WORK POWER & ENERGY

1. WORK :

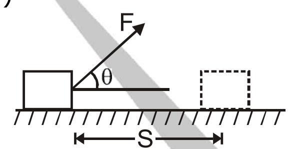
Work is said to be done by a force when the force produces a displacement in the body on which it acts in any direction except perpendicular to the direction of the force.

1.1 Work done by constant force

Consider an object undergoes a displacement S along a straight line while acted on a force F that makes an angle θ with S as shown.

The work done W by the agent is the product of the component of force in the direction of displacement and the magnitude of displacement.

i.e., $W = FS \cos \theta$ ...(1)



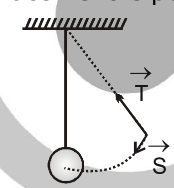
Work done is a scalar quantity and its S.I. unit is N-m or joule (J). We can also write work done as a scalar product of force and displacement.

$W = \vec{F}.\vec{S}$ ...(2)

where S is the displacement of the point of application of the force

From this definition, we conclude the following points

(A) work done by a force is zero if displacement is perpendicular to the force ($\theta = 90°$)



Example.

The tension in the string of a simple pendulum is always perpendicular to displacement. (Figure)

So, work done by the tension is zero.

(B) if the angle between force and displacement is acute ($\theta < 90°$), we say that the work done by the force is positive.

Example :

When a load is lifted, the lifting force and the displacement act in the same direction. So, work done by the lifting force is positive.

Example :

When a spring is stretched, both the stretching force and the displacement act in the same direction. So work done by the stetching force is positive.

(C) If the angle between force and displacement is obtuse ($\theta > 90°$), we say that the work done by the force is negative.

Example :

When a body is lifted, the work done by the gravitational force is negative. This is because the gravitational force acts vertically downwards while the displacement is in the vertically upwards direction.

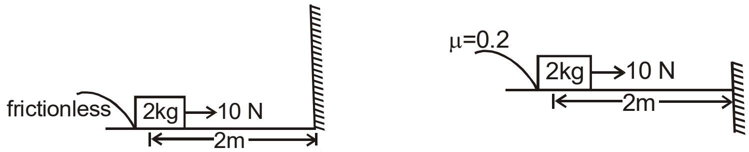
Important points about work :

1. Work is said to be done by a force when its point of application moves by some distance.Force does no work if point of application of force does not move (S = 0)

Example :

A person carrying a load on his head and standing at a given place does no work.

2. Work is defined for an interval or displacement. There is no term like instantaneous work similar to instantaneous velocity.



Work done by 10 N force in both the cases are same = 20 N

3. For a particular displacement, work done by a force is independent of type of motion i.e. whether it moves with constant velocity, constant acceleration or retardation etc.
4. If a body is in dynamic equilibrium under the action of certain forces, then total work done on the body is zero but work done by individual forces may not be zero.
5. When several forces act, work done by a force for a particular displacement is independent of other forces.
6. A force is independent of reference frame. Its displacement depends on frame so work done by a force is frame dependent therefore work done by a force can be different in different reference frame.

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2. UNITS OF WORK :

In cgs system, the unit of work is erg.

One erg of work is said to be done when a force of one dyne displaces a body through one centimetre in its own direction.

$\therefore$ 1 erg = 1 dyne × 1 cm = 1 g cm s^{-2} × 1 cm = 1 g cm^2 s^{-2}

Note : Another name for joule is newton metre.

<u>Relation between joule and erg</u>

1 joule = 1 newton × 1 metre

1 joule = 10^5 dyne × 10^2 cm = 10^7 dyne cm

1 joule = 10^7 erg

1 erg = 10^{-7} joule

Dimensions of Work :

[Work] = [Force] [Distance] = $[MLT^{-2}]$ [L] = $[ML^2T^{-2}]$

Work has one dimension in mass, two dimensions in length and '−2' dimensions in time, On the basis of dimensional formula, the unit of work is kg m^2 s^{-2}.

Note that 1 kg m^2 s^{-2} = (1 kg m s^{-2}) m = 1 N m = 1 J.

3. WORK DONE BY MULTIPLE FORCES :

If several forces act on a particle, then we can replace $\vec{F}$ in equation W = $\vec{F}\cdot\vec{S}$ by the net force $\sum\vec{F}$ where

$$\sum\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...$$

$$\therefore \quad W = \left[\sum\vec{F}\right]\cdot\vec{S} \qquad ...(i)$$

This gives the work done by the net force during a displacement $\vec{S}$ of the particle.

We can rewrite equation (i) as :

$$W = \vec{F}_1.\vec{S} + \vec{F}_2.\vec{S} + \vec{F}_3.\vec{S} + ...$$

or $\quad W = W_1 + W_2 + W_3 + ...$

So, the work done on the particle is the sum of the individual work done by all the forces acting on the particle.

Ex.1 A block of mass M is pulled along a horizontal surface by applying a force at an angle θ with horizontal. Coefficient of friction between block and surface is μ. If the block travels with uniform velocity, find the work done by this applied force during a displacement d of the block.

Sol. The forces acting on the block are shown in Figure. As the block moves with uniform velocity the resultant force on it is zero.

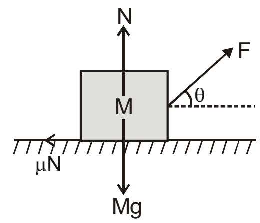
$\therefore$ $F \cos\theta = \mu N$ ...(i)

$F \sin\theta + N = Mg$ ...(ii)

Eliminating N from equations (i) and (ii),

$F \cos\theta = \mu(Mg - F\sin\theta)$

$$F = \frac{\mu Mg}{\cos\theta + \mu\sin\theta}$$



Work done by this force during a displacement d

$$W = F \cdot d\cos\theta = \frac{\mu Mg d\cos\theta}{\cos\theta + \mu\sin\theta}$$

Ex.2 A particle moving in the xy plane undergoes a displacement $\vec{S} = (2.0\hat{i} + 3.0\hat{j})$m while a constant force $\vec{F} = (5.0\hat{i} + 2.0\hat{j})$N acts on the particle.

(a) Calculate the magnitude of the displacement and that of the force.

(b) Calculate the work done by the force.

Sol. (a) $\vec{s} = (2.0\hat{i} + 3.0\hat{j})$ $\qquad \vec{F} = (5.0\hat{i} + 2.0\hat{j})$

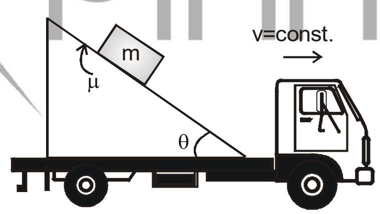
$|\vec{s}| = \sqrt{x^2 + y^2} = \sqrt{(2.0)^2 + (3.0)^2} = \sqrt{13}$ m

$|\vec{F}| = \sqrt{F_x^2 + F_y^2} = \sqrt{(5.0)^2 + (2.0)^2} = 5.4$N

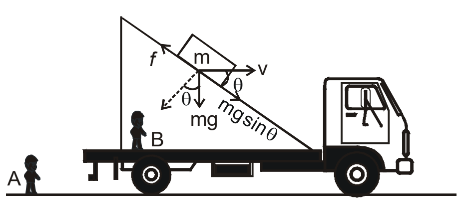
(b) Work done by force, $W = \vec{F}.\vec{s}$

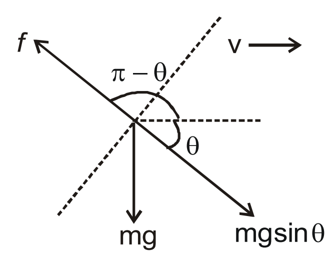
$= (5.0\hat{i} + 2.0\hat{j}) \cdot (2.0\hat{i} + 3.0\hat{j})$N.m $\qquad$ = 10 + 0 + 0 + 6 = 16 N.m = 16 J

Ex.3 A block of mass m is placed on an inclined plane which is moving with constant velocity v in horizontal direction as shown in figure. Then find out work done by the friction in time t if the block is at rest with respect to the incline plane.



Sol. F.B.D of block with respect to ground.





Block is at rest with respect to wedge

$\Rightarrow$ f = mg sin θ

In time t the displacement of block with respect to ground d = vt
Work done by friction for man A
W_f = (component of friction force along displacement) × displacement
$W_f = mg\sin\theta.vt\cos(180°-\theta)$
$W_f = -\, mg\ vt\cos\theta\sin\theta$
W_f for man B = 0 (displacement is zero with respect to man B)

4. WORK DONE BY A VARIABLE FORCE :

(A) When F as a function of x, y, z

When the magnitude and direction of a force vary in three dimensions, it can be expressed as a function of the position. For a variable force work is calculated for infinitely small displacement and for this displacement force is assumed to be constant.

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

The total work done will be sum of infinitely small work

$$W_{A\to B} = \int_A^B \vec{F}.d\vec{s} = \int_A^B (\vec{F}\cos\theta)d\vec{s}$$

It terms of rectangular components,

$$\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$$

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

$$W_{A\to B} = \int_{x_A}^{x_B} F_x dx + \int_{y_A}^{y_B} F_y dy + \int_{z_A}^{z_B} F_z dz$$

Ex.4 A force F = (4.0 x $\hat{i}$ + 3.0 y $\hat{j}$) N acts on a particle which moves in the x-direction from the origin to x = 5.0 m. Find the work done on the object by the force.

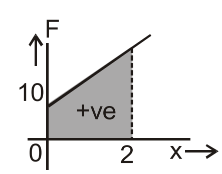
Sol. Here the work done is only due to x component of force because displacement is along x-axis.

i.e., $W = \int_{x_1}^{x_2} F_x dx = \int_0^5 4x\,dx = \left[2x^2\right]_0^5 = 50\ J$

Ex.5 A force F = 0.5x + 10 acts on a particle. Here F is in newton and x is in metre. Calculate the work done by the force during the displacement of the particle from x = 0 to x = 2 metre.

Sol. Small amount of work done dW in giving a small displacement $\overrightarrow{dx}$ is given by

$dW = \overrightarrow{F}.\overrightarrow{dx}$
or $dW = Fdx\cos 0°$
or $dW = Fdx$ $\quad [\therefore \cos 0° = 1]$



Total work done, $W = \int_{x=0}^{x=2} Fdx = \int_{x=0}^{x=2} (0.5x+10)dx$

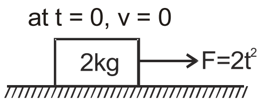
$= \int_{x=0}^{x=2} 0.5xdx + \int_{x=0}^{x=2} 10dx = 0.5\left|\frac{x^2}{2}\right|_{x=0}^{x=2} + 10|x|_{x=0}^{x=2}$

$= \frac{0.5}{2}[2^2 - 0^2] + 10[2 - 0] = (1 + 20) = 21\ J$

(B) When F is given as a function of Time(t) :

Ex.6 The force $F = 2t^2$ is applied on the 2 kg block. Then find out the work done by this force in 2sec. Initially at time t = 0, block is at rest.

Sol.



$F = ma$

$\Rightarrow \quad 2t^2 = 2a \quad \Rightarrow \quad a = t^2$

$\Rightarrow \quad \frac{dv}{dt} = t^2 \quad \Rightarrow \quad \int_0^v dv = \int_0^t t^2 dt$ (At t = 0 it is at rest)

$\Rightarrow \quad v = \frac{t^3}{3}$

Let the displacement of the block be dx from t = t to t = t +dt then, work done by the force F in this time interval dt is.

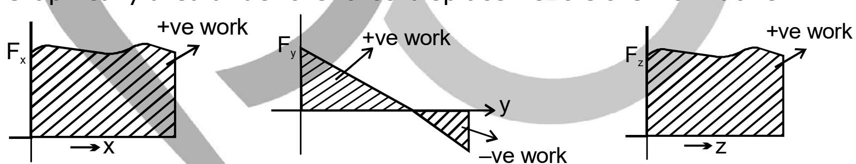
$dw = F.dx = 2t^2.dx$

$dw = 2t^2.\frac{dx}{dt}.dt \quad \Rightarrow \quad dw = 2t^2(v)dt$

$\int_0^w dw = \int_0^2 2t^2.\frac{t^3}{3}dt \quad \Rightarrow \quad W = \frac{2}{3}\int_0^2 t^5 dt \quad \Rightarrow \quad W = \frac{2}{3}\left[\frac{t^6}{6}\right]_0^2 = \frac{64}{9}$ Joule

5. AREA UNDER FORCE DISPLACEMENT CURVE :

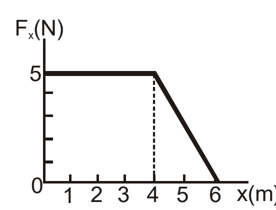
Graphically area under the force-displacement is the work done



The work done can be positive or negative as per the area above the x-axis or below the x-axis respectively.

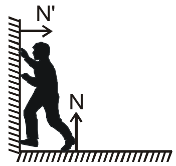
Ex.7 Force acting on a particle varies with x as shown in figure. Calculate the work done by the force as the particle moves from x = 0 to x = 6.0 m.

Sol. The work done by the force is equal to the area under the curve from x = 0 to x = 6.0 m. This area is equal to the area of the rectangular section from x = 0 to x = 4.0 m plus the area of the triangular section from x = 4.0 m to x = 6.0 m. The area of the rectangle is (4.0) (5.0) N.m = 20 J, and the area of the triangle is $\frac{1}{2}$(2.0), (5.0) N.m = 5.0 J. Therefore, the total work done is 25 J.



6. INTERNAL WORK :

Suppose that a man sets himself in motion backward by pushing against a wall. The forces acting on the man are his weight 'W' the upward force N exerted by the ground and the horizontal force N′ exerted by the wall. The works of 'W' and of N are zero because they are perpendicular to the motion. The force N' is the unbalanced horizontal force that imparts to the system a horizontal acceleration. The work of N', however, is zero because there is no motion of its point of application. We are therefore confronted with a curious situation in which a force is responsible for acceleration, but its work, being zero, is not equal to the increase in kinetic energy of the system.



The new feature in this situation is that the man is a composite system with several parts that can move in relation to each other and thus can do work on each other, even in the absence of any interaction with externally applied forces. Such work is called internal work. Although internal forces play no role in acceleration of the composite system, their points of application can move so that work is done; thus the man's kinetic energy can change even though the external forces do no work.

"Basic concept of work lies in following lines

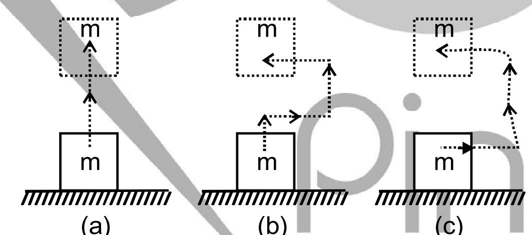
Draw the force at proper point where it acts that give proper importance of the point of application of force.

Think independently for displacement of point of application of force, Instead of relation the displacement of applicant point with force relate it with the observer or reference frame in which work is calculated.

$$W = (\text{Force vector}) \times \begin{pmatrix} \text{displacement vector of point of} \\ \text{application of force as seen by} \\ \text{observer} \end{pmatrix}$$

7. CONSERVATIVE FORCE :

A force is said to be conservative if work done by or against the force in moving a body depends only on the initial and final positions of the body and does not depend on the nature of path followed between the initial and final positions.



Consider a body of mass m being raised to a height h vertically upwards as shown in above figure. The work done is mgh. Suppose we take the body along the path as in (b). The work done during horizontal motion is zero. Adding up the works done in the two vertical parts of the paths, we get the result mgh once again. Any arbitrary path like the one shown in (c) can be broken into elementary horizontal and vertical portions. Work done along the horizontal path is zero. The work done along the vertical parts add up to mgh. Thus we conclude that the work done in raising a body against gravity is independent of the path taken. It only depends upon the intial and final positions of the body. We conclude from this discussion that the force of gravity is a conservative force.

Examples of Conservative forces.

(i) Gravitational force, not only due to Earth due in its general form as given by the universal law of gravitation, is a conservative force.

(ii) Elastic force in a stretched or compressed spring is a conservative force.

(iii) Electrostatic force between two electric charges is a conservative force.

(iv) Magnetic force between two magnetic poles is a conservative force.

Forces acting along the line joining the centres of two bodies are called central forces. Gravitational force and Electrosatic forces are two important examples of central forces. Central forces are conservative forces.

Properties of Conservative forces

- **Work done by or against a conservative force depends only on the initial and final position of the body.**
- Work done by or against a conservative force does not depend upon the nature of the path between initial and final position of the body.
- Work done by or against a conservative force in a round trip is zero.
  If a body moves under the action of a force that does no total work during any round trip, then the force is conservative; otherwise it is non-conservative.
  The concept of potential energy exists only in the case of conservative forces.
- The work done by a conservative force is completely recoverable.
  Complete recoverability is an important aspect of the work done by a conservative force.

Work done by conservative forces
Ist format : (When constant force is given)

Ex.8 ***Calculate the work done to displace the particle from (1, 2) to (4, 5). if*** $\vec{F} = 4\hat{i} + 3\hat{j}$

Sol. $dw = \vec{F}.d\vec{r}$ ($d\vec{r} = dx\hat{i} + dy\hat{j} + dz\hat{k}$)

$dw = (4\hat{i} + 3\hat{j}).(dx\hat{i} + dy\hat{j}) \Rightarrow dw = 4dx + 3dy$

$\int_0^w dw = \int_1^4 4dx + \int_2^5 3dy \Rightarrow w = [4x]_1^4 + [3y]_2^5$

$w = (16 - 4) + (15 - 6) \Rightarrow w = 12 + 9 = 21$ Joule

II format : (When F is given as a function of x, y, z)

If $\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$

then

$dw = (F_x\hat{i} + F_y\hat{j} + F_z\hat{k}).(dx\hat{i} + dy\hat{j} + dz\hat{k}) \Rightarrow dw = F_xdx + F_ydy + F_zdz$

Ex.9 ***An object is displaced 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*** $\vec{F} = (3x^2\hat{i} + 2y\hat{j})N$ ***. Find the work done by this force.***

Sol. $W = \int_{\vec{r}_i}^{\vec{r}_f} \vec{F}.\vec{d}r = \int_{\vec{r}_1}^{\vec{r}_2} (3x^2\hat{i} + 2y\hat{j}) \bullet (dx\hat{i} + dy\hat{j} + dz\hat{k}) = \int_{\vec{r}_1}^{\vec{r}_2} (3x^2dx + 2ydy) = [x^3 + y^2]_{(2,3)}^{(4,6)} = 83\,J$ **Ans.**

IIIrd format (perfect differential format)

Ex.10 ***If*** $\vec{F} = y\hat{i} + x\hat{j}$ ***then find out the work done in moving the particle from position (2, 3) to (5, 6)***

Sol. $dw = \vec{F}.d\vec{s}$

$dw = (y\hat{i} + x\hat{j}).(dx\hat{i} + dy\hat{j})$

$dw = ydx + xdy$

Now $ydx + xdy = d(xy)$ (perfect differential equation)

$\Rightarrow dw = d(xy)$

for total work done we integrate both side

$\int dw = \int d(xy)$

Put $xy = k$

then at (2, 3) $k_i = 2 \times 3 = 6$

at (5, 6) $k_f = 5 \times 6 = 30$

then $w = \int_6^{30} dk = [k]_6^{30}$ $\Rightarrow w = (30 - 6) = 24$ Joule

8. NON-CONSERVATIVE FORCES :

A force is said to be non-conservative if work done by or against the force in moving a body depends upon the path between the initial and final positions.

The frictional forces are non-conservative forces. This is because the work done against friction depends on the length of the path along which a body is moved. It does not depend only on the initial and final positions. Note that the work done by fricitional force in a round trip is not zero.

The velocity-dependent forces such as air resistance, viscous force, magnetic force etc., are non conservative forces.

Ex.11 Calculate the work done by the force $\vec{F} = y\hat{i}$ to move the particle from (0, 0) to (1, 1) in the following condition

(a) $y = x$ (b) $y = x^2$

Sol. We know that

$dw = \vec{F}.d\vec{s} \Rightarrow dw = (y\hat{i}).(dx\,\hat{i})$

$dw = ydx$ ...(1)

In equation (1) we can calculate work done only when we know the path taken by the particle.

either

$y = x$ or $y = x^2$ so now

(a) when $y = x$

$$\int dw = \int_0^1 x\,dx \Rightarrow w = \frac{1}{2}\text{Joule}$$

(b) when $y = x^2$

$$\int dw = \int_0^1 x^2 dx \Rightarrow w = \frac{1}{3}\text{Joule}$$

Difference between conservative and Non-conservative forces

S. No.	Conservative forces	Non-Conservative forces
1	Work done does not depend upon path	Work done depends on path.
2	Work done in a round trip is zero.	Work done in a round trip is not zero.
3	Central in nature.	Forces are velocity-dependent and retarding in nature.
4	When only a conservative force acts within a system, the kinetic energy and potential energy can change. However their sum, the mechanical energy of the system, does not change.	Work done against a non-conservative force may be disipiated as heat energy.
5	Work done is completely recoverable.	Work done in not completely recoverable.

9. ENERGY

A body is said to possess energy if it has the capacity to do work. When a body possessing energy does some work, part of its energy is used up. Conversely if some work is done upon an object, the object will be given some energy. Energy and work are mutually convertiable.

There are various forms of energy. Heat, electricity, light, sound and chemical energy are all familiar forms. In studying mechanics, we are however concerned chiefly with mechanical energy. This type of energy is a property of movement or position.

9.1 Kinetic Energy

Kinetic energy (K.E.), is the capacity of a body to do work by virtue of its motion.

If a body of mass m has velocity v its kinetic energy is equivalent to the work, which an external force would have to do to bring the body from rest up to its velocity v.

The numerical value of the kinetic energy can be calculated from the formula

$$K.E. = \frac{1}{2}mv^2 \qquad ...(8)$$

- Since both m and v^2 are always positive, K.E. is always positive and does not depend upon the direction of motion of the body.

9.2 Potential Energy

Potential energy is energy of the body by virtue of its position. A body is capable to do work by virtue of its position, configuration or state of strain.

Now relation between Potential energy and work done is

W.D = $-\Delta U$

where ΔU is change in potential energy

There are two common forms of potential energy, gravitational and elastic.

Important points related to Potential energy :

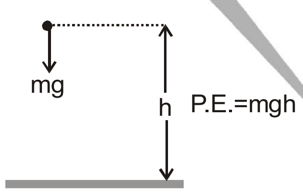
1. Potential energy is a straight function (defined only for position)
2. Potential energy of a point depends on a reference point
3. Potential energy difference between two position doesn't depend on the frame of reference.
4. Potential energy is defined only for conservative force because work done by conservative force is path independent.
5. If we define Potential energy for non conservative force then we have to define P.E. of a single point through different path which gives different value of P.E. at single point that doesn't make any sense.

9.2.1 (a) Gravitational Potential Energy :

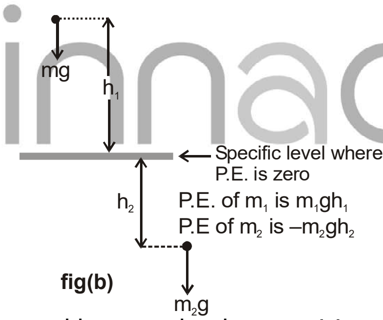
It is possessed by virtue of height.

When an object is allowed to fall from one level to a lower level it gains speed due to gravitational pull, i.e., it gains kinetic energy. Therefore, in possessing height, a body has the ability to convert its gravitational potential energy into kinetic energy. The gravitational potential energy is equivalent to the negative of the amount of work done by the weight of the body in causing the descent. If a mass m is at a height h above a lower level the P.E. possessed by the mass is (mg) (h). Since h is the height of an object above a specified level, an object below the specified level has negative potential energy.

Therefore GPE = $\pm$ mgh ...(9)



fig(a)



fig(b)

- The chosen level from which height is measured has no absolute position. It is important therefore to indicate clearly the zero P.E. level in any problem in which P.E. is to be calculated.
- GPE = $\pm$ mgh is applicable only when h is very small in comparison to the radius of the earth. We have discussed GPE in detail in 'GRAVITATION'.

9.2.2 (b) Elastic Potential Energy : It is a property of stretched or compressed springs.

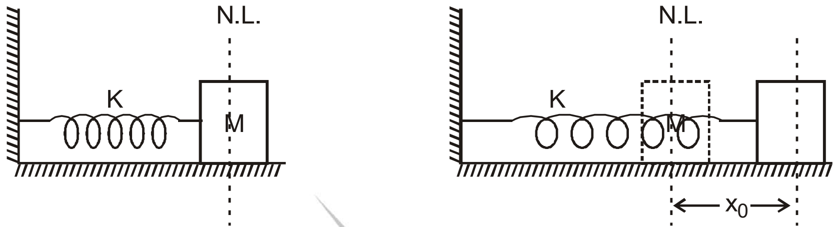
The end of a stretched elastic spring will begin to move if it is released. The spring. therefore possesses potential energy due to its elasticity. (i.e., due to change in its configuration)

The amount of elastic potential energy stored in a spring of natural length a and spring constant k when it is extended by a length x **(from the natural length)** is equivalent to the amount of work necessary to produce the extension.

$$\text{Elastic Potential Energy} = \frac{1}{2}kx^2 \quad ...(10)$$

It is never negative whether the spring is extended or compressed.

Proof :



Consider a spring block system as shown in the figure and let us calculate work done by spring when the block is displaceed by x_0 from the natural length.
At any moment if the elongation in spring is x, then the force on the block by the spring is kx towards left. Therefore, the work done by the spring when block further displaces by dx
dW = – kx dx

$\therefore$ Total work done by the spring, $W = -\int_0^{x_0} kx\,dx = -\frac{1}{2}kx_0^2$

Similarly, work done by the spring when it is given a compression x_0 is $-\frac{1}{2}kx_0^2$.

: We assume zero potential energy at natural length of the spring :

10. CONSERVATIVE FORCE AND POTENTIAL ENERGY :

$$F_s = -\frac{\partial U}{\partial s}$$

i.e. the projection of the force field , the vector F, at a given point in the direction of the displacement r equals the derivative of the potential energy U with respect to a given direction, taken with the opposite sign. The designation of a partial derivative $\partial/\partial s$ emphasizes the fact of deriving with respect to a definite direction.So, having reversed the sign of the partial derivatives of the function U with respect to x, y, z, we obtain the projection F_x, F_y and F_z of the vector F on the unit vectors i, j and k. Hence, one can readily find the vector itself :

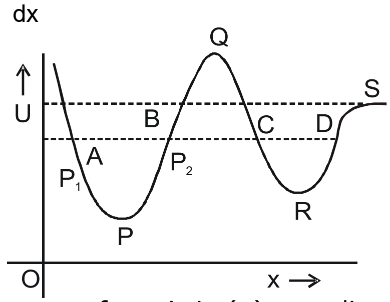
$$F = F_x i + F_y j + F_z k, \text{ or } F = -\left(\frac{\partial U}{\partial x}i + \frac{\partial U}{\partial y}j + \frac{\partial U}{\partial z}k\right)$$

The quantity in parentheses is referred to as the scalar gradient of the function U and is denoted by grad U or ∇U. We shall use the second, more convenient, designation where ∇ ("nabla") signifies the symbolic vector or operator

$$\nabla = i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z}$$

Potential Energy curve :

- A graph plotted between the PE of a particle and its displacement from the centre of force field is called PE curve.
- Using graph, we can predict the rate of motion of a particle at various positions.
- Force on the particle is $F_{(x)} = -\frac{dU}{dx}$



Case : I On increasing x, if U increases, force is in (–) ve x direction i.e. attraction force.
Case : II On increasing x, if U decreases, force is in (+) ve x-direction i.e. repulsion force.

Different positions of a particle :

Position of equilibrium

If net force acting on a body is zero, it is said to be in equilibrium. For equilibrium $\frac{dU}{dx} = 0$. Points P, Q, R and S are the states of equilbrium positions.

Types of equilirbium :

- **Stable equilibrium :**
When a particle is displaced slightly from a position and a force acting on it brings it back to the initial position, it is said to be in stable equilibrium position.
Necessary conditions:– $\frac{dU}{dx} = 0$,and $\frac{d^2U}{dx^2} = +$ ve
In figure P and R point shows stable equilibrium point.

- **Unstable Equilibrium :**
When a particle is displaced slightly from a position and force acting on it tries to displace the particle further away from the equilibrium position, it is said to be in unstable equilibrium.
Condition : $\frac{dU}{dx} = 0$ potential energy is maximum i.e. $= \frac{d^2U}{dx^2} = -$ ve
Q point in figure shows unstable equilibrium point

- **Neutral equilibrium** :
In the neutral equilibrium potential energy is constant. When a particle is displaced from its position it does not experience any force acting on it and continues to be in equilibrium in the displaced position. This is said to be neutral equilibrium.
In figure S is the neutral point
Condition : $\frac{dU}{dx} = 0$, $\frac{d^2U}{dx^2} = 0$

Ex.12 The potential energy between two atoms in a molecule is given by, $U_{(x)} = \frac{a}{x^{12}} - \frac{b}{x^6}$, where a and b are positive constants and x is the distance between the atoms. The system is in stable equilibrium when -

(A) $x = 0$ ***(B) $x = \frac{a}{2b}$*** ***(C) $x = \left(\frac{2a}{b}\right)^{1/6}$*** ***(D) $x = \left(\frac{11a}{5b}\right)$***

Sol. **(C)**

Given that, $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$ We, know $F = -\frac{du}{dx}$

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

or $\frac{6b}{x^7} = \frac{12a}{4x^{13}}$ or $x^6 = 12a/6b = 2a/b$ or $x = \left(\frac{2a}{b}\right)^{1/6}$

Ex.13 The potential energy of a conservative system is given by $U = ax^2 - bx$ where a and b are positive constants. Find the equilibrium position and discuss whether the equilibrium is stable, unstable or neutral.

Sol. In a conservative field $F = -\frac{dU}{dx}$ $\therefore F = -\frac{d}{dx}(ax^2 - bx) = b - 2ax$

For equilibrium F = 0 or b – 2ax = 0 $\therefore x = \frac{b}{2a}$

From the given equation we can see that $\frac{d^2U}{dx^2} = 2a$ (positive), i.e., U is minimum.

Therefore, $x = \frac{b}{2a}$ is the stable equilibrium positon.

11. WORK ENERGY THEOREM :

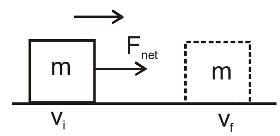
If the resultant or net force acting on a body is F_{net} then Newton's second law states that

$F_{net} = ma$ ...(1)

If the resultant force varies with x, the acceleration and speed also depend on x.

then $a = v\frac{dv}{dx}$ ...(2)

from eq. (1)



$F_{net} = mv\frac{dv}{dx} \Rightarrow F_{net}.dx = m\,v\,dv$

$\int F_{net}.dx = \int_{v_i}^{v_f} mvdv$

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

$W_{net} = k_f - k_i$

$W_{net} = \Delta K$ ...(3)

Work done by net force F_{net} in displacing a particle equals to the change in kinetic energy of the particle i.e.

we can write eq. (3) in following way

$(W.D)_c + (W.D)_{N.C} + (W.D)_{ext.} + (W.D)_{pseudo} = \Delta K$ ...(4)

where $(W.D)_c$ = work done by conservative force

$(W.D)_{N.C}$ = work done by non conservative force.

$(W.D)_{ext}$ = work done by external force

$(W.D)_{pseudo}$ = work done by pseudo force.

we know that

$(W.D)_c = -\Delta U \Rightarrow -\Delta U + (W.D)_{N.C} + (W.D)_{ext} + (W.D)_{pseudo} = \Delta K$

$\Rightarrow (W.D)_{N.C} + (W.D)_{ext.} + (W.D)_{pseudo} = (k_f + u_f) - (k_i + u_i)$

$\because$ k + u = Mechanical energy.

$\Rightarrow$ work done by forces (except conservative forces)

= change is mechanical energy.

If $(W.D)_{N.C} = (W.D)_{ext} = (W.D)_{pseudo} = 0$

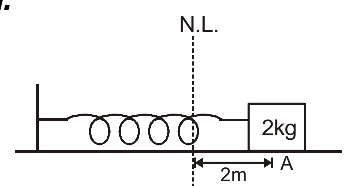
$K_f + U_f = K_i + U_i$

Initial mechanical energy = final mechanical energy. This is called mechanical energy conservation law.

Questions Based on work Energy Theorem :

(A) When only one conservative force is acting

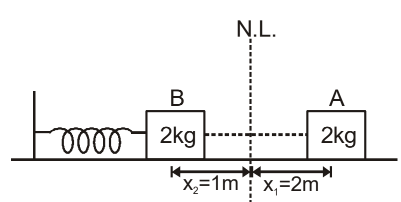
Ex.14 The block shown in figure is released from rest. Find out the speed of the block when the spring is compressed by 1 m.



Sol. In the above problem only one conservative force (spring force) is working on the block so from mechanical energy conservation

$k_f + u_f = k_i + u_i$ ...(i)

at A block is at rest so $k_i = 0$



$u_i = \frac{1}{2}kx_1^2 = \frac{1}{2}k(2)^2$ = 2k Joule

At position B if speed of the block is v then

$$k_f = \frac{1}{2}mv^2 = \frac{1}{2} \times 2 \times v^2 = v^2$$

$$u_f = \frac{1}{2}kx_2^2 = \frac{1}{2} \times k \times 1 = \frac{k}{2}$$

Putting the above values in equation (i), we get

$$\Rightarrow \quad v^2 + \frac{k}{2} = 2k \quad \Rightarrow \quad v^2 = \frac{3k}{2} \Rightarrow v = \sqrt{\frac{3k}{2}} \text{ m/sec}$$

Ex.15 ***A block of mass m is dropped from height h above the ground. Find out the speed of the block when it reaches the ground.***

Sol.

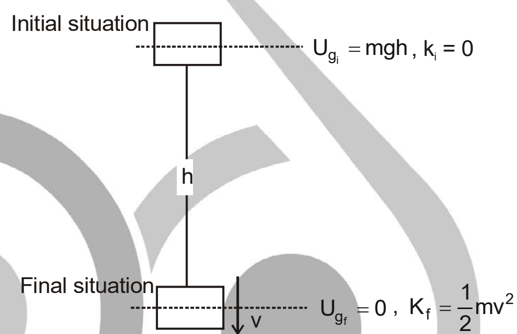


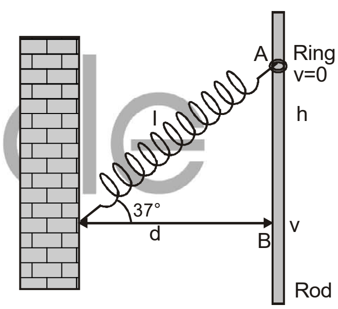
Figure shows the complete description of the problem only one conservative force is working on the block. So from mechanical energy conservation

$$k_f + u_f = k_i + u_i \quad \Rightarrow \quad \frac{1}{2}mv^2 + 0 = 0 + mgh$$

$$v = \sqrt{2gh} \text{ m/sec}$$

(B) When two conservative force are acting in problem.

Ex.16 ***One end of a light spring of natural length d and spring constant k is fixed on a rigid wall and the other is attached to a smooth ring of mass m which can slide without friction on a vertical rod fixed at a distance d from the wall. Initially the spring makes an angle of 37º with the horizontal as shown in fig. When the system is released from rest, find the speed of the ring when the spring becomes horizontal.***
[sin 37º = 3/5]



Sol. If l is the stretched length of the spring, then from figure

$$\frac{d}{l} = \cos 37° = \frac{4}{5}, \text{ i.e., } \quad l = \frac{5}{4}d$$

So, the stretch $\quad y = l - d = \frac{5}{4}d - d = \frac{d}{4}$

and $\quad h = l \sin 37º = \frac{5}{4}d \times \frac{3}{5} = \frac{3}{4}d$

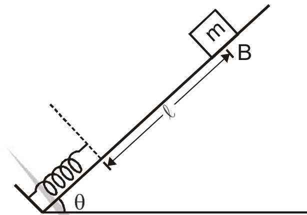
Now, taking point B as reference level and applying law of conservation of mechanical energy between A and B,

$E_A = E_B \quad$ or $\quad mgh + \frac{1}{2}ky^2 = \frac{1}{2}mv^2$

[as for, B, h = 0 and y = 0]

or $\frac{3}{4}mgd + \frac{1}{2}k\left(\frac{d}{4}\right)^2 = \frac{1}{2}mv^2 \quad$ [as for A, $h = \frac{3}{4}d$ and $y = \frac{1}{4}d$] $\quad$ or $\quad v = d\sqrt{\frac{3g}{2d} + \frac{k}{16m}}$ **Ans.**

Ex.17 ***The block shown in figure is released from rest and initially the spring is at its natural length. Write down the energy conservation equation. When the spring is compressed by l_1 ?***



Sol. Here two conservative forces are included in the problem.

(i) Gravitational force (ii) spring force

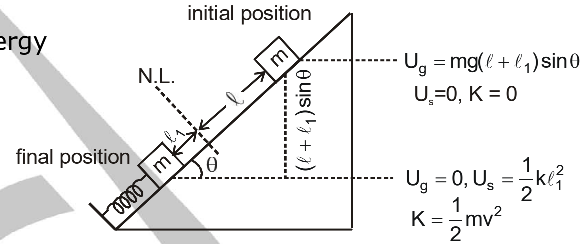
We assume zero gravitational potential energy

at A as shown in figure.

from mechanical energy conservation

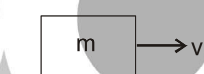
$k_f + u_f = k_i + u_i$ ...(i)

$\frac{1}{2}mv^2 + \frac{1}{2}k\ell_1^2 = mg(\ell_1 + \ell)\sin\theta$



(C) When only one non conservative force is included in problem.

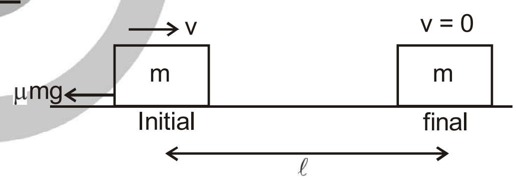
Ex.18 ***Find out the distance travelled by the block as shown in figure. If the initial speed of the*** block is v and ***μ is the friction coefficient between the surface of block and ground.***



Sol. Applying work energy theorem, we get

$\Rightarrow \quad (-\mu\, mg\, \ell) = (0 + 0) - \left(\frac{1}{2}mv^2 + 0\right)$

$\Rightarrow \quad \mu\, g\, \ell = \frac{1}{2}v^2 \quad \Rightarrow \quad \ell = \frac{v^2}{2\mu g}$



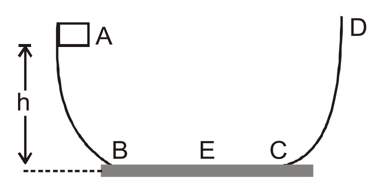
(D) When both conservative and non-conservative force in the problem

Ex.19 ***A particle slides along a track with elevated ends and a flat central part as shown in figure. The flat portion BC has a length l = 3.0 m. The curved portions of the track are frictionless. For the flat part the coefficient of kinetic friction is μ_k = 0.20, the particle is released at point A which is at height h = 1.5 m above the flat part of the track. Where does the particle finally comes to rest?***

Sol. As initial mechanical energy of the particle is mgh and final is zero, so loss in mechanical energy = *mgh*. This mechanical energy is lost in doing work against friction in the flat part,

So, loss in mechanical energy = work done against friction

or $mgh = \mu mgs$ i.e., $s = \frac{h}{\mu} = \frac{1.5}{0.2} = 7.5$ m



After starting from B the particle will reach C and then will rise up till the remaining KE at C is converted into potential energy. It will then again descend and at C will have the same value as it had when ascending, but now it will move from C to B. The same will be repeated and finally the particle will come to rest at E such that

BC + CB + BE = 7.5 or 3 + 3 + BE = 7.5

i.e., BE = 1.5

So, the particle comes to rest at the centre of the flat part.

Ex.20 A 0.5 kg block slides from the point A on a horizontal track with an initial speed 3 m/s towards a weightless horizontal spring of length 1 m and force constant 2 N/m. The part AB of the track is frictionless and the part BC has the coefficient of static and kinetic friction as 0.22 and 0.20 respectively. If the distance AB and BD are 2 m and 2.14 m respectively, find the total distance through which the block moves before it comes to rest completely. [g = 10 m/s²]

Sol. As the track AB is frictionless, the block moves this distance without loss in its initial

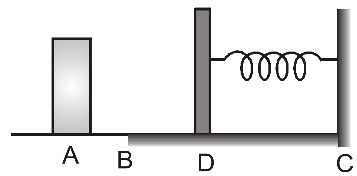
KE = $\frac{1}{2}mv^2$ = $\frac{1}{2}$ × 0.5 × 3^2 = 2.25 J. In the path BD as friction is present, so work done against friction

= $\mu_k\, mgs$ = 0.2 × 0.5 × 10 × 2.14 = 2.14 J

So, at D the KE of the block is = 2.25 – 2.14 = 0.11 J.

Now, if the spring is compressed by x

$$0.11 = \frac{1}{2} \times k \times x^2 + \mu_k mgx$$



i.e., $0.11 = \frac{1}{2} \times 2 \times x^2 + 0.2 \times 0.5 \times 10x$

or $x^2 + x - 0.11 = 0$

which on solving gives positive value of x = 0.1 m

After moving the distance x = 0.1 m the block comes to rest. Now the compressed spring exerts a force :

F = kx = 2 × 0.1 = 0.2 N

on the block while limiting frictional force between block and track is $f_L = \mu_s$ mg = 0.22 × 0.5 × 10 = 1.1 N. Since, F < f_L. The block will not move back. So, the total distance moved by block

= AB + BD + 0.1

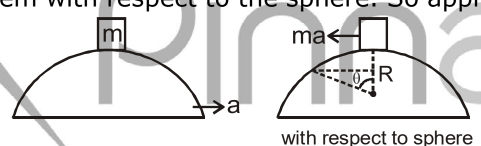
= 2 + 2.14 + 0.1

= 4.24 m

(E) Important Examples :

Ex.21 A smooth sphere of radius R is made to translate in a straight line with a constant acceleration a. A particle kept on the top of the sphere is released from there at zero velocity with respect to the sphere. Find the speed of the paritcle with respect to the sphere as a function of the angle θ it slides.

Sol. We solve the above problem with respect to the sphere. So apply a pseudo force on the particle



Now from work energy theorem.

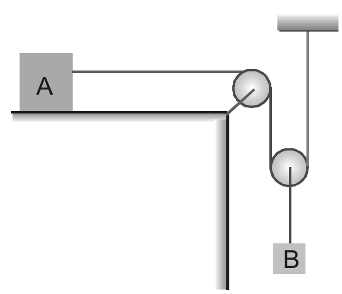
work done by ma = change in mechanical energy

⇒ ma R sin θ = $(k_f + u_f) - (k_i + u_i)$

maR sin θ = $\frac{1}{2}mv^2 - mgR(1-\cos\theta)$ ⇒ $\frac{1}{2}mv^2$ = maR sin θ + mgR (1 – cos θ)

⇒ v^2 = 2R(a sin θ + g – g cos θ) ⇒ v = $[2R\,(a \sin\theta + g - g\cos\theta)]^{1/2}$ m/sec

Ex.22 In the arrangement shown in figure m_A = 4.0 kg and m_B = 4.0 kg. The system is released from rest and block B is found to have a speed 0.3 m/s after it has descended through a distance of 1m. Find the coefficient of friction between the block and the table. Neglect friction elsewhere. (Take g = 10 m/s²)



Sol. From constraint relations, we can see that

$v_A = 2\, v_B$

Therefore, v_A = 2(0.3) = 0.6 m/s

as v_B = 0.3 m/s (given)

Applying $W_{nc} = \Delta U + \Delta K$

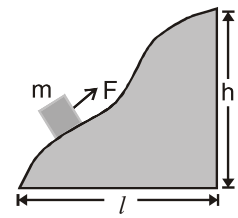
we get $-\mu m_A g S_A = -m_B g S_B + \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2$

Here, $S_A = 2S_B = 2m$ as $S_B = 1$ m (given)

$\therefore \quad -\mu(4.0)(10)(2) = -(1)(10)(1) + \frac{1}{2}(4)(0.6)^2 + \frac{1}{2}(1)(0.3)^2$

or $-80\mu = -10 + 0.72 + 0.045$ or $80\mu = 9.235$ or $\mu = 0.115$ **Ans.**

Ex.23 A body of mass 'm' was slowly hauled up the hill as shown in the figure by a force F which at each point was directed along a tangent to the trajectory. Find the work performed by this force, if the height of the hill is h, the length of its base is l and the coefficient of friction is μ.



Sol. Four forces are acting on the body :

1. weight (mg) 2. normal reaction (N)
3. friction (f) and 4. the applied force (F)

Using work-energy theorem

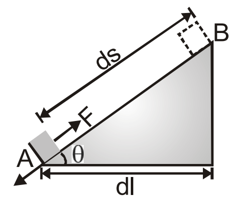
$$W_{net} = \Delta KE$$

or $W_{mg} + W_N + W_f + W_F = 0$

Here, $\Delta KE = 0$, because $K_i = 0 = K_f$

$W_{mg} = -mgh \Rightarrow W_N = 0$

(as normal reaction is perpendicular to displacement at all points)



W_f can be calculated as under :

$f = \mu mg\cos\theta$

$\therefore \quad (dW_{AB})_f = -f\,ds$

$= -(\mu mg\cos\theta)\,ds = -\mu mg\,(dl)$ (as $ds\cos\theta = dl$)

$\therefore \quad f = -\mu mg\sum dl = -\mu mgl$

Substituting these values in Eq. (i), we get

$$W_F = mgh + \mu mgl$$

: Here again, if we want to solve this problem without using work-energy theorem we will first find magnitude of applied force $\vec{F}$ at different locations and then integrate $dW\ (= \vec{F}.d\vec{r})$ with proper limits.

12. POWER

Power is defined as the time rate of doing work.

When the time taken to complete a given amount of work is important, we measure the power of the agent doing work.

The average power ($\bar{P}$ or P_{av}) delivered by an agent is given by

$$\bar{P} \text{ or } P_{av} = \frac{\Delta W}{\Delta t} = \frac{\text{Total work done}}{\text{Total time}}$$

where ΔW is the amount of work done in time Δt.

Power is the ratio of two scalars-work and time. So, power is a scalar quantity. If time taken to complete a given amount of work is more, then power is less.

- The instantaneous power is, $P = \frac{dW}{dt}$ where dW is the work done by a force $\vec{F}$ in a small time dt.
- $P = \frac{dW}{dt} = \vec{F}.\frac{d\vec{r}}{dt} = \vec{F}.\vec{v}$ where $\vec{v}$ is the velocity of the body.

By definition of dot product,

$$P = Fv\cos\theta$$

where θ is the smaller angle between $\vec{F}$ and $\vec{v}$

This P is called as instantaneous power if dt is very small.

12.1 Unit of Power :

A unit power is the power of an agent which does unit work in unit time.
The power of an agent is said to be one watt if it does one joule of work in one second.
1 watt = 1 joule/second = 10^7 erg/second

Also, 1 watt = $\dfrac{1\,\text{newton} \times 1\,\text{metre}}{1\,\text{second}}$ = 1 N ms^{-1}.

Dimensional formula of power

$$[\text{Power}] = \frac{[\text{Work}]}{[\text{Time}]} = \frac{[ML^2T^{-2}]}{[T]} = [ML^2T^{-3}]$$

Ex.24 A one kilowatt motor pumps out water from a well 10 metre deep. Calculate the quantity of water pumped out per second.

Sol. Power, P = 1 kilowatt = 10^3 watt

S = 10 m ; Time, t = 1 second ; Mass of water, m = ? Power = $\dfrac{mg \times S}{t}$

$\therefore$ $10^3 = \dfrac{m \times 9.8 \times 10}{1}$ or $m = \dfrac{10^3}{9.8 \times 10}$ kg
= 10.204 kg

Ex.25 The blades of a windmill sweep out a circle of area A. (a) If the wind flows at a velocity v perpendicular to the circle, what is the mass of the air passing through in time t? (b) What is the kinetic energy or the air? (c) Assume that the windmill converts 25% of the wind's energy into electrical energy, and that A = 30m², v = 36 km h⁻¹ and the density of air is 1.2 kg m⁻³. What is the electrical power produced?

Sol. (a) Volume of wind flowing per second = Av
Mass of wind flowing per second = Avρ
Mass of air passing in t second = Avρt

(b) Kinetic energy of air $= \dfrac{1}{2}mv^2 = \dfrac{1}{2}(Av\rho t)v^2 = \dfrac{1}{2}Av^3\rho t$

(c) Electrical energy produced $= \dfrac{25}{100} \times \dfrac{1}{2}Av^3\rho t = \dfrac{Av^3\rho t}{8}$

Electrical power $= \dfrac{Av^3\rho t}{8t} = \dfrac{Av^3\rho}{8}$

Now, A = 30 m^2, v = 36 km h^{-1} = 36 × $\dfrac{5}{18}$ m s^{-1} = 10 m s^{-1}, ρ = 1.2 kg ms^{-1}

$\therefore$ Electrical power $= \dfrac{30 \times 10 \times 10 \times 1.2}{8}$ W = 4500 W = 4.5 kW

Ex.26 One coolie takes one minute to raise a box through a height of 2 metre. Another one takes 30 second for the same job and does the same amount of work. Which one of the two has greater power and which one uses greater energy?

Sol. Power of first coolie $= \dfrac{\text{Work}}{\text{Time}} = \dfrac{M \times g \times S}{t} = \dfrac{M \times 9.8 \times 2}{60} Js^{-1}$

Power of second coolie $= \dfrac{M \times 9.8 \times 2}{30} Js^{-1} = 2\left(\dfrac{M \times 9.8 \times 2}{60}\right)$ J s^{-1} = 2 × Power of first coolie

So, the power of the second coolie is double that of the first. Both the coolies spend the same amount of energy.
We know that W = Pt
For the same work,

$W = p_1t_1 = P_2t_2$

or $\dfrac{P_2}{P_1} = \dfrac{t_1}{t_2} = \dfrac{1\,\text{minute}}{30\,\text{s}} = 2$ or $P_2 = 2P_1$

LEVEL-I

1. Calculate the work done against gravity by a coolie in carrying a load of mass 10 kg on his head when he walks uniformly a distance of 5 m in the (i) horizontal direction (ii) vertical direction. (Take g = 10 m/s^2)
(A) 0,500 (B) 500,0
(C) 250,250 (D) 400,100

2. A body is constrained to move in the y-direction. It is subjected to a force $(-2\hat{i}+15\hat{j}+6\hat{k})$ newton. What is the work done by this force in moving the body through a distance of 10 m ?
(A) 150 (B) −20
(C) 190 (D) 10

3. A body travels through a distance of 10 m on a straight line, under the influence of 5N. If the work done by the force is 25J, the angle between the force and displacement is-
(A) 0º (B) 30º
(C) 60º (D) 90º

4. The work done in pushing a block of mass 10 kg from bottom to the top of a frictionless inclined plane 5 m long and 3 m high is- (g = 9.8 m/sec^2)
(A) 392 J (B) 294 J
(C) 98 J (D) 0.98 J

5. Under the action of a force a 2kg mass moves such that its position x as a function of time is given by x = $t^3/3$ where x is in metres and t in seconds. The work done by the force in first two seconds is
(A) 1600 joules (B) 160joules
(C) 16joules (D) 1.6 joules

6. A force $\vec{F}=k[y\hat{i}+x\hat{j}]$ where k is a positive constant acts on a particle moving in x-y plane starting from the point (3, 5), the particle is taken along a straight line to (5, 7). The work done by the force is :
(A) zero (B) 35 K
(C) 20 K (D) 15 K

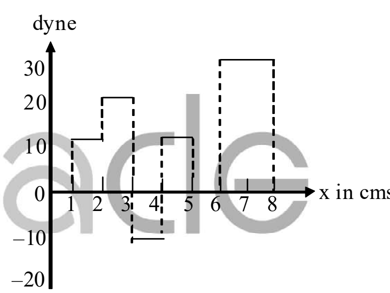
7. A locomotive of mass m starts moving so that its velocity varies according to the law v = $k\sqrt{s}$ where k is constant and s is the distance covered. Find the total work performed by all the forces which are acting on the locomotive during the first t seconds after the beginning of motion.
(A) W = $\frac{1}{8}mk^4t^2$ (B) W = $\frac{1}{4}m^2k^4t^2$
(C) W = $\frac{1}{4}mk^4t^4$ (D) W = $\frac{1}{8}mk^4t^4$

8. 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 of force of magnitude 30 N which is acting along $(\hat{i}+\hat{j}+\hat{k})$. The work done by the force is -
(A) $10\sqrt{3}$ J (B) $30\sqrt{3}$ J
(C) 30 J (D) None of these

9. 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-
(A) c x_1^2 (B) $\frac{1}{2}$c x_1^2
(C) c x_1^3 (D) zero.

10. A force **F** = $(3x\hat{i}+4\hat{j})$ Newton (where x is in metres) acts on a particle which moves from a position (2m, 3m) to (3m, 0m). Then the work done is
(A) 7.5J (B) −12J
(C) −4.5 J (D) +4.5 J

11. The relationship between force and position is shown in fig (in one dimensional case). The work done in displacing a body from x = 1cm to x = 5 cm is :



(A) 20 erg (B) 60 erg
(C) 70 erg (D) 700 erg

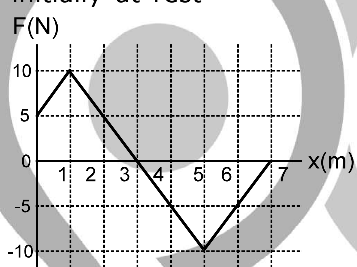
12. A force $\vec{F}$ = $2\hat{i}-3\hat{j}+7\hat{k}$ (N) acts on a particle which undergoes a displacement $\vec{r}$ = $7\hat{i}+3\hat{j}-2\hat{k}$ (M). Calculate the work done by the force
(A) 37 J (B) −9 J
(C) 49 J (D) 14 J

13. A body of mass 2 kg fall vertically, passing through two points A and B. The speeds of the body as it passes A and B are 1 m/s and 4m/s respectively. The resistance against which the body falls is 9.6N. What is the distance AB?
(A) 2m (B) 3m
(C) 6m (D) 1.5 m

14. A block of mass M is hanging over a smooth and light pulley through a light string. The other end of the string is pulled by a constant force F. The kinetic energy of the block increases by 20 J in 1s.
(A) The tension in the string is Mg
(B) The tension in the string is F
(C) The work done by the tension on the block is 20 J in the above 1s
(D) The work done by the force of gravity is –20 J in the above 1s

15. Force acting on a particle is $(2\hat{i}+3\hat{j})$N. Work done by this force is zero. when a particle is moved on the line 3y + kx = 5. Here value of k is:
(A) 2 (B) 4
(C) 6 (D) 8

16. The figure shows the force (F) versus displacement (s) graph for a particle of mass m = 2kg initially at rest



(i) The maximum speed of the particle occurs at x = ... m
(ii) The maximum speed of the particle is ..... ms^{-1}
(iii) The particle once again has its speed zero at x = ... m
(A) 5,3,6 (B) 3,4.18,6
(C) 6,5,3 (D) 4,5,6

17. A light and a heavy body have equal momentum. Which one has greater K.E.?
(A) the light body
(B) both have equal K.E.
(C) the heavy body
(D) data given is incomplete

18. A 300 g mass has a velocity of (3i + 4j) m/s at a certain instant what is its K.E. ?
(A) 1.35 J (B) 2.4 J
(C) 3.75 J (D) 7.35 J

19. Two bodies of mass 1 kg and 4 kg are moving with equal kinetic energies. The ratio of their linear momentum is-
(A) 1 : 2 (B) 2 : 1
(C) 4 : 1 (D) 1 : 4

20. The momentum of a body is increased by 50%. The K.E. of the body will be increased by-
(A) 50 % (B) 125 %
(C) 330 % (D) 400 %

21. A chain of mass m and length ℓ is placed on a table with one-sixth of it hanging freely from the table edge. The amount of work. done to pull the chain on the table is
(A) $mg\ell/4$ (B) $mg\ell/6$
(C) $mg\ell/72$ (D) $mg\ell/36$

22. A body of mass 2 kg is moved from a point A to a point B by an external agent in a conservative force field. It the velocity of the body at the points A and B are 5 m/s and 3 m/s respectively and the work done by the external agents is –10 J, then the change in potential energy between points A and B is-
(A) 6 J (B) 36 J
(C) 16 J (D) None of these

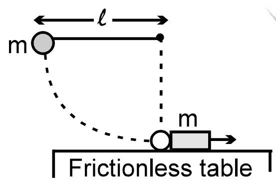
23. A running man has half the kinetic energy that a boy of half his mass has. The man speeds up by 1.0 meter/sec and then has the same kinetic energy as the boy. What were the original speeds of man and boy ?
(A) 2.4 m/sec, 4.8m/sec
(B) 4.8m/sec, 2.4m/sec
(C) 4.2 m/sec, 8.4m/sec
(D) 8.4m/sec, 4.2m/sec

24. A lead bullet of specific heat 's' moving with a velocity v strikes a wall and stops. If half of its energy is converted into heat, the rise in its temperature will be-
[where s is in cal/kg - ^oc]
(A) $\frac{v^3 s}{J}$ (B) $\frac{2V^2}{Js}$
(C) $\frac{V^2}{4Js}$ (D) $\frac{V^2 s}{2J}$

25. A man slides down a snow covered hill along a curved path and falls 20m below his initial position. The velocity in m/sec with which he finally strikes the ground is :
(g = 10 m/sec^2)
(A) 20 (B) 400
(C) 200 (D) 40

26. An inelastic ball is dropped from a height 100 metres. If due to impact it loses 35% of its energy the ball will rise to a height of -
(A) 35m (B) 65 m
(C) 100 m (D) 135 m

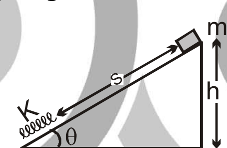
27. The bob of a simple pendulum of length ℓ dropped from a horizontal position strikes a block of the same mass, placed on a horizontal table (frictionless) as shown in the diagram, the block shall have kinetic energy-



(A) Zero (B) mgl.
(C) 1/2 mgl. (D) 2mgl.

28. A block of mass m slips down an inclined plane as shown in the figure. When it reaches the bottom it presses the spring by a length (spring length <<h and spring constant = K)-

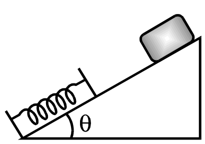
(A) $(2mgh/K)^{1/2}$
(B) $(mgh/K)^{1/2}$
(C) $(2gh/mK)^{1/2}$
(D) $(gh/mK)^{1/2}$



29. A uniform flexible chain of mass m and length 2ℓ hangs in equilibrium over a smooth horizontal pin of negligible diameter. One end of the chain is given a small vertical displacement so that the chain slips over the pin. The speed of chain when it leaves pin is-

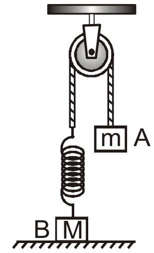
(A) $\sqrt{2g\ell}$ (B) $\sqrt{g\ell}$
(C) $\sqrt{4g\ell}$ (D) $\sqrt{3g\ell}$

30. In the given figure, the inclined surface is smooth. The body releases from the top. Then-



(A) the body has maximum velocity just before striking the spring
(B) The body performs periodic motion
(C) the body has maximum velocity at the compression $\frac{mg\sin\theta}{k}$ where k is spring constant
(D) both (B) and (C) are correct

31. In the figure the block A is released from rest when the spring is at its natural length. For the block B of mass M to leave contact with the ground at some stage, the minimum mass of must be -



(A) 2 M
(B) M
(C) $\frac{M}{2}$
(D) a function of M and the force constant of the spring

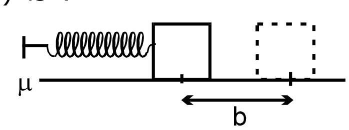
32. A machine, which is 72 percent efficient, uses 36 joules of energy in lifting up 1kg mass through a certain distance. The mass is the allowed to fall through that distance. The velocity at the end of its fall is

(A) 6.6 ms^{-1} (B) 7.2 ms^{-1}
(C) 8.1 ms^{-1} (D) 9.2 ms^{-1}

33. A 5 kg block is lifted vertically through a height of 5 metre by a force of 60N. Determine **(i)** the work done by applied force in lifting the block, **(ii)** the potential energy of the block at 5m, **(iii)** the kinetic energy of the block at 5 m **(iv)** the velocity of the block at 5 m-

(A) 300 J, 245 J, 55J, 4.69 m/s
(B) 200 J, 245 J, 50J, 4.69 m/s
(C) 150 J, 150 J, 50J, 4.69 m/s
(D) 300 J, 245 J, 100J, 10.69 m/s

34. For the system shown in the fig., initially the spring is compressed by a distance 'a' from its natural length and when released, it moves to a distance 'b' from its equillibrium position. The decrease in amplitude for half cycle (-a to +b) is :



(A) $\frac{\mu mg}{K}$ (B) $\frac{2\mu mg}{K}$
(C) $\frac{\mu g}{K}$ (D) $\frac{K}{\mu mg}$

35. A small ball of mass m =1 gm is placed at the bottom of a spherical glass of radius R = 1m. It is displaced by height, h = 1 cm long the glass surface and released. What is the total distance described by it before coming to rest at the bottom (μ = 0.1 between the wall and the glass)

(A) 16 cm (B) 7 cm
(C) 10 cm (D) 8 cm

36. Two equal lumps of putty are suspended side by side from two long strings so that they are just touching. One is drawn aside so that its centre of gravity rises a vertical distance h. It is released and then collides inelastically with the other one. The vertical distance risen by the centre of gravity of the combination is -
(A) h. (B) 3h/4
(C) h/2 (D) h/4

37. A car of mass 'm' is driven with acceleration 'a' along a straight level road against a constant external resistive force 'R'. When the velocity of the car is 'V', the rate at which the engine of the car is doing work will be :
(A) RV (B) maV
(C) (R + ma) V (D) (ma – R)V

38. A truck of mass 30,000 kg moves up an inclined plane of slope 1 in 100 at a speed of 30 kmph. The power of the truck is (given g = 10 ms^{-2})
(A) 25 kW (B) 10 kW
(C) 5 kW (D) 2.5 kW

39. A particle moves with a velocity $\vec{v} = (5\hat{i} - 3\hat{j} + 6\hat{k})$ m/s under the influence of a constant force $\vec{F} = (10\hat{i} + 10\hat{j} + 20\hat{k})$N. The instantaneous power applied to the particle is :
(A) 200 J/s (B) 40 J/s
(C) 140 J/s (D) 170 J/s

40. An object of mass m accelerates uniformly from rest to a speed v_f in time t_f. Then the instantaneous power delivered to the object, as a function of time t is -
(A) $mt\left(\frac{v_f}{t_f}\right)^2$ (B) $mt\,\frac{v_f}{t_f}$
(C) $\frac{1}{2}mt^2\left(\frac{v_f}{t_f}\right)^2$ (D) $\frac{1}{2}mt^2\left(\frac{v_f}{t_f}\right)$

41. A self propelled vehicle of mass m whose engine delivers constant power P has an acceleration $a = \frac{P}{mv}$ (assume that there is no friction). In order to increase its velocity from v_1 to v_2, the distance it has to travel will be
(A) $\frac{3P}{m}(v_2^2 - v_1^2)$ (B) $\frac{m}{3P}(v_2^3 - v_1^3)$
(C) $\frac{m}{3P}(v_2^2 - v_1^2)$ (D) $\frac{m}{3P}(v_2 - v_1)$

42. A body is moved along a straight line by a machine delivering constant power. The distance moved by the body in time t is proportional to-
(A) $t^{1/2}$ (B) $t^{3/4}$
(C) $t^{3/2}$ (D) t^2

43. Power applied to a particle varies with time as P = $(3t^2 - 2t + 1)$ watt, where t is in second. Find the change in its kinetic energy between time t = 2 s and t = 4 s.
(A) 46 J (B) 50 J
(C) 26 J (D) 12 J

44. Assume the aerodynamic drag force on a car is proportional to its speed. If the power output from the engine is doubled, then the maximum speed of the car.
(A) is unchanged
(B) increases by a factor of $\sqrt{2}$
(C) is also doubled
(D) increases by a factor of four.

45. An engine develops 10 kW of power. How much time will it take to lift a mass of 200 kg through a height of 40 m? Given : g = 10 ms^{-2}
(A) 8 sec. (B) 4 sec.
(C) 2 sec. (D) 6 sec.

46. A bomb initially at rest explodes by it self into three equal mass fragments. The velocities of two fragments are $(3\hat{i} + 2\hat{j})$ m/s and $(-\hat{i} - 4\hat{j})$ m/s. The velocity of the third fragment is (in m/s)-
(A) $2\hat{i} + 2\hat{j}$ (B) $2\hat{i} - 2\hat{j}$
(C) $-2\hat{i} + 2\hat{j}$ (D) $-2\hat{i} - 2\hat{j}$

47. A stone of mass m_1 moving with a uniform speed v suddenly explodes on its own into two fragments. If the fragment of mass m_2 is at rest, the speed of the other fragment is-
(A) $\frac{m_1 v}{(m_1 - m_2)}$ (B) $\frac{m_2 v}{(m_1 - m_2)}$
(C) $\frac{m_1 v}{(m_1 + m_2)}$ (D) $\frac{m_1 v}{m_2}$

48. A monkey of mass 20kg rides on a 40kg trolley moving with constant speed of 8m/s along a horizontal track. If the monkey jumps vertically to grab the overhanging branch of a tree, the speed of the trolley after the monkey has jumped off is -
(A) 8 m/s (B) 1 m/s
(C) 4 m/s (D) 12 m/s

49. A nucleus of mass number A originally at rest emits α-particle with speed v. The recoil speed of daughter nucleus is :

(A) $\frac{4v}{A-4}$ (B) $\frac{4v}{A+4}$

(C) $\frac{v}{A-4}$ (D) $\frac{v}{A+4}$

50. An elastic ball of mass m falls from a height h on an Aluminium disc of area A floating in a mercury pool. If the collision is perfectly elastic, the momentum transferred to the disc is-

(A) $\sqrt{2mgh}$ (B) $2\sqrt{mgh}$

(C) $m\sqrt{2gh}$ (D) $2m\sqrt{2gh}$.

51. A boy is standing at the centre of a boat which is free to move on water. If the masses of the boy and the boat are m_1 and m_2 respectively and the boy moves a distance of 1 m forward then the movement of the boat is ...... metres

(A) $\frac{m_1}{m_1+m_2}$ (B) $\frac{m_2}{m_1+m_2}$

(C) $\frac{m_1}{m_2}$ (D) $\frac{m_2}{m_1}$

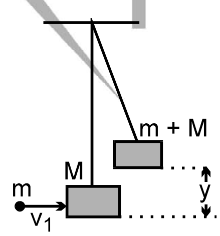
52. A bullet of mass m moving with velocity v_1 strikes a suspended wooden block of mass M as shown in the figure and sticks to it. If the block rises to a height y, the initial velocity of the bullet is -

(A) $v_1 = \frac{m+M}{m}\sqrt{2gy}$

(B) $v_1 = \sqrt{2gy}$

(C) $v_1 = \frac{M+m}{M}\sqrt{2gy}$

(D) $v_1 = \frac{m}{m+M}\sqrt{2gy}$



53. A bullet of mass m strikes a pendulum bob of mass M with velocity u. It passes through and emerges out with a velocity u/2 from bob. The length of the pendulum is ℓ. What should be the minimum value of u if the pendulum bob will swing through a complete circle?

(A) $\frac{2M}{m}\times\sqrt{5g\ell}$ (B) $\frac{M}{2m}\sqrt{5g\ell}$

(C) $\frac{2M}{m}\times\frac{1}{\sqrt{5g\ell}}$ (D) $\frac{M}{2m}\times\frac{1}{\sqrt{5g\ell}}$

54. Which of the following is not a perfectly inclastic collision-
(A) capture of an electron by proton
(B) man jumping onto a moving cart
(C) collision between glass balls
(D) a bullet fired into a block of wood such that it is embedded in the wood

55. When two bodies stick together after collision, the collision is said to be
(A) inelastic
(B) elastic
(C) partially elastic
(D) none of the above is correct

56. When two bodies collide eleastically, then
(A) kinetic energy of the system alone is conserved
(B) only momentum is conserved
(C) both energy and momentum are conserved
(D) neighter energy nor momentum is conserved

57. The coefficient of restitution e for a perfectly inelastic collision is-
(A) 1 (B) ∞
(C) Zero (D) -1

58. A body of mass 2kg moving with a velocity of 3m/sec towards left collides head-on with a body of mass 3kg moving in opposite direction with a velocity 2m/sec. After collision the two bodies stick to gether and move with a common velocity which is-
(A) 5m/sec towards left
(B) 12 m/sec.towards right
(C) 12/5 m/sec. towards left
(D) zero

59. A particle of mass m_1 hits another particle of mass m_2 at rest with a velocity $\vec{u}$. The collision is head-on and elastic. If $m_1 >> m_2$, then after collision, the velocity of m_2 will be-
(A) $\vec{u}$. (B) $-\vec{u}$.
(C) $2\vec{u}$. (D) $-2\vec{u}$.

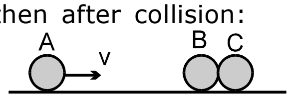
60. Two solid balls of rubber A and B whose masses are 200gm and 400gm respectively, are moving in mutually opposite directions. If the velocity A is 0.3 m/s and both the balls come to rest after collision, then the velocity of ball B is -
(A) $0.15\ ms^{-1}$ (B) $-0.15\ ms^{-1}$
(C) $1.5\ ms^{-1}$ (D) none of these

61. Two similar balls P and Q having velocities of 0.5m/s and –0.3 m/s respectively collide elastically. The velocities of P and Q after the collision will respectively be -
(A) –0.5 m/s and 0.3 m/s
(B) 0.5 m/s and 0.3 m/s
(C) –0.3 m/s and 0.5 m/s
(D) 0.3 m/s and 0.5 m/s

62. Two elastic bodies P and Q having equal masses are moving along the same line with velocities of 16 m/s and 10m/s respectively. Their velocities after the elastic collision will be in m/s -
(A) 0 and 25 (B) 5 and 20
(C) 10 and 16 (D) 20 and 5

63. Which of the following does not hold when two particles of masses m_1 and m_2 undergo elastic collision?
(A) when $m_1 = m_2$ and m_2 is stationary, there is maximum transfer of kinetic energy in head an collision
(B) when $m_1 = m_2$ and m_2 is stationary, there is maximum transfer of momentum in head on collision
(C) when $m_1 >> m_2$ and m_2 is stationary, after head on collision m_2 moves with twice the velocity of m_1.
(D) when the collision is oblique and $m_1 = m_2$ with m_2 stationary, after the collision the particle move in opposite directions.

64. As shown in figure A, B and C are identical balls B and C are at re st and, the ball A moving with velocity v collides elastically with ball B, then after collision:



(A) All the three balls move with velocity v/2
(B) A comes to rest and (B + C) moves with velocity $v/\sqrt{2}$
(C) A moves with velocity v and (B + C) moves with velocity v
(D) A and B come to rest and C moves with velocity v

65. A moving sphere of mass m suffer a perfect elastic collision (not head on) with an equally massive stationary sphere. After collision both fly off at angle θ, value of which is :
(A) 0 (B) π
(C) indeterminate (D) $\pi/2$

66. A body of mass m kg collides elastically with another body at rest and then continues to move in the original direction with one half of its original speed. what is the mass of the target body ?
(A) m kg (B) 2/3 m kg
(C) m/3 kg (D) m/2 kg

67. A bullet of mass a and velocity b is fired into a large block of mass c. The final velocity of the system is-
(A) $\frac{c}{a+b}b$ (B) $\frac{a}{a+c}b$
(C) $\frac{a+b}{c}.a$ (D) $\frac{a+c}{a}.b$

68. A particle falls from a height H, upon a fixed horizontal plane and rebounds. If e is the coefficient of restitution, the total distance travelled before it comes to rest is ______
(A) $H\left(\frac{1+e^2}{1-e^2}\right)$ (B) $H\left(\frac{1-e^2}{1+e^2}\right)$
(C) $\frac{H}{2}\left(\frac{1-e^2}{1+e^2}\right)$ (D) $\frac{H}{-}\left(\frac{1+e^2}{1+e^2}\right)$

69. A body of mass 20 g is moving with a certain velocity. It collides with another body of mass 80 g at rest. The collision is perfectly inelastic. The ratio of kinetic energies of the sytem before and after collision is ______
(A) 2 : 1 (B) 4 : 1
(C) 5 : 1 (D) 3 : 2

70. A body of mass 50 g collides elastically with another body of mass 30 g at rest. Then the percentage loss of the velocity of the colliding body during collision is ______
(A) 25% (B) 75%
(C) 50% (D) 67%

LEVEL-II

1. A labourer lifts 100 stones to a height of 6 metre in two minute. If mass of each stone be one kilogram, calculate the average power. Given : $g = 10\ ms^{-2}$

(A) 50 W (B) 100 W
(C) 25 W (D) 200 W

2. A block of mass 2kg slipped up a slant plane requires 300J of work. If height of slant is 10m the work done against friction is -

(A) 100J (B) 200J
(C) 300J (D) zero

3. The force required to row a boat over the sea is proportional to the speed of the boat. It is found that it takes 24 h.p. to row a certain boat at a speed of 8km/hr, the horse power required when speed is doubled -

(A) 12 h.p. (B) 6 h.p.
(C) 48 h.p. (D) 96h.p.

4. A man cycles up a hill rising 1 metre vertically for every 50 metres along the slope. Find the power of the man, if he cycles up at the rate of 3.6 km/hr. The weight of the cycle and man is equal to 120kg. Neglect force of friction.

(A) 32.25 watt (B) 23.52 watt
(C) 25.32 watt (D) 52.32 watt

5. A 242×10^4kg freight car moving along a horizontal rail road spur track at 7.2 km/hour strikes a bumper whose coil springs experiences a maximum compression of 30 cm in stopping the car. The elastic potential energy of the springs at the instant when they are compressed 15 cm is

(A) 12.1×10^4 joules
(B) 121×10^4 joules
(C) 1.21×10^4 joules
(D) 1.21×10^6 joules

6. A spring is held compressed. Its stored energy is 2.4 joule. Its ends are in contact with masses of 1gm and 48gm placed on a smooth horizontal surface. When the spring is released, the mass of 48gm will acquire a velocity of-

(A) $\frac{2.40}{149}$ m/s (B) $\frac{24 \times 49}{48}$ m/s

(C) $\frac{10}{7}$ m/s (D) $\frac{10^4}{7}$ m/s

7. An engine pumps a liquid of density 'd' continuously through a pipe of area of cross section A. If the speed with which the liquid passes through a pipe is v. then the rate at which the Kinetic energy is being imparted to the liquid is

(A) $Adv^3/2$ (B) (1/2)Adv
(C) $Adv^2/2$ (D) Adv^2

8. An open water tight railway wagon of mass 5×10^3 kg coasts at an initial velocity of 1.2 m/sec. without friction on a railway track. Rain falls vertically downwards into the wagon. What change then occurred in the kinetic energy of the wagon, when it has collected 10^3kg of water ?

(A) 1200J (B) 300J
(C) 600J (D) 900J

9. A ball moving on a horizontal frictionless plane hits an identical ball at rest with a velocity of 50cm/sec. If the collision is elastic, calculate the speed imparted to the target ball if the speed of the striking ball after the collision is 30cm/sec.

(A) 20 cm/sec (B) 30 cm/sec
(C) 40 cm/sec (D) 50 cm/sec

10. A ball after falling a distance of 5 metre from rest hits elastically the floor of a lift and rebounds. At the time of impact the lift was moving up with a velocity of 1m/sec. The velocity with which the ball rebounds just after impact is ($g = 10m/sec^2$)

(A) 10 m/sec. (B) 11m/sec.
(C) 12 m/sec (D) 13 m/sec.

11. A particle of mass m collides perfectly elastically with another particle of mass M = 2m. If the incident particle is deflected by 90º. The heavy mass will make an angle with the initial direction of m equal to -

(A) 15º (B) 30º
(C) 45º (D) 60º

12. A ball collides elastically with another ball of the same mass. The collision is oblique and initially one of the ball was at rest. After the collision, the two balls move with same speeds. What will be the angle between the velocity of the balls after the collision?

(A) 30º (B) 45º
(C) 60º (D) 90º

13. A billiard ball moving at a speed 2m/s strikes an identical ball initially at rest, at a glancing blow. After the collision one ball is found to be moving at a speed of 1m/s at 60º with the original line of motion. The velocity of the other ball shall be -
(A) $(C)^{1/2}$m/s at 30º to the original direction.
(B) 1m/s at 60º to the original direction.
(C) $(C)^{1/2}$m/s at 60º to the original direction.
(D) 1 m/s at 30º to the original direction.

14. An explosion blows a rock into three paths. Two pieces go off at right angles. to each other. 1.00kg piece with a velocity 12m/sec and the other 2.00 kg piece with a velocity 8m/sec. If the third piece flies off with a velocity 40m/sec. Then the mass of the third piece is -
(A) 0.2kg (B) 0.3 kg
(C) 0.4 kg (D) 0.5 kg

15. A shell lying in a smooth horizontal tube suddenly explodes and breaks of masses m_1 and m_2. If x is the distance of separation in the tube of the masses after time t seconds. Then energy released by explosion is -

(A) $\frac{2m_1m_2.x^2}{(m_1+m_2)t^2}$ (B) $\frac{m_1m_2\,t^2}{2x^2(m_1+m_2)}$

(C) $\frac{m_1m_2\,x^2}{2(m_1+m_2)t^2}$ (D) None of these

16. Three particles each of mass m are located at the vertices of an equilateral triangle ABC. They start moving with equal speeds υ each along the medians of the triangle and collide at its centroid G. If after collision, A comes to rest and B retraces its path along GB, then C
(A) also comes to rest
(B) moves with a speed υ along CG
(C) moves with a speed υ along BG
(D) moves with a speed along AG

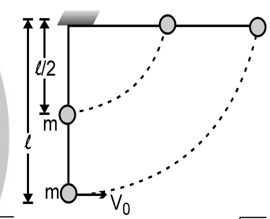
17. A stationary body of mass m gets exploded in 3 parts having mass in the ratio of 1 : 3 : 3. Its two fractions having equal mass moving at right angle to each other with velocity of 15 m/sec. Then the velocity of the third body is -

(A) $45\sqrt{(2)}$ m/sec (B) 5m/sec

(C) $5\sqrt{(32)}$ m/sec (D) none of these

18. A cannon ball is fired with a velocity 200m/sec at an angle of 60º with the horizontal. At the highest point of its flight. It explodes into 3 equal fragments, one going vertically upwards with a velocity 100m/sec, the second one falling vertically downwards with a velocity 100 m/sec. The third fragment will be moving with a velocity
(A) 100 m/sec in the horizontal direction
(B) 300m/sec in the horizontal direction
(C) 300 m/sec in a direction making an angle of 60º with the horizontal
(D) 200 m/sec in a direction making an angle of 60º with the horizontal

19. A light rod of length ℓ is pivoted at the upper end. Two masses (each m), are attached to the rod, one at the middle and the other at the free end. What horizontal velocity must be imparted to the lower end mass, so that the rod may just take up the horizontal position ?



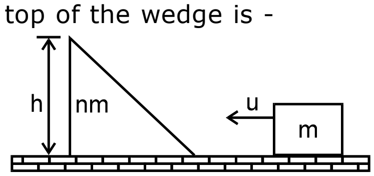
(A) $\sqrt{6\ell g}/5$ (B) $\sqrt{\ell g}/5$
(C) $\sqrt{12\ell g/5}$ (D) $\sqrt{2\ell g}/5$

20. A man of mass m moves with a constant speed on a plank of mass 'M' and length 'L' kept initially at rest on a frictionless horizontal surface, from one end to the other in time 't'. The speed of the plank relative to ground while man is moving, is -

(A) $\frac{L}{t}\left(\frac{M}{m}\right)$ (B) $\frac{L}{t}\left(\frac{m}{M+m}\right)$

(C) $\frac{L}{t}\left(\frac{m}{M-m}\right)$ (D) None of these

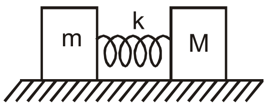
21. A block of mass m is pushed towards a movable wedge of mass nm and height h, with a velocity u. All surfaces are smooth. The minimum value of u for which the block reach the top of the wedge is -



(A) $\sqrt{2gh}$ (B) 2ngh

(C) $\sqrt{2gh\left(1+\frac{1}{n}\right)}$ (D) $\sqrt{2gh\left(1-\frac{1}{n}\right)}$

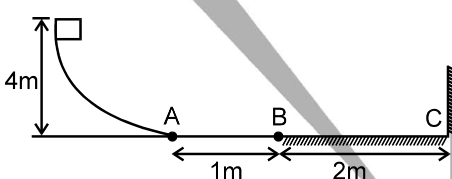
22. A light spring of spring constant k is kept compressed between two blocks of masses m and M on a smooth horizontal surface (figure) When released, the blocks acquire velocities in opposite directions. The spring loses contact with the blocks when it acquires natural length. If the spring was initially compressed through a distance x, find the final speed of mass m.



(A) $\sqrt{\frac{KM}{m(M+m)}}x$ (B) $\sqrt{\frac{Km}{M(m+M)}}x$

(C) $\sqrt{\frac{KM}{m(M-m)}}x$ (D) $\sqrt{\frac{Km}{M(M-m)}}x$

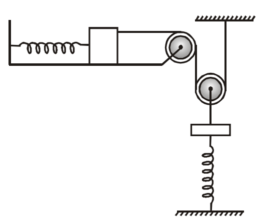
23. A block of mass m = 0.1 kg is released from a height of 4 m on a curved smooth surface. On the horizontal surface, path AB is smooth and path BC offers coefficient of friction μ = 0.1. If the impact of block with the vertical wall at C be perfectely elastic, the total distance covered by the block on the horizontal surface before coming to rest will be (take g = 10 ms^{-2}) -



(A) 29 m (B) 49 m
(C) 59 m (D) 109 m

Passage Based Questions -

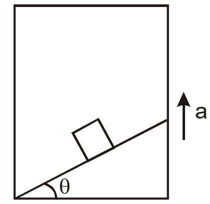
The system is released from rest with both the springs in unstretched positions. Mass of each block is 1 kg and force constant of each spring is 10 N/m.



24. Extension of horizontal spring in equilibrium is:
(A) 0.2 m (B) 0.4 m
(C) 0.6 m (D) 0.8 m

25. Maximum speed fo the block placed horizontally is:
(A) 3.21 m/s (B) 2.21 m/s
(C) 1.93 m/s (D) 1.26 m/s

26. A block of mass m is stationary with respect to a rough wedge as shown in figure. Starting from rest in time t, (m = 1kg, θ = 30°, a = 2m/s^2 t = 4s) work done on block:



Column-I	**Column-II**
(A) By gravity	(P) 144 J
(B) By normal reaction	(Q) 32 J
(C) By friction	(R) 56 J
(D) By all the forces	(T) None

27. Which of the following statements is true for work done by conservative forces :–
(A) It does not depend on path
(B) It is equal to the difference of final and initial energy function
(C) It can be recovered completely
(D) All of the above

28. The relation between conservative force and potential energy U is given by :–

(A) $\vec{F} = \frac{dU}{dx}$ (B) $\vec{F} = \int U\,dx$

(C) $\vec{F} = -\frac{dU}{dx}$ (D) $\vec{F} = \frac{dU}{dx}$

29. A constant force F is applied to a body of mass m moving with initial velocity u. If after the body undergoes a displacement S its velocity becomes v, then the total work done is

(A) $m[v^2 + u^2]$ (B) $\frac{m}{2}[u^2 + v^2]$

(C) $\frac{m}{2}[v^2 - u^2]$ (D) $m[v^2 - u^2]$

30. A bullet of mass P is fired with velocity Q in a large body of mass R. The final velocity of the system will be –

(A) $\frac{R}{P+R}$ (B) $\frac{PQ}{P+R}$

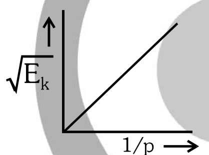
(C) $\frac{(P+Q)}{R}$ (D) $\frac{(P+R)}{P}Q$

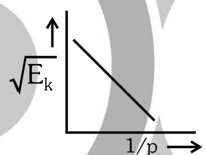
31. An electric motor produces a tension of 4500N in a load lifting cable and rolls it at the rate of 2m/s. The power of the motor is –
(A) 9KW (B) 15KW
(C) 225KW (D) 9 × 10^3 HP

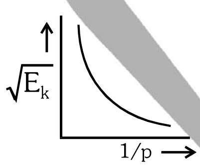
32. A ball falls from a height of 5m and strikes the roof of a lift. If at the time of collision, lift is moving in the upward direction with a velocity of 1m/s, then the velocity with which the ball rebounds after collision will be – (e = 1)
(A) 11 m/s downwards (B) 12 m/s upwards
(C) 13 m/s upwards (D) 12 m/s downwards

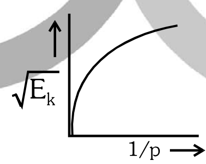
33. A motor of 100 H.P. is moving with a constant velocity of 72 km/hour. The forward force exerted by the engine on the car is –
(A) 3·73 × 10^3 N (B) 3·73 × 10^2 N
(C) 3·73 × 10^1 N (D) None of the above

34. The graph between $\sqrt{E_k}$ and $\frac{1}{p}$ is
(E_K = kinetic energy and p = momentum) –

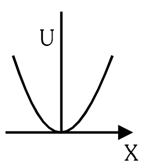
(A) 

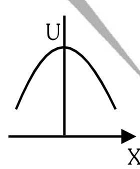
(B) 

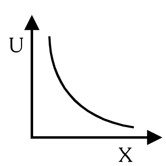
(C) 

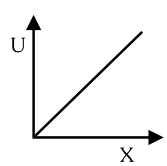
(D) 

35. The graph between potential energy U and displacement X in the state of stable equilibrium will be–

(A) 

(B) 

(C) 

(D) 

36. A metal ball does not rebound when struck on a wall, whereas a rubber ball of same mass when thrown with the same velocity on the wall rebounds. From this it is inferred that –
(A) Change in momentum is same in both
(B) Change in momentum in rubber ball is more
(C) Change in momentum in metal ball is more
(D) Initial momentum of metal ball is more than that of rubber ball

37. A force $\vec{F}$ = ($3x^2$+2x−7) N acts on a 2 kg body as a result of which the body gets displaced from x=0 to x=5m. The work done by the force will be –
(A) 35 Joule (B) 70 Joule
(C) 115 Joule (D) 270 Joule

38. A 50 gm bullet moving with a velocity of 10 m/s gets embedded into a 950 gm stationary body. The loss in kinetic energy of the system will be –
(A) 5% (B) 50%
(C) 100% (D) 95%

39. A crane lifts 300 kg weight from earth's surface upto a height of 2m in 3 seconds. The average power generated by it will be –
(A) 1960 W (B) 2205 W
(C) 4410 W (D) 0 W

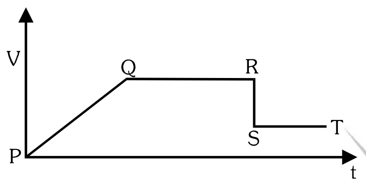
40. Two men with weights in the ratio 5 : 3 run up a staircase in times in the ratio 11 : 9. The ratio of power of first to that of second is –
(A) $\frac{15}{11}$ (B) $\frac{11}{15}$
(C) $\frac{11}{9}$ (D) $\frac{9}{11}$

41. A block of mass 16 kg is moving on a frictionless horizontal surface with velocity 4m/s and comes to rest after pressing a spring. If the force constant of the spring is 100 N/m then the compression in the spring will be –
(A) 3·2 m (B) 1·6 m
(C) 0·6 m (D) 6·1 m

42. A 10 kg satellite completes one revolution around the earth at a height of 100 km in 108 minutes. The work done by the gravitational force of earth will be –
(A) 108 × 100×10 J (B) $\frac{108 \times 10}{100}$ J
(C) 0 J (D) $\frac{100 \times 10}{108}$ J

43. A particle moves in a potential region given by U = $8x^2$ – 4x + 400 J. Its state of equilibrium will be
(A) x = 25 m (B) x = 0·25 m
(C) x = 0·025 m (D) x = 2·5 m

44. V–t graph is obtained as shown in the figure. The work done by the force is represented by the path–



(A) PQ B) QR
(C) RS (D) ST

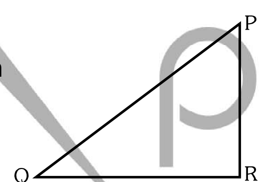
45. A rocket of mass 6×10^3 Kg is arranged to be released in the vertically upward direction. If the velocity of the gas coming out is 10^3 m/s then in order to balance the weight of the rocket how much gas per second must escape out –
(A) 49·75 Kg/s (B) 58·86 Kg/s
(C) 100 Kg/s (D) 117 Kg/s

46. A force $F = Kx^2$ acts on a particle at an angle of 60° with the x–axis. the work done in displacing the particle from x_1 to x_2 will be –

(A) $\frac{kx^2}{2}$ (B) $\frac{k}{2}\left(x_2^2 - x_1^2\right)$

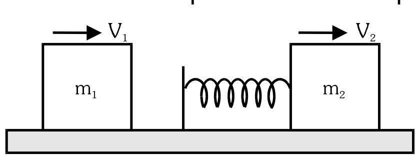
(C) $\frac{k}{6}\left(x_2^3 - x_1^3\right)$ (D) $\frac{k}{3}\left(x_2^3 - x_1^3\right)$

47. For the path PQR in a conservative force field the amounts work done in carrying a body from P to Q and from Q to R are 5 Joule and 2 Joule respectively. The work done in carrying the body from P to R will be –



(A) 7 Joule (B) 3 Joule
(C) $\sqrt{21}$ Joule (D) Zero

48. Two masses m_1 = 2kg and m_2 = 5kg are moving on a frictionless surface with velocities 10m/s and 3 m/s respectively. m_2 is ahead of m_1. An ideal spring of spring constant k = 1120 N/m is attached on the back side of m_2. The maximum compression of the spring will be.

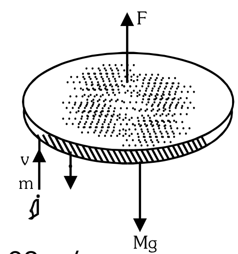


(A) 0·51 m (B) 0·062 m
(C) 0·25 m (D) 0·72 m

49. A solid sphere is moving and it makes an elastic collision with another stationary sphere of half of its own radius. After collision it comes to rest. The ratio of the densities of materials of second sphere and first sphere is –
(A) 2 (B) 4
(C) 8 (D) 16

50. The mass of a bucket full of water is 15 kg. It is being pulled up from a 15m deep well. Due to a hole in the bucket 6 kg water flows out of the bucket. The work done in drawing the bucket out of the well will be –
(A) 900 Joule (B) 1500 Joule
(C) 1800 Joule (D) 2100 Joule

51. A disc of mass 1·0 kg kept floating horizontally in air by firing bullets of mass 0·05 kg each vertically at it, at the rate of 10 per second. If the bullets rebound with the same speed, the speed with which these are fired will be–



(A) 0·098 m/s (B) 0·98 m/s
(C) 9·8 m/s (D) 98·0 m/s

Statement Based Ques.

(A)If both Statement- I and Statement- II are true, and Statement - II is the correct explanation of Statement– I.
(B)If both Statement - I and Statement-II are true but Statement - II is not the correct explanation of Statement – I.
(C) If Statement-I is true but Statement-II is false.
(D) If Statement-I is false but Statement-II is true.

52. ***Assertion :*** The work done on a particle by the resultant force is equal to the change in its kinetic energy.

Reason : $W = \int \vec{F}.d\vec{r} = \int \frac{d\vec{P}}{dt} . d\vec{r} = \int m\, v\, dv = \int dK = K_2 - K_1$ where $K = \frac{1}{2}mv^2$

(A) A (B) B
(C) C (D) D

53. ***Assertion :*** No work is done by a force on a object when the point of application of the force does not move.
Reason : A small block of mass m is kept on a rough inclined surface of inclination α fixed in an elevator. The elevator goes up with a uniform velocity u and the block does not slide on the wedge. Then the work done by the force of friction on the block in time t will be mg ut $\sin^2 \alpha$.
(A) A (B) B
(C) C (D) D

54. ***Assertion :*** A quick collision between two bodies is more violent than a slow collision, even when the initial and the final velocities are identical.
Reason : Because the rate of change of momentum which determines the force is greater in the first case.
(A) A (B) B
(C) C (D) D

55. ***Assertion :*** Kinetic energy of a body becomes four times, when its linear momentum is doubled.
Reason : This is because, **K.E. = $p^2/2m$**.
(A) A (B) B
(C) C (D) D

56. ***Assertion :*** A spring has potential energy, when it is compressed (or stretched).
Reason : In compressing or stretching, work is done on the spring against the restoring force which is stored as potential energy.
(A) A (B) B
(C) C (D) D

57. ***Assertion :*** Kinetic energy is conserved in both, perfectly elastic & inelastic collisions.
Reason : Because both the types of collisions are identical.
(A) A (B) B
(C) C (D) D

58. ***Assertion :*** All central forces which follows the inverse square law are conservative forces.
Reason : Work done by the force or against the force does not depend on path, then force is called conservative force.
(A) A (B) B
(C) C (D) D

59. ***Assertion :*** Potential energy is possible only in conservative force field.
Reason : Potential energy is a relative quantity but K.E. is a absolute quantity.
(A) A (B) B
(C) C (D) D

60. ***Assertion :*** A body can have energy without having momentum.
Reason : A body can have momentum without having mechanical energy.
(A) A (B) B
(C) C (D) D

61. ***Assertion :*** A truck and a car moving with the same kinetic energy are brought to rest by the application of breaks which provide equal retarding forces. Both come to rest in equal distance.
Reason : It is possible that the speed of a body is zero but velocity is not zero.
(A) A (B) B
(C) C (D) D

62. ***Assertion :*** If work done by the force depends on path then force is said to be conservative.
Reason : All the conservative forces are central force.
(A) A (B) B
(C) C (D) D

63. ***Assertion :*** If two objects of different masses have same momentum, the lighter body possess greater velocity.
Reason : For all bodies momentum always remains same.
(A) A (B) B
(C) C (D) D

64. ***Assertion :*** Mass is a measure of inertia of the body in linear motion.
Reason : Greater the mass, greater is the force required to change its state of rest or of uniform motion in same time interval.
(A) A (B) B
(C) C (D) D

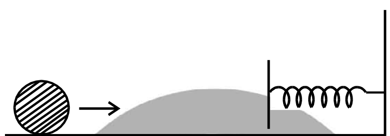
65. ***Assertion :*** In case of bullet fired from gun, the ratio of kinetic energy of gun and bullet is equal to ratio of mass of bullet and gun.
Reason : In firing, momentum is conserved.
(A) A (B) B
(C) C (D) D

LEVEL – III PREVIOUS YEARS

1. A stationary particle explodes into two particles of masses m_1 and m_2 which move in opposite directions with velocities v_1 and v_2. The ratio of their kinetic energies E_1/E_2 is :–

(A) m_2/m_1 (B) m_1/m_2
(C) 1 (D) m_1v_2/m_2v_1

2. A mass of 0.5 kg moving with a speed of 1.5 m/s on a horizontal smooth surface, collides with a nearly weightless spring of force constant k=50N/m. The maximum compression of the spring would be :-



(A) 0.12 m (B) 1.5 m
(C) 0.5 m (D) 0.15m

3. A ball of mass 2 kg and another of mass 4 kg are dropped together from a 60 feet tall building. After a fall of 30 feet each towards earth, their respective kinetic energies will be in the ratio of :-

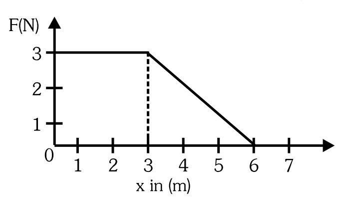
(A) 1 : 4 (B) 1 : 2
(C) 1 : $\sqrt{2}$ (D) $\sqrt{2}$: 1

4. A bomb of mass 30Kg at rest explodes into two pieces of masses 18 kg and 12 kg. The velocity of 18kg mass is $6ms^{-1}$. The kinetic energy of the other mass is :-

(A) 524 J (B) 256 J
(C) 486J (D) 324J

5. A force F acting on an object varies with distance x as shown here. The force is in N and x in m. The work done by the force in moving the object from x = 0 to x = 6m is

(A) 18.0 J
(B) 13.5 J
(C) 4.5 J
(D) 9.0 J



6. A body of mass 3 kg is under a constant force which causes a displacement s in metres in it, given by the relation $s = \frac{1}{3}t^2$, where t is in seconds. Work done by the force in 2 seconds is

(A) $\frac{5}{19}$ J (B) $\frac{3}{8}$ J
(C) $\frac{8}{3}$ J (D) $\frac{19}{5}$ J

7. 300 J of work is done in sliding a 2 kg block up an inclined plane of height 10 m. Taking $g = 10\ m/s^2$, work done against friction is

(A) 200 J (B) 100 J
(C) Zero (D) 1000 J

8. A vertical spring with force constant k is fixed on a table . A ball of mass m at a height h above the free upper end of the spring falls vertically on the spring, so that the spring is compressed by a distance d. The net work done in the process is

(A) $mg(h + d) + \frac{1}{2}kd^2$

(B) $mg(h + d) - \frac{1}{2}kd^2$

(C) $mg(h - d) - \frac{1}{2}kd^2$

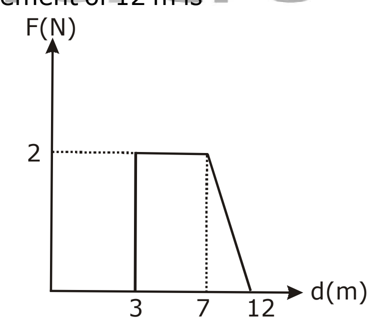
(D) $mg(h - d) + \frac{1}{2}kd^2$

9. A plate of mass m, length b and breadth a is initially lying on a horizontal floor with length parallel to the floor and breadth perpendicular to the floor. The work done to exect it on its breath is

(A) $mg\left[\frac{b}{2}\right]$ (B) $mg\left[a + \frac{b}{2}\right]$

(C) $mg\left[\frac{b-a}{2}\right]$ (D) $mg\left[\frac{b+a}{2}\right]$

10. Force F on a particle moving in a straight line varies with distance d as shown in the figure. The work done on the particle during its displacement of 12 m is



(A) 21 J (B) 26 J
(C) 13 J (D) 18 J

11. A body of mass M hits normally a rigid wall with velocity ν and bounces back with the same veloicty. The impulse experienced by the body is

(A) 1.5 Mν (B) 2 Mν
(C) zero (D) Mν

12. A person of mass 60 kg is inside a lift of mass 940 kg and preses the button on control panel. The lift starts moving upwards with an acceleration $1.0\ ms^{-2}$. If $g = 10\ ms^{-2}$, the tension in the supporting cable is .
(A) 9680 N (B) 11000 N
(C) 1200 N (D) 8600 N

13. The potential energy of a system increase, if work is done
(A) by the system against a conservative force
(B) by the system against a non-conservative force
(C) upon the system by a conservative force
(D) upon the system by a non-conservative force

14. A car of mass m starts from rest and accelerates so that, the instantaneous power delivered to the car has a constant magnitude P_0. The instantaneous velocity of this car is proportional to
(A) t^2P_0 (B) $t^{1/2}$
(C) $t^{-1/2}$ (D) $t/\sqrt{m}$

15. A neutron makes a head on elastic collision with a stationary deuteron. The fractional energy loss of the neutron in the collision is:-
(A) 16/82 (B) 8/9
(C) 8/27 (D) 2/3

16. A bomb of mass 3.0 kg explodes in air into two pieces of masses 2.0 kg and 1.0 kg. The smaller mass goes at a speed of 80 m/s. The total energy imparted to the two fragments is -
(A) 1.07 kJ (B) 2.14 kJ
(C) 2.4 kJ (D) 4.8 kJ

17. A block of mass 10 kg. is moving in x–direction with a constant speed of 10m/sec. It is subjected to a retarding force F = –0·1 x joules/meter during its travel from x=20 meters to x=30 meters. Its final kinetic energy will be –
(A) 475 joules (B) 450 joules
(C) 275 joules (D) 250 joules

18. For inelastic collision between two spherical rigid bodies –
(A) the total kinetic energy is conserved
(B) the total potential energy is conserved
(C) the linear momentum is not conserved
(D) the linear momentum is conserved

19. A spherical ball of mass 20 kg is stationary at the top of a hill of height 100 m. It rolls down a smooth surface to the ground, them climbs up another hill of height 30 m and finally rolls down to a horizontal base at a height of 20 m above the ground. The velocity attained by the ball is
(A) $40\ ms^{-1}$ (B) $20\ ms^{-1}$
(C) $10\ ms^{-1}$ (D) $10\sqrt{30}ms^{-1}$

20. An explosion blows a rock into three parts. Two parts go off at right angles to each other. These two are, 1 kg first part moving with a velocity of 12 ms^{-1} and 2 kg second part moving with a velocity of 8 ms^{-1}. If the third part flies off with a velocity of $4ms^{-1}$, its mass would be :-
(A) 3kg (B) 5 kg
(C) 7 kg (D) 17 kg

21. A block of mass M is attached to the lower end of a vertical spring. The spring is hung from a ceiling and has force constant value k. The mass is released from rest with the spring initially unstretched. the maximum extension produced in the length of the spring will be :-
(A) Mg/2k (B) Mg/k
(C) 2 Mg/k (D) 4 Mg/k

22. Two bodies of mass 1 kg and 3kg have position vectors $\hat{i}+2\hat{j}+\hat{k}$ and $-3\hat{i}-2\hat{j}+\hat{k}$, respectively. The centre of mass of this system has a position vecotor :-
(A) $-\hat{i}+\hat{j}+\hat{k}$ (B) $-2\hat{i}+2\hat{k}$
(C) $-2\hat{i}-\hat{j}+\hat{k}$ (D) $2\hat{i}-\hat{j}-2\hat{k}$

23. An engine pumps water continuously through a hose. Water leaves the hose with a velocity v and m is the mass per unit length of the water jet. What is the rate at which kinetic energy is imparted to water :-
(A) $\frac{1}{2}m^2v^2$ (B) $\frac{1}{2}mv^3$
(C) mv^3 (D) $\frac{1}{2}mv^2$

24. A body of mass 1 kg is thrown upwards with a velocity 20 m/s. It momentarily comes to rest after attaining a height of 18 m. How much energy is lost due to air friction ? ($g = 10\ m/s^2$) :-
(A) 10 J (B) 20 J
(C) 30 J (D) 40 J

25. A big ball of mass M, moving with velocity u strikes a small ball of mass m, which is at rest. Finally small ball attains velocity u and big ball v. What is the value of v :-
(A) $\frac{M-m}{M}u$ (B) $\frac{m}{M+m}u$
(C) $\frac{2m}{M+m}$ (D) $\frac{M}{M+m}v$

26. n bullet strikes per second elastically on wall and rebound then what will be the force exerted on the wall by bullets if mass of each bullet is m :-
(A) mnv (B) 4mnv
(C) 2mnv (D) $\frac{mnv}{2}$

27. A body of mass 2 kg falls from a height of 20 m. What is the loss in potential energy
(A) 400 J (B) 300 J
(C) 200 J (D) 100 J

28. A collision is said to be perfectly inelastic when
(A) Coefficient of restitution = 0
(B) Coefficient of restitution = 1
(C) Coefficient of restitution = ∞
(D) Coefficient of restitution < 1

29. In stretching a spring by 2 cm energy stored is given by U, then stretching by 10 cm energy stored will be :-

(A) U (B) 5U

(C) $\frac{U}{25}$ (D) 25U

30. A heavy nucleus at rest breaks into two fragments which fly off with velocities 8 : 1. The ratio of radii of the fragments is :-

(A) 1 : 2 (B) 1 : 4

(C) 4 : 1 (D) 2 : 1

31. A particle falls from a height 'h' upon a fixed horizontal plane and rebounds. If 'e' is the coefficient of restitution the total distance travelled before rebounding has stopped is :-

(A) $h\left(\frac{1+e^2}{1-e^2}\right)$ (B) $h\left(\frac{1-e^2}{1+e^2}\right)$

(C) $\frac{h}{2}\left(\frac{1-e^2}{1+e^2}\right)$ (D) $\frac{h}{2}\left(\frac{1+e^2}{1-e^2}\right)$

32. A body of mass 6 kg under a force which causes displacement in it given 'S = $\frac{t^2}{4}$' metres where 't' is time. The work done by the force in 2 seconds is:-

(A) 12J (B) 9J

(C) 6J (D) 3J

33. If the force applied is F and the velocity gained is v, then the power developed is :-

(A) $\frac{F}{v}$ (B) $\frac{v}{F}$

(C) Fv (D) Fv^2

34. A body A experiences perfectly elastic collision with a stationary body B. If after collision the bodies fly apart in the opposite direction with equal velocities, the mass ratio of A and B is :-

(A) 1/2 (B) 1/3

(C) 1/4 (D) 1/5

35. If the potential energy of two molecules is give by , $U = \frac{A}{r^{12}} - \frac{B}{r^6}$ then at equilibrium position, its potential energy is equal to :

(A) $\frac{A^2}{4B}$ (B) $-\frac{B^2}{4A}$

(C) $\frac{2B}{A}$ (D) 3A

36. A man m = 80 kg is standing on a trolley of mass 320 kg on a smooth surface. If man starts walking on trolley along rails at a speed of 1 ms^{-1}, then after 4 sec, his displacement relative to ground is

(A) 4 m (B) 4.8 m

(C) 3.2 m (D) 6 m

37. Two particles of mass M_A and M_B and there velocities are V_A and V_B respectively collides. After collision they inter changes their velocities then ratio of $\frac{M_A}{M_B}$ is :-

(A) $\frac{V_A}{V_B}$ (B) $\frac{V_B}{V_A}$

(C) $\frac{(V_A+V_B)}{(V_B-V_A)}$ (D) 1

38. A body of mass 4m at rest explodes into three pieces. Two of the pieces each of mass m move with a speed v each in mutually perpendicular directions. The total kinetic energy released is :

(A) $\frac{1}{2}mv^2$ (B) mv^2

(C) $\frac{3}{2}mv^2$ (D) $\frac{5}{2}mv^2$

39. If the kinetic energy of a body is double of its initial kinetic energy, then the momentum of the body will be

(A) $2\sqrt{2}$ times (B) $\sqrt{2}$ times

(C) $\frac{1}{\sqrt{2}}$ times (D) none of these

40. A force acts $\vec{F} = (5\hat{i} + 4\hat{j})N$ on a body and produced a displacement $\vec{S} = (6\hat{i} - 5\hat{j} + 3\hat{k})m$. The work done will be

(A) 30 J (B) 40 J

(C) 10 J (D) 20 J

41. The velocity of a particle of mass of 1 kg changes from 2 m/s north to 2 m/s east in 2 sec. The change in momentum of the particle is :

(A) zero

(B) $2\sqrt{2}$ kg m/s south-east

(C) $\sqrt{2}$ kg m/s south east

(D) $2\sqrt{2}$ kg/m/s north east

42. Two bodies of mass 1kg and 4kg have equal K.E. then the ratio of their momentum is

(A) 2 : 1 (B) 1 : 2

(C) 4 : 1 (D) 1 : 4

43. A stone of mass m is tied to a string of length ℓ at one end and by holding second end it is whirled into a horizontal circle, then work done will be –

(A) 0 (B) $\left(\frac{mv^2}{\ell}\right)2\pi\ell$

(C) $(mg)\cdot 2\pi\ell$ (D) $\left(\frac{mv^2}{\ell}\right)\ell$

44. Two identical balls, one moves with 12 m/s and second is at rest, collides elastically. After collision velocity of second and first ball will be :
(A) 6m/s, 6m/s (B) 12m/s, 12m/s
(C) 12m/s, 0m/s (D) 0m/s, 12m/s

45. The dirver of a car travelling at velocity v suddenly sees a broad wall infront of him at a distance d. He should
(A) brake sharply (B) turn sharply
(C) Both (a) and (b) (D) None of these

46. When the bob of a simple pendulum swings, the work done by tension in the string is
(A) >0 (B) <0
(C) zero (D) maximum

47. The work done by a particle moving with a velocity of 0.7 c (where c is the velocity of light) in empty space free of electromagnetic field and far away from all matter is
(A) positive (B) negative
(C) zero (D) infinite

48. A quarter horse power runs at a speed of 600 rpm. Assuiming 40% efficiency, the work done by the motor in one rotation will be
(A) 7.46 J (B) 7400 J
(C) 7.46 erg (D) 74.6 J

49. A particle of mass m at rest is acted upon by a force P for a time t. Its kinetic energy after an interval t is
(A) $\frac{P^2t^2}{m}$ (B) $\frac{P^2t^2}{2m}$
(C) $\frac{P^2t^2}{3m}$ (D) $\frac{Pt}{2m}$

50. A body of mass 2 kg makes an elastic collision with another body at rest and continues to move in the original direction with one-fourth its original speed. The mass of the second body which collides with the first body is
(A) 2 kg (B) 1.2 kg
(C) 3 kg (D) 1.5 kg

51. A cyclist rides up a hill at a constant velocity. Determine the power developed by the cyclist if the length of the connecting rod of the pedal is, r = 25 cm, the time of revolution of the rod is r = 2 s and the mean force exerted by his foot on the pedal is, F = 15 kg.
(A) 115.6 W (B) 215.6 W
(C) 15.6 W (D) 11.56 W

52. A coin is of mass 4.8 kg and radius 1 m, is rolling on a horizontal surface without sliding. with an angular velocity of 600 rad/min. What is the total kinetic energy of the coin ?
(A) 360 J (B) $1440\pi^2$ J
(C) $4000\pi^2$ J (D) $600\pi^2$ J

53. An open water tight railway wagon of mass 5×10^3 kg coast at an initial velocity of 1.2 m/s without friction on a railway track.
(A) 900 J (B) 300J
(C) 600 J (D) 1200 J

54. A particle is displaced from a postion $\left(2\hat{i} - \hat{j} + \hat{k}\right)$ to another postion $\left(3\hat{i} - 2\hat{j} + -2\hat{k}\right)$ under the action of the force $\left(2\hat{i} + \hat{j} - \hat{k}\right)$ The work done by the force in an arbitary unit is
(A) 8 (B) 10
(C) 10 (D) 16

55. The machine gun fires 240 bullets per minute. If the mass of each bullet is 10 g and the velocity of the bullets is 600 ms^{-1}, the power (in kW) of the gun is
(A) 43200 (B) 432
(C) 72 (D) 7.2

56. A particle of mass m is driven by a machine that delivers a constant power k watts. If the particle starts from rest the force on the particle at time t is -
(A) $\sqrt{2mkt}^{-1/2}$ (B) $\frac{1}{2}\sqrt{mkt}^{-1/2}$
(C) $\sqrt{\frac{mk}{2}t}^{-1/2}$ (D) $\sqrt{mkt}^{-1/2}$

57. A block of mass 10 kg, moving in x direction with a constant speed of 10 ms^{-1}, is subjected to a retarding force F = 0.1 × J/m during its travel from x = 20 m to 30 m. Its final KE will be -
(A) 275 J (B) 250 J
(C) 475 J (D) 450 J

58. Two spherical bodies of mass M and 5M and radii R and 2R are released in free space with initial separation between their centres equal to 12 R. If they attract each other due to gravitational force only, then the distance covered by the smaller body before collision is -
(A) 7.5 R (B) 1.5 R
(C) 2.5 R (D) 4.5 R

59. Two similar springs P and Q have spring constants K_P and K_Q, such that $K_P > K_Q$. They are stretched, first by the same amount (case a), then by the same force (case b). The work done by the springs W_P and W_Q are related as, in case (a) and case (b), respectively :
(A) $W_P > W_Q$; $W_Q > W_P$
(B) $W_P < W_Q$; $W_Q < W_P$
(C) $W_P = W_Q$; $W_P > W_Q$
(D) $W_P = W_Q$; $W_P = W_Q$

60. A body of mass 1 kg begins to move under the action of a time dependent force $\vec{F} = \left(2t\hat{i} + 3t^2\hat{j}\right)N$, where $\hat{i}$ and $\hat{j}$ are unit vectors along x and y axis. What power will be developed by the force at the time t?
(A) $(2t^2 + 3t^3)$W (B) $(2t^2 + 4t^4)$W
(C) $(2t^3 + 3t^4)$ (D) $(2t^3 + 3t^5)$W

ANSWER-KEY

Level -I

1.	A	2.	A	3.	C	4.	B	5.	C	6.	C	7.	A	8.	B
9.	B	10.	C	11.	A	12.	B	13.	D	14.	B	15.	A	16.	B
17.	A	18.	C	19.	A	20.	B	21.	C	22.	A	23.	A	24.	C
25.	A	26.	B	27.	B	28.	A	29.	B	30.	D	31.	C	32.	B
33.	A	34.	B	35.	C	36.	D	37.	C	38.	A	39.	C	40.	A
41.	B	42.	C	43.	A	44.	B	45.	A	46.	C	47.	A	48.	A
49.	A	50.	D	51.	A	52.	A	53.	A	54.	B	55.	A	56.	C
57.	C	58.	D	59.	C	60.	B	61.	C	62.	C	63.	D	64.	D
65.	D	66.	C	67.	B	68.	A	69.	C	70.	B				

Level-II

1.	A	2.	A	3.	D	4.	B	5.	B,D	6.	C	7.	A	8.	C
9.	C	10.	C	11.	B	12.	D	13.	A	14.	D	15.	C	16.	C
17.	A	18.	B	19.	C	20.	D	21.	C	22.	A	23.	C	24.	B
25.	C	26.	A→T, B→P,C→S,D→Q					27.	D	28.	C	29.	C	30.	B
31.	A	32.	B	33.	A	34.	C	35.	A	36.	B	37.	C	38.	D
39.	A	40.	A	41.	B	42.	C	43.	B	44.	A	45.	B	46.	C
47.	A	48.	C	49.	C	50.	C	51.	C	52.	A	53.	B	54.	A
55.	A	56.	A	57.	D	58.	B	59.	C	60.	B	61.	C	62.	D
63.	C	64.	A	65.	A										

Level-III

1.	A	2.	D	3.	B	4.	C	5.	B	6.	C	7.	B	8.	B
9.	C	10.	C	11.	B	12.	B	13.	A	14.	B	15.	B	16.	D
17.	A	18.	D	19.	A	20.	B	21.	C	22.	C	23.	B	24.	B
25.	A	26.	C	27.	A	28.	A	29.	D	30.	A	31.	A	32.	D
33.	C	34.	B	35.	B	36.	C	37.	D	38.	C	39.	B	40.	C
41.	B	42.	B	43.	A	44. C		45.	A	46.	C	47.	C	48.	A
49.	B	50.	B	51.	A	52.	A	53.	C	54.	A	55.	D	56.	C
57.	C	58.	A	59.	A	60.	D								