25	b
26	a	27	b	28	d	29	c	30	d

Critical Thinking Questions

1	c	2	d	3	b	4	b	5	c
6	c	7	a	8	c	9	d	10	b
11	c	12	d	13	c	14	a	15	a
16	c	17	b	18	d	19	c	20	bd

Graphical Questions

1	c	2	a	3	a	4	b	5	c
6	a	7	c	8	d	9	d	10	a
11	a	12	a	13	d	14	b	15	c
16	d	17	a	18	c	19	b	20	c
21	a	22	a	23	a	24	c	25	c
26	a	27	b	28	a				

Assertion and Reason

1	a	2	d	3	e	4	a	5	d
6	b	7	c	8	a	9	c	10	e
11	a	12	b	13	c	14	e	15	d
16	d	17	e	18	a	19	a	20	a
21	c	22	e	23	c	24	a	25	b
26	a	27	a	28	d	29	a	30	a

Answers and Solutions

Work Done by Constant Force

1. (b) Work done by centripetal force is always zero, because force and instantaneous displacement are always perpendicular.

$W = \vec{F}.\vec{s} = Fs\cos\theta = Fs\cos(90°) = 0$

2. (a) Work = Force × Displacement (length)

If unit of force and length be increased by four times then the unit of energy will increase by 16 times.

3. (c) No displacement is there.

4. (d) Stopping distance $S \propto u^2$. If the speed is doubled then the stopping distance will be four times.

5. (c) $W = Fs\cos\theta \Rightarrow \cos\theta = \frac{W}{Fs} = \frac{25}{50} = \frac{1}{2} \Rightarrow \theta = 60°$

6. (b) Work done = Force × displacement

= Weight of the book × Height of the book shelf

7. (b) Work done does not depend on time.

8. (c) $W = \vec{F}.\vec{s} = (5\hat{i} + 3\hat{j}).(2\hat{i} - \hat{j})$ = 10 – 3 = 7 J

9. (a) $v = \frac{dx}{dt} = 3 - 8t + 3t^2$

$\therefore\ v_0 = 3\,m/s$ and $v_4 = 19\,m/s$

$W = \frac{1}{2}m(v_4^2 - v_0^2)$ (According to work energy theorem)

$= \frac{1}{2} \times 0.03 \times (19^2 - 3^2) = 5.28\,J$

10. (d) As the body moves in the direction of force therefore work done by gravitational force will be positive.

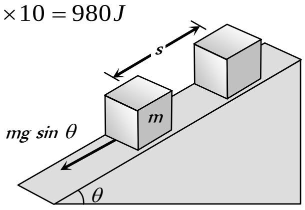
$W = Fs = mgh = 10 \times 9.8 \times 10 = 980\,J$

11. (d)

12. (b) $W = mg\sin\theta \times s$

$= 2 \times 10^3 \times \sin 15° \times 10$

$= 5.17\,kJ$



13. (d) $W = \vec{F}.\vec{s} = (5\hat{i} + 6\hat{j} - 4\hat{k}).(6\hat{i} + 5\hat{k}) = 30 - 20 = 10$ *units*

14. (b) $W = Fs = F \times \frac{1}{2}at^2$ $\left[\text{from } s = ut + \frac{1}{2}at^2\right]$

$\Rightarrow W = F\left[\frac{1}{2}\left(\frac{F}{m}\right)t^2\right] = \frac{F^2t^2}{2m} = \frac{25 \times (1)^2}{2 \times 15} = \frac{25}{30} = \frac{5}{6}\,J$

15. (b) Work done on the body = K.E. gained by the body

$Fs\cos\theta = 1 \Rightarrow F\cos\theta = \frac{1}{s} = \frac{1}{0.4} = 2.5\,N$

16. (b) Work done $= mgh = 10 \times 9.8 \times 1 = 98\,J$

17. (b)

18. (d) $s = \frac{t^2}{4}\ \therefore ds = \frac{t}{2}dt$

$F = ma = \frac{md^2s}{dt^2} = \frac{6d^2}{dt^2}\left[\frac{t^2}{4}\right] = 3N$

Now

$W = \int_0^2 F\,ds = \int_0^2 3\frac{t}{2}dt = \frac{3}{2}\left[\frac{t^2}{2}\right]_0^2 = \frac{3}{4}\left[(2)^2 - (0)^2\right] = 3J$

19. (d) Net force on body $= \sqrt{4^2 + 3^2} = 5N$

$\therefore a = F/m = 5/10 = 1/2\,m/s^2$

Kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}m(at)^2 = 125\,J$

20. (d) $s = \frac{u^2}{2\mu g} = \frac{10 \times 10}{2 \times 0.5 \times 10} = 10\,m$

21. (d) $W = \vec{F}.\vec{s} = (3\hat{i} + 4\hat{j}).(3\hat{i} + 4\hat{j}) = 9 + 16 = 25\,J$

22. (d) Total mass = (50 + 20) = 70 *kg*

Total height = 20 × 0.25 = 5*m*

∴ Work done = *mgh* = 70 × 9.8 × 5 = 3430 *J*

23. (d) $W = \vec{F}.\vec{s} = (6\hat{i} + 2\hat{j} - 3\hat{k}).(2\hat{i} - 3\hat{j} + x\hat{k}) = 0$

$12 - 6 - 3x = 0 \Rightarrow x = 2$

24. (a) $W = \vec{F}.(\vec{r_2} - \vec{r_1}) = (4\hat{i} + \hat{j} + 3\hat{k})(11\hat{i} + 11\hat{j} + 15\hat{k})$

$W = 44 + 11 + 45 = 100$ *Joule*

25. (c) $W = (3\hat{i} + c\hat{j} + 2\hat{k}).(-4\hat{i} + 2\hat{j} + 3\hat{k}) = 6\,J$

$W = -12 + 2c + 6 = 6 \Rightarrow c = 6$

26. (a) Both part will have numerically equal momentum and lighter part will have more velocity.

27. (d) *Watt* and *Horsepower* are the unit of power

28. (b) Work = Force × Displacement

If force and displacement both are doubled then work would be four times.

29. (d) $W = FS\cos\theta = 10 \times 4 \times \cos 60° = 20$ *Joule*

30. (a) $W = \vec{F}.\vec{s} = (5\hat{i} + 4\hat{j}).(6\hat{i} - 5\hat{j} + 3\hat{k}) = 30 - 20 = 10\,J$

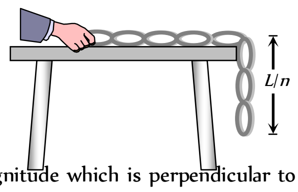
31. (b) Fraction of length of the chain hanging from the table

$= \frac{1}{n} = \frac{60cm}{200cm} = \frac{3}{10} \Rightarrow n = \frac{10}{3}$

Work done in pulling the chain on the table

$W = \frac{mgL}{2n^2}$

$= \frac{4 \times 10 \times 2}{2 \times (10/3)^2} = 3.6\,J$



32. (c) When a force of constant magnitude which is perpendicular to the velocity of particle acts on a particle, work done is zero and hence change in kinetic energy is zero.

33. (a) The ball rebounds with the same speed. So change in it's Kinetic energy will be zero *i.e.* work done by the ball on the wall is zero.

34. (b) $W = \vec{F}.\vec{r} = (5\hat{i} + 3\hat{j} + 2\hat{k}).(2\hat{i} - \hat{j}) = 10 - 3 = 7\,J$

35. (a) K.E. acquired by the body = work done on the body

$K.E. = \frac{1}{2}mv^2 = Fs$ *i.e.* it does not depend upon the mass of the body although velocity depends upon the mass

$v^2 \propto \frac{1}{m}$ [If F and s are constant]

36. (d) $W = \vec{F}.\vec{s} = (4\hat{i} + 5\hat{j} + 0\hat{k}).(3\hat{i} + 0\hat{j} + 6\hat{k}) = 4 \times 3$ *units*

37. (a) As surface is smooth so work done against friction is zero. Also the displacement and force of gravity are perpendicular so work done against gravity is zero.

38. (c) Opposing force in vertical pulling = mg

But opposing force on an inclined plane is $mg\sin\theta$, which is less than mg.

39. (c) Velocity of fall is independent of the mass of the falling body.

40. (a) Work done $= \vec{F}.\vec{s}$

$= (6\hat{i} + 2\hat{j})\cdot(3\hat{i} - \hat{j}) = 6 \times 3 - 2 \times 1 = 18 - 2 = 16\ J$

41. (c) When the ball is released from the top of tower then ratio of distances covered by the ball in first, second and third second

$h_I : h_{II} : h_{III} = 1:3:5:$ [because $h_n \propto (2n-1)$]

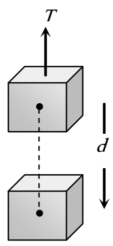
$\therefore$ Ratio of work done $mgh_I : mgh_{II} : mgh_{III}$ = 1:3:5

Work Done by Variable Force

1. (b) $W \int_0^{x_1} F.dx = \int_0^{x_1} Cx\ dx = C\left[\frac{x^2}{2}\right]_0^{x_1} = \frac{1}{2}Cx_1^2$

2. (c) When the block moves vertically downward with acceleration $\frac{g}{4}$ then tension in the cord

$T = M\left(g - \frac{g}{4}\right) = \frac{3}{4}Mg$



Work done by the cord = $\vec{F}.\vec{s} = Fs\cos\theta$

= $Td\cos(180°) = -\left(\frac{3Mg}{4}\right) \times d = -3Mg\frac{d}{4}$

3. (c) $W = \frac{F^2}{2k}$

If both springs are stretched by same force then $W \propto \frac{1}{k}$

As $k_1 > k_2$ therefore $W_1 < W_2$

i.e. more work is done in case of second spring.

4. (a) $\Delta P.E. = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2} \times 10[(0.25)^2 - (0.20)^2]$

$= 5 \times 0.45 \times 0.05 = 0.1\ J$

5. (a) $\frac{1}{2}kS^2 = 10\ J$ (given in the problem)

$\frac{1}{2}k\left[(2S)^2 - (S)^2\right] = 3 \times \frac{1}{2}kS^2$ = 3 × 10 = 30 J

6. (c) $U = \frac{F^2}{2k} \Rightarrow \frac{U_1}{U_2} = \frac{k_2}{k_1}$ (if force are same)

$\therefore \frac{U_1}{U_2} = \frac{3000}{1500} = \frac{2}{1}$

7. (d) Here $k = \frac{F}{x} = \frac{10}{1 \times 10^{-3}} = 10^4\ N/m$

$W = \frac{1}{2}kx^2 = \frac{1}{2} \times 10^4 \times (40 \times 10^{-3})^2 = 8\ J$

8. (d) $W = \int_0^5 F dx = \int_0^5 (7 - 2x + 3x^2)\,dx$ = $[7x - x^2 + x^3]_0^5$

= 35 − 25 + 125 = 135 J

9. (d) $S = \frac{t^3}{3}\ \therefore\ dS = t^2 dt$

$a = \frac{d^2S}{dt^2} = \frac{d^2}{dt^2}\left[\frac{t^3}{3}\right] = 2t\ m/s^2$

Now work done by the force $W = \int_0^2 F.dS = \int_0^2 ma.dS$

$\int_0^2 3 \times 2t \times t^2 dt = \int_0^2 6t^3 dt = \frac{3}{2}\left[t^4\right]_0^2$ = 24 J

10. (b) $W = \frac{1}{2}kx^2$

If both wires are stretched through same distance then $W \propto k$. As $k_2 = 2k_1$ so $W_2 = 2W_1$

11. (b) $\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \Rightarrow x = v\sqrt{\frac{m}{k}} = 10\sqrt{\frac{0.1}{1000}} = 0.1\,m$

12. (c) Force constant of a spring

$k = \frac{F}{x} = \frac{mg}{x} = \frac{1 \times 10}{2 \times 10^{-2}} \Rightarrow k = 500\ N/m$

Increment in the length = 60 − 50 = 10 cm

$U = \frac{1}{2}kx^2 = \frac{1}{2}500(10 \times 10^{-2})^2 = 2.5\ J$

13. (b) $W = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2} \times 800 \times (15^2 - 5^2) \times 10^{-4} = 8\ J$

14. (c) $100 = \frac{1}{2}kx^2$ (given)

$W = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2}k[(2x)^2 - x^2]$

$= 3 \times \left(\frac{1}{2}kx^2\right) = 3 \times 100 = 300\ J$

15. (d) $U = \frac{1}{2}kx^2$ if x becomes 5 times then energy will become 25 times *i.e.* $4 \times 25 = 100\ J$

16. (c) $W = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2} \times 5 \times 10^3(10^2 - 5^2) \times 10^{-4}$

$= 18.75\ J$

17. (a) The kinetic energy of mass is converted into potential energy of a spring

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \Rightarrow x = \sqrt{\frac{mv^2}{k}} = \sqrt{\frac{0.5 \times (1.5)^2}{50}} = 0.15\,m$

18. (a) This condition is applicable for simple harmonic motion. As particle moves from mean position to extreme position its potential energy increases according to expression $U = \frac{1}{2}kx^2$ and accordingly kinetic energy decreases.

19. (c) Potential energy $U = \frac{1}{2}kx^2$

$\therefore U \propto x^2$ [if k = constant]

If elongation made 4 times then potential energy will become 16 times.

20. (b)

21. (d) $U \propto x^2 \Rightarrow \frac{U_2}{U_1} = \left(\frac{x_2}{x_1}\right)^2 = \left(\frac{0.1}{0.02}\right)^2 = 25 \therefore U_2 = 25U$

22. (a) If x is the extension produced in spring.

$F = kx \Rightarrow x = \frac{F}{k} = \frac{mg}{k} = \frac{20 \times 9.8}{4000} = 4.9\, cm$

23. (a) $U = \frac{F^2}{2k} = \frac{T^2}{2k}$

24. (b) $U = A - Bx^2 \Rightarrow F = -\frac{dU}{dx} = 2Bx \Rightarrow F \propto x$

25. (d) Condition for stable equilibrium $F = -\frac{dU}{dx} = 0$

$\Rightarrow -\frac{d}{dx}\left[\frac{a}{x^{12}} - \frac{b}{x^6}\right] = 0 \Rightarrow -12ax^{-13} + 6bx^{-7} = 0$

$\Rightarrow \frac{12a}{x^{13}} = \frac{6b}{x^7} \Rightarrow \frac{2a}{b} = x^6 \Rightarrow x = \sqrt[6]{\frac{2a}{b}}$

26. (d) Friction is a non-conservative force.

Conservation of Energy and Momentum

1. (c) $P = \sqrt{2mE} \;\therefore P \propto \sqrt{m}$ (if E = const.) $\therefore \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$

2. (c) Work in raising a box

= (weight of the box) × (height by which it is raised)

3. (a) $E = \frac{P^2}{2m}$ if P = constant then $E \propto \frac{1}{m}$

4. (a) Body at rest may possess potential energy.

5. (b) Due to theory of relativity.

6. (d) $E = \frac{P^2}{2m} \;\therefore E \propto P^2$

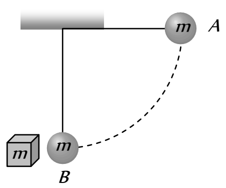
i.e. if P is increased n times then E will increase n times.

7. (c)

8. (c) P.E. of bob at point A = mgl

This amount of energy will be converted into kinetic energy

$\therefore$ K.E. of bob at point B = mgl



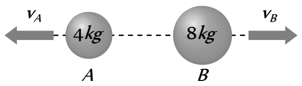
and as the collision between bob and block (of same mass) is elastic so after collision bob will come to rest and total Kinetic energy will be transferred to block. So kinetic energy of block = mgl

9. (b) According to conservation of momentum

Momentum of tank = Momentum of shell

$125000 \times v_{tank} = 25 \times 1000 \Rightarrow v_{tank}$ 0.2 *ft/sec.*

10. (d) As the initial momentum of bomb was zero, therefore after explosion two parts should possess numerically equal momentum



i.e. $m_A v_A = m_B v_B \Rightarrow 4 \times v_A = 8 \times 6 \Rightarrow v_A = 12\, m/s$

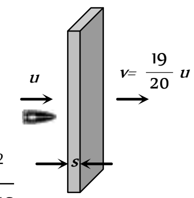
$\therefore$ Kinetic energy of other mass A, = $\frac{1}{2}m_A v_A^2$

= $\frac{1}{2} \times 4 \times (12)^2$ = 288 *J*.

11. (c) Let the thickness of one plank is s

if bullet enters with velocity u then it leaves with velocity

$v = \left(u - \frac{u}{20}\right) = \frac{19}{20}u$

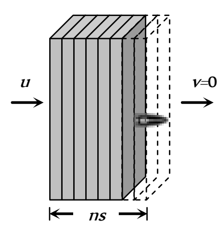


from $v^2 = u^2 - 2as$

$\Rightarrow \left(\frac{19}{20}u\right)^2 = u^2 - 2as \Rightarrow \frac{400}{39} = \frac{u^2}{2as}$

Now if the n planks are arranged just to stop the bullet then again from $v^2 = u^2 - 2as$

$0 = u^2 - 2ans$



$\Rightarrow n = \frac{u^2}{2as} = \frac{400}{39}$

$\Rightarrow n = 10.25$

As the planks are more than 10 so we can consider n = 11

12. (b) Let h is that height at which the kinetic energy of the body becomes half its original value *i.e.* half of its kinetic energy will convert into potential energy

$\therefore mgh = \frac{490}{2} \Rightarrow 2 \times 9.8 \times h = \frac{490}{2} \Rightarrow h = 12.5m.$

13. (c) $P = \sqrt{2mE}$. If E are same then $P \propto \sqrt{m}$

$\Rightarrow \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$

14. (a) Let initial kinetic energy, $E_1 = E$

Final kinetic energy, $E_2 = E + 300\%$ of E = $4E$

As $P \propto \sqrt{E} \Rightarrow \frac{P_2}{P_1} = \sqrt{\frac{E_2}{E_1}} = \sqrt{\frac{4E}{E}} = 2 \Rightarrow P_2 = 2P_1$

$\Rightarrow P_2 = P_1 + 100\%$ of P_1

i.e. Momentum will increase by 100%.

15. (b) $P = \sqrt{2mE}$ if E are equal then $P \propto \sqrt{m}$

i.e. heavier body will possess greater momentum.

16. (c) Let $P_1 = P$, $P_2 = P_1 + 50\%$ of $P_1 = P_1 + \frac{P_1}{2} = \frac{3P_1}{2}$

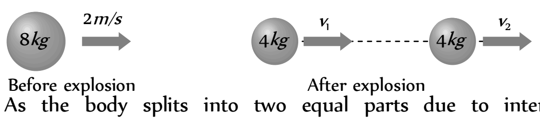
$$E \propto P^2 \Rightarrow \frac{E_2}{E_1} = \left(\frac{P_2}{P_1}\right)^2 = \left(\frac{3P_1/2}{P_1}\right)^2 = \frac{9}{4}$$

$\Rightarrow E_2 = 2.25E = E_1 + 1.25E_1$

$\therefore E_2 = E_1 + 125\%$ of E_1

i.e. kinetic energy will increase by 125%.

17. (b)



As the body splits into two equal parts due to internal explosion therefore momentum of system remains conserved

i.e. $8 \times 2 = 4v_1 + 4v_2 \Rightarrow v_1 + v_2 = 4$ ...(i)

By the law of conservation of energy

Initial kinetic energy + Energy released due to explosion

= Final kinetic energy of the system

$$\Rightarrow \frac{1}{2} \times 8 \times (2)^2 + 16 = \frac{1}{2}4v_1^2 + \frac{1}{2}4v_2^2$$

$\Rightarrow v_1^2 + v_2^2 = 16$ ...(ii)

By solving eq. (i) and (ii) we get $v_1 = 4$ and $v_2 = 0$

i.e. one part comes to rest and other moves in the same direction as that of original body.

18. (d) $P = \sqrt{2mE} \therefore P \propto \sqrt{E}$

i.e. if kinetic energy of a particle is doubled the its momentum will becomes $\sqrt{2}$ times.

19. (b) Potential energy = mgh

Potential energy is maximum when h is maximum

20. (c) If particle is projected vertically upward with velocity of $2m/s$ then it returns with the same velocity.

So its kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2} \times 2 \times (2)^2 = 4\ J$

21. (b)

22. (c) $E = \frac{P^2}{2m}$ if bodies possess equal linear momenta then

$E \propto \frac{1}{m}$ *i.e.* $\frac{E_1}{E_2} = \frac{m_2}{m_1}$

23. (d) $s \propto u^2$ *i.e.* if speed becomes double then stopping distance will become four times *i.e.* $8 \times 4 = 32m$

24. (c) $s \propto u^2$ *i.e.* if speed becomes three times then distance needed for stopping will be nine times.

25. (a) $P = \sqrt{2mE} \therefore P \propto \sqrt{E}$

Percentage increase in $P = \frac{1}{2}$ (percentage increase in E)

$= \frac{1}{2}(0.1\%) = 0.05\%$

26. (c) Kinetic energy $= \frac{1}{2}mv^2 \therefore$ K.E. $\propto v$

If velocity is doubled then kinetic energy will become four times.

27. (d) $P = \sqrt{2mE} \therefore \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$ (if E = constant)

$\therefore \frac{P_1}{P_2} = \sqrt{\frac{3}{1}}$

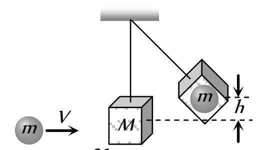
28. (d) In compression or extension of a spring work is done against restoring force.

In moving a body against gravity work is done against gravitational force of attraction.

It means in all three cases potential energy of the system increases.

But when the bubble rises in the direction of upthrust force then system works so the potential energy of the system decreases.

29. (a)



By the conservation of linear momentum

Initial momentum of sphere

= Final momentum of system

$mV = (m+M)v_{sys.}$ ...(i)

If the system rises up to height h then by the conservation of energy

$\frac{1}{2}(m+M)v_{sys.}^2 = (m+M)gh$ ...(ii)

$\Rightarrow v_{sys.} = \sqrt{2gh}$

Substituting this value in equation (i)

$$V = \left(\frac{m+M}{m}\right)\sqrt{2gh}$$

30. (b) $E = \frac{P^2}{2m}$. If momentum are same then $E \propto \frac{1}{m}$

$\therefore \frac{E_1}{E_2} = \frac{m_2}{m_1} = \frac{2m}{m} = \frac{2}{1}$

31. (d) $P = \sqrt{2mE}$. If kinetic energy are equal then $P \propto \sqrt{m}$

i.e., heavier body posses large momentum

As $M_1 < M_2$ therefore $M_1V_1 < M_2V_2$

32. (d) Condition for vertical looping $h = \frac{5}{2}r = 5cm$ $\therefore r = 2\ cm$

33. (a) Max. K.E. of the system = Max. P.E. of the system

$\frac{1}{2}kx^2 = \frac{1}{2} \times (16) \times (5 \times 10^{-2})^2 = 2 \times 10^{-2}\ J$

34. (d) $E = \frac{p^2}{2m} \therefore m \propto \frac{1}{E}$ (If momentum are constant)

$\frac{m_1}{m_2} = \frac{E_2}{E_1} = \frac{1}{4}$

35. (a) $P = \sqrt{2mE} \therefore P \propto \sqrt{E}$ *i.e.* if kinetic energy becomes four time then new momentum will become twice.

36. (a) $E = \frac{P^2}{2m}$. If P = constant then $E \propto \frac{1}{m}$

i.e. kinetic energy of heavier body will be less. As the mass of gun is more than bullet therefore it possess less kinetic energy.

37. (b) Potential energy of water = kinetic energy at turbine

$mgh = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 19.6} = 19.6\, m/s$

38. (c) $p = \sqrt{2mE}$ $\therefore \frac{p_1}{p_2} = \sqrt{\frac{m_1}{m_2}\frac{E_1}{E_2}} = \sqrt{\frac{2}{1} \times \frac{8}{1}} = \frac{4}{1}$

39. (a) The bomb of mass 12 *kg* divides into two masses m_1 and m_2 then $m_1 + m_2 = 12$ ...(i)

and $\frac{m_1}{m_2} = \frac{1}{3}$ ...(ii)

by solving we get $m_1 = 3kg$ and $m_2 = 9kg$

Kinetic energy of smaller part = $\frac{1}{2}m_1 v_1^2 = 216J$

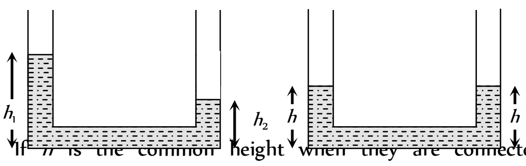
$\therefore v_1^2 = \frac{216 \times 2}{3} \Rightarrow v_1 = 12 m/s$

So its momentum = $m_1 v_1 = 3 \times 12 = 36$ *kg-m/s*

As both parts possess same momentum therefore momentum of each part is 36 *kg-m/s*

40. (c) $P = \sqrt{2mE}$. If E are const. then $\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{4}{1}} = 2$

41. (d)



If h is the common height when they are connected, by conservation of mass

$\rho A_1 h_1 + \rho A_2 h_2 = \rho h(A_1 + A_2)$

$h = (h_1 + h_2)/2$ [as $A_1 = A_2 = A$ given]

As $(h_1/2)$ and $(h_2/2)$ are heights of initial centre of gravity of liquid in two vessels., the initial potential energy of the system

$U_i = (h_1 A\rho)g\frac{h_1}{2} + (h_2 A\rho)\frac{h_2}{2} = \rho gA\frac{(h_1^2 + h_2^2)}{2}$ ...(i)

When vessels are connected the height of centre of gravity of liquid in each vessel will be $h/2$,

i.e. $\frac{(h_1 + h_2)}{4}$ [as $h = (h_1 + h_2)/2$]

Final potential energy of the system

$U_F = \left[\frac{(h_1 + h_2)}{2}A\rho\right]g\left(\frac{h_1 + h_2}{4}\right)$

$= A\rho g\left[\frac{(h_1 + h_2)^2}{4}\right]$ ...(ii)

Work done by gravity

$W = U_i - U_f = \frac{1}{4}\rho gA[2(h_1^2 + h_2^2) - (h_1 + h_2)^2]$

$= \frac{1}{4}\rho gA(h_1 \sim h_2)^2$

42. (c) $P = \sqrt{2mE}$. If m is constant then

$\frac{P_2}{P_1} = \sqrt{\frac{E_2}{E_1}} = \sqrt{\frac{1.22E}{E}} \Rightarrow \frac{P_2}{P_1} = \sqrt{1.22} = 1.1$

$\Rightarrow P_2 = 1.1P_1 \Rightarrow P_2 = P_1 + 0.1P_1 = P_1 + 10\%$ of P_1

So the momentum will increase by 10%

43. (b) $\Delta U = mgh = 0.2 \times 10 \times 200 = 400\, J$

$\therefore$ Gain in K.E. = decrease in P.E. = 400 *J*.

44. (a) $E = \frac{P^2}{2m}$. If m is constant then $E \propto P^2$

$\Rightarrow \frac{E_2}{E_1} = \left(\frac{P_2}{P_1}\right)^2 = \left(\frac{1.2P}{P}\right)^2 = 1.44$

$\Rightarrow E_2 = 1.44E_1 = E_1 + 0.44E_1$

$E_2 = E_1 + 44\%$ of E_1

i.e. the kinetic energy will increase by 44%

45. (a) $E = \frac{P^2}{2m} = \frac{(2)^2}{2 \times 2} = 1J$

46. (b) $\Delta U = mgh = 20 \times 9.8 \times 0.5 = 98\, J$

47. (b) $E = \frac{P^2}{2m} = \frac{(10)^2}{2 \times 1} = 50\, J$

48. (b) Because 50% loss in kinetic energy will affect its potential energy and due to this ball will attain only half of the initial height.

49. (d) If there is no air drag then maximum height

$H = \frac{u^2}{2g} = \frac{14 \times 14}{2 \times 9.8} = 10\, m$

But due to air drag ball reaches up to height 8 *m* only. So loss in energy

$= mg(10 - 8) = 0.5 \times 9.8 \times 2 = 9.8\, J$

50. (a) $1\, kcal = 10^3\, Calorie = 4200\, J = \frac{4200}{3.6 \times 10^6} kWh$

$\therefore 700\, kcal = \frac{700 \times 4200}{3.6 \times 10^6} kWh = 0.81\, kWh$

51. (b) $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 0.1} = \sqrt{1.96} = 1.4\, m/s$

52. (a)

53. (c) Let m = mass of boy, M = mass of man

v = velocity of boy, V = velocity of man

$\frac{1}{2}MV^2 = \frac{1}{2}\left[\frac{1}{2}mv^2\right]$ .....(i)

$\frac{1}{2}M(V+1)^2 = 1\left[\frac{1}{2}mv^2\right]$ .....(ii)

Putting $m = \frac{M}{2}$ and solving $V = \frac{1}{\sqrt{2} - 1}$

54. (d) $P = \sqrt{2mE} \Rightarrow \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{4}{9}} = \frac{2}{3}$

55. (d) $E=\frac{P^2}{2m} \Rightarrow E_2=E_1\left(\frac{P_2}{P_1}\right)^2=E_1\left(\frac{2P}{P}\right)^2$

$\Rightarrow E_2=4E=E+3E=E+300\%$ of E

56. (a) For first condition

Initial velocity = u, Final velocity = $u/2$, s = 3 *cm*

From $v^2=u^2-2as \Rightarrow \left(\frac{u}{2}\right)^2=u^2-2as \Rightarrow a=\frac{3u^2}{8s}$

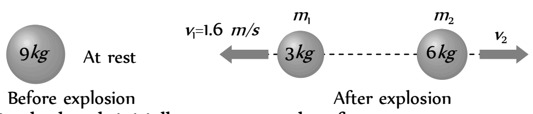
Second condition

Initial velocity = $u/2$, Final velocity = 0

From $v^2=u^2-2ax \Rightarrow 0=\frac{u^2}{4}-2ax$

$\therefore x=\frac{u^2}{4\times 2a}=\frac{u^2\times 8s}{4\times 2\times 3u^2}=s/3=1cm$

57. (c)



As the bomb initially was at rest therefore

Initial momentum of bomb = 0

Final momentum of system = $m_1v_1+m_2v_2$

As there is no external force

$\therefore m_1v_1+m_2v_2=0 \Rightarrow 3\times 1.6+6\times v_2=0$

velocity of 6 *kg* mass $v_2=0.8\,m/s$ (numerically)

Its kinetic energy $=\frac{1}{2}m_2v_2^2=\frac{1}{2}\times 6\times(0.8)^2=1.92\,J$

58. (b) $P=\sqrt{2mE}$. $P\propto\sqrt{m}$ $\therefore \frac{P_1}{P_2}=\sqrt{\frac{1}{16}}=\frac{1}{4}$

59. (c) Potential energy of a body = 75% of 12 *J*

$mgh = 9\,J \Rightarrow h=\frac{9}{1\times 10}=0.9m$

Now when this mass allow to fall then it acquire velocity

$v=\sqrt{2gh}=\sqrt{2\times 10\times 0.9}=\sqrt{18}$ *m/s*.

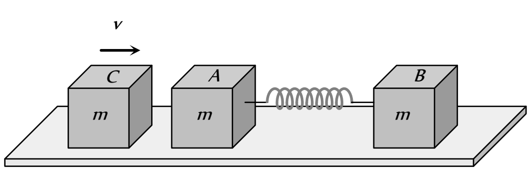
60. (a)

61. (b) Kinetic energy $E=\frac{P^2}{2m}=\frac{(Ft)^2}{2m}=\frac{F^2t^2}{2m}$ [As $P=F\,t$]

62. (b) Potential energy of spring = $\frac{1}{2}Kx^2$

$\therefore PE\propto x^2 \Rightarrow PE\propto a^2$

63. (a)



Initial momentum of the system (block *C*) = mv

After striking with *A*, the block *C* comes to rest and now both block *A* and *B* moves with velocity *V*, when compression in spring is maximum.

By the law of conservation of linear momentum

$mv=(m+m)V \Rightarrow V=\frac{v}{2}$

By the law of conservation of energy

K.E. of block *C* = K.E. of system + P.E. of system

$\frac{1}{2}mv^2=\frac{1}{2}(2m)V^2+\frac{1}{2}kx^2$

$\Rightarrow \frac{1}{2}mv^2=\frac{1}{2}(2m)\left(\frac{v}{2}\right)^2+\frac{1}{2}kx^2$

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

$\Rightarrow x=v\sqrt{\frac{m}{2k}}$

64. (c) $P=\sqrt{2mE}$ $\therefore P\propto\sqrt{m} \Rightarrow \frac{P_1}{P_2}=\sqrt{\frac{m_1}{m_2}}=\sqrt{\frac{m}{4m}}=\frac{1}{2}$

65. (d) $E=\frac{P^2}{2m} \Rightarrow E\propto\frac{1}{m} \Rightarrow \frac{E_1}{E_2}=\frac{m_2}{m_1}$

66. (b) $E=\frac{P^2}{2m}=\frac{4}{2\times 3}=\frac{2}{3}J$

67. (d) Both fragment will possess the equal linear momentum

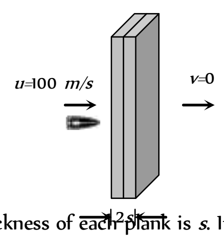
$m_1v_1=m_2v_2 \Rightarrow 1\times 80=2\times v_2 \Rightarrow v_2=40\,m/s$

$\therefore$ Total energy of system $=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2$

$=\frac{1}{2}\times 1\times(80)^2+\frac{1}{2}\times 2\times(40)^2$

= 4800 *J* = 4.8 *kJ*

68. (b)



Let the thickness of each plank is *s*. If the initial speed of bullet is 100 *m/s* then it stops by covering a distance 2*s*

By applying $v^2=u^2-2as \Rightarrow 0=u^2-2as$

$s=\frac{u^2}{2a}$ $s\propto u^2$ [If retardation is constant]

If the speed of the bullet is double then bullet will cover four times distance before coming to rest

i.e. $s_2=4(s_1)=4(2s) \Rightarrow s_2=8s$

So number of planks required = 8

69. (a) $E=\frac{P^2}{2m}$ if P = constant then $E\propto\frac{1}{m}$

According to problem $m_1>m_2$ $\therefore E_1<E_2$

70. (c) Kinetic energy $= \frac{1}{2}mv^2$

As both balls are falling through same height therefore they possess same velocity.

but $KE \propto m$ (If v = constant)

$\therefore \frac{(KE)_1}{(KE)_2} = \frac{m_1}{m_2} = \frac{2}{4} = \frac{1}{2}$

71. (b) $E = \frac{P^2}{2m}$ $\therefore$ $E \propto \frac{1}{m}$ (If P = constant)

i.e. the lightest particle will possess maximum kinetic energy and in the given option mass of electron is minimum.

72. (a) $P = E \Rightarrow mv = \frac{1}{2}mv^2 \Rightarrow v = 2\,m/s$

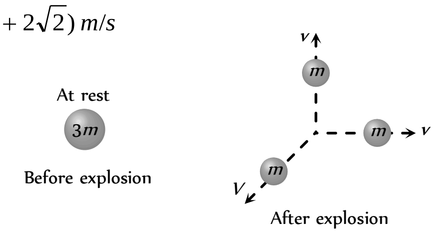
73. (c) Initial kinetic energy $E = \frac{1}{2}mv^2$ ...(i)

Final kinetic energy $2E = \frac{1}{2}m(v+2)^2$ ...(ii)

by solving equation (i) and (ii) we get

$v = (2 + 2\sqrt{2})\,m/s$

74. (c)



Initial momentum of $3m$ mass = 0 ...(i)

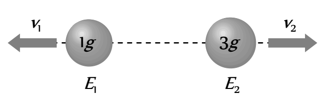
Due to explosion this mass splits into three fragments of equal masses.

Final momentum of system = $m\vec{V} + mv\hat{i} + mv\hat{j}$ ...(ii)

By the law of conservation of linear momentum

$m\vec{V} + mv\hat{i} + mv\hat{j} = 0 \Rightarrow \vec{V} = -v(\hat{i} + \hat{j})$

75. (c)



As the momentum of both fragments are equal therefore

$\frac{E_1}{E_2} = \frac{m_2}{m_1} = \frac{3}{1}$ *i.e.* $E_1 = 3E_2$ ...(i)

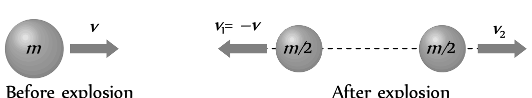
According to problem $E_1 + E_2 = 6.4 \times 10^4\,J$ ...(i)

By solving equation (i) and (ii) we get

$E_1 = 4.8 \times 10^4\,J$ and $E_2 = 1.6 \times 10^4\,J$

76. (a)

77. (b)



Let the initial mass of body = m

Initial linear momentum = mv ...(i)

When it breaks into equal masses then one of the fragment retrace back with same velocity

$\therefore$ Final linear momentum = $\frac{m}{2}(-v) + \frac{m}{2}(v_2)$ ...(ii)

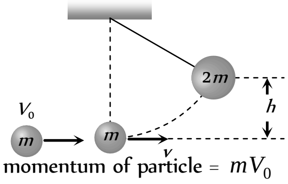
By the conservation of linear momentum

$\Rightarrow mv = \frac{-mv}{2} + \frac{mv_2}{2} \Rightarrow v_2 = 3v$

i.e. other fragment moves with velocity $3v$ in forward direction

78. (a)

79. (a)



Initial momentum of particle = mV_0

Final momentum of system (particle + pendulum) = $2mv$

By the law of conservation of momentum

$\Rightarrow mV_0 = 2mv \Rightarrow$ Initial velocity of system $v = \frac{V_0}{2}$

$\therefore$ Initial K.E. of the system = $\frac{1}{2}(2m)v^2 = \frac{1}{2}(2m)\left(\frac{V_0}{2}\right)^2$

If the system rises up to height h then P.E. = $2mgh$

By the law of conservation of energy

$\frac{1}{2}(2m)\left(\frac{V_0}{2}\right)^2 = 2mgh \Rightarrow h = \frac{V_0^2}{8g}$

80. (d) $\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{1}{9}} = \frac{1}{3}$

81. (d) Change in momentum = Force × time

$P_2 - P_1 = F \times t = 0.2 \times 10 = 2$

$\Rightarrow P_2 = 2 + P_1 = 2 + 10 = 12\,kg\text{-}m/s$

Increase in K.E. = $\frac{1}{2m}(P_2^2 - P_1^2) = \frac{1}{2 \times 5}\left[(12)^2 - (10)^2\right]$

$= \frac{44}{10} = 4.4\,J$

82. (b) $E \propto P^2$ (if m = constant)

Percentage increase in E = 2(Percentage increase in P)

= 2 × 0.01%=0.02%

83. (c) 1 $amu = 1.66 \times 10^{-27}\,kg$

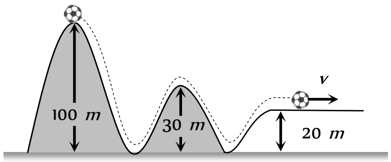
$E = mc^2 = 1.66 \times 10^{-27} \times (3 \times 10^8)^2 = 1.5 \times 10^{-10}\,J$

84. (b) Change in gravitational potential energy

= Elastic potential energy stored in compressed spring

$\Rightarrow mg(h + x) = \frac{1}{2}kx^2$

85. (c)



Ball starts from the top of a hill which is 100 m high and finally rolls down to a horizontal base which is 20 m above the ground so from the conservation of energy

$mg(h_1 - h_2) = \frac{1}{2}mv^2$

$\Rightarrow v = \sqrt{2g(h_1 - h_2)} = \sqrt{2 \times 10 \times (100 - 20)}$

$= \sqrt{1600} = 40\,m/s$.

86. (c) When block of mass *M* collides with the spring its kinetic energy gets converted into elastic potential energy of the spring.

From the law of conservation of energy

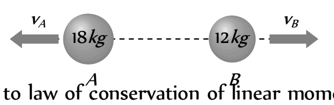
$\frac{1}{2}Mv^2 = \frac{1}{2}KL^2 \;\therefore\; v = \sqrt{\frac{K}{M}}L$

Where *v* is the velocity of block by which it collides with spring. So, its maximum momentum

$P = Mv = M\sqrt{\frac{K}{M}}L = \sqrt{MK}\,L$

After collision the block will rebound with same linear momentum.

87. (b)



According to law of conservation of linear momentum

$m_A v_A = m_B v_B = 18 \times 6 = 12 \times v_B \Rightarrow v_B = 9\ m/s$

K.E. of mass 12 *kg*, $E_B = \frac{1}{2}m_B v_B^2$

$= \frac{1}{2} \times 12 \times (9)^2 = 486J$

88. (c) Force = Rate of change of momentum

Initial momentum $\vec{P}_1 = mv\sin\theta\,\hat{i} + mv\cos\theta\,\hat{j}$

Final momentum $\vec{P}_2 = -mv\sin\theta\,\hat{i} + mv\cos\theta\,\hat{j}$

$\therefore \vec{F} = \frac{\Delta\vec{P}}{\Delta t} = \frac{-2mv\sin\theta}{2 \times 10^{-3}}$

Substituting $m = 0.1$ *kg*, $v = 5$ *m/s*, $\theta = 60°$

Force on the ball $\vec{F} = -250\sqrt{3}N$

Negative sign indicates direction of the force

Power

1. (a)

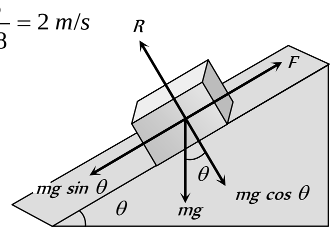
2. (d) $P = \vec{F}.\vec{v} = ma \times at = ma^2 t$ [as $u = 0$]

$= m\left(\frac{v_1}{t_1}\right)^2 t = \frac{mv_1^2 t}{t_1^2}$ $[\text{As}\ a = v_1/t_1]$

3. (d) $v = 7.2\frac{km}{h} = 7.2 \times \frac{5}{18} = 2\ m/s$

Slope is given 1 in 20

$\therefore \sin\theta = \frac{1}{20}$



When man and cycle moves up then component of weight opposes it motion *i.e.* $F = mg\sin\theta$

So power of the man $P = F \times v = mg\sin\theta \times v$

$= 100 \times 9.8 \times \left(\frac{1}{20}\right) \times 2 = 98\ Watt$

4. (b) If a motor of 12 *HP* works for 10 days at the rate of 8 *hr/day* then energy consumption = power × time

$= 12 \times 746\frac{J}{\sec} \times (80 \times 60 \times 60)\sec$

$= 12 \times 746 \times 80 \times 60 \times 60\ J = 2.5 \times 10^9\ J$

Rate of energy $= 50\frac{paisa}{kWh}$

i.e. $3.6 \times 10^6\ J$ energy cost 0.5 *Rs*

So $2.5 \times 10^9\ J$ energy cost $= \frac{2.5 \times 10^9}{2 \times 3.6 \times 10^6} = 358\ Rs$

5. (c) $P = Fv = 500 \times 3 = 1500\,W = 1.5\,kW$

6. (a) $P = Fv = F \times \frac{s}{t} = 40 \times \frac{30}{60} = 20W$

7. (b) $P = Fv = 4500 \times 2 = 9000\,W = 9\,kW$

8. (d) $P = \frac{\text{Workdone}}{\text{Time}} = \frac{mgh}{t} = \frac{300 \times 9.8 \times 2}{3} = 1960\,W$

9. (d) $P = \frac{mgh}{t} \Rightarrow m = \frac{p \times t}{gh} = \frac{2 \times 10^3 \times 60}{10 \times 10} = 1200\ kg$

As volume $= \frac{\text{mass}}{\text{density}} \Rightarrow v = \frac{1200kg}{10^3\,kg/m^3} = 1.2m^3$

Volume $= 1.2m^3 = 1.2 \times 10^3\,litre = 1200\ litre$

10. (c) $P = \frac{mgh}{t} = 10 \times 10^3 \Rightarrow t = \frac{200 \times 40 \times 10}{10 \times 10^3} = 8\sec$

11. (c) Force required to move with constant velocity

$\therefore$ Power = FV

Force is required to oppose the resistive force *R* and also to accelerate the body of mass with acceleration *a*.

$\therefore$ Power = $(R + ma)V$

12. (d) $P = \frac{mgh}{t} = \frac{100 \times 9.8 \times 50}{50} = 980\,J/s$

13. (a) $P = \left(\frac{m}{t}\right)gh = 100 \times 10 \times 100 = 10^5\,W = 100\ kW$

14. (a) $p = \frac{mgh}{t} = \frac{200 \times 10 \times 200}{10} = 40\,kW$

15. (c) Volume of water to raise = 22380 *l* = $22380 \times 10^{-3}\,m^3$

$P = \frac{mgh}{t} = \frac{V\rho gh}{t} \Rightarrow t = \frac{V\rho gh}{P}$

$t = \frac{22380 \times 10^{-3} \times 10^3 \times 10 \times 10}{10 \times 746} = 15\ min$

16. (c) Force produced by the engine $F = \frac{P}{v} = \frac{30 \times 10^3}{30} = 10^3 N$

Acceleration $= \frac{\text{Forward force by engine} - \text{resistive force}}{\text{mass of car}}$

$= \frac{1000-750}{1250} = \frac{250}{1250} = \frac{1}{5} m/s^2$

17. (b) $\text{Power} = \frac{\text{Work done}}{\text{time}} = \frac{\frac{1}{2}m(v^2-u^2)}{t}$

$P = \frac{1}{2} \times \frac{2.05 \times 10^6 \times [(25)^2 - (5^2)]}{5 \times 60}$

$P = 2.05 \times 10^6\ W = 2.05\ MW$

18. (a) As truck is moving on an incline plane therefore only component of weight ($mg \sin\theta$) will oppose the upward motion

Power = force × velocity = $mg \sin\theta \times v$

$= 30000 \times 10 \times \left(\frac{1}{100}\right) \times \frac{30 \times 5}{18} = 25 kW$

19. (c) $P = \frac{mgh}{t} \Rightarrow \frac{P_1}{P_2} = \frac{m_1}{m_2} \times \frac{t_2}{t_1}$ (As h = constant)

$\therefore \frac{P_1}{P_2} = \frac{60}{50} \times \frac{11}{12} = \frac{11}{10}$

20. (c) Power of a pump $= \frac{1}{2}\rho A v^3$

To get twice amount of water from same pipe v has to be made twice. So power is to be made 8 times.

21. (a) $p = \frac{mgh}{t} = \frac{80 \times 9.8 \times 6}{10} W = \frac{470}{746} HP = 0.63\ HP$

22. (b) $\text{Power} = \frac{\text{Work done}}{\text{time}} = \frac{\text{Increase in K.E.}}{\text{time}}$

$P = \frac{\frac{1}{2}mv^2}{t} = \frac{\frac{1}{2} \times 10^3 \times (15)^2}{5} = 22500 W$

23. (a) Motor makes 600 revolution per minute

$\therefore n = 600 \frac{\text{revolution}}{\text{minute}} = 10 \frac{rev}{\text{sec}}$

$\therefore$ Time required for one revolution $= \frac{1}{10} sec$

Energy required for one revolution = power × time

$= \frac{1}{4} \times 746 \times \frac{1}{10} = \frac{746}{40} J$

But work done = 40% of input

$= 40\% \times \frac{746}{40} = \frac{40}{100} \times \frac{746}{40} = 7.46\ J$

24. (a) Work output of engine = mgh = $100 \times 10 \times 10 = 10^4\ J$

Efficiency $(\eta) = \frac{\text{output}}{\text{input}}$ $\therefore$ Input energy $= \frac{\text{output}}{\eta}$

$= \frac{10^4}{60} \times 100 = \frac{10^5}{6} J$

$\therefore$ Power $= \frac{\text{input energy}}{\text{time}} = \frac{10^5/6}{5} = \frac{10^5}{30} = 3.3\ kW$

25. (a) $P = \frac{\vec{F}.\vec{s}}{t} = \frac{(2\hat{i}+3\hat{j}+4\hat{k}).(3\hat{i}+4\hat{j}+5\hat{k})}{4} = \frac{38}{4} = 9.5\ W$

26. (a) $P = \frac{W}{t} = \frac{mgh}{t} = \frac{200 \times 10 \times 50}{10} = 10 \times 10^3\ W$

27. (a) Power of gun $= \frac{\text{Total K.E. of fired bullet}}{\text{time}}$

$= \frac{n \times \frac{1}{2}mv^2}{t} = \frac{360}{60} \times \frac{1}{2} \times 2 \times 10^{-2} \times (100)^2 = 600 W$

28. (a) Energy supplied to liquid per second by the pump

$= \frac{1}{2}\frac{mv^2}{t} = \frac{1}{2}\frac{V\rho v^2}{t} = \frac{1}{2} A \times \left(\frac{l}{t}\right) \times \rho \times v^2 \quad \left[\frac{l}{t} = v\right]$

$= \frac{1}{2} A \times v \times \rho \times v^2 = \frac{1}{2} A\rho v^3$

29. (a) $\text{Power} = \frac{\text{workdone}}{\text{time}} = \frac{\text{pressure} \times \text{change in volume}}{\text{time}}$

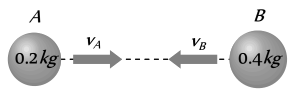
$= \frac{20000 \times 1 \times 10^{-6}}{1} = 2 \times 10^{-2} = 0.02\ W$

30. (c) $\text{Power} = \frac{W}{t}$. If W is constant then $P \propto \frac{1}{t}$

i.e. $\frac{P_1}{P_2} = \frac{t_2}{t_1} = \frac{20}{10} = \frac{2}{1}$

Elastic and Inelastic Collision

1. (a)
2. (a)
3. (c) According to law of conservation of linear momentum both pieces should possess equal momentum after explosion. As their masses are equal therefore they will possess equal speed in opposite direction.
4. (a)
5. (c)



Initial linear momentum of system = $m_A\vec{v}_A + m_B\vec{v}_B$

= 0.2 × 0.3 + 0.4 × v_B

Finally both balls come to rest

$\therefore$ final linear momentum = 0

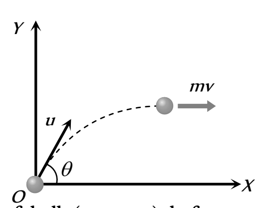
By the law of conservation of linear momenum

0.2 × 0.3 + 0.4 × v_B = 0

$\therefore \quad v_B = -\frac{0.2 \times 0.3}{0.4} = -0.15\ m/s$

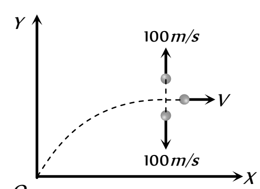
6. (c) For a collision between two identical perfectly elastic particles of equal mass, velocities after collision get interchanged.

7. (b)



Momentum of ball (mass m) before explosion at the highest point $= mv\hat{i} = mu\cos 60°\hat{i}$

$= m \times 200 \times \frac{1}{2}\hat{i} = 100\ m\hat{i}\ kgms^{-1}$



Let the velocity of third part after explosion is V

After explosion momentum of system = $\vec{P}_1 + \vec{P}_2 + \vec{P}_3$

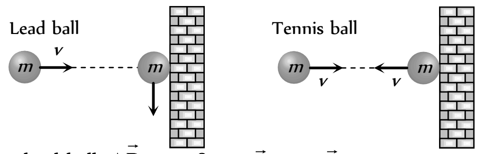
$$= \frac{m}{3} \times 100\hat{j} - \frac{m}{3} \times 100\hat{j} + \frac{m}{3} \times V\hat{i}$$

By comparing momentum of system before and after the explosion

$$\frac{m}{3} \times 100\hat{j} - \frac{m}{3} \times 100\hat{j} + \frac{m}{3} V\hat{i} = 100m\hat{i} \Rightarrow V = 300\, m/s$$

8. (c) Change in the momentum

= Final momentum – initial momentum



For lead ball $\Delta \vec{P}_{\text{lead}} = 0 - m\vec{v} = -m\vec{v}$

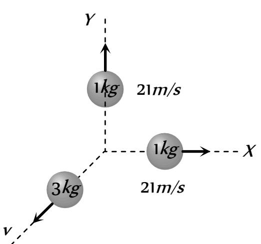
For tennis ball $\Delta \vec{P}_{\text{tennis}} = -m\vec{v} - m\vec{v} = -2m\vec{v}$

i.e. tennis ball suffers a greater change in momentum.

9. (c)

10. (d)

11. (d)



$P_x = m \times v_x = 1 \times 21 = 21\ kg\ m/s$

$P_y = m \times v_y = 1 \times 21 = 21\ kg\ m/s$

$\therefore$ Resultant = $\sqrt{P_x^2 + P_y^2} = 21\sqrt{2}\ kg\ m/s$

The momentum of heavier fragment should be numerically equal to resultant of $\vec{P}_x$ and $\vec{P}_y$.

$3 \times v = \sqrt{P_x^2 + P_y^2} = 21\sqrt{2} \therefore v = 7\sqrt{2} = 9.89\ m/s$

12. (b) We know that when heavier body strikes elastically with a lighter body then after collision lighter body will move with double velocity that of heavier body.

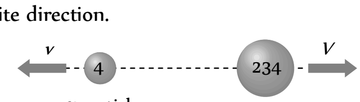
i.e. the ping pong ball move with speed of $2 \times 2 = 4\ m/s$

13. (d) Change in momentum $= m\vec{v}_2 - m\vec{v}_1 = -mv - mv = -2mv$

14. (c) $m_G = \frac{m_B v_B}{v_G} \frac{50 \times 10^{-3} \times 30}{1} = 1.5\ kg$

15. (d)

16. (a) Initially ^{238}U nucleus was at rest and after decay its part moves in opposite direction.

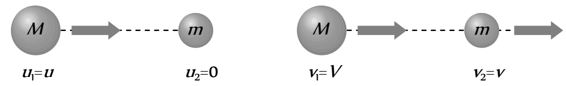


α particle   Residual nucleus

According to conservation of momentum

$$4v + 234V = 238 \times 0 \Rightarrow V = -\frac{4v}{234}$$

17. (c)



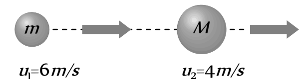
Before collision   After collision

$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) u_2 + \frac{2m_1 u_1}{m_1 + m_2} = \frac{2Mu}{M + m} = \frac{2u}{1 + \frac{m}{M}}$$

18. (c) Velocity exchange takes place when the masses of bodies are equal

19. (d) In perfectly elastic head on collision of equal masses velocities gets interchanged

20. (a)



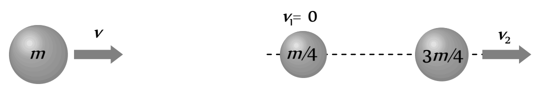
$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u_1 + \frac{2m_2 u_2}{m_1 + m_2}$$

Substituting $m_1 = 0$, $v_1 = -u_1 + 2u_2$

$\Rightarrow v_1 = -6 + 2(4) = 2m/s$

i.e. the lighter particle will move in original direction with the speed of 2 m/s.

21. (d)

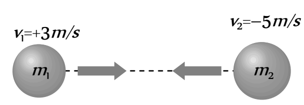


Before explosion   After explosion

According to conservation of momentum

$$mv = \left(\frac{m}{4}\right) v_1 + \left(\frac{3m}{4}\right) v_2 \Rightarrow v_2 = \frac{4}{3} v$$

22. (d)



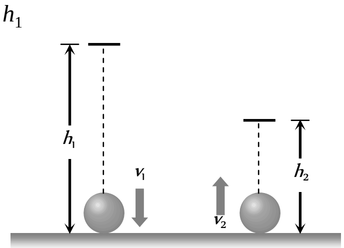
As $m_1 = m_2$ therefore after elastic collision velocities of masses get interchanged

i.e. velocity of mass $m_1 = -5\ m/s$

and velocity of mass $m_2 = +3\ m/s$

23. (b) If ball falls from height h_1 and bounces back up to height h_2

then $e = \sqrt{\frac{h_2}{h_1}}$



Similarly if the velocity of ball before and after collision are v_1 and v_2 respectively then $e = \frac{v_2}{v_1}$

So $\dfrac{v_2}{v_1} = \sqrt{\dfrac{h_2}{h_1}} = \sqrt{\dfrac{1.8}{5}} = \sqrt{\dfrac{9}{25}} = \dfrac{3}{5}$

i.e. fractional loss in velocity $= 1 - \dfrac{v_2}{v_1} = 1 - \dfrac{3}{5} = \dfrac{2}{5}$

24. (a) $h_n = he^{2n} = 32\left(\dfrac{1}{2}\right)^4 = \dfrac{32}{16} = 2m$ (here $n = 2$, $e = 1/2$)

25. (c) As the body at rest explodes into two equal parts, they acquire equal velocities in opposite directions according to conservation of momentum.

When the angle between the radius vectors connecting the point of explosion to the fragments is 90°, each radius vector makes an angle 45° with the vertical.

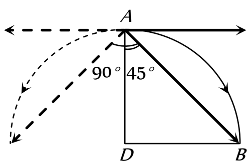
To satisfy this condition, the distance of free fall *AD* should be equal to the horizontal range in same interval of time.

$AD = DB$

$AD = 0 + \dfrac{1}{2} \times 10t^2 = 5t^2$

$DB = ut = 10t$

$\therefore\ 5t^2 = 10t \Rightarrow t = 2\,\text{sec}$



26. (a) $v_1 = \left(\dfrac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\dfrac{2m_2}{m_1 + m_2}\right)u_2$ and

$v_2 = \left(\dfrac{2m_1}{m_1 + m_2}\right)u_1 + \left(\dfrac{m_1 - m_2}{m_1 + m_2}\right)u_2$

on putting the values $v_1 = 6\,m/s$ and $v_2 = 12\,m/s$

27. (b) $F = \dfrac{dp}{dt} = m\dfrac{dv}{dt} = \dfrac{m \times 2v}{1/50} = \dfrac{2 \times 2 \times 100}{1/50} = 2 \times 10^4\,N$

28. (d) $h_n = he^{2n} = 1 \times e^{2\times 1} = 1 \times (0.6)^2 = 0.36m$

29. (d) $h_n = he^{2n}$, if $n = 2$ then $h_n = he^4$

30. (b) Impulse = change in momentum

$mv_2 - mv_1 = 0.1 \times 40 - 0.1 \times (-30)$

31. (b) In elastic head on collision velocities gets interchanged.

32. (a) Impulse = change in momentum = 2 *mv*

$= 2 \times 0.06 \times 4 = 0.48\ kg\ m/s$

33. (b) When ball falls vertically downward from height h_1 its velocity

$\vec{v}_1 = \sqrt{2gh_1}$

and its velocity after collision $\vec{v}_2 = \sqrt{2gh_2}$

Change in momentum

$\Delta\vec{P} = m(\vec{v}_2 - \vec{v}_1) = m(\sqrt{2gh_1} + \sqrt{2gh_2})$

(because $\vec{v}_1$ and $\vec{v}_2$ are opposite in direction)

34. (a) Velocity of 50 *kg.* mass after 5 *sec* of projection

$v = u - gt = 100 - 9.8 \times 5 = 51\ m/s$

At this instant momentum of body is in upward direction

$P_{\text{initial}} = 50 \times 51 = 2550\ kg - m/s$

After breaking 20 *kg* piece travels upwards with 150 *m/s* let the speed of 30 *kg* mass is *V*

$P_{\text{final}} = 20 \times 150 + 30 \times V$

By the law of conservation of momentum

$P_{\text{initial}} = P_{\text{final}}$

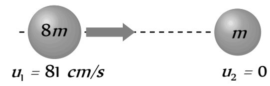
$\Rightarrow 2550 = 20 \times 150 + 30 \times V \Rightarrow V = -15\ m/s$

i.e. it moves in downward direction.

35. (c) Ratio in radius of steel balls = 1/2

So, ratio in their masses $= \dfrac{1}{8}$ [As $M \propto V \propto r^3$]

Let $m_1 = 8m$ and $m_2 = m$



$v_2 = \dfrac{2m_1u_1}{m_1 + m_2} = \dfrac{2 \times 8m \times 81}{8m + m} = 144\,cm/s$

36. (a) After explosion *m* mass comes at rest and let Rest $(M - m)$ mass moves with velocity *v*.

By the law of conservation of momentum $MV = (M - m)v$

$\Rightarrow v = \dfrac{MV}{(M - m)}$

37. (c) As the ball bounces back with same speed so change in momentum = 2 *mv*

and we know that force = rate of change of momentum

i.e. force will act on the ball so there is an acceleration.

38. (d) According to conservation of momentum

$m_Bv_B + m_Gv_G = 0 \Rightarrow v_G = -\dfrac{m_Bv_B}{m_G}$

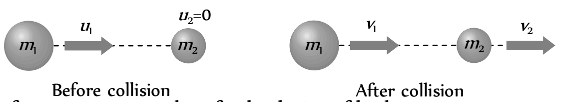
$v_G = \dfrac{-50 \times 10^{-3} \times 10^3}{5} = -10\,m/s$

39. (a) As 20% energy lost in collision therfore

$mgh_2 = 80\%\ \text{of}\ mgh_1 \Rightarrow \dfrac{h_2}{h_1} = 0.8$

but $e = \sqrt{\dfrac{h_2}{h_1}} = \sqrt{0.8} = 0.89$

40. (b)



If target is at rest then final velocity of bodies are

$v_1 = \left(\dfrac{m_1 - m_2}{m_1 + m_2}\right)u_1$ ...(i) and $v_2 = \dfrac{2m_1u_1}{m_1 + m_2}$ ...(ii)

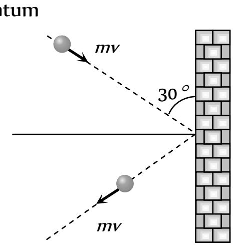
From (i) and (ii) $\dfrac{v_1}{v_2} = \dfrac{m_1 - m_2}{2m_1} = \dfrac{2}{5} \Rightarrow \dfrac{m_1}{m_2} = 5$

41. (b) F = Rate of change in momentum

$= \dfrac{2mv\sin\theta}{t}$

$= \dfrac{2 \times 10^{-1} \times 10\sin 30°}{0.1}$

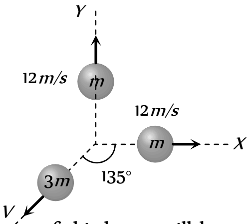
$\therefore F = 10\,N$



42. (d) By the conservation of momentum

$40\times 10+(40)\times(-7)=80\times v \Rightarrow v=1.5\,m/s$

43. (d)



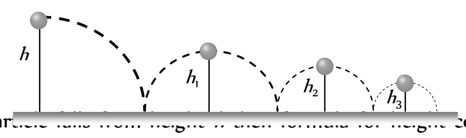
The momentum of third part will be equal and opposite to the resultant of momentum of rest two equal parts

let V is the velocity of third part.

By the conservation of linear momentum

$3m\times V=m\times 12\sqrt{2}\Rightarrow V=4\sqrt{2}\ m/s$

44. (a)



Particle falls from height h then formula for height covered by it in nth rebound is given by

$$h_n=he^{2n}$$

where e = coefficient of restitution, n = No. of rebound

Total distance travelled by particle before rebounding has stopped

$H=h+2h_1+2h_2+2h_3+2h_n+........$

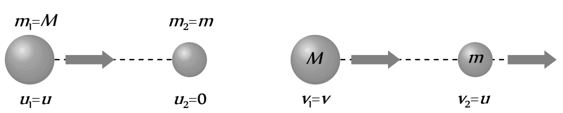
$=h+2he^2+2he^4+2he^6+2he^8+.........$

$=h+2h(e^2+e^4+e^6+e^8+.......)$

$=h+2h\left[\dfrac{e^2}{1-e^2}\right]=h\left[1+\dfrac{2e^2}{1-e^2}\right]=h\left(\dfrac{1+e^2}{1-e^2}\right)$

45. (d) Due to the same mass of A and B as well as due to elastic collision velocities of spheres get interchanged after the collision.

46. (a)



Before collision After collision

From the formulae $v_1=\left(\dfrac{m_1-m_2}{m_1+m_2}\right)u_1$

We get $v=\left(\dfrac{M-m}{M+m}\right)u$

47. (a) Momentum conservation

$5\times 10+20\times 0=5\times 0+20\times v\Rightarrow v=2.5\,m/s$

48. (d) Due to elastic collision of bodies having equal mass, their velocities get interchanged.

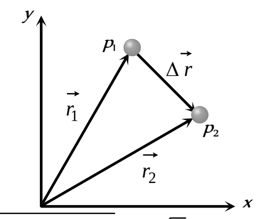
49. (c)

50. (b) $m_1=2\,kg$ and $v_1=\left(\dfrac{m_1-m_2}{m_1+m_2}\right)u_1=\dfrac{u_1}{4}$ (given)

By solving we get $m_2=1.2\,kg$

51. (c)

52. (d) It is clear from figure that the displacement vector $\Delta\vec{r}$ between particles p_1 and p_2 is $\Delta\vec{r}=\vec{r}_2-\vec{r}_1=-8\hat{i}-8\hat{j}$



$|\Delta\vec{r}|=\sqrt{(-8)^2+(-8)^2}=8\sqrt{2}$ .....(i)

Now, as the particles are moving in same direction ($\because \vec{v}_1$ and $\vec{v}_2$ are $+ve$), the relative velocity is given by

$\vec{v}_{rel}=\vec{v}_2-\vec{v}_1=(\alpha-4)\hat{i}+4\hat{j}$

$\vec{v}_{rel}=\sqrt{(\alpha-4)^2+16}$ .....(ii)

Now, we know $|\vec{v}_{rel}|=\dfrac{|\Delta\vec{r}|}{t}$

Substituting the values of $\vec{v}_{rel}$ and $|\Delta\vec{r}|$ from equation (i) and (ii) and $t=2s$, then on solving we get $\alpha=8$

53. (b) Fractional decrease in kinetic energy of neutron

$=1-\left(\dfrac{m_1-m_2}{m_1+m_2}\right)^2$ [As $m_1=1$ and $m_2=2$]

$=1-\left(\dfrac{1-2}{1+2}\right)^2=1-\left(\dfrac{1}{3}\right)^2=1-\dfrac{1}{9}=\dfrac{8}{9}$

54. (a)

55. (b) When target is very light and at rest then after head on elastic collision it moves with double speed of projectile *i.e.* the velocity of body of mass m will be $2v$.

56. (a) In head on elastic collision velocity get interchanged (if masses of particle are equal). *i.e.* the last ball will move with the velocity of first ball *i.e* 0.4 m/s

57. (a) By the principle of conservation of linear momentum,

$Mv=mv_1+mv_2\Rightarrow Mv=0+(M-m)v_2\Rightarrow v_2=\dfrac{Mv}{M-m}$

58. (a) Since bodies exchange their velocities, hence their masses are equal so that $\dfrac{m_A}{m_B}=1$

59. (d) $mgh=$ initial potential energy

$mgh'=$ final potential energy after rebound

As 40% energy lost during impact $\therefore mgh'$=60% of mgh

$\Rightarrow h'=\dfrac{60}{100}\times h=\dfrac{60}{100}\times 10=6\,m$

60. (c)

61. (a) Fractional loss $=\dfrac{\Delta U}{U}=\dfrac{mg(h-h')}{mgh}=\dfrac{2-1.5}{2}=\dfrac{1}{4}$

62. (c) $\dfrac{\Delta K}{K}=\left[1-\left(\dfrac{m_1-m_2}{m_1+m_2}\right)^2\right]=\left[1-\left(\dfrac{m-2m}{m+2m}\right)^2\right]=\dfrac{8}{9}$

$\Delta K = \frac{8}{9}K$ *i.e.* loss of kinetic energy of the colliding body is $\frac{8}{9}$ of its initial kinetic energy.

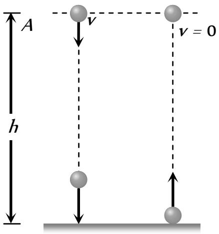
63. (d)

64. (a) $mgh = \frac{80}{100} \times mg \times 100 \Rightarrow h = 80\,m$

65. (a) Let ball is projected vertically downward with velocity v from height h

Total energy at point $A = \frac{1}{2}mv^2 + mgh$

During collision loss of energy is 50% and the ball rises up to same height. It means it possess only potential energy at same level.



$50\%\left(\frac{1}{2}mv^2 + mgh\right) = mgh$

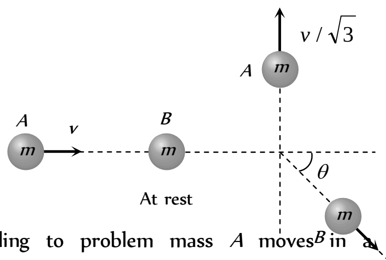
$\frac{1}{2}\left(\frac{1}{2}mv^2 + mgh\right) = mgh$

$v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20}$

$\therefore v = 20\,m/s$

66. (a) $h_n = he^{2n}$ after third collision $h_3 = he^6$ [as $n = 3$]

67. (a) Let mass A moves with velocity v and collides inelastically with mass B, which is at rest.



According to problem mass A moves in a perpendicular direction and let the mass B moves at angle θ with the horizontal with velocity v.

Initial horizontal momentum of system (before collision) $= mv$ ....(i)

Final horizontal momentum of system (after collision) $= mV\cos\theta$ ....(ii)

From the conservation of horizontal linear momentum $mv = mV\cos\theta \Rightarrow v = V\cos\theta$ ...(iii)

Initial vertical momentum of system (before collision) is zero.

Final vertical momentum of system $\frac{mv}{\sqrt{3}} - mV\sin\theta$

From the conservation of vertical linear momentum

$\frac{mv}{\sqrt{3}} - mV\sin\theta = 0 \Rightarrow \frac{v}{\sqrt{3}} = V\sin\theta$ ...(iv)

By solving (iii) and (iv)

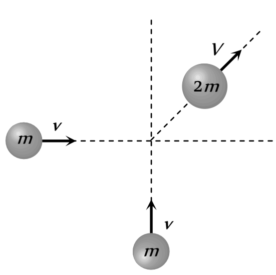
$v^2 + \frac{v^2}{3} = V^2(\sin^2\theta + \cos^2\theta)$

$\Rightarrow \frac{4v^2}{3} = V^2 \Rightarrow V = \frac{2}{\sqrt{3}}v$.

68. (d) Angle will be 90° if collision is perfectly elastic

Perfectly Inelastic Collision

1. (c)



Initial momentum of the system

$\vec{P}_i = mv\hat{i} + mv\hat{j}$

$|\vec{P}_i| = \sqrt{2}mv$

Final momentum of the system $= 2mV$

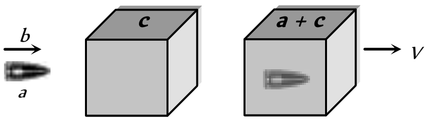
By the law of conservation of momentum

$\sqrt{2}mv = 2mV \Rightarrow V = \frac{v}{\sqrt{2}}$

2. (b)

3. (c)

4. (b)



Initially bullet moves with velocity b and after collision bullet get embedded in block and both move together with common velocity.

By the conservation of momentum

$\Rightarrow a \times b + 0 = (a + c)\,V \Rightarrow V = \frac{ab}{a+c}$

5. (d) Initially mass 10 gm moves with velocity 100 cm/s

$\therefore$ Initial momentum $= 10 \times 100 = 1000 \frac{gm \times m}{sec}$

After collision system moves with velocity $v_{sys.}$ then

Final momentum $= (10 + 10) \times v_{sys.}$

By applying the conservation of momentum

$10000 = 20 \times v_{sys.} \Rightarrow v_{sys.} = 50\ cm/s$

If system rises upto height h then

$h = \frac{v^2_{sys.}}{2g} = \frac{50 \times 50}{2 \times 1000} = \frac{2.5}{2} = 1.25\ cm$

6. (b)

7. (c)

8. (c) $m_1v_1 - m_2v_2 = (m_1 + m_2)v$

$\Rightarrow 2 \times 3 - 1 \times 4 = (2+1)v \Rightarrow v = \frac{2}{3}\,m/s$

9. (c) Initial momentum of the system $= mv - mv = 0$

As body sticks together $\therefore$ final momentum $= 2mV$

By conservation of momentum $2mV = 0 \;\therefore\; V = 0$

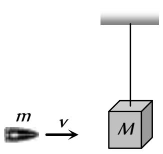
10. (a) If initially second body is at rest then

Initial momentum $= mv$

Final momentum $= 2mV$

By conservation of momentum $2mV = mv \Rightarrow V = \frac{v}{2}$

11. (d)



Initial momentum = mv

Final momentum = $(m+M)V$

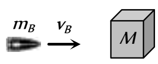
By conservation of momentum $mv=(m+M)V$

$\therefore$ Velocity of (bag + bullet) system $V=\dfrac{mv}{M+m}$

$\therefore$ Kinetic energy = $\dfrac{1}{2}(m+M)V^2$

$=\dfrac{1}{2}(m+M)\left(\dfrac{mv}{M+m}\right)^2=\dfrac{1}{2}\dfrac{m^2v^2}{M+m}$

12. (b)



Initial K.E. of system = K.E. of the bullet $=\dfrac{1}{2}m_Bv_B^2$

By the law of conservation of linear momentum

$m_Bv_B+0=m_{sys.}\times v_{sys.}$

$\Rightarrow v_{sys.}=\dfrac{m_Bv_B}{m_{sys.}}=\dfrac{50\times 10}{50+950}=0.5\ m/s$

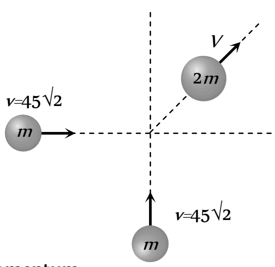
Fractional loss in K.E. $=\dfrac{\frac{1}{2}m_Bv_B^2-\frac{1}{2}m_{sys.}v_{sys.}^2}{\frac{1}{2}m_Bv_B^2}$

By substituting $m_B=50\times 10^{-3}\,kg,\ v_B=10\ m/s$

$m_{sys.}=1kg,\ v_s=0.5\ m/s$ we get

Fractional loss = $\dfrac{95}{100}$ $\therefore$ Percentage loss = 95%

13. (b)



Initial momentum

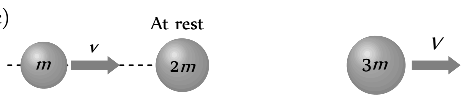
$\vec{P}=m45\sqrt{2}\,\hat{i}+m45\sqrt{2}\,\hat{j}\Rightarrow|\vec{P}|=m\times 90$

Final momentum $2m\times V$

By conservation of momentum $2m\times V=m\times 90$

$\therefore V=45\ m/s$

14. (c)



Before collision After collision

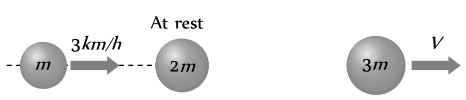
Initial momentum = mv

Final momentum = $3mV$

By the law of conservation of momentum $mv=3mV$

$\therefore V=v/3$

15. (c)



Before collision After collision

Initial momentum = $m\times 3+2m\times 0=3m$

Final momentum = $3m\times V$

By the law of conservation of momentum

$3m=3m\times V\Rightarrow V=1\ km/h$

16. (d) Loss in K.E. = (initial K.E. – Final K.E.) of system

$\dfrac{1}{2}m_1u_1^2+\dfrac{1}{2}m_2u_2^2-\dfrac{1}{2}(m_1+m_2)V^2$

$=\dfrac{1}{2}3\times(32)^2+\dfrac{1}{2}\times 4\times(5)^2-\dfrac{1}{2}\times(3+4)\times(5)^2$

= 986.5 J

17. (a) Momentum of earth-ball system remains conserved.

18. (b) $v=36\ km/h=10\ m/s$

By law of conservation of momentum

$2\times 10=(2+3)V\ \Rightarrow\ V=4\ m/s$

Loss in K.E. $=\dfrac{1}{2}\times 2\times(10)^2-\dfrac{1}{2}\times 5\times(4)^2=60\ J$

19. (d) Initial momentum = $\vec{P}=mv\hat{i}+mv\hat{j}$

$|\vec{P}|=\sqrt{2}mv$

Final momentum = $2m\times V$

By the law of conservation of momentum

$2m\times V=\sqrt{2}\,mv\Rightarrow V=\dfrac{v}{\sqrt{2}}$

In the problem $v=10m/s$ (given) $\therefore V=\dfrac{10}{\sqrt{2}}=5\sqrt{2}\ m/s$

20. (a) Because in perfectly inelastic collision the colliding bodies stick together and move with common velocity

21. (b) $m_1v_1+m_2v_2=(m_1+m_2)v_{sys.}$

$20\times 10+5\times 0=(20+5)v_{sys.}\Rightarrow v_{sys.}=8\ m/s$

K.E. of composite mass $=\dfrac{1}{2}(20+5)\times(8)^2=800\ J$

22. (c) According to law of conservation of momentum.

Momentum of neutron = Momentum of combination

$\Rightarrow 1.67\times 10^{-27}\times 10^{8}=(1.67\times 10^{-27}+3.34\times 10^{-27})v$

$\therefore v=3.33\times 10^{7}\ m/s$

23. (b)

24. (c) Loss in kinetic energy

$=\dfrac{1}{2}\dfrac{m_1m_2(u_1-u_2)^2}{m_1+m_2}=\dfrac{1}{2}\left(\dfrac{40\times 60}{40+60}\right)(4-2)^2=48\ J$

25. (b) By momentum conservation before and after collision.

$m_1V+m_2\times 0=(m_1+m_2)v\ \Rightarrow\ v=\dfrac{m_1}{m_1+m_2}V$

i.e. Velocity of system is less than V.

26. (a) By conservation of momentum, $mv + M \times 0 = (m+M)V$

Velocity of composite block $V = \left(\frac{m}{m+M}\right)v$

K.E. of composite block $= \frac{1}{2}(M+m)V^2$

$$= \frac{1}{2}(M+m)\left(\frac{m}{M+m}\right)^2 v^2 = \frac{1}{2}mv^2\left(\frac{m}{m+M}\right)$$

27. (b)

28. (d) Velocity of combined mass, $v = \frac{m_1v_1 - m_2v_2}{m_1+m_2}$

$$= \frac{0.1\times1 - 0.4\times0.1}{0.5} = 0.12\ m/s$$

∴ Distance travelled by combined mass

$= v \times t = 0.12 \times 10 = 1.2\ m.$

29. (c) Loss in K.E. $= \frac{m_1m_2}{2(m_1+m_2)}(u_1-u_2)^2$

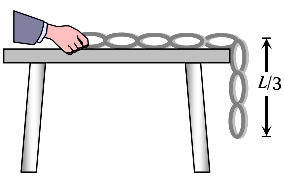
$$= \frac{4\times6}{2\times10}\times(12-0)^2 = 172.8\ J$$

30. (d) In case of perfectly inelastic collision, the bodies stick together after impact.

Critical Thinking Questions

1. (c) By the conservation of momentum in the absence of external force total momentum of the system (ball + earth) remains constant.

2. (d)



$$W = \frac{MgL}{2n^2} = \frac{MgL}{2(3)^2} = \frac{MgL}{18} \quad (n = 3 \text{ given})$$

3. (b) Gravitational force is a conservative force and work done against it is a point function *i.e.* does not depend on the path.

4. (b) Here $\frac{mv^2}{r} = \frac{K}{r^2}$ ∴ $\text{K.E.} = \frac{1}{2}mv^2 = \frac{K}{2r}$

$$U = -\int_\infty^r F.dr = -\int_\infty^r\left(-\frac{K}{r^2}\right)dr = -\frac{K}{r}$$

Total energy $E = \text{K.E.} + \text{P.E.} = \frac{K}{2r} - \frac{K}{r} = -\frac{K}{2r}$

5. (c) $x = (t-3)^2 \Rightarrow v = \frac{dx}{dt} = 2(t-3)$

at $t = 0$; $v_1 = -6\ m/s$ and at $t = 6$ sec , $v_2 = 6\ m/s$

so, change in kinetic energy $= W = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = 0$

6. (c) While moving from (0,0) to (*a*,0)

Along positive *x*-axis, y = 0 $\therefore \vec{F} = -kx\hat{j}$

i.e. force is in negative *y*-direction while displacement is in positive *x*-direction.

$\therefore W_1 = 0$

Because force is perpendicular to displacement

Then particle moves from $(a,0)$ to (a,a) along a line parallel to *y*-axis $(x = +a)$ during this $\vec{F} = -k(y\hat{i} + a\hat{j})$

The first component of force, $-ky\hat{i}$ will not contribute any work because this component is along negative *x*-direction $(-\hat{i})$ while displacement is in positive *y*-direction (*a*,0) to (*a*,*a*). The second component of force *i.e.* $-ka\hat{j}$ will perform negative work

$\therefore W_2 = (-ka\hat{j})(a\hat{j}) = (-ka)(a) = -ka^2$

So net work done on the particle $W = W_1 + W_2$

$= 0 + (-ka^2) = -ka^2$

7. (a) Gain in potential energy $\Delta U = \frac{mgh}{1+\frac{h}{R}}$

If $h = R$ then $\Delta U = \frac{mgR}{1+\frac{R}{R}} = \frac{1}{2}mgR$

8. (c) $\text{Stopping distance} = \frac{\text{kinetic energy}}{\text{retarding force}} \Rightarrow s = \frac{1}{2}\frac{mu^2}{F}$

If lorry and car both possess same kinetic energy and retarding force is also equal then both come to rest in the same distance.

9. (d) Potential energy of the particle $U = k(1-e^{-x^2})$

Force on particle $F = \frac{-dU}{dx} = -k[-e^{-x^2}\times(-2x)]$

$$F = -2kxe^{-x^2} = -2kx\left[1 - x^2 + \frac{x^4}{2!} - ......\right]$$

For small displacement $F = -2kx$

$\Rightarrow F \propto -x$ *i.e.* motion is simple harmonic motion.

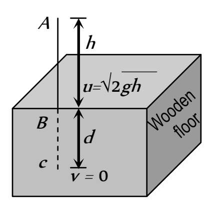
10. (b) Kinetic energy acquired by the body

= Force applied on it × Distance covered by the body

K.E. = $F \times d$

If *F* and *d* both are same then K.E. acquired by the body will be same

11. (c) Let the blade stops at depth *d* into the wood.



$v^2 = u^2 + 2aS$

$\Rightarrow 0 = (\sqrt{2gh})^2 + 2(g-a)d$

by solving $a = \left(1 + \frac{h}{d}\right)g$

So the resistance offered by the wood $= mg\left(1 + \frac{h}{d}\right)$

12. (d) Because linear momentum is vector quantity where as kinetic energy is a scalar quantity.

13. (c) $P = Fv = mav = m\left(\frac{dv}{dt}\right)v \Rightarrow \frac{P}{m}dt = v\,dv$

$\Rightarrow \frac{P}{m} \times t = \frac{v^2}{2} \Rightarrow v = \left(\frac{2P}{m}\right)^{1/2}(t)^{1/2}$

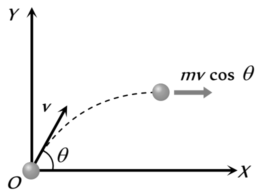
Now $s = \int v\,dt = \int \left(\frac{2P}{m}\right)^{1/2} t^{1/2} dt$

$\therefore\ s = \left(\frac{2P}{m}\right)^{1/2}\left[\frac{2t^{3/2}}{3}\right] \Rightarrow s \propto t^{3/2}$

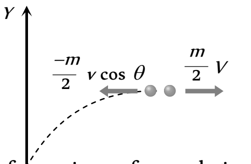
14. (a) Shell is fired with velocity v at an angle θ with the horizontal. So its velocity at the highest point

= horizontal component of velocity = $v\cos\theta$

So momentum of shell before explosion = $mv\cos\theta$



When it breaks into two equal pieces and one piece retrace its path to the canon, then other part move with velocity V.



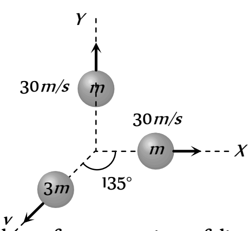
So momentum of two pieces after explosion

$= \frac{m}{2}(-v\cos\theta) + \frac{m}{2}V$

By the law of conservation of momentum

$mv\cos\theta = \frac{-m}{2}v\cos\theta + \frac{m}{2}V \Rightarrow V = 3v\cos\theta$

15. (a) Let two pieces are having equal mass m and third piece have a mass of $3m$.



According to law of conservation of linear momentum. Since the initial momentum of the system was zero, therefore final momentum of the system must be zero *i.e.* the resultant of momentum of two pieces must be equal to the momentum of third piece. We know that if two particle possesses same momentum and angle in between them is 90° then resultant will be given by $P\sqrt{2} = mv\sqrt{2} = m30\sqrt{2}$

Let the velocity of mass $3m$ is V. So $3mV = 30m\sqrt{2}$

$\therefore\ V = 10\sqrt{2}$ and angle 135° from either.

(as it is clear from the figure)

16. (c) The momentum of the two-particle system, at $t = 0$ is

$\vec{P}_i = m_1\vec{v}_1 + m_2\vec{v}_2$

Collision between the two does not affect the total momentum of the system.

A constant external force $(m_1 + m_2)g$ acts on the system.

The impulse given by this force, in time $t = 0$ to $t = 2t_0$ is $(m_1 + m_2)g \times 2t_0$

$\therefore$ |Change in momentum in this interval

$= |m_1\vec{v}'_1 + m_2\vec{v}'_2 - (m_1\vec{v}_1 + m_2\vec{v}_2)| = 2(m_1 + m_2)gt_0$

17. (b) If the masses are equal and target is at rest and after collision both masses moves in different direction. Then angle between direction of velocity will be 90°, if collision is elastic.

18. (d) K.E. of colliding body before collision $= \frac{1}{2}mv^2$

After collision its velocity becomes

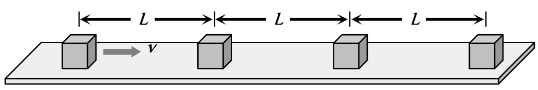
$v' = \frac{(m_1 - m_2)}{(m_1 + m_2)}v = \frac{m}{3m}v = \frac{v}{3}$

$\therefore$ K.E. after collision $\frac{1}{2}mv'^2 = \frac{1}{2}\frac{mv^2}{9}$

Ratio of kinetic energy $= \frac{\text{K.E}_{\text{before}}}{\text{K.E}_{\text{after}}} = \frac{\frac{1}{2}mv^2}{\frac{1}{2}\frac{mv^2}{9}} = 9:1$

19. (c)

20. (b,d)



Since collision is perfectly inelastic so all the blocks will stick together one by one and move in a form of combined mass.

Time required to cover a distance 'L' by first block $= \frac{L}{v}$

Now first and second block will stick together and move with $v/2$ velocity (by applying conservation of momentum) and combined system will take time $\frac{L}{v/2} = \frac{2L}{v}$ to reach up to block third.

Now these three blocks will move with velocity $v/3$ and combined system will take time $\frac{L}{v/3} = \frac{3L}{v}$ to reach upto the block fourth.

So, total time $= \frac{L}{v} + \frac{2L}{v} + \frac{3L}{v} + \ldots \frac{(n-1)L}{v} = \frac{n(n-1)L}{2v}$

and velocity of combined system having n blocks as $\frac{v}{n}$.

Graphical questions

1. (c) At time t_1 the velocity of ball will be maximum and it goes on decreasing with respect to time.

At the highest point of path its velocity becomes zero, then it increases but direction is reversed

This explanation match with graph (c).

2. (a) Work done = area between the graph and position axis

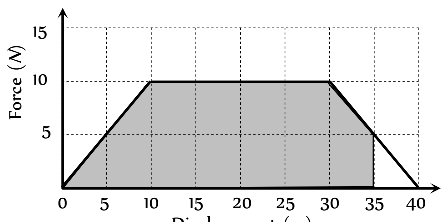
$W = 10\times1 + 20\times1 - 20\times1 + 10\times1 = 20\, erg$

3. (a) Spring constant $k = \frac{F}{x}$ = Slope of curve

$\therefore k = \frac{4-1}{30} = \frac{3}{30} = 0.1 kg/cm$

4. (b) As the area above the time axis is numerically equal to area below the time axis therefore net momentum gained by body will be zero because momentum is a vector quantity.

5. (c)



Work done = (Shaded area under the graph between $x = 0$ to $x = 35\ m$) $= 287.5\ J$

6. (a) Work done = Area covered in between force displacement curve and displacement axis

= Mass × Area covered in between acceleration-displacement curve and displacement axis.

$= 10\times\frac{1}{2}(8\times10^{-2}\times20\times10^{-2})$

$= 8\times10^{-2}\ J$

7. (c) Work done = Gain in potential energy

Area under curve = mgh

$\Rightarrow \frac{1}{2}\times11\times100 = 5\times10\times h$

$\Rightarrow h = 11 m$

8. (d) Initial K.E. of the body $= \frac{1}{2}mv^2 = \frac{1}{2}\times25\times4 = 50\ J$

Work done against resistive force

= Area between F-x graph

$= \frac{1}{2}\times4\times20 = 40 J$

Final K.E. = Initial K.E. – Work done against resistive force

$= 50 - 40 = 10\ J$

9. (d) Area between curve and displacement axis

$= \frac{1}{2}\times(12+4)\times10 = 80\ J$

In this time body acquire kinetic energy $= \frac{1}{2}mv^2$

by the law of conservation of energy

$\frac{1}{2}mv^2 = 80 J$

$\Rightarrow \frac{1}{2}\times0.1\times v^2 = 80$

$\Rightarrow v = 1600$

$\Rightarrow v = 40\ m/s$

10. (a) Work done = Area under curve and displacement axis

= Area of trapezium

$= \frac{1}{2}\times$(sum of two parallel lines) × distance between them

$= \frac{1}{2}(10+4)\times(2.5-0.5)$

$= \frac{1}{2}14\times2 = 14\ J$

As the area actually is not trapezium so work done will be more than 14 J *i.e.* approximately 16 J

11. (a) As particle is projected with some velocity therefore its initial kinetic energy will not be zero.

As it moves downward under gravity then its velocity increases with time K.E. $\propto v \propto t$ (As $v \propto t$)

So the graph between kinetic energy and time will be parabolic in nature.

12. (a) From the graph it is clear that force is acting on the particle in the region AB and due to this force kinetic energy (velocity) of the particle increases. So the work done by the force is positive.

13. (d) $F = \frac{-dU}{dx} \Rightarrow dU = -F\ dx$

$\Rightarrow U = -\int_0^x(-Kx + ax^3)dx = \frac{kx^2}{2} - \frac{ax^4}{4}$

$\therefore$ We get $U = 0$ at $x = 0$ and $x = \sqrt{2k/a}$

and also U = negative for $x > \sqrt{2k/a}$.

So $F = 0$ at $x = 0$

i.e. slope of $U - x$ graph is zero at $x = 0$.

14. (b) Work done = Area enclosed by $F - x$ graph

$= \frac{1}{2}\times(3+6)\times3 = 13.5\ J$

15. (c) As slope of problem graph is positive and constant upto certain distance and then it becomes zero.

So from $F = \frac{-dU}{dx}$, up to distance a, F = constant (negative) and becomes zero suddenly.

16. (d) Work done = change in kinetic energy

$W = \frac{1}{2}mv^2$ $\therefore$ $W \propto v^2$ graph will be parabolic in nature

17. (a) Potential energy increases and kinetic energy decreases when the height of the particle increases it is clear from the graph (*a*).

18. (c) $P = \sqrt{2mE}$ it is clear that $P \propto \sqrt{E}$

So the graph between P and $\sqrt{E}$ will be straight line.

but graph between $\frac{1}{P}$ and $\sqrt{E}$ will be hyperbola

19. (b) When particle moves away from the origin then at position $x = x_1$ force is zero and at $x > x_1$, force is positive (repulsive in nature) so particle moves further and does not return back to original position.

i.e. the equilibrium is not stable.

Similarly at position $x = x_2$ force is zero and at $x > x_2$, force is negative (attractive in nature)

So particle return back to original position *i.e.* the equilibrium is stable.

20. (c) $F = \frac{-dU}{dx}$ it is clear that slope of $U - x$ curve is zero at point B and C. $\therefore$ $F = 0$ for point B and C

21. (a) Work done = area under curve and displacement axis

$= 1 \times 10 - 1 \times 10 + 1 \times 10 = 10\ J$

22. (a) When the length of spring is halved, its spring constant will becomes double. (because $k \propto \frac{1}{x} \propto \frac{1}{L} \therefore k \propto \frac{1}{L}$)

Slope of force displacement graph gives the spring constant (k) of spring.

If k becomes double then slope of the graph increases *i.e.* graph shifts towards force-axis.

23. (a) Kinetic energy $E = \frac{1}{2}mv^2 \Rightarrow E \propto v^2$

graph will be parabola symmetric to E-axis.

24. (c) Change in momentum = Impulse

= Area under force-time graph

$\therefore$ mv = Area of trapezium

$\Rightarrow mv = \frac{1}{2}\left(T + \frac{T}{2}\right)F_0$

$\Rightarrow mv = \frac{3T}{4}F_0 \Rightarrow F_0 = \frac{4mu}{3T}$

25. (c) When body moves under action of constant force then kinetic energy acquired by the body K.E. = $F \times S$

$\therefore$ KE $\propto$ S (If F = constant)

So the graph will be straight line.

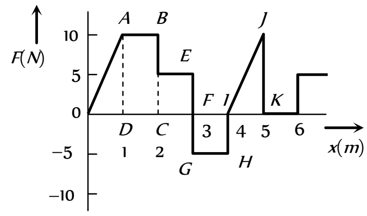
26. (a) When the distance between atoms is large then interatomic force is very weak. When they come closer, force of attraction increases and at a particular distance force becomes zero. When they are further brought closer force becomes repulsive in nature.

This can be explained by slope of $U - x$ curve shown in graph (a).

27. (b) Work done = area under F-x graph

= area of rectangle $ABCD$ + area of rectangle $LCEF$

+ area of rectangle $GFIH$ + area of triangle IJK



$= (2-1)\times(10-0)+(3-2)(5-0)+(4-3)(-5-0)$

$+\frac{1}{2}(5-4)(10-0) = 15\ J$

28. (a) $U = -\int F dx = -\int kx\ dx = -k\frac{x^2}{2}$

This is the equation of parabola symmetric to U axis in negative direction

Assertion and Reason

1. (a) The work done, $W = \vec{F}.\vec{s} = Fs\cos\theta$, when a person walk on a horizontal road with load on his head then $\theta = 90°$.

Hence $W = Fs\cos 90° = 0$

Thus no work is done by the person.

2. (d) In a round trip work done is zero only when the force is conservative in nature.

Force is always required to move a body in a conservative or non-conservative field

3. (e) When a body slides down on inclined plane,

work done by friction is negative because it opposes the motion ($\theta = 180°$ between force and displacement)

If $\theta < 90°$ then W =positive because $W = F.s.\cos\theta$

4. (a) Since the gaseous pressure and the displacement (of piston) are in the same direction. Therefore $\theta = 0°$

$\therefore$ Work done = $Fs\cos\theta = Fs$ = Positive

Thus during expansion work done by gas is positive.

5. (d) When two bodies have same momentum then lighter body possess more kinetic energy because $E = \frac{P^2}{2m}$

$\therefore E \propto \frac{1}{m}$ when P = constant

6. (b) $P = \vec{F}.\vec{v}$ and unit of power is *Watt.*

7. (c) Change in kinetic energy = work done by net force.

This relationship is valid for particle as well as system of particles.

8. (a) The work done on the spring against the restoring force is stored as potential energy in both conditions when it is compressed or stretched.

9. (c) The gravitational force on the comet due to the sun is a conservative force. Since the work done by a conservative force over a closed path is always zero (irrespective of the nature of path), the work done by the gravitational forces over every complete orbit of the comet is zero.

10. (e) Rate of change of momentum is proportional to external forces acting on the system. The total momentum of whole system remain constant when no external force is acted upon it.

Internal forces can change the kinetic energy of the system.

11. (a) When the water is at the top of the fall it has potential energy *mgh* (where *m* is the mass of the water and *h* is the height of the fall). On falling, this potential energy is converted into kinetic energy, which further converted into heat energy and so temperature of water increases.

12. (b) The power of the pump is the work done by it per sec.

$$\therefore \text{ Power} = \frac{\text{work}}{\text{time}} = \frac{mgh}{t} = \frac{100 \times 10 \times 100}{10}$$

$$= 10^4 W = 10\,kW$$

Also 1 *Horse power* (*hp*) =746 *W.*

13. (c) For conservative forces the sum of kinetic and potential energies at any point remains constant throughout the motion. This is known as law of conservation of mechanical energy. According to this law,

Kinetic energy + Potential energy = constant

or, $\Delta K + \Delta U = 0$ or, $\Delta K = -\Delta U$

14. (e) When the force retards the motion, the work done is negative. Work done depends on the angle between force and displacement $W = Fs\cos\theta$

15. (d) In an elastic collision both the momentum and kinetic energy remains conserved. But this rule is not for individual bodies, but for the system of bodies before and after the collision. While collision in which there occurs some loss of kinetic energy is called inelastic collision. Collision in daily life are generally inelastic. The collision is said to be perfectly inelastic, if two bodies stick to each other.

16. (d) A body can have energy without having momentum if it possess potential energy but if body possess momentum then it must posses kinetic energy. Momentum and energy have different dimensions.

17. (e) Work done and power developed is zero in uniform circular motion only.

18. (a) $K = \frac{1}{2}mv^2 \; \therefore \; K \propto v^2$

If velocity is doubled then K.E. will be quadrupled.

19. (a) In a quick collision, time t is small. As $F \times t =$ constant, therefore, force involved is large, *i.e.* collision is more violent in comparison to slow collision.

20. (a) From, definition, work done in moving a body against a conservative force is independent of the path followed.

21. (c) When we supply current through the cell, chemical reactions takes place, so chemical energy of cell is converted into electrical energy. If a large amount of current is drawn from wire for a long time only then wire get heated.

22. (e) Potential energy $U = \frac{1}{2}kx^2$ *i.e.* $U \propto x^2$

This is a equation of parabola, so graph between *U* and *x* is a parabola, not straight line.

23. (c) When two bodies of same mass undergo an elastic collision, their velocities get interchanged after collision. Water and heavy water are hydrogenic materials containing protons having approximately the same mass as that of a neutron. When fast moving neutrons collide with protons, the neutrons come to rest and protons move with the velocity of that of neutrons.

24. (a) From Einstein equation $E = mc^2$

it can be observed that if mass is conserved then only energy is conserved and vice versa. Thus, both cannot be treated separately.

25. (b) If two protons are brought near one another, work has to be done against electrostatic force because same charge repel each other. This work done is stored as potential energy in the system.

26. (a) $E = \frac{P^2}{2m}$. In firing momentum is conserved $\therefore E \propto \frac{1}{m}$

So $\frac{E_{\text{gun}}}{E_{\text{bullet}}} = \frac{m_{\text{bullet}}}{m_{\text{gun}}}$

27. (a) K.E. of one bullet = *k* ∴ K.E. of *n* bullet = *nk*

According to law of conservation of energy, the kinetic energy of bullets be equal to the work done by machine gun per sec.

28. (d) Work done in the motion of a body over a closed loop is zero only when the body is moving under the action of conservative forces (like gravitational or electrostatic forces). *i.e.* work done depends upon the nature of force.

29. (a) If roads of the mountain were to go straight up, the slope θ would have been large, the frictional force $\mu mg\cos\theta$ would be small. Due to small friction, wheels of vehicle would slip. Also for going up a large slope, a greater power shall be required.

30. (a) The rise in temperature of the soft steel is an example of transferring energy into a system by work and having it appear as an increase in the internal energy of the system. This works well for the soft steel because it is soft. This softness results in a deformation of the steel under blow of the hammer. Thus the point of application of the force is displaced by the hammer and positive work is done on the steel. With the hard steel, less deformation occur, thus, there is less displacement of point of application of the force and less work done on the steel. The soft steel is therefore better in absorbing energy from the hammer by means of work and its temperature rises more rapidly.