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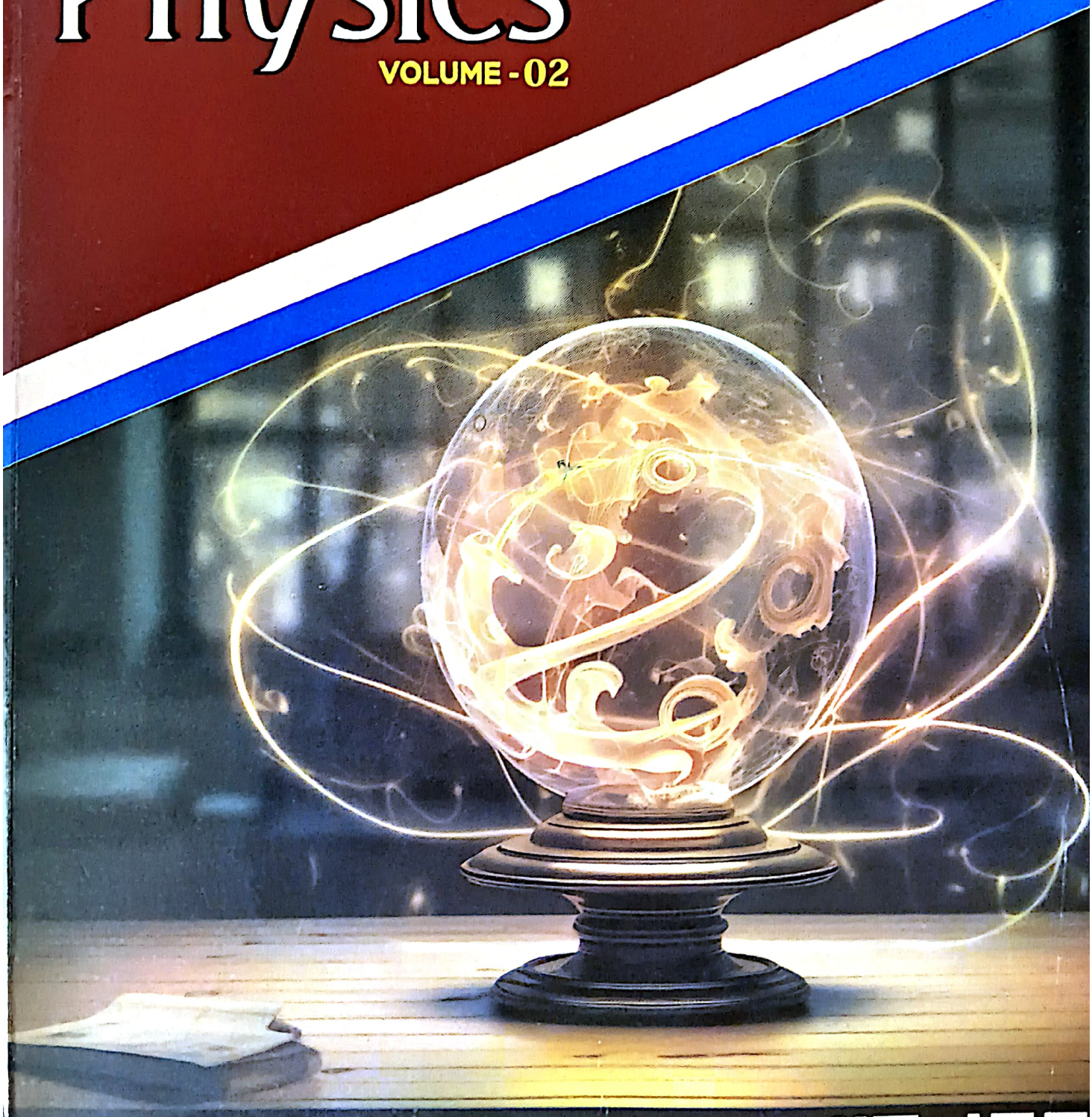
I Year

Physics

VOLUME - 02



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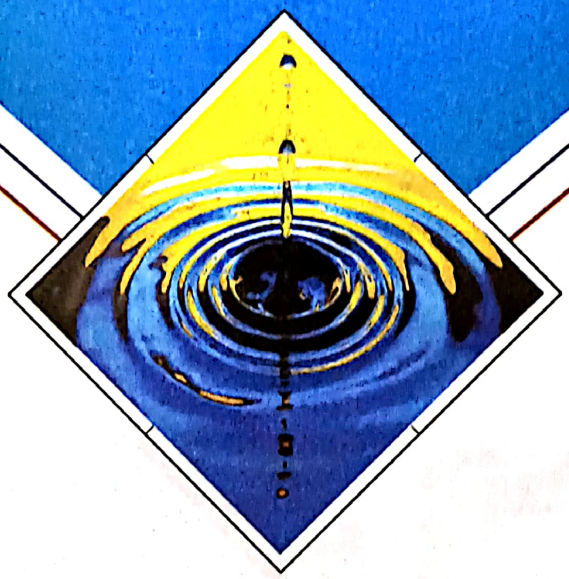
PHYSICS



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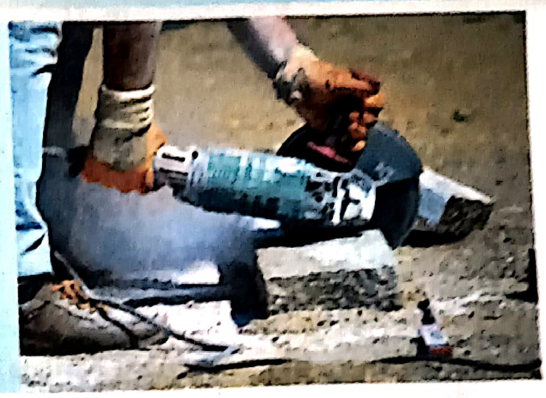
1 WORK POWER ENERGY



INTERNALS OF THE TOPIC

- Work
- Conservative And Non-Conservative Forces
- Potential Energy
- Power
- Motion In A Vertical Circle
- Collisions
- Work Done By Constant Force
- Work Done By Variable Force
- Kinetic Energy Potential Energy
- Potential Energy of A Spring
- Work Energy Theorem By Constant Force
- Work Energy Theorem For Variable Force
- Conservation of Mechanical Energy
- Elastic And Inelastic Collisions In One Dimension
- Coefficient of Restitution

CRT CONCEPT

Work done by constant force:

- When a constant force $\vec{F}$ acts on a particle and the particle moves through a displacement $\vec{S}$, then the force is said to do work W on the particle.

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

The scalar (dot) product of $\vec{F}$ and $\vec{S}$, can be evaluated as $W = \vec{F}.\vec{S} = FS\cos\theta$

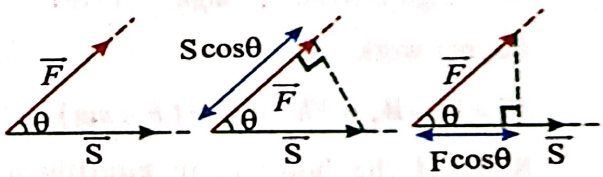
Where F is the magnitude of $\vec{F}$, S is the magnitude of $\vec{S}$ and θ is the angle between $\vec{F}$ and $\vec{S}$.

$W = FS\cos\theta = F(S\cos\theta)$

= magnitude of the force × component of displacement in the direction of force

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

W = component of the force in the direction of displacement × magnitude of the displacement



- Work is a scalar quantity.
- SI Unit is Nm or joule (J).
- CGS unit is erg.

$1J = 1N \times 1m$; 1 erg = 1 dyne x 1cm

Dimensional formula of work is $[ML^2T^{-2}]$.

- Relation between joule and erg:

$1\ joule = 10^7\ erg$

Other units of work:

Electron Volt $(eV) = 1.6 \times 10^{-19} J$

Kilowatt hour $= 3.6 \times 10^6 J$

- **Work done by multiple forces:**

If a number of forces act on a body or particle then:

$$W = W_1 + W_2 + W_3 + \ldots\ldots$$

or $W = \int \vec{F_1}.\vec{ds} + \int \vec{F_2}.\vec{ds} + \ldots\ldots$

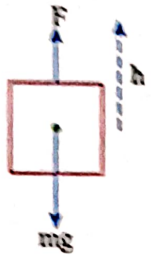
or $W = \int (\vec{F_1} + \vec{F_2} + \ldots\ldots).\vec{ds}$

or $W = \int \vec{F_R}.\vec{ds} \left[as\ \vec{F_R} = \Sigma \vec{F} \right]$

Work done in displacing a particle under the action of a number of forces is equal to the work done by the resultant force.

- **Nature of Work:** Work done by a force may be positive or negative or zero.

Ex:(a) If we lift a body from rest to a height h



- Work done by lifting force F

$W_1 = Fh\cos 0^\circ = Fh \quad (+ve)$

- Work done by gravitational force

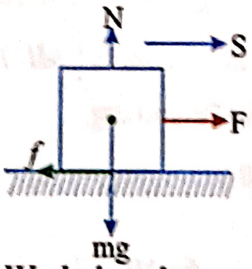
$W_2 = mgh\cos 180^\circ = -mgh \quad (-ve)$

So, net work

$W = W_1 + W_2 = Fh - mgh = (F - mg)h$

Now, if the body is in equilibrium $F = mg, W = 0$

Ex: (b) If a body is pulled on a rough horizontal road through a displacement S



- Work done by normal reaction and gravity

$W_1 = 0$ as force is $\perp$ to S

- Work done by pulling force F,

$W_2 = FS\cos 0^\circ = FS \quad (+ve)$

- Work done by frictional force f,

$W_3 = fs\cos 180^\circ = -\mu mgs\ (-ve)$

Net work

$W = W_1 + W_2 + W_3 = 0 + FS - fS = (F - f)S$

Now, if the body is in dynamic equilibrium $f = F$

So, $W = 0$

Zero Work:

- Work done is zero if

1. Force and displacement are perpendicular.
2. Displacement of point of application of force is zero.
3. Net force acting on the body is zero.

- As $W = \int \vec{F}.\vec{ds}$ so, if $\vec{ds} = 0$, W=0 i.e., if the displacement of a particle or body is zero whatever be the force , work done is zero (except non-conservative force)

(a) When a person tries to displace a wall or stone by applying a force and it (actually its centre of mass) does not move, the work done is zero.

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

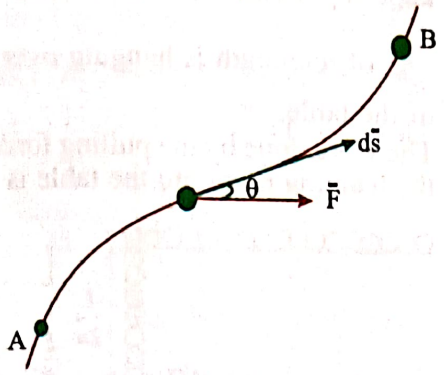
- As $W = \int F\,ds\cos\theta$, so $W = 0$, if $\theta = 90^\circ$, i.e., if force is always perpendicular to motion, work done by the force will be zero though neither force nor displacement is zero. This is why:

(a) When a porter moves with a suitcase on his head on a horizontal level road, the work done by the lifting force or force of gravity is zero.

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

(c) When the bob of a simple pendulum swings, the work done by tension in the string is zero.

WORK DONE BY VARIABLE FORCE:



- When the magnitude and direction of a force varies with position, then the work done by such a force for an infinitesimal displacement ds is given by $dW = \vec{F}.\vec{ds}$

The total work done in going from A to B is

$$W_{AB} = \int_A^B \vec{F}.\vec{ds} = \int_A^B (F\cos\theta)\,ds$$

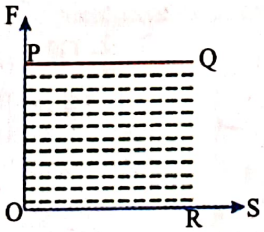
In terms of rectangular components

$$\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}\,;\ \vec{ds} = dx\hat{i} + dy\hat{j} + dz\hat{k}$$

$$W = \int_{x_1}^{x_2} F_x dx + \int_{y_1}^{y_2} F_y dy + \int_{z_1}^{z_2} F_z dz$$

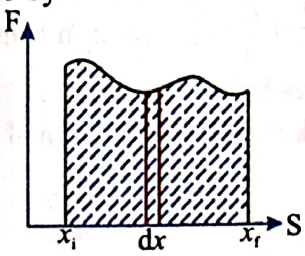
Graphical representation of work done:

- The area enclosed by the F-S graph and displacement axis gives the amount of work done by the force.



Work = FS = Area of OPQR

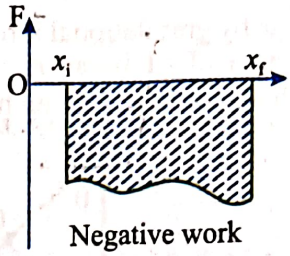
- Work done by variable force.



- For a small displacement dx the work done will be the area of the strip of width dx

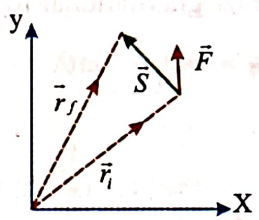
$$W = \int_{x_i}^{x_f} dW = \int_{x_i}^{x_f} F\,dx$$

- If area enclosed above X-axis, work done is +ve and if the area enclosed below X-axis, work done is –ve.



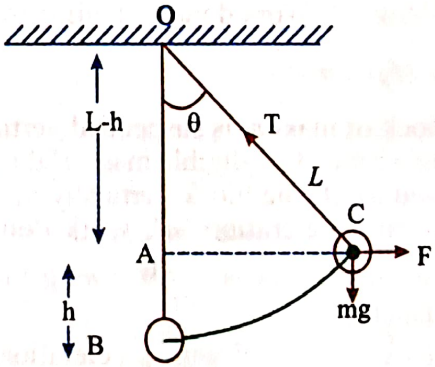
Applications on work

- If a force is changing linearly from F_1 to F_2 over a displacement S then work done is $W = \left(\frac{F_1 + F_2}{2}\right)S$
- If a force displaces the particle from its initial position $\vec{r_i}$ to final position $\vec{r_f}$ then displacement vector is $\vec{S} = \vec{r_f} - \vec{r_i}$.



$$W = \vec{F}.\vec{S} = \vec{F}.\left(\vec{r_f} - \vec{r_i}\right)$$

- Work done in pulling the bob of mass m of a simple pendulum of length L through an angle θ to vertical by means of a horizontal force F.



$$\cos\theta = \frac{L-h}{L} = 1 - \frac{h}{L};\ \frac{h}{L} = 1 - \cos\theta$$

$h = L(1-\cos\theta)$

Work done by gravitational force

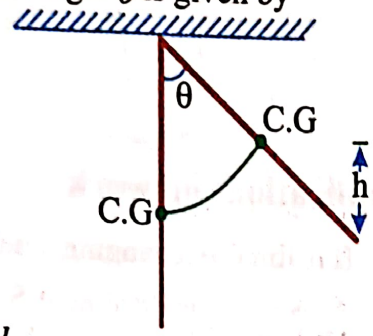
$W = -mgh = -mgL(1-\cos\theta)$

Work done by horizontal force F is

$W = FL\sin\theta$

Work done by tension T in the string is zero.

- Work done by gravitational force in pulling a uniform rod of mass m and length l through an angle θ is given by

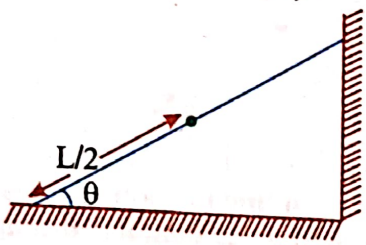


$W = -mg\frac{l}{2}(1-\cos\theta)$, Where $\frac{l}{2}$ is the distance of centre of mass from the support.

- A ladder of mass 'm' and length 'L' resting on a level floor is lifted and held against a wall at an angle θ with the floor

Work done by gravitational force is

$W_g = -mgh = -mg\left(\frac{L}{2}\right)\sin\theta$



- A bucket full of water of total mass M is pulled by using a uniform rope of mass m and length l. Work done by pulling force

$W = Mgl + mg\frac{l}{2}$

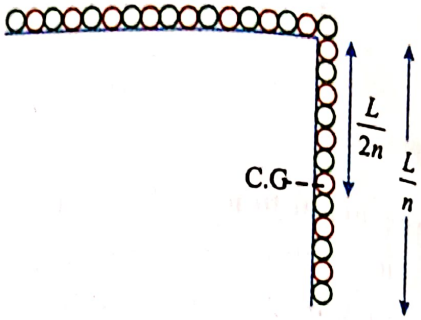
- A block of mass m is suspended vertically using a rope of negligible mass. If the rope is used to lift the block vertically up with uniform acceleration 'a', work done by tension in the rope is $W = m(g+a)h$ (h= height)

If block is lowered with acceleration 'a', then

$W = -m(g-a)h$

- A uniform chain of mass M and length kept on smooth horizontal table such $\frac{1}{n^{th}}$ of its length is hanging over the of the table.

The work done by the pulling force to the hanging part onto the table is



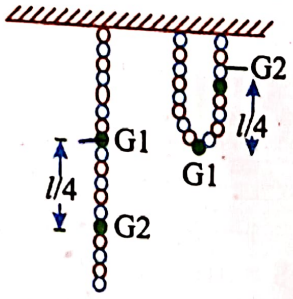
$W = \left(\frac{M}{n}\right)gh = \left(\frac{M}{n}\right)g\left(\frac{L}{2n}\right) = \frac{MgL}{2n^2}$

Mass of hanging part is $\frac{M}{n}$

- A uniform chain of mass M and length rests on a smooth horizontal table with part of its length is hanging from the ed of the table. Work done in pulling the cha partially such that

$\frac{1}{n_2^{th}}$ part is hanging from the edge of t table is given by $W = \frac{MgL}{2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

- A uniform chain of mass 'M' and length is suspended vertically. The lower end the chain is lifted upto point of suspensi

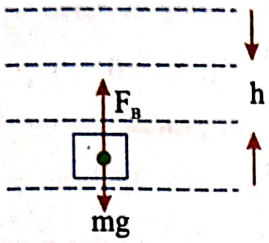


$h = \frac{L}{4} + \frac{L}{4} = \frac{L}{2}$ = raise in centre of mass of lower half of the chain .

Work done by gravitational force is

$W_g = -\frac{M}{2}g\frac{L}{2} = -\frac{MgL}{4}$

- The Work done in lifting a body of mass 'm' having density 'd_1' inside a liquid of density 'd_2' through a height 'h' is



$$W = mg'h = mgh\left[1-\frac{d_2}{d_1}\right]$$

- A body of mass 'm' is placed on a frictionless horizontal surface. A force F acts on the body parallel to the surface such that it moves with an acceleration 'a', through a displacement 'S'. The work done by the force is

$$W = FS = maS \quad (\because \theta = 0^0)$$

- A body of mass 'm' is placed on a rough horizontal surface of coefficient of friction μ. A force F acts on the body parallel to the surface such that it moves with an acceleration 'a', through a displacement 'S'. The work done by the frictional force is

$$f = \mu mg\cos\theta;\ but\ \theta = 0^0$$

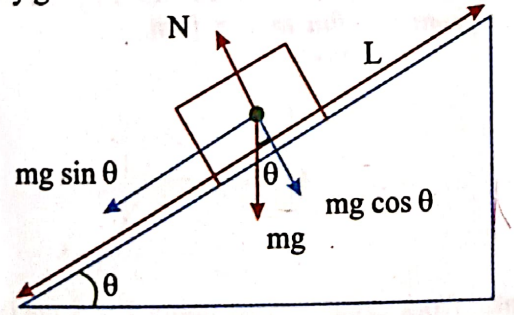
$$\therefore f = \mu mg\cos 0^0 = \mu mg \Rightarrow W_f = \mu mgs$$

$$W_{net} = (f+ma)S = (\mu mg + ma)S = m(\mu g + a)S$$

If the body moves with uniform velocity then

$$W = fS = \mu mgS$$

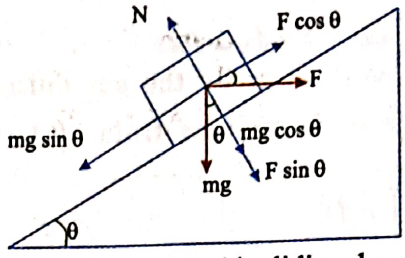
- A body of mass m is sliding down on a smooth inclined plane of inclination θ. If L is length of inclined plane then work done by gravitational force is



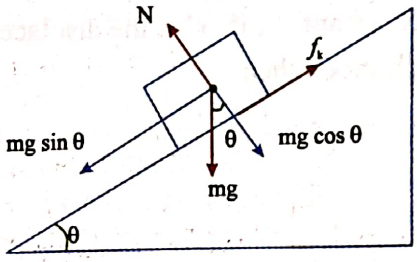
$$W_g = FS = mg\sin\theta L$$

- A body of mass 'm' is moved up the smooth inclined plane of inclination θ and length L by a constant horizontal force F then work done by the resultant force is

$$W = (F\cos\theta - mg\sin\theta)L$$



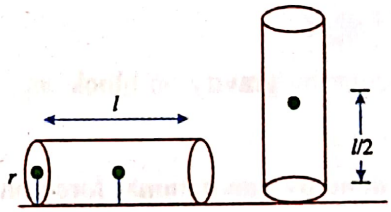
- A body of mass 'm' is sliding down on rough inclined plane of inclination θ. If L is the length of incline and μ_K is the coefficient of kinetic friction then work done by the resultant force on the body is



$$W = (mg\sin\theta - f_k)L = (mg\sin\theta - \mu_k mg\cos\theta)L$$

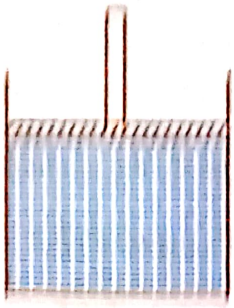
$$= mgL(\sin\theta - \mu_k\cos\theta)$$

- A uniform solid cylinder of mass m, length l and radius r is lying on ground with curved surface in contact with ground. If it is turned such that its circular face is in contact with ground then work done by applied force is



$$W = mgh = mg\left(\frac{l}{2} - r\right) \quad \left(\because h = \frac{l}{2} - r\right)$$

- A gas at a pressure P is enclosed in a cylinder with a movable piston. Work done by the gas in producing small displacement dx of the piston is

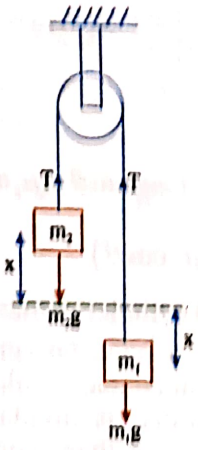


$dW = Fdx = PA\,dx = PdV$

Total work done by the gas during the change in its volume from V_1 to V_2 is

$$W = \int_{V_1}^{V_2} PdV$$

- Two blocks of masses m_1 and m_2 $(m_1 > m_2)$ connected by an inextensible string are passing over a smooth, massless pulley. The two blocks are released from the same level. At any instant 't', if 'x' is the displacement of each block then



Work done by gravity on block m_1,

$W_1 = +m_1gx$

Work done by gravity on block m_2,

$W_2 = -m_2gx$

Work done by gravitational force on the system, $W_g = m_1gx - m_2gx$

$$W_g = (m_1 - m_2)gx = (m_1 - m_2)g\left(\frac{1}{2}at^2\right)$$

$$\left[\because v^2 - u^2 = 2as\right]$$

$$W_g = \frac{(m_1 - m_2)^2 g^2 t^2}{2(m_1 + m_2)} \quad \left[\because a = \frac{(m_1 - m_2)g}{m_1 + m_2}\right]$$

Note: In this case work done on the two blocks by tension is zero.

$W = T(x) + T(-x) = 0$

SE-1: *A body is displaced from $\vec{r}_A = (2\hat{i} + 4\hat{j} - 6\hat{k})$ to $\vec{r}_B = (6\hat{i} - 4\hat{j} + 2\hat{k})$ under a constant force $\vec{F} = (2\hat{i} + 3\hat{j} - \hat{k})$. Find the work done.*

Sol. Work done $W = \vec{F}.\vec{d}$; $W = \vec{F}.(\vec{r}_B - \vec{r}_A)$

$$W = (2\hat{i} + 3\hat{j} - \hat{k}).[(6\hat{i} - 4\hat{j} + 2\hat{k}) - (2\hat{i} + 4\hat{j} - 6\hat{k})]$$

$$W = (2\hat{i} + 3\hat{j} - \hat{k}).(4\hat{i} - 8\hat{j} + 8\hat{k})$$

$W = 8 - 24 - 8 = -24$ units

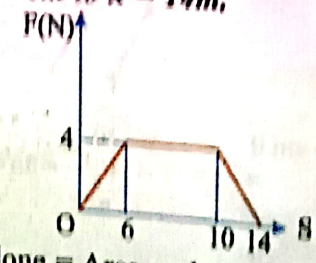
SE-2: *A force $\vec{F} = 2x\hat{i} + 2\hat{j} + 3z^2\hat{k}$ N is acting on a particle. Find the work done by the force in displacing the body from (1,2,3)m to (3,6,1)m.*

Sol. Work done $W = \int_{x_1}^{x_2} F_x dx + \int_{y_1}^{y_2} F_y dy + \int_{z_1}^{z_2} F_z dz$

$$W = \int_1^3 2x\,dx + \int_2^6 2\,dy + \int_3^1 3z^2 dz$$

$$W = 2\left[\frac{x^2}{2}\right]_1^3 + 2[y]_2^6 + 3\left[\frac{z^3}{3}\right]_3^1 = -10\text{ J}$$

SE-3: *The force acting on an object varies with the distance travelled by the object as shown in the figure. Find the work done by the force in moving the object from x = 0m to x = 14m.*



Sol. Work done = Area under F - S curve.

$$W=\left(\frac{1}{2}\times 6\times 4\right)+(4\times 4)+\left(\frac{1}{2}\times 4\times 4\right)$$

$=36J.$

SE-4: *When a rubber band is stretched by a distance 'x', it exerts a restoring force of magnitude $F=ax+bx^2$, where a and b are constants. Find the work done in stretching the unstretched rubber band by 'L'.(JEE MAIN 2014)*

Sol: The restoring force exerted by the rubber band when it is stretched by a distance 'x' is

$F=ax+bx^2$.

The small amount of work done on the rubber band in stretching through a small distance 'dx' is

$dW=Fdx=(ax+bx^2)dx$

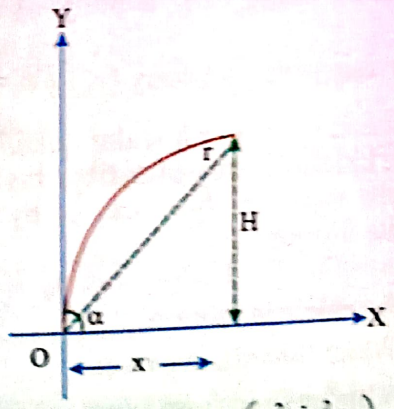
The total work done in stretching the unstretched rubber band by 'L' is

$$W=\int_0^L Fdx=\int_0^L (ax+bx^2)dx=\int_0^L axdx+\int_0^L bx^2dx$$

$$W=a\left[\frac{x^2}{2}\right]_0^L+b\left[\frac{x^3}{3}\right]_0^L=\frac{aL^2}{2}+\frac{bL^3}{3}$$

SE-5: *A particle of mass 'm' is projected at an angle α to the horizontal with an initial velocity u. Find the workdone by gravity during the time it reaches the highest point.*

Sol:

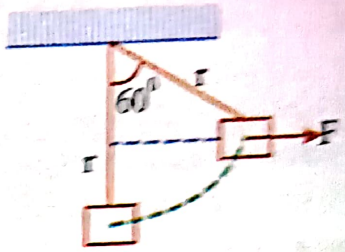


$$\overline{F}_y=-mg\hat{j};\ \overline{r}_y=\overline{H}_{max}=\left(\frac{u^2\sin^2\alpha}{2g}\right)\hat{j}$$

$$W=\overline{F}_y.\overline{r}_y=(-mg\hat{j}).\left(\frac{u^2\sin^2\alpha}{2g}\right)\hat{j}$$

$$W=-\frac{1}{2}mu^2\sin^2(\alpha)$$

SE-6: *A 10 kg block is pulled along a frictionless surface in the form of an arc of a circle of radius10 m. The applied force is 200 N. Find the work done by (a) applied force and (b) gravitational force in displacing through an angle 60°*



Sol: Work done by applied force $W=Fr\sin\theta$

$$W=200\times 10\times\sin 60^0=200\times 10\times\frac{\sqrt{3}}{2}=1732J$$

work done by gravitational force

$$W=-mgr(1-\cos\theta)$$

$$W=-10\times 9.8\times 10(1-\cos 60^0)$$

$$W=-98\times 10\left(1-\frac{1}{2}\right)=-490J$$

SE-7: *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 back onto the table?*

Sol: M = 4 kg, L = 2 m, l = 0.6 m, g = 10 m/s²

Work done $W=mg\frac{l}{2}=\left(\frac{M}{L}\right)lg\frac{l}{2}$

$$W=\left(\frac{4}{2}\right)\times 0.6\times 10\times\frac{0.6}{2}=3.6J$$

SE-8: *Find the work done in lifting a body of mass 20 kg and specific gravity 3.2 to a height of 8 m in water? (g = 10 m/s²)*

Sol: Given specific gravity $\frac{\rho_b}{\rho_w}=3.2$

$$\rho_b=3.2\times\rho_w=3.2\times 1000=3200$$

Workdone

$$W = mgh\left(1-\frac{\rho_w}{\rho_b}\right) = 20\times10\times8\left(1-\frac{1000}{3200}\right)$$

$$W = 20\times10\times8\left(\frac{2200}{3200}\right) = 1100\,J$$

SE-9: A block of mass 'm' is lowered with the help of a rope of negligible mass through a distance 'd' with an acceleration of g/3. Find the work done by the rope on the block?

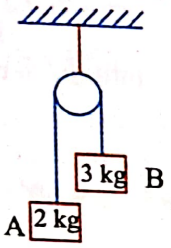
Sol: During lowering a block, tension in rope is

$T = m(g-a)$ and S = d

work done $W = -m(g-a)d$

$$W = -m\left(g-\frac{g}{3}\right)d = -\frac{2mgd}{3}$$

SE-10: If the system shown is released from rest. Find the net workdone by tension in first one second (g=10m/s²)



Sol. $a = \left(\frac{m_2-m_1}{m_1+m_2}\right)g = \left(\frac{3-2}{2+3}\right)10 = 2\text{m/s}^2$

$$T = \frac{2m_1m_2g}{m_1+m_2} = \frac{2\times2\times3\times10}{2+3} = 24\text{N}$$

for each block $S = \frac{1}{2}at^2 = \frac{1}{2}\times2\times1 = 1m$

$\therefore\ W_{net} = W_1 + W_2 = TS - TS = 0$

Energy:

- Energy is the ability or capacity to do work. Greater the amount of energy possessed by the body, greater the work it will be able to do.
- Energy is cause for doing work and work is effect of energy.
- Energy is a scalar. Energy and work have same units and dimensions.
- The different forms of energy are Mechanical energy, Light energy, Heat energy, Sound energy, Electrical energy, Nuclear energy etc.
- Mechanical energy is of two types
  a) Potential Energy b) Kinetic Energy

Potential energy (U)

- Potential energy of a body is the energy possessed by a body by virtue of its position or configuration in the field.
- Potential energy is defined only for conservative forces. It does not exist for non-conservative forces. In case of conservative forces.

$$F = -\left(\frac{dU}{dr}\right) \therefore\ dU = -\vec{F}.\vec{dr} \Rightarrow \int_{U_1}^{U_2} dU = -\int_{r_1}^{r_2}\vec{F}.\vec{dr}$$

$$U_2 - U_1 = -\int_{r_1}^{r_2}\vec{F}.\vec{dr} = -W$$

$$If\ r_1 = \infty, U_1 = 0 \quad \therefore\ U = \int_{\infty}^{r}\vec{F}.\vec{dr} = -W$$

- P.E can be +ve or -ve or can be zero.
- P.E depends on frame of reference.
- **Ex:** Water stored in a dam , A stretched bow, A loaded spring etc., possesses P.E
- In case of conservative force (field) potential energy is equal to negative of work done in shifting the body from some reference position to given position
- A moving body may or may not have potential energy.
- Potential energy should be considered to be a property of the entire system, rather than assigning it to any specific particle.

Kinetic energy

- Kinetic energy is the energy possessed by a body by virtue of its motion.
- Kinetic energy of a body of mass 'm' moving with a velocity 'v', $KE = \frac{1}{2}mv^2$
- Kinetic energy is a scalar quantity.
- The kinetic energy of an object is a measure of the work an object can do by the virtue of its motion.

Examples for bodies having K.E

1) A vehicle in motion.
2) Water flowing in a river.
3) A bullet fired from a gun.

- Kinetic energy depends on frame of reference.

Ex: 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 earth.

Relation between K.E. and linear momentum

- $KE = \frac{1}{2}mv^2 = \frac{P^2}{2m} = \frac{1}{2}Pv \quad (\because P = mv)$
- If two bodies of different masses have same momentum then lighter body will have greater KE $\left(\because KE \alpha \frac{1}{m}\right)$
- When a bullet is fired from a gun the momentum of the bullet and gun are equal and opposite.

$$i.e \quad \frac{KE_{bullet}}{KE_{gun}} = \frac{M_{gun}}{M_{bullet}}$$

Hence, the KE of the bullet is greater than that of the gun

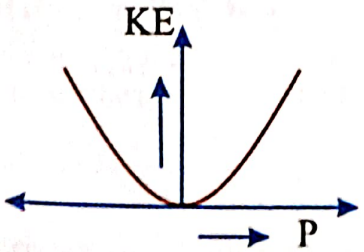
- A body can have energy without momentum. But it can not have momentum without energy.
- A bullet of mass 'm' moving with velocity 'v' stops in wooden block after penetrating through a distance 'x'. If F is resistance offered by the block to the bullet

(Assuming F is constant inside the block)

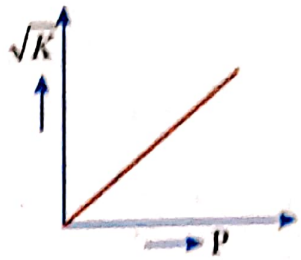
$$\frac{1}{2}mv^2 = Fx \; ; \quad F = \frac{mv^2}{2x} \quad \therefore v^2 \alpha x$$

- **For a given body**

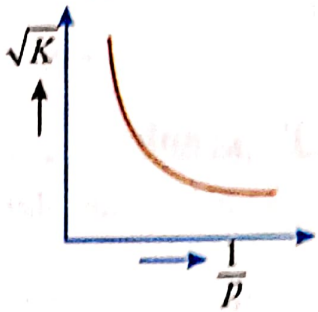
1) The graph between KE and P is a parabola.



2) The graph between $\sqrt{KE}$ and P is a straight line passing through the origin.Its slope = $\frac{1}{\sqrt{2m}}$



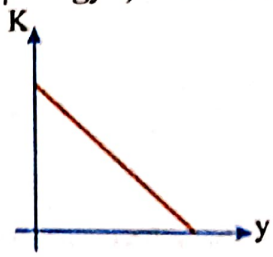
3) The graph between $\sqrt{KE}$ and $\frac{1}{P}$ is a rectangular hyperbola.



- A particle is projected up from a point at an angle 'θ' with the horizontal. At any time 't' if 'P' is linear momentum, 'y' is vertical displacement and 'x' is horizontal displacement, then nature of the curves drawn for KE of the particle (K) against these parameters are

i) K - y graph:

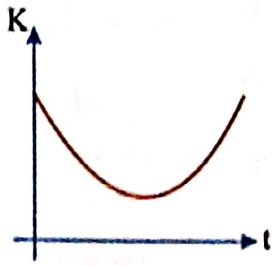
$K = K_i - mgy$; It is a straight line



ii) K - t graph

$$K = K_i - mg\left(u_y t - \frac{1}{2}gt^2\right)$$

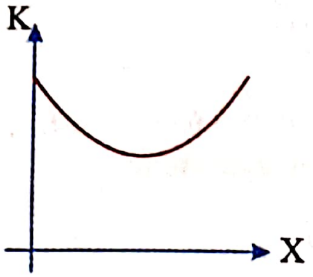
$\because y = u_y t - \frac{1}{2}gt^2$; It is a parabola



iii) K - x graph

$$K = K_i - mg\left(x\tan\theta - \frac{gx^2}{2u_x^2}\right)$$

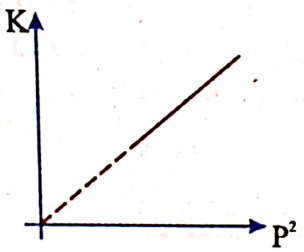
$\because y = (\tan\theta)x - \left(\frac{g}{2u_x^2}\right)x^2$; It is also a parabola



iv) K - P^2 graph

It is a straight line passing through origin and slope $= \frac{1}{2m}$

$P^2 = 2mK$



$P^2 \alpha K$

Conservative and non - Conservative forces

- If work done by a force around a closed path is zero and is independent of path then the force is said to be conservative force.
- Under conservative force $F = -\frac{dU}{dr}$ where U is Potential Energy. $U = \int dU = -\int \vec{F}.\vec{dr}$

  ($\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$ and $\vec{dr} = dx\hat{i} + dy\hat{j} + dz\hat{k}$)

  $$\vec{F} = -\left(\frac{\partial u}{\partial x}\hat{i} + \frac{\partial u}{\partial y}\hat{j} + \frac{\partial u}{\partial z}\hat{k}\right)$$

Ex1: Gravitational force is a conservative force

Ex2: Elastic force in a stretched spring is a conservative force

Non-Conservative Forces:

- If the work done by a force around a closed path is not equal to zero and is dependent on the path then the force is non-conservative force

  Ex:-Force of friction , Viscous force.
- Work done by the non-conservative force will not be stored in the form of Potential energy.
- Potential energy is defined only for conservative forces.

Spring force

- Spring force is an example of a variable force which is conservative.
- In an ideal spring, the spring force F_s is directly proportional to 'x'. Where x is the displacement of the block from equilibrium position. i.e., $F_s = -Kx$ .The constant K is called spring constant.
- The work done on the block by the spring force as the block moves from undeformed position $x = 0 \, to \, x = x_1$

  $dW = \vec{F}.\vec{dx} = -Kxdx$

  $$W = \int dW = \int_0^{x_1} -Kxdx = -\frac{1}{2}K\left(x^2\right)_0^{x_1} = -\frac{1}{2}Kx_1^2$$
- If the block moves from $x = x_1 \, to \, x = x_2$ the work done by spring force is $W = \int_{x_1}^{x_2} -Kxdx$

  $$W = \frac{1}{2}K\left(x_1^2 - x_2^2\right) = \frac{1}{2}Kx_1^2 - \frac{1}{2}Kx_2^2$$

Potential energy stored in a spring:

- The change in potential energy of a system corresponding to a conservative internal force is $dU = -\int_0^x \vec{F}.\vec{dx}$,

  dU = - (work done by the spring force)

  $$dU = -\left(\frac{-Kx^2}{2}\right) \; ; \; U_f - U_i = \frac{1}{2}Kx^2$$

since U_i is zero when spring is at its natural length

$$\therefore U_f = \frac{1}{2}Kx^2$$

S.E-11 Two spheres whose radii are in the ratio 1 : 2 are moving with velocities in the ratio 3 : 4. If their densities are in the ratio 3 : 2, then find the ratio of their kinetic energies.

Sol. $\frac{r_1}{r_2} = \frac{1}{2}, \frac{v_1}{v_2} = \frac{3}{4}, \frac{\rho_1}{\rho_2} = \frac{3}{2}$

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}(V\rho)v^2 = \frac{1}{2}\left(\frac{4}{3}\pi r^3\rho\right)v^2$$

$$\frac{KE_1}{KE_2} = \frac{\rho_1}{\rho_2} \times \left(\frac{r_1}{r_2}\right)^3 \times \left(\frac{v_1}{v_2}\right)^2 = \frac{3}{2} \times \left(\frac{1}{2}\right)^3 \times \left(\frac{3}{4}\right)^2$$

$$\frac{KE_1}{KE_2} = \frac{3}{2} \times \frac{1}{8} \times \frac{9}{16} = \frac{27}{256}$$

S.E-12:A particle is projected at 60⁰ to the horizontal with a kinetic energy 'K'.Find the kinetic energy at the highest point ?(JEE MAIN 2007)

Sol. Initial kinetic energy is $K = \frac{1}{2}mu^2$

The velocity at highest point $v_x = u\cos\theta$. kinetic energy of a particle at highest point

$$K_H = \frac{1}{2}mv_x^2 = \frac{1}{2}mu^2\cos^2\theta = K\cos^2 60^0 = \frac{K}{4}$$

SE-13: An athlete in the Olympic games covers a distance of 100 m in 10s. His kinetic energy can be estimated to be in the range

1) 200 J - 500 J 2) $2\times10^5 J - 3\times10^5 J$

3) 20,000J - 50,000J 4) 2,000 J - 5, 000 J

Sol:Approximate mass of the athlete = 60 kg

Average velocity = 10 m/s.

Approximate

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}\times 60\times 10^2 = 3000J$$

Range of KE = 2000 J to 5000J

S.E-14:Kinetic energy of a particle moving along a circle of radius 'r' depends on the distance as KE = cs², (c is constant,s is displacement). Find the force acting on the particle

Sol. $KE = \frac{1}{2}mv^2 = cs^2 \Rightarrow v = \left(\sqrt{\frac{2c}{m}}\right)s$

$$a_t = \frac{dv}{dt} = \sqrt{\frac{2c}{m}} \times \frac{ds}{dt} = v\sqrt{\frac{2c}{m}}$$

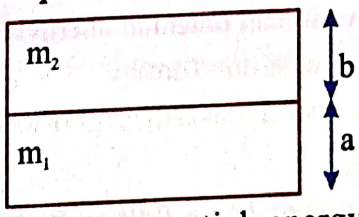
$$F_t = ma_t = mv\sqrt{\frac{2c}{m}} = \left[m\sqrt{\frac{2c}{m}}s\right]\sqrt{\frac{2c}{m}} = 2cs$$

Total force

$$F = \sqrt{F_t^2 + F_c^2} = \sqrt{(2cs)^2 + \left(\frac{mv^2}{r}\right)^2}$$

$$F = 2cs\sqrt{1 + \frac{s^2}{r^2}}$$

S.E-15: A rectangular plank of mass m_1 and height 'a' is on a horizontal surface. On the top of it another rectangular plank of mass m_2 and height 'b' is placed. Find the potential energy of the system?

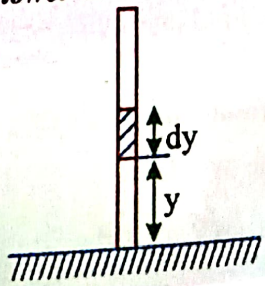


Sol: Total potential energy of system

$$U = U_1 + U_2$$

$$= m_1 g\frac{a}{2} + m_2 g\left(a + \frac{b}{2}\right) = \left[\left(\frac{m_1}{2} + m_2\right)a + m_2\left(\frac{b}{2}\right)\right]g$$

SE-16: A rod of mass m and length L is held vertical. Find its gravitational potential energy with respect to zero potential energy at the lower end?



Sol. Choose a small element of length dy, then

mass of the element $dm = \left(\frac{m}{L}\right)dy$.

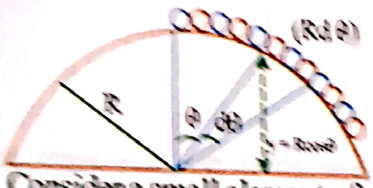
The potential energy of the element dU= (dm)g(y) Potential energy of the entire rod

$$U = \int_0^L (dm)gy = \int_0^L \left(\frac{m}{L}\right)(dy)gy = \frac{m}{L}g\int_0^L y\,dy$$

$$U = \frac{m}{L}g\left(\frac{y^2}{2}\right)_0^L = \frac{mgL}{2}$$

SE-17: *A chain of length l and mass 'm' lies on the surface of a smooth hemisphere of radius $R > l$ with one end tied to top of the hemisphere. Find the gravitational potential energy of the chain?*

Sol.



Consider a small element of chain of width $d\theta$ at an angle θ from the vertical

The mass of the element $dm = \left(\frac{m}{l}\right)Rd\theta$

The gravitational potential energy of the element du= (dm)gy

The gravitational potential energy of total chain

$$U = \int_0^{\frac{l}{R}} (dm)gy = \int_0^{\frac{l}{R}} \left(\frac{m}{l}Rd\theta\right)g(R\cos\theta)$$

$$U = \frac{mgR^2}{l}[\sin\theta]_0^{\frac{l}{R}} = \frac{mgR^2}{l}\sin\left(\frac{l}{R}\right)$$

SE-18: ***A spring of force constant 'k' is stretched by a small length 'x'. Find work done in stretching it further by a small length 'y'?***

Sol: Initial potential energy $U_i = \frac{1}{2}kx^2$

Final potential energy $U_f = \frac{1}{2}k(x+y)^2$

Work done W= U_f -

$$W_s = \frac{1}{2}k(x+y)^2 - \frac{1}{2}kx^2$$

$$W = \frac{1}{2}ky(2x+y)$$

Work - energy theorem

- Work done by all forces acting on a body is equal to change in its kinetic energy. i.e., $W = K_f - K_i = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$
  Where K_f and K_i are the final and initial kinetic energies of the body.
- Work energy theorem is applicable not only for a single particle but also for a system of particles.
- When it is applied to a system of two or more particles change in kinetic energy of the system is equal to work done on the system by the external as well as internal forces.
- Work-energy theorem can also be applied to a system under the action of variable forces, pseudo forces, conservative as well as non-conservative forces.

Applications of work-energy theorem:

- A body of mass m starting from rest acquire a velocity 'v' due to constant force F. Neglecting air resistance.

  Work done =change in Kinetic energy $= \frac{1}{2}mv^2$
- A particle of mass 'm' is thrown vertically up with a speed 'u'. Neglecting the air friction, the work done by gravitational force, as particle reaches maximum height is $W_g = \Delta K = K_f - K_i$

  $$W_g = \frac{1}{2}m(0)^2 - \frac{1}{2}m\times u^2 = -\frac{1}{2}mu^2$$
- A particle of mass 'm' falls freely from a height 'h' in air medium onto the ground. If 'v' is the velocity with which it reaches the ground, the work done by air friction is W_f and work done by gravitational force W_g then, $W_g + W_f = \frac{1}{2}mv^2 - 0 = \frac{1}{2}mv^2$
- A block of mass 'm' slides down a frictionless incline of inclination 'θ' to the horizontal. If h is the height of incline, the velocity with which body reaches the bottom of incline is

$W_s = \Delta K$; $mgh = \frac{1}{2}mv^2 - 0$

$mgh = \frac{1}{2}mv^2$; $v = \sqrt{2gh}$

- A body of mass 'm' starts from rest from the top of a rough inclined plane of inclination 'θ' and length 'l'. The velocity 'v' with which it reaches the bottom of incline if μ_k is the coefficient of kinetic friction is $W_g + W_f = \Delta k$

$(mg\sin\theta)l + (-\mu_k mg\cos\theta)l = \frac{1}{2}mv^2 - 0$

$v = \sqrt{2gl(\sin\theta - \mu_k\cos\theta)}$

- A bob of mass m suspended from a string of length l is given a speed u at its lowest position then the speed of the bob v when it makes an angle θ with the vertical is

$W_g + W_T = \Delta K \Rightarrow -mgl(1-\cos\theta) + 0 = \frac{1}{2}m(v^2 - u^2)$

$v = \sqrt{u^2 - 2gl(1-\cos\theta)}$

- A bullet of mass 'm' moving with velocity 'v' stops in a wooden block after penetrating through a distance x. If 'f' is the resistance offered by the block to the bullet.

$W_f = K_f - K_i$; $-fx = 0 - KE_i$

i.e., stopping distance $x = \frac{KE_i}{f} = \frac{mv^2}{2f} = \frac{P^2}{2mf}$

- A block of mass 'm' attached to a spring of spring constant 'K' oscillates on a smooth horizontal table. The other end of the spring is fixed to a wall. It has a speed 'v' when the spring is at natural length. The distance it moves on a table before it comes to rest is calculated as below

$W_{S.F} + W_g + W_N = \Delta K$ (S.F=spring force)

Let the mass be oscillating with amplitude 'x'.

On compressing the spring $W_{S.F} = -\frac{1}{2}Kx^2$

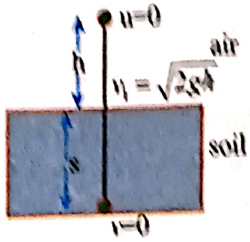
$W_g = FS\cos 90^0 = 0$; $W_N = NS\cos 90^0 = 0$

$W_{S.F} = K_f - K_i \Rightarrow -\frac{1}{2}Kx^2 = 0 - \frac{1}{2}mv^2 \Rightarrow x = v\sqrt{\frac{m}{K}}$

- A pile driver of mass 'm' is dropped from a height 'h' above the ground. On reaching the ground it pierces through a distance 's' and then stops finally. If R is the average resistance offered by ground then

$W_g + W_R = K_f - K_i = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

$mg(h+s) + (-Rs) = 0$; $R = mg\left(1 + \frac{h}{s}\right)$



Here time of penetration is given by impulse equation $(R - mg)t = 0 - m\sqrt{2gh}$

- A body of mass 'm' is initially at rest. By the application of a constant force, its velocity changes to v_0 in time t_0 the kinetic energy of the body at time 't' is

$W = \Delta K = K_f - K_i = K_f - 0$

$K_f = W = mas = ma\left(\frac{1}{2}at^2\right) = \frac{1}{2}ma^2t^2$

Since $a = \frac{v_0}{t_0}$; $K_f = \frac{1}{2}m\left(\frac{v_0}{t_0}\right)^2 t^2$

SE-19: Under the action of force 2kg body moves such that its position 'x' varies as a function of time t given by $x = \frac{t^3}{3}$, x is in metre and t in second. Calculate the workdone by the force in first two seconds.

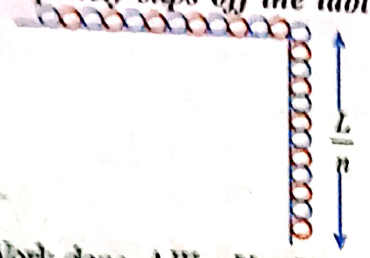
Sol. From work-energy theorem $W = \Delta KE$

$x = \frac{t^3}{3}$, Velocity $v = \frac{dx}{dt} = t^2$

At t = 0, v_1 =0, At t = 2s, v_2 = 4m/s

$W = \frac{1}{2}m(v_2^2 - v_1^2) = \frac{1}{2} \times 2(4^2 - 0) = 16J$

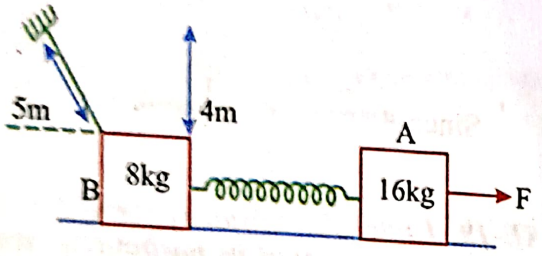
SE-20: *A uniform chain of length 'l' and mass 'M' is on a smooth horizontal table, with (1/n)th part of its length hanging from the edge of the table. Find the kinetic energy of the chain as it completely slips off the table.*



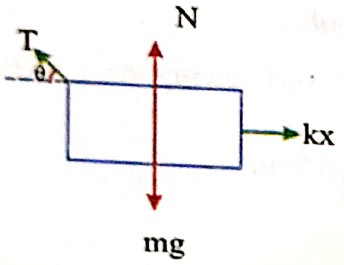
Sol: Work done $\Delta W = U_i - U_f = K_f - K_i$

$$\frac{Mgl}{2} - \frac{Mgl}{2n^2} = \frac{1}{2}Mv^2; \quad v = \sqrt{gl\left[1 - \frac{1}{n^2}\right]}$$

SE-21: *Two blocks having masses 8 kg and 16kg are connected to the two ends of a light spring. The system is placed on a smooth horizontal floor. An inextensible string also connects B with ceiling as shown in figure at the initial moment. Initially the spring has its natural length. A constant horizontal force F is applied to the heavier block as shown. What is the maximum possible value of F so that lighter block doesn't loose contact with ground.*



Sol: Draw FBD of B to get extension in spring. When block B just looses contact with ground resultant force on it is zero.



$Kx - T\cos\theta = 0$

$; T\sin\theta + N - mg = 0$ When $N = 0$

$T\sin\theta = mg \Rightarrow \frac{Kx}{\cos\theta}\sin\theta = mg$

$$x = \frac{mg}{K\tan\theta} = \frac{80}{K \times (4/3)} = \frac{60}{K}$$

If spring has to just extend till this val then from work energy theorem we get

$$Fx = \frac{1}{2}Kx^2 \Rightarrow F = 30N$$

SE-22: *A 2kg block slides on a horizontal floo with a speed of 4 m/s. It strikes a uncompressed spring and compresses it till the block is motionless. The kineti frictional force is 15 N and spring constant is 10,000 Nm^{-1}. Find the compression in the spring?*

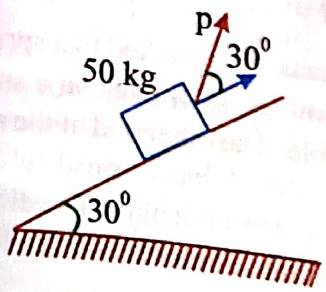
Sol: $KE = \frac{1}{2}mv^2 = W_{friction} + \frac{1}{2}Kx^2$

$$\Rightarrow \frac{1}{2} \times 2 \times 4^2 = 15x + \frac{1}{2} \times 10000 \times x^2$$

$$\Rightarrow 5000x^2 + 15x - 16 = 0$$

$$\Rightarrow x = 0.055m \text{ or } x = 5.5\ cm$$

SE-23: *In the below figure, what constant force 'P' is required to bring the 50kg body, which starts from rest to a velocity of 10m/s in moving 7m along the plane? (Neglect friction)*



Sol. Work done by force P in displacing the block by 7m, $W_1 = (F\cos\theta)(S)$

$$W_1 = (P\cos 30^0)7 = \frac{7\sqrt{3}}{2}PJ$$

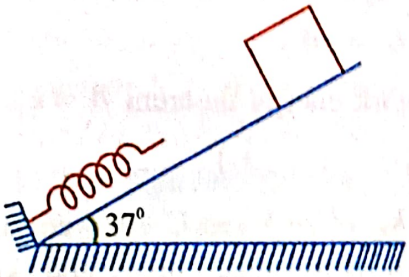
$W_2 = -mgh = -50\times 9.8\times 7\sin 30^0 = -1715\,J$

According to work energy theorem

$W_1 + W_2 = \frac{1}{2}m\left(v_2^2 - v_1^2\right)$

$\frac{7\sqrt{3}}{2}P - 1715 = \frac{1}{2}\times 50\times\left(10^2 - 0^2\right) \Rightarrow P = 607\,N$

SE-24: Figure shows a spring fixed at the bottom end of an incline of inclination 37⁰. A small block of mass 2 kg starts slipping down the incline from a point 4.8 m away from the spring. The block compresses the spring by 20 cm, stops momentarily and then rebounds through a distance 1 m up the incline. Find (i) the friction coefficient between the plane and the block and (ii) the spring constant of the spring. (g = 10 ms⁻²)



Sol: Applying work energy theorem for downward motion of the body $W = \Delta KE$

$mg\sin\theta(x+d) - f\times l_1 - \frac{1}{2}Kx^2 = \Delta KE$

$20\sin 37^0(5) - \mu\times 20\cos 37^0\times 5 - \frac{1}{2}K(0.2)^2 = 0$

$80\mu + 0.02K = 60 \rightarrow (1)$

For the upward motion of the body

$-mg\sin\theta\, l_2 + (f\times l_2) + \frac{1}{2}Kx^2 = \Delta KE$

$-2\times 10\sin 37^0\times 1 - \mu\times 20\cos 37^0\times 1 + \frac{1}{2}K(0.2)^2 = 0$

$16\mu - 0.02K = -12 \rightarrow (2)$

Adding equations (1) and (2), we get

$96\mu = 48 \Rightarrow \mu = 0.5$

Now, use the value of μ in equation (1), we get K = 1000 N/m.

Types of Equilibrium

A body is said to be in translatory equilibrium, if net force acting on the body is zero i.e., $\vec{F}_{net} = 0$

If the forces are conservative $F = -\frac{dU}{dr}$

and for equilibrium $F = 0$,

so $-\frac{dU}{dr} = 0$ or $\frac{dU}{dr} = 0$, ∴ At equilibrium position slope of U-r graph is zero or the potential energy is optimum (maximum or minimum or constant)

There are three types of equilibrium

(i) Stable equilibrium

(ii) Unstable equilibrium

(iii) Neutral equilibrium.

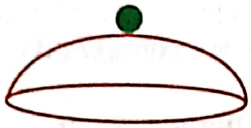
Stable equilibrium

1. Net force is Zero
2. $\frac{dU}{dr} = 0$ or slope of U-r graph is zero
3. When displaced from its equilibrium position, a net retarding forces starts acting on the body, which has a tendency to bring the body back to its equilibrium position
4. PE in equilibrium position is minimum as compared to its neighbouring points as $\frac{d^2U}{dr^2}$ is positive
5. When displaced from equilibrium position the centre of gravity of the body comes down

Unstable equilibrium

1. Net force is zero
2. $\frac{dU}{dr} = 0$ (or) slope of U-r graph is zero
3. When displaced from its equilibrium position, a net force starts acting on the body which moves the body in the direction of displacement or away from the equilibrium position

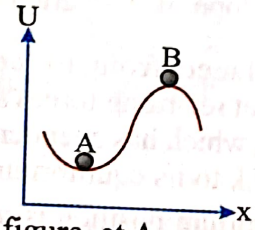
4. PE in equilibrium position is maximum as compared to other positions as $\frac{d^2U}{dr^2}$ is negative
5. When displaced from equilibrium position the centre of gravity of the body goes up



Neutral equilibrium

1. Net force is zero
2. $\frac{dU}{dr} = 0$ or slope of U-r graph is zero
3. When displaced from its equilibrium position the body has neither the tendency to come back nor move away from the original position.
4. PE remains constant even if the body is moving to neighbouring points $\frac{d^2U}{dr^2} = 0$
5. When displaced from equilibrium position the centre of gravity of the body remains constant

Potential energy and Equilibrium

1. 

In the figure, at A :

$\frac{dU}{dx} = 0$, and $\frac{d^2U}{dx^2}$ is positive

Thus at A the particle is in stable equilibrium.

At B; $\frac{dU}{dx} = 0$, and $\frac{d^2U}{dx^2}$ is negative

Thus at B the particle is in unstable equilibrium

***SE-25:** In a molecule, the potential energy between two atoms 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 atoms. Find the value of 'x' at which force is zero and minimum P.E at that point. (JEE MAIN 2010)*

Sol: Force is zero $\Rightarrow \frac{dU}{dx} = 0$

i.e., $a(-12)x^{-13} - b(-6)x^{-7} = 0$

$$\frac{-12a}{x^{13}} + \frac{6b}{x^7} = 0 \Rightarrow \frac{12a}{x^{13}} = \frac{6b}{x^7}$$

$$\Rightarrow x^6 = \frac{2a}{b} \quad \therefore x = \left(\frac{2a}{b}\right)^{\frac{1}{6}}$$

Substituting the value of x

$$\Rightarrow U_{min} = a\left(\frac{b}{2a}\right)^{\frac{12}{6}} - b\left(\frac{b}{2a}\right)^{\frac{6}{6}}$$

$$U_{min} = \left(\frac{b^2}{4a}\right) - \left(\frac{b^2}{2a}\right) \Rightarrow U_{min} = \frac{-b^2}{4a}$$

Law of conservation of Mechanical energy:

- Total mechanical energy of a system remains constant, if only conservative forces are acting on a system of particles and the work done by all other forces is zero.

$\therefore U_f - U_i = -W$

From work energy theorem $W = k_f - k_i$

$\therefore U_f - U_i = -(k_f - k_i)$

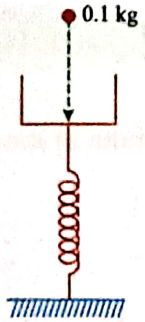
$\therefore U_f + k_f = U_i + k_i \Rightarrow U + K = \text{constant}$

The sum of potential energy and kinetic energy remains constant in any state.

- A body is projected vertically up from the ground. When it is at height 'h' above the ground, its potential and kinetic energies are in the ratio x : y. If H is the maximum height reached by the body, then $\frac{x}{y} = \frac{h}{H-h}$

or $\frac{h}{H} = \frac{x}{x+y}$

***SE-26:** A massless platform is kept on a light elastic spring as shown in figure. When a sand particle of 0.1kg mass is dropped on the pan from a height of 0.24m, the particle strikes the pan and the spring compresses by 0.01m. From what height should particle be dropped to cause a compression of 0.04m.*



Sol. By conservation of mechanical energy

$$mg(h+y)=\frac{1}{2}Ky^2$$

h = height of particle

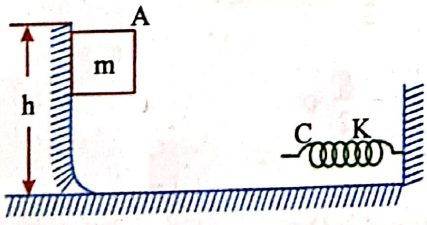
y = compression of the spring

As here particle and spring remain same

$$\frac{h_1+y_1}{h_2+y_2}=\left(\frac{y_1}{y_2}\right)^2;\ \frac{0.24+0.01}{h_2+0.04}=\left(\frac{0.01}{0.04}\right)^2;$$

h_2 =3.96 m

SE-27 ***A small mass 'm' is sliding down on a smooth curved incline from a height 'h' and finally moves through a horizontal smooth surface. A light spring of force constant K is fixed with a vertical rigid stand on the horizontal surface, as shown in the figure. Find the value for the maximum compression in the spring if mass 'm' is released from rest from height 'h' and hits the spring on the horizontal surface.***



Sol. Conservation of energy b/w positions A and C

$$(PE_A)_{block}+KE_A=(PE_C)_{spring}+KE_C$$

$$mgh+0=\frac{1}{2}Kx^2+0;$$

$$mgh=\frac{1}{2}Kx^2;\ x=\sqrt{\frac{2mgh}{K}}$$

SE-28: ***A vehicle of mass 15 quintal climbs up a hill 200m high. It then moves on a level road with a speed of $30ms^{-1}$. Calculate the potential energy gained by it and its total mechanical energy while running on the top of the hill***

Sol. m = 15 quintal = 1500kg, g=$9.8ms^{-2}$, h = 200m

P.E.gained,U=mgh =1500 x 9.8 x 200=2.94 x 10^6 J

$$K.E.=\frac{1}{2}mv^2=\frac{1}{2}\times 1500\times(30)^2=0.675\times10^6 J$$

Total mechanical energy

E = K + U = (0.675 + 2.94) x 10^6

E = 3.615 x 10^6J

SE-29 ***A particle is released from height H. At certain height from the ground its kinetic energy is twice its gravitational potential energy. Find the height and speed of particle at that height***

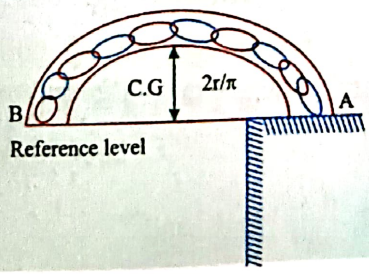
Sol. K.E = 2PE But KE = TE – PE

mg(H – h) = 2mgh; mgH = 3mgh

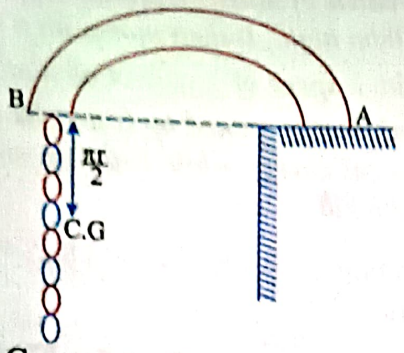
$\Rightarrow h=\frac{H}{3}$; Also K.E = 2P.E ,

$$\frac{1}{2}mv^2=2mg\left(\frac{H}{3}\right)\Rightarrow v=2\sqrt{\frac{gH}{3}}$$

SE-30: ***A heavy flexible uniform chain of length πr and mass $\lambda\pi r$ lies in a smooth semicircular tube AB of radius 'r'. Assuming a slight disturbance to start the chain in motion, find the velocity v with which it will emerge from the end of the tube?***



Sol:



Centre of gravity of a semicircular arc is at a distance $\frac{2r}{\pi}$ from the centre .

Initial potential energy $U_i = (\lambda\pi r)g\left(\frac{2r}{\pi}\right)$

Final potential energy $U_f = (\lambda\pi r)g\left(\frac{-\pi r}{2}\right)$

When the chain is completely slipped off the tube, all the links of the chain have the same velocity v.

kinetic energy of chain

$$k=\frac{1}{2}mv^2 = \frac{1}{2}(\lambda\pi r)v^2$$

From conservation of energy ,

$$\lambda\pi rg\left(\frac{2r}{\pi}\right)=(\lambda\pi r)g\left(\frac{-\pi r}{2}\right)+\frac{1}{2}(\lambda\pi r)v^2$$

On solving we get, $v=\sqrt{2rg\left(\frac{2}{\pi}+\frac{\pi}{2}\right)}$

SE-31: ***The potential energy of 1 kg particle free to move along X - axis is given by $U(x)=\left(\frac{x^4}{4}-\frac{x^2}{2}\right)$ J. The total mechanical energy of the particle is 2 J. Find the maximum speed of the particle.***

Sol: For maximum value of U, $\frac{dU}{dx}=0$.

$$\therefore \frac{4x^3}{4}-\frac{2x}{2}=0 \text{ or } x=0,\ x=\pm 1.$$

At $x=0$, $\frac{d^2U}{dx^2}=-1$ and

At $x=\pm 1$, $\frac{d^2U}{dx^2}=2$

Hence U is minimum at $x=\pm 1$ with va

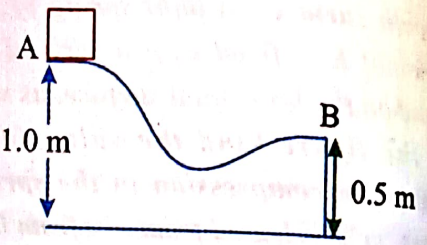
$$U_{min}=\frac{1}{4}-\frac{1}{2}=-\frac{1}{4}J$$

$K_{max}+U_{min}=E$ or $K_{max}-\frac{1}{4}=2$ or

$$K_{max}=\frac{9}{4}$$

$$\Rightarrow \frac{1}{2}mv^2=\frac{9}{4} \Rightarrow v_{max}=\frac{3}{\sqrt{2}}ms^{-1}$$

SE-32: ***Figure shows a particle sliding on frictionless track which terminates in straight horizontal section. If the particle starts slipping from the point A, how far away from the track will the particle hit the ground?***



Sol: Applying the law of conservation of mechanical energy for the points A and B,

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

$$g-\frac{v^2}{2}=\frac{g}{2} \text{ or}$$

$$v^2=g \Rightarrow v=\sqrt{g}=3.1ms^{-1}$$

After point B the particle exhibits projectil motion with $\theta=0^0$ and $y=-0.5$m

Horizontal distance travelled by the body

$$R=u\sqrt{\frac{2h}{g}}=3.1\times\sqrt{\frac{2\times 0.5}{9.8}}=1m$$

POWER

- The rate of doing work is called power. Power or average power is given by

$P_{av} = \frac{\text{work done}}{\text{time}}$. Power is a scalar

SI Unit: watt(W) (or) J/s, CGS Unit : erg/sec

Other Units : kilo watt, mega watt and horse power

One horse power (H.P)=746 watt

- **Instantaneous Power:**

$$P = \underset{\Delta t \to 0}{Lt}\left(\frac{\Delta W}{\Delta t}\right)$$

It is also calculated by

$$P = FV\cos\theta = \vec{F}\vec{V}$$

- **Relation Between P_{avg} and P_{max}:**

$$P_{avg} = \frac{W}{t} = \frac{mv^2}{2t} = \frac{1}{2}mv\left(\frac{v}{t}\right) = \frac{1}{2}mav = \frac{1}{2}\vec{F}\vec{V}$$

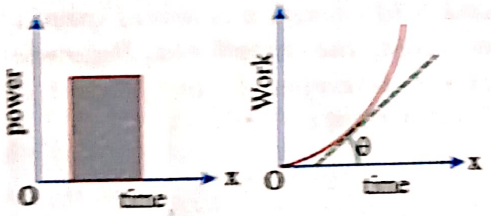
$$P_{avg} = \frac{1}{2}P_{max}$$

- The area under $P-t$ graph gives work done

$$P = \frac{dW}{dt} \qquad \therefore W = \int P.dt$$

The slope of W-t curve gives instantaneous power

$$P = \frac{dW}{dt} = \tan\theta$$



Applications on power

- The power of a machine gun firing 'n' bullets each of mass 'm' with a velocity 'v' in a time interval 't' is given by

$$P = \frac{n\left(\frac{1}{2}mv^2\right)}{t} = \frac{nmv^2}{2t}$$

- A crane lifts a body of mass 'm' with a constant velocity v from the ground, its power is $P = Fv = mgv$
- Power of lungs of a boy blowing a whistle is $P = \frac{1}{2}$(mass of air blown per sec) (velocity)^2
- Power of a heart pumping blood = (pressure) (volume of blood pumped per sec)
- A conveyor belt is moving with a constant speed 'v' horizontally and gravel is falling on it at a rate of $\frac{dm}{dt}$. Then additional force required to maintain speed v is $F = v\frac{dm}{dt}$ and additional power required to drive the belt is,

$$P = Fv = v^2\frac{dm}{dt}$$

- When a liquid of density 'ρ' coming out of a hose pipe of area of cross section 'A' with a velocity 'v' strikes the wall normally and stops dead. Then power exerted by the liquid is $P = \frac{1}{2}\frac{mv^2}{t} = \frac{1}{2}\rho Av^3$

($\because$ mass=density x volume $= m = \rho \times A \times l$)

- A vehicle of mass 'm' is driven with constant acceleration along a straight level road against a constant external resistance 'R' when the velocity is 'v', power of engine is $P = Fv = (R + ma)v$
- If P is a rated power of a device and if its efficiency is x%, useful power is (output power) $P^1 = \frac{x}{100}P$
- If a motor lifts water from a well of depth 'h' and delivers with a velocity 'v' in a time t then power of the motor

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

- If a body of mass 'm' starts from rest and accelerated uniformly to a velocity v_0 in a time t_0, then the work done on the body in a time 't' is given by

$$W = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{v_0 t}{t_0}\right)^2;$$

$$a = \frac{v_0}{t_0}; \quad v = at = \left(\frac{v_0}{t_0}\right)t$$

- **Velocity of the body at any point on the vertical circle:**

$TE_A = TE_P$; $\frac{1}{2}mV_1^2 + 0 = \frac{1}{2}mV_\theta^2 + mgh$

$V_\theta^2 = V_1^2 - 2gh$, but $h = r(1-\cos\theta)$

$V_\theta^2 = V_1^2 - 2gr(1-\cos\theta)$;

$V_\theta = \sqrt{V_1^2 - 2gr(1-\cos\theta)}$

If V_2 is the velocity of the body at highest point ($\theta = 180^0$)

$V_2 = \sqrt{V_1^2 - 2gr(1+1)} = \sqrt{V_1^2 - 4gr}$

Tension in the string at any point :

- Let T_θ be the tension in the string when the string makes an angle θ with vertical.

$T_\theta = \frac{mV_\theta^2}{r} + mg\cos\theta$

- 1) At the lowest point $\theta = 0^0$ tension in the string is

$T_L = \frac{mV_1^2}{r} + mg$ (maximum).

- 2) At the highest point $\theta = 180^0$.

The tension in the string is $T_H = \frac{mV_2^2}{r} - mg$ (minimum)

- 3) When the string is horizontal, $\theta = 90^0$, tension in the string at this position is

$T_{(hor)} = \frac{mV_{hor}^2}{r}$

- 4) The difference in maximum and minimum tension in the string is

$T_{max} - T_{min} = \frac{mV_1^2}{r} + mg - \frac{mV_2^2}{r} + mg$

$= \frac{m}{r}(V_1^2 - V_2^2) + 2mg$

$= \frac{m}{r}(4gr) + 2mg = 4mg + 2\,mg = 6\,mg$

- 5) Ratio of maximum tension to minimum tension in the string is

$$\frac{T_{max}}{T_{min}} = \frac{\frac{mV_1^2}{r} + mg}{\frac{mV_2^2}{r} - mg} = \frac{V_1^2 + rg}{V_2^2 - rg}$$

- **When the particle is at 'P'**

a) Tangential force acting on the particle is $F_t = mg\sin\theta$.

Tangential acceleration $a_t = g\sin\theta$

b) Centripetal force acting on the particle is $F_c = \left(\frac{mV_\theta^2}{r}\right) = T_\theta - mg\cos\theta$.

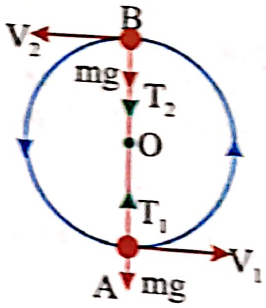
Centripetal acceleration $a_c = \frac{V_\theta^2}{r}$

c) Net acceleration of the particle at the point 'P' is $a = \sqrt{a_t^2 + a_c^2}$.

d) The net force acting on the particle at point 'P' is $F = \sqrt{F_t^2 + F_c^2}$

- Angle made by net force or net acceleration with centripetal component is ϕ and $\tan\phi = \frac{F_t}{F_c} = \frac{a_t}{a_c}$

Condition for vertical circular motion of a body



We know that $T_2 = \frac{mV_2^2}{r} - mg$

The body will complete the vertical circular path when tension at highest point is such that

$T_2 \geq 0$, $\frac{mV_2^2}{r} - mg \geq 0$; $V_{2min} = \sqrt{gr}$

Hence the minimum speed at highest point to just complete the vertical circle is $\sqrt{gr}$

From the law of conservation of mechanical energy total energy at lowest point A = total energy at highest point B

$U_A + KE_A = U_B + KE_B$

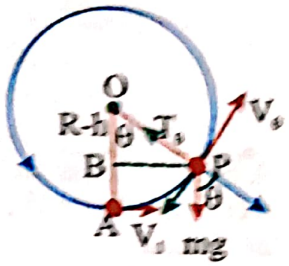
$O + \frac{1}{2}mV_1^2 = mg(2r) + \frac{1}{2}mV_2^2$

$\frac{1}{2}mV_1^2 = 2mgr + \frac{1}{2}mgr \quad [\because V_1 = \sqrt{gr}]$

$= \frac{5}{2}mgr \Rightarrow \boxed{V_1 = \sqrt{5gr}}$

For the body to continue along a circular path the critical velocity at lowest point is $\sqrt{5gr}$

Critical velocity at any point on the vertical circle:



From the Law of conservation of energy total energy at point 'A' = total energy at point P

$U_A + KE_A = U_P + KE_P$

$O + \frac{1}{2}mV_1^2 = mgh + \frac{1}{2}mV_\theta^2$

$\frac{1}{2}m(5gR) = mgR(1-\cos\theta) + \frac{1}{2}mV_\theta^2$

$\frac{5gmR}{2} = mgR - mgR\cos\theta + \frac{1}{2}mV_\theta^2$

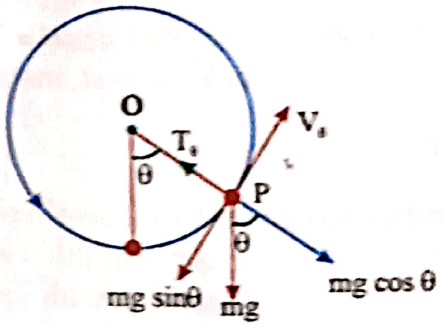
$\frac{5gmR}{2} - mgR + mgR\cos\theta = \frac{1}{2}mV_\theta^2$

$\frac{mgR}{2}[3+2\cos\theta] = \frac{1}{2}mV_\theta^2$

$V_\theta = \sqrt{gR(3+2\cos\theta)}$

Minimum tension in the string to just complete vertical circle:

- Let T_θ be the tension in the string when the string is making an angle θ from lowest point



$T_\theta = mg\cos\theta + \frac{mV_\theta^2}{R} = mg\cos\theta + \frac{m}{R}gR(3+2\cos\theta)$

$= mg\cos\theta + 3mg + 2mg\cos\theta$

$= 3mg\cos\theta + 3mg = 3mg(1+\cos\theta)$

- In case of non uniform circular motion in a vertical plane if velocity of the body at the lowest point is less than $\sqrt{5gr}$, the particle will not complete the circle in vertical plane, the particle may either oscillate about the lowest point or it leaves the circle with out looping.

Condition for oscillating about the lowest position:

1) If $0 < V_L < \sqrt{2gr}$, in this case, velocity becomes zero before tension vanishes and the particle oscillates about its lowest position with angular amplitude $0^0 < \theta < 90^0$
2) If velocity of the body at the lowest point $V_L < \sqrt{2gr}$, then the maximum height reached by the body just before its velocity becomes zero is given by $h = \frac{V_L^2}{2g}$.
3) The angle made by the string with the vertical when its velocity becomes zero is given by $\cos\theta = 1 - \frac{V_L^2}{2gr}$

Note: If $0 < V_L \le \sqrt{2gr}$ then the particle oscillates such that $0^0 < \theta \le 90^0$

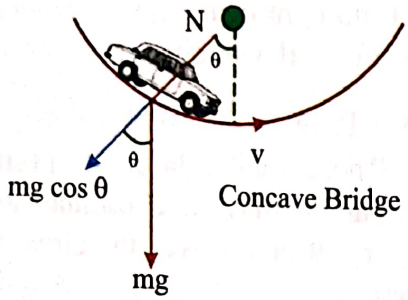
Condition for leaving the circular path without looping:

- If $\sqrt{2gr} < V_L < \sqrt{5gr}$, the particle is not able to complete the vertical circle, it goes to certain height and leaves the circular path ($90^0 < \theta < 180^0$)

  while leaving the circular path $T = 0$ but $V \neq 0$
- The angle made by the string with downward vertical when the tension in the string becomes zero is given by

$\cos\theta = \frac{2}{3} - \frac{V_L^2}{3gr}$

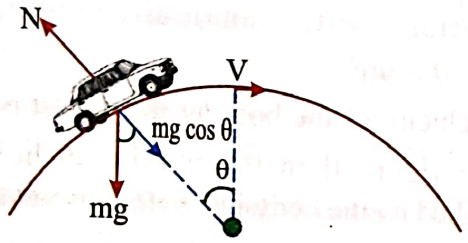
- The height at which the tension in the string becomes zero is given by $h=\frac{V_L^2+gr}{3g}$
- When car moves on a concave bridge of radius



Centripetal force = $N-mg\cos\theta=\frac{mv^2}{r}$

and normal reaction $N=mg\cos\theta+\frac{mv^2}{r}$

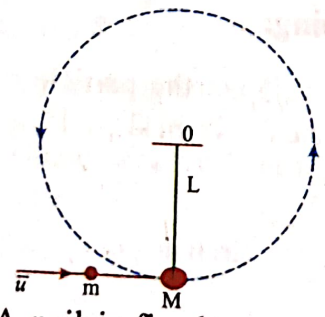
- When car moves on a convex bridge of radius r



Centripetal force = $mg\cos\theta-N=\frac{mv^2}{r}$

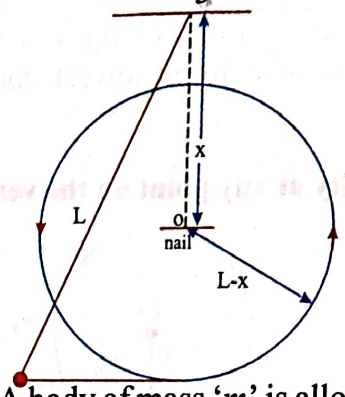
and normal reaction $N=mg\cos\theta-\frac{mv^2}{r}$

- A ball of mass 'M' is suspended vertically by a string of length 'L'. A bullet of mass 'm' is fired horizontally with a velocity 'u' onto the ball, sticks to it. For the system to complete the vertical circle, the minimum value of 'u' is given by $u=\frac{(M+m)}{m}\sqrt{5gL}$



- A nail is fixed at a certain distance 'x' vertically below the point of suspension of a simple pendulum of length L. The bob is released when the string makes an angle θ with vertical. The bob reaches the lowest position then describes a vertical cir whose centre coincides with the nail. Th

$$x_{min}=\frac{L(3+2\cos\theta)}{5}$$



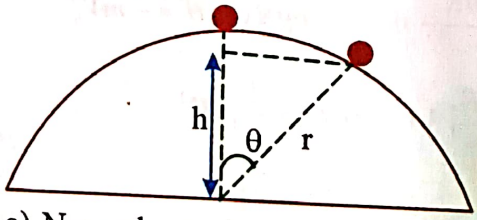
- A body of mass 'm' is allowed to slide dow from rest, from the top of a smooth incli of height 'h'. For the body to move in loop of radius 'r' on arriving at the botto

a) Minimum height of smooth inclin

$h=\left(\frac{5r}{2}\right)$

b) 'h' is independent of mass of the body

- A small body is freely sliding down fro the top of a smooth convex hemisphere o radius r, placed on a table with its flat fac on the table then



a) Normal reaction on the body is zero a the instant the body leaves the hemisphere,
b) the vertical height from table at which the body leaves the hemisphere is h=2r/3
c) If the position vector of the body with respect to the centre of curvature makes an angle θ with vertical when the body leaves the hemisphere, then $\cos\theta=2/3$
d) velocity of block at that instant is

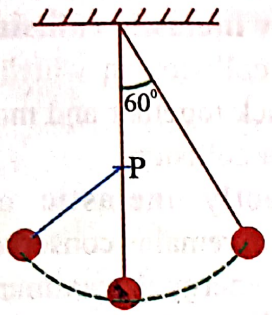
$V=\sqrt{\frac{2gr}{3}}$

e) If the block is given a horizontal velocity 'u' from the top of the smooth convex hemisphere then the angle θ with vertical

at which the block leaves hemisphere is

$$\cos\theta = \frac{2}{3} + \frac{u^2}{3gr}$$

SE-39: A nail is located at certain distance vertically below the point of suspension of a simple pendulum. The pendulum bob is released from the position where the string makes an angle 60⁰ from the vertical. Calculate the distance of the nail from the point of suspension such that the bob will just perform revolutions with the nail as the centre. Assume the length of the pendulum to be 1m.



Sol. Velocity of bob at lowest position

$$V = \sqrt{2g\ell(1-\cos\theta)}$$

$$= \sqrt{2g\times\ell(1-\cos 60^0)} = \sqrt{2g\frac{\ell}{2}} = \sqrt{g\ell} \quad ..(1)$$

Let 'd' be the distance of nail from the point of suspension. The bob will have to complete the circle of radius $r = l - d$

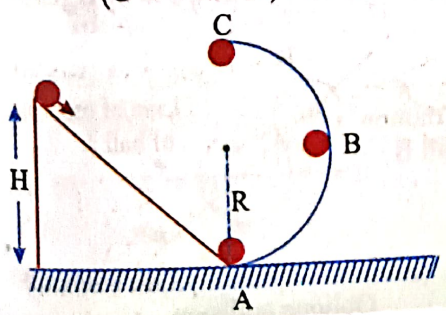
To complete vertical circle

$$V_{min} = \sqrt{5gr} = \sqrt{5g(l-d)} \quad — (2)$$

Equating ,equations (1) and (2), we get

$$\sqrt{gl} = \sqrt{5g(l-d)} \Rightarrow d = \frac{4l}{5} = \frac{4}{5} = 0.80m$$

SE-40: A body slides without friction from a height H = 60cm and then loops the loop of radius R = 20cm at the bottom of an incline. Find the ratio of forces exerted on the body by the track at the positions A, B and C $(g = 10ms^{-2})$



Sol. From data H = 3R

Velocity at A,

$$V_A = \sqrt{2gH} = \sqrt{2g(3R)} = \sqrt{6gR}$$

Velocity at B, $V_B = \sqrt{4gR}$

Velocity at C, $V_C = \sqrt{2gR}$

$$\text{Reaction force at A} = R_1 = \frac{mV_A^2}{R} + mg\cos(0^0)$$

$$= \frac{m\times 6gR}{R} + mg = 7mg$$

$$\text{Reaction force at B} = R_2 = \frac{mV_B^2}{R} + mg\cos(90^0)$$

$$= \frac{m\times 4gR}{R} + 0 = 4mg$$

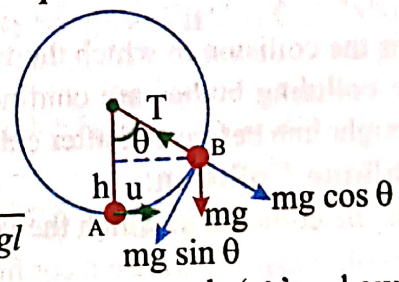
$$\text{Reaction force at C} = R_3 = \frac{mV_C^2}{R} + mg\cos(180^0)$$

$$= \frac{m\times 2gR}{R} - mg = mg$$

$$\therefore R_1 : R_2 : R_3 = 7:4:1$$

SE-41 A heavy particle hanging from a fixed point by a light inextensible string of length ℓ is projected horizontally with a speed of $\sqrt{g\ell}$. Find the speed of the particle and the inclination of the string to the vertical at the instant of the motion, when the tension in the string is equal to the weight of the particle.

Sol:



$u = \sqrt{gl}$

Let T = mg at an angle 'θ' as shown in the figure and $h = \ell(1-\cos\theta)$ → (i)

Applying law of conservation of mechanical energy between the points A and B,

we get $\frac{1}{2}m(u^2 - v^2) = mgh$

Here $u^2 = g\ell$ → (ii)

and $v^2 = u^2 - 2gh$ → (iii)

Further $T - mg\cos\theta = \frac{mv^2}{\ell}$ (T = mg)

$v^2 = g\ell(1-\cos\theta) \rightarrow$(iv)

From equations (i), (ii), (iii) and (iv) we have

$g\ell(1-\cos\theta) = g\ell - 2g\ell(1-\cos\theta)$

$\cos\theta = \frac{2}{3}$; $\theta = \cos^{-1}\left(\frac{2}{3}\right)$

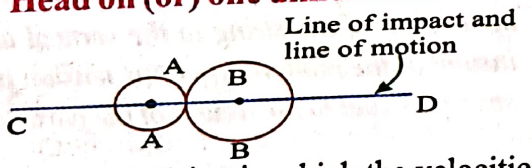
From equation (iv) $v = \sqrt{\frac{g\ell}{3}}$

Collisions

- The strong interaction among bodies involving exchange of momentum in a short interval of time is called collision.
- During collision bodies may or may not come into physical contact.

  Ex: In the collision of α particle with nucleus, due to coulombic repulsive forces α particle is scattered away without any physical contact.
- Based on the direction of motion of colliding bodies, collisions are classified into
  (i) Head on or one dimensional collision
  (ii) oblique collision

Head on (or) one dimensional collision



- It is the collision in which the velocities of the colliding bodies are confined to same straight line before and after collision.

Oblique Collision:

- It is the collision in which the velocities of the colliding bodies are not confined to same straight line before and after collision.
- Oblique collision may be two dimensional or three dimensional.
- When a particle hits elastically and obliquely another stationary particle of same mass, then they move perpendicular to each other after collision.

Types of Collision: Based on conservation of kinetic energy collisions are classified into
(i) Elastic Collision (ii) Inelastic collision

Elastic Collision: It is the collision in which both momentum and kinetic energy conserved. Forces involved during colli are conservative in nature

Ex. 1. Collision between atomic partic
2. Collision between two smooth bil balls.
3. Collision of α particle with nucl

Inelastic collision: It is the collision in w momentum is conserved but not kin energy. Some or all the forces involved du collision are non conservative.

Ex: Collision between two vehicles.

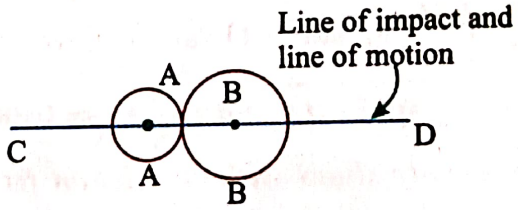
Perfectly inelastic collision:

- It is the collision in which the collid bodies stick together and move as a sin body after collision.
- In perfectly inelastic collision momentum remains conserved but the of kinetic energy is maximum.

Ex: A bullet is fired into a wooden bl and remains embedded in it.

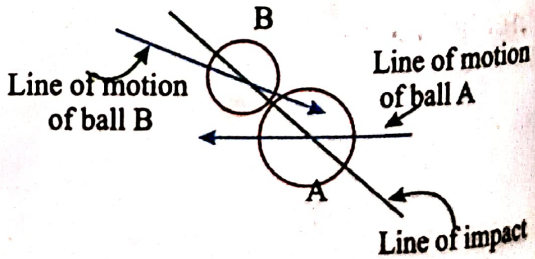
Line of impact: The line passing thro the common normal to the surfaces contact during impact is called line impact. The force during collision acts al this line on both bodies.

Ex 1: Two balls A and B are approach each other such that their centres are mov along line CD.



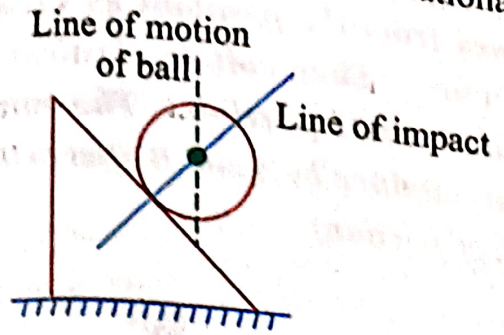
Head on Collision

Ex 2: Two balls A and B are approachi each other such that their centres are mov along dotted lines as shown in figure.



Oblique collision

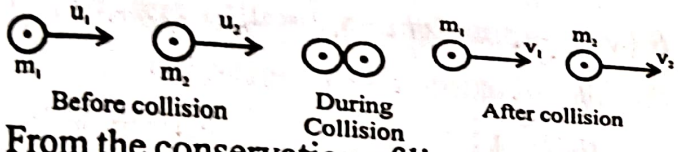
Ex 3: Ball is falling on a stationary wedge



Oblique Collision

Elastic collision in one dimension:

When two particles of masses m_1 and m_2 are moving along the line joining their centers with velocities u_1 and u_2 $(u_1 > u_2)$ before collision. Then v_1 and v_2 are their velocities after collision



From the conservation of linear momentum

$$m_1(\vec{u}_1 - \vec{v}_1) = m_2(\vec{v}_2 - \vec{u}_2)$$

From Law of conservation of K.E

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

$$\therefore\ \vec{u}_1 - \vec{u}_2 = \vec{v}_2 - \vec{v}_1$$

i.e Relative velocity of approach before collision

= Relative velocity of separation after collision

Velocities after collision are

$$\vec{v}_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)\vec{u}_1 + \left(\frac{2m_2}{m_1 + m_2}\right)\vec{u}_2$$

$$\vec{v}_2 = \left(\frac{2m_1}{m_1 + m_2}\right)\vec{u}_1 + \left(\frac{m_2 - m_1}{m_1 + m_2}\right)\vec{u}_2$$

Special cases:

If colliding particles have equal masses

i.e $m_1 = m_2 = m$; $\boxed{\vec{v}_1 = \vec{u}_2}$, $\boxed{\vec{v}_2 = \vec{u}_1}$

If two bodies are of equal masses and the second body is at rest ie., $m_1 = m_2 = m$ and $\vec{u}_2 = \vec{0}$ then $\boxed{\vec{v}_1 = \vec{0}}$; $\boxed{\vec{v}_2 = \vec{u}_1}$

3) A lighter particle collides with heavier particle which is at rest $m_1 <<< m_2$, $\vec{u}_2 = \vec{0}$

$\boxed{\vec{v}_1 = -\vec{u}_1}$, $\boxed{\vec{v}_2 = \vec{0}}$

4) A heavier body collides with lighter body at rest

$m_1 >>> m_2$, $\vec{u}_2 = \vec{0}$;

$\boxed{\vec{v}_1 = \vec{u}_1}$, $\boxed{\vec{v}_2 = 2\vec{u}_1}$

Applications:

A body of mass m_1 moving with a velocity v_1 collides elastically with a stationary mass m_2

1) Velocity of first body after collision $\vec{v}_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)\vec{u}_1$

2) Velocity of second body after collision

$$\vec{v}_2 = \left(\frac{2m_1}{m_1 + m_2}\right)\vec{u}_1$$

3) KE of first body after collision (or) KE retained by first body

$$K.E_1 = \frac{1}{2}m_1v_1^2 = \frac{1}{2}m_1\left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 u_1^2$$

$$K.E_{ret} = \frac{1}{2}m_1u_1^2\left[\frac{m_1 - m_2}{m_1 + m_2}\right]^2 = KE_i\left[\frac{m_1 - m_2}{m_1 + m_2}\right]^2$$

4) Fraction of KE retained by 1st body

$$\frac{K.E_{ret}}{K.E_i} = \left[\frac{m_1 - m_2}{m_1 + m_2}\right]^2$$

5) KE of second body after collision (or) KE transferred to the second body

$$KE_2 = \frac{1}{2}m_2v_2^2 = \frac{1}{2}m_2\left(\frac{2m_1}{m_1 + m_2}\right)^2 u_1^2$$

$$KE_2 = \left(\frac{4m_1m_2}{(m_1 + m_2)^2}\right)\left(\frac{1}{2}m_1u_1^2\right)$$

$$KE_{tra} = \left(\frac{4m_1m_2}{(m_1 + m_2)^2}\right)KE_i$$

6) Fraction of KE transferred from 1st body to second body (or) Fraction of KE lost by 1st body is

$$\frac{KE_{lost}}{KE_i} = \frac{4m_1m_2}{(m_1+m_2)^2}$$

7) Fraction of momentum retained by m_1

$$\frac{P_f}{P_i} = \frac{m_1v_1}{m_1u_1} = \frac{m_1-m_2}{m_1+m_2}$$

8) Fraction of momentum transferred from 1st body to second body

$$\frac{P_2}{P_i} = \frac{P_i-P_f}{P_i} = 1-\frac{P_f}{P_i} = 1-\left(\frac{m_1-m_2}{m_1+m_2}\right) = \frac{2m_2}{m_1+m_2}$$

SE-42: A bullet of mass 'm' moving at a speed 'v' hits a ball of mass 'M' kept at rest. A small part having mass m_1 breaks from the ball and sticks to the bullet. The remaining ball is found to move at a speed v_2 in the direction of the bullet. Find the velocity of the bullet after the collision.

Sol: Mass of bullet = m and speed = v.

Mass of the ball M and fractional mass of the ball m_1

According to law of conservation of linear momentum

$$mv+0=(m+m_1)v_1+(M-m_1)v_2$$

Where v_1 = final velocity of the (bullet + fractional mass)

$$v_1=\frac{mv-(M-m_1)v_2}{(m+m_1)}$$

SE-43: Two bodies of masses m_1 and m_2 are moving with velocities $1ms^{-1}$ and $3ms^{-1}$ respectively in opposite directions. If the bodies undergo one dimensional elastic collision, the body of mass m_1 comes to rest. Find the ratio of m_1 and m_2

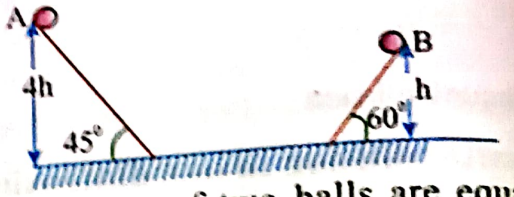
Sol. $u_1 = 1m/s, u_2 = -3m/s, v_1 = 0$

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

$$0=\left(\frac{m_1-m_2}{m_1+m_2}\right)1+\left(\frac{2m_2}{m_1+m_2}\right)(-3)$$

$$m_1-m_2=6m_2;\ m_1=7m_2;\ \frac{m_1}{m_2}=\frac{7}{1}$$

SE-44: Two identical balls A and B released from the positions as shown the figure. They collide elastically the horizontal portion. The ratio heights attained by A and B after collis (neglect friction)



Sol. As mass of two balls are equal, exchange their velocities after collision

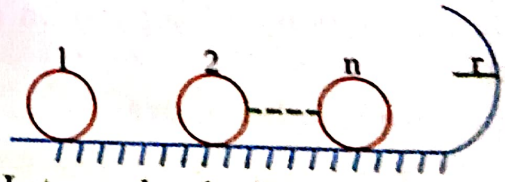
$$u_A=\sqrt{2gh}, u_B=\sqrt{2g(4h)}=\sqrt{8gh}, h_A=\frac{u_A^2}{2g}$$

$$h_B=h+\frac{v_B^2\sin^2 60^0}{2g}=h+\frac{9h}{4}=\frac{13h}{4}$$

$$(\because (v_B)^2-u_B^2=-2gh \Rightarrow v_B^2=u_B^2-2gh \Rightarrow v_B^2=$$

$$\frac{h_A}{h_B}=\frac{4}{13}$$

SE-45 n elastic balls are placed at rest smooth horizontal plane which circular at the end with radius 'r shown in the figure. The masses of balls are $m, \frac{m}{2}, \frac{m}{2^2}, \ldots\ldots \frac{m}{2^{n-1}}$ respecti Find the minimum velocity that sh be imparted to the first ball of mass such that the 'n^{th}' ball will complet vertical circle.



Sol: Let speed to be imparted to the first b v_0.

Consider the impact between the first balls and v_1 and v_2 be the velocities of 1 and 2 after the impact respectively. According to law of conservation of l

momentum $mv_0=mv_1+\frac{m}{2}v_2 \rightarrow (1)$

According to law of conservation of k

energy $\frac{1}{2}mv_0^2=\frac{1}{2}mv_1^2+\frac{1}{2}\left(\frac{m}{2}\right)v_2^2 \rightarrow$

Solving equations (1) and (2), we get $v_2 = \frac{4}{3} v_0$

Similarly, for n^{th} ball, $v_n = \left(\frac{4}{3}\right)^{n-1} v_0 \rightarrow (3)$

For the nth ball to complete the vertical circular motion $v_n = \sqrt{5gr} \rightarrow (4)$

From equations (3) and (4), we have

$\left(\frac{4}{3}\right)^{n-1} v_0 = \sqrt{5gr}$; $v_0 = \left(\frac{3}{4}\right)^{n-1} \sqrt{5gr}$

Coefficient of restitution

- Newton introduced a dimensionless parameter called the coefficient of restitution (e) to measure the elasticity of collision. It is defined as the ratio of the relative velocity of separation to the relative velocity of approach of the two colliding bodies

$$e = \frac{\text{Relative velocity of separation}}{\text{Relative velocity of approach}} = \frac{|\vec{v}_2 - \vec{v}_1|}{|\vec{u}_1 - \vec{u}_2|}$$

- This formula is applied along the line of impact. Here the velocities mentioned in the expression should be taken along the line of impact.

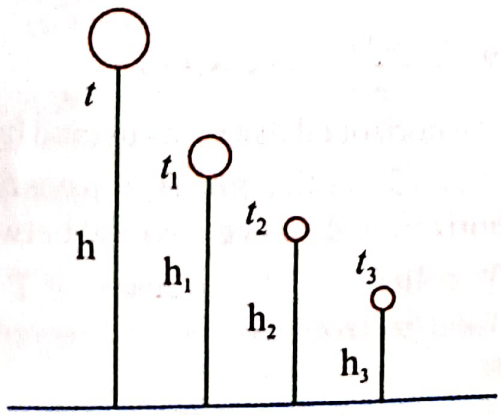
For a perfectly elastic collision $e = 1$

For an inelastic collision $o < e < 1$

For completely inelastic collision $e = 0$

- A body dropped freely from a height 'h' strikes the floor and rebounds to a height h_1

$e = \sqrt{\frac{h_1}{h}}$ and after n^{th} rebound $h_n = e^{2n} h$



- When a freely falling ball strikes the ground with a velocity 'v' and rebounds with a velocity v_1 then $e = \frac{v_1}{v}$ and after n^{th} rebound $v_n = e^n v$

- Total distance travelled by the ball before it stops bouncing

$$d = h + 2h_1 + 2h_2 + 2h_3 + \ldots\ldots$$
$$= h + 2e^2 h + 2e^4 h + 2e^6 h + \ldots\ldots$$
$$= h + 2e^2 h\left[1 + e^2 + e^4 + \ldots\ldots\right]$$
$$d = h\left[\frac{1+e^2}{1-e^2}\right]$$

- Total time taken by the ball to stop bouncing

$$T = t + 2t_1 + 2t_2 + 2t_3 + \ldots\ldots$$
$$= \sqrt{\frac{2h}{g}} + 2\sqrt{\frac{2h_1}{g}} + 2\sqrt{\frac{2h_2}{g}} + 2\sqrt{\frac{2h_3}{g}} + \ldots\ldots$$
$$= \sqrt{\frac{2h}{g}} + 2e\sqrt{\frac{2h}{g}}\left[1 + e + e^2 + \ldots\ldots\right]$$
$$= \sqrt{\frac{2h}{g}}\left[\frac{1+e}{1-e}\right]$$

- Average speed of the ball during its entire journey is given by

$$\text{Average speed} = \frac{\textit{Total distance travelled}}{\textit{Total time taken}}$$

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

- Average velocity of the ball during its entire journey is given by

$$\text{Average velocity} = \frac{\textit{Net displacement}}{\textit{Total time taken}}$$

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

Change in momentum in 1st collision

$\Rightarrow mv_1 - (-mu) = (mv_1 + mu)$

$= meu + mu = mu(1+e)$

Change in momentum in 2nd collision

$\Rightarrow m(v_2 + v_1) = m(e^2u + eu) = meu(1+e)$

Total change in momentum before it stops is

$\Delta p = mu(1 + 2e + 2e^2 + ...)$ $\quad [u = \sqrt{2gh}]$

$= mu\left[\frac{1+e}{1-e}\right] = m\sqrt{2gh}\left[\frac{1+e}{1-e}\right]$

Distance travelled before second impact is

$d_2 = h + 2h_1 = h(1 + 2e^2)$

Distance travelled before third impact is

$d_3 = h + 2h_1 + 2h_2 = h(1 + 2e^2 + 2e^4)$

Time taken for second impact is

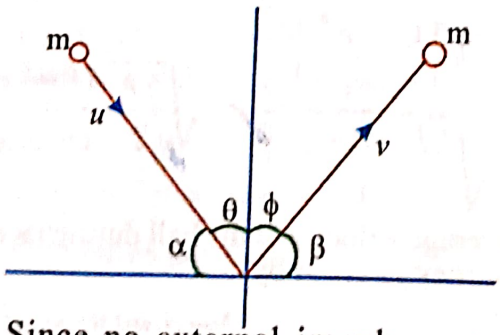
$t_2 = t + 2t_1 = \sqrt{\frac{2h}{g}}(1 + 2e)$

Time taken for third impact is

$t_3 = t + 2t_1 + 2t_2 = \sqrt{\frac{2h}{g}}(1 + 2e + 2e^2)$

Application

A particle of mass m moving with a speed u strikes a smooth horizontal surface at an angle α. The particle rebounds at an angle β with a speed v. The coefficient of restitution is 'e'.



Since no external impulse acts in the horizontal direction, momentum of the ball is conserved in the horizontal direction.

$mu\cos\alpha = mv\cos\beta$

$u\cos\alpha = v\cos\beta$ .....(1)

By def of coefficient of restitution we get

$eu\sin\alpha = v\sin\beta$ $\quad -(2)$

from (1) and (2), $\tan\beta = e\tan\alpha$

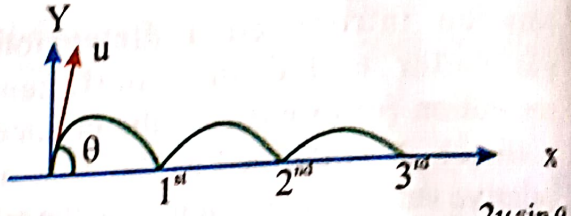
$\boxed{\tan\alpha = \frac{\tan\beta}{e}}$

On squaring eq (1) and (2) and adding get

$v^2 = u^2(\cos^2\alpha + e^2\sin^2\alpha)$

$v = u\sqrt{\cos^2\alpha + e^2\sin^2\alpha}$

A ball is projected with an initial velocity an angle θ to the horizontal surface. If the coefficient of restitution between the and the surface then



1) Time taken for 1st collision, $T = \frac{2u\sin\theta}{g}$

2) Time interval between 1st and 2nd collisi

$T_1 = \frac{2v_1\sin\theta}{g}$ $\quad (\because v_1 = eu)$

$T_1 = \frac{2(eu)\sin\theta}{g} = eT$

3) Time interval between 2nd and 3rd collisi

$T_2 = \frac{2v_2\sin\theta}{g} = \frac{2(e^2u)\sin\theta}{g} = e^2T$ $\quad (\because v_2 = e$

4) The total time of flight is

$T' = T + T_1 + T_2 + ...$

$= T + eT + e^2T + e^3T + ...$

$= T[1 + e + e^2 + e^3 + ...]$

$\boxed{T' = \frac{T}{1-e}}$

If collision is elastic, $e = 1$ then $T' = \infty$

5) The horizontal distance covered by the before 1st collision

$R = \frac{u^2\sin 2\theta}{g} = u\cos\theta \times T$

6) The horizontal distance covered by it betw 1st and 2nd collisions, $R_1 = u\cos\theta \times eT =$

7) horizontal distance covered between 2nd 3rd collisions, $R_2 = u\cos\theta \times e^2T = e^2R$

8) Total horizontal distance covered by the is

$R' = R_0 + R_1 + R_2 + R_3 + ...$

$= R + eR + e^2R + ...$

$$= R\left[1+e+e^2+.....\right]$$

$$\boxed{R^1 = \frac{R}{1-e}}$$

For perfectly elastic collision e = 1 and $R^1 = \infty$

9) The maximum height reached by the ball before 1st collision $H = \frac{u^2\sin^2\theta}{2g} = \frac{(u\sin\theta)^2}{2g}$

10) Maximum height it reaches between 1st and 2nd collisions is $H^1 = \frac{(eu\sin\theta)^2}{2g} = e^2H$

11) The sum of maximum heights reached by the ball is

$$H^1 = H + H_1 + H_2 + ...$$

$$= H + e^2H + e^4H + ...$$

$$= H\left[1+e^2+e^4+.....\right],\ H^1 = \frac{H}{1-e^2}$$

If the collision is elastic $e = 1$ and $H' = \infty$

Head on inelastic collision

Two bodies of masses m_1 and m_2 moving with initial velocities $\vec{u}_1$ and $\vec{u}_2$ $(u_1 > u_2)$ collide. After collision two bodies will move with velocities $\vec{v}_1$ and $\vec{v}_2$.

From Law of conservation of linear momentum

$$m_1(\vec{u}_1 - \vec{v}_1) = m_2(\vec{v}_2 - \vec{u}_2)$$

By the definition of coefficient of restitution

$$\vec{v}_2 - \vec{v}_1 = e(\vec{u}_1 - \vec{u}_2)$$

$$\vec{v}_1 = \left(\frac{m_1 - em_2}{m_1+m_2}\right)\vec{u}_1 + \left(\frac{(1+e)m_2}{m_1+m_2}\right)\vec{u}_2$$

$$\vec{v}_2 = \left(\frac{(1+e)m_1}{m_1+m_2}\right)\vec{u}_1 + \left(\frac{m_2 - em_1}{m_1+m_2}\right)\vec{u}_2$$

☞ If $m_1 = m_2 = m,\ u_2 = 0$ then

$$v_1 = (1-e)\frac{u_1}{2}\ ;\ v_2 = (1+e)\frac{u_1}{2}$$

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

Loss of kinetic energy of the system:

$$\Delta KE = KE_I - KE_F$$

$$\Delta KE = \frac{1}{2}\left(\frac{m_1m_2}{m_1+m_2}\right)(\vec{u}_1 - \vec{u}_2)^2(1-e^2)$$

In case of perfectly in-elastic collision, $e = 0$

∴ loss in KE of system is

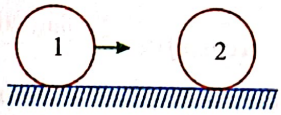
$$\Delta KE = \frac{1}{2}\left(\frac{m_1m_2}{m_1+m_2}\right)(\vec{u}_1 - \vec{u}_2)^2$$

☞ If two bodies are approaching each other then

loss in KE of the system is maximum

$$\Delta KE_{max} = \frac{1}{2}\left(\frac{m_1m_2}{m_1+m_2}\right)(u_1+u_2)^2$$

SE-46: Ball 1 collides with an another identical ball 2 at rest as shown in the figure. For what value of coefficient of restitution e, the velocity of second ball becomes two times that of first ball after collision?



Sol. Here $m_1 = m_2$ and $u_2 = 0$

After collision, $v_2 = \left(\frac{1+e}{2}\right)u$ & $v_1 = \left(\frac{1-e}{2}\right)u$

Given $v_2 = 2v_1$; $\left(\frac{1+e}{2}\right)u = 2\left(\frac{1-e}{2}\right)u$

$1+e = 2-2e$; $3e = 1$; $e = \frac{1}{3}$

SE-47: A body 'A' with a momentum 'P' collides with another identical stationary body 'B' one dimensionally. During the collision, 'B' gives an impulse 'J' to the body 'A'. Then the coefficient of restitution is

Sol : From the law of conservation of linear momentum,

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

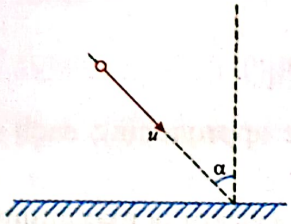
$mu + m(0) = mv_1 + mv_2$

$\Rightarrow P - P_1 = P_2$ where $P_2 = J$, (given)

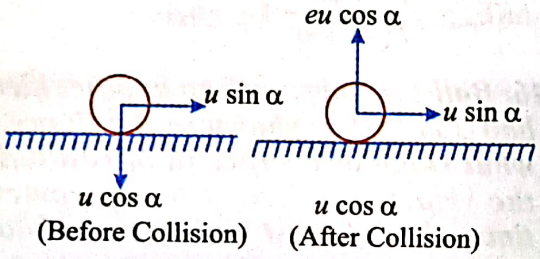
$$\therefore e = \frac{v_2 - v_1}{u_1 - u_2} = \frac{mv_2 - mv_1}{mu - 0} = \frac{P_2 - P_1}{P}$$

$$= \frac{P_2 - (P - P_2)}{P} = \frac{2P_2 - P}{P} = \frac{2J}{P} - 1$$

SE-48 ***A ball of mass m collides with the ground at an angle α with the vertical. If the collision lasts for time t, the average force exerted by the ground on the ball is : (e =coefficient of restitution between the ball and the ground)***



Sol : Impulse = change in linear momentum.



$\therefore Ft = m(eu\cos\alpha + u\cos\alpha)$ or $F = \dfrac{mu\cos\alpha(1+e)}{t}$

SE-49: A ball strikes a horizontal floor at an angle $\theta = 45^0$ with the normal to floor. The coefficient of restitution between the ball and the floor is e = 1/2. The fraction of its kinetic energy lost in the collision is

Sol : Let 'u' be the velocity of ball before collision. Speed of the ball after collision will become

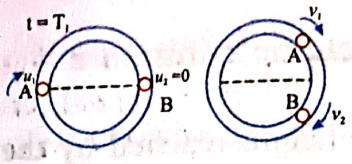
$$v = \sqrt{u^2\sin^2\theta + e^2u^2\cos^2\theta}$$

$$= \sqrt{\left(\frac{u}{\sqrt{2}}\right)^2 + \left(\frac{u}{2\sqrt{2}}\right)^2} = \sqrt{\frac{5}{8}}.u$$

$\therefore$ Fraction of KE lost in collision

$$= \frac{\frac{1}{2}mu^2 - \frac{1}{2}mv^2}{\frac{1}{2}mu^2} = 1 - \left(\frac{v}{u}\right)^2 = 1 - \frac{5}{8} = \frac{3}{8}$$

SE-50: Two equal spheres A and B lie on a smooth horizontal circular groove at opposite ends of a diameter. At time t = 0, A is projected along the groove and it first impinges on B at time $t = T_1$ and again at time $t = T_2$. If 'e' is the coefficient of restitution, find the ratio of $\frac{T_2}{T_1}$



Sol : $T_1 = \dfrac{\pi R}{u_1}$ ..... (1), $\dfrac{v_2 - v_1}{u_1} = e \Rightarrow v_2 - v_1 = eu_1$

Time taken for A to collide with B again

$$T_2 - T_1 = \frac{2\pi R}{v_2 - v_1} \Rightarrow T_2 - T_1 = \frac{2\pi R}{eu_1} \quad .... (2)$$

from (1) and (2), $\dfrac{T_2}{T_1} = \dfrac{2+e}{e}$

SE-51: After perfectly inelastic collision betwe two identical particles moving with sa speed in different directions, the speed of t combined particle becomes half the init speed of either particle. The angle betwe the velocities of the two before collision is

Sol : In perfectly inelastic collision between tw particles, linear momentum is conserved Let θ be the angle between the velocities the two particles before collision. Then

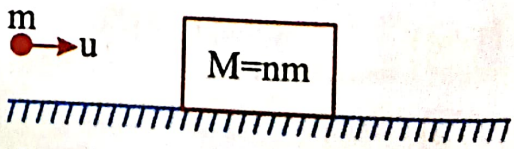
$P^2 = P_1^2 + P_2^2 + 2P_1P_2\cos\theta$ or

$$\left(2m\frac{v}{2}\right)^2 = (mv)^2 + (mv)^2 + 2(mv)(mv)\cos\theta$$

or $1 = 1 + 1 + 2\cos\theta$ or $\cos\theta = -\dfrac{1}{2}$; (or

$\theta = 120^0$

SE-52 A bullet of mass 'm' moving wit velocity 'u' passes through a wooden bloc of mass M = nm as shown in figure. Th block is resting on a smooth horizonta floor. After passing through the block velocity of the bullet becomes 'v'. In velocity relative to the block is



Sol : Let v' be the velocity of block. Then from conservation of linear momentum.

$mu = mv + mnv'$ (or) $v' = (u - v)$

$\therefore$ velocity of bullet relative to block will be

$$v_r = v - v' = v - \left(\frac{u-v}{n}\right) = \frac{(1+n)v-u}{n}$$

SE-53: ***A block of mass 0.50Kg is moving with a speed of 2.00 m/s on a smooth surface. It strikes another mass of 1.00 kg and then they move together as a single body. Find the energy loss during the collision***

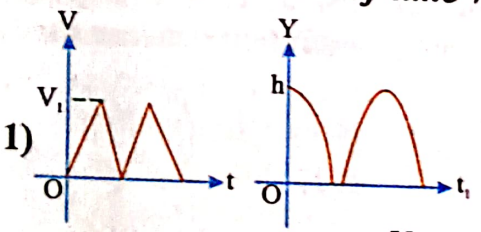
Sol: From LCLM, $m_1u_1 + m_2u_2 = (m_1+m_2)v$

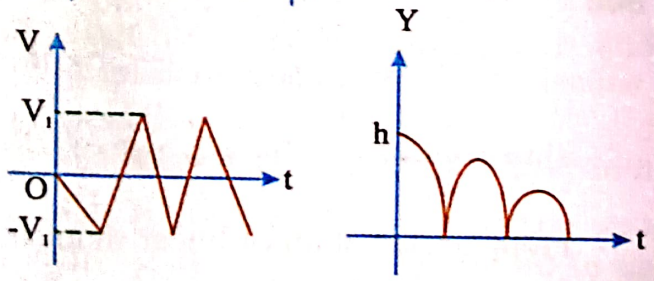
$$0.50\times 2 + 1\times 0 = (0.5+1)v \Rightarrow v = \frac{2}{3}\ ms^{-1}$$

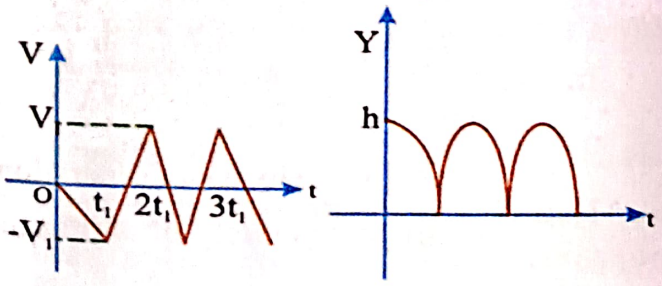
$\therefore$ Energy loss $\Delta KE = \frac{1}{2}m_1u_1^2 - \frac{1}{2}(m_1+m_2)v^2$

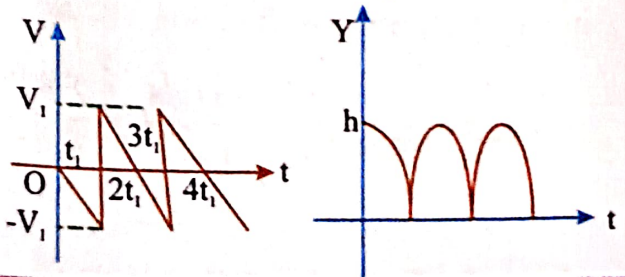
$$\Delta KE = \frac{1}{2}(0.5)(2)^2 - \frac{1}{2}(1.5)\left(\frac{2}{3}\right)^2 = 0.67\ J$$

SE-54: ***Consider a rubber ball freely falling from a height h = 4.9 m on a horizontal elastic plate. Assume that the duration of collision is negligible and the collision with the plate is totally elastic. Then the velocity as a function of time and the height as a function of time will be;***

1)


2)


3)


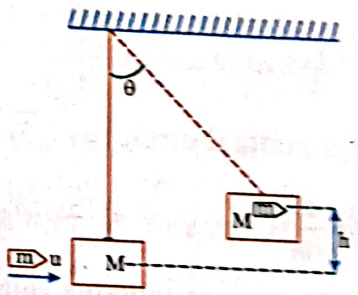
4)


Sol: When ball strikes the surface its velocity will be reversed so correct option is (3).

Ballistic pendulum:

It is an arrangement used to determine the velocities of bullets .A log of wood of mass 'M' is suspended by a string of length 'l' as shown in the figure. A bullet of mass 'm' is fired horizontally into the wooden block with a velocity 'u'

Case I : Let the bullet gets embedded in the block and system rises to a height 'h' as shown in the figure.



From the law of conservation of linear momentum

$$m_1u_1 + m_2u_2 = (m_1+m_2)v$$

$$mu + 0 = (m+M)v \Rightarrow v = \frac{mu}{m+M} \quad .....(1)$$

KE of the system after collision is given by

$$KE = \frac{1}{2}(m+M)v^2$$

PE at highest point $= (m+M)gh$

From LCE, $\frac{1}{2}(m+M)v^2 = (m+M)gh$

$$v^2 = 2gh (or) v = \sqrt{2gh} \quad ....(2)$$

From (1) and (2) velocity of the bullet

$$u = \frac{M+m}{m}\sqrt{2gh} = \frac{M+m}{m}\sqrt{2gl(1-\cos\theta)}$$

Loss in KE of the system $= KE_1 - KE_2$

$$\Delta KE = \frac{1}{2}mu^2 - \frac{1}{2}(m+M)v^2$$

$$\Delta KE = \frac{1}{2}\left[mu^2 - (m+M)\frac{m^2u^2}{(m+M)^2}\right]$$

$$\Delta KE = \frac{1}{2}\left[\frac{mM}{m+M}\right]u^2$$

Case II :

If the bullet emerges out of the block with velocity 'v' then

$mu = mv + MV$ Where $V = \sqrt{2gh}$

SE-55 ***A pendulum consists of a wooden bob of mass 'm' and of length l. A bullet of mass m_1 is fired towards the pendulum with a speed v_1 and it emerges out of the bob with a speed $\frac{v_1}{3}$. Find the initial speed of the bullet if the bob just completes the vertical circle.***

Sol: From the Law of conservation of momentum

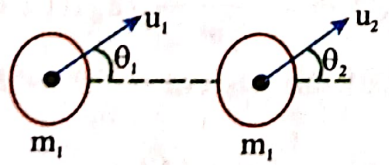
$$mv = m_1\left(v_1 - \frac{v_1}{3}\right) \text{ or } v = \frac{m_1}{m} \times \frac{2v_1}{3}$$

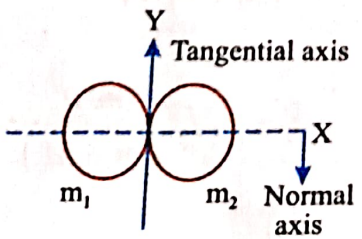
To describe a vertical circle $v = \sqrt{5gl}$

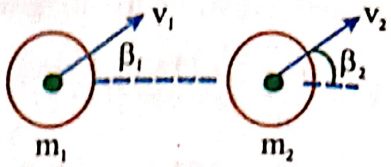
hence $\sqrt{5gl} = \frac{m_1}{m} \times \frac{2v_1}{3} \Rightarrow v_1 = \frac{m}{m_1} \times \frac{3\sqrt{5gl}}{2}$

Collisions in two dimensions (oblique collisions)

1. A pair of equal and opposite impulses act along common normal direction. Hence, linear momentum of individual particles changes along common normal direction.
2. No component of impulse acts along common tangent direction. Hence, linear momentum (or) linear velocity of individual particles remains unchanged along this direction.
3. Net impulse on both the particles is zero during collision. Hence, net momentum of both the particles remain conserved before and after collision in any direction.
4. Definition of coefficient of restitution can be applied along common normal direction.







From law of conservation of linear momentum along x-axis:

$$m_1u_1\cos\theta_1 + m_2u_2\cos\theta_2$$
$$= m_1v_1\cos\beta_1 + m_2v_2\cos\beta_2$$

Along y-axis:

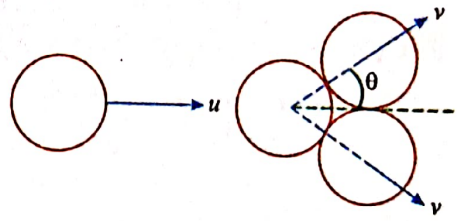
$$m_1u_1\sin\theta_1 + m_2u_2\sin\theta_2$$
$$= m_1v_1\sin\beta_1 + m_2v_2\sin\beta_2$$

Coefficient of restitution

$$e = -\frac{v_1\cos\beta_1 - v_2\cos\beta_2}{u_1\cos\theta_1 - u_2\cos\theta_2}$$

SE-56: ***Two billiard balls of same size (radi r) and same mass are in contact on a billia table. A third ball also of the same size a mass strikes them symmetrically a remains at rest after the impact. Th coefficient of restitution between the balls***

Sol: :



$$\sin\theta = \frac{r}{2r} = \frac{1}{2}; \quad \therefore \theta = 30^0$$

From conservation of linear momentum

$$mu = 2mv\cos 30^0 \quad \text{or} \quad v = \frac{u}{\sqrt{3}}$$

Now $e = \dfrac{\text{relative velocity of separation}}{\text{relative velocity of approach}}$

in common normal direction

Hence, $e = \dfrac{v}{u\cos 30^0} = \dfrac{u/\sqrt{3}}{u\sqrt{3}/2} = \dfrac{2}{3}$

Concept Based QUESTIONS

WORK

1. **In which of the following, the work done by the mentioned force is negative? The work done by**
   1) the tension in the cable while the lift is ascending
   2) the gravitational force when a body slides down an inclined plane
   3) the applied force to maintain uniform motion of a block on a rough horizontal surface
   4) the gravitational force when a body is thrown up

2. **A man pushes a wall and fails to displace it. He does**
   1) negative work
   2) positive but not maximum work
   3) maximum work 4) no work at all

3. **A bucket full of water is drawn up by a person. In this case the work done by the gravitational force is**
   1) negative because the force and displacement are in opposite directions
   2) positive because the force and displacement are in the same direction
   3) negative because the force and displacement are in the same direction
   4) positive because the force and displacement are in opposite directions

4. **A man is rowing a boat upstream and inspite of that the boat is found to be not moving with respect to the bank. The work done by the man is**
   1) zero 2) positive
   3) negative 4) may be +ve or –ve

5. **A ball is thrown vertically upwards from the ground. Work done by air resistance during its time of flight is**
   1) positive during ascent and negative during descent
   2) positive during ascent and descent
   3) negative during ascent and positive during descent
   4) negative during ascent and descent

6. **An agent is moving a positively charged body towards another fixed positive charge. The work done by the agent is**
   1) positive 2) negative
   3) zero 4) may be positive or negative

7. **Workdone by force of friction**
   1) can be zero 2) can be positive
   3) can be negative
   4) any of the above

CONSERVATIVE AND NON-CONSERVATIVE FORCES

8. **Potential energy is defined for**
   1) non-conservative forces only
   2) conservative forces only
   3) both conservative & non-conservative forces
   4) neither conservative nor non-conservative forces

9. **Which of the following forces is called a conservative force?**
   1) Frictional force 2) Air resistance
   3) Electrostatic force 4) Viscous force

10. **Identify the non-conservative force in the following**
    1) Weight of a body
    2) Force between two ions
    3) Magnetic force 4) Air resistance

11. **If x, F and U denote the displacement, force acting on and potential energy of a particle, then**
    1) $U = F$ 2) $F = +\frac{dU}{dx}$
    3) $F = -\frac{dU}{dx}$ 4) $F = \frac{1}{x}\left(\frac{dU}{dx}\right)$

12. **In the case of conservative force**
    1) work done is independent of the path
    2) work done in a closed loop is zero
    3) work done against conservative force is stored is the form of potential energy
    4) all the above

KINETIC ENERGY

13. **The change in kinetic energy per unit 'space' (distance) is equal to**
    1) power 2) momentum
    3) force 4) pressure

14. When the momentum of a body is doubled, the kinetic energy is
1) doubled 2) halved
3) becomes four times
4) becomes three times

15. For the same kinetic energy, the momentum shall be maximum for which of the following particle?
1) Electron 2) Proton
3) Deuteron 4) Alpha particle

16. If the momentum of a particle is plotted on X-axis and its kinetic energy on the Y-axis, the graph is a
1) straight line 2) parabola
3) rectangular hyperbola 4) circle

17. When two identical balls are moving with equal speeds in opposite direction, which of the following is true? For the system of two bodies
1) momentum is zero, kinetic energy is zero
2) momentum is not zero, kinetic energy is zero
3) momentum is zero, kinetic energy is not zero
4) momentum is not zero, kinetic energy is not zero

18. The product of linear momentum and velocity of a body represents
1) half of the kinetic energy of the body
2) kinetic energy of the body
3) twice the kinetic energy of the body
4) mass of the body

19. The KE of a freely falling body
1) is directly proportional to height of its fall
2) is inversely proportional to height of its fall
3) is directly proportional to square of time of its fall
4) 1 and 3 are true

20. Consider the following statements

A) Linear momentum of a system of particles is zero

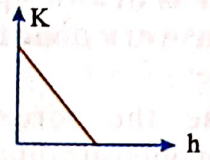
B) Kinetic energy of a system of particles is zero then

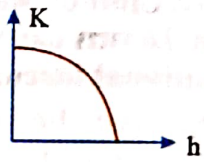
1) A does not imply B & B does not imply A
2) A implies B and B does not imply A
3) A does not imply B but B implies A
4) A implies B and B implies A

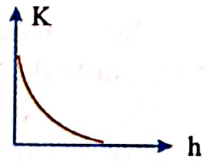
21. Internal forces can change
1) Linear momentum as well as kine energy
2) Linear momentum but not the kine energy
3) Kinetic energy but not linear momentu
4) neither the linear momentum nor t kinetic energy

22. If the force acting on a body is inverse proportional to its speed, then its kinet energy is
1) linearly related to time
2) inversely proportional to time
3) inversely proportional to the square of tim
4) a constant

23. Which of the following graphs depicts th variation of KE of a ball bouncing on horizontal floor with height? (Neglect a resistances)

1) 

2) 

3) 

4) None of these

24. Which of the following statement is correct
1) KE of a system cannot be change without changing its momentum
2) KE of a system can be changed withou changing its momentum
3) Momentum of a system cannot be change without changing its KE
4) A system cannot have energy withou having momentum

25. Two bodies of different masses have sam linear momentum. The one having mor KE is
1) lighter body 2) heavier body
3) both 4) none

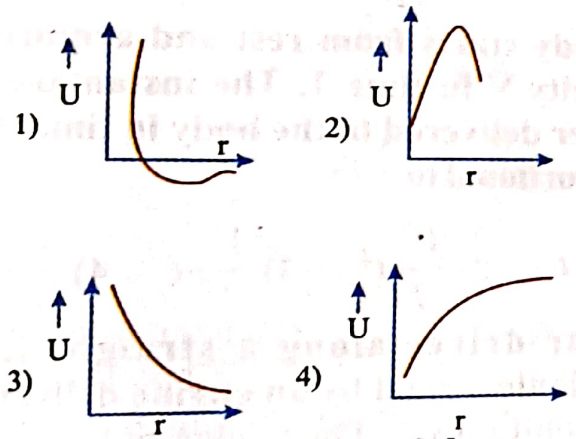
26. **Two bodies of masses m_1 and m_2 have equal KE. Their momenta is in the ratio**
1) $\sqrt{m_2} : \sqrt{m_1}$ 2) $m_1 : m_2$ 3) $\sqrt{m_1} : \sqrt{m_2}$ 4) $m_1^2 : m_2^2$

27. **A body can have**
1) changing momentum and finite kinetic energy
2) zero kinetic energy and finite momentum
3) zero acceleration and increasing kinetic energy
4) finite acceleration and zero kinetic energy

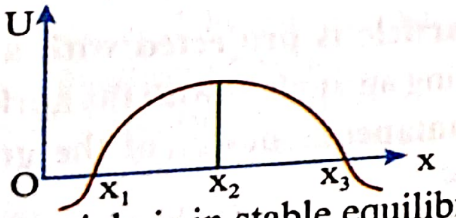
8. **A rock of mass m is dropped to the ground from a height h. A second rock with mass 2m is dropped from the same height. When second rock strikes the ground, its kinetic energy wii be**
1) twice that of the first rock
2) four times that of the first rock
3) the same as that of the first rock
4) half that of the first rock

POTENTIAL ENERGY

. **These diagrams represent the potential energy U of a diatomic molecule as a function of the inter-atomic distance r. The diagram corresponds to stable molecule found in nature is**



. **In the fig. the potential energy U of a particle plotted against its position x from origin. Which of the following statement is correct?**



1) at x_1 particle is in stable equilibrium
2) at x_2 particle is in stable equilibrium
3) at x_3 particle is in stable equilibrium
4) at x_1, x_2 *and* x_3 particle is in unstable equilibrium

POTENTIAL ENERGY OF A SPRING

31. **When a spring is wound, a certain amount of PE is stored in it. If this wound spring is dissolved in acid, the stored energy**
1) is completely lost
2) appears in the form of electromagnetic waves
3) appears in the form of heat raising the temperature of the acid
4) appears in the form of KE by splashing acid drops

32. **Two springs have their force constants K_1 and K_2 and they are stretched to the same extension. If $K_2 > K_1$ work done is**
1) same in both the springs
2) more in spring K_1
3) more in spring K_2
4) independent of spring constant K

33. **Two springs have their force constants K_1 and K_2 ($K_2 > K_1$). When they are stretched by the same force, work done is**
1) same in both the springs
2) more in spring K_1
3) more in spring K_2
4) independent of spring constant K

WORK ENERGY THEOREM

34. **A lorry and a car moving with the same KE are brought to rest by applying the same retarding force. Then**
1) lorry will come to rest in a shorter distance
2) car will come to rest in a shorter distance
3) both come to rest in same distance
4) any of above

CONSERVATION OF MECHANICAL ENERGY

35. **A shell is fired into air at an angle θ with the horizontal from the ground. On reaching the maximum height,**
1) its kinetic energy is not equal to zero
2) its kinetic energy is equal to zero
3) its potential energy is equal to zero
4) both its potential and kinetic energies are zero

PHYSICS

36. A cricket ball and a ping-pong ball are dropped in a vacuum chamber from same height. When they have fallen half way down, they have the same
1) velocity 2) potential energy
3) kinetic energy
4) mechanical energy

37. A cyclist free-wheels from the top of a hill, gathers speed going down the hill, applies his brakes and eventually comes to rest at the bottom of the hill. Which one of the following energy changes take place.
1) Potential to kinetic and to heat energy
2) Kinetic to potential and to heat energy
3) chemical to heat and to potential energy
4) Kinetic to heat and to chemical energy

38. If 'E' represents total mechanical energy of a system while 'U' represents the potential energy, then E - U is
1) always zero 2) negative
3) either positive or negative 4) positive

39. For a body thrown vertically upwards, its direction of motion changes at the point where its total mechanical energy is
1) greater than the potential energy
2) less than the potential energy
3) equal to the potential energy 4) zero

40. Internal forces can change
1) Kinetic energy 2) mechanical energy
3) Momentum 4) 1 and 2

41. Negative of work done by the conservation forces on a system is equal to
1) the change in kinetic energy of the system
2) the change in potential energy of the system
3) the change in total mechanical energy of the system
4) the change in the momentum of the system

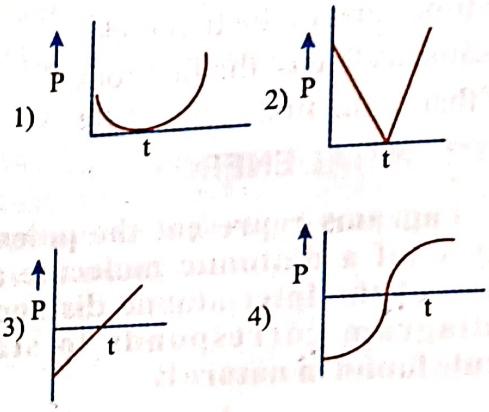
42. Which of the following statement is wrong?
1) KE of a body is independent of the direction of motion
2) In an elastic collision of two bodies, the momentum and energy of each body is conserved
3) If two protons are brought towards each other, the PE of the system increases
4) A body can have energy without momentum

43. When a body falls from an aeropl there is increase in its:
1) acceleration 2) potential energy
3) kinetic energy 4) mass

POWER

44. A body is moved along a straight by a machine delivering consta power. The distance moved by the bo in time t is proportional to
1) $t^{1/2}$ 2) $t^{3/4}$ 3) $t^{3/2}$ 4) t^2

45. A particle is projected at t = 0 from point on the ground with certain veloc at an angle with the horizontal. T power of gravitational force is plott against time. Which of the following the best representation?



46. A body starts from rest and acquires velocity V in time T. The instantaneo power delivered to the body in time 't' proportional to

1) $\frac{V}{T}t$ 2) $\frac{V^2}{T}t^2$ 3) $\frac{V^2}{T^2}t$ 4) $\frac{V^2}{T^2}t^2$

47. A car drives along a straight lev frictionless road by an engine deliverin constant power. Then velocity is directl proportional to

1) t 2) $\frac{1}{\sqrt{t}}$ 3) $\sqrt{t}$ 4) t^2

48. A particle is projected with a velocity making an angle θ with the horizontal. Th instantaneous power of the gravitationa force
1) varies linearly with time
2) is constant throughout the path
3) is negative for complete path
4) varies inversly with time

MOTION IN A VERTICAL CIRCLE

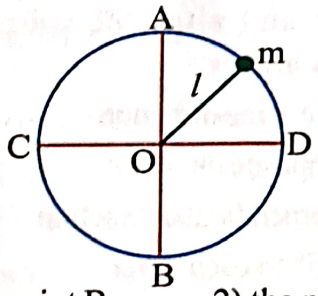
49. A motor car of mass m travels with a uniform speed v on a convex bridge of radius r. When the car is at the middle point of the bridge, then the force exterted by the car on the bridge is

1) mg
2) $mg+\frac{mv^2}{r}$
3) $mg-\frac{mv^2}{r}$
4) $mg\pm\frac{mv^2}{r}$

50. A gramphone record is revolving with an angular velocity ω. A coin is placed at a distance R from the centre of the record. The static coefficient of friction is μ. The coin will revolve with the record if

1) $R>\frac{\mu g}{\omega^2}$
2) $R=\frac{\mu g}{\omega^2}$ only
3) $R<\frac{\mu g}{\omega^2}$
4) $R\leq\frac{\mu g}{\omega^2}$

51. A small sphere of mass 'm' is attached to a cord and rotates in a vertical plane about a point O. If the average speed of the sphere is increased, the cord is most likely to break at the orientation when the mass is at :



1) bottom point B
2) the point C
3) the point D
4) top point A

52. A car is moving up with uniform speed along a fly over bridge which is part of a vertical circle. The true statement from the following is

1) Normal reaction on the car gradually decreases and becomes minimum at highest position of bridge
2) Normal reaction on the car gradually increases and becomes maximum at highest position
3) Normal reaction on car does not change
4) Normal reaction on the car gradually decreases and becomes zero at highest position

53. A bottle of soda water is rotated in a vertical circle with the neck held in hand. The air bubbles are collected

1) near the neck
2) near the bottom
3) at the middle
4) uniformly in the bottle

54. A vehicle is moving with uniform speed along horizontal, concave and convex surface roads. The surface on which, the normal reaction on the vehicle is maximum is

1) concave
2) convex
3) horizontal
4) same at all surfaces

COLLISIONS

55. A ball with initial momentum $\vec{P}$ collides with rigid wall elastically. If $\vec{P^1}$ be its momentum after collision then

1) $\vec{P^1}=\vec{P}$
2) $\vec{P^1}=-\vec{P}$
3) $\vec{P^1}=2\vec{P}$
4) $\vec{P^1}=-2\vec{P}$

56. Choose the false statement

1) In a perfect elastic collision the relative velocity of approach is equal to the relative velocity of separation
2) In an inelastic collision the relative velocity of approach is less than the relative velocity of separation
3) In an inelastic collision the relative velocity of separation is less than the relative velocity of approach
4) In perfect inelastic collision relative velocity of separation is zero

57. Two particles of different masses collide head on. Then for the system

1) loss of KE is zero, if it was perfect elastic collision
2) If it was perfect inelastic collision, the loss of KE of the bodies moving in opposite directions is more than that of the bodies moving in the same direction
3) loss of momentum is zero for both elastic and inelastic collision
4) 1, 2 and 3 are correct

58. A 2 kg mass moving on a smooth frictionless surface with a velocity of $10ms^{-1}$ hits another 2kg mass kept at rest, in a perfect inelastic collision. After collision, if they move together
1) they travel with a velocity of $5ms^{-1}$ in the same direction
2) they travel with a velocity of $10ms^{-1}$ in the same direction
3) they travel with a velocity of $10ms^{-1}$ in opposite direction
4) they travel with a velocity of $5ms^{-1}$ in opposite direction

59. A body of mass 'm' moving with a constant velo-city v hits another body of the same mass moving with the same velocity v but in opposite direction and sticks to it. The velocity of the compound body after the collision is
1) 2v 2) v 3) v/2 4) zero

60. In an inelastic collision, the kinetic energy after collision
1) is same as before collision
2) is always less than before collision
3) is always greater than before collision
4) may be less or greater than before collision

61. A ball hits the floor and rebounds after an inelastic collision. In this case
1) the momentum of the ball just after the collision is same as that just before the collision
2) The mechanical energy of the ball remains the same in the collision
3) The total momentum of the ball and the earth is conserved
4) the total kinetic energy of the ball and the earth is conserved

62. About a collision which is not correct
1) physical contact is must
2) colliding particles can change their direction of motion
3) the effect of the external force is not considered
4) linear momentum is conserved

63. In one– dimensional elastic collisi the relative velocity of approach befo collision is equal to
1) relative velocity of separation af collision
2) 'e' times relative velocity of separati after collision
3) '1/e' times relative velocity of separati after collision
4) sum of the velocities after collision

64. Two identical bodies moving in oppos direction with same speed, collide wi each other. If the collision is perfect elastic then
1) after the collision both comes to rest
2) after the collision first comes to rest a second moves in the opposite directi with same speed.
3) after collision they recoil with same spe
4) both and 1 and 2

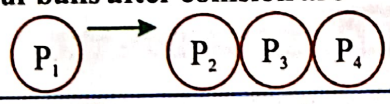
65. A body of mass 'm' moving with certai velocity collides with another identic body at rest. If the collision is perfectl elastic and after the collision both th bodies moves
1) in the same direction
2) in opposite direction
3) in perpendicular direction
4) at 45° to each other

66. Six steel balls of identical size are lined u along a straight frictionless groove. Tw similar balls moving with speed v alon the groove collide with this row on th extreme left end. Then
1) one ball from the right end will move o with speed v
2) two balls from the extreme right en will move on with speed v and th remaining balls will be at rest
3) all the balls will start moving to the righ with speed v/8
4) all the six balls originally at rest will mov on with speed v/6 and the incident bal will come to rest

67. A lighter body moving with a velocity v collides with a heavier body at rest. Then
1) the lighter body rebounced with twice the velocity of bigger body
2) the lighter body retraces its path with the same velocity in magnitude
3) the heavier body does not move practically
4) both (2) and (3)

68. A heavier body moving with certain velocity collides head on elastically with a lighter body at rest, then
1) smaller body continues to be in the same state of rest
2) smaller body starts to move in the same direction with same velocity as that of bigger body
3) the smaller body start to move with twice the velocity of the bigger body in the same direction
4) the bigger body comes to rest

69. A perfectly elastic ball P_1 of mass 'm' moving with velocity v collides elastically with three exactly similar balls P_2, P_3, P_4 lying on a smooth table. Velocity of the four balls after collision are



1) 0,0,0,0 2) v, v, v, v
3) v, v, v,0 4) 0, 0, 0, v

70. Two bodies P and Q of masses m_1 and m_2 $(m_2 > m_1)$ are moving with velocity v_1 and v_2 respectively, collide with each other. Then the force exerted by P on Q during the collision is
1) greater that the force exerted by Q on P
2) less than the force exerted by Q on P
3) same as the force exerted by Q on P
4) same as the force exerted by Q on P but opposite in direction

71. The coefficient of restitution (e) for a perfectly elastic collision is
1) -1 2) 0 3) ∞ 4) 1

72. A ball of mass M moving with a velocity v collides perfectly inelastically with another ball of same mass but moving with a velocity v in the opposite direction. After collision
1) both the balls come to rest
2) the velocities are exchanged between the two balls
3) both of them move at right angles to the original line of motion
4) one ball comes to rest and another ball travels back with velocity 2v

73. A ball of mass 'm' moving with speed 'u' undergoes a head-on elastic collision with a ball of mass 'nm' initially at rest. Find the fraction of the incident energy transferred to the second ball.

1) $\frac{n}{n+1}$ 2) $\frac{n}{(n+1)^2}$
3) $\frac{2n}{(1+n)^2}$ 4) $\frac{4n}{(1+n)^2}$

74. A small bob of a simple pendulum released from 30° to the vertical hits another bob of the same mass and size lying at rest on the table vertically below the point of suspension. After elastic collision, the angular amplitude of the pendulum will be
1) 30° 2) 60° 3) 15° 4) zero

75. Two spheres 'X' and 'Y' collide. After collision, the momentum of X is doubled. Then
1) the initial momentum of X and Y are equal
2) the initial momentum of X is greater then that of Y
3) the initial momentum of Y is double that of X
4) the loss in momentum of Y is equal to the initial momentum of X

76. A bullet is fired into a wooden block. If the bullet gets embedded in wooden block, then
1) momentum alone is conserved
2) kinetic energy alone is conserved
3) both momentum and kinetic energy are conserved
4) neither momentum nor kinetic energy are conserved

77. During collision, which of the following state-ment is wrong?
1) there is a change in momentum of individual bodies
2) the change in total momentum of the system of colliding particle is zero
3) the change in total energy is zero
4) law of conservation of momentum is not valid

PHYSICS

KEY

01) 4	02) 4	03) 1	04) 1	05) 4	06) 1
07) 4	08) 2	09) 3	10) 4	11) 3	12) 4
13) 3	14) 3	15) 4	16) 2	17) 3	18) 3
19) 4	20) 3	21) 3	22) 1	23) 1	24) 1
25) 1	26) 3	27) 1	28) 1	29) 1	30) 4
31) 3	32) 3	33) 2	34) 3	35) 1	36) 1
37) 1	38) 4	39) 3	40) 4	41) 2	42) 2
43) 3	44) 3	45) 3	46) 3	47) 3	48) 1
49) 3	50) 4	51) 1	52) 2	53) 1	54) 1
55) 2	56) 2	57) 4	58) 1	59) 4	60) 2
61) 3	62) 1	63) 1	64) 3	65) 3	66) 2
67) 4	68) 3	69) 4	70) 4	71) 4	72) 1
73) 4	74) 4	75) 4	76) 1	77) 4	

EXERCISE - I

CRTQ & SPQ - LEVEL-I

WORK DONE BY CONSTANT FORCE

C.R.T.Q. Class Room Teaching Questions

1. If $\vec{F} = 2\hat{i} + 3\hat{j} + 4\hat{k}$ acts on a body and displaces it by $\vec{S} = 3\hat{i} + 2\hat{j} + 5\hat{k}$, then the work done by the force is
   1) 12 J 2) 20 J 3) 32 J 4) 64 J
2. A force of 1200 N acting on a stone by means of a rope slides the stone through a distance of 10m in a direction inclined at 60^0 to the force. The work done by the force is
   1) $6000\sqrt{3}J$ 2) $6000J$
   3) $12000J$ 4) $8000J$
3. A man weighing 80 kg climbs a staircase carrying a 20 kg load. The staircase has 40 steps, each of 25 cm height. If he takes 20 seconds to climb, the work done is
   1) 9800J 2) 490 J 3) 98×10^5J 4) 7840J
4. The work done by a force $\vec{F} = 3\hat{i} - 4\hat{j} + 5\hat{k}$ N displaces the body from a point (3,4,6) to a point (7,2,5) is
   1) 15 units 2) 25 units
   3) 20 units 4) 10 units
5. A force $\vec{F} = (6\hat{i} - 8\hat{j})N$, acts particle and displaces it over 4 m the X-axis and 6m along the Y The work done during the displacement is
   1) 72 J 2) 24 J 3) - 24 J
6. A lawn roller is pulled al horizontal surface through a di of 20 m by a rope with a force of If the rope makes an angle of 60 the vertical while pulling, the am of work done by pulling force is
   1) 4000 J 2) 1000 J
   3) $2000\sqrt{3}$ J 4) 2000 J
7. If a force $\vec{F} = (\vec{i} + 2\vec{j} + \vec{k})$ N acts on body produces a displacement of $\vec{S} = (4\vec{i} + \vec{j} + 7\vec{k})$ m, then the work don
   1) 9J 2) 13J 3) 5J
8. Work done by the gravitational forc a body of mass "m" moving on a sm horizontal surface through a distance
   1) mgs 2) -mgs 3) 0 4) 2

S.P.Q. Student Practice Questions

9. A body of mass 1 kg is made to tr with a uniform acceleration of 30 cm over a distance of 2m, then work to done is
   1) 6J 2) 60J 3) 0.6J 4) 0.3J
10. A uniform cylinder of radius 'r' le 'L' and mass 'm' is lying on the gro with the curved surface touching ground. If it is to be oriented on ground with the flat circular end contact with the ground, the work to done is
    1) mg[(L/2)-r] 2) mL[(g/2)-r]
    3) mr(gL-1) 4) mgLr
11. A meter scale of mass 400 gm is h horizontally on the floor. If it is u held vertically with one end touch the floor, the work to be done is
    1) 6 J 2) 4 J 3) 40J 4) 2

A force F is applied on a lawn moves at an angle of 60° with the horizontal. If it moves through a distance x, the work done by the force is

1) $Fx/2$ 2) $F/2x$ 3) $2Fx$ 4) $2x/F$

A weight lifter jerks 220 kg vertically through 1.5 metre and holds still at that height for two minutes. The work done by him in lifting and in holding it still are respectively

1) 220J, 330J 2) 3234 J, 0 J
3) 2334 J, 10 J 4) 0 J, 3234 J

A tennis ball has a mass of 56.7 gm and is served by a player with a speed of 180 kmph. The work done in serving the ball is nearly

1) 710J 2) 71J 3) 918J 4) 91.8J

A body of mass 2kg is projected vertically up with velocity $5ms^{-1}$. The work done on the body by gravitational force before it is brought to rest momentarily is

1) 250J 2) 25J 3) 0J 4) -25J

WORK DONE BY VARIABLE FORCE

C.R.T.Q Class Room Teaching Questions

An object has a displacement from position vector $\vec{r}_1 = (2\hat{i} + 3\hat{j})$ m to $\vec{r}_2 = (4\hat{i} + 6\hat{j})$ m under a force $\vec{F} = (3x^2\hat{i} + 2y\hat{j})$ N, then work done by the force is

1) 24J 2) 33J 3) 83J 4) 45J

S.P.Q. Student Practice Questions

A force F = (2+x) N acts on a particle in x-direction where 'x' is in metre. The work done by this force during a displacement from $x = 1$ m to $x = 2$ m is

1) 2 J 2) 3.5 J 3) 4.5 J 4) 5 J

KINETIC ENERGY

C.R.T.Q Class Room Teaching Questions

A shot is fired at 30° with the vertical from a point on the ground with kinetic energy K. If air resistance is ignored, the kinetic energy at the top of the trajectory is

1) 3K/4 2) K/2 3) K 4) K/4

A body starts from rest and is acted on by a constant force. The ratio of kinetic energy gained by it in the first five seconds to that gained in the next five seconds is

1) 2 : 1 2) 1 : 1 3) 3 : 1 4) 1 : 3

The mass of a simple pendulum bob is 100 gm. The length of the pendulum is 1 m. The bob is drawn aside from the equilibrium position so that the string makes an angle of 60° with the vertical and let go. The kinetic energy of the bob while crossing its equilibrium position will be

1) 0.49 J 2) 0.94 J
3) 1 J 4) 1.2 J

A body starts from rest and moves with uniform acceleration. What is the ratio of kinetic energies at the end of 1st, 2nd and 3rd seconds of its journey?

1) 1 : 8 : 27 2) 1 : 2 : 3
3) 1 : 4 : 9 4) 3 : 2 : 1

A liquid of specific gravity 0.8 is flowing in a pipe line with a speed of 2 m/s. The K.E. per cubic meter of it is

1) 160 J 2) 1600 J
3) 160.5 J 4) 1.6 J

A 60 kg boy lying on a surface of negligible friction throws horizontally a stone of mass 1 kg with a speed of 12 m/s away from him. As a result with what kinetic energy he moves back?

1) 2.4 J 2) 72 J 3) 1.2 J 4) 36 J

Two stones of masses m and 2 m are projected vertically upwards so as to reach the same height. The ratio of the kinetic energies of their projection is

1) 2 : 1 2) 1 : 2 3) 4 : 1 4) 1 : 4

A neutron, one of the constituents of a nucleus, is found to pass two points 60 metres apart in a time interval of 1.8×10^{-4} sec. The mass of the neutron is 1.67×10^{-27} kg. Assuming that the speed is constant, its kinetic energy is

1) 9.3×10^{-17} joule 2) 9.3×10^{-14} joule
3) 9.3×10^{-21} joule 4) 9.3×10^{-11} joule

S.P.Q. Student Practice Questions

26. On increasing the speed of a body to 2 ms^{-1}, its kinetic energy is quadrupled. Then its original speed must be

1) $0.25ms^{-1}$ 2) $1ms^{-1}$ 3) $4ms^{-1}$ 4) $2ms^{-1}$

27. A bullet of mass 10 gm strikes a target at 400 m/s velocity and loses half of its initial velocity. The loss of kinetic energy in joules is

1) 800 2) 200 3) 400 4) 600

28. An object is acted on by a retarding force of 10 N and at a particular instant its kinetic energy is 6J. The object will come to rest after it has travelled a distance of.

1) 3/5m 2) 5/3m 3) 4m 4) 16m

29. A man standing on the edge of the roof of a 20 m tall building projects a ball of mass 100 gm vertically up with a speed of $10ms^{-1}$. The kinetic energy of the ball when it reaches the ground will be [$g=10\ ms^{-2}$]

1) 5J 2) 20J 3) 25J 4) Zero

30. A river of salty water is flowing with a velocity 2 m/sec. If the density of water is 1.2 gm/cc, the kinetic energy of each of cubic metre of water is

1) 2.4 J 2) 24 J 3) 4.8 KJ 4) 2.4 KJ

31. If the kinetic energy of a body increases by 125% , the percentage increase in its momentum is

1) 50% 2) 62.5% 3) 250% 4) 200%

32. The kinetic energy of a body is 'K'. If one-fourth of its mass is removed and velocity is doubled, its new kinetic energy is

1) K 2) 3K 3) 4K 4) 9K/4

POTENTIAL ENERGY

C.R.T.Q Class Room Teaching Questions

33. A tank of size 10 m × 10 m × 10 m is full of water and built on the ground. If $g = 10\ ms^{-2}$, the potential energy of the water in the tank is

1) 5×10^7J 2) 1×10^8 J
3) 5×10^4J 4) 5×10^5 J

34. A bolt of mass 0.3kg falls from ceiling of an elevator moving d with an uniform speed of 7m/s. It the floor of the elevator (length of elevator = 3m) and does not rebo What is the heat produced by impa

1) 8.82J 2) 7.72J 3) 6.62J 4) 5

S.P.Q. Student Practice Questions

35. An inelastic ball falls from a height of meters. It loses 20% of its total energy d impact. The ball will now rise to a heigh

1) 80 m 2) 120m 3) 60m 4) 9.8

36. A woman weighing 63 kg eats plum whose energy content is 9800 calorie all this energy could be utilized by she can ascend a height of

1) 1m 2) 67m 3) 100m 4) 42m

POTENTIAL ENERGY OF A SPRING

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

C.R.T.Q Class Room Teaching Questions

37. A spring when compressed by 4 cm 2 J energy stored in it. The fo required to extend it by 8 cm will be

1) 20 N 2) 2 N 3) 200 N 4) 200

38. The elastic potential energy of stretched spring is given by E = 5 Where x is the displacement in meter E is in joule, then the force constan the spring is

1) 50Nm 2) $100N\ m^{-1}$
3) $100\ N/m^2$ 4) 100 Nm

S.P.Q. Student Practice Questions

39. A spring of spring constant $5x10^3$ N stretched initially by 5cm from unstretched position. Then the w required to stretch it further by anot 5cm is.

1) 6.25Nm 2) 12.50Nm
3) 18.75Nm 4) 25Nm

40. A spring with spring constant K w stretched through 1cm, the poten energy is U. If it is stretched by the potential energy will be

1) 4U 2) 8U 3) 16U 4)

WORK ENERGY THEOREM BY CONSTANT FORCE

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

C.R.T.Q Class Room Teaching Questions

A body of mass 2 kg is projected with an initial velocity of 5 ms^{-1} along a rough horizontal table. The work done on the body by the frictional forces before it is brought to rest is

1) 250 J 2) 25 J 3) -250 J 4) -25 J

An object is acted on by a retarding force of 10 N and at a particular instant its kinetic energy is 6 J. The object will come to rest after it has travelled a distance of

1) 3/5 m 2) 5/3 m 3) 4 m 4) 16 m

By applying the brakes without causing a skid, the driver of a car is able to stop his car with in a distance of 5 m, if it is going at 36 kmph. If the car were going at 72 kmph, using the same brakes, he can stop the car over a distance of

1) 10 m 2) 2.5 m 3) 20 m 4) 40 m

A bullet fired into a trunk of a tree loses 1/4 of its kinetic energy in travelling a distance of 5 cm. Before stopping it travels a further distance of

1) 150 cm 2) 1.5 cm 3) 1.25 cm 4) 15 cm

S.P.Q. Student Practice Questions

A body moving with a kinetic energy of 6J comes to rest at a distance of 1m due to a retarding force of

1) 4 N 2) 6 N 3) 5 N 4) 8 N

A ship of mass 3×10^7 kg initially at rest is pulled by a force of 5×10^4N through a distance of 3 meters. Assuming that the resistance due to water is negligible, the speed of the ship is

1) 0.1m/s 2) 1.5 m/s 3) 5m/s 4) 60 m/s

A vehicle of mass 1000 kg is moving with a velocity of 15 ms^{-1} .It is brought to rest by applying brakes and locking the wheels. If the sliding friction between the tyres and the road is 6000N, then the distance moved by the vehicle before coming to rest is

1) 37.5 m 2) 18.75 m
3) 75 m 4) 15 m

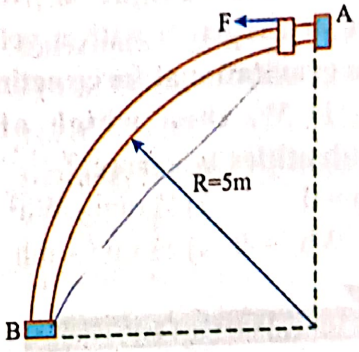
48. The workdone to accelerate a body from 30 ms^{-1} to 60 ms^{-1} is three times the work done to accelerate it from 10 ms^{-1} to 'v' . The value of 'v'in ms^{-1} is

1) 30 2) $20\sqrt{2}$ 3) $30\sqrt{3}$ 4) $10\sqrt{10}$

WORK ENERGY THEOREM FOR VARIABLE FORCE

C.R.T.Q Class Room Teaching Questions

49. A bead of mass $\frac{1}{2}kg$ starts from rest from "A" to move in a vertical plane along a smooth fixed quarter ring of radius 5m, under the action of a constant horizontal force F = 5 N as shown. The speed of bead as it reaches point "B" is



1) 14.14 m/s 2) 7.07 m/s
3) 5 m/s 4) 25 m/s

S.P.Q. Student Practice Questions

50. A block of mass 4 kg is initially at rest on a horizontal frictionless surface. A horizontal force $\vec{F}=(3+x)\hat{i}$ newtons acts on it, when the block is at x=0. The maximum kinetic energy of the block between x=0 and x=2m is

1) 6J 2) 8J 3) 9J 4) 10J

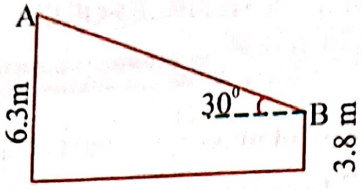
CONSERVATION OF MECHANICAL ENERGY

C.R.T.Q Class Room Teaching Questions

51. A cradle is 'h' meters above the ground at the lowest position and 'H' meters when it is at the highest point. If 'v' is the maximum speed of the swing of total mass 'm' the relation between 'h' and 'H' is

1) ½ mv^2 + h = H 2) $(v^2/2g)$ + h = H
3) (v^2/g) + 2h = H 4) $(v^2/2g)$ + H = h

52. AB is a frictionless inclined surface making an angle of 30^0 with horizontal. A is 6.3 m above the ground while B is 3.8 m above the ground. A block slides down from A, initially starting from rest. Its velocity on reaching B is



1) 7 m s^{-1} 2) 14 m s^{-1}
3) 7.4 m s^{-1} 4) 4.9 m s^{-1}

53. A stone of mass "m" initially at rest and dropped from a height "h" strikes the surface of the earth with a velocity "v". If the gravitational force acting on the stone is W, then which of the following identities is correct?

1) $mv - mh = 0$ 2) $\frac{1}{2}mv^2 - Wh^2 = 0$
3) $\frac{1}{2}mv^2 - Wh = 0$ 4) $\frac{1}{2}mv^2 - mh = 0$

S.P.Q. Student Practice Questions

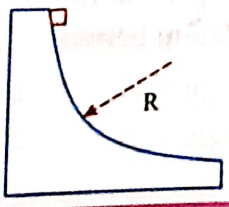
54. A block of mass 4 kg slides on a horizontal frictionless surface with a speed of 2m/s. It is brought to rest in compressing a spring in its path. If the force constant of the spring is 400 N/m, by how much the spring will be compressed

1) 2×10^{-2}m 2) 0.2m 3) 20 m 4) 200m

55. At what height above the ground must a mass of 5 kg be to have its PE equal in value to the KE possessed by it when it moves with a velocity of 10 m/s? ($g=10$ m/s^2)

1) 1m 2) 5m 3) 10m 4) 50m

56. A body slides down a fixed curved track that is one quadrant of a circle of radius R, as in the figure. If there is no friction and the body starts from rest, its speed at the bottom of the track is



1) 5gR 2) $\sqrt{5gR}$
3) $\sqrt{2gR}$ 4) $\sqrt{gR}$

POWER

C.R.T.Q Class Room Teaching Questio

57. A motor boat is going in a river wi velocity $\vec{V}=(4\hat{i}-2\hat{j}+\hat{k})ms^{-1}$. If resisting force due to str is $\vec{F}=(5\hat{i}-10\hat{j}+6\hat{k})$ N, then the powe the motor boat is

1) 100 W 2) 50 W 3) 46 W 4) 2

58. Two riffles fire the same numbe bullets in a given interval of time. second fires bullets of mass twice fired by the first and with a velo that is half that of the first. The rati their powers is

1) 1 : 4 2) 4 : 1 3) 1 : 2 4) 1

59. A car weighing 1000 kg is going up incline with a slope of 2 in 25 at a ste speed of 18 kmph. If $g= 10$ ms^{-2}, power of its engine is

1) 4 kW 2) 50 kW 3) 625 kW 4) 25

60. A crane can lift up 10,000 kg of coal 1 hour from a mine of 180 m depth. the efficiency of the crane is 80 %, input power must be ($g = 10$ ms^{-2})

1) 5 kW 2) 6.25 kW
3) 50 kW 4) 62.5 kW

61. A man carries a load of 50 kg throug height of 40 m in 25 seconds. If power of the man is 1568 W, his mas

1) 5 kg 2) 1000 kg
3) 200 kg 4) 50 kg

62. An electric motor creates a tension 4500 newton in a hoisting cable reels it at the rate of 2m/s. What is power of the motor?

1) 15 kW 2) 9 kW
3) 225 W 4) 9000 kW

63. A juggler throws contineously balls at the rate of three in each second, each with a velocity of 10 ms^{-1}. If the mass of each ball is 0.05 kg his power is
1) 2 W 2) 50 W 3) 0.5 W 4) 7.5 W

S.P.Q. Student Practice Questions

64. An electric motor in a crane while lifting a load produces a tension of 4000 N in the cable attached to the load. If the motor is winding the cable at the rate of 3ms^{-1}, the power of the motor expressed in kilo watt units must be
1) 4 2) 3 3) 12 4) 6

65. An electric motor operates with an efficiency of 90%. A pump operated by the motor has an efficiency of 80%. The overall efficiency of the system is
1) 85% 2) 100% 3) 72% 4) 60%

66. A machine gun fires 420 bullets per minute. The velocity of each bullet is 300ms^{-1} and the mass of each bullet is 1gm. The power of the machine gun is
1) 315W 2) 315000W 3) 630W 4) 3150W

67. A 1 kg mass at rest is subjected to an acceleration of 5 m/s^2 and travels 40m. The average power during the motion is
1) 40W 2) 8W 3) 50W 4) 200W

68. If the power of the motor of a water pump is 3kW, then the volume of water in litres that can be lifted to a height of 10m in one minute by the pump is (g=10 ms^{-2})
1) 1800 2) 180 3) 18000 4) 18

69. A particle moves with a velocity $(5\hat{i}+3\hat{j}+6\hat{k})$ m/s under the influence of a constant force $(5\hat{i}+5\hat{j}+10\hat{k})$ N. The instantaneous power applied to the particle is
1) 100W 2) 40W 3) 140W 4) 170W

MOTION IN A VERTICAL CIRCLE

C.R.T.Q. Class Room Teaching Questions

70. A body of mass 2 kg attached at one end of light string is rotated along a vertical circle of radius 2 m. If the string can withstand a maximum tension of 140.6 N, the maximum speed with which the stone can be rotated is
1) 22 m/s 2) 44 m/s 3) 33 m/s 4) 11m/s

71. A pilot of mass m can bear a maximum apparent weight 7 times of mg. The aeroplane is moving in a vertical circle. If the velocity of aeroplane is 210 m/s while diving up from the lowest point of vertical circle, then the minimum radius of vertical circle should be
1) 375 m 2) 420 m 3) 750 m 4) 840 m

72. The length of a ballistic pendulum is 1 m and mass of its block is 0.98 kg. A bullet of mass 20 gram strikes the block along horizontal direction and gets embedded in the block. If block + bullet completes vertical circle of radius 1m, then the striking velocity of bullet is
1) 280m/s 2) 350m/s
3) 420m/s 4) 490m/s

73. A simple pendulum is oscillating with an angular amplitude 60°. If mass of bob is 50 gram, then the tension in the string at mean position is (g = 10ms^{-2})
1) 0.5 N 2) 1 N 3) 1.5 N 4) 2N

74. A body is moving in a vertical circle such that the velocities of body at different points are critical. The ratio of velocities of body at angular displacements 60° and 120° from lowest point is
1) $\sqrt{5}:\sqrt{2}$ 2) $\sqrt{3}:\sqrt{2}$ 3) $\sqrt{3}:1$ 4) $\sqrt{2}:1$

S.P.Q. Student Practice Questions

75. A body of mass m is rotated in a vertical circle of radius R by means of light string. If the velocity of body is $\sqrt{gR}$ while it is crossing highest point of vertical circle then the tension in the string at that instant is
1) 2mg 2) mg 3) $\frac{mg}{2}$ 4) Zero

76. A body of mass m is rotated in a vertical circle with help of light string such that velocity of body at a point is equal to critical velocity at that point. If T_1, T_2 be the tensions in the string when the body is crossing the highest and the lowest positions then the following relation is correct

1) T_2-T_1=6mg 2) T_2-T_1=4mg
3) T_2-T_1=3mg 4) T_2-T_1=2mg

77. A vehicle is travelling with uniform speed along a concave road of radius of curvature 19.6m. At lowest point of concave road if the normal reaction on the vehicle is three times its weight, the speed of vehicle is

1) 4.9m/s 2) 9.8m/s 3) 14.7m/s 4) 19.6m/s

78. A car is travelling along a flyover bridge which is a part of vertical circle of radius 10m. At the highest point of it the normal reaction on the car is half of its weight, the speed of car is

1) 7m/s 2) 10m/s 3) 14m/s 4) 20m/s

79. A very small particle rests on the top of a hemisphere of radius 20 cm. The smallest horizontal velocity to be given to it, if it has to leave the hemisphere without sliding down its surface ($g=9.8\ ms^{-2}$) is

1) $\sqrt{9.8}$ m/s 2) $\sqrt{4.9}$ m/s
3) $\sqrt{1.96}$ m/s 4) $\sqrt{3.92}$ m/s

ELASTIC AND INELASTIC COLLISIONS IN ONE DIMENSION

C.R.T.Q Class Room Teaching Questions

80. A 6 kg mass travelling at $2.5\ ms^{-1}$ collides head on with a stationary 4 kg mass. After the collision the 6 kg mass travels in its original direction with a speed of $1\ ms^{-1}$. The final velocity of 4 kg mass is

1) $1\ ms^{-1}$ 2) $2.25 ms^{-1}$ 3) $2\ ms^{-1}$ 4) $0\ ms^{-1}$

81. A body of mass 10 kg moving wi velocity of $5\ ms^{-1}$ hits a body of 1 gr rest. The velocity of the second b after collision, assuming it to perfectly elastic is

1) $10\ ms^{-1}$ 2) $5\ ms^{-1}$
3) $15\ ms^{-1}$ 4) $0.10\ ms^{-1}$

82. A block of mass 1 kg moving wit speed of $4\ ms^{-1}$, collides with anot block of mass 2 kg which is at rest. lighter block comes to rest at collision. The loss in KE of the syster

1) 8 J 2) 4×10^{-7} J 3) 4 J 4) 0

83. A marble going at a speed of $2\ ms^{-1}$ another marble of equal mass at rest. the collision is perfectly elastic, then velocity of the first marble after collisio

1) $4\ ms^{-1}$ 2) $0\ ms^{-1}$
3) $2\ ms^{-1}$ 4) $3\ ms^{-1}$

84. A massive ball moving with a speed collides head on with a fine ball havi mass very much smaller than the m of the first ball at rest. The collision elastic and then immediately after t impact, the second ball will move wi a speed approximately equal to

1) v 2) 2v 3) v/3 4) infinite

85. A 1 kg ball moving at 12 m/s collid head on with a 2 kg ball moving in t opposite direction at 24 m/s. T velocity of each ball after the impact, the coefficient of restitution is 2/3 is

1) -28 m/s ; -4 m/s 2) 28 m/s ; -4 m/s
3) 20 m/s ; 24 m/s 4) -20 m/s ; -4 m/

86. A 6 kg mass collides with a body at res After the collision, they travel togeth with a velocity one third the velocity of kg mass. The mass of the second body

1) 6 kg 2) 3 kg 3) 12 kg 4) 18 k

87. A body of mass 'm' moving at a constant velocity 'v' hits another body of the same mass moving with a velocity v/2 but in the opposite direction and sticks to it. The common velocity after collision is

1) v 2) v/4 3) 2v 4) v/2

88. An 8 gm bullet is fired horizontally into a 9 kg block of wood and sticks in it. The block which is free to move, has a velocity of 40 cm/s after impact. The initial velocity of the bullet is

1) 450 m/s 2) 450 cm/s
3) 220 m/s 4) 220 cm/s

89. A block of wood of mass 9.8 kg is suspended by a string. A bullet of mass 200 gm strikes horizontally with a velocity of $100\ ms^{-1}$ and gets embedded in it. The maximum height attained by the block is $(g = 10\ ms^{-2})$

1) 0.1 m 2) 0.2 m 3) 0.3 m 4) 0 m

S.P.Q. Student Practice Questions

90. A 15 gm bullet is fired horizontally into a 3 kg block of wood suspended by a string. The bullet sticks in the block, and the impact causes the block to swing 10 cm above the initial level. The velocity of the bullet nearly is (in ms^{-1})

1) 281 2) 326 3) 184 4) 58

91. A body of mass 20 gm is moving with a certain velocity. It collides with another body of mass 80 gm at rest. The collision is perfectly inelastic. The ratio of the kinetic energies before and after collision of the system is

1) 2 : 1 2) 4 : 1 3) 5 : 1 4) 3 : 2

92. A ball of 4 kg mass moving with a speed of $3\ ms^{-1}$ has a head on elastic collision with a 6 kg mass initially at rest. The speeds of both the bodies after collision are respectively

1) $0.6\ ms^{-1}, 2.4\ ms^{-1}$
2) $-0.6\ ms^{-1}, -2.4\ ms^{-1}$
3) $-0.6\ ms^{-1}, 2.4\ ms^{-1}$
4) $-0.6\ ms^{-1}, -2.4\ ms^{-1}$

93. A ping - pong ball strikes a wall with a velocity of $10\ ms^{-1}$. If the collision is perfectly elastic, find the velocity of ball after impact

1) $-20\ ms^{-1}$ 2) $-5\ ms^{-1}$
3) $1.0\ ms^{-1}$ 4) $-10\ ms^{-1}$

94. Two identical balls collide head on. The initial velocity of one is $0.75\ ms^{-1}$, while that of the other is $-0.43 ms^{-1}$. If the collision is perfectly elastic, then their respective final velocities are

1) $0.75 ms^{-1}; -0.43 ms^{-1}$
2) $-0.43 ms^{-1}; 0.75 ms^{-1}$
3) $-0.75 ms^{-1}; 0.43 ms^{-1}$
4) $0.43 ms^{-1}; 0.75 ms^{-1}$

95. A truck of mass 15 tons moving with $1\ ms^{-1}$ collides with a stationary truck of mass 10 tons and automatically connected to move together. The common velocity is

1) $1 ms^{-1}$ 2) $0 ms^{-1}$ 3) $0.4 ms^{-1}$ 4) $0.6 ms^{-1}$

96. In the above problem the total KE before collision is

1) 4500J 2) 7500J 3) 3000J 4) 0J

97. In the above problem loss of KE during collision is

1) 4500J 2) 7500J 3) 3000J 4) 0J

98. A bullet of mass 'x' moves with a velocity 'y', hits a wooden block of mass 'z' at rest and gets embedded in it. After collision, the wooden block and bullet moves with a velocity

1) $\frac{x}{x+z}y$ 2) $\frac{x+y}{x}y$ 3) $\frac{z}{x+y}y$ 4) $\frac{x+y}{z}y$

99. A railway truck of mass 16000kg moving with a velocity of $5 ms^{-1}$ strikes another truck of mass 4000kg at rest. If they move together after impact, their common velocity is

1) $2 ms^{-1}$ 2) $4 ms^{-1}$ 3) $6 ms^{-1}$ 4) $8 ms^{-1}$

COEFFICIENT OF RESTITUTION

C.R.T.Q Class Room Teaching Questions

100. A rubber ball drops from a height 'h'. After rebounding twice from the ground, it rises to h/2. The co - efficient of restitution is

1) $\frac{1}{2}$ 2) $\left(\frac{1}{2}\right)^{1/2}$ 3) $\left(\frac{1}{2}\right)^{1/4}$ 4) $\left(\frac{1}{2}\right)^{1/6}$

101. A body dropped freely from a height 'h' onto a horizontal plane, bounces up and down and finally comes to rest. The coefficient of restitution is e. The ratio of velocities at the beginning and after two rebounds is

1) 1 : e 2) e : 1
3) 1 : e^2 4) e^2 : 1

102. In the above problem, the ratio of times of two consecutive rebounds is

1) 1 : e 2) e : 1 3) 1 : e^2 4) e^2 : 1

103. In the above problem the ratio of distances travelled in two consecutive rebounds is

1) 1 : e 2) e : 1 3) 1 : e^2 4) e^2 : 1

104. A ball is dropped onto a horizontal floor. It reaches a height of 144 cm on the first bounce and 81 cm on the second bounce. The coefficient of restitution is

1) 0 2) 0.75 3) 81/144 4) 1

105. A ball is dropped onto a horizontal floor. It reaches a height of 144 cm on the first bounce and 81 cm on the second bounce. The height it attains on the third bounce is

1) 45.6 cm 2) 81 cm 3) 144 cm 4) 0 cm

S.P.Q. Student Practice Questions

106. A ball is dropped from height 'H' onto a horizontal surface. If the coefficient of restitution is 'e' then the total time after which it comes to rest is

1) $\sqrt{\frac{2H}{g}}\left(\frac{1-e}{1+e}\right)$ 2) $\sqrt{\frac{2H}{g}}\left(\frac{1+e}{1-e}\right)$

3) $\sqrt{\frac{2H}{g}}\left(\frac{1+e^2}{1-e^2}\right)$ 4) $\sqrt{\frac{2H}{g}}\left(\frac{1-e^2}{1+e^2}\right)$

107. A stationary body explodes into frag-ments of masses m_1 and m_2 momentum of one fragment is p, energy of explosion is

1) $\frac{p^2}{2(m_1+m_2)}$ 2) $\frac{p^2}{2\sqrt{m_1m_2}}$

3) $\frac{p^2(m_1+m_2)}{2m_1m_2}$ 4) $\frac{p^2}{2(m_1-m_2)}$

108. A ball falls from a height of 10m on horizontal plane. If the coefficient restitution is 0.4, then the velocity which it rebounds from the plane af second collision is

1) 2.24ms^{-1} 2) 5.6ms^{-1}
3) 2.8ms^{-1} 4) 0.9ms^{-1}

109. A ball is dropped from a height of 3m coefficient of restitution between surface and ball is 0.5, then the to distance covered by the ball before comes to rest is

1) 3m 2) 4m 3) 5m 4) 6m

110. A glass sphere of mass 5mg, falls from height of 3 meters on to a horizont surface. If the coefficient of restitution 0.5, then after the impact the sphere w rise to a height of

1) 0.075m 2) 0.75m 3) 7.5m 4) 75

111. A particle falls from a height 'h' upon fixed horizontal plane and rebounds. If is the coefficient of restitution, then t total distance travelled before it com to rest is

1) $h\left(\frac{1+e^2}{1-e^2}\right)$ 2) $h\left(\frac{1-e^2}{1+e^2}\right)$

3) $\frac{h}{2}\left(\frac{1-e^2}{1+e^2}\right)$ 4) $\frac{h}{2}\left(\frac{1+e^2}{1-e^2}\right)$

KEY

01)3	02)2	03)1	04)1	05)
06)3	07) 2	08) 3	09) 3	10)
11) 4	12) 1	13) 2	14) 2	15)
16)3	17) 2	18)4	19)4	20)

21)3	22)2	23)3	24)2	25)1
26) 4	27) 4	28) 1	29) 3	30) 4
31) 1	32) 2	33)1	34)1	35) 1
36) 2	37)3	38)2	39) 3	40) 3
41)4	42)1	43)3	44)4	45) 2
46) 1	47) 2	48) 4	49)1	50) 2
51)2	52)1	53) 3	54) 2	55) 2
56) 3	57)3	58)4	59)1	60)2
61)4	62)2	63)4	64) 3	65) 3
66) 1	67) 3	68) 1	69) 1	70)4
71) 3	72) 2	73)2	74) 4	75) 4
76) 1	77) 4	78) 1	79) 3	80) 2
81)1	82)3	83)2	84)2	85)1
86)3	87)2	88)1	89)2	90) 1
91) 3	92) 3	93) 4	94) 2	95) 4
96) 2	97) 3	98) 1	99) 2	100)3
101)3	102)1	103) 3	104) 2	105)1
106)2	107) 3	108) 1	109) 3	110)2
111) 1				

Hints & Solutions

1. $W = \vec{F}.\vec{S}$
2. $W = FS\cos\theta$
3. $W = \vec{F}.\vec{S} = FS = (M+m)g(n \times h_{each\ step})$
4. $W = \vec{F}.\vec{S} = \vec{F}.(\vec{r}_2 - \vec{r}_1)$
5. $\vec{S} = \vec{S}_x\hat{i} + \vec{S}_y\hat{j}$
   $= 4\hat{i} + 6\hat{j}$
   $W = \vec{F}.\vec{S}$
6. $W = \vec{F}.\vec{S} = FS\cos\theta$
7. $W = \vec{F}.\vec{S}$
8. $W = \vec{F}.\vec{S} = FS\cos\theta$ and $\theta = 90^0$
9. $W = \vec{F}.\vec{S} = FS = maS$
10. $W = U_i - U_f$; where $U_i = mgh_1$; $U_f = mgh_2$; $\therefore$ W $= mg(h_1 - h_2)$
11. $W = \vec{F}.\vec{S} = FS_{com}$; where $F = mg$ and $S_{com} = \frac{L}{2}$
12. $W = \vec{F}.\vec{S} = FS\cos\theta$
13. $W = \vec{F}.\vec{S} = FS\cos\theta$
    In lifting the weight $F = mg, \theta = 0^0$;
    in holding the weight, $S = 0$
14. $W = \frac{1}{2}mv_f^2$;
15. $W = -mgh = -\frac{1}{2}mu^2$
16. $W = \int dw = \int_{x_1}^{x_2} F_x dx + \int_{y_1}^{y_2} F_y dy$
17. $W = \int_1^2 F\,dx$
18. At projection, $K = \frac{1}{2}mu^2$
    At maximum height, $K^1 = \frac{1}{2}mu^2\cos^2\theta$
19. $KE = \frac{1}{2}mv^2 = \frac{1}{2}m(gt)^2\ (\because v = gt)$
    $\frac{K_1}{K_2} = \frac{t_1^2}{t_2^2 - t_1^2}$ where t_1=5sec and t_2=10sec
20. $K.E_{mean} = P.E_{extreme} = mgl(1 - \cos\theta)$
21. $KE = \frac{1}{2}mv^2 = \frac{1}{2}mg^2t^2\ (\because v = gt)$
22. $KE = \frac{1}{2}mv^2 = \frac{1}{2}(\rho V)v^2; \frac{K.E}{V} = \frac{1}{2}\rho v^2$
23. $m_1v_1 = m_2v_2; KE = \frac{1}{2}m_2v_2^2$
24. $KE = \frac{1}{2}mv^2$, when two bodies reach the same height, $v_1 = v_2; \frac{KE_1}{KE_2} = \frac{m_1}{m_2}\ (\because v = \sqrt{2gh})$
25. $KE = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{s}{t}\right)^2$
26. $K = \frac{1}{2}Mv^2$ and $4K = \frac{1}{2}M(v+2)^2$
27. $\Delta KE = \frac{1}{2}m(v_1^2 - v_2^2)$, $v_2 = \frac{v_1}{2}$
28. $\Delta KE = W \Rightarrow KE_i = FS$

29. $K.E_f = K.E_i + P.E_i$

30. $\frac{KE}{V} = \frac{\frac{1}{2}mv^2}{V} = \frac{1}{2}\rho v^2$

31. $P = \sqrt{2mKE}$

$\left(\frac{P_2 - P_1}{P_1}\right) \times 100 = \left(\frac{\sqrt{KE_2} - \sqrt{KE_1}}{\sqrt{KE_1}}\right) \times 100$

32. $KE = \frac{1}{2}mv^2$, $KE' = \frac{1}{2}m'(v')^2$

$m' = \frac{3m}{4}, v' = 2v$

33. P.E=mgh$_1$; here $h_1 = \frac{h}{2}$ and $m = \rho \times V$

34. Heat produced = loss of potential energy = mgh

35. with 80% of available energy it can rise to height

$h' = 0.8h$

36. $W = JQ \Rightarrow mgh = JQ$ (1cal= 4.2J)

37. $U = \frac{1}{2}Kx_1^2 \Rightarrow K = \frac{2U}{x_1^2}$ and $F = Kx_2$

38. $U = \frac{1}{2}Kx^2$ --(1),U=50x²--(2), compare equation (1) and (2) to find K

39. $W = \frac{1}{2}K(x_2^2 - x_1^2)$

40. $U = \frac{1}{2}Kx^2 \Rightarrow \frac{U_1}{U_2} = \frac{x_1^2}{x_2^2}$

41. $W_f = \left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2\right)$

42. According to work energy theorem
W= Δ KE= -FS

43. $W = \Delta KE; \frac{\Delta KE_1}{\Delta KE_2} = \frac{W_1}{W_2} = \frac{FS_1}{FS_2}$

44. W= $\overline{F}.\overline{S} = \Delta KE$; $\frac{S_1}{S_2} = \frac{\Delta KE_1}{\Delta KE_2}$

45. $W = \Delta KE \Rightarrow KE_i = F_{ret}S$

46. W= $FS = \Delta KE$

47. W= $FS = \Delta KE$

48. $W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

49. Applying the work - energy theorem, we get

$\frac{1}{2} \times mv^2 - 0 = W_1 + W_2$

= Horizontal force × displaceme
Vertical force × displacement.

$\frac{1}{2}mv^2 = F \times R + mg \times R$

50. $\Delta KE = W = \int_{x_1}^{x_2} \vec{F}.\vec{dx}$

51. K.E at mean= P.E at extreme position

52. gain in K.E=Loss of P.E $= mg(h_1 - h_2)$

53. gain in K.E=Loss of P.E

54. K.E of block is converted into elastic P.
spring i.e $\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

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

56. Loss of P.E= gain in K.E ; $mgh = \frac{1}{2}mv^2$

57. $P = \vec{F}.\vec{V}$

58. $\frac{P_1}{P_2} = \left(\frac{m_1}{m_2}\right)\left(\frac{v_1^2}{v_2^2}\right)$

59. $P = \vec{F}.\vec{v} = Fv = mg\sin\theta \ v$

60. $\eta = \frac{P_{out}}{P_{in}}$, where $P_{out} = \frac{W}{t} = \frac{mgh}{t}$

61. $P = \frac{W}{t} = \frac{(m+M)gh}{t}$

62. $P_{inst} = \vec{F}.\vec{V} = FV\cos\theta$

63. $P = \frac{W}{t} = \frac{n\left(\frac{1}{2}mv^2\right)}{t}$

64. $P = \vec{F}.\vec{V}$

65. $\eta = \eta_1 \times \eta_2$

66. $P = \frac{W}{t} = \frac{n\left(\frac{1}{2}mv^2\right)}{t}$

67. $P_{avg} = \frac{W}{t} = \frac{FS}{t} = \frac{maS}{t}$; $v = \sqrt{2as}$,t =

68. $P = \frac{W}{t} = \frac{mgh}{t}$ and $m = V\rho$

69. $P = \vec{F}.\vec{V}$

70. $T_{max} = m\left(\frac{v^2}{r} + g\right)$

71. At lowest point of vertical circ

$T_{max} = \frac{mv^2}{r_{min}} + mg$

72. According to law of conservation of linear momentum mu=(M+m)v

$$u = \frac{(M+m)\sqrt{5gr}}{m}$$

73. $T = mg + \frac{mv^2}{r} = mg + \frac{m}{l}[2gl(1-\cos\theta)]$

74. $v = \sqrt{gR(3+2\cos\theta)}$

$$\Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{3+2\cos\theta_1}{3+2\cos\theta_2}}$$

75. Tension at the highest point

$$T = \frac{mv^2}{r} - mg \text{ where } v = \sqrt{gr}$$

76. $T_1 = \frac{mv_1^2}{r} - mg$, $T_2 = \frac{mv_2^2}{r} + mg$

$$v_2^2 - v_1^2 = 4gr, v_1 = \sqrt{gr}$$

77. Normal reaction, $N = mg + \frac{mv^2}{r}$;Given N=3mg

78. Normal reaction, $N = mg - \frac{mv^2}{r}$

Given that $N = \frac{mg}{2}$

79. $V_{min} = \sqrt{rg}$

80. According to law of conservation of linear momentum, $m_1u_1+m_2u_2=m_1v_1+m_2v_2$

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

82. $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$\Delta KE = \frac{1}{2}m_1u_1^2 - \frac{1}{2}m_2v_2^2$$

83. $\vec{v}_1 = \left(\frac{m_1-m_2}{m_1+m_2}\right)\vec{u}_1 + \left(\frac{2m_2}{m_1+m_2}\right)\vec{u}_2$

velocities interchange

84 $m_2 <<< m_1$ and

$$\vec{v}_2 = \left(\frac{2m_1}{m_1+m_2}\right)\vec{u}_1 + \left(\frac{m_2-m_1}{m_1+m_2}\right)\vec{u}_2$$

85. $\vec{v}_1 = \left(\frac{m_1-em_2}{m_1+m_2}\right)\vec{u}_1 + \left(\frac{m_2(1+e)}{m_1+m_2}\right)\vec{u}_2$

$$\vec{v}_2 = \left(\frac{m_1(1+e)}{m_1+m_2}\right)\vec{u}_1 + \left(\frac{m_2-em_1}{m_1+m_2}\right)\vec{u}_2$$

86. $m_1u_1 + m_2u_2 = (m_1+m_2)v$

87. $m_1u_1 - m_2u_2 = (m_1+m_2)v$

88. $mu = (m+M)v$

89. $mu = (m+M)v$ and $h = \frac{v^2}{2g}$

90. $mu = (m+M)v$ and $h = \frac{v^2}{2g}$

91. $m_1u_1=(m_1+m_2)v$

$$KE_i = \frac{1}{2}m_1u_1^2;\ KE_f = \frac{1}{2}(m_1+m_2)v^2$$

92. $\vec{v}_1 = \left(\frac{m_1-m_2}{m_1+m_2}\right)\vec{u}_1 + \left(\frac{2m_2}{m_1+m_2}\right)\vec{u}_2$

$$\vec{v}_2 = \left(\frac{2m_1}{m_1+m_2}\right)\vec{u}_1 + \left(\frac{m_2-m_1}{m_1+m_2}\right)\vec{u}_2$$

93. $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

94. After the head on collision between identical bodies velocities interchange

95. $\vec{v} = \frac{m_1\vec{u}_1 + m_2\vec{u}_2}{m_1+m_2}$;

96. $KE_{before} = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$

97. Loss in $KE = KE_{before} - KE_{after} = \frac{m_1m_2}{m_1+m_2}(u_1-u_2)^2$

98. $\vec{v} = \frac{m_1\vec{u}_1 + m_2\vec{u}_2}{m_1+m_2}$

99. $\vec{v} = \frac{m_1\vec{u}_1 + m_2\vec{u}_2}{m_1+m_2}$

100. $h_n = e^{2n}h$ 101. $V_n = e^{n}V$

102. $t_n = e^n t$

103. $h_n = e^{2n}h$ 104. $e = \sqrt{\frac{h_2}{h_1}}$

105. $h_n = e^{2n}h$

106. $t = \sqrt{\frac{2h}{g}} + 2\sqrt{\frac{2h_1}{g}} + 2\sqrt{\frac{2h_2}{g}} + \cdots$ and $h_n = e^{2n}h$

107. $E = E_1 + E_2 = \frac{p_1^2}{2m_1} + \frac{p_2^2}{2m_2}$

108. $v_n = e^n v$ where $v = \sqrt{2gh}$

109. $d = h\left(\frac{1+e^2}{1-e^2}\right)$

110. $h_n = e^{2n} h$

111. $d = h + 2h_1 + 2h_2 + \text{——}$ and $h_n = e^{2n} h$

EXERCISE - II

CRTQ & SPQ - LEVEL-II

WORK DONE BY CONSTANT FORCE

C.R.T.Q Class Room Teaching Questions

1. A body of mass 5 kg is moved up over 10 m along the line of greatest slope of a smooth inclined plane of inclination 30° with the hori-zontal. If $g = 10\ m/s^2$, the work done will be

1) 500 J 2) 2500 J 3) 250 J 4) 25 J

2. A particle of mass 0.5 kg is displaced from position $\vec{r}_1(2,3,1)$ to $\vec{r}_2(4,3,2)$ by applying a force of magnitude 30 N which is acting along $(\hat{i}+\hat{j}+\hat{k})$. The work done by the force is

1) $10\sqrt{3}$ J 2) $30\sqrt{3}$ J 3) 30 J 4) 40 J

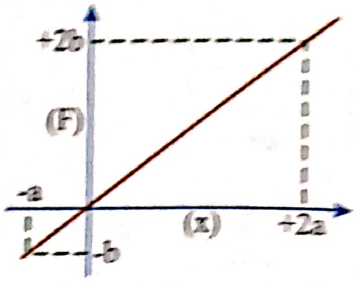
3. Kinetic energy of a particle moving in a straight line varies with time t as $K = 4t^2$. The force acting on the particle

1) is constant 2) is increasing
3) is decreasing
4) first increases and then decreases

4. A block of mass 5 kg initially at rest at the origin is acted upon by a force along the positive X - direction represented by
F=(20 +5x)N. Calculate the work done by the force during the displacement of the block from $x = 0$ to $x = 4$m.

1) 100 J 2) 150 J 3) 120 J 4) 75 J

5. A force F acting on a particle v[illegible] with the position x as shown in [illegible] graph. Find the work done by the fo[illegible] in displacing the particle from $x = -$[illegible] x=+2a



1) $\frac{3ab}{2}$ 2) $\frac{4ab}{2}$ 3) $\frac{2}{3ab}$ 4) $\frac{2}{4ab}$

6. A force $\vec{F} = (2\hat{i}+3\hat{j}-4\hat{k})N$ acts on particle which is constrained to move [illegible] the XOY plane along the line x = y. If [illegible] particle moves $5\sqrt{2}m$, the work done [illegible] force in joule is

1) $25\sqrt{2}$ 2) $5\sqrt{58}$ 3) 25 4) [illegible]

7. Two forces each of magnitude 10 N a[illegible] simultaneously on a body with the directions inclined to each other at a angle of 120° and displaces the bo[illegible] over 10 m along the bisector of [illegible] angle between the two forces. Then [illegible] work done by each force is

1) 5 J 2) 1 J 3) 50 J 4) 100 [illegible]

8. 'n' identical cubes each of mass 'm' a[illegible] edge 'L' are on a floor. If the cubes a[illegible] to be arranged one over the other in vertical stack, the work to be done is

1) Lmng (n-1)/2 2) Lg(n-1)/mn
3) (n-1)/Lmng 4) Lmng/2(n-1)

9. A chain of mass m and length 'L' is ov[illegible] hanging from the edge of a smoo[illegible] horizontal table such that 3/4 th of its leng[illegible] is lying on the table. The work done [illegible] pulling the chain completely on to the table

1) mgL/16 2) mgL/32 3) 3mgL/32 4) mg[illegible]

10. A bicycle chain of length 1.6 m and [illegible] mass 1 kg is lying on a horizontal floo[illegible] If $g=10ms^{-2}$, the work done in lifting [illegible] with one end touching the floor and [illegible] other end 1.6 m above the floor is

1) 10 J 2) 3.2 J 3) 8 J 4) 16 [illegible]

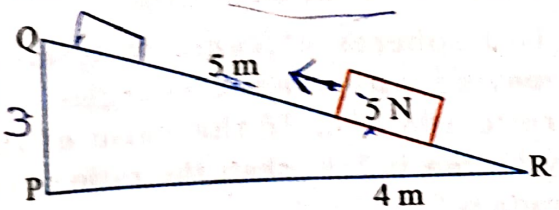
S.P.Q. Student Practice Questions

11. A bucket of mass 'm' tied to a light rope is lowered at a constant acceleration of g/4. If the bucket is lowered by a distance 'd', the work done by the rope will be (neglect the mass of the rope)

1) $\frac{1}{4}mgd$ 2) $\frac{3}{4}mgd$

3) $-\frac{3}{4}mgd$ 4) $-\frac{5}{4}mgd$

12. A weight of 5 N is moved up a frictionless inclined plane from R to Q as shown.



What is the work done in joules?

1) 15 2) 20 3) 25 4) 35

13. A 5 kg stone of relative density 3 is resting at the bed of a lake. It is raised through a height of 5 m in the lake. If $g = 10\ m/s^2$, then work done is

1) $\frac{500}{3}J$ 2) $\frac{350}{3}J$ 3) $\frac{750}{3}J$ 4) $\frac{550}{3}J$

14. Water is drawn from a well in a 5 kg drum of capacity 55 L by two ropes connected to the top of the drum. The linear density of each rope is 0.5 kgm^{-1}. The work done in lifting water to the ground from the surface of water in the well 20 m below is ($g = 10\ ms^{-2}$)

1) 1.4×10^4J 2) 1.5×10^4J

3) $9.8\times6\times10$ J 4) 18 J

15. A ball is dropped from the top of a tower.The ratio of work done by force of gravity in 1st, 2nd, and 3rd second of the motion of ball is

1) 1:2:3 2) 1:4:16 3) 1:3:5 4) 1:9:25

16. A plate of mass m, breadth 'a' and length 'b'is initially lying on a horizontal floor with length parallel to the floor and breadth perpendicular to the floor. The work done to erect it on its breadth is

1) $mg\frac{b}{2}$ 2) $mg\left(a+\frac{b}{2}\right)$

3) $mg\left(\frac{b-a}{2}\right)$ 4) $mg\left(\frac{b+a}{2}\right)$

17. A block of mass 10 kg slides down a rough slope which is inclined at 45° to the horizontal. The coefficient of sliding friction is 0.30. When the block has to slide 5 m, the work done on the block by the force of friction is nearly

1)115J 2)-75$\sqrt{2}$ J 3) 321.4J 4) -321.4 J

18. A uniform rope of length 'L and linear density 'μ' is on a smooth horizontal table with a length 'ℓ' lying on the table. The work done in pulling the hanging part on to the table is

1) $\frac{\mu g(L-l)^2}{2}$ 2) $\frac{\mu g(L-l)^2}{2l^2}$

3) $\frac{\mu g(L-l)^2}{2L^2}$ 4) $\frac{\mu gL}{2(L-l)}$

19. A uniform rod of mass 2 kg and length l is lying on a horizontal surface. If the work done in raising one end of the rod through an angle 45° is 'W', then the work done in raising it further 45° is

1) W 2) $\sqrt{2}W$ 3) $\frac{W}{\sqrt{2}}$ 4) $(\sqrt{2}-1)W$

WORK DONE BY VARIABLE FORCE

C.R.T.Q Class Room Teaching Questions

20. A body is displaced from (0,0) to (1m, 1m) along the path x = y by a force $F = \left(x^2\hat{j} + y\hat{i}\right)$N. The work done by this force will be

1) $\frac{4}{3}J$ 2) $\frac{5}{6}J$ 3) $\frac{3}{2}J$ 4) $\frac{7}{5}J$

21. A particle moves under the effect of a force F = C x from x = 0 to x = x_1. The work done in the process is (treat C as a constant)

1) C^2 / x_1^2 2) Cx_1^2
3) $\frac{1}{2} Cx_1^2$ 4) $\frac{1}{2} C^2/x_1^2$

22. Under the action of a force, a 2 kg body moves such that its position 'x' in meters as a function of time 't' in seconds given by: $x = t^2/2$. The work done by the force in the first 5 seconds is

1) 2.5 J 2) 0.25 J 3) 25 J 4) 250 J

23. A body of mass 5 kg at rest under the action of a force which gives its velocity given by v = 3×t m/s, here 't' is time in seconds. The work done by the force in two seconds will be

1) 90 J 2) 45 J 3) 180 J 4) 30 J

S.P.Q. Student Practice Questions

24. A block is constrained to move along x-axis under a force F = - (2x)N. Find the work done by the force when the block is displaced from x = 2m to x = 4m

1)12J 2)8J 3)-12J 4)-8J

25. A force of $(4x^2+3x)$N acts on a particle which displaces it from x=2m to x= 3m. The work done by the force is

1)32.8J 2) 3.28J 3) 0.328J 4) Zero

26. A body of mass 6kg is under a force which causes a displacement in it which is given by $S = \frac{t^2}{4} m$, where 't' is time. The work done by the force in 2sec is

1)12J 2)9J 3)6J 4)3J

KINETIC ENERGY

C.R.T.Q Class Room Teaching Questions

27. A body freely falls from a certain height onto the ground in a time 't'. During the first one third of the interval it gains a kinetic energy ΔK_1 and during the last one third of the interval, it gains a kinetic energy ΔK_2. The ratio $\Delta K_1 : \Delta K_2$ is

1) 1 : 1 2) 1 : 3 3) 1 : 4 4) 1 : 5

28. A man has twice the mass of a boy has half the kinetic energy of the The ratio of the speeds of the man the boy must be

1) 2 : 1 2) 4 : 1 3) 1 : 4 4) 1:

29. The speed of a car changes from 0 ms^{-1} in the first phase and from 5 m 10 ms^{-1} in the second phase and 10 ms^{-1} to 15 ms^{-1} during the t phase. In which phase the increas kinetic energy is more?

1) first phase
2) second phase
3) third phase
4) same in all the three phases

30. Two spheres of same material moving with kinetic energies in ratio 108:576. If the ratio of th velocities is 2:3 , then the ratio of th radii is

1)1:1 2)2:3 3)3:4 4) 4

S.P.Q. Student Practice Questions

31. If the momentum of a body decreases 30%, then kinetic energy decreases b

1) 60% 2) 51% 3) 69% 4) 9

32. If the mass of a moving body decrea by one third of its initial mass a velocity is tripled, then the percent change in its kinetic energy is

1)500% 2) 600% 3) 300% 4) 20

33. The kinetic energy of a projectile at highest point of its path is found to 3/4th of its initial kinetic energy. If th body is projected from the ground, angle of projection is

1) 0^0 2) 30^0 3) 60^0 4) 40^0

34. The kinetic energy of a moving body given by $k = 2v^2$, k being in joules and in m/s. It's momentum when travelli with a velocity of 2 m/s will be (in kgms

1)16 2) 4 3) 8 4) 2

POTENTIAL ENERGY

C.R.T.Q Class Room Teaching Questions

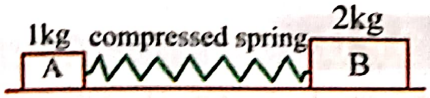
35. A rubber ball falling from a height of 5m rebounds from a hard floor to a height of 3.5m. The % loss of energy during the impact is

1) 20% 2) 30% 3) 43% 4) 50%

36. When a long spring is stretched by x cm, its P.E is U. If the spring is stretched by Nx cm, the P.E stored in it will be

1) $\frac{U}{N}$ 2) NU 3) N^2U 4) $\frac{U}{N^3}$

37. An elastic spring is compressed between two blocks of masses 1 kg and 2 kg resting on a smooth horizontal table as shown. If the spring has 12J of energy and suddenly released, the velocity with which the larger block of 2 kg moves will be



1) 2 m/s 2) 4 m/s
3) 1 m/s 4) 8 m/s

S.P.Q. Student Practice Questions

38. A block of mass 2 kg is on a smooth horizontal surface. A light spring of force constant 800 N/m has one end rigidly attached to a vertical wall and lying on that horizontal surface. Now the block is moved towards the wall compressing the spring over a distance of 5 cm and then suddenly released. By the time the spring regains its natural length and looses contact with the block, the velocity acquired by the block will be

1) 200m/s 2) 100 m/s 3) 2m/s 4) 1m/s

39. A simple pendulum is swinging in vertical plane. The ratio of its potential energy when it is making 45° and 90° with the vertical is

1) 1:1 2) $1:(\sqrt{2}+1)$
3) $\sqrt{2}:1$ 4) $(\sqrt{2}-1):\sqrt{2}$

WORK ENERGY THEOREM FOR CONSTANT FORCE

C.R.T.Q Class Room Teaching Questions

40. A bullet of mass 10gm is fired horizontally with a velocity $1000ms^{-1}$ from a riffle situated at a height 50 m above the ground. If the bullet reaches the ground with a velocity $500ms^{-1}$, the work done against air resistance in the trajectory of the bullet is (in joule) $(g=10ms^{-2})$

1) 5005 2) 3755 3) 3750 4) 17.5

41. A drop of mass 1.00 g falling from a height 1.00 km. It hits the ground with a speed of $50.0ms^{-1}$. What is the work done by the unknown resistive force?

1) -8.75J 2) 8.75J 3) -4.75J 4) 4.75J

42. A block of mass 5 kg is initially at rest on a rough horizontal surface. A force of 45 N acts on it in a horizontal direction and pushes it over a distance of 2 m. The force of friction acting on the block is 25 N. The final kinetic energy of the block is

1) 40 J 2) 90 J 3) 50J 4) 140 J

43. A bullet of mass 'm' is fired with a velocity 'v' into a fixed log of wood and penetrates a distance 's' before coming to rest. Assuming that the path of the bullet in the log of wood is horizontal, the average resistance offered by the log of wood is

1) $\frac{mv}{2s^2}$ 2) $\frac{mv^2}{2s}$ 3) $\frac{2s}{mv^2}$ 4) $\frac{ms^2}{2v}$

44. A ball of mass 'm' is thrown in air with speed v_1 from a height h_1 and it is caught at a height $h_2 > h_1$ when its speed becomes v_2. Find the work done on the ball by air resistance.

1) $mg(h_2-h_1)+\frac{1}{2}m(v_2^2-v_1^2)$

2) $mg(h_2-h_1)$ 3) $\frac{1}{2}m(v_2^2-v_1^2)$

4) $mg(h_2-h_1)-\frac{1}{2}m(v_2^2-v_1^2)$

S.P.Q. Student Practice Questions

45. An object of mass 5 kg falls from rest through a vertical distance of 20 m and attains a velocity of 10 m/s. How much work is done by the resistance of the air on the object ($g = 10\ m/s^2$)

1)750 J 2)– 750 J 3) 850 J 4)- 650 J

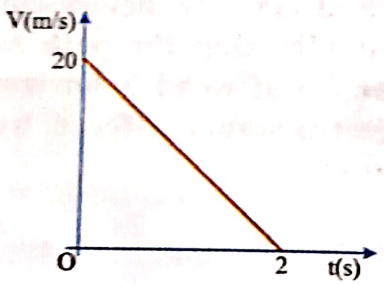
46. The velocity of a 2 kg body is changed from $(4\hat{i}+3\hat{j})$ ms^{-1} to 6 ms^{-1}. The work done on the body is

1)9 J 2)11 J 3)1 J 4) 5 J

47. An out fielder throws a cricket ball with an initial kinetic energy of 800J and an infielder catches the ball when its kinetic energy is 600J. If the path of the ball between them is assumed straight and is 20m long, the air resistance acting on the ball is

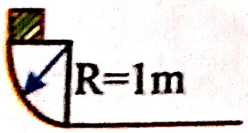
1) 26.6N 2) 1.33N 3) 100N 4)10N

48. Velocity -time graph of a particle of mass 2kg moving in a straight line is as shown in the figure. Work done by all the forces on the particle is



1)400J 2)-400J 3)-200J 4)200J

49. A block of mass of 1kg slides down a curved track that is one -quadrant of circle of radius 1m. Its speed at the bottom is 2m/s. The workdone by the frictional force is



1) 8J 2) -8J 3) 4J 4) -4J

WORK ENERGY THEOREM FOR VARIABLE FORCE

C.R.T.Q Class Room Teaching Questions

50. A block of mass 2 kg is initially at r on a horizontal frictionless surface, horizontal force $\vec{F} = (9-x^2)\vec{i}$ newt acts on it, when the block is at x = The maximum kinetic energy of t block between x = 0m and x = 3 m joule is

1) 24 2) 20 3) 18 4) 15

51. A block of mass 4kg is initially at rest a horizontal frictionless surface. A for $\vec{F}=(2x+3x^2)\hat{i}\ N$ acts horizontally on The maximum kinetic energy of the bl between x=2m and x=4m in joules is

1) 40 2) 36 3) 68 4) 5

S.P.Q. Student Practice Questions

52. A force $F=Ay^2+By+C$ acts on a body a rest in the Y-direction. The kinetic energy of the body during a displacem y = - a to y = a is

1) $\frac{2Aa^3}{3}$ 2) $\frac{2Aa^3}{3}+2ca$

3) $\frac{2Aa^3}{3}+\frac{Ba^2}{2}+ca$ 4) $\frac{2Aa^3}{3}+\frac{Ba^2}{2}$

CONSERVATION OF MECHANIC ENERGY

C.R.T.Q Class Room Teaching Questions

53. A freely falling body takes 4s to reach t ground. One second after release, t percentage of its potential energy, th is still retained is

1) 6.25% 2) 25% 3) 37.5% 4) 93.7

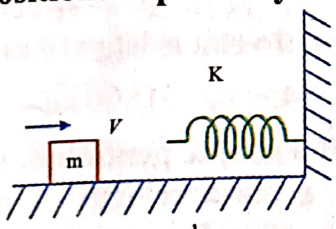
54. A vertically projected body attains t maximum height in 6s. The ratio kinetic energy at the end of 3rd second decrease in kinetic energy in the la three seconds is

1) 1: 1 2) 1 : 3 3) 3 : 1 4) 9:

55. 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 the 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:

1) $v\sqrt{\frac{m}{2k}}$ 2) $m\sqrt{\frac{v}{2k}}$ 3) $\sqrt{\frac{mv}{2k}}$ 4) $\frac{mv}{2k}$

56. A block of mass m=25kg on a smooth horizontal surface with a velocity $\vec{v}=3ms^{-1}$ meets the spring of spring constant k = 100 N/m fixed at one end as shown in figure. The maximum compression of the spring and velocity of block as it returns to the original position respectively are



1) $1.5m, -3ms^{-1}$ 2) $1.5m, 0ms^{-1}$

3) $1.0m, 3ms^{-1}$ 4) $0.5m, 2ms^{-1}$

57. A body is thrown vertically up with certain initial velocity, the potential and kinetic energies of the body are equal at a point P in its path. If the same body is thrown with double the velocity upwards, the ratio of potential and kinetic energies of the body when it crosses the same point, is

1) 1:1 2) 1:4 3) 1:7 4) 1:8

S.P.Q. Student Practice Questions

58. A 3kg model rocket is launched straight up with sufficient initial speed to reach a maximum height of 100 m, even though air resistance (a non-conservative force) performs - 900 J of work on the rocket. The height the rocket would have gone without air resistance will be

1) 70 m 2) 130 m 3) 180 m 4) 230 m

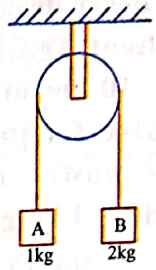
59. A simple pendulum bob has a mass "m" and length "L". The bob is drawn aside such that the string is horizontal and then it is released. The velocity of the bob while it crosses the equilibrium position is

1) $\sqrt{gL}$ 2) $\sqrt{2gL}$ 3) $\sqrt{5gL}$ 4) $\sqrt{3gL}$

60. A 100 gm light bulb dropped from a tower reaches a velocity of 20 m/s after falling through 100 m. The energy transferred to the air due to viscous force is

1) 98 J 2) 20 J 3) 118 J 4) 78 J

61. In the arrangement shown in figure, string is light and inextensible and friction is absent every where .The speed of both blocks after the block 'A' has ascend a height of 1m will be ($g=10m/s^2$)



1)2m/s 2) 2.58m/s 3) 3m/s 4) 3.58 m/s

POWER

C.R.T.Q Class Room Teaching Questions

62. A machine rated as 150W, changes the velocity of a 10kg mass from $4\,ms^{-1}$ to $10\,ms^{-1}$ in 4s. The efficiency of the machine is nearly

1) 70% 2) 30% 3) 50% 4) 40%

63. A pump is required to lift 600 kg of water per minute from a well 25m deep and to eject it with a speed of $50\,ms^{-1}$. The power required to perform the above task is

1) 10 kW 2) 15 kW 3) 20 kW 4) 25 kW

64. A tank on the roof of a 20 m high building can hold 10 m^3 of water. The tank is to be filled from a pond on the ground in 20 minutes. If the pump has an efficiency of 60 %, then the input power in kW is

1) 1.1 2) 2.74 3) 5.48 4) 7.0

65. An electric fan, with effective area of cross-section 'A', accelerates air of density 'ρ' to a speed 'v'. What is the power needed for this process?

1) ρ Av 2) ½ ρ Av 3) ρAv^2 4) ½ ρAv^3

66. A car drives along a straight level frictionless road by an engine delivering constant power. Then velocity is directly proportional to

1) t 2) $\frac{1}{\sqrt{t}}$ 3) $\sqrt{t}$ 4) t^2

S.P.Q. Student Practice Questions

67. The input power to an electric motor is 200kW. Its efficiency is 80%. It operates a crane of efficiency 90%. If the crane is lifting a load of 3.6 tonnes, the velocity with which the load moves is

1) 8 ms^{-1} 2) 4 ms^{-1} 3) 2 ms^{-1} 4) 40 ms^{-1}

68. The human heart discharges 75 cm^3 of blood per beat against an average pressure of 10 cm of Hg. Assuming that the pulse frequency is 75 per minute, the power of the heart is (density of Hg = 13.6 gm cm^{-3})

1) 1.25W 2) 12.5W
3) 0.125W 4)125W

69. An elevator can carry a maximum load of 1800kg(elevator+passengers) is moving up with a constant speed of 2m/s. The frictional force opposing the motion is 4000 N. Determine the minimum power delivered by the motor to the elevator(in horse power).

1) 59 2)8 3)22 4)20

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

1) $t^{\frac{1}{2}}$ 2) t 3) $t^{\frac{2}{3}}$ 4) t^2

71. A dam is situated at a height of 550 m above sea level and supplies water to a power house which is at a height of 50 m above sea level. 2000 kg of water passes through the turbines per second. What would be the maximum electrical power output of the power house if the whole system were 80% efficient

1) 8MW 2) 10MW 3) 12.5MW 4) 16MW

MOTION IN A VERTICAL CIRCLE

C.R.T.Q. Class Room Teaching Questi

72. A point size mass 100 gm is rotated vertical circle using a cord of le 20cm. When the string makes an 60° with the vertical , the speed of mass is 1.5m/s. The tange acceleration of the mass in that pos is (in ms^{-2})

1) 4.9 2) $4.9\sqrt{2}$ 3) $4.9\sqrt{3}$ 4) 9

73. A vehicle is travelling along conc road then along convex road of a radius of curvatures at uniform sp If the normal reactions on the vehi as it crosses the lowest point of conc surface, highest point of convex sur are $1.5\times10^4 N$, $3\times10^3 N$ respectiv then the mass of vehicle is(g=10 m/s

1) 400 kg 2) 450 kg 3) 800 kg 4) 90

74. The length of a simple pendulum is The bob is given a velocity 7 ms horizontal direction from mean posi During upward motion of bob, if string breaks when the bob is horizon then the maximum vertical heigh ascent of bob from rest position is

1) 2.5 m 2) 2 m 3) 3 m 4) 3

75. A body is allowed to slide dow frictionless track from rest position top under gravity. The track ends circular loop of diameter D. Then minimum height of the inclined trac terms of D) so that it may comp successfully the loop is

1) 7D/4 2) 9D/4 3) 5D/4 4) 3

76. A body of mass m is rotating vertical circle of radius 'r' with cri speed. The difference in its K.E. at top and at the bottom is

1) 2mgr 2) 4 mgr 3) 6 mgr 4) 3

77. A simple pendulum of length 'ℓ' carri bob of mass 'm'. If the breaking streng the string is 2 mg, the maximum ang amplitude from the vertical can be

1) 0° 2) 30° 3) 60° 4) 90

S.P.Q. Student Practice Questions

78. A stone tied to a string of length 'L' is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of the change in its velocity as it reaches a position, where the string is horizontal is

1) $\sqrt{u^2-2gL}$ 2) $\sqrt{2gL}$
3) $\sqrt{u^2-gL}$ 4) $\sqrt{2(u^2-gL)}$

79. A pilot of mass 'm' can withstand a maximum apparent weight 6 times of mg. The minimum radius of curvature of vertical circle in which the aeroplane dives up from lowest point with a speed 504 kmph is

1) 200 m 2) 300 m 3) 400 m 4) 500m

80. A simple pendulum is oscillating with an angular amplitude 90^0. If the direction of resultant acceleration of the bob is horizontal at a point where angle made by the string with vertical is

1) $\sin^{-1}\left(\frac{1}{3}\right)$ 2) $\cos^{-1}\left(\frac{1}{3}\right)$
3) $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$ 4) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$

81. A small block is freely sliding down from top of a smooth inclined plane. The block reaches bottom of inclined plane then the block describes a vertical circle of radius 0.5m along smooth track. The minimum vertical height of inclined plane should be

1) 1m 2) 1.25 m 3) 3m 4) 2.5 m

82. A stone of mass 6 kg is revolved in a vertical circle of diameter 6m., such that its speed is minimum at a point. If the K.E at the same point is 250 J, then minimum PE at that point is

1) 200J 2) 150J 3) 100J 4) 450J

83. The breaking strength of a string is 55 kg wt. The maximum permissible speed of a stone of mass 5 kg which is revolved in a vertical circle of radius 4m with the help of this string is ($g = 10m/s^2$)

1) 10m/sec 2)15m/sec
3) 20 m/sec 4)25m/sec

ELASTIC AND INELASTIC COLLISIONS

C.R.T.Q Class Room Teaching Questions

84. A body of mass 5kg moving with a speed of $3ms^{-1}$ collides head on with a body of mass 3kg moving in the opposite direction at a speed of $2ms^{-1}$. The first body stops after the collision. The final velocity of the second body is

1) $3ms^{-1}$ 2) $5ms^{-1}$ 3) $-9ms^{-1}$ 4) $30ms^{-1}$

85. Three identical particles moving with velocities, $v_0\hat{i}, -3v_0\hat{j}$ and $5v_0\hat{k}$ collide successively with each other in such a way that they form a single particle. The velocity of resultant particle in i, j, k form is

1) $v_0\left(\hat{i}-3\hat{j}+5\hat{k}\right)$ 2) $\frac{v_0}{3}\left(\hat{i}-3\hat{j}+5\hat{k}\right)$
3) $\frac{v_0}{2}\left(\hat{i}-3\hat{j}+5\hat{k}\right)$ 4) $\frac{v_0}{3}\left(\hat{i}+3\hat{j}+5\hat{k}\right)$

86. From the top of a tower of height 100m 'A' 10 gm block is dropped freely and a 6gm bullet is fired vertically upwards from the foot of the tower with velocity $100ms^{-1}$ simultaneously. They collide and stick together. The common velocity after collision is ($g=10ms^{-2}$)

1) $27.5ms^{-1}$ 2) $150ms^{-1}$
3) $40ms^{-1}$ 4) $100ms^{-1}$

87. A steel ball of radius 2cm is initially at rest. It is struck head on by another steel ball of radius 4cm travelling with a velocity of 81 cm/s. If the collision is elastic their respective final velocities are

1) 63 cm/s, 144 cm/s
2) 144 cm/s, 63 cm/s
3) 19 cm/s,100 cm/s 4) 100 cm/s, 19 cm/s

S.P.Q. Student Practice Questions

88. A steel ball of radius 2cm is initially at rest. It is struck head on by another steel ball of radius 4cm travelling with a velocity of 81cm/s. The common velocity if it is perfectly inelastic collision

1)144 cm/s 2) 61 cm/s
3) 81 cm/s 4) 72 cm/s

89. A 16 gm mass is moving in the +x direction at 30 cm/s while a 4 gm is moving in the -x direction at 50 cm/s. They collide head - on and stick together. Their common velocity after impact is

1) 0.14cm/s 2) 0.14 m/s
3) 0 ms^{-1} 4) 0.3 m/s

90. A bullet of mass 50 grams going at a speed of 200 ms^{-1} strikes a wood block of mass 950 gm and gets embedded in it. The velocity of the block after the impact is

1) 5 ms^{-1} 2) 10 ms^{-1}
3) 20 ms^{-1} 4) 50 ms^{-1}

91. A block of mass 1 kg moving with a speed of 4 ms^{-1}, collides with another block of mass 2 kg which is at rest. If the lighter block comes to rest after collision, then the speed of the heavier body is

1) 2 ms^{-1} 2)1 ms^{-1} 3)1.5 ms^{-1} 4) 0.5 ms^{-1}

COEFFICIENT OF RESTITUTION

C.R.T.Q Class Room Teaching Questions

92. A tennis ball bounces down a flight of stairs, striking each step in turn and rebounding to half of height of the step. The coefficient of restitution is

1) 1/2 2) $\frac{1}{\sqrt{2}}$ 3) $\left(\frac{1}{\sqrt{2}}\right)^{1/2}$ 4) $\left(\frac{1}{\sqrt{2}}\right)^{1/4}$

93. A ball hits the ground and loses 20% of its momentum. Coefficient of restitution is

1) 0.2 2) 0.4 3) 0.6 4) 0.8

S.P.Q. Student Practice Questions

94. A plastic ball falling from a height rebounds number of times. If total for second collision is2.4 sec, coefficient of restitution is

1) 0.3 2) 0.4 3) 0.7

95. A neutron travelling with a velo and kinetic energy E collides per elastically head on with the nucl an atom of mass number A at rest fraction of the total kinetic e retained by the neutron is

1) $\left(\frac{A-1}{A+1}\right)^2$ 2) $\left(\frac{A+1}{A-1}\right)^2$
3) $\left(\frac{A-1}{A}\right)^2$ 4) $\left(\frac{A+1}{A}\right)^2$

POTENTIAL ENERGY OF A SPRING

C.R.T.Q Class Room Teaching Questi

96. A spring of force constant 800 N stretched initially by 5 cm. The done in stretching from 5 cm to 15

1) 12.50 N-m 2) 18.75 N-m
3) 25.00 N-m 4) 6.25 N-m

97. When a spring is compressed distance 'x', the potential energy is U_1. It is further compressed distance '2x', the increase in pote energy is U_2. The ratio of $U_1:U_2$ is

1)1:7 2)1:4 3)1:8 4)1:

S.P.Q. Student Practice Questions

98. A massless spring with a force con K=40N/m hangs vertically from ceiling. A 0.2kg block is attach the end of the spring and held in position that the spring has its n length and suddenly released maximum elastic strain energy in the spring is(g=10m/s²)

1)0.1J 2)0.2J 3)0.05J 4)

01) 3 02)
06)3 07)
11) 3 12)
16) 3 17
21) 3 22
26)4 27
31)2 32
36)3 3
41)1 4
46)2 4
51)3 5
56)1
61)2
66)3
71)1
76)1
81) 2
86)1
91)1
96)3

1. $W = \vec{F}$ $\theta = 0°$
2. $F_x =$ $W =$
3. $\frac{1}{2}mv$ comp i.e., cons
4. W=
5. W =
6. $\vec{S}$
7. W=
8. U

WO

KEY

01) 3	02) 2	03) 1	04) 3	05) 1
06)3	07)3	08)1	09)2	10) 3
11) 3	12) 1	13) 1	14) 1	15) 3
16) 3	17) 2	18) 1	19)4	20)2
21) 3	22)3	23)1	24)3	25)1
26)4	27)4	28)4	29)3	30)3
31)2	32)1	33)2	34)3	35)2
36)3	37)1	38)4	39)4	40)2
41)1	42)1	43)2	44)1	45)2
46)2	47)4	48)2	49)2	50)3
51)3	52)2	53)4	54)1	55)1
56)1	57)3	58)2	59)2	60) 4
61)2	62)1	63)2	64)2	65)4
66)3	67)2	68)1	69)1	70) 2
71)1	72)3	73)4	74)1	75)3
76)1	77)3	78)4	79)3	80) 4
81) 2	82)1	83)3	84)1	85) 2
86)1	87)2	88)4	89)2	90)2
91)1	92)2	93)4	94)3	95)1
96)3	97)3	98)3		

Hints & Solutions

1. $W = \vec{F}.\vec{S}$ =FScosθ; here F=mgsinα and $\theta = 0^0, \alpha = 30^0$

2. $F_x = F\cos\alpha, F_y = F\cos\beta, F_z = F\cos\gamma,$
$W = F.S$

3. $\frac{1}{2}mv^2 = 4t^2$; $\therefore v = \sqrt{\frac{8}{m}}t$
comparing with v=at, a = constant
i.e., the force acting on the particle is constant

4. W=$\int_0^4 Fdx$

5. W = area under F - S curve.

6. $\vec{S} = 5\hat{i} + 5\hat{j}$, $W = \vec{F}.\vec{S}$

7. W= FS cos θ

8. $U_i = nmg\left(\frac{L}{2}\right), U_f = nmg\left(\frac{nL}{2}\right),$
$W = U_i - U_f$

9. $W = \frac{mgl}{2n^2}$

10. W=$\vec{F}.\vec{S} = FS\cos\theta$; here
F=mg; $S = \frac{l}{2}, \theta = 0^0$

11. W = $FS\cos\theta$ here F=m(g-a),S=h, $\theta = 180^0$

12. W = mgh

13. $W = mgh\left(1 - \frac{d_L}{d_B}\right)$

14. $W = Mgh + \rho_w Vgh + \left(mg\frac{h}{2}\right)2$

15. $W = FS \Rightarrow \frac{W_1}{W_2} = \frac{S_1}{S_2} = \frac{(2n-1)_1}{(2n-1)_2}$
$\left(\because S = u + a\left(n - \frac{1}{2}\right)\right)$

16. $W = mg(h_2 - h_1)$

17. $W = -f \times S = -\mu mg\cos\theta \times S$

18. $W = m^1gh = \mu(L-l)g\frac{(L-l)}{2}$
Where m¹ is mass of hanging part

19. $W_1 = W = mg\frac{l}{2}\sin\theta_1$ here $\theta_1 = 45^0$
$W_2 = mg\frac{l}{2}\sin\theta_2$ here $\theta_2 = 90^0$
required work $= W_2 - W_1$

20. $W = \int_{(0,0)}^{(1,1)} \vec{F}.\vec{ds}$;
Here $\vec{ds} = dx\hat{i} + dy\hat{j} + dz\hat{k}$
$\therefore W = \int_{(0,0)}^{(1,1)} (x^2dy + ydx)$
$= \int_{(0,0)}^{(1,1)} (y^2dy + x.dx)$
(as x = y)

21. $W = \int_0^{x_1} Fdx$

22. $W = \frac{1}{2}mv^2$ where $v = \frac{dx}{dt}$

23. $W = \frac{1}{2}mv^2$

24. $W = \int_{x_i}^{x_f} F(x)dx$

25. $W = \int_{x_i}^{x_f} F(x)dx$

26. $W = \frac{1}{2}mv^2 ; v = \frac{ds}{dt}$

27. $\Delta k_1 = \frac{1}{2}mg^2\left(\frac{t^2}{9}\right)\left(\because \Delta k = \frac{1}{2}mv^2 ; v = gt\right)$

$\Delta k_2 = \frac{1}{2}mg^2\left(t^2 - \frac{4t^2}{9}\right)$

28. $K.E_{man} = \frac{1}{2}\left(K.E_{boy}\right)$

$\frac{1}{2}Mu^2 = \frac{1}{2}\left(\frac{1}{2}mv^2\right)(\because M = 2m)$

29. $\Delta KE = \frac{1}{2}m\left(v^2 - u^2\right)$

30. $K = \frac{1}{2}mv^2 = \frac{1}{2}\rho\left(\frac{4}{3}\pi r^3\right)v^2$

31. $K = \frac{P^2}{2m} \Rightarrow \frac{K_1}{K_2} = \frac{P_1^2}{P_2^2}$

32. $K = \frac{1}{2}mv^2 \Rightarrow \frac{K_1}{K_2} = \frac{m_1v_1^2}{m_2v_2^2}$

33. $K.E_{top} = \frac{3}{4}\left(K.E_i\right)$;

$\frac{1}{2}m\left(u\cos\theta\right)^2 = \frac{3}{4}\left(\frac{1}{2}mu^2\right)$

34. $K = 2v^2 = \frac{1}{2}mv^2$ and $P = mv$

35. percentage loss of energy $= \frac{h_1 - h_2}{h_1} \times 100\%$

36. $U = \frac{1}{2}kx^2 \& U' = \frac{1}{2}K\left(Nx\right)^2$

37. $\frac{1}{2}Kx^2 = KE_1 + KE_2$ and $m_1v_1 = m_2v_2$

38. $\frac{1}{2}Kx^2 = \frac{1}{2}mv^2$

39. $U = mgl\left(1 - \cos\theta\right)$

40. By work energy theorem

$W = \left(mgh + \frac{1}{2}mu^2\right) - \frac{1}{2}mv^2$

41. Work done = $P.E_i$-$K.E_f$

42. $\Delta K = W$; $K.E_f - 0 = F_{net}S\cos\theta$

43. $W = F \times S = \Delta K.E$

44. $W_{mg} + W_{air} = \Delta K.E.$

45. $W_{mg} + W_{air} = \Delta K.E.$

46. Work done = change in kinetic energy

47. $W = -FS = K_2 - K_1$

48. $W = K_2 - K_1$

49. $W_{friction} = K.E_f - P.E_i$

50. $KE_{max} = w = \int_0^3 Fdx$

51. $K.E = W = \int_{x_i}^{x_f} F(x)dx$

52. $K.E = W = \int_{y_i}^{y_f} F(y)dy$

53. height of fall, $H_1 = \frac{1}{2}.g \times 4^2 = 8g$

After one second, body is at a height

$H_2 = 8g - \frac{1}{2}.g \times 1^2 = \frac{15g}{2}$

% of P.E retained $= \frac{H_2}{H_1} \times 100\%$

54. $t_a = \frac{u}{g} = 6 \Rightarrow u = 6g$

$KE : \Delta KE = \frac{1}{2}m\left(u - gt\right)^2 : \left(\frac{1}{2}m\left(u - gt\right)^2 - \right.$

55. mv =(m+m) v^1 and $\frac{1}{2}$ (m+m) $(v^1)^2$

kx^2

56. K.E of block is converted into elastic

in spring i.e $\frac{1}{2}mv^2 = \frac{1}{2}kx^2$

57. In first case, at 'P' ,TE=PE+KE=2PE and $TE_{bottom} = \frac{1}{2}mu^2$

In second case,

$TE^1_{bottom} = \frac{1}{2}m(2u)^2 = 4TE = 8PE$

At 'P', $\frac{PE^1}{KE^1} = \frac{PE^1}{TE^1 - PE^1} = \frac{PE}{8PE - PE}$

58. $mgh + W_f = mgH$

59. Loss of P.E= Gain in K.E ; $mgL = \frac{1}{2}MV^2$

60. $W = P.E_i - K.E_f$

61. $m_B gh = m_A gh + \frac{1}{2}m_A v^2 + \frac{1}{2}m_B v^2$

62. $\eta = \frac{P_0}{P_i} \times 100$ where $p_0 = \frac{\frac{1}{2}m\left[v^2 - u^2\right]}{t}$

63. $P = \frac{W}{t} = \frac{Mgh + \frac{1}{2}Mv^2}{t}$

64. $\eta = \frac{P_{out}}{P_{in}} = \frac{(mgh)/t}{P}$, $\frac{x}{100}p = \frac{mgh}{t}$

65. $P = \frac{1}{2}Av^3\rho$

66. $P = Fv = m\frac{dv}{dt}v$; Hence, $vdv = \frac{P}{m}dt$

On integration, we find $v \propto \sqrt{t}$

67. $\eta = \eta_1 \times \eta_2$; $\frac{72}{100}P = FV$ here $F = mg$

68. $P = \frac{W}{t} = \frac{\text{Pressure} \times \text{volume}}{t}$

69. F = mg+frictional force ; $P = \vec{F}.\vec{v}$

70. F = ma = constant; $a = \frac{dv}{dt} = \text{constant}$

P = Fv and v=u+at

71. $\text{Power output} = \frac{80}{100}\frac{dm(gh)}{dt}$

72. $a_t = g\sin\theta$

73. $mg = \frac{R_1 + R_2}{2}$

since $R_1 = mg + \frac{mv^2}{r}$ and $R_2 = mg - \frac{mv^2}{r}$

74. If v is velocity when the string is horizontal

$7^2 - v^2 = 2gL$ hence $H = \frac{v^2}{2g} + L$

75. Loss of P.E=gain in K.E; $mgh = \frac{1}{2}m\left[\sqrt{5gr}\right]^2$

76. $\Delta K.E = \frac{1}{2}m\left(v^2_{bottom} - v^2_{top}\right)$

77. If θ is angular amplitude , $T = mg(3 - 2\cos\theta)$

78. Using $K.E_B = P.E_H + K.E_H$ find v

$\overline{\Delta V} = \vec{v} - \vec{u} = v\hat{j} - u\hat{i}$;

$|\Delta V| = \sqrt{v^2 + (-u)^2} = \sqrt{v^2 + u^2}$;

79. $T_{max} = \frac{mv^2}{r} + mg = 6mg$

80. $\tan\theta = \frac{a_c}{a_t} \Rightarrow \frac{\sin v}{\cos\theta} = \frac{2g\cos v}{g\sin\theta} \Rightarrow \frac{\text{Tan}^2 v = 2}{\text{Tan}\theta = 2}$

but $v^2 = 2gh$; $h = r\cos\theta$

81. Loss of P.E =Gain in K.E ;

$mgh = \frac{1}{2}m\left(\sqrt{5rg}\right)^2$

82. $T.E_{bottom} = T.E_{given\ point}$;

$\frac{1}{2}m\left(\sqrt{5gr}\right)^2 = P.E + K.E$

83. $T_{max} = m\left(\frac{v^2}{r} + g\right)$

84. $m_1u_1 - m_2u_2 = m_1v_1 + m_2v_2$

85. $mv_0\bar{i} - 3mV_0\bar{j} + 5mv_0\bar{k} = (m + m + m)v$

$\therefore v = \frac{mv_o(\hat{i} - 3\hat{j} + 5\hat{k})}{3m}$

86. time, $t = \frac{h}{u}$

For freely falling body: $u_1 = gt$

For upward projected body, $u_2 = u - gt$

$-m_1u_1 + m_2u_2 = (m_1 + m_2)v$

87. As mass, $m = \rho(\text{volume}) = \rho\frac{4}{3}\pi r^3$

$m \alpha r^3$ so, $v_1 = \left(\frac{r_1^3 - r_2^3}{r_1^3 + r_2^3}\right)u_1$ and $v_2 = \frac{2r_1^3 u_1}{r_1^3 + r_2^3}$

88. $r_1^3 u_1 + r_2^3 u_2 = (r_1^3 + r_2^3)\, v \; \{\because m \alpha r^3\}$

89. $v = \frac{m_1 u_1 + m_2 u_2}{m_1 + m_2}$

90. $v = \frac{m_1 u_1 + m_2 u_2}{m_1 + m_2}$

91. $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

92. $e = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{h_2}{h}} = \frac{1}{\sqrt{2}}$

93. $e = \frac{\text{Rebound momentum}}{\text{Striking momentum}}$

94. $T = t + 2t_1 = \sqrt{\frac{2h}{g}}[1 + 2e]$ since $t_n = e^n t$

95. $\frac{KE_1}{KE} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2$

96. $W = \frac{1}{2}K(x_2^2 - x_1^2)$

97. $U = \frac{1}{2}kx^2$

98. $PE = \frac{1}{2}kx^2; k = \frac{mg}{x}$

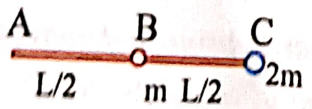
EXERCISE - III

CRTQ & SPQ - LEVEL-III

WORK DONE BY A FORCE

C.R.T.Q Class Room Teaching Questions

1. A long rod ABC of mass "m" and length "L" has two particles of masses "m" and "2m" attached to it as shown in the figure. The system is initially in the horizontal position. The work to be done to keep it vertical with A hinged at the bottom is

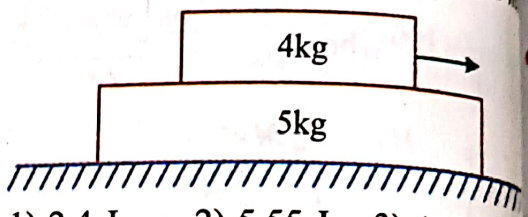


1) 2mgL
2) 3mgL/2
3) 5mgL/2
4) 3mgL

2. A particle of mass 100g is th vertically upwards with a spe 5m/s. The work done by the fo gravity during the time the pa goes up is

1) $-0.5J$ 2) $-1.25J$ 3) $1.25J$ 4)

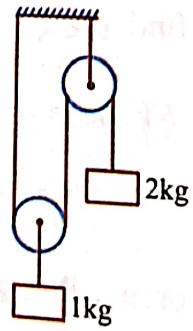
3. A large slab of mass 5 kg lies smooth horizontal surface, w block of mass 4 kg lying on the t it. The coefficient of friction bet the block and the slab is 0.25. I block is pulled horizontally by a f of F = 6 N, then the work done b force of friction on the slab, bet the instants t=2s to t=3s is $(g = 10$



1) 2.4 J 2) 5.55 J 3) 4.44J 4)

S.P.Q. Student Practice Questions

4. In the pulley – block system show figure, strings are light. Pulleys are mas and smooth. System is released fr rest. In 0.3 seconds



a) work done on 2 kg block by gravity i
b) work done on 2 kg block by string i
c) work done on 1 kg block by gravity 1.5J
d) work done on 1 kg block by string is

1) only a, d are correct
2) only b, d are correct
3) only a, b, c are correct
4) All are correct

5. A body of mass 0.5 kg travels in a straight line with a velocity $v = ax^{\frac{3}{2}}$ where $a = 5m^{-\frac{1}{2}}s^{-1}$. What is the work done by the net force during its displacement from x = 0 to x = 2m?

1) 50 J 2) 20 J

3) 80 J 4) 45.5 J

P.E AND K.E

C.R.T.Q Class Room Teaching Questions

6. A particle of mass 2 kg starts moving in a straight line with an initial velocity of 2m/s at a constant acceleration of 2m/s². Then rate of change of kinetic energy

1) is four times the velocity at any moment

2) is two times the displacement at any moment

3) is four times the rate of change of velocity at any moment

4) is constant throughout

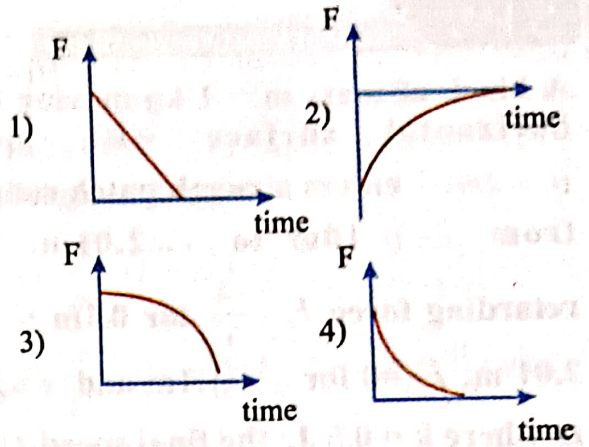
7. A running man has half the kinetic energy that a running boy of half his mass has. The man speeds up by 1.0 m/s and now has the same kinetic energy as the boy. The original speed of the man expressed in m/s units must be

1) $\sqrt{2}+1$ 2) $\sqrt{2}-1$

3) $\sqrt{2}+2$ 4) $\sqrt{2}-2$

S.P.Q. Student Practice Questions

8. The kinetic energy (KE) versus time graph for a particle moving along a straight line is shown in the figure. The force vs time graph for the particle may be



WORK - ENERGY THEOREM

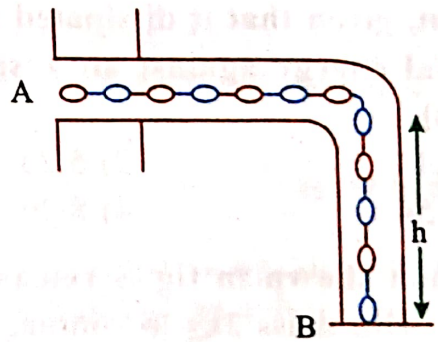
C.R.T.Q Class Room Teaching Questions

9. A lifting machine, having an efficiency of 80% uses 2500 J of energy in lifting a 10 kg load over a certain height. If the load is now allowed to fall through that height freely, its velocity at the end of the fall will be (g=10 m/s²)

1) 10 m s⁻¹ 2) 15 m s⁻¹

3) 20 m s⁻¹ 4) 25 m s⁻¹

10. A chain AB of length L is lying in a smooth horizontal tube so that a fraction h of its length L, hangs freely and touches the surface of the table with its end B. At a certain moment, the end A of the chain is set free. The velocity of end A of the chain, when it slips out of tube , is



1) $h\sqrt{\frac{2g}{Lh}}$ 2) $\sqrt{2gh\log_e\left(\frac{L}{h}\right)}$

3) $\sqrt{2gl\log_e\left(\frac{L}{h}\right)}$ 4) $\frac{1}{hL}\sqrt{2g}$

S.P.Q. Student Practice Questions

11. A block of mass m = 1 kg moving on a horizontal surface with speed $v_i = 2ms^{-1}$ enters a rough patch ranging from $x = 0.10m$ to $x = 2.01m$. The retarding force $F_r = \frac{-k}{x}$ for 0.1m < x < 2.01 m, $F_r = 0$ for $x < 0.1m$ and $x > 2.01$ m where k = 0.5 J, the final speed v_f of the block as it crosses this patch

1) $2ms^{-1}$ 2) $1ms^{-1}$ 3) $3ms^{-1}$ 4) $0.5ms^{-1}$

12. A 1.5kg block is initially at rest on a horizontal frictionless surface. A horizontal force $\vec{F} = (4 - x^2)\hat{i}$ is applied on the block. Initial position of the block is at x = 0. The maximum kinetic energy of the block between x = 0 and x = 2m is

1) 2.33J 2) 8.67 J 3) 5.33 J 4) 6.67 J

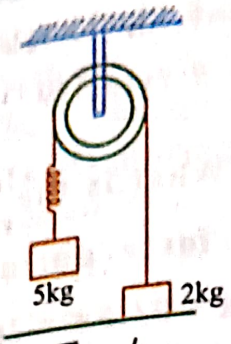
CONSERVATION OF MECHANICAL ENERGY

C.R.T.Q Class Room Teaching Questions

13. The bob of a pendulum is released from a horizontal position. If the length of the pendulum is 1.5 m, the speed with which the bob arrives at the lowest point, given that it dissipated 5% of its initial energy against air resistance is (m/s)

1) 3.14 2) 5.28
3) 1.54 4) 8.26

14. System shown in fig is released from rest with mass 2kg in contact with the ground. Pulley and spring are massless and the friction is absent everywhere. The speed of 5kg block when 2kg block leaves the contact with the ground is (force constant of the spring k=40 N/m and $g = 10m/s^2$)



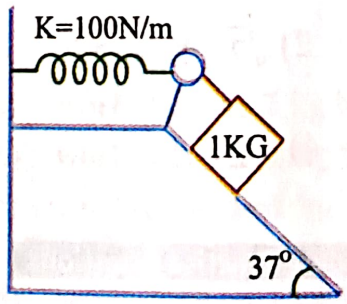
1) $\sqrt{2}$ m/s 2) $2\sqrt{2}$ m/s
3) 2 m/s 4) $\sqrt{2}$ m/s

15. The potential energy of a partic mass m is given by $U = \frac{1}{2}kx^2$ for and U=0 for $x \geq 0$. If total mecha energy of the particle is E. Then its at $x = \sqrt{\frac{2E}{k}}$ is

1) zero 2) $\sqrt{\frac{2E}{m}}$ 3) $\sqrt{\frac{E}{m}}$ 4)

S.P.Q. Student Practice Questio

16. A 1 kg block situated on a ro inclined plane is connected to spri a spring constant 100 Nm^{-1} as show fig. The block is released from rest the spring in the unstretched posi The block moves 10 cm down incline before coming to rest. Find coefficient of friction between the bl and the incline. Assume that the sp has a negligible mass and the pulle frictionless. ($g = 10m/s^2$)



1) 0.125 2) 1.25 3) 5.2 4)

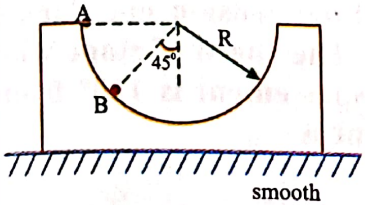
17. A light spring of force constant 'K' held between two blocks of masses and '2m'. The two blocks and spring system rests on a smo

horizontal floor. Now the blocks are moved towards each other compressing the spring by 'x' and suddenly released. The relative velocity between the blocks when the spring attains its natural length will be

1) $\left(\sqrt{\frac{3K}{2m}}\right)x$ 2) $\left(\sqrt{\frac{2K}{3m}}\right)x$

3) $\left(\sqrt{\frac{K}{3m}}\right)x$ 4) $\left(\sqrt{\frac{K}{2m}}\right)x$

18. A ball of mass m is released from A inside a smooth wedge of mass m as shown in fig. What is the speed of the wedge when the ball reaches point B?



1) $\left(\frac{gR}{3\sqrt{2}}\right)^{\frac{1}{2}}$ 2) $\sqrt{2gR}$

3) $\left(\frac{5gR}{2\sqrt{3}}\right)^{\frac{1}{2}}$ 4) $\sqrt{\frac{3}{2}gR}$

POWER

C.R.T.Q Class Room Teaching Questions

19. Power supplied to a particle of mass 2kg varies with time as $P = 3t^2/2$ W. Here t is in second. If velocity of particle at t=0 is v=0, the velocity of particle at time t= 2s will be

1) 1 m/s 2) 4 m/s

3) 2 m/s 4) $2\sqrt{2}$ m/s

20. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration a_c is varying with time t as $a_c = k^2rt^2$ where k is a constant. The power delivered to the particle by the forces acting on it, is

1) zero 2) $mk^2r^2t^2$

3) mk^2r^2t 4) mk^2rt

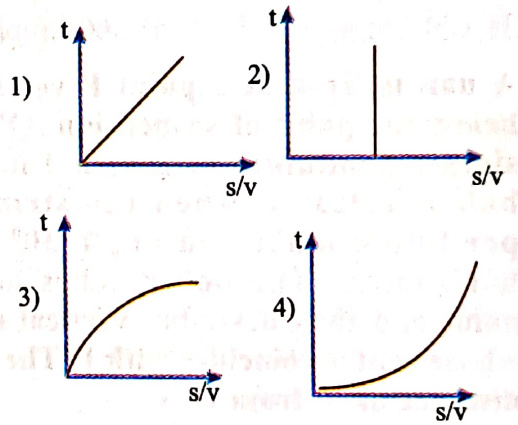
21. A constant power P is applied to a particle of mass m. The distance travelled by the particle when its velocity increases from v_1 to v_2 is (neglect friction)

1) $\frac{3P}{m}(v_2^2 - v_1^2)$ 2) $\frac{m}{3P}(v_2 - v_1)$

3) $\frac{m}{3P}(v_2^3 - v_1^3)$ 4) $\frac{m}{3P}(v_2^2 - v_1^2)$

S.P.Q. Student Practice Questions

22. A body is moved from rest along a straight line by a machine delivering constant power. The ratio of displacement and velocity (s/v) varies with time t as



23. Power applied to a particle varies with time as P=(3t²-2t+1) watt, where 't' is in second. Find the change in kinetic energy between t=2s and t=4s

1)32J 2)46J 3)61J 4)100J

24. A car of mass M accelerates starting from rest. Velocity of the car is given by $v = \left(\frac{2Pt}{M}\right)^{\frac{1}{2}}$ where P is the constant power supplied by the engine. The position of car as a function of time is given as

1) $\left(\frac{8P}{9M}\right)^{\frac{1}{2}} t^{\frac{3}{2}}$ 2) $\left(\frac{9P}{8M}\right)^{\frac{1}{2}} t^{\frac{3}{2}}$

3) $\left(\frac{8P}{9M}\right)^{\frac{1}{2}} t^{\frac{2}{3}}$ 4) $\left(\frac{9P}{8M}\right) t^3$

MOTION IN VERTICAL CIRCLE

C.R.T.Q Class Room Teaching Questions

25. Dry gas of negligible mass is sealed in a test tube of mass 50 gm with the help of a stopper of mass 3.5 gm. The test tube is suspended from a fixed point with help of massless string such that the test tube is horizontal and distance between point of suspension and centre of mass of test tube is 25 cm. The test tube is heated to a temperature due to which stopper is ejected out horizontally while test tube completes a vertical circle of radius 25 cm. The minimum velocity with which stopper should be ejected out is

1) 72 kmph 2) 90 kmph
3) 180 kmph 4) 360 kmph

26. A nail is fixed at a point P vertically below the point of suspension 'O' of a simple pendulum of length 1m. The bob is released when the string of pendulum makes an angle 30^0 with horizontal. The bob reaches lowest point and then describes vertical circle whose centre coincides with P. The least distance of P from O is

1) 0.4 m 2) 0.5 m 3) 0.6 m 4) 0.8 m

27. A simple pendulum with a bob of mass 'm' swings with angular amplitude of 60°. When its angular displacement is 30°, the tension in the string would be

1) $3\sqrt{3}mg$ 2) $\frac{mg}{2}(3\sqrt{3}-2)$
3) $\frac{1}{2}mg\left(\frac{3}{\sqrt{3}+2}\right)$ 4) $\frac{1}{2}mg\left(3-\sqrt{2}\right)$

28. A block is freely sliding down from a vertical height 4 m on smooth inclined plane. The block reaches bottom of inclined plane and then it describes vertical circle of radius 1 m along smooth track. The ratio of normal reactions on the block while it is crossing lowest point and highest point of vertical circle is

1) 6 : 1 2) 5 : 1 3) 3 : 1 4) 5 : 2

29. The length of a ballistic pendulu m and mass of its block is 1.9 bullet of mass 0.1 kg strikes the in horizontal direction with a ve 100 ms^{-1} and got embedded i block. After collision the com mass swings away from lowest The tension in the string when it an angle 60° with vertical is (g = 10

1) 20 N 2) 30 N 3) 40 N 4)

S.P.Q. Student Practice Questions

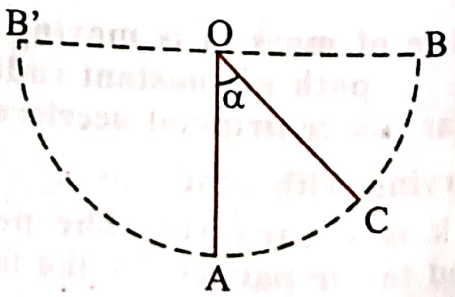
30. A stone attached to a string is ro in a vertical circle such that when i the top of the circle its speed is V there is neither tension nor slacki the string. The speed of stone whe angular displacement is 120° from lowest point is

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

31. Mass of the bob of a simple pendulu length L is m. If the bob is proje horizontally from its mean position velocity $\sqrt{4gL}$, then the tension in string becomes zero after a vert displacement of

1) L/3 2) 3L/4 3) 4L/3 4)

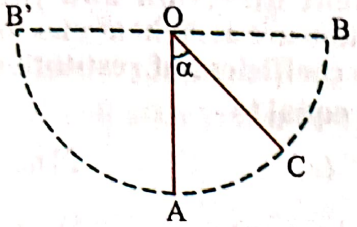
32. A bob of mass M is suspended b massless string of length L. horizontal velocity v at position just sufficient to make it reach point B. The angle θ at which speed of the bob is half of that at satisfies



1) $\theta = \frac{\pi}{4}$ 2) $\frac{\pi}{4} < \theta < \frac{\pi}{2}$

3) $\frac{\pi}{2} < \theta < \frac{3\pi}{4}$ 4) $\frac{3\pi}{4} < \theta < \pi$

33. A simple pendulum is vibrating with an angular amplitude of 90^0 as shown in the figure. For what value of α is the acceleration directed



i) vertically upwards
ii) horizontally
iii) vertically downwards

1) $0^0, \cos^{-1}\left(\frac{1}{\sqrt{3}}\right), 90^0$ 2) $90^0, \cos^{-1}\left(\frac{1}{\sqrt{3}}\right), 0^0$

3) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right), 0^0, 90^0$ 4) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right), 90^0, 0^0$

COLLISIONS

C.R.T.Q Class Room Teaching Questions

34. A block of wood of mass 3M is suspended by a string of length $\frac{10}{3}$ m. A bullet of mass M hits it with a certain velocity and gets embedded in it. The block and the bullet swing to one side till the string makes 120^0 with the initial position. The velocity of the bullet is ($g=10ms^{-2}$)

1) $\frac{40}{\sqrt{3}} ms^{-1}$ 2) $20ms^{-1}$

3) $30ms^{-1}$ 4) $40ms^{-1}$

35. A wooden block of mass 10gm is dropped from the top of a cliff 100m high. Simultaneously a bullet of same mass is fired from the foot of the cliff vertically upwards with a velocity of $100ms^{-1}$. If the bullet after collision gets embedded in the block, the common velocity of the bullet and the block immediately after collision is ($g=10\ ms^{-2}$)

1) $40\ ms^{-1}$ downward 2) $40ms^{-1}$ upward

3) $80ms^{-1}$ upward 4) zero

36. A particle of mass m has a velocity $-v_0\hat{j}$, while a second particle of same mass has a velocity $v_0\hat{j}$. After the particles collide, first particle is found to have a velocity $\frac{-1}{2}v_0\hat{i}$ then the velocity of other particle is

1) $\frac{-1}{2}v_0\hat{i} + v_0\hat{j}$ 2) $\frac{1}{2}v_0\hat{i} + v_0\hat{j}$

3) $v_0\hat{i} + v_0\hat{j}$ 4) $-v_0\hat{i} + v_0\hat{j}$

37. At high altitude a body at rest explodes into two fragments of equal masses with one fragment receiving horizontal velocity of $10\ ms^{-1}$. Time taken by the two radius vectors connecting point of explosion to fragment to make 90^0 is ($g=10ms^{-2}$)

1) 10 s 2) 4 s 3) 2 s 4) 1 s

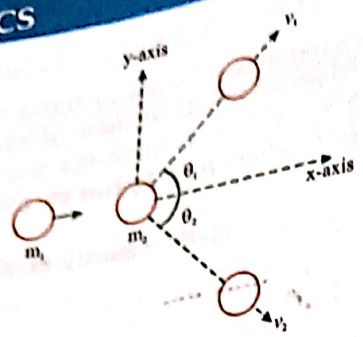
38. A test tube of mass 20 gm is filled with a gas and fitted with a stopper of 2gm. It is suspended horizontally by means of a thread of 1m length and heated. When the stopper kicks out, the tube just completes a circle in vertical plane. The velocity with which the stopper kicked out is

1) $7ms^{-1}$ 2) $10ms^{-1}$
3) $70ms^{-1}$ 4) $0.1ms^{-1}$

39. Two bodies move towards each other and collide inelastically. The velocity of the first body is 2m/s and that of the second is 4m/sec before impact.The common velocity after collision is 1m/s in the direction of the first body. The number of times did the KE of the first body exceed that of the second body before collision.

1) 4.25 2) 3.25 3) 2.25 4) 1.25

40. Three particles A, B and C of equal masses, moving with the same speed 'v' along the medians of an equilateral triangle, collide at the centroid G of the triangle. After collision, A comes to rest and B retraces its path with a speed 'v'. The speed of C after the collision is



1) v along BG
2) $\frac{v}{2}$ along GB
3) Zero
4) v along CG

41. A moving sphere P collides another sphere Q at rest. If the collision takes place along the line joining their centers of mass such that their total kinetic energy is conserved and the fraction of K.E. transferred by the colliding particle is $\frac{8}{9}$, then the mass of P and the mass of Q bears a ratio

1) $\sqrt{8}:3$ 2) $9:8$ 3) $2:3$ 4) $2:1$

42. A particle strikes a horizontal frictionless floor with a speed 'u' at an angle 'θ' with the vertical and rebounds with a speed 'v' at an angle 'α' with the vertical. Find the value of 'v' if 'e' is the coefficient of restitution.

1) $v=u\sqrt{e^2\sin^2\theta+\cos^2\theta}$

2) $v=u\sqrt{e^2\cos^2\theta+\sin^2\theta}$

3) $v=u\sqrt{e^2\cos^2\theta+\tan^2\theta}$

4) $v=u\sqrt{\cot^2\theta+e^2\cos^2\theta}$

S.P.Q. Student Practice Questions

43. Two spheres A and B of equal masses lie on the smooth horizontal circular groove at opposite ends of diameter and at the end of time 't', 'A' impinges on 'B'. If 'e' is the coefficient of restitution, the second impinge will occur after

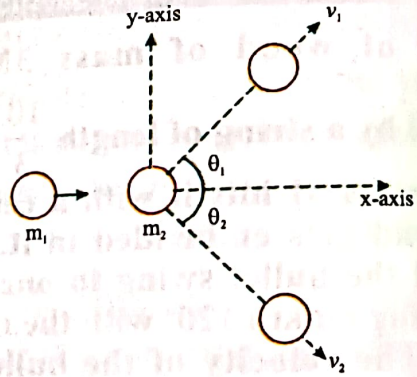
1) $\frac{2t}{e}$ 2) $\frac{t}{e}$ 3) $\frac{\pi t}{e}$

44. A ball is thrown at an angle of in 'θ' on a horizontal plane such incident direction and the re direction are at right angles to each If the coefficient of restitution is 'θ' is equal to

1) $\tan^{-1}(e)$ 2) $\tan^{-1}(2e$

3) $\tan^{-1}(\sqrt{2}e)$ 4) $\tan^{-1}(\sqrt{e}$

45. Consider the collision depicted to be between two billiard balls equal masses $m_1 = m_2$. The first called the target. The billiard wants to 'sink' the target bal corner pocket, which is at an $\theta_2 = 37^o$. Assume that the collis elastic and that friction and rota motion are not important, then



1. 37° 2) 90° 3) 45° 4)

46. A projectile is fixed on a horiz ground. Coefficient of restitu between the projectile and the gr is 'e'. If a, b and c be the ratio of of flight $\left[\frac{T_1}{T_2}\right]$, maximum height and horizontal range $\left[\frac{R_1}{R_2}\right]$ in first collisions with the ground, then

1) $a=\frac{1}{e}$ 2) $b=\frac{1}{e^2}$

3) $e=\frac{1}{e}$ 4) 1,2 & 3

47. A wall moving with velocity $2cms^{-1}$ towards the ball and ball is moving towards the wall with a velocity $10cms^{-1}$.It hits the wall normally and makes elastic collision with wall. The velocity of ball after collision with wall in cms^{-1}

1) 12 2) 8 3)14 4)16

48. A body A moves towards a wall with velocity V. The wall also moves towards the body A with velocity V_0. After collision the body moves in opposite direction with velocity V' which is $\left(1+\frac{2V_0}{V}\right)$ times the velocity V. The coefficient of restitution is

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

49. A sphere A of mass m moving with certain velocity hits another stationary sphere B of different mass. If the ratio of velocities of the spheres after collision is $\frac{V_A}{V_B}=\frac{1-e}{1+e}$, where e is coefficient of restitution. The initial velocity of sphere A with which it strikes is

1) V_A+V_B 2) V_A-V_B

3) V_B-V_A 4) $\frac{(V_B+V_A)}{2}$

50. A ball A of mass 3m is placed at a distance d from the wall on a smooth horizontal surface. Another ball B of mass m moving with velocity u collides with ball A. The coefficient of restitution between the balls and the wall and between the balls is e

a) the velocity of ball B after collision is $\frac{u(3e-1)}{4}$

b) the velocity of ball B after collision is $\frac{u(2e+1)}{4}$

c) after collision, ball A will move away by distance $\frac{d(2e+1)}{(2e-1)}$ during the time ball B returns back to wall.

d) after collision, ball A will move away by distance $\frac{d(e+1)}{(3e-1)}$ during the time ball B returns back to wall

1) a,d 2) a,c 3) b,d 4) c,d

KEY

01)4	02)2	03)2	04)4	05)1	06)1
07)1	08)4	09)3	10)2	11)2	12)3
13)2	14)2	15)2	16)1	17)1	18)1
19)3	20)3	21)3	22)1	23)2	24)1
25)3	26)4	27)2	28)3	29)3	30)2
31)4	32)4	33)1	34)4	35)2	36)1
37)4	38)3	39)4	40)1	41)4	42)2
43)1	44)4	45)4	46)4	47)3	48)3
49)1	50)1				

Hints & Solutions

1. $W=mg\frac{L}{2}+mg\frac{L}{2}+2mgL$

2. $h=\frac{u^2}{2g}$; workdone by gravity $=FS\cos\theta$

here $F=mg, S=h, \theta=180^0$ W= - mgh

3. Maximum frictional force between the slab and the block

$f_{max}=\mu N=\mu mg$; m=mass of upper block

Evidently, $F<f_{max}$

so, the two bodies will move together as a single unit. If 'a' be their combined acceleration, then

$a=\frac{F}{m+M}$

Therefore, frictional force acting can be obtained as $f = Ma$,Using $s = \frac{1}{2}at^2$, find S_2 and S_3. $W = (S_3 - S_2)f$

4. $a = \frac{(2m_1 - m_2)}{\left(2m_1 + \frac{m_2}{2}\right)}g$, $T = \left(\frac{3m_1m_2}{4m_1 + m_2}\right)g$

On 2kg block , $W_1 = m_1gx = m_1g\left(\frac{1}{2}at^2\right)$;

$W_T = T \times x = T\left(\frac{1}{2}at^2\right)$

On 1kg block, $W_2 = m_2g\frac{x}{2}$

5. $W = \Delta KE = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

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

$\therefore \frac{dK}{dt} = mv\frac{dv}{dt} = \left(m\frac{dv}{dt}\right)v = (ma)v$

7. K.E of man $= \frac{1}{2}$(K.E of boy)

$\frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{1}{2}\frac{m}{2}v_1^2\right)$----------(1)

Also given, $\frac{1}{2}m(v+1)^2 = \frac{1}{2}\frac{m}{2}v_1^2$ -------(2)

Divide (1) with (2) to get v

8. $E_k = \frac{1}{2}mv^2 = kt$; $\Rightarrow V = \sqrt{\frac{2kt}{m}}$

'P'$= \left(\frac{dE_k}{dt}\right) = k$

In this case, P=Fv

Hence, $F = \frac{P}{v} = \frac{K}{\sqrt{\frac{2Kt}{m}}} = \frac{K'}{\sqrt{t}}$

where K^1 is another constant

9. $\frac{80}{100} \times E = \frac{1}{2}mv^2$

10. Let 'x' be the length of chain inside the tube

$a = \frac{\left(\frac{Mh}{L}\right)g}{\frac{M}{L}(h+x)} = \frac{hg}{h+x}$; $-\frac{vdv}{dx} = \frac{hg}{h+x}$

on integrating both sides,

$-\int_0^v vdv = \int_{l-h}^0 \frac{hg}{h+x}dx$

11. $K_f = K_i + \int_{0.1}^{2.01} \frac{(-k)}{x}dx = \frac{1}{2}mv_i^2 - k\ln(x)$

$v_f = \sqrt{2K_f / m}$

12. $\Delta k = W \Rightarrow K_f = \int_0^x (4 - x^2).dx$

13. According to the law of conservatio energy, the total energy of the system rem constant.

95% of P.E$_i$=K.E$_f$

i.e., $\frac{1}{2}mv^2 = \frac{95}{100} \times mgl$

14. $x = \frac{2g}{K}$; from conservation of mechanical energy ;

$mgx = \frac{1}{2}Kx^2 + \frac{1}{2}mv^2$, here $m = 5kg$

15. Potential energy of particle at $x = \sqrt{\frac{2E}{k}}$

zero (x > 0) ; KE =E or $\frac{1}{2}mv^2 = E$

16. $mg(\sin\theta - \mu\cos\theta)x = \frac{1}{2}kx^2$

17. Using reduced mass concept, $\mu = \frac{m_1m_2}{m_1+m}$

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

18. Loss of PE=Gain in KE

$mgR\cos\theta = \frac{1}{2}mv^2 + \frac{1}{2}m(v_1\cos\theta -$

$+\frac{1}{2}m(v_1\sin\theta)^2$ ---(1)

From conservation of linear momentum

$m(v_1\cos 45^o - v) = mv$ -------(2)

Here v_1 is the velocity of ball w.r.t wedg solve to get speed of wedge (v)

19. $\Delta KE = W_{net}$ or $K_f - K_i = \int Pdt$

20. $a_c = \frac{v^2}{r} = k^2rt^2$ or $v = krt$

tangential acceleration is, $a_t = \frac{dv}{dt} = kr$

hence $\therefore$ $P = F_t v\cos\theta = ma_t v\cos\theta$

21. $P = mav = m\frac{dv}{ds}v^2$; $\frac{P}{m}\int_0^s ds = \int_{v_1}^{v_2} v^2 dv$

22. $w = \Delta K.E \Rightarrow Pt = \frac{1}{2}mv^2$; $v = \sqrt{\frac{2Pt}{m}}$

$\frac{ds}{dt} = \sqrt{\frac{2P}{m}}t^{1/2}$

23. $\Delta K.E = W = \int_{t_1}^{t_2} Pdt$

24. Here $v = \left(\frac{2Pt}{M}\right)^{\frac{1}{2}}$ or $\frac{ds}{dt} = \left(\frac{2Pt}{M}\right)^{\frac{1}{2}}$ or

$ds = \left(\frac{2Pt}{M}\right)^{\frac{1}{2}} dt$. Integrate to find 's'.

25. $mu = Mv$ but $v = \sqrt{5gr}$

26. If v is velocity at the lowest point

$v^2 = 2gL(1-\sin\theta)$ but,

$v^2 = 5gr$ & $r = L - x$

where x is minimum distance between 0 and P.

27. $T = mg(3\cos\theta - 2\cos\phi)$;

$(\phi = 60^0; \theta = 30^0)$

28. Let v_2, v_1 be the velocities at lowest point, highest point of vertical circle.

$v_2^2 = 2gh = 2g\times 4 = 8g$

$v_2^2 - v_1^2 = 4gr = 4g\times 1 = 4g$ $\therefore v_1^2 = 4g$

normal reaction at lowest

point, $R_2 = \frac{mv_2^2}{r} + mg$, At highest point,

$R_1 = \frac{mv_1^2}{r} - mg$

29. mu=(m+M)v; If v_θ is Velocity at an angle θ.

$v^2 - v_\theta^2 = 2gl(1-\cos\theta)$; find v_θ

then $T_\theta = \frac{mv_\theta^2}{r} + mg\cos\theta$

30. $\frac{mv^2}{r} = mg \Rightarrow v^2 = gr$

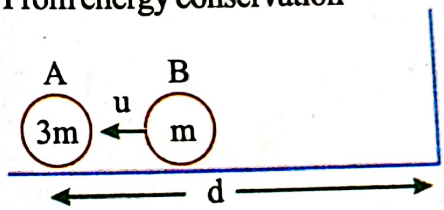
If θ is angle from highest point

$v_\theta^2 - v^2 = 2gr(1-\cos\theta)$

31. $v = \sqrt{g(3h-r)}$; Where h is maximum height at which the tension in the string is zero.

32. From given condition, $v = \sqrt{5gL}$

From energy conservation

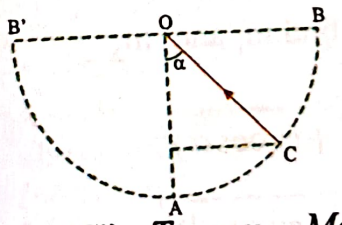


$\frac{m(v/2)^2}{2} - \frac{mv^2}{2} = -mgL(1-\cos\theta)$

or $\cos\theta = -\frac{7}{8}$

The value of θ given in option (4) can only have a value of θ as computed above, so (4) is correct

33.



At "C", $T\cos\alpha = Mg$ .....(i)

$P.E_B = K.E_A \Rightarrow mgr = \frac{1}{2}mv_A^2$

hence at "C", $v = \sqrt{v_A^2 - 2gr(1-\cos\alpha)}$

$T - Mg\cos\alpha = \frac{Mv^2}{r} = \frac{M.2gr\cos\alpha}{r}$

34. $mu = (M+m)\sqrt{2gl(1-\cos\theta)}$

35. Time after which collision takes place

$t = \frac{h}{u}$

before collision, Initial velocity of the wooden block (u_1): $u_1 = gt$

Intial velocity of the bullet (u_2) = $u - gt$

$\Rightarrow m_1u_1 - m_2u_2 = (m_1 + m_2)v$

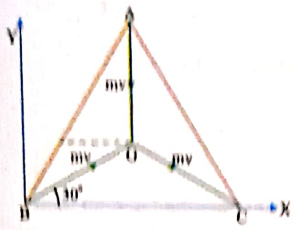
36. $\begin{pmatrix}\text{Total momentum}\\ \text{before collision}\end{pmatrix} = \begin{pmatrix}\text{Total momentum}\\ \text{after collision}\end{pmatrix}$.

37. $t = \dfrac{\sqrt{u_1u_2}}{g}$ 38. $M\sqrt{5gl} = mv$

39. Calculate $K.E_1$ and $K.E_2$ before collision

$\therefore n = \dfrac{K.E_1}{K.E_2}$

40.



Along X- axis:

$0 + mv\cos\theta - mv\cos\theta = 0 - mv\cos\theta + mv_x$

$v_x = v\cos\theta$ $(\theta = 30^0)$, Along Y - axis:

$-mv + mv\sin\theta + mv\sin\theta = 0 - mv\sin\theta + mv_y$

$v_y = v\sin\theta$ $(\theta = 30^0)$; $v_{net} = \sqrt{v_x^2 + v_y^2}$

41. $\dfrac{4m_1m_2}{(m_1+m_2)^2} = \dfrac{8}{9}$, find m_1 and m_2

42. $v = \sqrt{(v\sin\alpha)^2 + (v\cos\alpha)^2}$

$v = \sqrt{(u\sin\theta)^2 + (eu\cos\theta)^2}$

$v = u\sqrt{e^2\cos^2\theta + \sin^2\theta}$

43. $t = \dfrac{\pi r}{u_1}$; $e = \dfrac{v_2 - v_1}{u_1}$; $v_2 - v_1 = eu_1$

and second impact

, $t_1 = \dfrac{2\pi r}{v_2 - v_1} = \dfrac{2\pi r}{eu_1} = \dfrac{2t}{e}$

44. $Tan\alpha = e\,Tan\theta$; given $\theta + \alpha = 90^0$

45. $\theta_1 + \theta_2 = 90^0$

46. $T_n = e^nT$; $H_n = e^{2n} \times H$; $R_n = e^n$

47. $e = \dfrac{v_2 - v_1}{u_1 - u_2} = 1$

48. $e = \dfrac{v_2 - v_1}{u_1 - u_2} = \dfrac{-v_0 + v'}{v + v_0}$; given

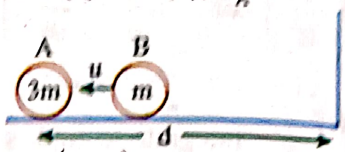
$v' = \left(1 + \dfrac{2v_0}{v}\right)v$

49. $\dfrac{v_A}{v_B} = \dfrac{1-e}{1+e} \Rightarrow e = \dfrac{v_B - v_A}{v_A + v_B}$ ---(1)

we have $e = \dfrac{v_2 - v_1}{u_1 - u_2} = \dfrac{v_B - v_A}{u_A - 0}$ ----

from (1) and (2), u_A=?

50.



$v_A = \dfrac{(1+e)m_1u_1}{m_1 + m_2}$, $v_B = -\dfrac{(m_1 - em_2)u_1}{m_1 + m_2}$

$t_B = \dfrac{d}{v_B}$, $d_A = v_At_B$

EXERCISE - IV

LEVEL-IV

MATCHING TYPE

1. Match the following

Column I	Column II
a) Work	p) Slope of (momentum) p-t (time) gr
b) Power	q) Slope of W- graph
c) Force	r) Area under F graph
d) Impulse	s) Area under F-t graph
	t) unit in SI sy joule

2.

Column I	Column II
a) Force is equal to	p) Work is path independent
b) For the conservative force	q) Rate of change of linear momentum
c) Power is equal to	r) Rate of work done
d) Area of P-t curves to	s) Product of force the give velocity
	t) Work done
	u) Negative of the potential energy gradient

3. **Match the following**

Column I	Column II
a) Work done by a force is	p) Sum of kinetic energy and potential energy is constant
b) Work done by A conservative force is	q) Work done by conservative and non conservative forces
c) Change in kinetic energy is	r) Independent of path followed
d) Under conservative time forces, sum of kinetic energy and potential energy is	s) Independent of for which force acts

4. **Match the following**

Column I	Column II
a) Mechanical energy is	p) Always positive
b) Kinetic energy is	q) Always negative
c) Gravitational potential energy of a body at any height above surface of Earth is	r) May be positive or negative
d) A body having zero momentum has kinetic energy	s) Always zero

5. **Match the following :**

Column I	Column II
a) Stable equilibrium	p) Potential energy is zero ; $\frac{dU}{dr}=0$
b) Unstable equilibrium	q) Potential energy is minimum i.e., $\frac{dU}{dr}=zero$, $\frac{d^2U}{dr^2}is+ve$
c) Neutral equilibrium	r) Potential energy is maximum $\frac{dU}{dr}=zero$, $\frac{d^2U}{dr^2}is-ve$
d) Most unstable position of body	s) $\frac{d^2U}{dr^2}=0$

6. **Match the pairs in two lists given below**

List – I	List – II
a) Gravitational force	e) decreases
b) Frictional force	f) conservative force
c) KE of a dropped body	g) non-conservative force
d) PE of a dropped body	h) increases

7. **A body is allowed to fall from a height h above the ground. Then match the following**

List – I	List – II
a) PE = KE	e) at height h/2
b) PE = 2KE	f) constant at any point
c) KE = 2PE	g) at height 2h/3
d) PE + KE	h) at height h/3

ASSERTION & REASON TYPE

In each of the following questions, a statement is given and a corresponding statement or reason is given just below it. In the statements, mark the correct answer as

1) If both Assertion and Reason are true and Reason is correct explanation of Assertion.
2) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
3) If Assertion is true but Reason is false.
4) If both Assertion and Reason are false.

8. Assertion(A) : No work is done by the centri-petal force acting on a body moving along the circumfe-rence of a circle

Reason (R) : At any instant, the motion ofthe body is along the tangent to the circle where as the centri-petal force is along the radius vector towards the centre of the circle

9. Assertion(A) : No work is done by gravita-tional force if a body moves along a horizontal surface.

Reason (R) : In horizontal motion, angle between gravity and displace-ment is 90^0

10. Assertion(A) : Work done by the gravitational force is zero, in closed path

Reason (R) : Gravitational force is a conservative force

11. Assertion(A) : The change in kinetic energy of a particle is equal to work done on it by the resultant force.

Reason (R) : Change in kinetic energy is equal to work done in case of system of one particle.

12. Assertion(A) : Graph between potential energy of a spring versus the extension or compression of the spring is parabola

Reason (R : Potential energy of a stretched or compressed spring propor-tional to square of extension or compression

13. Assertion(A) : the kinetic energy body is quadrupled its velocity is doub

Reason (R : Kinetic energy proportional to sq velocity

14. Assertion(A) : If a spring is comp energy is stored and is elongated, ener released.

Reason (R) : The energy store spring is proportiona linear deformation spring.

15. Assertion(A) : When a body mov certain velocity co head on with an body of same ma rest, the collision perfectly elastic he collision, 100% of is transferred to the

Reason (R) : Both momentum an are conserved in the of perfectly el collision

16. Assertion(A) : If the momentum body increases by then its KE also incre by 20%

Reason (R) : The KE of a bo directly proportional momentum

17. Assertion(A) : In one dimensi perfectly elastic coll between two mo bodies of equal mas the bodies mu exchange their velo after collision.

Reason (R) : If a lighter body a suffers perfectly el collision with a very h body moving with a sm velocity, then collision both travel same velocities

18. Assertion(A) : Two particles movin the same direction di loose all their energy completely inel collision.

Reason (R) : Principle of conservation of momentum holds good for all kinds of collisions

19. **Assertion(A)** : n small balls each of mass 'm' colliding elastically each second on a surface with a velocity u. The force experienced by the surface is 2nmu.

Reason (R) : In elastic collision, the ball rebounds with the same velocity

20. **Assertion(A)** : A body of mass "m_1" collides head on elastically with another body of mass "m_2" at rest the ratio of the final energy of the first body to the final energy of the second body is $\frac{(m_1 - m_2)^2}{4m_1m_2}$

Reason (R) : The collision is perfectly elastic and the coefficient of restitution is 1.

21. **Assertion(A)** : A body of mass "m_1" collides another body of mass "m_2" at rest elastically. The fraction of energy transferred to the second body is $\frac{m_1}{m_1 + m_2}$

Reason (R) : In an "inelastic collision" both linear momentum and KE is conserved

STATEMENTS TYPE

1) Statement I & II are true.
2) Statement I is true, Statement II is false
3) Statement I is false, Statement II is true
4) Statement I & II are false

22. **Statement - I** : An engine A can perform a given work in 1 hr and engine B can perform the same work in 1/2 hr. then B has greater power than A.

Statement - II : Power is the dot product of force and velocity.

23. **Statement - I** : A quick collision between two bodies is more violent than slow collision, even when initial and final velocities are identical.

Statement - II : The rate of change of momen-tum determines that the force is small or large.

24. **Statement - I** : If collision occurs between two elastic bodies their kinetic energy decreases during the time of collision.

Statement- II : During collision intermolecular space decreases and hence elastic potential energy increases .

25. **Statement - I** : When a body is rotated along a vertical circle with uniform speed then the sum of its kinetic energy and potential energy is constant at all positions

Statement- II : To make a body to move along a vertical circle, its critical speed at a point is independent of mass of body

26. **Statement - I** : Work done by spring force on a block connected to the spring may be positive or negative.

Statement - II : spring force is both pushing and pulling.

27. **Statement - I** : The normal force on a body by the floor is not a conservative force

Statement - II : The normal force does no work at all. Hence it will not store energy in the system.

28. **Statement - I :** The workdone in pushing a block is more than the work done in pulling the block on a rough surface.

Statement - II : In the pushing condition normal reaction in more.

29. **Statement - I :** A cyclist always bends inwards while negotiating a curve.

Statement - II : By bending he lowers his centre of gravity.

30. **Statement - I :** The work done by all forces on a system equals to the change in kinetic energy of that system. This statement is true even if non-conservative forces act on the system.

Statement II : The total work done by internal forces may be positive.

OTHER MODEL QUESTIONS

31. **Nature of work done by gravitational force**
   a) may be negative
   b) may be positive
   c) may be zero
   d) always positive
   1) a,b & d are correct
   2) a, b & c are correct
   3) a,c & d are correct 4) all correct

32. **When workdone on a particle is positive**
   a) K.E remains constant
   b) momentum increases
   c) K.E increases
   d) K.E decreases
   1) a, b 2) b, c 3) b, d 4) a only

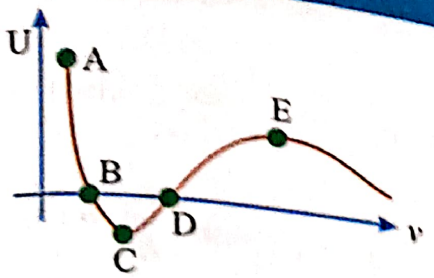
33. **During "elastic collision"**
   a) there is no loss of kinetic energy
   b) the bodies are perfectly elastic
   c) temporarily some of the kinetic energy is used to deform the bodies
   d) after collision the bodies regain the original shape keeping the total energy constant
   1) only "a" is true 2) a, b, c, d are
   3) b, c, d are true 4) a, b, c are tr

34. **Identify the correct statements f the following**
   a) the collisions between the nu and fundamental particles considered as elastic collisions
   b) Emission of an alpha particle f heavy nucleus is an "ela collision"
   c) The collision between two ly balls is considered as "ela collision"
   d) A running man jumps into a tr It is an "elastic collision"
   1) only a & b are true
   2) only b & c are true
   3) a, b & c are true
   4) b, c & d are true

35. **If force is always perpendicula motion**
   a) KE remains constant
   b) workdone by the force is zero
   c) momentum remains constant
   d) speed remains constant
   1) a,b,d 2) a,b,c
   3) b,c,d 4) a,b,c,d

36. **A ball hits a floor and rebounds a an inelastic collision. In this case,**
   a) total energy of the ball and the ea remains the same
   b) total momentum of the ball and earth is conserved
   c) momentum of the ball just after collision is same as that just bef the collision
   d) mechanical energy of the b remains the same during collision
   1) a, b, d 2) a, b, c
   3) a, b 4) a, b, c, d

37. **The given plot shows the variation U, the potential energy of interacti between two particles with the distan separating them *r*.**



1) B and D are equilibrium points
2) C is a point of stable equilibrium
3) The force of interaction between the two particles is attractive between points C and B and repulsive between points D and E on the curve
4) The force of interaction between the particles is repulsive between points C and A

Which of the above statement are correct?

1) 1 & 3 2) 1 & 4 3) 2 & 4 4) 2 & 3

8. For an isolated system in the absence of any dissipative effect
a) KE is conserved
b) PE is conserved
c) energy is conserved
d) ME is conserved

1) a, b 2) a, b, d 3) c, d 4) c only

9. The KE of a particle continuously increases with time. Then
a) The resultant force on the particles is parallel to the velocity at all instants
b) The resultant force on the particle is at an angle less than 90^0 with velocity all the times
c) Its height above the ground level must continuously decrease
d) The magnitude of its linear momentum is increasing continuously

1) b, d 2) a, d 3) a, b, c, d 4) a, b, d

40. Select the correct alternative (s)
a) Work done by static friction is always zero
b) Work done by kinetic friction can be positive also
c) Kinetic energy of a system can not be increased without applying any external force on the system
d) Work energy theorem is valid in non-inertial frames also

1) a, b 2) a, b, d
3) b, c, d 4) a, d

41. Two Solid spheres of same material having radii in the ratio 1 : 2 are moving with same kinetic energy on a horizontal path. They are brought to rest by applying same retarding force. Then
i) their initial momenta are in the ratio $1:2\sqrt{2}$
ii) distance travelled are in the ratio 1 : 1 before coming to rest
iii) the times taken by them coming to rest is $1:2\sqrt{2}$

1. i) and (ii) are correct
2. ii) and (iii) are correct
3. All the three are correct
4. (i) and (iii) are correct

KEY

Matching Type

1. a – r,t , b – q, c – p, d – s
2. a – q,u, b – p,u, c – r,s, d –t
3. a – q, b – s,c – r, d – p
4. a – r, b – p,c – q,d – s
5. a – q, b – r, c – s, d –p
6. a – f, b – g,c – h,d – e
7. a – e, b – g,c – h,d – f

Assertion & Reason Type

08) 1 9) 1 10) 1 11) 1 12) 1 13) 1
14) 4 15) 1 16) 4 17) 3 18) 1 19) 1
20) 1 21) 4

Statements Type

22) 1 23) 1 24) 1 25) 3 26) 1
27) 2 28) 1 29) 1 30) 1

Other Model Questions

31) 2 32) 2 33) 2 34) 3 35) 1 36) 3
37) 3 38) 3 39) 4 40) 2 41)1

Hints & Solutions

7. From L.C.E, the total energy of a system is conserved. Hence at all points TE + KE = constant. Hence $\boxed{d \to f}$

When the PE = KE, half the total energy is converted to K.E. Hence, the initial P.E has dropped to half. Therefore the ball must have fallen by $\frac{h}{2}$. Hence $\boxed{a \to e}$

When the PE = 2KE, one third the total energy is converted to K.E. Hence, the initial P.E has dropped to two-third of it therefore the ball must have fallen by $\frac{h}{3}$.

Hence $\boxed{b \to g}$

When the 2PE = KE, two third of the total energy is converted to K.E. Hence, the inital P.E has dropped to one third. Therefore the ball must have fallen by $2h/3$. Hence $\boxed{c \to h}$

8. As centripetal force and displacement of the body are perpendicular to each other, work done is zero.

9. As angle between gravity and displacement is 90^0, work done by the gravitational force is zero.

10. A force is said to be conservative, if workdone by the force along any closed path is zero.

11. $\Delta K.E. = W_{net\ force}$. This relation is valid for particle as well as a system of particles.

12 Potential energy stored in a spring $U = \frac{1}{2}kx^2$,

$U \propto x^2$. So, U - x graph is a parabola.

13. Kinetic energy $K = \frac{1}{2}mv^2$, when 'm' constant, $K \propto v^2$ and $\frac{K_1}{K_2} = \frac{v_1^2}{v_2^2}$.

14. $U = \frac{1}{2}Kx^2$, where 'x' may compression or elongation and in b cases energy is stored in the spring

15. In perfectly elastic collision b momentum and KE are conserved a transfer of KE is maximum when m so both statements are correct bu is correct explanation to A.

16. $K.E = \frac{P^2}{2m}$

17. $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2$

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

If $m_1 = m_2 = m$, $v_1 = u_2$ and $v_2 = u_1$

If $m_2 << m_1, v_1 = u_1$ and $v_2 = 2u_1$

so A is true R is false

18. If it is a perfectly inelastic collision th

$m_1u_1 + m_2u_2 = (m_1 + m_2)v$

$v = \frac{m_1u_1 + m_2u_2}{m_1 + m_2}$; $KE = \frac{P_1^2}{2m_1} + \frac{P_2^2}{2m_2}$

As P_1 and P_2 both simultaneously cann be zero, there fore total K.E cannot be lo

19. In elastic collision K.E remains conserv therefore the ball rebounds with the sam velocity according to newton's II law

Fxt=Change in linear momentum

Fx1=mn(u+u) ; F=2nmu

20. $KE_1 = \frac{1}{2}m_1v_1^2$; $KE_2 = \frac{1}{2}m_2v_2^2$

$$\frac{KE_1}{KE_2}=\frac{\frac{1}{2}m_1\left(\frac{m_1-m_2}{m_1+m_2}\right)^2u_1^2}{\frac{1}{2}m_2\left(\frac{2m_1}{m_1+m_2}\right)^2u_1^2}=\frac{(m_1-m_2)^2}{4m_1m_2}$$

For perfectly elastic collision, e=1

21. Fraction of KE transferred to the second body

$=\frac{4m_1m_2}{(m_1+m_2)^2}$. In an inelastic collision only linear momentum is conserved

INTEGER & NUMERIC VALUE QUESTIONS

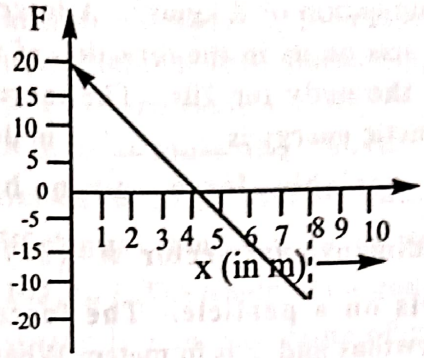
1. When the bob of a simple pendulum swings, the work done by tension in the string is____

2. A force $F=(5\hat{i}+3\hat{j})$ newtons is applied over a particle which displaces it from its origin to the point $r=(2\hat{i}-1\hat{j})$ meters. The work done on the particle___ in Joule

3. A cart is set rolling a cross a level table, at the same speed on every trial. If it runs into a patch of sand, the cart exerts on the sand an average horizontal force of 6N and travels a distance of 6cm through the sand as it comes to a stop. If instead the car turns into a patch of gravel on a stop. If instead the car runs into a patch of gravel on which the cart exerts an average horizontal force of 9N, how far into the gravel will the cart roll before stopping___ in cm

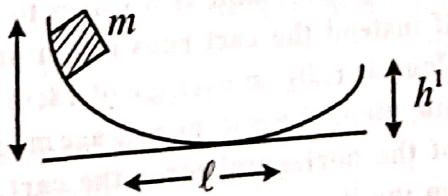
4. A body of mass 6kg is under a force which causes displacement in it gives by $S=\frac{t^2}{4}$ meters where t is time. The work done by the force in 2 seonds is____ in Joule

5. A force F acting on an object varies with distance x as shown in the figure. The work done by force in moving the object from $x=0$ to $x=8m$ is_____ in Joule



6. A uniform chain of length 2m is kept on a table suh that a length of 60cm hanges freely from the edgte of the table. The total mass of the chain is 4kg. The work done in pulling the entire chain on the table is in Joule (Take g = ms^{-2}).

7. A block is released from rest from a height h=5m. After travelling through the smooth curved surface it moves on the rough horizontal surface through a length $\ell=8m$ and climbs onto the other smooth curved surface through height h^1. If $\mu=0.5$, find h^1._____ in metres



8. The displacement x in meters of a particle of mass $m kg$ moving in one dimension under the action of a force is releated to the time t in seconds by the equation $t=\sqrt{x+3}$, the work done by the force (in J) in first six seconds is_____

9. A raindrop of mass 1g falling from a height of 1 km hits the ground with a speed of $50ms^{-1}$. If the resistive force is porportional to the speed of the drop, then the work done by the resistive force is (Take g 10 ms^{-2})_____

10. A body of mass 4kg is moving with momentum of 8 $kgms^{-1}$. A force of 0.2 N acts on its in the direction of motion of the body for 10s. The increase in kinetic energy is_____ in Joule

11. A variable force, given by the 2-dimensional vector $\vec{F}=\left(3x^2\hat{i}+4\hat{j}\right)$, acts on a particle. The force is in Newtons and x is in meter. What is the change in the kinetic energy of the particle as it moves from the point with coordinates (2,3) to (3,0)_in Joule (The coordinate are in metres)

12. A block of mass 2kg is dropped from a height of 40cm on aspring whose force-constant is 1960 Nm^{-1}. The maximum distance through which the spring is compressed by_____ in cm

13. A cart is set rolling across a level table, at the same speed on every trial. If it runs into a patch of sand, the cart exerts on the sand an average horizontal force of 6N and travels a distance of 6 cm through the stand as it comes to a stop. If instead the cart runs into a patch of flour, it rolls an average of 18cm before stopping. What is the average magnitude of the horizontal force the cart exerts on the flour__ in N

14. An athlete jumping vertically on a tram-poline levels the surface with a velocity of 10 m/s upward. What maximum height does she reach_____ in m

15. A bomb of mass 9 kg explodes into 2 pieces of mass 3kg and 6kg. The velocity of mass 3kg is 1.6 m/s. The K.E. of mass 6kg is___ in Joule

16. A body of mass 5kg is moving w momentum of 10kg-m/s. A force N acts on it in the direction of m of the body for 10seconds. The incr in its kinetic energy is_____ in J

17. An 800N marine in basic training cl a 12.0 m vertical rope at a con speed in 8.00s. What is his power put_____ in kw.

18. An engine pumps up 100kg of w through a height of 10m in 5. I efficiency of the engine is 60%. Wh the power of the engine_____ in (Take g=10ms^{-2})

19. A billiard ball moving with a speed m/s collides with an identical b originally at rest. If the first ball s dead after collision, then the second will move forward with a sp of_____ in ms^{-1}

20. A ball of mass m is moving norm towards a wall of mass(M) (>>m) wi velocity 4m/s. The wall is also mov After striking elastically with the w velocity of ball becomes 8 m/s. F the speed of the ball _____

21. A body of mass 6kg is under a fo which causes displacement in it gi by $S=\frac{t^2}{4}$ metres where t is time. T work done by the force in 2 secon is____ in Joule

22. A 15gm ball is shot from a spring wh spring has a force constant of 600 N The spring is compressed by 5cm. T greatest possible horizontal range of ball for this compression is_____

23. While running, a person transform but 0.60 J of chemical energy mechanical energy per step per kilogr of body mass. If a 60kg run

transforms energy at a rate of 72 W during a race, how fast is the person running? Assume that a running step is 1.5m long_____

24. 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 6J, then the vaue of 'C' is_____

25. A body of mass m = 10 kg is attached to one end of a wire of length 0.3 m. The maximum angular speed (in rad s^{-1}) with which it can be rotated about its other end in space station is (Breaking stress of wire $= 4.8\times10^{7}\,Nm^{-2}$ and area of cross-section of the wire = 10^{-2} cm²) is:

26. A body of mass 2 kg is driven by an engine delivering a constant power of 1 J/s. The body starts from rest and moves in a straight line. After 9 seconds, the body has moved a distance (in m)_____

27. Two solids A and B of mass 1 kg and 2 kg respectively are moving with equal linear momentum. The ratio of their kinetic energies $(K.E.)_A : (K.E.)_B$ will be $\frac{A}{1}$, so the value of A will be_

28. A small bob tied at one end of a thin string of length 1m is describing a vertical circle so that the maximum and minimum tension in the string are in the ratio 5 : 1. The velocity of the bob at the height position is_____m/s. (Take g = 10 m/s²)

29. The potential energy (U) of a diatomic molecule is a function dependent on r (interatomic distance) as $U = \frac{\alpha}{r^{10}} - \frac{\beta}{r^{5}} - 3$ where, α and β are positive constants. The equilibrium distance between two atoms will be $\left(\frac{2\alpha}{\beta}\right)^{\frac{a}{b}}$, where a = ____.

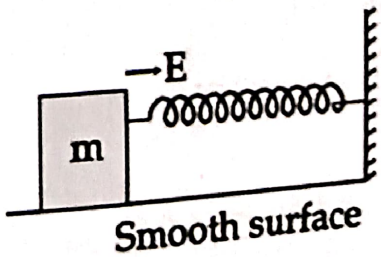
30. Two particles having masses 4 g and 16 g respectively are moving with equal kinetic energies. The ratio of the magnitudes of their linear momentum is n : 2. The value of n will be_____.

31. A ball of mass 4kg, moving with a velocity of 10 ms^{-1}, colides with a spring of length 8m and force constant 100 Nm^{-1}. The length of the compressed spring is x m. the value of x, to the nearest integer, is___.

32. A 0.5kg block moving at a speed of 12ms^{-1} compress a spring through a distance 30cm when its speed is halved. The spring constant of the spring will be_____ Nm^{-1}

33. A pendulum of length 2m consists of a wooden bob of mass 50g. A bullet of mass 75g is fired towards the stationary bob with a speed v. The bullet emerges out of the bob with a speed $\frac{v}{3}$ and the bob just completes the vertical circle. The value of v is_____ms^{-1} (if g=10m/s^2)

34. A block of mass 'm' (as shown in figure) moving with kinetic energy E compresses a spring through a distance 25cm When its speed is halved The value of spring constant of used spring will be nE Nm^{-1} for n=____



Answers

01) 0	02) 7	03) 4	04) 3	05) 0
06) 3.6	07) 1	08) 0	09) –8.75	10) 4.5
11) 7	12) 10	13) 2	14) 5	15) 1.92
16) 4.4	17) 1.2	18) 3.3	19) 5	20) 2
21) 3	22) 10	23) 3	24) 6	25) 4.00
26) 18	27) 2	28) 5	29) 1	30) 1
31) 6	32) 600		33) 10	34) 24

Hints & Solutions

1. Tension in the string is along the radius of circulr path adopted by the bob, while displacement of the bob is along the circumference of the path, hnce angle between $\vec{F}$ and $\vec{S}$ is always 90^0 and so $\omega = 0$

2. $\omega = \vec{F}.\vec{S} = (5\hat{i}+3\hat{j}).(2\hat{i}-\hat{j}) = 10-3 = 7J$

3. The system consisting of the craft's fixed, initital kinetic energy is the mechanical energy that can be transformed due to friction from the surface. Demech $= -f_k d$ $= -(6N)$.

$(0.06m) = 0.376J$. This product must remain the same in all cases. For the cart rolling through gravel, $-(9N)(d) = 0.36J$ yells us $d = 4cm$.

4. $S = \frac{t^2}{4}$ $\quad \therefore ds = \frac{t}{2}dt$

$$F = ma = \frac{md^2S}{dt^2} = \frac{6d^2}{dt^2}\left(\frac{t^2}{4}\right) = 3N$$

Now, $\omega = \int_0^2 Fds = \int_0^2 3\frac{t}{2}dt = \frac{3}{2}\left[\frac{t^2}{2}\right]_0^2 = \frac{3}{4}$

$\left[(2)^2-(0)^2\right] = 3J$

5. Work done = Area under $F-x$ graph with proper algebraic sign

$= \frac{1}{2}\times 20\times 4 - \frac{1}{2}\times 20\times 4 = 0J$

6. Mass of length 2m of the chain = 4kg mass of length 60 cm or 0.60 cm of the chain $= \frac{4\times 0.60}{2} = 1.2kg$ weight of the hanging part of the chain $= 1.2\times 10 = 12N$. Since of centre of gravity of the hanging part lies at its mid-point, i.e, 30cm or 0.30cm

$\therefore W = 12\times 0.30 = 3.6J$

7. The forces acting on the block and N, gravity and friction.

$\omega_f + \omega_f + \omega_{gr} = \Delta K$

where $\omega_N = 0, \omega_f = -\mu mgl$

and $\omega_{gr} = mg(h-h^1)$ and $\Delta K = 0$

Thus, $-\mu mgl + mg(h-h^-) = 0$

$h^1 = h - \mu l = 5 - \frac{1}{2}\times 8 = 1m$

8. Here $t = \sqrt{x}+3$ or $x = (t-3)^2 = t^2-6t+9$

$V = \frac{dx}{dt} = 2t-6 \Rightarrow$ at $t = 0, V = 2\times 0 - 6 = -6$

at $t = 6, V = 2\times 6 - 6 = +6$

Initial and final KE are same hence no work is done.

9. Here, $m = 1$ g$=10^{-3}kg, h = 1$km $= 1000$ $m = 10^3 m$

The change in kinetic energy of the drop is

$\Delta K = \frac{1}{2}mV^2 - 0 (\because u = 0)$

$= \frac{1}{2} \times 10^{-3} \times 50 \times 50 = 1.25\,J$

The work done by the gravitational force is $\omega_g = mgh = 10^{-3} \times 10 \times 10^3 = 10J$.

According to work-energy theorem

$\Delta K = \omega_g + \omega_r \Rightarrow \omega_r = \Delta K - \omega_g = 1.25J - 10J = -8.75J$

10. Momentum = mass × velocity $\Rightarrow P = mu$

or $u = \frac{P}{m} = \frac{5kgms^{-1}}{4kg} = 2ms^{-1}$

Acceleration $= \frac{\text{Force}}{\text{Mass}} a = \frac{0.2N}{4kg} = 0.05ms^{-2}$

Distance travelled by the body in 10 sec is

$d = ut + \frac{1}{2}at^2 = (2\,ms^{-1})(10s)$

$+\frac{1}{2}(0.05ms^{-2})(10s)^2 = 20m + 2.5m = 22.5M$

workdone,

$W = Fd = (0.2N)(22.5m) = 4.5J$

According to work energy theorem. Increase in kinetic energy = work done = 4.5 J

11. $\vec{F} = 3x^2\hat{i} + 4\hat{j}$, $\vec{r} = x\hat{i} + y\hat{j}$

$\therefore d\vec{r} = dx\hat{i} + dy\hat{j}$

work done, $W = \int \vec{F}.\vec{dr} = \int_{(2,3)}^{(3,0)} (3x^2\hat{i} + 4\hat{j}).$

$(dx\hat{i} + dy\hat{j}) = \int_{(2,3)}^{(3,0)} 3x^2dx + 4dy$

$W = [x^3 + 4y]_{(2,3)}^{(3,0)} = 3^3 + 4 \times 0 - (2^3 + 4 \times 3)$

$W = 27 + 0 - (8 + 12) = 27 - 20 = +7J$

12. $mg(h+x) = \frac{1}{2}Kx^2$.

Here, $m = 2kg, h = 40cm$

$K = 1960\,Nm^{-1}$ and $g = 10ms^{-2}$

$\therefore 2 \times 10(0.5 + x) = \frac{1}{2} \times 1960x^2$

on solving, we get $x = 10cm$.

13. The system consisting of the cart's fixed, initital kinetic nergy is the mechanical energy that can be transformed due to friction from the surface. Therefore, the loss of mechanical energy is

$\Delta E_{mech} = -f_k d = -(6N)(0.06m) = 0.36J$.

This product must remain the same in all cases. For the cart rolling through gravel,

$(f_k)(0.18m) = 0.36J$ tell us $f_k = 2N$.

14. k_i, or $m_g y_{max} = \frac{1}{2}mV_i^2$, which gives the maximum height as

$y_{max} = \frac{V_i^2}{2g} = \frac{(10.0m/s)^2}{2(10.0m/s^2)} = 5m$

15. Given mass of the bomb $(m) = 9$ kg

initial velocity of bomb = 0 m/s

Mass of smaler fragment $= 3\,kg \rightarrow m_1$

Mass of bigger fragment $= 6\,kg \rightarrow m_2$

P (just after explosion)

= P(just before explossion)

$m_1 \times 1.6 + m_2 \times V = M \times 0$

$\Rightarrow 3 \times 1.6 + 6 \times V = 0 \Rightarrow \boxed{V = 0.8\,m/s}$

Kinetic energy of mass $6Kg = \frac{1}{2}m_2V^2$

$= \frac{1}{2} \times 6 \times 64 \times 10^{-2}$

$= 1.92\,J$.

16. Change in momentum = Force × time

$P_2 - P_1 = F \times t = 0.2 \times 10 = 2$

$\Rightarrow P_2 = 2 + P_1 = 2 + 10 = 12 kg\ m/s.$

Increase in K.E.

$= \frac{1}{2m}\left(P_2^2 - P_1^2\right) = \frac{1}{2\times 5}\left[(12)^2 - (10)^2\right]$

$= \frac{44}{10} = 4.4J$

17. The marine must exert an 800N upward force, opposite the gravitational force, to lift his body at constant speed. The marine's power out put is the work he does divided by the time interval power $= \frac{W}{t}$

$P = \frac{mgh}{t} = \frac{(800N)(12.0m)}{8.00s} = 1200W = 1.2KW$

18. Power used to pump the water

$\frac{mgh}{t} = 100 \times 10 \times \frac{10}{5} = 2,000W$

Power of engine $= 2000 \times \frac{100}{60} = 3.3KW$

19. It is a case of elastic collision. As masses of two balls are equal and 2nd ball is at rest before collision, hence after the collision the speeds are just while the second ball will move forward with the same speed as that of the first i.e, $5ms^{-1}$.

20. Let V be the velocity of ball. Relative velocity of separation = relative velocity of approach. 8–V = 4+V, if wall is moving towards left V=2m/s towards left and 87+V=4–V, if wall is moving towards right V = –2m/s = 2m/s towards left.

21. $S = \frac{t^2}{4}$

$V = \frac{2t}{4}\ V = \frac{2t^2}{4}$

V = 1 mn

$W = \frac{1}{2} \times 6 \times 1^2 = 35$

22. $R_{max} = \frac{u^2}{g}$ at $\theta = 45^0$

$R_{max} = \left(\frac{mu^2}{2}\right)\left(\frac{2}{mg}\right) = \left(\frac{1}{2}Kx^2\right)\left(\frac{2}{mg}\right)$

As $\left(\frac{1}{2}mu^2 = \frac{1}{2}Kx^2\right) \Rightarrow R_{max} = \frac{Kx^2}{mg}$

Substituting the values

$R_{max} = \frac{(600)(5\times 10^{-2})^2}{(15\times 10^{-3})(10)} = 10$

23. We first determine the energy output the runner.

$= (0.60J/Kg.step)(60kg)\left(\frac{1\ step}{1.50m}\right)$

$= 24.0J/m = 3.0J$

24. $W = (3\hat{i} + C\hat{j} + 2\hat{k}) - (4\hat{i} + 2\hat{j} + 3\hat{k}) = 6\ jou$

$W = -12 + 2C + 6 = 6 \Rightarrow C = 6.$

25. $T = m\omega^2\ell$

Breaking stress $= \frac{T}{A} = \frac{m\omega^2\ell}{A}$

$\Rightarrow \omega^2 = \frac{4.8\times 10^7 \times (10^{-2}\times 10^{-4})}{10\times 0.3} = 16$

$\Rightarrow \omega = 4$

26. P = Fv = mav

$a = \frac{p}{mv};\ \frac{dv}{dt} = \frac{p}{mv};\ \int_0^u vdv = \frac{p}{m}\int_0^t dt$

$$\frac{u^2}{2}=\frac{p}{m}t;\ u=\sqrt{\frac{2p}{m}}\sqrt{t};\ \frac{dx}{dt}=\sqrt{\frac{2p}{m}}\sqrt{t}$$

$$\int_0^x dx=\sqrt{\frac{2p}{m}}\int_0^9\sqrt{t}dt;\ x=\frac{2}{3}\left[(9)^{1/2}\right]^3$$

$$=\frac{2}{3}\times 27$$

X = 18

II - method

$$pt=w=\frac{1}{2}mv^2-0;\ 1\times t=\frac{1}{2}\times 2\times u^2$$

$$u=\sqrt{t};\ \frac{dx}{dt}=\sqrt{t}=\int_0^1 dx=\int_0^9\sqrt{t}dt$$

$$x=\frac{\left[t^{3/2}\right]_0^9}{\frac{3}{2}}=18\,m$$

27. Kinetic energy $K=\frac{P^2}{2m},(P_A=P_B)$

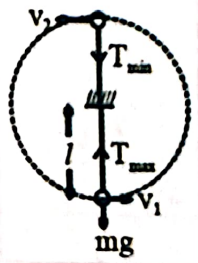
$$K\propto\frac{1}{m};\ \frac{K_A}{K_B}=\frac{m_B}{m_A}$$

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

28. Let the speed of bob at lowest position be v_1 and at the highest position be v_2. Maximum tension is at lowest position and minimum tension is at the highest position. Now, using, conservation of mechanical energy,

$$\frac{1}{2}mv_1^2=\frac{1}{2}mv_2^2+mg\,2l$$

$$\Rightarrow v_1^2=v_2^2+4gl \qquad .....(1)$$



Now $T_{max}-mg=\frac{mv_1^2}{l}$

$$\Rightarrow T_{max}=mg+\frac{mv_1^2}{l}$$

$$\&\,T_{min}+mg+\frac{mv_2^2}{l}$$

$$\Rightarrow T_{min}=\frac{mv_2^2}{l}-mg$$

$$\frac{T_{max}}{T_{min}}=\frac{5}{1}$$

$$\Rightarrow\frac{mg+\frac{mv_1^2}{l}}{\frac{mv_2^2}{l}-mg}=\frac{5}{1}$$

$$\Rightarrow mg+\frac{mv_1^2}{l}=\left[\frac{mv_2^2}{l}-mg\right]5$$

$$\Rightarrow mg+\frac{m}{l}\left[v_2^2+4gl\right]=\frac{5mv_2^2}{l}-5mg$$

$$\Rightarrow mg+\frac{mv_2^2}{l}+4mg=\frac{5mv_2^2}{l}-5mg$$

$$\Rightarrow 10mg=\frac{4mv_2^2}{l},\ v_2^2=\frac{10\times10\times1}{4}$$

$$\Rightarrow v_2^2=25\Rightarrow v_2=5\ m/s$$

Thus, velocity of bob at highest position is 5 m/s.

29. For equilibrium

$$\frac{dU}{dr}=0,\ \frac{-10\alpha}{r^{11}}+\frac{5\beta}{r^6}=0,\ \frac{5\beta}{r^6}=\frac{10\alpha}{r^{11}}$$

$$r^5=\frac{2\alpha}{\beta},\ r=\left(\frac{2\alpha}{\beta}\right)^{\frac{1}{5}}$$

$$a=1$$

30. $\frac{p_1^2}{2\times 4}=\frac{p_2^2}{2\times 16}$

$\frac{p_1}{p_2}=\frac{1}{2}$

31. Let's say the compression in the spring be 'y'

So, by work energy theorem we have

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

$\Rightarrow y=\sqrt{\frac{m}{k}}.v$

$\Rightarrow y=\sqrt{\frac{4}{100}}\times 10=2$

$\Rightarrow$ Final length of spring

$=8-2=6m$

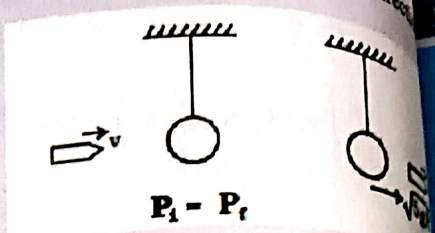
32. $U_i+K_i=U_f+K_f$

$\Rightarrow 0+\frac{1}{2}m(12)^2=\frac{1}{2}K(0.3)^2+\frac{1}{2}m(6)^2$

$\Rightarrow 0.5(12^2-6^2)=K(0.3)^2$

K=600N/m

33. Considering only Horizontal direc



$(75v)+0=50\left(\sqrt{5gR}\right)+75\frac{v}{3}$

$75\left(v-\frac{v}{3}\right)=50\sqrt{100}$

34. Using work-energy theorem

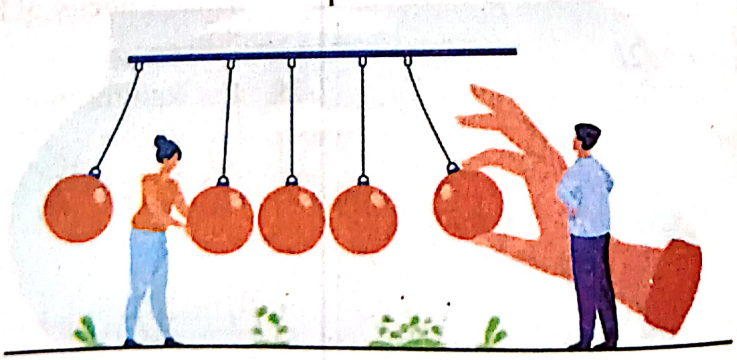
$W_{net}=(K_f-K_i)$

$\Rightarrow -\frac{1}{2}Kx^2=\frac{1}{2}m\left(\frac{v}{2}\right)^2-\frac{1}{2}mv^2=\frac{E}{4}-E$

$\Rightarrow \frac{1}{2}Kx^2=\frac{3E}{4}\Rightarrow K=\frac{3E}{2x^2}$

$\Rightarrow K=\frac{3E}{2\times\left(\frac{1}{4}\right)^2}=24E$

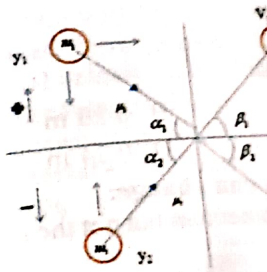
n=24



2

COLLISIONS

Collision in a plane:
When two bodies strike in
is no external force on
momentum can be
X & Y direction's indep



Along X - direction

$m_1u_1\cos\alpha_1+m_2u_2$ co

$=m_1v_1\cos\beta_1+m_2v_2$

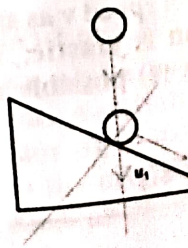
Along Y - directio

$-m_1u_1\sin\alpha_1+m_2u$

$=m_1v_1\sin\beta_1-m_2$

And if collision is
energy also rema

$\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2$

Imp:During the
of collision KE

Collision with