PHYSICS

NCERT - NCERT PHYSICS(ENGLISH)

WORK, ENERGY AND POWER

Solved Example

1. Find the angle vetween force $\vec{F} = \left(3\hat{I} + 4\hat{j} - 5\hat{k}\right)$ and displacement

$\vec{d} = \left(5\hat{I} + 4\hat{j} + 3\hat{k}\right)$ unit. Also find the projection of $\vec{F}$ $along\vec{d}$.

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2. It is well known that a rain drop falls under the influence of the downward gravitational force and the opposing resistive force. The latter is known to be proportional to the speed of the drop, but is otherwise undetermined. Consider a drop of mass 1.0g falling from a height of 1.00km. It hits the ground with a speed of $50.0ms^{-1}$ (a) What is the work done by the gravitational force ? (b) What is the work done by the unknown resistive force ?

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3. A cyclist comes to a skidding stop in $10m$. During this process, the force on the cycle due to the road is $200N$ and is directly opposite to the motion.

a. How much work does the road do on the cycle?

b. How much work does the cycle do on the road?

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4. In a ballistics demonstration, a police officer fires a bullet mass $50.0g$ with speed $200ms^{-1}$ on soft plywood of thickness 2.00cm. The bullet emerges only with 10% of its initial kinetic energy. What is the emergent speed of the bullet ?

5. A woman pushes a trunk on a railway platform which has a rough surface. She applies a force of 100N over a distance of 10m. Thereafter, she gets progressively tired and her applied force reduces linearly with distance to 50N. The total distance through which trunk has been moved is 20m. Plot the force applied by the woman and the frictional force, which is 50N against the distance.

Calculat the work done by the two forces over 20m.

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6. A block of mass $m = 1kg$ moving on a horizontal surface with speed $v_i = 2ms^{-1}$ enters a rough patch ranging from $x0.10m \rightarrow x = 2.01m$. The retarding force F_r on the block in this range ins inversely proportional to x over this range

$$F_r = -\frac{k}{x} for 0.1 < x < 2.01m$$

$= 0$ for $< 0.1m$ and $x > 2.01m$ where $k = 0.5J$. What is the final K.E. and speed v_f of the block as it crosses the patch?

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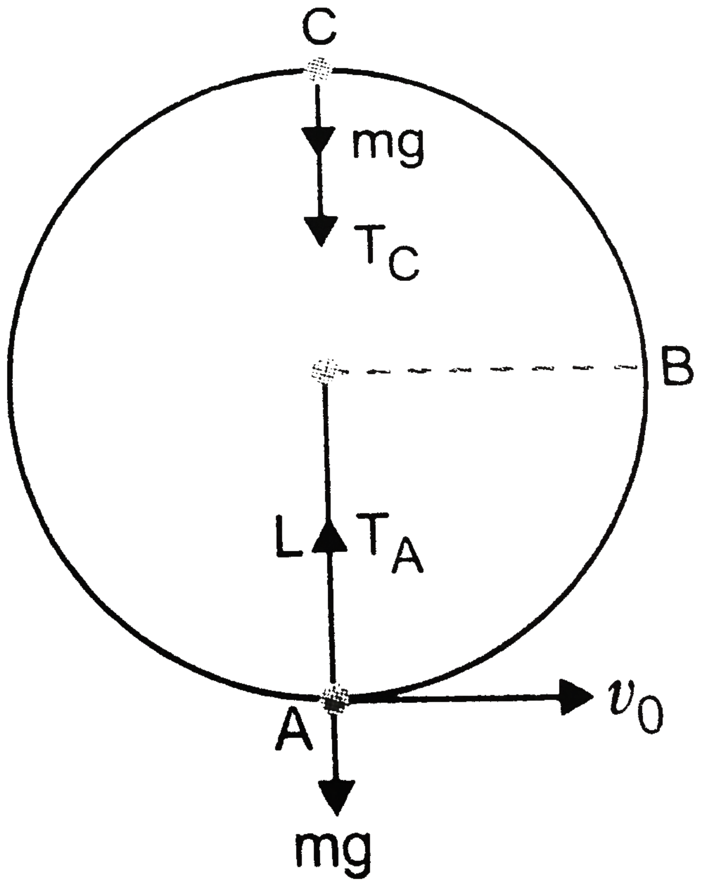
7. A bob of mass m is suspended by a light string of length L. It is imparted a horizontal velocity v_0 at the lowest point A such that it completes a semi-circular trajectory in the vertical plane with the string becoming slack on reaching the topmost point C, figure, Obtain an expression for (i) v_0 (ii) the speeds at points B and C, (ii) the ration of kinetic energies (K_B / K_C) at B and C.

Comment on the nature of the trajectory of the bob after it reahes the poing C.



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8. To stimulat car accidents, the auto manufacturers study the collisions of moving cars with mounted springs of different spring constants. Consider a typical simulation with a car of mass 1000kg moving with a speed of $18.0 km/h$ on a smooth road and colliding with a horizontally mounted spring of spring constant $6.25 \times 10^3 Nm^{-1}$. What is the maximum compression of the spring?

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9. Consider Example 8, taking the coefficient of friction, μ, to be 0.5 and calculate the maximm compression of the spring.

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10. Examine table.s and express a) The energy required to break one bond in DNA in eV, b) the kinetic energy of an air molecule $\left(10^{-2}\right.$ J in eV, c) The daily intake of a human adult in kilocalories.

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11. An elevator can carry a maximum load of $1800kg$ (elevator + passengers) is moving up with a constant speed of $2ms^{-1}$. The friction force opposite the motion is $4000N$.What is minimum power delivered by the motor to the elevator?

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12. In a nuclear reactor, a neutron of high speed $(\approx 10^7 ms^{-1})$ must be slowed down to $10^3 ms^{-1}$ so that it can have a high probality of interacting with isotipe $\_92U^{235}$ and causing it to fission. Show that a neutron can lose most of its K.E. in an elastic collision with a light nuclei like deuterium or carbon which has a mass of only a fewe times the neutron mass. The material making up the light nuclei usually heavy water (D_2O) or graphite is called modertaor.

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13. Consider the collision depicted in Figure, to be between two billiard balls with equal masses $m_1 = m_2$. The first ball is called the cue and the second ball is called the target. The billiard player wants to sink the target ball in a corner pocket, which is at an angle $\theta_2 = \phi = 37^\circ$. Assume that the collision is elastic and that friction and rotational motion are not important. Obtain $\theta_1 = \theta$.

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Exercise

1. The sign of work done by a force is important to understanstant. State carefully if the following quantities are positive or negative. (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 the 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 froce 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.

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2. A body of mass 2 kg initially at rest moves under the action of an applied horizontal force of 7N on a table with coefficient of kinetic friction $= 0.1$. Calculate the

(a) work done by applied force in 10s. (b) work done by friction in 10s.

(c) work done by the net force on the body in 10s.

(d) change in K.E. of body in 10s, and interpret your result.

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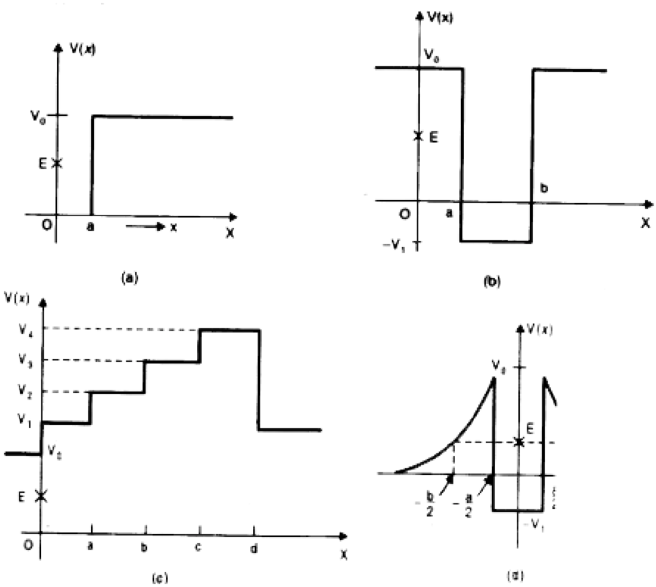
3. Given in fig are examples of some potential energy functions in one dimension. The total enrgy of the particle is indicated by a cross on the ordinate axis. In each case, specify the regions, if any, in which the particle cannot be found for the given energy. Also, indicate the minimum total energy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



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4. The potential energy function for a particle executing simple harmonic motion is given by $V(x) = \frac{1}{2}kx^2$, where k is the force constant of the oscillatore. For $k = \frac{1}{2}Nm^{-1}$, show that a particle of total energy 1 joule moving under this potential must turn back when it reaches $x = \pm 2m$.

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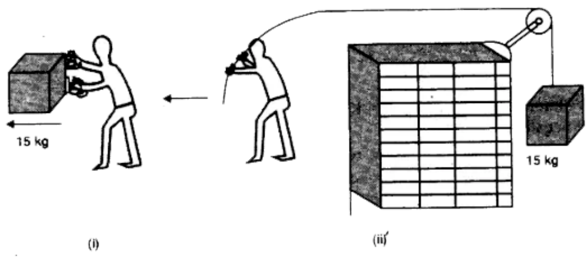
5. Answer the following:

a) The casing of a rocket in flight burns up due to friction. At whose expense is the heat 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 gravitatonal force over every complete orbit of the comet is zero. Why?

c) An artificial satellite orbiting the earth in very atmosphere loses its energy grdually due to dissipation against atmospheric resistance, howerver small. Why then does its speed increase progressively as it comes closer and closer tothe earth? d)In fig i) the man walks 2m 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 pulley, and a mass of 15 kg hangs at its other end. In which case is the work done greater?



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6. Underline the correct alterntaive:

a) when a conservative force does positivie work on a body, the potential energy of the body increase/decreases/remains unaltered.

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 on the system.

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 enregy of the system of two bodies.

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7. 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.

b)Total energy of a systm is always

conserved,no matter what internal and external forces on the body are present.

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

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

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8. Anwer 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)?

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 potenital energy of two billiard balls depends only on the separation distance between their centers, is the collision elastic or inelastic? (note we are talking here of potential energy corresponding to the force during collision, not gravitational potential energy).

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

A. $t^{1/2}$

B. t

C. $t^{3/3}$

D. t^2

Answer:

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

A. $t^{1/2}$

B. t

C. $t^{3/3}$

D. t^{2}

Answer:

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11. A body constrained to move along the z-axis of a co-ordinate system, is subjected to a constant force $\vec{F}$ given by

$\vec{F} = -\hat{i} + 2\hat{j} + 3\hat{k}$ Newton where $\hat{i}$, $\hat{j}$and $\hat{k}$ represent unit vectors along x-,y-,and z-axes of the system, respectively. Calculate the work done by this force in displacing the body through a distance of $4m$ along the z-axis.

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12. 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 $= 9.11 \times 10^{-31} kg$, proton mass $= 1.67 \times 10^{-27} kg, 1eV = 1.60 \times 10^{-19} J$).

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13. A rain drop of radius 2mm, falls from a height of 500 m above the ground. It falls with decreasing acceleration due to viscous resistance of air until half its original height. It attains its maximum (terminal) speed, and moves with uniform speed there after. What is the work done by the gravitational force on the drop in the first half and second half of its journey ? Take density of water $= 10^3 kg/m^3$. What is the work done by the resistive force in the entire journey if its speed on reaching the ground is $10 ms^{-1}$?

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14. A molecules in a gas container hits the wall with speed 200m/s at an angle 30° with the normal, and reboudns with the same speed. Is momentum conserved in the collision ? Is the collision elastic or inelastic ?

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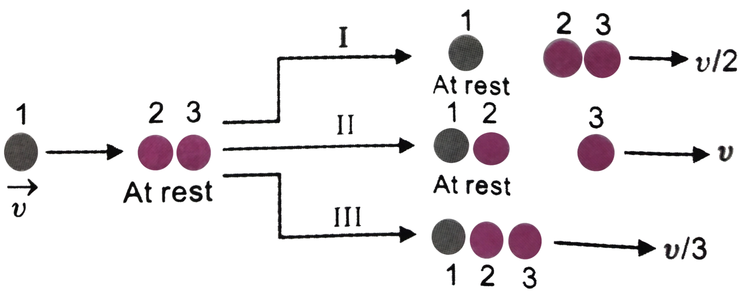
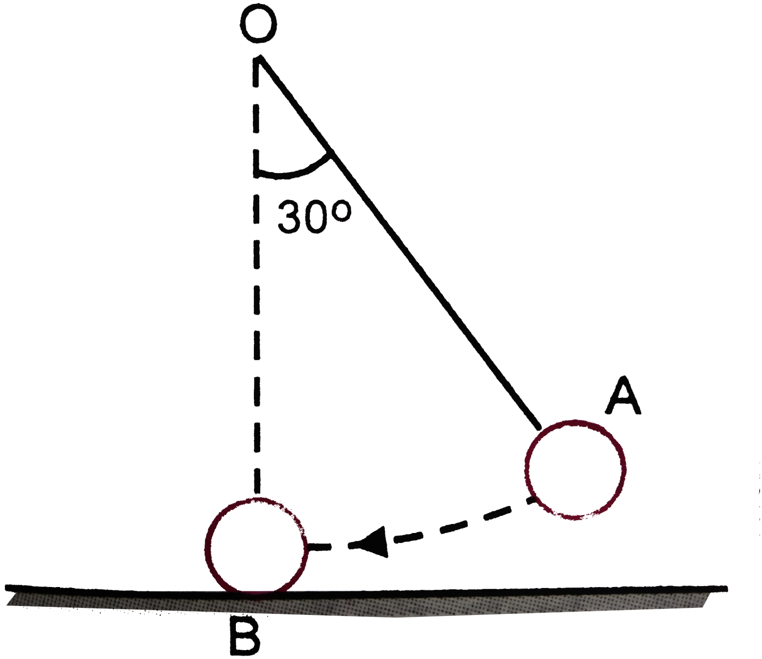
15. A pump on the ground floor of a building can pump of water to fill a tank of volume $30ms^3$ in $15 \min$. If the tank is $40m$ above the ground and the efficiency of the pump is 30% , how much electric power is consumed by the pump? $(\text{Take} g = 10ms^2)$

16. Two identical ball bearings in contact with each other and resting on a frictionless table are hit head on by another ball bearing of the same mass moving initially with a speed v, figure,. If the collision is elastic, which of the following is a possible result after collisioin?



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



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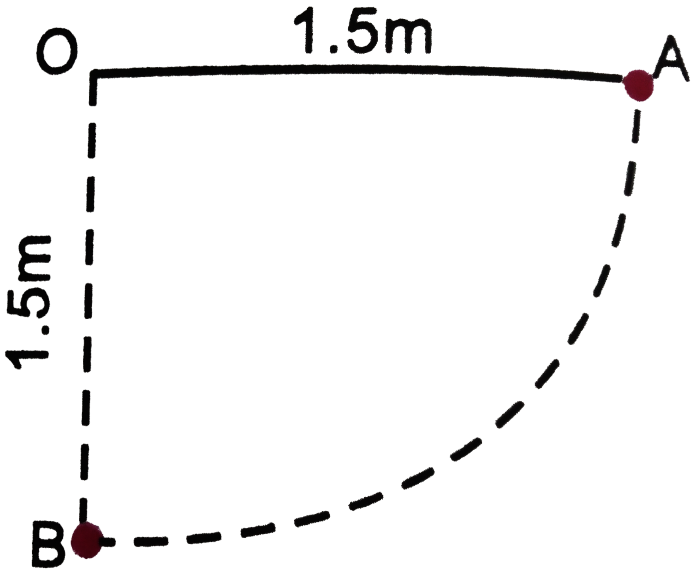
18. The bob A of a simple pendulum is released

from a horizontal position A as shownin in figure. If the length of the pendulum is 1.5m , what is the speed with which the bob arrives at the lowermost point B, given that it dissipates 5% of its initial energy against air resistance ?



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

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20. A particle of mass $0.5kg$ travels in a straight line with velocity $v = ax^{3/2}$ where

$a = 5m^{-1/2}s^{-1}$. What is the work done by the net force during its displacement from $x = 0$ to $x = 2m$?

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21. The blades of a windmill sweep out a circle of area A. (a) If the wind flows at a velocity v perpendicular to the circle, what is the mass of the air passing through in time t? (b) What is the kinetic energy of the air? (c) Assume that the windmill converts 25% of the wind's energy into electrical energy, and that $A = 30m^2, v = 36kmh^{-1}$ and the density of air is $1.2kgm^{-3}$, what is the electrical power produced?

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22. A person trying to lose weight (dieter) lifts a 10 kg mass through 0.5m, 1000 times, A ssume that the potential energy lost each time she lowers the mass is dissipated (a) How much work does she does against the gravitational force ? (b) Fat supplies $3.8 \times 10^7 J$ of energy per kilogram which is converted to mechanical energy with a 20% efficiency rate. How much fat will the dieter use up ?

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23. A family uses 8kW of power. (a) Direct solar energy is incident on the horizontal surface at an average rate of 200 W per square metre. If 20% of this energy can be converted to useful electrical energy, how large an area is needed to supply 8kW? (a) Compare this area to that of the roof of a typical house.

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24. A bullet of mass 0.012 kg and horizontal speed $70ms^{-1}$ 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.

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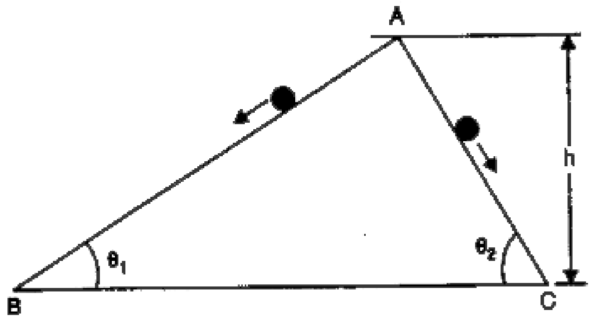
25. Two inclined frictionless tracks, one gradual and the other steep meet at A from where to stones are allowed to slide down from rest, one on each track (fig.) Will hte stones reach the bottom at the same time? Will they reach there with the same speed? Explain, given $\theta_1 = 30^\circ$, $\theta_{92}) = 60^\circ$ and h=10m. What are the speeds and time taken by the two stones?



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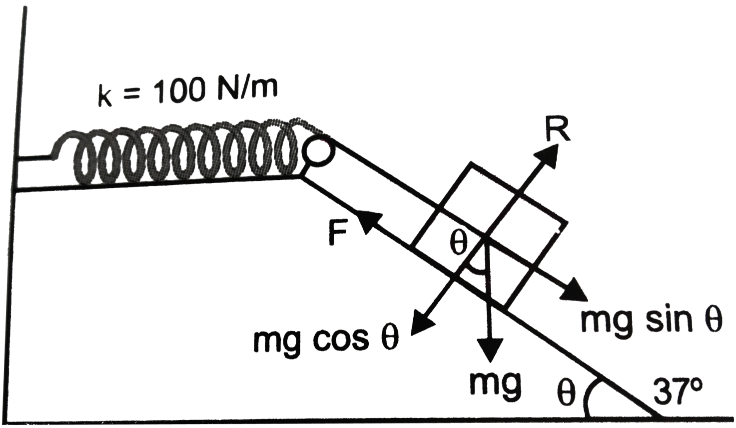
26. A 1kg block situated on a rough incline is connected to a spring of spring constant $100 Nm^{-1}$ as shown in figure,. The block is released from rest with the spring in the unstretched position. The block moves 10cm down the incline before coming to rest. Find the coefficient of friction between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



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

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28. A trolly of mass 200kg moves with a uniform speed of 36 km/h on a frictionless track. A child of mass 20kg runs on the trolly from one end to the other (10m away) with a speed of $4m/s$ relative to the trolly in a direction opposite to the trolly's motion and jumps out of the trolly. How much has teh trolly moved from the time the child begins to run ?

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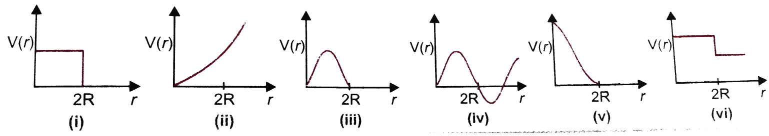
29. Which of the following potential energy curves in figure., cannot possibley describly describe the elastic collision of two billiard balls ? Here r is distance between centres of the balls.



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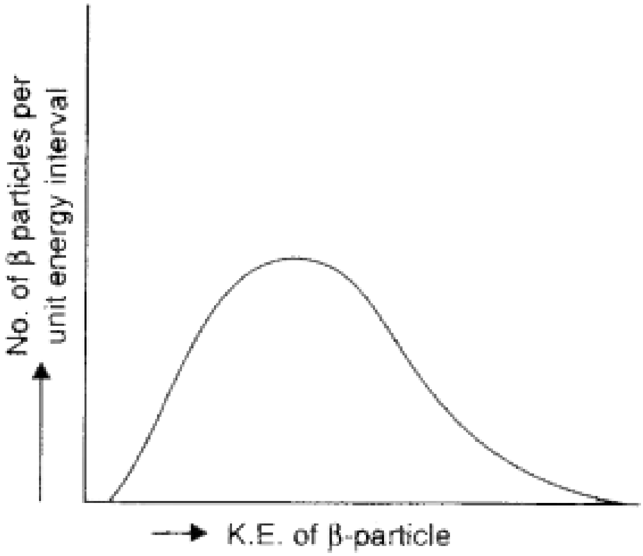
30. Consider the decay of a free neutron at rest: n ⊤ $+ e^{-}$ Show that the tow-body dacay of this type must necessarily give an electron of fixed energy and, therefore, cannot for the observed continous energy distribution in the β-decay of a neutron or a nucleus.



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