WORK,POWER AND ENERGY

LEARNING OBJECTIVES:
- Work and it’s nature.
- Expressions for workdone in different cases.
- Energy and it’s forms.
- Relation betwen K.E and linear momentum.
- Work-Energy theorem.
- Law of conservation of energy.
- Power and it’s applications.

Real life applications :

Φ The main advantage of using Work and Energy methods is that it allows you to easily find the velocity of a body or system of bodies knowing how much "work" went into the system (provided energy is conserved, and there are no frictional losses)

Φ We can apply the work energy methods In our dialy life in order to convert one form of energy into another form.

Φ In the field of space, for a space shuttle heat proof tiles are needed to protect it from the heat resulting from doing work against the drag with a lot of KE,what must be the strength of heat proof tile can be calculated by work energy methods.

Φ To produce the electricity the energy of wind movement performs work when it turns a Wind Turbine.

Φ In the field of mechanics,To run our vehicles the chemical energy in gasoline performs work on a piston, which in turn performs work on a vehicle to create kinetic energy.

Φ Work is performed on air as it enters a Jet Engine to speed up the air, which results in higher kinetic energy of the air particles, which pushes the aeroplane

Important Formulae :

1) $W = \overline{F}.\overline{S} = FSCos\theta$	6) $W = \dfrac{mgl}{2n^2}$	11) $W = \dfrac{1}{2}mv^2 - \dfrac{1}{2}mu^2$
2) $W = mgh\left(1 - \dfrac{d_2}{d_1}\right)$	7) $W = (mg\ Sin\theta)S$	12) $P = \dfrac{w}{t}$
3) $W = mgl(1 - Cos\theta)$	8) W = m(g+a) h	13) $P = \vec{F}.\vec{V}$
4) $W = \dfrac{mgl}{2}(1 - Cos\theta)$	9) $p = \sqrt{2mE}$	14) $P = n\left(\dfrac{1}{2}mv^2\right)$
5) $W = {mgl}/{4}$	10) P.E.=mgh	15) $p = \dfrac{mgh}{t}$

§§ **Work:**

In ordinary language the word ‘’Work’’means any physical or mental activity but in physics, Work is said to be done by a force if the point of application of force undergoes displacement either in the direction of force or in the direction of component of force.

Amount of work done is equal to the dot product of force and displacement. If $\overline{F}$ is the force acting on a body and $\overline{S}$ is displacement,

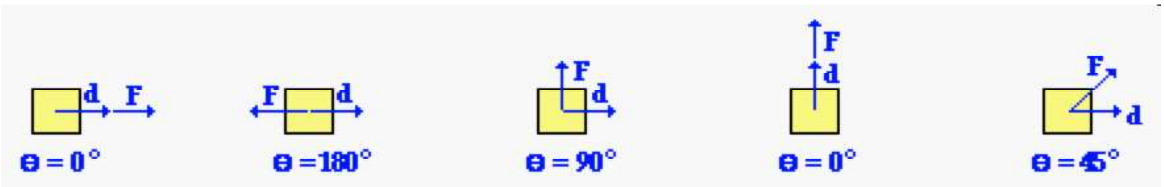
i.e. $W = \overline{F}.\overline{S} = FSCos\theta$

Since work is the dot product between force and displacement it is a scalar quantity.

Units of work : erg in CGS system, joule in S I system

Conversion: one joule = 10^7 erg

¶¶ NATURE OF WORK:



§§ POSITIVE WORK:

Workdone is said to be positive if applied force or one of it's components is in the direction of displacement.

therefore W=FScos0°=positive.

If the force is in the same direction as the displacement, then the angle is 0 degrees

EX: 1.Workdone by the gravitational force on a freely falling body is positive.

2.When a spring is stretched ,both the stretching force and displacement act in the same direction so workdone is positive.

3.When a block is lifted from the ground the workdone by lifting force is positive.

4.When a horse pulls a cart the applied force and displacement are in the same direction so work done by horse is positive.

§§ NEGATIVE WORK:

Workdone by a force is said to be negative if the applied force has a component in a direction opposite to that of the displacement.

EX:1.When a body is dragged on rough surface,workdone by frictional force is negative.

2.Workdone by the gravitational force on a vertically projected up body is negative.

§§ ZERO WORK:

If a body displaces perpendicular to the direction of force then the workdone is zero.

If there is no displacement then workdone is zero.

EX: 1.A person carriyng a load and moving horizontally on a platform does no work against gravity.

2.When abody moves in a circle the workdone by the centripetal force is zero.

3.The tension in the string of a simple pendulum is always perpendicular to it's displacement so,workdone by tension is zero.

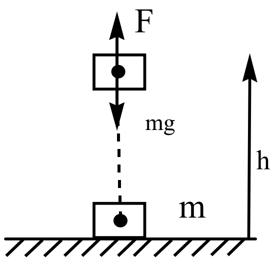
4.A person carrying a load on his head and standing at a given place is zero.

§§ EXPRESSIONS FOR WORKDONE IN DIFFERENT CASES:

Case-1 :

A body of mass 'm' is lifted from ground to a height 'h' by using a minimum force *F*.

The minimum workdone by the lifting force is W_F = Fh = + mgh



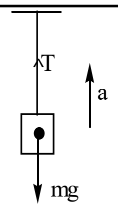
Work done by the gravitational force is

$$\boxed{W_g = -mgh}$$

Case–2 :

One end of a string is fixed to a support and a body of mass '*m*' is attached to the other end of the string. If the point of support moves with acceleration *'a'* in the upward direction, Work done by tension in the string when the body moves upward through a distance *'h'* is

$\boxed{W = m(g+a)h}$



In the above case if the body moves downward with acceleration *'a'* then workdone by the tension in the string is $\boxed{W = -m(g-a)h}$. Here workdone is negative as force and displacement are opposite to each other.

Case–3 :

a). A body of mass 'm' is placed on a friction less horizontal surface. A force *F* acts on the body parallel to the surface, such that it moves with an acceleration 'a'. The workdone by the force acting on the body when its displacement is *S*, is given by $\boxed{W = FS = mas}$.

b). If body moves with uniform velocity on a horizontal frictionless surface. The workdone on the body is W = 0.

c). If frictional force is considered between the body and the surface then the workdone by the force to move the body with uniform velocity is $\boxed{W = fs = \mu_K mgs}$.

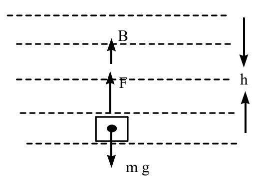
d). In the above case if the body moves with uniform acceleration a workdone by the force is

$\boxed{W = (f+ma)s = (\mu_K mg + ma)s}$

Case–4 :

A body of mass 'm' and of density 'd_1' lies in a non viscous liquid of density 'd_2'. The minimum workdone to lift the body with uniform velocity through a height '*h*' in the liquid is

$$\boxed{W = mgh\left(1 - \frac{d_2}{d_1}\right)}$$

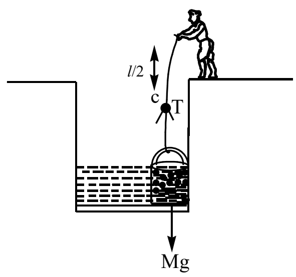


Case–5 :

A bucket full of water of total mass 'M' is lifted up with uniform velocity using a uniform rope of mass 'm' and length 'ℓ'

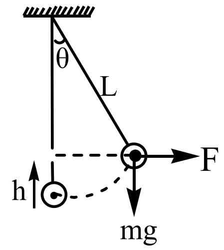
Work done by the lifting force in lifting the bucket full of water by means of the rope is

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



Case–6 :

A pendulum of length 'L' carries a bob of mass 'm' . The bob is pulled aside through an angle θ with the lower vertical by a horizontal force F.



Work done by the gravitational force

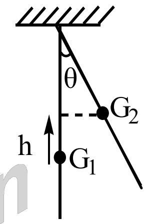
$$\boxed{W_g = -mgL(1-\cos\theta)}$$

Work done by the horizontal force F is

$$\boxed{W = FL\sin\theta}$$

Case–7 :

A uniform rod of mass'm' and length 'L' is suspended vertically. If it is pulled a side through an angle 'θ' to lower vertical, work done by gravitational force



$$\boxed{W_g = -mg\frac{L}{2}(1-\cos\theta)}$$

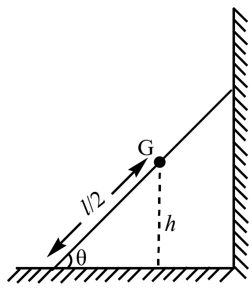
Case–8 :

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

Work done by the gravitational force is

W_g = –mgh

Where 'h' is the height gained by centre of gravity.



$h = \frac{\ell}{2}\sin\theta$ Since $\sin\theta = \frac{h}{l/2}$

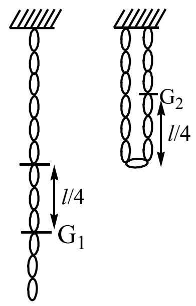
$$\boxed{\therefore W_g = -mg\frac{l}{2}\sin\theta}$$

Case–9 :

A uniform chain of mass 'm' and length 'ℓ' is suspended vertically. The lower end of the chain is lifted upto the point of suspension.

Work done by gravitational force is W_g = – mgh.

Where 'h' is the height gained by center of gravity of the lower half of chain, with respect to its initial position G_1.



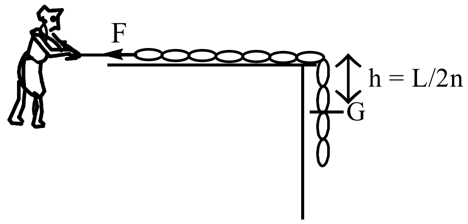
h = $l/4 + l/4 = l/2$

Work done by the gravitational force is

$W_g = -\frac{m}{2} g . \frac{l}{2} \quad \therefore \quad \boxed{W_g = -\frac{mg\ell}{4}}$

Case–10 :

A uniform chain of mass 'm' and length 'L' rests on a table, having $\frac{1^{th}}{n}$ part of its length hanging down from the edge of table. The work done by the pulling force to bring the hanging part of chain on to the table is W = $\frac{m}{n} g.h$



Where 'h' is the height gained by C.G. of hanging chain with respect to the edge of table.

W = $\frac{m}{n} g . \frac{L}{2n} \quad \therefore \quad \boxed{W = mgL/2n^2}$

Case–11 :

A uniform chain of mass 'm' and length 'L'rests on a smooth horizontal table with $\frac{1^{\text{th}}}{n_1}$ part of its length is hanging from the edge of the table. Work done in pulling the chain partially, such that $\frac{1^{\text{th}}}{n_2}$ part is hanging from the edge of the table is given by

$$\boxed{W = \frac{mgL}{2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]}$$

EXAMPLE

Problem 1:

A force of 10N acts on a body of mass 1.0 kg at rest. Find the work done in 4 seconds.

Solution:

F = 10 N; m = 1.0 kg ; u = 0, t = 4s; acceleration

a = $\frac{F}{m} = \frac{10}{1}$ = 10 ms^{-2}.

Its displacement

$S = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(10)4^2 = 80$ m

The work done

W = FS = maS = 1.0 ´ 10 ´ 80 = 800 J

Problem 2 :

Find the work done in lifting a stone of mass 10 kg and specific gravity 3 from the bed of a lake to a height of 6 m in water.

Solution:

Weight in air = 10 kg.wt

Specific gravity = $\frac{d_s}{d_w} = 3$

$$W = mgh\left(1 - \frac{d_w}{d_s}\right)$$

$$W = 10 \times 9.8 \times 6 \times \left(1 - \frac{1}{3}\right)$$

$$W = 98 \times 6 \times \frac{2}{3} = 392J$$

Problem: 3

A massive box is dragged along a horizontal floor by a rope. The rope makes an angle of 60^0 with the horizontal. Find the work done if the tension in the rope is 200 N and the box is moved through a distance of 20 m.

Solution:

Tension T = 200 N; distance S = 20 m , $\theta = 60^0$

Work done W = $\vec{F}.\vec{S} = FS\ \cos\theta = (F\ \cos\theta)\ s$

$$= 200 \times \cos 60^0 \times 20 = 2000\ J$$

Problem :4

A rod of length 2 m and mass 0.5 kg is fixed at one end and allowed to hang vertically from a rigid support. Find the work done in raising the other end of the rod until it makes an angle of 60^0 with the vertical . ($g = 10ms^{-2}$)

Solution:

m = 0.5 kg, l = 2 m, $\theta = 60^0$

Work done $W = mg\frac{l}{2}(1 - \cos\theta)$

$$= 0.5 \times 10 \times \frac{2}{2}(1 - \cos 60^0) \qquad = 5 \times \left(1 - \frac{1}{2}\right) = 5 \times \frac{1}{2} = 2{\cdot}5J$$

Problem :5

A man of mass 70 kg ascends a flight of 36 steps each 20 cm high. What is the work he does against gravity ?

Solution:

m = 70 kg; S = 36 ´ 0.20=7.2 m; g=9.8ms^{-2}

W=Fs=mg s = 70 ´ 9.8 ´ 7.2 = 4932J

Problem :6

Two identical cylindrical vessels with their bases at the same level, contain a liquid of density ρ. The height of the liquid in one vessel is h_1 and that in the other is h_2 . The area of either base is A. What is the work done by gravity in equalising the levels when the vessels are connected ?

Solution:

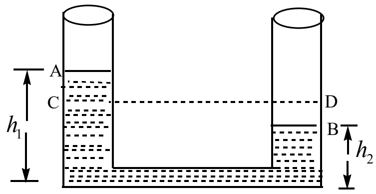
As the total volume of water is constant, the height 'h' in each vessel after interconnection will be given by:

$$h_1A_1 + h_2A_2 = h(A_1 + A_2)$$

$$h = \frac{(h_1 + h_2)}{2} \qquad [\text{ as } A_1 = A_2]$$

The level in the left vessel shown in the figure, drops from A to C and that in the right vessel rises from B to D.

The mass of water descended is



$$m = \rho A\left[h_1 - \frac{(h_1 + h_2)}{2}\right] = \rho A\frac{(h_1 - h_2)}{2}$$

The height descended by this water is

$$AC = h_1 - h = \frac{(h_1 - h_2)}{2}$$

So work done by the force of gravity in equalising the level

$$W = mg \text{ x } AC = \frac{1}{4}\rho gA(h_1 \sim h_2)^2$$

TEACHING TASK

Single Answer Type:

1. A body of mass 5 kg is moved up over 10 m along the line of greatest slope of a smooth inclined plane of inclination of 30° with the horizontal. If g = 10 m/s^2, the work done will be

1) 500 J 2) 2500 J 3) 250 J 4) 25 J

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

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

3. A bicycle chain of length 1.6 m and of mass 1 kg is lying on a horizontal floor. If g = 10ms^{-2}, the work done in lifting it with one end touching the floor and the other end 1.6 m above the floor is

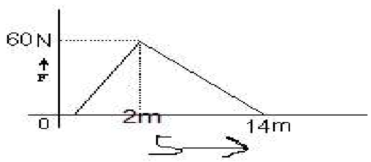
1) 10 J 2) 3.2 J 3) 8 J 4) 16 J

4. A rain drop of mass (1/10) gram falls vertically at constant speed under the influence of the forces of gravity and viscous drag. In falling through 100 m, the work done by gravity is
1) 0.98 J 2) 0.098 J 3) 9.8 J 4) 98 J

5. A force $\overline{F} = (6i - 8j)$ N, acts on a particle and displaces it over 4 m along the X-axis and then displaces it over 6 m along the Y-axis. The total work done during the two displacements is
1) 72 J 2) 24 J 3) - 24 J 4) zero

6. A lawn roller is pulled along a horizontal surface through a distance of 20 m by a rope with a force of 200 N. If the rope makes an angle of 60° with the vertical while pulling, the amount of work done by the pulling force is
1) 4000 J 2) 1000 J 3) $2000\sqrt{3}$ J 4) 2000 J

7. A force acts on a body and displaces it in its direction. The graph shows the relation between the force and displacement, the work done by the force is



1) 420 J 2) 360 J 3) 840 J 4) 720 J

8. A uniform chain is held on a frictionless table with half of its length hanging over the edge. If the chain has a mass 'm' and length 'L', how much work is required to pull the hanging part back onto the table?
1) mgL/4 2) mgL/2 3) mgL/8 4) mgL/16

9. If $\overline{F} = 2\hat{i} + 3\hat{j} + 4\hat{k}$ acts on a body and displaces it by $\overline{S} = 3\hat{i} + 2\hat{j} + 5\hat{k}$ then the work done by the force is
1) 12 J 2) 20 J 3) 32 J 4) 64 J

II **<u>More than one correct option questions</u>**

♦ *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which* ***ONE or MORE*** *is correct. Choose the correct options*

1. Which of the following are correct
a) When a body is dragged on rough surface,workdone by frictional force is negative.
b) Workdone by the gravitational force on a vertically projected up body is positive.
c) When a body is dragged on rough surface,workdone by frictional force is positive.
d) Workdone by the gravitational force on a vertically projected up body is negative.
A) a,b are corect B) a,d are correct C) b,c are correct D)c,d are correct

2. When a body of mass m is lifted to a height h above the ground without any acceleration,
a) work done by the applied force = mgh
b) work done by the gravitational force = -mgh
c) work done by the resultant force = 0
d) work done by the resultant force = 2mgh
A) a,b,c are corect B) a,b,d are correct C) b,c,d are correct D)a,c,d are correct

3. In which of the following work is said to be not done
a) the workdone by the centripetal force on a body moving in a circle.
b) workdone by tension in the string of a simple pendulum.
c) A person carrying a load on his head and standing at a given place is zero.
A) a,b are corect B) a,c are correct C) b,c are correct D) all are correct

4. a) Workdone by the frictional force is always negative
b) If a body of mass m slides down distance S, work done by gravity is $W = (mg\cos\theta)S$

c) If a body of mass m slides down distance S, work done by gravity is $W = (mg\,Sin\theta)S$

d) Workdone by the frictional force is always zero.

A) a,b are corect B) a,c are correct C) b,d are correct D)c,d are correct

Assertion - A and Reason - R:

♦ *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

5. **A:** Workdone by a force is a vector
R: Workdone by a force is the dot product of force and displacment.

6. **A:**The work done during a round trip is always zero.
R: No force is required to move a body in its round trip.

7. **A:** A man pushes a wall and fails to displace it then the work done by him is negative
R: Work is said to be done when a force doesn't displace a body.

Match the following

♦ *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in **Column–I** have to be matched with statements (p, q, r, s) in **Column–II**. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

8. Nature of work	**Angle b/w $\vec{F}$ & $\vec{S}$**
a) Positive work	1) 90^0
b) Negative work	2) 0^0
c) Zero work	3) 180^0
d) Finite work	4) otherthan 0^0

A) a-1,b-4,c-3,d-2 B) a-3,b-1,c-2,d-4 C) a-2,b-3,c-1,d-4 D) a-4,b-2,c-1,d-3

Comprehension type questions

♦ *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which **ONLY ONE i**s correct. Choose the correct option.*

9. A 300kg motorcycle is accelerated from rest to a speed of 90kmph in 5s.If the motorcycle travels 1.5km

ci) Find the acceleration of motorcycle

A) $2ms^{-2}$ B)$3ms^{-2}$ C)$4ms^{-2}$ D)$5ms^{-2}$

ii) Find the force exerted by the engine on the motorcycle

A) 1200N B) 1125N C) 1500N D) 2400N

iii) Find the workdone in moving the motorcycle

A) $225X10^5$J B) $225X10^4$J C) $18X10^3$J D) $18X10^2$J

KEY

ΦΦ TEACHING TASK :

I:1) 3, 2) 2, 3) 3, 4) 2, 5) 3, 6) 3, 7) 1, 8)3 , 9) 3

II:1)B, 2)A, 3)D, 4)B, 5)D, 6)C, 7)C, 8)C, 9) i)D,ii)C,iii)A

LEARNER'S TASK

BEGINNERS (Level - I)

Single Answer Type:

1. Work done by the gravitational force on a body of mass "m" moving on a smooth horizontal surface through a distance 's' is

1) mgs 2) -mgs 3) 0 4) 2 mgs

2. A body of mass 1 kg is made to travel with a uniform acceleration of 30 cm/s^2 over a distance of 2 m, the work done is

1) 6 J 2) 60 J 3) 0.6 J 4) 0.3 J

3. A uniform cylinder of radius 'r' length 'L' and mass 'm' is lying on the ground with the curved surface touching the ground. If it is to be oriented on the ground with the flat circular end in contact with the ground the work to be done is

1) mg[(L/2)-r] 2) mL[(g/2)-r] 3) mr(gL -1) 4) mgLr

4. A meter scale of mass 400 gm is lying horizontally on the floor. If it is to be held vertically with one end touching the floor, the work to be done is

1) 6 J 2) 4 J 3) 40 J 4) 2 J

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

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

ACHIEVERS (Level - II)

Solve the following

1. A body of mass 5 kg is placed at the origin, and can move only on the x-axis. A force of 10 N is acting on it in a direction making an angle of 60^o with the x-axis and displaces it along the x-axis by 4 metres. Calculate the amount of work done by the force.

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

3. A horizontal force of 5 N is required to maintain a velocity of 2 m/s for a block of 10 kg mass sliding over a rough surface. Calculate the work done by this force in one minute.

4. A 10 kg satellite completes one revolution around the earth at a height of 100 km in 108 min. Calculate the work done by the gravitational force of earth. When the distance covered by the body is $5m$,Find its kinetic energy.

5. A chain is placed on a frictionless table with one fourth of it hanging over the edge. If the length of the chain is 2m and its mass is 4kg, Calculate the energy need to be spent to pull it back to the table.

6. A uniform chain of length 2m is held on a smooth horizontal table so that half of it hangs over the edge. If it is released from rest.Find the velocity with which it leaves the table.

7. The lenght of a smooth inclined plane of inclination 30 is 20 m. What is The work done in moving 50 kg mass from the bottom of the inclined plane to top.

8. A body moves a distance of 20 m along a straight line under the action of force of 10 N if the work done is 200J. The angle between force and displacement vector is

9. A force 5 N is applied on a 20 kg mass at rest. the work done in the third second is

10. The work done in lifting a body of mass 20 kg and specific gravity 3.2 to a height of 8 m in water.

EXPLORERS (Level - III)

More than one correct option questions

♦ *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which* ***ONE or MORE*** *is correct. Choose the correct options*

1. You lift a suitcase from the floor and keep it on a table the work done by you on the suit case does not depend on

a)The path taken by the suit case b) The time taken by you in lifting bag
c)The weight of the suit case d) your weight

A) a,b,d are corect B) a,b,c are correct C) b,c,d are correct D)a,b,c,d are correct

2. The work done by gravity in lifting a body to a certain height depend upon

a) time of its rise b) path followed by the body
c) mass of the body d)Height of the body

A) a,b are corect B) c,d are correct C) b,c are correct D) all are correct

Assertion - A and Reason - R:

♦ *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which* ***ONLY ONE*** *is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

3 **A:** The graph drawn between force and displacement is useful in calculating workdone a force.
B:The area under a 'force - displacement' curve gives work.

4. **A:** A man is waiting at a bus stop by holding a box on his head. Work done by him is negative.
R:Work is said to be done when a force displaces a body.

5. **A:** Two identical bodies of same mass are raised to same heights by two persons X and Y in 10s and 20s respectively. The work done by X is same as by Y.
R:The workdone by the force doesn't depend on time of application of it.

Match the following

♦ *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in* ***Column–I*** *have to be matched with statements (p, q, r, s) in* ***Column–II****. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

6. Expression for work — Angle b/w $\vec{F}$ & $\vec{S}$

a) W=FS — 1) 90^0
b) W=-FS — 2) 0^0
c) W=0 — 3) 180^0
d) $W=FS\cos\theta$ — 4) anywhere between 0^0 and 180^0

A) a-1,b-4,c-3,d-2 B) a-3,b-1,c-2,d-4 C) a-2,b-3,c-1,d-4 D) a-4,b-2,c-1,d-3

7. a) work — 1) Scalar
b) Force — 2) vector
c) 1J — 3) 10^7erg
d) 1N — 4) 10^5 dyne

A) a-1,b-2,c-3,d-4 B) a-3,b-1,c-2,d-4 C) a-2,b-3,c-1,d-4 D) a-4,b-2,c-1,d-3

Comprehension type questions

♦ *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which* ***ONLY ONE i****s correct. Choose the correct option.*

8. A box of mass 1 kg is pulled on a horizontal plane of length 1 m by a force of 8 N then it is raised vertically to a height of 2m, (g=10 ms-2)

i) Find the workdone in while moving horizentally

A) 8J B)20J C)28J D)12J

ii) Find the workdone in while moving vertically

A) 8J B)20J C)28J D)12J

iii) Find the net workdone on the box

A) 8J B)20J C)28J D)12J

KEY

ΦΦ LEARNER'STASK :

- **BEGINNERS :** 1) 3, 2) 3, 3) 1, 4) 4, 5) 1
- **ACHIEVERS :** 1) 20J, 2) +7J, 3) 600J, 4) 0J, 5) 2.5J, 6) 4 m/s, 7)4900J, 8)0, 9)25/8J, 10)1100J,
- **EXPLORERS :** 1) A, 2) B, 3) A, 4) D, 5) A, 6) C, 7) A, 8) i) A, ii) B, iii) C.

§§ Energy

"Energy of a body is it's capacity to do work"

Greater the amount of energy possessed by the body, greater the work it will be able to do. All the agents which are able to do work are said to be energetic.

i) A bullet fired into a wall is able to penetrate into the wall by doing work against friction due to its energy.

ii) Fast blowing wind is able to turn a wheel.

iii) A moving vehicle possess energy since it does work against friction and air resistance before coming to rest after the engine is switched off.

iv) Water stored in a dam has energy since it can run the turbines when the water flows down onto the turbines.

The different forms of energy are mechanical energy, light energy, heat energy, sound energy. electrical energy, nuclear energy etc.

In mechanics, we divide mechanical energy into two types, namely

(1) Kinetic Energy (2) Potential Energy.

The dimensional formula for energy is ML^2T^{-2} same as that of work.

SI unit of energy is **joule (J)**

C.G.S unit is **erg.**

$1J = 10^7$ erg.

Note: The other units of energy are:

$1eV \approx 1.6\times10^{-19}J$; $1MeV \approx 1.6\times10^{-13}J$

$1cal \approx 4.2J$; $1Kcal \approx 4200J$

$1KWH = 36\times10^5 J = 36\times10^{12}$ erg

Note : Many students think that KWH is the unit of power. But it is the unit of energy.
Usually electrical energy is measured in KWH.

§§ Kinetic Energy :

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

Examples for body having kinetic energy ;

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

(ii) Moving vehicle possesses kinetic energy.

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

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

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

¶¶ Expression for kinetic energy :

Let

m = mass of the body, *u* = Initial velocity of the body (= 0)

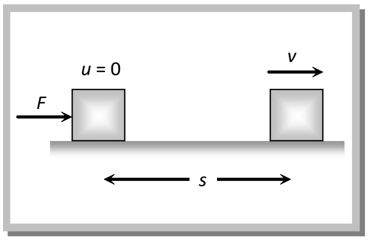
F = Force acting on the body, *a* = Acceleration of the body

s = Distance travelled by the body, *v* = Final velocity of the body

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

$\Rightarrow v^2 = 0 + 2as$

$$\therefore s = \frac{v^2}{2a}$$



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

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

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

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

Examples :

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

(ii) Moving vehicle possesses kinetic energy.

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

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

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

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

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

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

¶¶ **Kinetic energy depends on frame of reference :**

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

§§ **Potential Energy :**

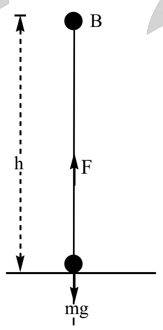
Potential energy of a body is the energy possessed by a body by virtue of its position or configuration

* It is measured by the work that the body can do in position or configuration.
* Potential energy is defined only for conservative forces.
  It does not exist for non – conservative forces.

¶¶ **Expression for gravitational potential energy :**

Consider a body of mass 'm' is on the ground. It is lifted verticaly upwards through a height 'h'. Considering the height to be very small compared to the radius of the earth (R)i.e., h<<R, we can neglect the variation of g. The gravitational force 'mg' on the body can be taken to be constant. The work done by the external agency against gravitational force is

W = Fs = mgh. $(\because F = mg; s = h)$



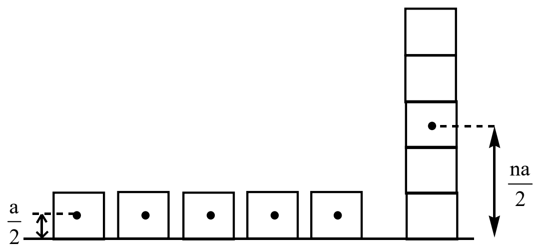
This work gets stored as potential energy of the body. Potential energy of the body $\boxed{U = mgh.}$

The above expression actually represents the increase in the stored energy from the reference position (earth surface) to the final position at a height *'h'*.

EXAMPLE

Problem 1:

Consider "n" number of indentical cubes each of mass "m" and side "a" lying on a level ground. Find the work done in piling them one above the other.



Sol. The initial total potential energy of all the blocks lying on the ground is

$$U_1 = n \times mg\frac{a}{2}$$

The potential energy, when the blocks are piled to form a signle column is

$$U_2 = nmg\frac{na}{2} = n^2mg\frac{a}{2}$$

$\therefore$ Work done in arranging the blocks one above the other is $W = U_2 - U_1$

$$W = n^2mg\frac{a}{2} - n \times mg\frac{a}{2} \quad = mg\frac{a}{2}\left(n^2 - n\right)$$

or $\boxed{W = mg\frac{a}{2}n(n-1)}$

§§ Spring Force :

Spring force is an example of a variable force which is conservative. When a spring is compressed or streched the tension or spring force is F=Kx(numerically)

$\Rightarrow F \alpha - x$ or $F = -Kx$.

The constant 'K' is called the spring constant. Its S.I unit Nm^{-1}, and is a measure of the stiffness of the spring.

1. When a spring compressed or elongated from its natural length work done by the spring force is $W = -\frac{1}{2}Kx^2$.

2. If the spring gets its natural length on releasing it form compressed or elon gated position work done by the spring force is $W = \frac{1}{2}Kx^2$

3. The work done in changing the elongation of a spring from x_1 to x_2 is $W = \frac{1}{2}K(x_2^2 - x_1^2)$

4. Spring constant of a spring is inversely proportional to its length $K \alpha \frac{1}{l}$

5. Spring constant of a spring is inversely proportional to number of terms $K \alpha \frac{1}{n}$

6. Shorter the spring it will be more stiffer.

7. If a spring of spring constant K is cut into two equal parts then the spring constant of each part is 2K.

8. If the spring is cut into n equal parts then force constant of each part is nK.

EXAMPLE

Problem: 1

A spring of force constant 'k' is stretched by a small length 'x'. Find the work done in stretching it further by a small length 'y'.

Sol. Let W_1 is the work done in stretching a spring of force constant 'K' through a length "x". Then

$$W_1 = \frac{1}{2}Kx^2$$

Let "W_2" is the workdone in stretching the spring through a length (x+y). Then $W_2 = \frac{1}{2}K(x+y)^2$

$\therefore$ Additional work done, to increase the elongation by "y" is $W = W_2 - W_1$

$$W = \frac{1}{2}K(x+y)^2 - \frac{1}{2}Kx^2 \quad \therefore \boxed{W = \frac{1}{2}Ky(y+2x)}$$

§§ Relation of kinetic energy with linear momentum:

As we know when a body of mass m moves with a velocity ' v ' its kinetic energy is

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

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

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

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

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

This is the relation between kinetic energy and linear momentum.

When a bullet is fired from a gun the momenta of the bullet and gun are equal and opposite.It can be seen from the above expression that the ratio of the kinetic energies of two bodies having the same magnitude of momenta is in the inverse ratio of their masses i.e., $\frac{K_{bullet}}{K_{gun}} = \frac{M_{gun}}{M_{bullet}}$

Hence, the kinetic energy of the bullet is greater than that of the gun.

¶¶ Points to remember regarding Kinetic energy :

1. As mass 'm' and v^2 are always positive, kinetic energy is always a positive scalar.
2. The kinetic energy depends on frame of reference . The kinectic energy of a person of mass 'm' sitting in a train moving with speed 'v' is zero in the frame of train but $1/2mv^2$ in the frame of earth
3. The relation kinetic energy $K=p^2/2m$ shows that a body cannot have kinetic energy without having momentum and vice versa.

EXAMPLE

Sample problems based on kinetic energy

***Problem* :1**

Consider the following two statements

1. Linear momentum of a system of particles is zero

2. Kinetic energy of a system of particles is zero. Then

(a) 1 implies 2 and 2 implies 1

(b)1 does not imply 2 and 2 does not imply 1

(c) 1 implies 2 but 2 does not imply 1

(d) 1 does not imply 2 but 2 implies 1

Solution : (d)

Momentum is a vector quantity whereas kinetic energy is a scalar quantity. If the kinetic energy of a system is zero then linear momentum definitely will be zero but if the momentum of a system is zero then kinetic energy may or may not be zero.

***Problem* :2**

A running man has half the kinetic energy of that of a boy of half of his mass. The man speeds up by 1 *m/s* so as to have same *K.E.* as that of boy. The original speed of the man will be

(a) $\sqrt{2}\, m/s$ (b) $(\sqrt{2}-1)m/s$ (c) $\frac{1}{(\sqrt{2}-1)} m/s$ (d) $\frac{1}{\sqrt{2}} m/s$

Solution :

(c) Let m = mass of the boy, M = mass of the man, v = velocity of the boy and V = velocity of the man

Initial kinetic energy of man $= \frac{1}{2}MV^2 = \frac{1}{2}\left[\frac{1}{2}mv^2\right] = \frac{1}{2}\left[\frac{1}{2}\left(\frac{M}{2}\right)v^2\right]$ $\left[\text{As } m = \frac{M}{2} \text{ given}\right]$

$\Rightarrow V^2 = \frac{v^2}{4} \Rightarrow V = \frac{v}{2}$ .....(i)

When the man speeds up by 1 *m/s* ,

$$\frac{1}{2}M(V+1)^2 = \frac{1}{2}m\,v^2 = \frac{1}{2}\left(\frac{M}{2}\right)v^2$$

$$\Rightarrow \quad (V+1)^2 = \frac{v^2}{2} \qquad \Rightarrow \quad V+1 = \frac{v}{\sqrt{2}} \qquad .....(ii)$$

From (i) and (ii) we get speed of the man $V = \frac{1}{\sqrt{2}-1} m/s$.

Problem :3

A body of mass 10 *kg* at rest is acted upon simultaneously by two forces 4*N* and 3*N* at right angles to each other. The kinetic energy of the body at the end of 10 sec is

(a)100 *J* (b)300 *J* (c) 50 *J* (d) 125 *J*

Solution **:**

(d) As the forces are working at right angle to each other therefore net force on the body

$F = \sqrt{4^2 + 3^2} = 5N$ Kinetic energy of the body = work done = $F \times s$

$$= F \times \frac{1}{2}at^2 = F \times \frac{1}{2}\left(\frac{F}{m}\right)t^2 = 5 \times \frac{1}{2}\left(\frac{5}{10}\right)(10)^2 = 125 \text{ J.}$$

Problem :4

If the momentum of a body increases by 0.01%, its kinetic energy will increase by

(a)0.01% (b)0.02 % (c)0.04 % (d) 0.08 %

Solution : (b)

Kinetic energy $E = \frac{P^2}{2m}$

$E \propto P^2$

Percentage increase in kinetic energy = 2(% increase in momentum)

[If change is very = 2(0.01%) = 0.02%.

Problem :5

If the momentum of a body is increased by 100 %, then the percentage increase in the kinetic energy is

(a)150 % (b)200 % (c)225 % (d) 300 %

Solution : (d)

$$E = \frac{P^2}{2m} \Rightarrow \frac{E_2}{E_1} = \left(\frac{P_2}{P_1}\right)^2 = \left(\frac{2P}{P}\right)^2 = 4$$

$E_2 = 4E_1 = E_1 + 3E_1 = E_1 + 300$ % of E_1.

Problem :6

A body of mass 5 *kg* is moving with a momentum of 10 *kg-m/s*. A force of 0.2 *N* acts on it in the direction of motion of the body for 10 seconds. The increase in its kinetic energy is

(a)2.8 *J* (b)3.2 *J* (c) 3.8 *J* (d) 4.4 *J*

Solution : (d)

Change in momentum $= P_2 - P_1 = F \times t \Rightarrow P_2 = P_1 + F \times t = 10 + 0.2 \times 10 = 12\,kg\text{-}m/s$

Increase in kinetic energy $E = \frac{1}{2m}[P_2^2 - P_1^2]$

$= \frac{1}{2m}[(12)^2 - (10)^2] = \frac{1}{2 \times 5}[144 - 100] = \frac{44}{10} = 4.4\,J.$

Problem **:7**

Two masses of 1*g* and 9*g* are moving with equal kinetic energies. The ratio of the magnitudes of their respective linear momenta is

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

Solution : (c)

$P = \sqrt{2mE}$

$P \propto \sqrt{m}$ if *E* = constant .

So $\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{1}{9}} = \frac{1}{3}$.

Problem **:8**

A body of mass 2 *kg* is thrown upward with an energy 490 *J*. The height at which its kinetic energy would become half of its initial kinetic energy will be

[$g = 9.8\,m/s^2$ **]**

(a)35 *m* (b)25 *m* (c) 12.5 *m* (d) 10 *m*

Solution : (c)

If the kinetic energy would become half, then Potential energy = $\frac{1}{2}$(Initial kinetic energy)

$\Rightarrow mgh = \frac{1}{2}[490] \Rightarrow 2 \times 9.8 \times h = \frac{1}{2}[490] \Rightarrow h = 12.5\,m$

Problem **:9**

A 300 *g* mass has a velocity of $(3\hat{i} + 4\hat{j})$ *m/sec* at a certain instant. What is its kinetic energy

(a)1.35 *J* (b) 2.4 *J* (c)3.75 *J* (d) 7.35 *J*

Solution : (c)

$\vec{v} = (3\hat{i} + 4\hat{j})$ $v = \sqrt{3^2 + 4^2} = 5\,m/s$.

So kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2} \times 0.3 \times (5)^2 = 3.75\,J$

§§ Stopping of Vehicle by Retarding Force

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

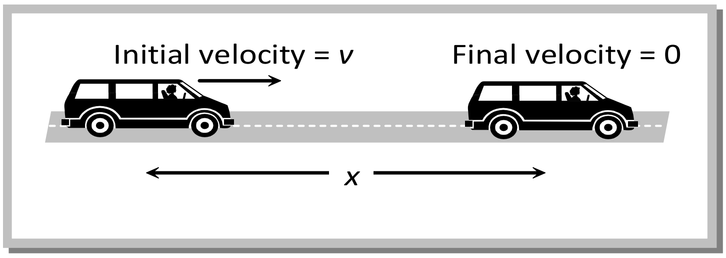
(1) **Stopping distance :**

Let *m* = Mass of vehicle, *v* = Velocity, *P* = Momentum, *E* = Kinetic energy

F = Stopping force, *x* = Stopping distance, *t* = Stopping time

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

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



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

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

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

(2) **Stopping time :**

By the impulse-momentum theorem

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

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

(3) **Comparison of stopping distance and time for two vehicles :**

Two vehicles of masses m_1 and m_2 are moving with velocities v_1 and v_2 respectively. When they are stopped by the same retarding force (F).

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

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

If vehicles possess same velocities

$v_1 = v_2$

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

If vehicle possess same momentum

$P_1 = P_2$

$$\frac{x_1}{x_2} = \frac{E_1}{E_2} = \left(\frac{P_1^2}{2m_1}\right)\left(\frac{2m_2}{P_2^2}\right) = \frac{m_2}{m_1} \qquad \frac{t_1}{t_2} = \frac{P_1}{P_2} = 1$$

If vehicle possess same kinetic energy

$E_1 = E_2$

$$\frac{x_1}{x_2} = \frac{E_1}{E_2} = 1 \qquad \frac{t_1}{t_2} = \frac{P_1}{P_2} = \frac{\sqrt{2m_1E_1}}{\sqrt{2m_2E_2}} = \sqrt{\frac{m_1}{m_2}}$$

Note : If vehicle is stopped by friction then

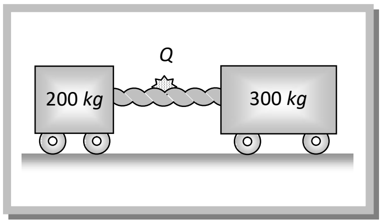
Stopping distance $x = \frac{\frac{1}{2}mv^2}{F} = \frac{\frac{1}{2}mv^2}{ma} = \frac{v^2}{2\mu g}$ [As $a = \mu g$]

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

EXAMPLE

Sample problems based on stopping of vehicle

***Problem* :1** Two carts on horizontal straight rails are pushed apart by an explosion of a powder charge *Q* placed between the carts. Suppose the coefficients of friction between the carts and rails are identical. If the 200 *kg* cart travels a distance of 36 *metres* and stops, the distance covered by the cart weighing 300 *kg* is



a) 32 *metres* b) 24 *metres*
c) 16 *metres* d) 12 *metres*

Solution **:** (c)

Kinetic energy of cart will goes against friction.

$$E = \frac{P^2}{2m} = \mu mg \times s$$

$$\Rightarrow s = \frac{P^2}{2\mu gm^2}$$

As the two carts pushed apart by an explosion therefore they possess same linear momentum and coefficient of friction is same for both carts (given). Therefore the distance covered by the cart before coming to rest is given by

$$s \propto \frac{1}{m^2}$$

$$\frac{s_2}{s_1} = \left(\frac{m_1}{m_2}\right)^2 = \left(\frac{200}{300}\right)^2 = \frac{4}{9} \Rightarrow S_2 = \frac{4}{9} \times 36 = 16 \text{ metres} .$$

***Problem* :2**

An unloaded bus and a loaded bus are both moving with the same kinetic energy. The mass of the latter is twice that of the former. Brakes are applied to both, so as to exert equal retarding force. If x_1 and x_2 be the distance covered by the two buses respectively before coming to a stop, then

(a) $x_1 = x_2$ (b) $2x_1 = x_2$ (c) $4x_1 = x_2$ (d) $8x_1 = x_2$

Solution : (a)

If the vehicle stops by retarding force then the ratio of stopping distance $\frac{x_1}{x_2} = \frac{E_1}{E_2}$.

But in the given problem kinetic energy of bus and car are given same

i.e. $E_1 = E_2$.

$\therefore x_1 = x_2$.

***Problem* :3.** A bus can be stopped by applying a retarding force *F* when it is moving with a speed *v* on a level road. The distance covered by it before coming to rest is *s*. If the load of the bus increases by 50 % because of passengers, for the same speed and same retarding force, the distance covered by the bus to come to rest shall be

(a)1.5 *s* (b)2 *s* (c)1 *s* (d) 2.5 *s*

Solution : (a)

Retarding force (*F*) ´ distance covered (*x*) = Kinetic energy $\left(\frac{1}{2}mv^2\right)$

If *v* and *F* are constants then $x \ \alpha \ m$

$\therefore \frac{x_2}{x_1} = \frac{m_2}{m_1} = \frac{1.5\,m}{m} = 1.5 \Rightarrow x_2 = 1.5\ s$.

***Problem* :4**

A vehicle is moving on a rough horizontal road with velocity *v*.The stopping distance will be directly proportional to

(a) $\sqrt{v}$ (b) *v* (c) v^2 (d) v^3

Solution : (c)

As $s = \frac{v^2}{2a}$

$s \propto v^2$.

Problem :5

The momentum of a body is doubled. By what percentage does its kinetic energy increase?

Sol . $K = \frac{p^2}{2m} \Rightarrow \frac{K_1}{K_2} = \frac{p_1^2}{p_2^2}$

Let $K_1 = K$, $p_1 = p$ then $p_2 = 2p$, K_2=?

$\frac{K}{K_2} = \frac{p^2}{(2p)^2}$; $K_2 = 4K$.

% increase in kinetic energy = $\frac{\text{Increase in kinetic energy}}{\text{Initial kinetic energy}} \times 100$

$\frac{K_2 - K_1}{K_1} \times 100 = \frac{4K - K}{K} \times 100 = 300\%$

Problem :6

A car and truck have same momentum. Which will have more kinetic energy?

Sol : From the expression $K = \frac{p^2}{2m}$

If 'p' is cosntant, 'K' is inversely proportional to the mass of the body. Hence, the kinetic energy of the car is more than that of the truck.

Problem :7

If v = (3i + 4j + 5k) ms^{-1} is the instantaneous velocity of a body of mass 1.50 kg. calculate its kinetic energy.

Sol. $V = (3i + 4j + 5k)ms^{-1}$ M = 1.5 kg

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

$= \frac{1}{2} 1.5(3i + 4j + 5k).(3i + 4j + 5k;)$ = 37.5 joules

Problem :8

A man standing on the edge of a roof of a 20 m tall building projects a ball of mass 100 g vertically up with a speed of 10 ms^{-1} and simultaneously throws another ball of same mass vertically down with the same speed. Find the kinetic energy of each ball when they reach the ground (g = 10 ms^{-2}).

Sol. Both the two balls reach the ground with the same velocity

h = 20m, m = 100g $= 10^{-1}$ kg , $u = 10\ ms^{-1}$

$v^2 - u^2 = 2gh$

$v^2 = u^2 + 2gh = 10^2 + 2 \times 10 \times 20 = 500$

K.E. of each ball $= \frac{1}{2}mv^2 = \frac{1}{2} \times 10^{-1} \times 500 = 25$ J

$\therefore$ K.E. of balls $= 25$ J, 25 J.

Problem :9

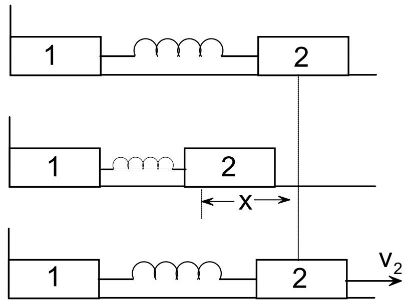
A cart of mass 250 kg is taken along a polished inclined surface to the top of a platform which is at a height of 2 m above the ground level. Find the work done by the external force moving the cart to the top.

Sol. m = 250 kg; h = 2 m, Work done W = mgh

$= 250 \times 9.8 \times 2 = 250 \times 196$ = 4900 J = 4.9 KJ

Problem :10

Two bars of masses 'm_1' and 'm_2' connected by a weightless spring of stiffness constant K as shown in figure, rest on a smooth horizontal plane. Bar 2 is shifted through a small distance x to the left and then released. Find the velocity of the centre of mass of the system after bar 1 breaks off the wall.



Sol. Velocity of the bar 2 at the instant of break off will be obtained as

$$\frac{1}{2}m_2v_2^2 = \frac{1}{2}kx^2$$

$$v_2 = x\sqrt{\frac{k}{m_2}}$$

The velocity of the bar 1 at that instant is zero (v_1 = 0)

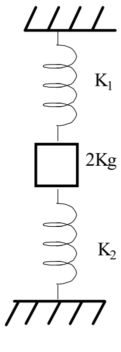
The velocity of the centre of mass is give by

$$v_c = \frac{(m_1v_1 + m_2v_2)}{(m_1 + m_2)}$$

After the substitution of the value of v_1 and v_2, we get $v_c = x\sqrt{\frac{km_2}{(m_1+m_2)}}$

Problem :11

A 2kg block is connected with two springs of force constants K_1 = 100 N/m and K_2=300 N/m as shown in figure. The block is released from rest with the springs unstretched. Find the acceleration of the block in its lowest position (g = 10 m/s^2)



Sol. Let 'x' be the maximum displacement of block downwards. Then from conservation of mechanical energy : decrease in potential energy of 2 kg block = increase in elastic potential energy of both the springs

$\therefore$ mg x = $\frac{1}{2}$(k_1 + k_2) x^2

or $x = \frac{2mg}{k_1 + k_2} = \frac{(2)(2)(10)}{100+300} = 0.1m$

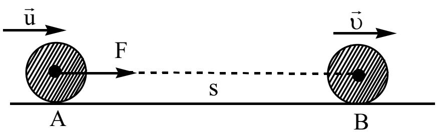
Acceleration of block in this position is

$$a = \frac{(k_1 + k_2)x - mg}{m} \quad \text{(upwards)}$$

$$= \frac{(400)(0.1)-(2)(10)}{2} = 10 m/s^2 \text{ upwards}$$

§§ Work - Energy Theorem

Statement : "The work done on a particle by the net force is equal to the change in its kinetic energy".



Proof : Consider a particle of mass 'm' is moving with an initial velocity 'u'. When it is under the action of a constant net force F, let it gain uniform acceleration 'a'. Its velocity becomes 'v' after a displacement S. Work done by the net force

W = FS = maS **(**$\because$ F = ma)

$$= m\left(\frac{v^2 - u^2}{2S}\right)S \quad \left(\because a = \frac{v^2 - u^2}{2S}\right)$$

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

W = $K_f - K_i$

where K_f and K_i are the final and initial kinetic energies of the particle. K_f - K_i is the change in kinetic energy of the particle

Hence, the theorem is proved.

Note

1) The theorem is applicable not only for a single particle but also for a system. When it is applied to a system of two or more particles, change in the kinetic energy of the system is equal to work done on the system by the external as well as the internal forces.

2) Work-energy theorem can also be applied to a system under the action of variable forces, conservative as well as non conservative forces.

§§ Special cases in work energy theorem.

1. A particle of mass 'm' is thrown vertically up with a speed 'u' . Neglecting the air friction , the work done by gravitational force, as particle reaches maximum height is

$W_g = \Delta k = K_f - K_i$

$W_g = -\frac{1}{2}mu^2 \qquad [\because k_f = 0]$

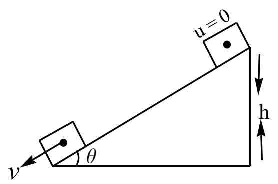
2. A pariticle of mass 'm' falls freely from a height 'h' in air medium onto the ground.If 'V' is the velocity with which it reaches the ground , the work done by air friction is W_f and work done by gravitational force W_g = mgh

$W_g + W_f = \Delta k$, $mgh + W_f = \frac{1}{2}mv^2 - 0$ $\boxed{W_f = \frac{1}{2}mv^2 - mgh}$

3. A block of mass 'm' slides down a

frictionless smooth incline of inclination 'θ' to the horizontal . If 'h' is the height of incline , the velocity with which the body reaches the bottom of incline is

$W_g = \Delta k = mgh = \frac{1}{2}mv^2 - 0 \Rightarrow \boxed{v = \sqrt{2gh}}$



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

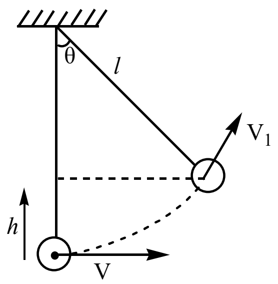
$(mg\sin\theta)\ell + (-\mu_k mg\cos\theta)\ell = \frac{1}{2}\text{mv}^2 - 0$

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

5. Bob of pendulum of length 'ℓ' is projectile horizontally with a speed 'u' at its lowest position then the speed of the bob when it makes an angle θ with the lower vertical is

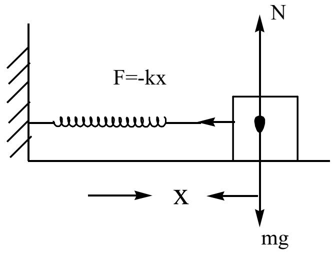
$W_g = \Delta k$, $W_g = k_f - k_i$

thus $-mgl(1-\cos\theta) = \frac{1}{2}m\left(v_1^2 - v^2\right)$



$\boxed{\text{v}_1 = \sqrt{\text{v}^2 - 2gl(1-\cos\theta)}}$

6. A block of mass 'm' attached to a spring of spring constant 'k' oscillates on a smooth horizontal table . The other end of the spring is fixed to a wall . It has a speed 'V' when the spring is at natural length . The distance it moves on table before it comes to instantaneous rest is



$$W_{S.F} + W_g + W_N = \Delta k$$

Let the mass be oscillating with amplitude x on compressing the spring.

$W_{S.F.} = -\frac{1}{2}Kx^2$; W_g = mgx cos 90^0 = 0

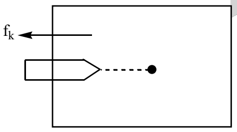
W_N = Nx cos 90^0= 0

since no work is done by gravity and normal reaction (N)

$$W_{S.F} = k_f - k_i$$

$-\frac{1}{2}kx^2 = 0 - \frac{1}{2}mv^2$ or $\boxed{x = v.\sqrt{\frac{m}{k}}}$

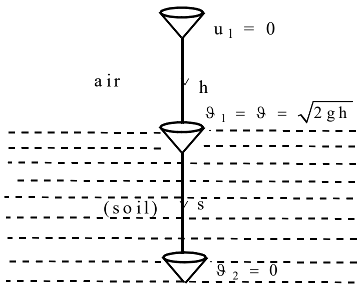
7. A bullet of mass 'm' moving with velocity 'v' stops in a wooden block after penetrating through a distance x . If 'F' is the resistance offered by the block to the bullet



$$W_F = k_f - k_i$$

$-f_k x = 0 - \frac{1}{2}mv^2$ or $\boxed{f_k = \frac{1}{2}.\frac{mv^2}{x}}$

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



$W_g + W_R = k_f - k_i$

$mg(h+s) + (-R.s) = 0$ or $\boxed{R = mg\left[1 + \frac{h}{s}\right]}$

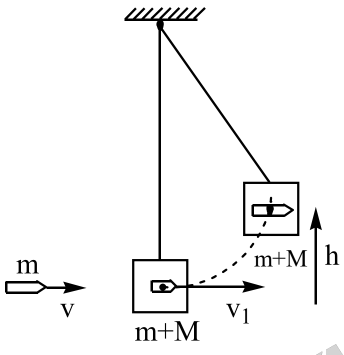
Here time of penetration is given by impulse equation

$(R - mg)t = 0 - m.\sqrt{2gh}$ or $\boxed{t = \frac{2s}{\sqrt{2gh}}}$

9. A bullet of mass 'm' is fired horizontally with a velocity 'V' which strikes a wooden block of mass 'M' suspended vertically. If the bullet is embedded in the block ,the height 'h' to which the system would rise is

By the principle of conservation of linear momentum mv = (M+m)V_1

or V_1=mv/M+m



where V_1 is the common velocity of bullet + block system

By work energy theorem $W_g = k_f - k_i$

$$-(M+m)gh = 0 - \frac{1}{2}(M+m)V_1^2$$

$$\therefore \boxed{h = \left(\frac{mv}{M+m}\right)^2 \cdot \frac{1}{2g}}$$

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

$W = \Delta k$ or W = k_f - k_i, $K_f = W = ma.s$

$= ma\left(\frac{1}{2}at^2\right)$ or $k_f = \frac{ma^2t^2}{2}$

since $a = \frac{V_0}{t_0}$ $\therefore \boxed{k_f = \frac{1}{2}mv_0^2\left(\frac{t}{t_0}\right)^2}$

EXAMPLE

Problem :1

A bullet of mass 25 g moving with a velocity of 500 ms^{-1} enters into a wooden block and comes out of it with a velocity of 100 ms^{-1}. Find the work done by the bullet while passing through the wooden block.

Sol. $m = 25 \times 10^{-3}$ kg , u=500m/s, v = 100 m/s

Work energy theorem $W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$= \frac{1}{2} \times 25 \times 10^{-3}[(100)^2 - (500)^2]$ = 300 J

Problem :2

A lorry and a car moving with the same kinetic energy are brought to rest by the application of brakes, which provide equal retarding forces. Which of them will come to rest in shorter time? Which will come to rest in less distance?

Sol . a) Initial kinetic energy of each vehicle is K and when they come to rest their final kinetic energy is zero. The change in kinetic energy of both the car and lorry is K. By work–energy theorem

FS = change in kinetic energy

FS = K; $S = \frac{K}{F}$

where F is the retarding force. As K and F are same for both the vehicles, they come to rest after travelling the *same distance*.

b) To find the time in which each vehicle comes to rest, we have to consider the momentum, $p = \sqrt{2m \times K}$ since $K = \frac{p^2}{2m}$. The initial momentum of the car is less than that of the lorry as K is same for both but mass of the car is less than that of the lorry. Final momentum is zero for both the vehicles. So, change in momentum is less for the car. By Newton's second law,

$F = \frac{\Delta p}{\Delta t}$; $\Delta t = \frac{\Delta p}{F}$

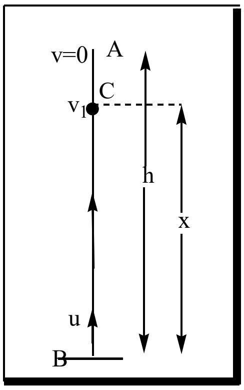
Since 'F' is same, $\Delta t \propto \Delta p$

As car has smaller momentum, the car comes to rest earlier.

§§ **Law of conservation of Energy:** ”Energy neither been created ,nor been destroyed but it can convert into one form to another form.”

§§ **Law of Conservation of Energy in case of Vertically Projected Body**

Consider a body of mass ‘m’ is projected vertically upwards from the ground with velocity ‘u’ so that it reaches a maximum height ‘h’ from the ground. As the body moves up against gravity its potential energy increases and kinetic energy decreases



At ground B, as the height of the body is zero, the P.E. of the body = mgx 0 = 0

The K.E. of the body $=\frac{1}{2}mu^2$

$\therefore$ T.E=P.E. + K.E $=0+\frac{1}{2}mu^2=\frac{1}{2}mu^2$

At point C : During its motion, consider a point C where the velocity of the body is v_1.

Let BC = x

At C, the P.E. of the body = mgx

But $v_1^2-u^2=-2gx \text{ or } v_1^2=u^2-2gx$

The K.E. of the body

$$=\frac{1}{2}mv_1^2=\frac{1}{2}m\left(u^2-2gx\right)=\frac{1}{2}mu^2-mgx$$

$\therefore$The T.E. of the body = P.E. +K.E. =

mgx+$\frac{1}{2}$mu^2-mgx=$\frac{1}{2}$mu^2 ______ (2)

At point A : When the body reaches the maximum heigh 'h' above the ground, its final velocity becomes zero.

In the equation,

$v^2–u^2=2as$.

v=0,

u=u

a =–g and s = h. Then $0 – u^2 = –2gh$ or $h=\frac{u^2}{2g}$

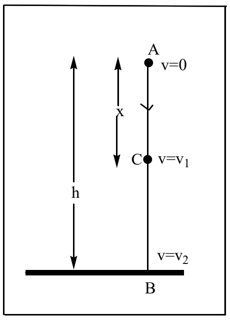
$\therefore$ The P.E. of the body =

$mg\times h=mg\times\frac{u^2}{2g}=\frac{1}{2}mu^2$ _______ (3)

Thus the total energy at all points A, B and C remains constant and equal to $\frac{1}{2}mu^2$. Hence the law of conservation of energy is verified in the case of a body projected vertically upwards.

§§ Law of Conservation of Energy in case of Freely Falling Body :

A body of mass 'm' is at a height 'h' from the ground. As the body falls freely under gravity its potential energy decreases and kinetic energy increases



At point A: The highest point

P.E. of the body=mgh

Velocity of the body, 'v'=0

$\therefore$K.E. of the body $=\frac{1}{2}mv^2 = 0$

Total energy at A=P.E.+ K.E.

=mgh + 0 = mgh ________ (1)

At point C : As the body falls freely consider any point 'C' in its path where AC = x.

P.E. of the body = mg (h-x) = mgh - mgx

Let v_1 be the velocity of the body at 'C'.

Initial velocity u = 0 (at A)

Velocity at C = v = v_1 (Say)

Acceleration a = g

Distance travelled = s = x

Using the formula $v^2-u^2 = 2as$

$v_1^2 = 2gx$

K.E. of the body at

$$C = \frac{1}{2}mv_1^2 = \frac{1}{2}m.2gx = mgx$$

Total energy at C=P.E.+K.E.

= mgh - mgx + mgx = mgh __ (2)

At point B : The body touches the ground at 'B' with a velocity 'v_2'.

P.E. at B = mg x 0 = 0

Again u=0; v=v_2;a=g and s = h

$$v_2^2 - 0 = 2gh$$

$$\therefore K.E.at\ B = \frac{1}{2}mv_2^2 = \frac{1}{2}mx2gh = mgh$$

Thus at any point on the path of a freely falling body the total energy is 'mgh'.

Thus the law of conservation of energy is verified.

EXAMPLE

Problem :1

A ball of mass 50 g falls from rest vertically downwards through a distance of 40 m and hits the ground. Find the kinetic energy and final velocity of the ball before it hits the ground $(g = 9.8\,ms^{-2})$.

Sol. $m = 50\ gm = 50 \times 10^{-3}\ kg$,

h = 40 m; $g = 9.8\ ms^{-2}$

From law of conservation of energy

loss in P.E $=$ gain in K.E.

$$\Rightarrow mgh = \frac{1}{2}mv^2 \quad \text{and } v = \sqrt{2gh}$$

Final velocity , $v = \sqrt{2 \times 9.8 \times 40} = 28\ ms^{-1}$

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2} \times 50 \times 10^{-3} \times 28 \times 28 = 19.6\ J$$

Problem :2

In a spring gun having spring constant 100 N/m, a small ball of mass 0.1 kg is put in its barrel by compressing the spring through 0.05 m as shown in Figure. The ball leaves the gun horizontally at a height of 2 m above the ground. Find

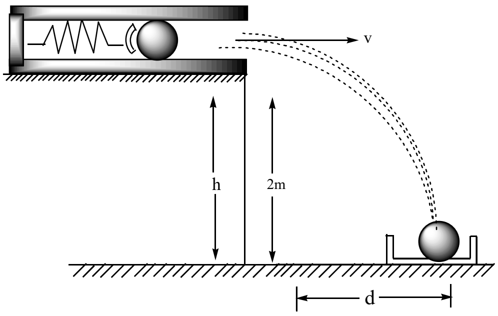
(a) The velocity of the ball when the spring is released. (b) Where should a box be placed on the ground so that the ball falls in it. (g = 10 m/s^2)

Sol: (a) When the spring is released its elastic potential energy (1/2) kx^2 is converted into kinetic energy (1/2) mv^2 of the ball; so, by conservation of mechanical energy

$$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \Rightarrow v = x\sqrt{\frac{k}{m}}$$

$$So \quad v = 0.05\sqrt{\frac{100}{0.1}}m/s = \sqrt{\frac{5}{2}}m/s$$

(b) As initial vertical component of velocity of ball is zero, time taken by the ball to reach the ground,



$$t=\sqrt{\frac{2h}{g}}=\sqrt{\frac{2\times 2}{10}}=\sqrt{\frac{2}{5}}s$$

So the horizontal distance travelled by the ball in this time $d=vt=\sqrt{\frac{5}{2}}\times\sqrt{\frac{2}{5}}=1m$

Problem :3

A uniform chain of length 'L' and mass 'm' is on a smooth horizontal table, with $\frac{1}{n}$ th part of its length hanging from the edge of the table. Find the kinetic energy of the chain as it completely slips off the table.

Sol: With respect to the top of the table, the initial potential energy of the chain,

U_1 = PE of the chain lying on the table + PE of the hanging part of the chain

$$= L\left(1-\frac{1}{n}\right)mg(0)+\frac{m}{n}g\left(-\frac{L}{2n}\right)=-\frac{mgL}{2n^2}$$

P.E of the chain, when it just slips off the table, $U_2=mg\left(\frac{-L}{2}\right)=-\frac{mgL}{2}$

From law of conservation of energy

$$\Delta K=-\Delta U$$

$K_f - K_i = -(U_f - U_i)$

$$\because K_i=0\ ;\ K_f=-\left[-\frac{mgL}{2}-\left(-\frac{mgL}{2n^2}\right)\right]$$

$$\boxed{K_f=\frac{mgL}{2}\left[1-\frac{1}{n^2}\right]}$$

If 'V' is the velocity of the chain, then,

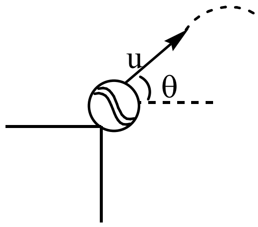
$$\frac{1}{2}mv^2=\frac{mgL}{2}\left[1-\frac{1}{n^2}\right]$$

$$\therefore \boxed{v = \sqrt{gL\left[1 - \frac{1}{n^2}\right]}}$$

If 'ℓ' is the initial length of the hanging part, then $n = \frac{L}{\ell}$ $\therefore K = \frac{mgL}{2}\left[1 - \frac{\ell^2}{L^2}\right]$

or $\boxed{K = \frac{mg\left(L^2 - \ell^2\right)}{2L}}$ and $\boxed{v = \sqrt{\frac{g\left(L^2 - \ell^2\right)}{L}}}$

Problem :4



A boy throws a ball with initial velocity u at an angle of projection θ from a tower of height H. Neglecting air resistance, find

(a) how high above the building the ball rise, and

(b) its speed just before it hits the ground.

Sol. (a) Only gravitational force acts on the ball, which is conservative; therefore we can apply conservation of energy. We assign reference level at the top of the building i.e., $U_{gi} = 0$. At the topmost point in the path, the ball is moving horizontally with velocity $u\cos\theta$.

Initial total mechanical energy: $E_i = 0 + \frac{1}{2}mu^2$

Total mechanical energy at the topmost point:

$$E_f = \frac{1}{2}mu^2\cos^2\theta + mgh$$

From conservation of energy, we have $E_i = E_f$

a) $\frac{1}{2}mu^2 = \frac{1}{2}mu^2\cos^2\theta + mgh$ or $h = \frac{u^2 - u^2\cos^2\theta}{2g}$

b) If v is the speed of the ball at the ground,

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

From conservation of energy, we have

$E_i = E_f \Rightarrow \frac{1}{2}mu^2 = \frac{1}{2}mv^2 - mgH$, $v = \sqrt{u^2 + 2gH}$

TEACHING TASK

Single correct answer type

Energy, Relation between KE and momentum

1. A tank of size 10 m $\times$ 10 m $\times$ 10 m is full of water and built on the ground. If g = 10 m s^{-2}, the potential energy of the water in the tank is

1) 5×10^7 J 2) 1×10^8 J 3) 5×10^4 J 4) 5×10^5 J

2. An inelastic ball falls from a height of 100 meters. It loses 20 % of its total energy due to impact. The ball will now rise to a height of

1) 80 m 2) 120 m 3) 60 m 4) 9.8 m

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

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

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

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

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

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

6. The momentum of a particle is found to be numerically equal to its kinetic energy, if all units are expressed in SI, the velocity of the particle must be

1) 1 m/s 2) 2 m/s 3) ½ m/s 4) 4 m/s

7. If the momentum of a body is increased by 50 %, the percentage increase in its kinetic energy is

1) 100 2) 50 3) 125 4) 200

8. When a gun of mass "M" fires a bullet of mass "m", the total energy released in the explosion is found to be "E". the kinetic energy of the bullet is

1) EM/(M+m) 2) Em/(M+m) 3) E(M+m)/M 4) E(M+m)/m

9. A ball of mass 'm' at rest receives an impulse I_1 in the direction of north. After some time it received another impulse I_2 in the direction of south. The final kinetic energy of the ball is

1) $\frac{(I_1+I_2)^2}{2m}$ 2) $\frac{(I_1-I_2)^2}{2m}$ 3) $\frac{I_1^2+I_2^2}{2m}$ 4) $\frac{I_1^2-I_2^2}{2m}$

WORK ENERGY THEOREM

10. By applying the brakes without causing a skid, the driver of a car is able to stop his car in a distance of 5 m, if it is going at 36 kph. If the car were going at 72 kph, using the same brakes, he can stop the car over a distance of

1) 10 m 2) 2.5 m 3) 20 m 4) 40 m

11. A bullet fired into a trunk of a tree loses 1/4 of its kinetic energy in traveling a distance of 5 cm. Before stopping it travels a further distance of

1) 150 cm 2) 1.5 cm 3) 1.25 cm 4) 15 cm

12. A block of mass 5 kg is initially at rest on a rough horizontal surface. A force of 45 N acts on it in a horizontal direction and pushes it over a distance of 2 m. The force of friction acting on the block is 25 N. The final kinetic energy of the block is

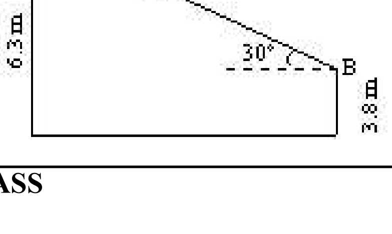
1) 40 J 2) 90 J 3) 50J 4) 140 J

CONSERVATION OF ENERGY

13. A cradle is 'h' meters above the ground at the lowest position and 'H' meters when it is at the highest point. If 'v' is the maximum speed of the swing of total mass 'm' the relation between 'h' and 'H' is

1) $\frac{1}{2}mv^2 + h = H$ 2) $(v^2/2g) + h = H$ 3) $(v^2/g) + 2h = H$ 4) $(v^2/2g) + H = h$

14. AB is a frictionless inclined surface making an angle olf 30^0 with horizontal. A is 6.3 m above the ground while B is 3.8 m above the ground. A block slides down from A, initially starting from rest. Its velocity on reaching B is



1) 7 m s^{-1} 2)14 m s^{-1} 3)7.4 m s^{-1} 4) 4.9 m s^{-1}

15. The bob of a pendulum is drawn aside so that it is at a height of 4.5 m above the ground and released. If it reaches the equilibrium position which is at a height of 2 m above the ground, the speed of the bob will be

1) 49 m/s 2) 7 m/s 3) $7\sqrt{2}$ m/s 4) $7/\sqrt{2}$ m/s

II More than one correct option questions

♦ *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which* ***ONE or MORE*** *is correct. Choose the correct options*

1. Which of the following are the units for energy

a) eV b)joule c)erg d)Btu

A) a,b,c are corect B) a,b,d are correct C) b,c,d are correct D) all are correct

2. Which of the following are conservative forces?

a) Gravitational force b) Electrostatic force c) Magnetic force d)Elastic force

A) a,b,c are corect B) a,b,d are correct C) b,c,d are correct D) all are correct

Assertion - A and Reason - R:

♦ *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which* ***ONLY ONE*** *is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

3. **A :** A body can possess mechanical energy without momentum.
R : A bent bow possess potential energy by virtue of deformation.

4. **A:** A lighter body and heavier body have same momentum.Then they also have same K.E.
R: Kinetic energy does not depend on mass of the body.

5. **A:** Two bodies of different masses have same momentum.Then the ratio of their K.E is in the inverse ratio of their mass
R: K.E=1/2(mv^2)

Match the following

♦ *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in* ***Column–I*** *have to be matched with statements (p, q, r, s) in* ***Column–II****. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

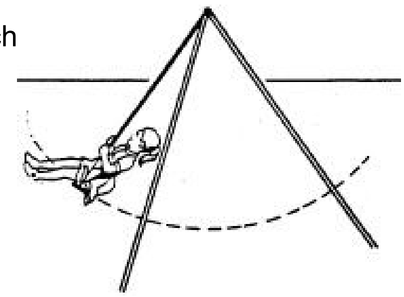
6.

Set-I	Set-II
a) Conservative force	1) Workdone in a closed path is zero
b) Non-Conservative force	2) Workdone in a closed path is not zero
c) Kinetic energy	3) By virtue of position of a body
d) Potential energy	4) By virtue of motion of a body

A) a-1,b-4,c-3,d-2 B) a-1,b-2,c-4,d-3 C) a-2,b-3,c-1,d-4 D) a-4,b-2,c-1,d-3

Comprehension type questions

7. A 12 kg child swings on a swing which



is 0.30 m above the ground. If she reaches a maximum height of 1.5 m
i) What is her potential energy at the highest point in her swing?
A) 140J B)120J
C) 180J D)150J
ii) What is her speed when she reaches this point(above problem) in ms^{-1}?
A) 8 B)7 C)20 D)0

KEY

ΦΦ TEACHING TASK :

I: 1)1, 2)1, 3)4, 4)4, 5)1, 6) 2, 7)3, 8)1, 9)2, 10)3, 11)4, 12)1, 13)2, 14)1, 15)2

II: 1) D, 2) D, 3) B, 4) B, 5) D, 6) B, 7) i) A, ii) D

LEARNER'S TASK

BEGINNERS (Level - I)

Energy, Relation between KE and momentum

1. A spring when compressed by 4 cm has 2 J energy stored in it. The force required to extend it by 8 cm will be
1) 20 N 2) 2 N 3) 200 N 4) 2000 N

2. The elastic potential energy of a stretched spring is given by $E = 50x^2$ where x is the displacement in meter and E is in joule, then the force constant of the spring is
1) 50 Nm 2) 100 N m^{-1} 3) 100 N/m² 4) 100 Nm

3. A rubber ball falling from a height of 5 m rebounds from a hard floor to a height of 3.5 m. The % loss of energy during the impact is
1) 20% 2) 30% 3) 43% 4) 50%

4. A woman weighing 63 kg eats plum cake whose energy content is 9800 calories. If all this energy could be utilized by her, she can ascend a height of
1) 1 m 2) 67 m 3) 100 m 4) 42 m

5. A body has a unit mass and is at a state of rest. Then suddenly it receives an impulse 'x', then it will acquire a kinetic energy of
1) x 2)x^2 3) $x^2/2$ 4) $2/x^2$

6. Two masses of 1 gm and 4 gm are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta is
1) 4 : 1 2) 2 : 1 3) 1 : 2 4) 2 : 1

7. Two bodies having kinetic energies K_1 and K_2 have equal masses. Their momenta are p_1 and p_2 respectively, then p_1/p_2 is
1) $K_1 : K_2$ 2) $K_2 : K_1$ 3) $\sqrt{K_2} : \sqrt{K_1}$ 4) $\sqrt{K_1} : \sqrt{K_2}$

8. A proton and a deuteron have kinetic energies in the ratio 1 : 2. The ratio of their linear momenta is
1) $1 : \sqrt{2}$ 2) $\sqrt{2} : 1$ 3) 2 : 1 4) 1 : 2

9. A body of mass 4 kg is moving with a momentum of 12 kg ms^{-1}. Its kinetic energy is
1) 18 J 2) 24 J 3) 96 J 4) 12 J

10. A nucleus of mass 218 amu in free state decays to emit an alpha-particle. Kinetic energy of the alpha-particle emitted is 6.7 MeV. The recoil energy (in MeV) of the daughter nucleus is
1) 1.0 2) 0.5 3) 0.25 4) 0.125

11. A man weighing 80 kg climbs a staircase carrying a 20 kg load. The staircase has 40 steps each of 25 cm height. If he takes 20 seconds to climb, the work done is
1) 9800 J 2) 490 J 3) 98 x 10^5 J 4) 7840 J

12. A tennis ball has a mass of 56.7 gm and is served by a player with a speed of 180 kmph. The work done in serving the ball is nearly
1) 710 J 2) 71 J 3) 918 J 4) 91.8 J

13. A body of mass 2 kg is projected with an initial velocity of 5 m s^{-1} along a rough horizontal table. The work done on the body by the frictional forces before it is brought to rest is
1) 250 J 2) 2.5 J 3) 10 J 4) 25 J

14. A neutron, one of the constituents of a nucleus, is found to pass two points 60 meters apart in a time interval of 1.8×10^{-4} sec. The mass of a neutron is 1.7×10^{-27} kg, assuming that the speed is constant, its kinetic energy is
1) 9.3×10^{-17} joule 2) 9.3×10^{-14} joule
3) 9.3×10^{-21} joule 4) 9.3×10^{-11} joule

15. A 150 gm mass has a velocity (2i + 6j) m/s at a certain instant. It's kinetic energy is
1) 6 J 2) 2 J 3) 3 J 4) 8 J

16. A body starts from rest and moves with uniform acceleration. What is the ratio of kinetic energies at the end of 1st, 2nd and 3rd seconds of its journey?
1) 1 : 8 : 27 2) 1 : 2 : 3 3) 1 : 4 : 9 4) 3 : 2 : 1

17. On increasing the speed of a body to 2 m s^{-1}, its kinetic energy is quadrupled. Then its original speed must be
1) 0.25 m s^{-1} 2) 1 m s^{-1} 3) 4 m s^{-1} 4) 2 m s^{-1}

18. A liquid of specific gravity 0.8 is flowing in a pipe line with a speed of 2 m/s. The K.E. per cubic meter of it is
1) 160 J 2) 1600 J 3) 160.5 J 4) 1.6 J

19. A bullet of mass 10 gm strikes a target at 400 m/s velocity and loses half of its initial velocity. The loss of kinetic energy in joules is
1) 800 2) 200 3) 400 4) 600

20. A 60 kg boy lying on a surface of negligible friction throws horizontally a stone of mass 1 kg with a speed of 12 m/s away from him. As a result with what kinetic energy he moves back?
1) 2.4 J 2) 72 J 3) 1.2 J 4) 36 J

21. An object is acted on by a retarding force of 10 N and at a particular instant its kinetic energy is 6 J. The object will come to rest after it has travelled a distance of
1) 3/5 m 2) 5/3 m 3) 4 m 4) 16 m

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

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

23. A man standing on the edge of the roof of a 20 m tall building projects a ball of mass 100 gm vertically up with a speed of 10 m s^{-1}. The kinetic energy of the ball when it reaches the ground will be [g =10 m s^{-2}]

1) 5 J 2) 20 J 3) 25 J 4) zero

WORK ENERGY THEOREM

24. A cyclotron accelerates a proton to a final speed of 3×10^7 m s^{-1}, which is initially at rest. The work done on the proton in mega electron volts, by the electrical field of the cyclotron is (Mass of the proton is 1.6×10^{-27} kg)

1) 0.45 2) 4.5 3) 45 4) 450

25. A ship of mass 3×10^7 kg initially at rest is pulled by a force of 5×10^4 N through a distance of 3 meters. Assuming that the resistance due to water is negligible, the speed of the ship is

1) 0.1 m/s 2) 1.5 m/s 3) 5 m/s 4) 60 m/s

26. A vehicle of mass 1000 kg is moving with a velocity of 15 m s^{-1}. It is brought to rest by applying brakes and locking the wheels. If the sliding friction between the tires and the rod is 6000 N, distance moved by the vehicle before coming to rest is

1) 37.5 m 2)18.75 m 3) 75 m 4) 15 m

27. A body of mass 2 kg is at rest. A force of 4i + 3j - 5k N acts on it and displaces through 2i + j + 2k m. The velocity acquired by the body is

1) 0 2) 1 m s^{-1} 3) 2 m s^{-1} 4) ½ m s^{-1}

28. A bullet of mass 'm' is fired with a velocity 'v' into a fixed log of wood and penetrates a distance 's' before coming to rest. Assuming that the path of the bullet in the log of wood is horizontal, the average resistance offered by the log of wood is

1) $mv/2s^2$ 2) $mv^2/2s$ 3) $2s/mv^2$ 4) $ms^2/2v$

29. Two trucks A and B are moving with the same kinetic energy. A is twice as massive as B. The same brake force is applied on A and B and they stop over distances "a" and "b". The correct relation between "a" and "b" is

1) a = 2 b 2) b = 2 a 3) a = b 4) a = 4 b

30. A car is going with a linear momentum 'p'. When brakes are applied, it comes to a stop in a distance 's'. If the same car were going with a linear momentum '2p' and the brakes are applied, it comes to a stop in a distance of (assume that the brake force is same in the two cases)

1) 2s 2) s 3)4s 4) s/4

LAW OF CONSERVATION OF ENERGY

31. A block of mass 4 kg slides on a horizontal frictionless surface with a speed of 2 m/s. It is brought to rest in compressing a spring in its path. If the force constant of the spring is 400 N/m, by how much the spring will be compressed?

1) 2×10^{-2} m 2) 0.2 m 3) 20 m 4) 200 m

32. A 4.0 kg mass moving with a speed of 2.0 m/sec collides with a spring bumper of negligible mass and having a force constant 100 N/meter. The maximum compression of the spring bumper will be

1) 1.6 m 2) 0.4 m 3) 2.0 m 4) 1.0 m

33. A stone of mass "m" initially at rest and dropped from a height "h" strikes the surface of the earth with a velocity "v". If the gravitational force acting on the stone is W, then which of the following identities is correct?

1) mv - mh = 0 2) ½ mv^2 - Wh^2 = 0

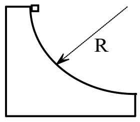
3) ½ mv^2 - Wh = 0 4) ½ mv^2 - mh = 0

34. At what height above the ground must a mass of 5 kg be to have its P.E. equal in value to the K.E. possessed by it when it moves with a velocity of 10 m/s? (Assume g = 10 m/s^2)

1) 1 m 2) 5 m 3) 10 m 4) 50 m

35. A body slides down a fixed curved track that is one quadrant of a circle of radius R, as in the figure. If there is no friction and the body starts from rest, its speed at the bottom of the track is

1) 5gR 2) $\sqrt{5gR}$



3) $\sqrt{2gR}$ 4) $\sqrt{gR}$

36. Two identical blocks A and B, each of mass 'm' resting on smooth floor are connected by a light spring of natural length L and the spring constant K, with the spring at its natural length. A third identical block C (mass m) moving with a speed v along the line joining A and B collides with A. The maximum compression in the spring is:

1) $v\sqrt{\frac{m}{2k}}$ 2) $m\sqrt{\frac{v}{2k}}$ 3) $\sqrt{\frac{mv}{2k}}$ 4) $\frac{mv}{2k}$

ACHIEVERS (Level - II)

Solve the following:

1. Calculate the velocity of an alpha particle which has a kinetic energy of 3.50 x 10^{17}J
The mass of an alpha particle is 6.65 x 10^{-27} kg.

2. Two bodies have their masses $m_1/m_2=3/1$ and their K.E.s $K_1/K_2=1/3$.Find the ratio of their velocities.

3. Two bodies having kinetic energies K_1 and K_2 have equal masses. Their momenta are p_1 and p_2 respectively, then find the value of p_1/p_2.

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

5. A river is flowing at a speed 4ms^{-1}. Find the K.E. of cubic metre of water.

6. Two masses of 2kg and 8kg are moving with linear momenta in the ratio 1 : 2. Calculate the ratio of their K.E.

7. The momentum of two bodies are in the ratio 2 : 3 and their K.E. are in the ratio 8 : 27. Find the ratio of masses.

8. The KE of the body is K if 1/4th of its mass is removed and velocity is doubled its new KE is.....

9. A river of salty water is flowing with a velocity 2 m/s. if the density of water is 1.2g/cc.then the KE of each of cubic metre of water is....

10. If the KE of a body increases by125%.the percentage increases in its momentum is

11. A spring is kept compressed by a toy cart of mass 150 g on realising the cart it moves with a speed of 0.2 m/s. calculate the PE of the spring.

EXPLORERS (Level - III)

I. More than one correct option questions

♦ *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which* ***ONE or MORE*** *is correct. Choose the correct options*

1. Which of the following are correct relations?

a)1KWH=3.6X10^{6}J b) $1\,eV = 1.6\times10^{-19}\,J$ c) 1J=10^{7}erg

A) a,b are corect B) a,c are correct C) b,c are correct D) all are correct

2. Which of the following have the same units

a) Work b) P.E c) K.E d) Gravitational force

A) a,b,c are corect B) a,b,d are correct C) b,c,d are correct D) all are correct

3. Which of the following belongs to same category?
a) Gravitational force b) Electrostatic force
c) Magnetic force d) frictional force force
A) a,b,c are corect B) a,b,d are correct C) b,c,d are correct D) all are correct

II. <u>Assertion - A and Reason - R:</u>

♦ *This section contains certain number of questions. Each question contains Statement – 1(Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which* ***ONLY ONE*** *is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true.

4. **A:** The rate of change of total momentum of a many particle system is proportional to the sum of internal forces of system.
R: Internal forces can changes the K.E but not the momentum of the system.

5. **A:**Both P.E and K.E have the same units.
R: Both P.E and K.E are scalar quantities.

6. **A:** Energy is a scalar quantity.
R: Both energy and work have the same units

7. **A:** KWH is the unit of electrical energy.
R: 1KWH = 3.6×10^{6} joule

<u>Match the following</u>

♦ *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in* ***Column–I*** *have to be matched with statements (p, q, r, s) in* ***Column–II****. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

8.

Set-I	**Set-II**
a) PE=KE	1) at height h/2
b) PE=2KE	2) constant at any point
c) KE=2PE	3) at height 2h/3
d) PE+KE	4) at height h/3

A) a-1,b-4,c-3,d-2 B) a-1,b-3,c-4,d-2 C) a-2,b-3,c-1,d-4 D) a-4,b-2,c-1,d-3

<u>Comprehension type questions</u>

♦ *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which* ***ONLY ONE i****s correct. Choose the correct option.*

9. A body of mass 5 kg is moving with a momentum of 10 kg-m/s. A force of 0.2 N acts on it in the direction of motion of the body for 10 seconds.
i)The change in momentum is
A) $12kgms^{-1}$ B)$20kgms^{-1}$ C) $15kgms^{-1}$ D)$18kgms^{-1}$
ii)The increased in its kinetic energy is
A) 6J B)10J C)8J D)4.4J

KEY

ΦΦ <u>LEARNER'STASK :</u>

☐ **BEGINNERS:** 1)3, 2)2, 3)2, 4)2, 5)3, 6)3, 7)4, 8)4, 9)1, 10)4, 11)1,
12)3, 13)4, 14)1, 15)3, 16)3, 17)2, 18)2, 19)4, 20)3, 21)1, 22)2,
23)3, 24)2, 25)1, 26)2, 27)2, 28)2, 29)3, 30)3, 31)2, 32)2, 33)3,
34)2, 35)3, 36)1

- ☐ **ACHIEVERS :** 1)$1.03\times10^5 ms^{-1}$, 2) 1:3, 3) $\sqrt{K_1}:\sqrt{K_2}$, 4) 1600 J, 5) 8000J/m^3, 6)1 : 1, 7)3 : 2 8)3K, 9)2.4kJ, 10)50%, 11)3×10^{-3} J
- ☐ **EXPLORERS :** 1) A, 2) A, 3) D, 4) B, 5) B, 6) A, 7) B, 8) C, 9) i) A, ii) D.

§§ POWER:

1. Power is the rate of doing work. It is scalar.
2. Power = $\dfrac{workdone}{time}=\dfrac{W}{t}$
3. Units of power : erg s^{-1} (CGS),Js^{-1} or Watt (SI) Dimensional formula is ML^2T^3
4. If the work is done at the rate of one joule per second, then power is said to be one Watt.
5. Power is also measured in horse power 1HP = 746 Watt.
6. Power of a vehicle $P=\vec{F}.\vec{V}=FV\cos\theta$. Here $\vec{F}$ is force applied by engine and $\vec{F}$ is its constant velocity.

§§ Relation between average power and instantaneous power :

A particle starts from rest and moving with uniform acceleretion and gains a velocity 'V' in time 't'

$$P_{av}=\frac{W}{t}=\frac{\frac{1}{2}mV^2}{t}=\frac{1}{2}mV\left(\frac{V}{t}\right);\quad \begin{pmatrix}V=at\\ a=V/t\end{pmatrix}$$

$$P_{av}=\frac{W}{t}=\frac{m\vec{a}\cdot\vec{V}}{2}=\frac{\vec{F}\cdot\vec{V}}{2}$$

we know instantaneous power is $P_{inst}=\vec{F}.\vec{V}$

From the above it can be concluded that $\boxed{P_{av}=\frac{1}{2}.P_{inst}}$

¶¶ Efficiency of Crane or Motor :

The ratio of output power to the input power is called efficiency.

$$\eta=\frac{output\ power}{Input\ power}\times100 \quad \eta=\frac{p_0}{p_i}\times100$$

Total input power $P_i=\dfrac{100}{\eta}\times\dfrac{mgh}{t}$

§§ Applications of power :

1) if a machine gun fires 'n' bullets per second such that mass of each bullet is 'm' and comming out with a velocity 'v' then the power of the machine gun is

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

(where N bullets are fired in time 't' then n = N/t)

$P_{av} = \frac{1}{2} mnV^2$

(power of heart=pressure x volume of blood pumped per second)

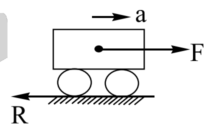
2) A conveyor belt moves horizontally with a constant speed 'v' Gravel is falling on it at a rate of 'dm/dt' then,

a) Extra force required to drive the belt is $F = \frac{dm}{dt} \cdot v$

b) Extra power required to drive the belt is

$P = FV = \left(\frac{dm}{dt}.V\right)V \qquad P = \frac{dm}{dt} \cdot v^2$

3) A car of mass 'm' is moving on a horizontal road with constant accelerction 'a'. If R is the resistantce offered to its motion, then the instaneous power of the engine when its velocity is 'v'



Net force on the car is F – R = ma

driving force of the engine is F = R + ma

Instantaneous power P = F. V

$P = (R + ma)V$

4) The car moves on a rough horizontal road with a constant speed 'V' then the instaneous power of engine is

P = F.V (V constant)

But F = f

P = fV (Here f = frictional force on rough horizontal surface) P = μ mg. V

5) A body of mass 'm' is initially at rest. By the application of constant force its velocity changes to "V_0" in time ' t_o' then

$v = u + at$

$v_0 = at_0$

acceleration of the body is $a = \frac{v_0}{t_0}$

a) Find instantaneous power at an instant of time 't' is

P = F.V = (ma) (at) = m a^2 t

$P_{inst} = m\left(\frac{v_0}{t_0}\right)^2 t \quad \left[\because a = \frac{v_0}{t_0}\right]$

b) Average power during the time 't' is

$P_{av} = \frac{1}{2}.p_{inst}$; $P_{av} = \frac{1}{2}m\left(\frac{v_0}{t_0}\right)^2 t$

6) A motor pump is used to deliver water at a certain rate from a given pipe. To obtain 'n' times water from the same pipe in the same time by what amout (a) force and (b) power of the motor should be increased.

If a liquid of density 'ρ' is flowing through a pipe of cross section 'A' at speed 'V', the mass comming out per second will be

$$\frac{dm}{dt} = AV\rho$$

To set 'n' times water in the same time

$$\left(\frac{dm}{dt}\right)^1 = n\left(\frac{dm}{dt}\right)$$

$A^{|}V^{|}\rho^{|} = n(AV\rho)$

As the pipe and liquid are same $\rho^{|} = \rho$ $A^{|}=A$, $V^{|} = nV$

a) Now as F = $V \cdot \frac{dm}{dt}$

$$\frac{F^{|}}{F} = \frac{V^{|}.\left(\frac{dm}{dt}\right)^{|}}{V.\frac{dm}{dt}} = \frac{(nV)\left(n.\frac{dm}{dt}\right)}{V\left(\frac{dm}{dt}\right)} = n^2$$

$\therefore$ $\boxed{F^1 = n^2.F}$

b) and as P = F.V

$$\frac{P^{|}}{P} = \frac{F^{|}V^{|}}{FV} = \frac{(n^2F)(nV)}{FV} = n^3 \quad \therefore \boxed{P^1 = n^3.P}$$

To get 'n' time of water. force must be increased n^2 times while power n^3 times

EXAMPLE

Problem :1

An electric pump on the ground floor of a building taken 15 minutes to fill a tank of volume $30m^3$ with water. If the tank is 40m above the ground and the efficiency of the pump is 30%, find the electric power consumed by the pump in filling the tank. [density of water = 10^3 kg/m^3

Sol: mass of the water to be filled =

(volume of the tank) × density of water

m = 30 × 10^3kg h = 40m, t=15 × 60 =900sec.

Efficiency η =30%

Inputpower $P_i = \frac{100}{\eta} \times \frac{mgh}{t}$

$$= \frac{100 \times 30 \times 10^3 \times 9.8 \times 40}{30 \times 900}$$

= 43.56KW

Problem :2

Sand drops from a stationary hopper at the rate of 5 kgs^{-1} onto a conveyor belt moving with a constant speed of 2 ms^{-1}. What is the force required to keep the belt moving and what is the power delivered by the motor moving the belt ?

Sol. Impulse $J = Ft = mv$, $F = \frac{mv}{t}$

$v = 2\ ms^{-1}; \frac{m}{t} = 5 kg s^{-1} \Rightarrow F = 10N$

Power $P = \frac{W}{t} = \frac{Fs}{t} = Fv = 10 \times 2 = 20$ watt.

Problem :3

An automobile is moving at 100 kmph and is exerting a tractive force of 3920 N. What horse power must the engine develop, if 20 % of the power developed is wasted?

Sol. $V = 100 kmph = 100 \times \frac{5}{8}$ m/s ; F = 3920 N

Wastage of power = 20%

Used power = 80%

Power $= \frac{W}{t} = \frac{Fs}{t}$, 80% P = FV

$\frac{80}{100} P = 3920 \times 100 \times \frac{5}{18}$

$\therefore P = \frac{100}{80} \times 3920 \times 100 \times \frac{5}{18} = 13.16 \times 10^4 = 182.5 Hp$

Problem :4

Calculate the power of an engine which can pull a mass of 500 metric ton up an incline rising 1 in 100 with a velocity of 10ms^{-1}.

Sol. $\sin\theta = \frac{1}{100}$. V= 10 m/s, m $= 500 \times 10^3$ kg

$F = mg\sin\theta = 500 \times 10^3 \times 9.8 \times \frac{1}{100}$

$= 49 \times 10^3$ N

Power P = FV

$= 49 \times 10^3 \times 10 = 49 \times 10^4$ watt = 490 KW

Problem :5

Find the power of an electric motor ; if it lifts 200 kg of water in 5 minutes from a well of 120 m depth.

Sol. Mass of water m = 200 kg

Depth of well $=$ height lifted $=$ 120 m

Time $t = 5 \times 60 \text{ sec} = 300 \text{ sec}$

Power $= \dfrac{\text{Work done against gravitational force}}{\text{time}}$

Power $= \dfrac{mgh}{t} = \dfrac{200 \times 9.8 \times 120}{5 \times 60} = 784\,\text{W}.$

Problem :6

A man carried a load of 50 kg through a height of 40 m in 25 s. If the power of the man is 1568 watt, find his mass.

Sol. Mass of the man = m

Total mass lifted = (M + 50) kg

Power P = 1568 watt

$h = 40\,\text{m},\ t = 25\ \text{s}$

Power $P = \dfrac{mgh}{t}$

$1586 = \dfrac{(M + 50) \times 9.8 \times 40}{25}$

$M + 50 = \dfrac{1586 \times 25}{9.8 \times 40} = 100$

Mass of the man = 50 kg

Problem :7

The power of the motor placed near a waterpond is 3 kW. Find how much of water can be lifted to a height of 10 m in one minute. (g = 10ms^{-2}).

Sol. $P = 3\ \text{kW} = 3 \times 10^3$ watt, h = 10 m, t = 60 sec.

Power $= \dfrac{mgh}{t}$

$3 \times 10^3 = \dfrac{m \times 10 \times 10}{60}$

$\therefore\ m = \dfrac{3 \times 10^3 \times 60}{100}$ =1800kg

Problem :8

A machine gun fires 240 bullets per minute with certain velocity . If the mass of each bullet is 10^{-2} kg and the power of the gun is 7.2 kW, find the velocity with which each bullet is fired.

Sol. Mass of each bullet $m = 10^{-2}$ kg

Power $= 7.2 \text{ kW} = 7.2 \times 10^3 \text{ W}$

$\frac{n}{t} = 240$ bullets / min $= \frac{240}{60}$ bullets / sec.

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

$= 7.2 \times 10^3 = \frac{240 \times \frac{1}{2} \times 10^{-2} \times v^2}{60}$

$v^2 = \frac{7.2 \times 10^3 \times 2}{4 \times 10^{-2}} = \frac{7.2}{2} \times 10^5 = 3.6 \times 10^5$

$v = 600$ m/s

Problem :9

An engine of power 1.5 MW applies a force for 6 minutes on a train moving with a velocity of 10 ms^{-1}. If there is no friction and the velocity attained is 25 ms^{-1}, find the mass of the train.

Sol. P $= 1.5 \text{ MW} = 1.5 \times 10^6 \text{ W}$, t = 360sec.

u = 10 m/s, v = 25 m/s

Mass of the train = m

Power $= \frac{w}{t} = \frac{\frac{1}{2}mv^2 - \frac{1}{2}mu^2}{t}$

$1.5 \times 10^6 = \frac{\frac{1}{2}m[25^2 - 10^2]}{360}$ $m = \frac{1.5 \times 10^6 \times 2 \times 360}{625 - 100}$

m $= 2.05 \times 10^6$ kg

TEACHING TASK

POWER

1. A boy whose weight is 600 N runs up a flight of stairs 10 m high in a time of 12 s. The average power he develops, in watts is

1) 72 2) 500 3) 720 4) 5000

2. It is said that the power of human heart is typically 10 W for a 70 kg adult. In one year time the total energy required expressed in kWh will be approximately

1) 10 kWh 2) 100 kWh 3) 1000 kWh 4) 1 kWh

3. A motor pump set of efficiency 80 %, lifts 800 litres of water in 19.6 seconds over a head of 20 m. Its input power is

1) 64 kW 2) 40 kW 3) 10 kW 4) 196 kW

4. A car weighing 1000 kg is going up an incline with a slope of 2 in 25 at a steady speed of 18 kmph. If g = 10 m s^{-2}, the power of its engine is
1) 4 kW 2) 50 kW 3) 625 kW 4) 25 kW

5. A crane can lift up 10,000 kg of coal in 1 hour from a mine of 180 m depth. If the efficiency of the crane is 80 %, its input power must be (g = 10 m s^{-2})
1) 5 kW 2) 6.25 kW 3) 50 kW 4) 62.5 kW

6. A machine gun fires 240 bullets per minute with a certain velocity. If the mass of each bullet is 10 gm and the power of the gun is 7.2 kW, the velocity with which each bullet is fired must be
1) 300 m/s 2) 600 m/s 3) 1200 m/s 4) 60 m/s

7. Two rifles fire the same number of bullets in a given interval of time. The second fires bullets of mass twice that fired by the first and with a velocity that is half that of the first. The ratio of their powers is
1) 1 : 4 2) 4 : 1 3) 1 : 2 4) 2 : 1

8. A tank on the roof of a 20 m high building can hold 10 m^3 of water. The tank is to be filled from a pond on the ground in 20 minutes. If the pump has an efficiency of 60 %, the input power required is
1) 1.1 kW 2) 2.74 kW 3) 5.48 kW 4) 7.0 kW

9. An electric fan, with effective area of cross-section ‘A’, accelerates air of density ‘d’ to a speed ‘v’. What is the power needed for this process?
1) d Av 2) ½ d Av 3) d Av^2 4) ½ d Av^3

10. A machine lifts a load of 2 tonnes wt with an effort of 100 kg wt. when the effort moves through 5 m the load moves through 0.2 m. The efficiency of the machine is
1) 20 % 2) 40 % 3) 80% 4) 0.8 %

11. The input power to an electric motor is 200 kW. Its efficiency is 80 %. It operates a crane of efficiency 90 %. If the crane is lifting a load of 3.6 tonnes, the velocity with which the load moves is
1) 8 m s^{-1} 2) 4 m s^{-1} 3) 2 m s^{-1} 4) 40 m s^{-1}

12. The human heart discharges 75 cm^3 of blood per beat against an average pressure of 10 cm of Hg. Assuming that the pulse frequency is 75 per minute, the power of the heart is
(density of Hg = 13.6 gm cm^{-3})
1) 1.25 W 2) 12.5 W 3) 0.125 W 4) 125 W

KEY

ΦΦ **TEACHING TASK :** 1)2, 2)2, 3)3, 4)1, 5)2, 6)2, 7)4, 8)2, 9)4, 10)3, 11)2, 12)1

LEARNER’S TASK

BEGINNERS (Level - I)

1. A man carries a load of 50 kg through a height of 40 m in 25 seconds. If the power of the man is 1568 W, his mass is
1) 5 kg 2) 1000 kg 3) 200 kg 4) 50 kg

2. An electric motor creates a tension of 4500 newton in a hoisting cable and reels it in at the rate of 2m/s. What is the power of the motor?
1) 15 kW 2) 9 kW 3) 225 W 4) 9000 kW

3. A motor drives a body along a straight line with a steady force. If the body moves with velocity ‘v’ the power P developed is

1) FV^2 2) FV 3) $\frac{F}{V}$ 4) $\frac{F}{V^2}$

4. A juggler throws continuously balls at the rate of three in each second each with a velocity of 10 m s^{-1}. If the mass of each ball is 0.05 kg his power is
1) 2 W 2) 50 W 3) 0.5 W 4) 7.5 W

5. A pump delivers water at the rate of 2400 litres in six minutes over a head of 12 m. If g = 10 m/s^2, its power is
1) 200 W 2) 800 W 3) 240 W 4) 24 kW

6. A boy blowing a whistle sends in air at 2 gm/sec with a speed of 150 m/s. His lung power is
1) 2.25 W 2) 22.5 W 3) 225 W 4) 0.225 W

7. A pump lifts 500 litres of water from a well of depth 50 meter in 98 seconds. The power of the pump is
1) 9.8 kW 2) 10 kW 3) 5 kW 4) 2.5 kW

8. An electric motor in a crane while lifting a load produces a tension of 4000 N in the cable attached to the load. If the motor is winding the cable at the rate of 3 m s^{-1}, the power of the motor expressed in kilo watt units must be
1) 4 2) 3 3) 12 4) 6

9. A crane is powered by a motor delivering 20 kW. The crane is raising a load of 5 tonnes. If g = 10 m s^{-2}, the maximum speed with which the load can be lifted is
1) 40 m s^{-1} 2) 4 m s^{-1} 3) 0.04 m s^{-1} 4) 0.4 m s^{-1}

10. An electric motor operates with an efficiency of 90 %. A pump operated by the motor has an efficiency of 80 %. The overall efficiency of the system is
1) 85 % 2) 100 % 3) 72 % 4) 60 %

11. A machine gun fires 420 bullets per minute. The velocity of each of the bullets is 300 m s^{-1} and the mass of each bullet is 1 gm. The power of machine gun is
1) 315W 2) 315000W 3) 630W 4) 3150 W

12. A machine gun of mass "M" fires "n" bullets each of mass "m" with a velocity "v" in a time "t". The power of the machine gun is
1) $mMnv^2/2\,t$ 2) $mnv^2/2t$ 3) $Mnv^2/2t$ 4) mnv/t

13. An engine lifts a load of 1200 N from a depth of 200 m in four minutes bringing it to the ground level. The power developed by the engine is
1) 500 W 2) 5,000 W 3) 10,000 W 4) 1000 W

14. A 1 kg mass at rest is subjected to an acceleration of 5 m/s^2 and travels 40 m. The average power during the motion is
1) 40 W 2)) 8 W 3) 50 W 4) 200 W

15. If the power of the motor of a water pump is 3 kW, then the volume of water that can be lifted to a height of 10m in one minute by the pump is (g = 10 m s^{-2})
1) 1800 liters 2) 180 liters 3) 18,000 liters 4) 18 liters

16. A machine gun fires 180 bullets per minute with a velocity of 300 m s^{-1}. If the mass of each bullet is 10 gm, the power of the machine gun will be
1) 1.35 kW 2) 0.675 kW 3) 5.4 kW 4) 2.7 kW

17. A particle moves with a velocity $\left(5\hat{i}+3\hat{j}+6\hat{k}\right)m/s$ under the influence of a constant force $(10\hat{i}+10\hat{j}+20\hat{k})$ N. The instantaneous power applied to the particle is
1) 200 W 2) 40 W 3) 140 W 4) 170 W

18. The power of a crane is 6.25 kW. How much mass of coal it can lift in 1 hour from a mine of 100 m depth? The efficiency of the crane is 80%and g = 10 m s^{-2}.
1) 1800 kg 2) 18,000 kg 3) 180 kg 4) 1,80,000 kg

ACHIEVERS (Level - II)

Solve the following

1. An electric pump takes 30 minutes to fill a tank of volume 30 m^3 with water. If the height over which the water is lifted be 30 m, and the efficiency of the pump is 50 %, the input electric power required by the pump is

2. An engine pumps a liquid of density 'd' continuously through a pipe of area of cross-section 'A'. If the speed of the liquid through the pipe is 'v', then the average power of the engine is

3. A motor is used to lift water from a well 60m below to fill a tank $4m \times 5m \times 10m$ in 50 minutes. Power of the motor is

4. A man carries a load of 50Kg through a height of 40m in 25s. If the power of the man is 1568 W, mass of the man is

5. The input power to an electric motor is 200 kW. Its efficiency is 80%. It operates a crane of efficiency 90 %. If the crane is lifting a load of 3.6 tonnes, the velocity with which the load moves is (in m/s)

6. When K.E. of a body is increases by 300%. The momentum of the body is increases by

7. A bullet loses 1/10 of its velocity after penetrating a plank. How many planks in a row are required to stop the bullet?

8. A helicopter starts from the ground and reaches a height of 500 m, meanwhile attaining a velocity of 50 m/s. The energy spent by its engine for taking it to the height is E_1 and the energy spent by its engine to impart the velocity is E_2, then the ratio $E_1 : E_2$ is

9. A body of mass 2 kg, initially at rest, is acted upon simultaneously by two forces, one of 4 N and the other of 3 N, acting at right angles to each other. The kinetic energy of the body after 20 s is

10. A body is projected freely vertically upward with a velocity of 50m/s. The percentage of its initial kinetic energy converted into potential energy after 4s is (g = 10m/s^2)

EXPLORERS (Level - III)

More than one correct option questions

♦ *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which* ***ONE or MORE*** *is correct. Choose the correct options*

1. Which of the following are correct?

a)1 horse power = 746 W b)1 horse power = 546 W

c)1 horse power =550 foot - pounds/sec d)1 horse power =500 foot - pound/s

A) a,b are corect B) a,c are correct C) b,d are correct D)c,d are correct

2. Ramu, having his own mass 50 kg, climbs 20 m height along with 30 kg mass in 40s(take g = 10m/s^2)

a) power delivered by him is 400W b) work done by him is 16000J

c) power delivered by him is 300W d) work done by him is 12000J

A) a,b are corect B) a,c are correct C) b,d are correct D)c,d are correct

Assertion - A and Reason - R:

♦ *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which* ***ONLY ONE*** *is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.

B) Both A and R are true and R is not correct explanation of A.

C) A is true but R is false. D) A is false but R is true

3. **A:**P.E of a freely falling body from a certain height is equal to K.E of it on touching the ground.

R:Energy neigher be created nor be distroyed.

4. **A:** If $\vec{F}$ =(i+j+k)N is the force acting on a body and $\vec{V}$ =(i-j+k)m/s is its velocity at an instant, instantaneous power is eual to 1W

R: $P = \vec{F}.\vec{V}$

Match the following

♦ *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in **Column–I** have to be matched with statements (p, q, r, s) in **Column–II**. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

5.

List - I	**List - II**
a) Work	1) ML^2T^{-2}
b) Linear momentum	2) MLT^{-1}
c) Power	3) ML^2T^{-3}
d) Efficiency of motor	4) $M^0L^0T^0$

A) a-1,b-2,c-3,d-4 B) a-1,b-2,c-4,d-3 C) a-4,b-3,c-2,d-1 D) a-4,b-2,c-1,d-3

Comprehension type questions

♦ *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which **ONLY ONE i**s correct. Choose the correct option.*

6. A stone projected vertically upwards from the ground reaches a maximum height h. When it is at a height $\frac{3h}{4}$,

i)The potential energy is

A) $\frac{3}{4}mgh$ B) $\frac{1}{4}mgh$ C)mgh D) $\frac{1}{2}mgh$

ii) The kinetic energy is

A) $\frac{3}{4}mgh$ B) $\frac{1}{4}mgh$ C)mgh D) $\frac{1}{2}mgh$

iii)the ratio of its kinetic and potential energies is

A) 1:4 B)3:4 C)1:3 D)3:1

7. A motor pump is used to delivery water at certain rate from a given pipe. To obtain 'n' time water from the same pipe in the same time

i) by what amount force of the motor should be increased

A) n times B) n^2 times C) n^3 times D) n^4 times

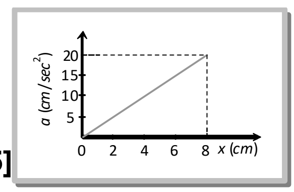
ii) by what amount power of the motor should be increased

A) n times B) n^2 times C) n^3 times D) n^4 times

RESEARCHERS(Level - IV)

I. Single correct answer type

1. A 10 kg mass moves along x-axis. Its acceleration as a function of its position is shown in the figure. What is the total work done on the mass by the force as the mass moves from $x = 0$ to $x = 8$ cm **[AMU (Med.) 2015]**



A) $8 \times 10^{-2}\ J$ B) $16 \times 10^{-2}\ J$ C) $4 \times 10^{-4}\ J$ D) $1.6 \times 10^{-3}\ J$

2. A uniform chain of length L and mass M is lying on a smooth table and one third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, the work required to pull the hanging part on to the table is **[IIT-JEE 1985; MNR 1990; MP PMT 1994, 97, 2000; JIMPER 2000; AIEEE 2002]**

A) MgL B) $\frac{MgL}{3}$ C) $\frac{MgL}{9}$ D) $\frac{MgL}{18}$

3. A particle of mass 'm' and charge 'q' is accelerated through a potential difference of 'V' volt. Its energy is **[UPSEAT 2016]**

A)qV B)mqV C)qV/m D) q/mV

4. A running man has half the kinetic energy of that of a boy of half of his mass. The man speeds up by 1 m/s so as to have same K.E. as that of boy. The original speed of the man will be **[Pb. PMT 2017]**

A) $\sqrt{2}\, m/s$ B) $(\sqrt{2}-1) m/s$ C) $\frac{1}{(\sqrt{2}-1)} m/s$ D) $\frac{1}{\sqrt{2}} m/s$

5. A body of mass 10 kg at rest is acted upon simultaneously by two forces 4N and 3N at right angles to each other. The kinetic energy of the body at the end of 10 sec is **[(Engg.) 2018]**

A)100 J B) 300 J C) 50 J D) 125 J

6. If the momentum of a body increases by 0.01%, its kinetic energy will increase by

A)0.01% B)0.02 % C) 0.04 % D) 0.08 % **[MP PET 2001]**

7. If the momentum of a body is increased by 100 %, then the percentage increase in the kinetic energy is **[NCERT1990; BHU 1999; Pb.PMT 1999; CPMT 1999, 2000]**

A) 150 % B)200 % C)225 % D) 300 %

8. A bread gives a boy of mass 40kg an energy of 21kJ. If the efficiency is 28% then the height can be climbed by him using this energy is **[AFMC 1997]**

A) 22.5 m B) 15 m C)10 m D)5 m

9. A force (3i + 4j) newton acts on a body and displaced it by (3i + 4j) meter. The work done by this force is ... **[AIIMS 2001]**

A)5 J B) 25 J C)10 J D)30 J

10. If a water falls from a dam into a turbine wheel 19.6 m below, then the velocity of water at the turbines is (take g=9.8 m/s2) **[AIIMS 2007]**

A) 9.8 m/s B) 19.6 m/s C)39.2 m/s D)98.0 m/s

11. A ball loses 15.0% of its kinetic energy when it bounces back from a concrete wall. With what speed you must throw it vertically down from a height of 12.4 m to have it bounce back to the same height (ignore resistance)? **[AIIMS 2010]**

A) 6.55 m/s B) 12.0 m/s C)8.6 m /s D)4.55 m/s

12. A car of mass 'm' is driven with acceleration 'a' along a straight level road against a constant external resistive force 'R'. When the velocity of the car is 'v', the rate at which the engine of the car is doing work will be **[MP PMT/PET 1998; JIMPER 2000]**

A)Rv B)mav C) $(R+ma)v$ D) $(ma-R)v$

13. A force applied by an engine of a train of mass $2.05 \times 10^6 kg$ changes its velocity from 5 m/s to 25 m/s in 5 minutes. The power of the engine is **[EAMCET 2001]**

A)1.025 MW B) 2.05 MW C) 5MW D) 5 MW

14. From a water fall, water is falling at the rate of 100 kg/s on the blades of turbine. If the height of the fall is 100m then the power delivered to the turbine is approximately equal to **[BHU 1997]**

A) 100kW B)10 kW C)1kW D) 1000 kW

II **Additionl problems for Problems**

Work

1. A force $\overline{F} = 2\hat{i} + 3\hat{j} - 4\hat{k}N$ acts on a particle which is constrained to move in the XOY plane along the line x = y. If the particle moves $5\sqrt{2}m$, the work done by force in joule is
1) $25\sqrt{2}$ 2) $5\sqrt{58}$ 3) 25 4) 10

2. A bullet of mass 10gm of fired horizontally with a velocity $1000ms^{-1}$ from a rifle situated at a height 50 m above the ground. If the bullet reaches the ground with a velocity $500ms^{-1}$, the work done against air resistance in the trajectory of the bullet is (in joules) $\left(g = 10ms^{-2}\right)$
1) 5005 2) 3755 3) 3750 4) 17.5

3. A 5.0 kg box rests on a horizontal surface. The coefficient of kinetic friction between the box and the surface is 0.5. A horizontal force pulls the box at constant velocity for 10 cm. The work done by the applied horizontal force and the frictional force are respectively (take g=10m/s^2)
1) 2.5 J and 2.5 J 2) zero and 2.5 J 3) 2.5 J and zero 4) 2.5 J and - 2.5J

4. A particle moves under the effect of a force F = C x from x = 0 to x = x_1. The work done in the process is (treat C as a constant)
1) C^2 / x_1^2 2) Cx_1^2 3) ½ Cx_1^2 4) ½ C^2/x_1^2

5. Two forces each of magnitude 10 N act simultaneously on a body with their directions inclined to each other at an angle of 120° and displaces the body over 10 m along the bisector of the angle between the two forces. Then the work done by each force is
1) 5 J 2) 1 J 3) 50 J 4) 100 J

6. A spring obeying the linear law F = - Kx is first compressed by 10 cm and the work done is W_1. Next it is compressed by another 10 cm, the work done now is W_2, then $W_1 : W_2$
1) 1 : 3 2) 3 : 1 3) 1 : 6 4) 6 : 1

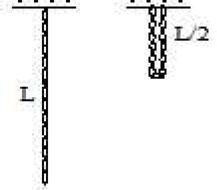
7. A body of mass 'm' starting from rest is acted on by a force producing a velocity $v = \sqrt{k \times s}$ where k is a constant and *s* is displacement. The work done by the force in the first 't' seconds is
1) $m^2 k^2 t^2 /8$ 2) $mk^2 t^2 / 4$ 3) $m k^2 t^2 /8$ 4) $m^2 k^2 t/$

8. A body freely falls from a certain height on to the ground in a time 't'. During the first one third of the interval it gains a kinetic energy ΔK_1 and during the last one third of the interval, it gains a kinetic energy ΔK_2. The ratio $\Delta K_1 : \Delta K_2$ is
1) 1 : 1 2) 1 : 3 3) 1 : 4 4) 1 : 5

9. A trolley of mass 60 kg moves on a smooth horizontal surface and has kinetic energy 120 J. A mass of 40 kg is lowered vertically on to the trolley. The total kinetic energy of the system after lowering the mass is
1) 60 J 2) 72 J 3) 120 J 4) 144 J

10. A chain of mass m and length 'L' is over hanging from the edge of a smooth horizontal table such that 3/4 th of its length is lying on the table. The work done in pulling the chain completely on to the table is
1) mgL/16 2) mgL/32 3) 3mgL/32 4) mgL/8

11. A uniform chain of length 'L' and mass 'm' is hanging down vertically from a hook fixed to the roof. The work done in hooking the other end of the chain as shown is

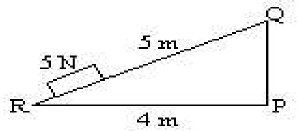


1) mgL
2) mgL/2
3) mgL/4
4) mgL/8

12. A solid rectangular block of mass 200 kg has the dimensions L = 2 m, b = 1 m, h = 0.5 m. It lies on a horizontal floor on sides L and b. The minimum work needed to turn it so that it lies on the sides b and h is

1) zero 2) 1500 J 3) 3000 J 4) 2000 J

13. A weight of 5 N is moved up a frictionless inclined plane from R to Q as shown. What is the work done in joules?



1) 15
2) 20
3) 25
4) 35

14. Under the action of a force a 2 kg body moves such that its position 'x' in meters as a function of time 't' in seconds given by: $x = t^2/2$. The work done by the force in the first 5 seconds is

1) 2.5 J 2) 0.25 J 3) 25 J 4) 250 J

15. 'n' identical cubes each of mass 'm' and edge 'L' are on a floor. If the cubes are to be arranged one over the other in a vertical stack, the work to be done is

1) Lmng (n-1)/2 2) Lg(n-1)/mn 3) (n-1)/Lmng 4) Lmng/2(n-1)

16. When a body of mass m slides down from the top of a smooth inclined plane of length L and inclination q, the work done by the gravitational force on the body is

1) mgL cosq 2) mgL sinq 3) mgL tanq 4) 2mgL sinq

17. A body of mass 5 kg at rest is under the action of a force which gives it a velocity given by v = 3×t m/s, here 't' is time in seconds. The work done by the force in two seconds will be

1) 90 J 2) 45 J 3) 180 J 4) 30 J

18. A body of mass 6 kg is subjected to a steady force, which causes some displacement in it. The equation of motion is given by:s(in meters) = $2\,t^2$, here 't' is time in seconds. The work done by the force in the first two seconds is

1) 192 J 2) 384 J 3) 96 J 4) 48 J

19. A tomato is thrown vertically upward from a point on the ground. As it rises to the highest point, the gravitational force does work of W_1 on it. As the tomato descends to the ground, the gravitational force does a work of W_2 on it. Regarding W_1 and W_2, which of the following is correct?

1) $W_1 = W_2$ 2) W_1 is positive, W_2 is negative
3) W_1 is negative, W_2 is positive 4) both W_1 and W_2 are negative

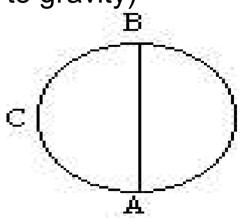
20. A bucket of mass 'm' tied to a light rope is lowered at a constant acceleration of 'g/4'. If the bucket is lowered by a distance 'd', the work done by the rope will be (neglect the mass of the rope)

1) $\frac{1}{4}mgd$ 2) $\frac{3}{4}mgd$ 3) $-\frac{3}{4}mgd$ 4) $-\frac{5}{4}mgd$

21. A body of mass 2 kg falls from a height of 20 m at a place where acceleration due to gravity is 10 m s^{-2}, and is found to acquire a velocity of 15 m s^{-1}. The work done against the air resistance is

1) 400 J 2) 225 J 3) 175 J 4) zero

22. A circular track of radius 'R' is in a vertical plane. AB is a vertical diameter. The work done in moving a mass of 'm' along the path ACB is (g = acceleration due to gravity)



1) πR mg
2) 2 mgR
3) zero
4) πR^2mg

23. A man has twice the mass of a boy and has half the kinetic energy of the boy. The ratio of the speeds of the man and the boy must be

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

24. Consider the following statements A and B and identify the correct answer given below:

(A) A body initially at rest is acted upon by a constant force. The rate of change of its kinetic energy varies linearly with time.

(B) When a body is at rest, it must be in equilibrium.

1) A and B are correct 2) A and B are wrong
3) A is correct and B is wrong 4) A is wrong and B is correct

25. The kinetic energy of a projectile at the highest point of its path is found to be 3/4th of its initial kinetic energy. If the body is projected from the ground, the angle of projection must be

1) 0° 2) 30° 3) 60° 4) 40°

26. The speed of a car changes from 0 to 5 m s^{-1} in the first phase and from 5 m s^{-1} to 10 m s^{-1} in the second phase and from 10 m s^{-1} to 15 m s^{-1} during the third phase. In which phase the increase in kinetic energy is more?

1) first phase 2) second phase
3) third phase 4) same in all the three phases

27. A body of mass 'm' has a kinetic energy equal to one-fourth kinetic of another body of mass $m/4$ .If the speed of the heavier body is increased by 4 m/s, its new kinetic energy equals the original kinetic energy of the lighter body. The original speed of the heavier body in m/s is

1) 8 2) 6 3) 4 4) 2

III <u>**Energy, Relation between KE and momentum**</u>

1. A body of mass 2kg is thrown up vertically with kinetic energy of 490J. If $g = 9.8 m/s^2$, the height at which the kinetic energy of the body becomes half of the original values, is

1) 50m 2) 25m 3) 12.5m 4) 19.6 m

2. A simple pendulum bob has a mass "m" and length "L". The bob is drawn aside such that the string is horizontal and then it is released. The velocity of the bob while it crosses the equilibrium position is

1) $\sqrt{gL}$ 2) $\sqrt{2gL}$ 3) $\sqrt{5gL}$ 4) $\sqrt{3gL}$

3. A 100 gm light bulb dropped from a tower reaches a velocity of 20 m/s after falling through 100 m. The energy transferred to the air due to viscous force is

1) 98 J 2) 20 J 3) 118 J 4) 78 J

4. A 2 kg block is dropped from a height of 0.4 m on to the top of a vertical helical spring whose force constant K is 1960 N m^{-1}. The spring then suffers a maximum compression of

1) 0.1 m 2) 0.01 m 3) 1 m 4) 1 × 10^{-3}

5. A body of mass 2 kg has a potential energy of 800 J when it is at a certain height.(g = 10 m/s^2). If it begins to fall, its velocity when its K.E. and P.E. are equal is

1) 4 m s^{-1} 2) 400 ms^{-1} 3)20 m s^{-1} 4)80 m s^{-1}

6. A spring is held between two blocks of masses "m_1" and "m_2" but not connected to them and then the blocks are moved towards each other so as to compress the spring. If the blocks are suddenly released, and if K_1 and K_2 are the kinetic energies of the blocks when the spring just gets detached from the blocks, then the ratio $K_1 : K_2$ must be

1) $m_1 : m_2$ 2) $m_2 : m_1$ 3) $m_1^2 : m_2^2$ 4) $m_2^2 : m_1^2$

7. A body of mass 10 kg projected vertically upward from the ground has potential energy 580 joules and kinetic energy 1380 joules at a certain point in its path. The velocity of projection of the body must be

1) 16.6 m s^{-1} 2) 19.8 m s^{-1} 3) 14 m s^{-1} 4) 10.8 m s^{-1}

8. A typical rain drop formed in a cloud at an altitude of 800 m reaches the earth's surface with a speed of 8 m/s. The ratio of the mechanical energy of the rain drop before and after the trip is

1) 500 : 1 2) 250 : 1 3) 125 : 1 4) 1000 : 1

9. A bomb of mass 'm' initially at rest, on the ground suddenly explodes in to two fragments. The fragment of mass '2m/3' moves out with a velocity 'v'. With the total energy released during the explosion, the unexploded bomb can be raised to what height above the ground?

1) $\frac{v^2}{2g}$ 2) $\frac{2v^2}{g}$ 3) $\frac{v^2}{g}$ 4) $\frac{v^2}{4g}$

10. When a body of mass 1.0 kg is suspended from a certain light spring hanging vertically, its length increases by 5 cm. By suspending 2.0 kg block to the spring and if the block is pulled through 10 cm and released, the maximum velocity in it in m/s is (Acceleration due to gravity = 10 m/s^2)

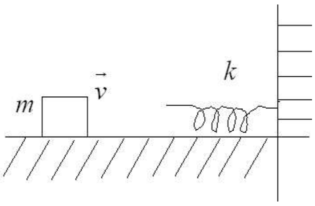
1) 0.5 2) 1 3) 2 4) 4

11. A river of salty water is flowing with a velocity $2m/\sec$. If the density of the water is , then the kinetic energy of each cubic metre of water is **(2008 E)**

1) $2.4J$ 2) $24J$ 3) $2.4KJ$ 4) $4.8KJ$

IV. **<u>Practice problems</u>**

1. A block of mass m = 25 kg on a smooth horizontal surface with a velocity $\vec{v} = 3ms^{-1}$ meets the spring of spring constant k=100N/m fixed at one end as shown in figure. The maximum compression of the spring and velocity of block as it returns to the original position respectively are **(2007 E)**



1) $1.5m, -3ms^{-1}$ 2) $1.5m, 0ms^{-1}$ 3) $1.0m, 3ms^{-1}$ 4) $0.5m, 2ms^{-1}$

2. A body is thrown vertically up with certain intial velocity, the potential and kinetic energies of the body are equal at a point P in its path. If the same body is thrown with double the velocity upwards, the ratio of potential and kinetic energies of the body when it crosses the same point, is **(2007 M)**

1) $1:1$ 2) $1:4$ 3) $1:7$ 4) $1:8$

3. A toy gun consists of a spring and a rubber dart of mass 25 gm. When the spring is compressed by 4 cm and the dart is fired vertically, it projects the dart to a height of 2 m. If the spring is compressed by 8 cm and the same dart is projected vertically, the dart will rise to a height of

1) 16 m 2) 8 m 3) 4 m 4) 2 m

4. An elastic spring is compressed between two blocks of masses 1 kg and 2 kg resting on a smooth horizontal table as shown. If the spring has 12 J of energy and suddenly released, the velocity with which the larger block of 2 kg moves will be

1) 2 m/s 2) 4 m/s 3) 1 m/s 4) 8 m/s

5. A block of mass 2 kg is on a smooth horizontal surface. A light spring of force constant 800 N/m has one end rigidly attached to a vertical wall and lying on that horizontal surface. Now the block is moved towards the wall compressing the spring over a distance of 5 cm and then suddenly released. By the time the spring regains its natural length and breaks contact with the block, the velocity acquired by the block will be

1) 200 m/s 2) 100 m/s 3) 2 m/s 4) 1 m/s

6. A helicopter starts from the ground and reaches a height of 500 m, meanwhile attaining a velocity of 50 m/s. The energy spent by its engine for taking it to the height is E_1 and the energy spent by its engine to impart the velocity is E_2, then the ratio $E_1 : E_2$ is

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

7. A 3-kg model rocket is launched straight up with sufficient initial speed to reach a maximum height of 100 m, even though air resistance (a non-conservative force) performs - 900 J of work on the rocket. The height the rocket would have gone without air resistance will be
1) 70 m 2) 130 m 3) 180 m 4) 230 m

8. Two identical blocks A and B, each of mass 'm' resting on smooth floor are connected by a light spring of natural length L and the spring constant K, with the spring at its natural length. A third identical block C (mass m) moving with a speed v along the line joining A and B collides with A. The maximum compression in the spring is:
1) $v\sqrt{\frac{m}{2k}}$ 2) $m\sqrt{\frac{v}{2k}}$ 3) $\sqrt{\frac{mv}{2k}}$ 4) $\frac{mv}{2k}$

V. PRACTICE QUESTIONS POWER

1. A motor is used to deliver water at a certain rate through a given horizontal pipe. To deliver n-times the water through the same pipe in the same time the power of the motor must be increased as follows. **(2006 E)**
1) *n*-times 2) n^2 - times 3) n^3 - times 4) n^4 - times

2. From a waterfall, water is pouring down at the rate of 160 kg per second on the blades of a turbine. If the height of the fall be 50 m, the power delivered to the turbine is approximately equal to
1) 7.84×10^4 W 2) 7.84×10^7 W 3) 8400 W 4) 784 kW

3. A motor pump-set of efficiency 80 % lifts 6000 litres of water per minute from a well 20 meters deep. If g = 10 m s^{-2}, its input power is
1) 20 kW 2) 25 kW 3) 16 kW 4) 250 kW

4. 50 kg of sand is deposited each second on to a conveyor belt moving at 5 m s^{-1}. The extra power required to maintain the belt in motion is
1) 1250 W 2) 250 W 3) 625 W 4) 2500 W

5. An engine lifts 2,250 litres of water per minute from a well 20 m deep. If 25 % energy of the engine is wasted, the power to be given to the engine must be
1) 29,400 W 2) 9,800 W 3) 7,350 W 4) 13,067 W

6. A body initially at rest has an acceleration of – 10 j m/s^2. If the force acting on the body is $\overline{F}$ = (2 i – 3 j + 5 k) N, the instantaneous power at t = 5 seconds will be
1) 100 W 2) 150 W 3) 50 W 4) 200 W

7. An electric pump takes 30 minutes to fill a tank of volume 30 m^3 with water. If the height over which the water is lifted be 30 m, and the
efficiency of the pump is 50 %, the input electric power required by the pump is
1) 100,000 W 2) 10,000 W 3) 1000 W 4) 100 W

8. An electric motor of power 300 W is used to drive the stirrer in a water bath. The work done in one minute, if 60 % of the energy of the motor is utilized to drive the stirrer will be
1)10,800J 2) 1080J 3)1,08,000J 4)108 J

9. An engine pumps a liquid of density 'd' continuously through a pipe of area of cross-section 'A'. If the speed of the liquid through the pipe is 'v', then the power of the engine is
1) Adv^3/2 2) ½ Adv 3) Adv^2/2 4) Adv^2

10. An electric pump draws water from a well of depth 50 m at a rate of 2 m^3 per second. The water is ejected from the pump with velocity *v* = 10 m s^{-1}. If the efficiency of the pump η = 80%, the input power consumption of the pump is (*g* = 10 m s^{-2})
1) 1100 kW 2) 880 kW 3) 1375 kW 4) 1080 kW

11. The velocity of a train is increased from 10m s^{-1} to 25 m s^{-1} in 2 minutes due to the application of some force by its engine developing an average power of 525 kW. Neglecting frictional forces, the mass of the train must be
1) 2.4×10^4 kg 2) 2.4×10^5 kg 3) 2.4×10^6 kg 4) 2.4×10^3 kg

KEY

ΦΦ LEARNER'STASK :

- **BEGINNERS :** 1) 4, 2) 2, 3) 2, 4) 4, 5) 2, 6) 2, 7) 4, 8) 3, 9) 4, 10) 3, 11) 1, 12) 2, 13) 4, 14) 3, 15) 1, 16) 1, 17) 1, 18) 2
- **ACHIEVERS :**
  1)10,000W , 2) Adv3/2, 3) 39.4kW, 4) 50Kg, 5) 8.944 6)200%, 7)6, 8)4:1, 42500J 9)96%
- **EXPLORERS :** 1) B, 2) A, 3) A, 4) A, 5) A, 6) i) A, ii) B, iii) C, 7) i)B, ii) C
- **RESEARCHERS:**

I: 1) A, 2) D, 3) A, 4) C, 5) D, 6) D, 7) D, 8) B, 9) B, 10) B, 11) A, 12) C, 13) B, 14) A.

II: 1) 3 , 2) 2 , 3) 4 , 4) 3 , 5) 3 , 6) 1, 7) 3 , 8) 4 , 9) 2 , 10) 2 , 11) 3 , 12) 2, 13) 1 , 14) 3 , 15) 1 , 16) 2 , 17) 1, 18) 1, 19) 3 , 20) 3 , 21) 3 , 22) 2, 23) 4 , 24) 3, 25) 2, 26) 3, 27) 3

III: 1) 3 2) 3 3) 4 4) 1 5) 3 6) 2 7) 2 8) 2 9) 3 10) 2 11) 3

IV: 1) 1 2) 3 3) 2 4) 1 5) 4 6) 2 7) 2 8) 1

V: 1) 3 2) 1 3) 2 4) 1 5) 2 6) 2 7) 2 8) 1 9) 1 10) 3 11) 2

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