CLASS – 11

WORKSHEET- WORK, ENERGY, POWER

A. WORK

(1 Mark Questions)

1. An artificial satellite is at a height of 36,500km above earth's surface. What is the work done by earth's gravitational force in keeping it in its orbit?

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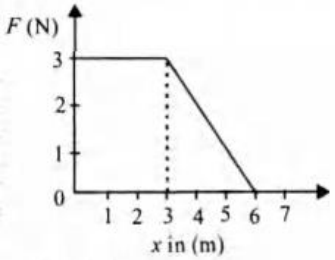
2. A body is being raised to a height h from the surface of earth. What is the sign of work done by (i) applied force (ii) gravitational force?
(a) Positive, positive (b) Positive, Negative (c) Negative, Positive (d) Negative, negative

3. A weightlifter lifts a weight off the ground and holds it up
(a) work is done in lifting as well as holding the weight.
(b) no work is done in both lifting and holding the weight.
(c) work is done in lifting the weight but no work is required to be done in holding it up.
(d) no work is done in lifting the weight by work is required to be done in holding it up.

4. A force F acting on an object varies with distance x as shown in the figure. The work done by the force is moving the object from x = 0 to x = 20m is



(a) 500J (b) 1000J (c) 1500J (d) 2000J

5. The sign of work done by a force on a body is important to understand. State carefully if the following quantities are positive or negative: (1 mark each)
(a) Work done by a man in lifting a bucket out of a well by means of a rope tied to the bucket,
(b) Work done by gravitational force in the above case,
(c) Work done by friction on a body sliding down an inclined plane,
(d) Work done by an applied force on a body moving on a rough horizontal plane with uniform velocity,
(e) Work done by the resistive force of air on a vibrating pendulum in bringing it to rest.

6. A bicyclist comes to a skidding stop in 10 m. During this process, the force on the bicycle due to the road is 200N and is directly opposed to the motion. The work done by the cycle on the road is
(a) + 2000J (b) – 200J (c) zero (d) – 20,000J

7. A body is being raised to a height h from the surface of earth. What is the sign of work done by (a) applied force (b) gravitational force?

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(2 Marks Questions)

8. A force $\vec{F} = \hat{i} + 5\hat{j} + 7\hat{k}$ acts on a particle and displaces it through $\vec{s} = 6\hat{i} + 9\hat{k}$. Calculate the work done if the force is in newton and displacement in metre. [Ans. 69J]

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9. Calculate the work done in lifting a 300N weight to a height of 10m with an acceleration 0.5 ms^{-2}. Take g = 10 ms^{-2}. [Ans. 3150J]

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10. If a force $\vec{F} = (-2\hat{i} + 3\hat{j} + \hat{k})$, causes a displacement $\vec{S} = (\hat{i} + 2\hat{j} - 4\hat{k})$, of an object, what will be the work done on the object?

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11. Find the work done if a particle moves from position $\vec{r_1} = (4\hat{i} + 3\hat{j} + 6\hat{k})m$ to a position $\vec{r_2} = (14\hat{i} + 13\hat{j} + 16\hat{k})m$ under the effect of force $\vec{F} = (4\hat{i} + 4\hat{j} - 4\hat{k})N$?

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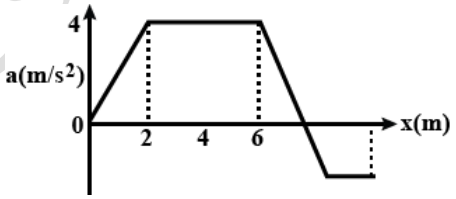
(3 Marks Questions)

12. A am weighing 50 kg f supports a body of 25 kg f on his head. What is the work done when he moves a distance of 20m up in an incline of 1 in 10? Take g = 9.8 ms^{-2}.

[Ans. 1470J]

13. While catching a cricket ball of mass 200g moving with a velocity of 20m/s, the player draws his hands backwards through 20cm. Find the work done in catching the ball and the average force exerted by the ball on the hand. [Ans. 40J, 200N]

14. Figure gives the acceleration of a 2.0kg body as it moves from rest along x-axis while a valuable force acts on it from x = 0m to x = 9m. Find the work done by the force on the body when it reaches (i) x = 4m and (ii) x = 7m.



15. A bullet of mass 0.012kg and horizontal speed 70 m/s strikes a block of wood of mass 0.4kg and instantly comes to rest with respect to the block. The block is suspended from

the ceiling by means of thin wires. Calculate the height to which the block rises. Also, estimate the amount of heat produced in the block.

16. A body constrained to move along the z-axis of a coordinate system is subject to a constant force F given by

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

where $\hat{i}, \hat{j}$ and $\hat{k}$ are unit vectors along the x- y- and z-axis of the system respectively. What is the work done by this force in moving the body a distance of 4 m along the z-axis? [Ans. 12J]

(5 Marks Questions)

17. A body of mass 2 kg initially at rest moves under the action of an applied horizontal force of 7 N on a table with coefficient of kinetic friction = 0.1. Compute the
(a) Work done by the applied force in 10 s
(b) Work done by friction in 10 s
(c) Work done by the net force on the body in 10 s
(d) Change in kinetic energy of the body in 10 s and interpret your results.
[Ans. 882 J, - 246.9J, 635J, 635J]

B. POWER

(1 Mark Questions)

1. Define power and its SI unit.

2. How many watts are there in one horse power?

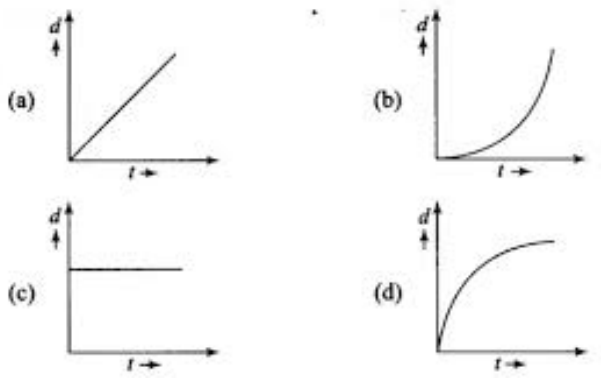
3. The power of a water pump is 2kW. If g = 10 ms^{-2}, the amount of water it can raise in one minute to a height of 10m is
(a) 2000 litre (b) 1000 litre (c) 100 litre (d) 1200 litre

4. Water is flowing in a river at 2m/s. The river is 50m wide and has an average depth of 5m. The power available from the current in the river is (density of water = 1000 kg m^{-2})
(a) 0.5 MW (b) 1 MW (c) 1.5 MW (d) 2 MW

5. A body is initially at rest. It undergoes a one-dimensional motion with constant acceleration. The power delivered to it at time t is proportional to
(i) $t^{1/2}$ (ii) t (iii) $t^{3/2}$ (iv) t^2

6. A body is moving unidirectionally under the influence of a source of constant power. Its displacement in time t is proportional to
(i) $t^{1/2}$ (ii) t (iii) $t^{3/2}$ (iv) t^2

7. A body is moving unidirectionally under the influence of a source of constant power supplying energy. Which of the diagrams shown in Fig. 6.5 correctly shows the displacement-time curve for its motion?



8. Calculate the power of a crane in watts, which lifts a mass of 100 kg to a height of 10 m in 20s.

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(2 Marks Questions)

9. A man weighs 60 kg climbs up a staircase carrying a load of 20kg on his head. The stair case has 20 steps each of height 0.2m. If he takes 10s to climb, find his power.
[Ans. 313.6W]

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(3 Marks Questions)

10. The human heart discharges 75ml of blood at each beat against a pressure of 0.1m of Hg. Calculate power of heart assuming that pulse frequency is 80 beats per minute. Density of Hg = 13.6×10^{3} kgm^{-3}. [Ans. 1.33W]

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11. A man cycles up a hill, whose slope is 1m in 20 with it velocity of 6.4 kmh^{-1}. The weight of man and the cycle is 98kg. What work per minute is he doing? What is his horse power? [Ans, 0.144 hp, 5122.1J]

12. The turbine pits at the Niagra falls are 50m deep. The average horse power developed is 5000. If the efficiency of the generator is 85%, how much water passes through the turbines per minute? Take g = 10 ms^{-2}.

13. A pump on the ground floor of a building can pump up water to fill a tank of volume 30 m^3 in 15 min. If the tank is 40 m above the ground, and the efficiency of the pump is 30%, how much electric power is consumed by the pump? [Ans. 43.6 kW]

14. A family uses 8 kW of power, (a) Direct solar energy is incident on the horizontal surface at an average rate of 200 W per square meter. If 20% of this energy can be converted to useful electrical energy, how large an area is needed to supply 8 kW? (b) Compare this area to that of the roof of a typical house. [Ans. 200 m^2 , 21:21]

C. KINETIC ENERGY AND WORK ENERGY THEOREM

(1 Mark Questions)

1. Can a body have energy without momentum?

2. Can a body have momentum without energy?

3. A light body and a heavy body have the same momentum. Which one will have greater kinetic energy?

4. The work energy theorem states that the change in
(a) kinetic energy of a particle is equal to the work done on it by the net force.
(b) kinetic energy of a particle is equal to the work done by one of the forces acting on it.
(c) potential energy of a particle is equal to the work done on it by the net force.
(d) potential energy of a particle is equal to the work done by one of the forces acting on it.

5. How will the momentum of a body change if its kinetic energy is doubled?

6. A mass of 5 kg is moving along a circular path of radius 1 m. If the mass moves with 300 revolutions per minute, its kinetic energy would be
(a) $250\pi^2$ (b) $100\pi^2$ (c) $5\pi^2$ (d) 0

7. Give example of a situation in which an applied force does not result in a change in kinetic energy.

(2 Marks Questions)

8. Two bodies of masses m_1 and m_2 have the same linear momentum. What is the ratio of their kinetic energies?

9. A particle is projected making an angle of 45° with the horizontal having kinetic energy K. What is the kinetic energy of highest point?

10. A particle of mass 0.5 kg travels in a straight line with velocity $u = a x^{3/2}$, where $a = 5\ m^{-1/2}\ s^{-1}$. What is the work done by the net force during its displacement from x = 0 to x = 2 m? [Ans. 50J]

(3 Marks Questions)

11. Prove work-energy theorem.

12. A shot travelling at the rate of 100 ms^{-1} is just able to pierce a plank 4cm thick. What velocity is required to just pierce a plank 9cm thick? [Ans. 150m/s]

13. If the kinetic energy of a body increases by 300%, by what % will the linear momentum of the body increase? [Ans. 100%]

14. A molecule in a gas container hits a horizontal wall with speed 200 msA and angle 30° with the normal, and rebounds with the same speed. Is momentum conserved in the collision? Is the collision elastic or inelastic?

D. POTENTIAL ENERGY

(1 Mark Questions)

1. Give three examples of forces which are conservative in nature.

2. The potential energy of a system increases if work is done
   (a) upon the system by a non conservative force
   (b) by the system against a conservative force
   (c) by the system against a non-conservative force
   (d) upon the system by a conservative force

3. The negative of the work done by the conservative internal forces on a system equals to the change in
   (a) total energy (b) kinetic energy (c) potential energy (d) none of these

4. Two springs of spring constants 1000N m^{-1} and 2000N m^{-1} are stretched with same force. They will have potential energy in the ratio of
   (a) 2:1 (b) $2^2:1^2$ (c) 1:2 (d) $1^2:2^2$

(2 Marks Questions)

5. An elastic spring of force constant k is compressed by an amount x. Show that its potential energy is ½ kx^2.

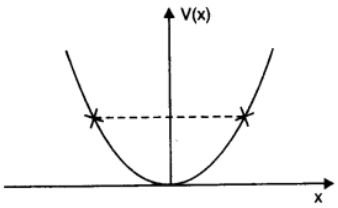
(3 Marks Questions)

6. Two springs have force constants k_1 and k_2 ($k_1 > k_2$). On which spring is more work done, if (i) they are stretched by the same factor and (ii) they are stretched by the same amount?

7. Define the term potential energy, and derive its dimensions. Write an expression for the gravitational potential energy of a body of mass m raised to a height h above the earth's surface.

8. If the elongation in a spring of force constant k is tripled, calculate
(a) ratio of final to initial force in the spring.
(b) ratio of elastic energies stored in the two cases
(c) work done in changing to the state of elongation.

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



E. CONSERVATION OF MECHANICAL ENERGY

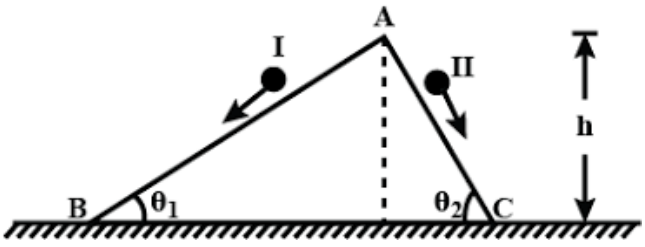
(1 Mark Questions)

1. A spark is produced, when two stones are struck against each other. Why?

2. Can kinetic energy be negative? What about potential energy?

3. A body is falling freely under the action of gravity alone in vacuum. Which of the following quantities remain constant during the fall?
   (a) Kinetic energy (b) Potential energy
   (c) Total mechanical energy (d) Total linear momentum

4. Two inclined frictionless tracks, one gradual and the other steep meet at A from where two stones are allowed to slide down from rest, one on each track as shown in Figure. Which of the following statement is correct?



(a) Both the stones reach the bottom at the same time but not with the same speed.
(b) Both the stones reach the bottom with the same speed and stone I reaches the bottom earlier than stone II.
(c) Both the stones reach the bottom with the same speed and stone II reaches the bottom earlier than stone I.
(d) Both the stones reach the bottom at different times and with different speeds.

5. Calculate the work done by a car against gravity in moving along a straight horizontal road. The mass of the car is 400 kg and the distance moved is 2m.

(2 Marks Questions)

6. How high must a body be lifted to gain an amount of potential energy equal to the kinetic energy it has when moving at speed 20m/s? The value of acceleration due to gravity at a place is $g = 9.8\ m/s^2$. [Ans. 20.2m]

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7. Can there be a solution in which $E - U < 0$?

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8. Define work, power and energy and give their SI units.

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9. A ball is dropped vertically from rest at a height of 12m. After striking the ground it bounces at a height of 1m. What fraction of kinetic energy does it loose on striking the ground?

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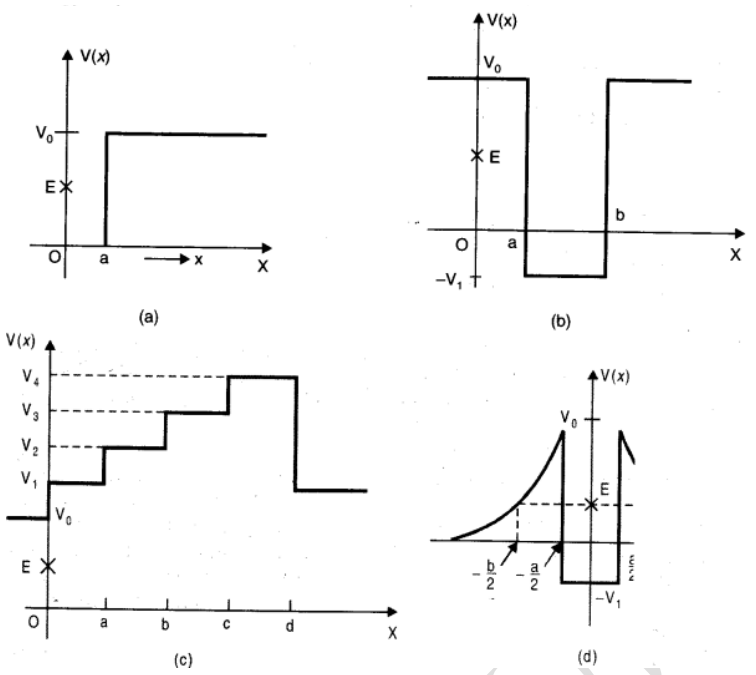
10. Given figures are examples of some potential energy functions in one dimension. The total energy of the particle is indicated by a cross on the ordinate axis. In each case, specify the regions, if any, in which the particle cannot be found for the given energy. Also, indicate the minimum total energy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

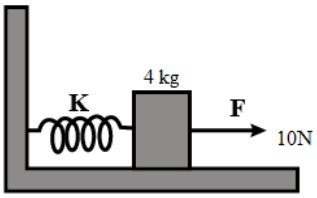


(3 Marks Questions)

11. A block of mass 2kg is dropped from a height of 40cm on a spring whose force-constant is 1960 Nm^{-1}. What will be the maximum distance x through which the spring is compressed?

12. Show that the total mechanical energy of a body falling freely under gravity is conserved. Discuss it graphically.

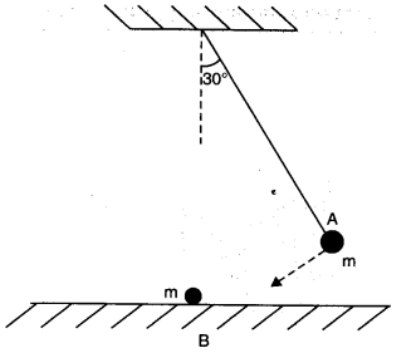
13. The spring shown in figure has a force constant 24 n/m. The mass of the block attached to the spring is 4kg. Initially the block is at rest and spring is unstretched. The horizontal force of 10N is applied on the block, then what is the speed of the block when it has been moved through a distance of 0.5m?



14. An electron and a proton are detected in a cosmic ray experiment, the first with kinetic energy 10 keV, and the second with 100 keV. Which is faster, the electron or the proton? Obtain the ratio of their speeds, (electron mass = 9.11 x 10^{-31} kg, proton mass = 1.67 x 10^{-27} kg, 1 eV= 1.60 x 10^{19}J). [Ans. 13.53]

15. A raindrop of radius 2 mm falls from a height of 500 m above the ground. It falls with decreasing acceleration (due to viscous resistance of the air) until at half its original height, it attains its maximum (terminal) speed, and moves with uniform speed thereafter. What is the work done by the gravitational force on the drop in the first and second half of its journey? What is the work done by the resistive force in the entire journey if its speed on reaching the ground is 10 ms^{-1}? [Ans. 0.1623 J]

16. The bob A of a pendulum released from 30° to the vertical hits another bob B of the same mass at rest on a table as shown in Fig. How high does the bob A rise after the collision? Neglect the size of the bobs and assume the collision to be elastic.



17. The bob of a pendulum is released from a horizontal position. If the length of the pendulum is 1.5 m, what is the speed with which the bob arrives at the lowermost point, given that it dissipated 5% of its initial energy against air resistance? [Ans. 5.3 m/s]

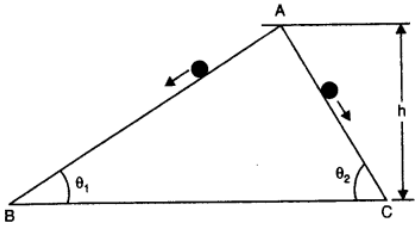
18. A trolley of mass 300 kg carrying a sandbag of 25 kg is moving uniformly with a speed of 27 km/h on a friction less track. After a while, sand starts leaking out of a hole on the trolley's floor at the rate of 0.05 kg s^{-1}. What is the speed of the trolley after the entire sand bag is empty?

19. A person trying to lose weight (dieter) lifts a 10 kg mass, one thousand times, to a height of 0.5 m each time. Assume that the potential energy lost each time she lowers the mass

is dissipated, (a) How much work does she do against the gravitational force? (b) Fat supplies 3.8 x 10^7J of energy per kilogram which is converted to mechanical energy with a 20% efficiency rate. How much fat will the dieter use up? [Ans. 49000J, 6.45×10^{-3}kg]

20. A bullet of mass 0.012 kg and horizontal speed 70 ms^{-1} strikes a block of wood of mass 0.4 kg and instantly comes to rest with respect to the block. The block is suspended from the ceiling by thin wire. Calculate the height to which the block rises. Also, estimate the amount of heat produced in the block. [Ans. 0.212m, 28.54J]

21. Two inclined frictionless tracks, one gradual and the other steep meet at A from where two stones are allowed to slide down from rest, one on each track (Fig). Will the stones reach the bottom at the same time? Will they reach there at the same speed? Explain. Given $\theta_1 = 30°$, $\theta_2 = 60°$, and h = 10 m, what are the speeds and times taken by the two stones?



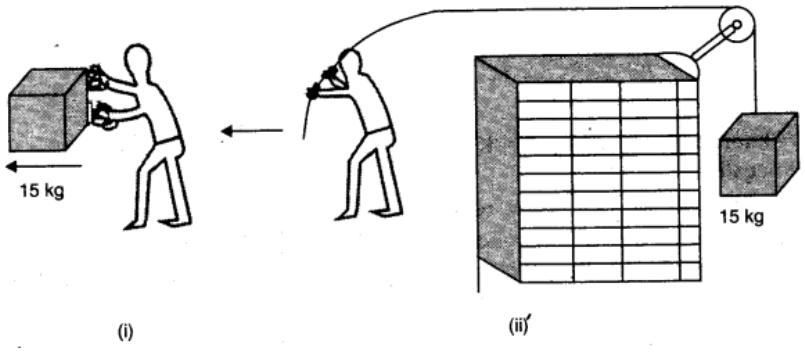
[Ans. 14.14 ms^{-1}]

22. A bolt of mass 0.3 kg falls from the ceiling of an elevator moving down with a uniform speed of 7 ms^{-1}. It hits the floor of the elevator (length of elevator = 3 m) and does not rebound. What is the heat produced by the impact? Would your answer be different if the elevator were stationary? [Ans. 8.82 J]

(5 Marks Questions)

23. State the law of conservation of mechanical energy. Show that the total mechanical energy of a body falling freely under gravity is conserved. Show it graphically.

24. Answer the following:
(a) The casing of a rocket in flight bums up due to friction. At whose expense is the heat energy required for burning obtained? The rocket or the atmosphere?
(b) Comets move around the sun in highly elliptical orbits. The gravitational force on the comet due to the sun is not normal to the comet's velocity in general. Yet the work done by the gravitational force over every complete orbit of the comet is zero. Why?
(c) An artificial satellite orbiting the earth in very thin atmosphere loses its energy gradually due to dissipation against atmospheric resistance, however small. Why then does its speed increase progressively as it comes closer and closer to the earth?
(d) In Fig.(i), the man walks 2 m carrying a mass of 15 kg on his hands. In Fig. (ii), he walks the same distance pulling the rope behind him. The rope goes over a pulley, and a mass of 15 kg hangs at its other end. In which case is the work done greater?



F. COLLISION

(1 Mark Questions)

1. What is the value of coefficient of restitution in (i) perfectly elastic collision and (ii) perfectly inelastic collision?

2. Point out the correct alternative:
(a) When a conservative force does positive work on a body, the potential energy of the body increases/decreases/remains unaltered.

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

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

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

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3. State if each of the following statements is true or false. Give reasons for your answer.
(a) In an elastic collision of two bodies, the momentum and energy of each body is conserved.

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

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

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

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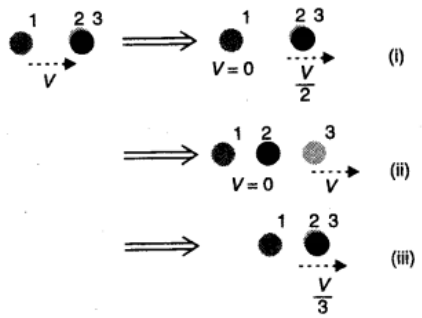
4. Two identical ball bearings in contact with each other and resting on a friction less table are hit head-on by another ball bearing of the same mass moving initially with a speed V. If the collision is elastic, which of the following (Fig.) is a possible result after collision?



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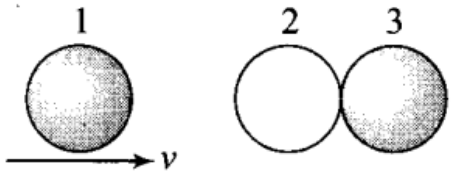

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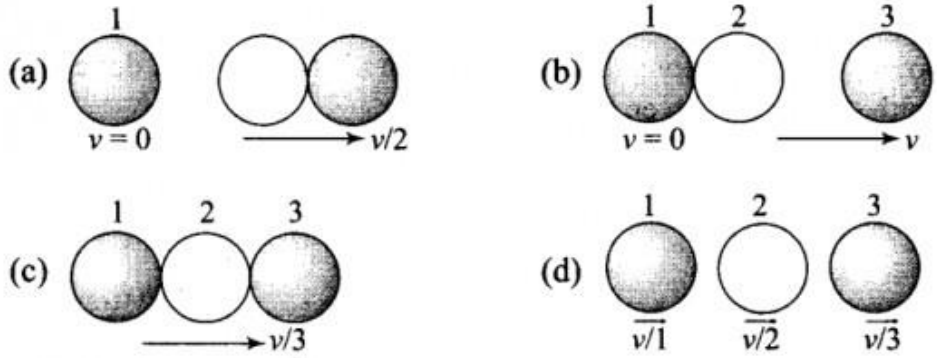

6. In an elastic collision of two billiard balls, which of the following quantities remain conserved during the short time of collision of the balls (i.e., when they are in contact). (a) Kinetic energy. (b) Total linear momentum? Give reason for your answer in each case.

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(3 Marks Questions)

7. A 10kg ball and 20kg ball approach each other with velocities 20 ms^{-1} and 10 ms^{-1} respectively. What are their velocities after collision if the collision is perfectly elastic?

[Ans. 20 ms^{-1}, 10ms^{-1}]

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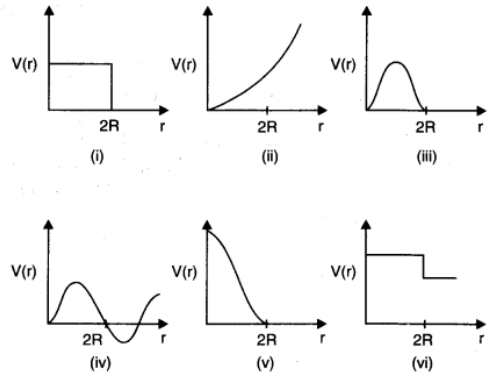
8. A ball of 0.1kg makes an elastic head on collision with a ball of unknown mass that is initially at rest. If the 0.1kg ball rebounds at one-third of its original speed, what is the mass of the other ball? [Ans. 0.2 kg]

9. What is the meaning of 'Collision' in physics? Differentiate between elastic and inelastic collision. Give one example each.

10. Show that in case of one dimensional elastic collision of two bodies, the relative velocity of separation after the collision is equal to the relative velocity of approach before the collision.

11. Prove that bodies of identical masses exchange their velocities after head on elastic collision.

12. Which of the following potential energy curves in Fig. cannot possibly describe the elastic collision of two billiard balls? Here r is distance between centres of the balls.



(5 Marks Questions)

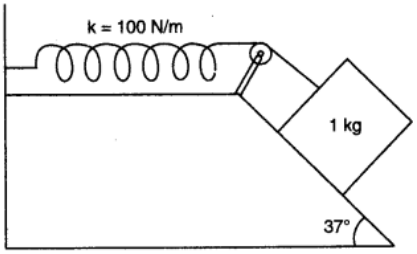
13. Define elastic collision and discuss it for two bodies in one dimension. Calculate the velocities of bodies after collision. Discuss special cases only.

14. A large mass 'M' moving with a velocity 'v' collides head on with a very small mass 'm' at rest. If the collision is elastic, obtain an expression for the energy lost by the large mass M (take $M + m \approx M$).

15. Answer carefully, with reasons:
(a) In an elastic collision of two billiard balls, is the total kinetic energy conserved during the short time of collision of the balls (i.e., when they are in contact)?
(b) Is the total linear momentum conserved during the short time of an elastic collision of two balls?
(c) What are the answers to (a) and (b) for an inelastic collision?
(d) If the potential energy of two billiard balls depends only on the separation distance between their centres, is the collision elastic or inelastic? (Note, we are talking here of potential energy corresponding to the force during collision, not gravitational potential energy).

G. CHALLENGING PROBLEMS

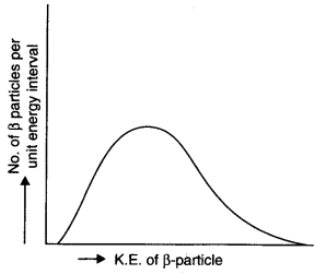
1. A 1 kg block situated on a rough incline is connected to a spring with spring constant 100 Nm^{-1} as shown in Figure. The block is released from rest with the spring in the unstretched position. The block moves 10 cm down the incline before coming to rest. Find the coefficient of friction between the block and the incline. Assume that the spring has negligible mass and the pulley is frictionless.



[Ans. 0.126]

2. A trolley of mass 200 kg moves with a uniform speed of 36 km h^{-1} on a friction less track. A child of mass 20 kg runs on the trolley from one end to the other (10 m away) with a speed of 4 ms^{-1} relative to the trolley in a direction opposite to the trolley's motion, and jumps out of the trolley. What is the final speed of the trolley? How much has the trolley moved from the time the child begins to run? [Ans. 10.36 ms^{-1}, 25.9m]

3. Consider the decay of a free neutron at rest: $n > p + e^{-}$. Show that the two body decay of this type must necessarily give an electron of fixed energy, and therefore, cannot account for the observed continuous energy distribution in the β -decay of a neutron or a nucleus, Fig.



4. The blades of a windmill sweep out a circle of area A. (a) If the wind flows at a velocity v perpendicular to the circle, what is the mass of the air passing through it in time t? (b) What is the kinetic energy of the air? (c) Assume that the windmill converts 25% of the wind's energy into electrical energy, and that A = 30 m^2, v = 36 km/h and the density of air is 1.2 kg m^{-3}. What is the electrical power produced?

[Ans. (a) ρAvt (b) $\frac{1}{8}\rho Av^3t$ (c) 4.5 kW]

SPACE FOR ROUGH WORK

SPACE FOR NOTES