EXERCISE-1

SECTION (A) : WORK DONE BY CONSTANT FORCE

A 1. Calculate the work done by a coolie in carrying a load of mass 10 kg on his head when the walks uniformly a distance of 5 m in the (i) horizontal direction (ii) vertical direction. (Take g = 10 m/s^2)

A 2. A cluster of clouds at a height of 1000 metre above the Earth burst and enough rain fell to cover an area of 10^6 square metre with a depth of 2 cm. How much work would have been done in raising water to the height of clouds? Given : g = 980 cm s^{-2} and density of water = 1 g cm^{-3}.

SECTION (B) : WORK DONE BY A VARIABLE FORCE

B 1. A particle moves along the x-axis from x = 0 to x = 5 m under the influence of a force F(in N) given by $F = 3x^2 - 2x + 7$. Calculate the work done by this force.

B 2. A flexible chain of length ℓ and mass m is slowly pulled at constant speed up over the edge of a table by a force F parallel to the surface of the table. Assuming that there is no friction between the table and chain, calculate the work done by force F till the chain reaches to the horizontal surface of the table.

SECTION (C) : WORK ENERGY THEOREM

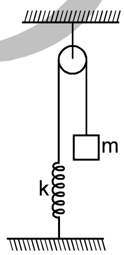
C 1. In a ballistics demonstration, a police officer fires a bullet of mass 50.0 g with speed 200 m s^{-1} on soft plywood of thickness 2.00 cm. The bullet emerges with only 10% of its initial kinetic energy. What is the emergent speed of the bullet ?

C 2. It is well known that a raindrop or a small pebble 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 or small pebble of 1 g falling from a cliff of height 1.00 km. It hits the ground with a speed of 50.0 m s^{-1}. What is the work done by the unknown resistive force?

C 3. A force of 1000 N acts on a particle parallel to its direction of motion which is horizontal. Its velocity increases from 1 m s^{-1} to 10 m s^{-1}, when the force acts through a distance of 4 metre. Calculate the mass of the particle. Given : a force of 10 newton is necessary for overcoming friction.

C 4. A block of mass m moving at a speed v compresses a spring through a distance x before its speed is halved. Find the spring constant of the spring.

C 5. Consider the situation shown in figure. Initially the spring is unstretched when the system is released from rest. Assuming no friction in the pulley, find the maximum elongation of the spring.



C 6. A rigid body of mass 0.3 kg is taken slowly up an inclined plane of length 10 m and height 5 m, and then allowed to slide down to the bottom again. The co-efficient of friction between the body and the plane is 0.15. Using g = 9.8 m/s^2 find the

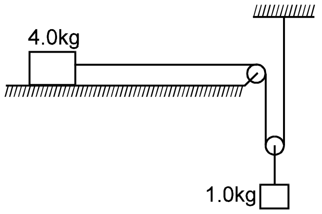
(a) work done by the gravitational force over the round trip.

(b) work done by the applied force(assuming it to be parallel to the inclined plane) over the upward journey

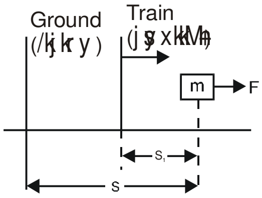
(c) work done by frictional force over the round trip.

(d) kinetic energy of the body at the end of the trip?

C 7. Consider the situation shown in figure. The system is released from rest and the block of mass 1.0 kg is found to have a speed 0.3 m/s after it has descended through a distance of 1m. Find the coefficient of kinetic friction between the block and the table.



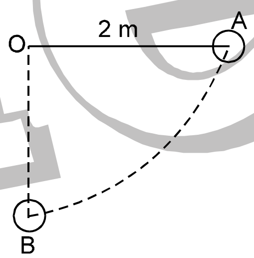
C 8. A block of mass m sits at rest on a frictionless table in a rail car that is moving with speed v_c along a straight horizontal track (fig.) A person riding in the car pushes on the block with a net horizontal force F for a time t in the direction of the car's motion.



(a) What is the final speed of the block according to a person in the car?
(b) According to a person standing on the ground outside the train?
(c) How much did K of the block change according to the person in the car?
(d) According to the person on the ground?
(e) In terms of F, m, & t, how far did the force displace the object according to the person in car?
(f) According to the person on the ground?
(g) How much work does each say the force did?
(h) Compare the work done to the K gain according to each person.
(i) What can you conclude from this computation?

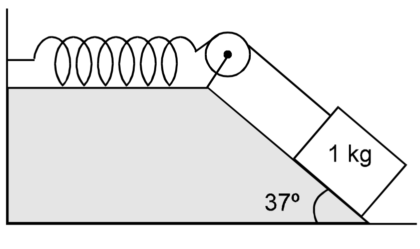
SECTION (D) : POTENTIAL ENERGY AND MECHANICAL ENERGY CONSERVATION

D 1. The bob of a pendulum is released from a horizontal position A as shown in figure. If the length of the pendulum is 2 m, what is the speed with which the bob arrives at the lowermost point B, given that it dissipated 10% of its initial energy against air resistance?



D 2. A person trying to lose weight (dieter) lifts a 10 kg mass through 0.5 m, 1000 times. 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 4×10^7 J of energy per kilogram which is converted to mechanical energy with a 20% efficiency rate. How much fat will the dieter use up? (use g = 10 m/s^2)

D 3. A 1 kg block situated on a rough inclined plane is connected to a spring of spring constant 100 N m^{-1} as shown. 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. Take g = 10 ms^{-2}.



D 4. The potential energy function of a particle in a region of space is given as :

$$U = (2x^2 + 3y^3 + 2z)\ J$$

Here x, y and z are in metres. Find the force acting on the particle at point P(1m, 2m, 3m).

D 5. The potential energy function of a particle in a region of space is given as

$$U = (2xy + yz)J$$

Here x, y and z are in metre. Find the force acting on the particle at a general point P(x, y, z).

D 6. Force acting on a particle in a conservative force field is :

(i) $\vec{F} = (2\hat{i} + 3\hat{j})$ (ii) $\vec{F} = (2x\hat{i} + 3y\hat{j})$

(iii) $\vec{F} = (y\hat{i} + x\hat{j})$

Find the potential energy function, if it is zero at origin.

SECTION (E) : POWER

E 1. An elevator weighing 500 kg is to be lifted up at a constant velocity of 0.4 m s^{-1}. What should be the minimum horse power of the motor to be used? (Take g = 10 m s^{-2} and 1 hp = 750 watts).

E 2. A lift is designed to carry a load of 4000 kg in 10 seconds through 10 floors of a building averaging 6 metre per floor . Calculate the hourse power of the lift. (Take g = 10 m s^{-2} and 1 hp = 750 watts).

E 3. A labourer lifts 100 stones to a height of 6 metre in two minute. If mass of each stone be one kilogram, calculate the average power. Given : g = 10 m s^{-2}.

E 4. An engine lifts 90 metric ton of coal per hour from a mine whose depth is 200 metre. Calculate the power of the engine (use g=9.8 m/s^2)

E 5. A motor is capable of rasing 400 kg of water in 5 minute from a well 120 m deep. What is the power developed by the man?

E 6. A man weighing 70 kg climbs up a vertical staircase at the rate of 1 ms^{-1}. What is the power developed by the man?

EXERCISE-2

SECTION : (A) WORK DONE BY CONSTANT FORCE

A 1. A rigid body moves a distance of 10 m along a straight line under the action of a force of 5 N. If the work done by this force on the body is 25 joules, the angle which the force makes with the direction of motion of the body is

(A) 0º (B) 30º (C) 60º (D) 90º

A 2. A rigid body of mass 6 kg is under a force which causes displacement in it given by S = $\frac{t^2}{4}$ metres where t is time. The work done by the force in 2 seconds is

(A) 12 J (B) 9 J (C) 6 J (D) 3 J

A 3. A ball is released from the top of a tower. The ratio of work done by force of gravity in first, second and third second of the motion of the ball is

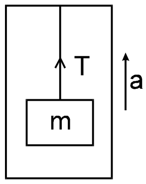
(A) 1 : 2 : 3 (B) 1 : 4 : 9 (C) 1 : 3 : 5 (D) 1 : 5 : 3

A 4. When a rigid body of mass M slides down an inclined plane of inclination θ, having coefficient of friction μ through a distance s, the work done against friction is :

(A) μ (Mg cos θ)s (B) μ (Mg sin θ) s

(C) Mg (μcos θ – sinθ)s (D) None of the above

A 5. A block of mass m is suspended by a light thread from an elevator. The elevator is accelerating upward with uniform acceleration a. The work done by tension on the block during t seconds is :



(A) $\frac{m}{2}(g + a)\, at^2$ (B) $\frac{m}{2}(g - a)at^2$ (C) $\frac{m}{2}gat^2$ (D) 0

SECTION (B) : WORK DONE BY A VARIABLE FORCE

B 1. A particle moves under the effect of a force F = Cx from x = 0 to x = x_1. The work done in the process is

(A) Cx_1^2 (B) $\frac{1}{2}Cx_1^2$ (C) Cx_1 (D) Zero

B 2. Two springs have their force constant as k_1 and k_2($k_1 > k_2$). When they are stretched by the same force
(A) No work is done by this force in case of both the springs
(B) Equal work is done by this force in case of both the springs
(C) More work is done by this force in case of second spring
(D) More work is done by this force in case of first spring

B 3. Two equal masses are attached to the two ends of a spring of spring constant k. The masses are pulled out symmetrically to stretch the spring by a length x over its natural length. The work done by the spring on each mass during the above pulling is

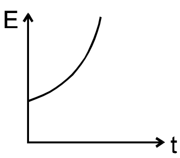
(A) $\frac{1}{2}kx^2$ (B) $-\frac{1}{2}kx^2$ (C) $\frac{1}{4}kx^2$ (D) $-\frac{1}{4}kx^2$

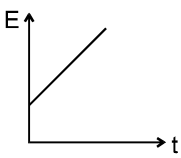
B 4. The work done by the frictional force on a surface in drawing a circle of radius r on the surface by a pencil of negligible mass with a normal pressing force N (coefficient of friction μ_k) is :
(A) $4\pi r^2\mu_K N$ (B) $-2\pi r^2\mu_K N$ (C) $-3\pi r^2\mu_K N$ (D) $-2\pi r\mu_K N$

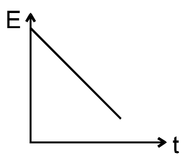
B 5. A uniform chain of length 2m is kept on a table such that a length of 60 cm hangs freely from the edge of the table. The total mass of the chain is 4 kg. What is the work done by a force parallel to the horizontal surface in pulling the entire chain slowly on the table?
(A) 7.2 J (B) 3.6 J (C) 120 J (D) 1200 J

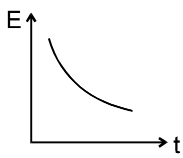
SECTION (C) : WORK ENERGY THEOREM

C 1. A particle is dropped from a height h. A constant horizontal velocity is given to the particle. Taking g to be constant every where, kinetic energy E of the particle with respect to time t is correctly shown in

(A)


(B)


(C)


(D)


C 2. If v, p and E denote the velocity, momentum and kinetic energy of the particle, then :
(A) p = dE/dv (B) p = dE/dt (C) p = dv/dt (D) None of these

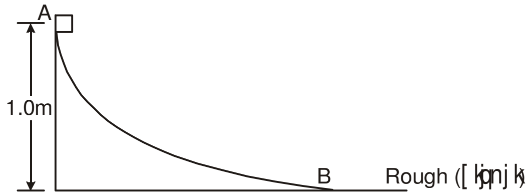
C 3. A heavy stone is thrown from a cliff of height h with a speed v. The stone will hit the ground with maximum speed if it is thrown
(A) vertically downward (B) vertically upward
(C) horizontally (D) the speed does not depend on the initial direction.

C 4. A body moving at 2 m/s can be stopped over a distance x. If its kinetic energy is doubled, how long will it go before coming to rest, if the retarding force remains unchanged ?
(A) x (B) 2x (C) 4x (D) 8x

C 5. A rod of length 1m and mass 0.5 kg hinged at one end, is initially hanging vertical. The other end is now raised slowly until it makes an angle 60º with the vertical. The required work is :(use g=9.8 m/s²)
(A) 1.522 J (B) 1.225 J (C) 2.125 J (D) 3.125 K

C 6. A particle moves in a straight line with retardation proportional to its displacement. Its loss of kinetic energy for any displacement x is proportional to
(A) x^2 (B) e^x (C) x (D) $\log_e x$

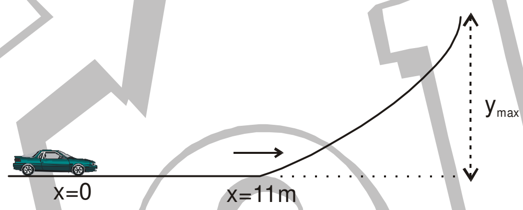
C 7. A block weighing 10 N travles down a smooth curved track AB joined to a rough horizontal surface (figure). The rough surface has a friction coefficient of 0.20 with the block. If the block starts slipping on the track from a point 1.0 m above the horizontal surface, the distance it will move on the rough surface is :

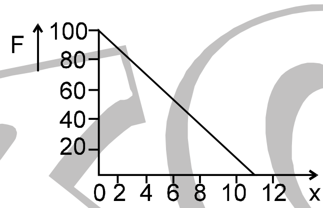


(A) 5.0 m (B) 10.0 m (C) 15.0 m (D) 20.0 m

SECTION (D) : MECHANICAL ENERGY CONSERVATION

D 1. A toy car of mass 5 kg moves up a ramp under the influence of force F plotted against displacement x. The maximum height attained is given by





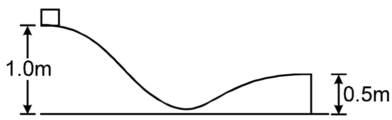
(A) y_{max} = 20 m (B) y_{max} = 15 m (C) y_{max} = 11 m (D) y_{max} = 5 m

D 2. The negative of the work done by the conservative internal forces on a system equals the change in
(A) total energy (B) kinetic energy (C) potential energy (D) none of these

D 3. __________________ of a two particle system depends only on the separation between the two particles. The most appropriate choice for the blank space in the above sentence is
(A) kinetic energy (B) total mechanical energy
(C) potential energy (D) total energy

D 4. A stone projected up with a velocity u reaches a maximum height h. When it is at a height of 3h/4 from the ground, the ratio of KE and PE at that point is : (consider PE = 0 at the point of projectory)
(A) 1 : 1 (B) 1 : 2 (C) 1 : 3 (D) 3 : 1

D 5. Figure shows a particle sliding on a frictionless track which terminates in a straight horizontal section. If the particle starts slipping from the point A, how far away from the track will the particle hit the ground ?



(A) At a horizontal distance of 1 m from the end of the track.
(B) At a horizontal distance of 2 m from the end of the track.
(C) At a horizontal distance of 3 m from the end of the track.
(D) Insufficient information

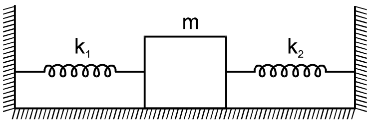
D 6. Two springs A and B ($k_A = 2k_B$) are strettched by applying forces of equal magnitudes at the four ends. If the energy stored in A is E, that in B is

(A) E/2 (B) 2E (C) E (D) E/4

D 7. When a spring is stretched by 2 cm, it stores 100 J of energy. If it is stretched further by 2 cm, the stored energy will be increased by

(A) 100 J (B) 200 J (C) 300 J (D) 400 J

D 8. A block of mass m is attached to two unstretched springs of spring constants k_1 and k_2 as shown in figure. The block is displaced towards right through a distance x and is released. Find the speed of the block as it passes through the mean position shown.

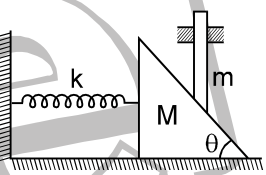


(A) $\sqrt{\frac{k_1+k_2}{m}}\,x$ (B) $\sqrt{\frac{k_1k_2}{m(k_1+k_2)}}\,x$ (C) $\sqrt{\frac{k_1^2k_2^2}{m(k_1^2+k_2^2)}}\,x$ (D) $\sqrt{\frac{k_1^3k_2^3}{m(k_1^3+k_2^3)}}$

D 9. A spring of spring constant k placed horizontally on a rough horizontal surface is compressed against a block of mass m placed on the surface so as to store maximum energy in the spring. If the coefficient of friction between the block and the surface is μ, the potential energy stored the spring is :

(A) $\frac{\mu^2m^2g^2}{k}$ (B) $\frac{2\mu m^2g^2}{k}$ (C) $\frac{\mu^2m^2g^2}{2k}$ (D) $\frac{3\mu^2mg^2}{k}$

D 10. A wedge of mass M fitted with a spring of stiffness 'k' is kept on a smooth horizontal surface. A rod of mass m is kept on the wedge as shown in the figure. System is in equilibrium. Assuming that all surfaces are smooth, the potential energy stored in the spring is :



(A) $\frac{mg^2\tan^2\theta}{2K}$ (B) $\frac{m^2g\tan^2\theta}{2K}$ (C) $\frac{m^2g^2\tan^2\theta}{2K}$ (D) $\frac{m^2g^2\tan^2\theta}{K}$

SECTION (E) : POWER

E 1. A car of mass 'm' is driven with acceleration 'a' along a straight level road against a constant external resistive force 'R'. When the velocity of the car is 'V', the rate at which the engine of the car is doing work will be

(A) RV (B) maV (C) (R + ma)V (D) (ma – R)V

E 2. A particle moves with a velocity $\vec{v} = (5\hat{i} - 3\hat{j} + 6\hat{k})$ m/s under the influence of a constant force $\vec{F} = (10\hat{i} + 10\hat{j} + 20\hat{k})$N. The instantaneous power applied to the particle is :

(A) 200 J/s (B) 40 J/s (C) 140 J/s (D) 170 J/s

E 3. An electric motor creates a tension of 4500 N in hoisting cable and reels it at the rate of 2 m/s. What is the power of electric motor ?

(A) 9 W (B) 9 KW (C) 225 W (D) 9000 H.P.

E 4. A man M_1 of mass 80 kg runs up a staircase in 15 s. Another man M_2 also of mass 80 kg runs up the stair case in 20 s. The ratio of the power developed by them (P_1 / P_2) will be :

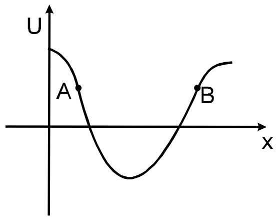
(A) 1 (B) 4/3 (C) 16/9 (D) None of the above

SECTION (F) : CONSERVATIVE & NONCONSERVATIVE FORCES AND EQUILIBRIUM

F 1. The potential energy of a particle in a field is $U = \frac{a}{r^2} - \frac{b}{r}$, where a and b are constant. The value of r in terms of a and b where force on the particle is zero will be :

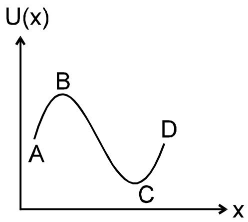
(A) $\frac{a}{b}$ (B) $\frac{b}{a}$ (C) $\frac{2a}{b}$ (D) $\frac{2b}{a}$

F 2. Potential energy v/s displacement curve for one dimensional conservative field is shown. Force at A and B is respectively.



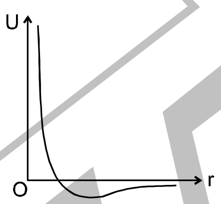
(A) Positive, Positive (B) Positive, Negative
(C) Negative, Positive (D) Negative, Negative

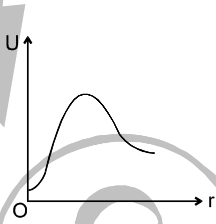
F 3. The potential energy of a particle varies with distance x as shown in the graph.

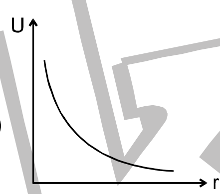


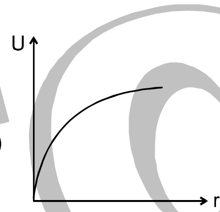
The force acting on the particle is zero at
(A) C (B) B (C) B and C (D) A and D.

F 4. The diagrams represent the potential energy U of a function of the inter-atomic distance r. Which diagram corresponds to stable molecules found in nature.

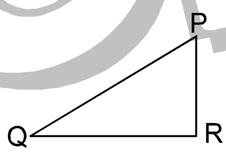
(A) 

(B) 

(C) 

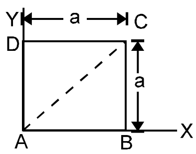
(D) 

F 5. For the path PQR in a conservative force field (fig.), the amounts work done in carrying a body from P to Q & from Q to R are 5 J & 2 J respectively . The work done in carrying the body from P to R will be -



(A) 7 J (B) 3 J (C) $\sqrt{21}$ J (D) zero

F 6. A force **F** = x^2y^2**i** + x^2y^2**j** (N) acts on a particle which moves in the XY plane.



(a) Determine if F is conservative and
(b) find the work done by **F** as it moves the particle from A to C (fig.) along each of the paths ABC, ADC, and AC.

F 7. Calculate the forces F(y) associated with the following one–dimensional potential energies:
(a) $U = -\omega y$ (b) $U = ay^3 - by$ (c) $U = U_0 \sin \beta y$

F 8. The potential energy for a force field $\vec{F}$ is given by U(x, y) = sin (x + y). The force acting on the particle of mass m at $\left(0, \frac{\pi}{4}\right)$ is

(A) 1 (B) $\sqrt{2}$ (C) $\frac{1}{\sqrt{2}}$ (D) 0

F 9. A particle is taken from point A to point B under the influence of a force field. Now it is taken back from B to A and it is observed that the work done in taking the particle from A to B is not equal to the work done in taking it from B to A. If W_{nc} and W_c is the work done by non-conservative forces and conservative forces present in the system respectively, ΔU is the change in potential energy, Δk is the change kinetic energy, then
(A) $W_{nc} - \Delta U = \Delta k$ (B) $W_c = -\Delta U$ (C) $W_{nc} + W_c = \Delta k$ (D) $W_{nc} - \Delta U = -\Delta k$

EXERCISE-3

1. The work done by the external forces on a system equals the change in
(A) total energy (B) kinetic energy (C) potential energy (D) none of these

2. A small block of mass m is kept on a rough inclined surface of inclination θ fixed in a elevator. The elevator goes up with a uniform velocity v and the block does not slide on the wedge. The work done by the force of friction on the block in time t will be
(A) zero (B) mgvt $\cos^2\theta$ (C) mgvt $\sin^2\theta$ (D) mgvt $\sin 2\theta$

3*. A heavy stone is thrown from a cliff of height h in a given direction. The speed with which it hits the ground
(A) must depend on the speed of projection (B) must be larger than the speed of projection
(C) must be independent of the speed of projection (D) may be smaller than the speed of projection

4. The total work done on a particle is equal to the change in its kinetic energy
(A) always (B) only if the forces acting on it are conservative
(C) only if gravitational force alone acts on it (D) only if elastic force alone acts on it.

5*. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane. If follows that
(A) its velocity is constant (B) its acceleration is constant
(C) its kinetic energy is constant (D) it moves in a circular path

6. Consider two observers moving with respect to each other at a speed v along a straight line.They observe a block of mass m moving a distance ℓ on a rough surface. The following quantities will be same as observed by the two observers
(A) kinetic energy of the block at time t (B) work done by friction
(C) total work done on the block (D) acceleration of the block.

7*. You lift a suitcase from the floor and keep it on a table. The work done by you on the suitcase does not depend on
(A) the path taken by the suitcase (B) the time taken by you in doing so
(C) the weight of the suitcase (D) your weight.

8*. No work is done by a force on an object if
(A) the force is always perpendicular to its velocity
(B) the force is always perpendicular to its acceleration
(C) the object is stationary but the point of application of the force moves on the object
(D) the object moves in such a way that the point of application of the force remains fixed.

9*. The kinetic energy of a particle continuously increases with time
(A) the resultant force on the particle must be parallel to the velocity at all instants.
(B) the resultant force on the particle must be at an angle less than 90° all the time
(C) its height above the ground level must continuously decrease
(D) the magnitude of its linear momentum is increasing continuously

10*. One end of a light spring of spring constant k is fixed to a wall and the other end is tied to a block placed on a smooth horizontal surface. In a displacement , the work done by the spring is $\frac{1}{2}kx^2$. The possible cases are

(A) the spring was initially compressed by a distance x and was finally in its natural length
(B) it was initially stretched by a distance x and finally was in its natural length
(C) it was initially in its natural length and finally in a compressed position
(D) it was initially in its natural length and finally in a stretched position

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

12*. If force is always perpendicular to motion
(A) KE remains constant
(B) work done = 0
(C) speed is constant
(D) velocity is constant

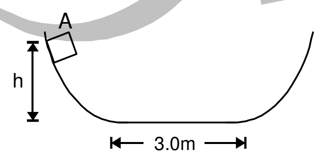
13*. Work done by force of friction
(A) can be zero
(B) can be positive
(C) can be negative
(D) information insufficient

14*. When work done by force of gravity is negative (Assume only gravitational force to be acting)
(A) KE increases
(B) KE decreases
(C) PE increases
(D) PE stays constant

15*. When total work done on a particle is positive
(A) KE remains constant
(B) Momentum increases
(C) KE decreases
(D) KE increases

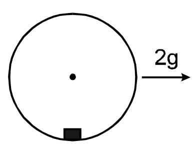
16*. When a man walks on a horizontal surface with constant velocity, work done by
(A) friction is zero
(B) contact force is zero
(C) gravity is zero
(D) man is zero

17. A small particle slides along a track with elevated ends and a flat central part, as shown in figure. The flat part has a length 3m. the curved portions of the track are frictionless, but for the flat part the coefficient of kinetic friction is $\mu = 0.2$. The particle is released at point A, which is at a height h = 1.5 m above the flat part of the track. The position where the particle finally come to rest is:



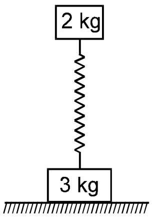
(A) left to mid point of the flat part
(B) right to the mid point of the flat part
(C) Mid point of the flat part
(D) None of these

18. A block of mass m is placed inside a smooth hollow cylinder of radius R kept horizontally. Initially system was at rest. Now cylinder is given constant acceleration 2g in the horizontal direction by external agent. The maximum angular displacement of the block with the vertical is:



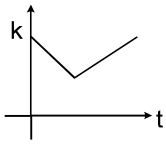
(A) $2\tan^{-1}2$
(B) $\tan^{-1}2$
(C) $\tan^{-1}1$
(D) $\tan^{-1}\left(\frac{1}{2}\right)$

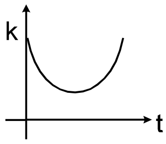
19. The ends of a spring are attached to blocks of masses 3 kg and 2 kg. The 3 kg block rests on a horizontal surface and the 2 kg block which is vertically above it is in equilibrium producing a compression of 1 cm of the spring. The value of the length to which the 2 kg mass must be compressed, so that when it is released, the 3 kg block may be lifted off the ground is :

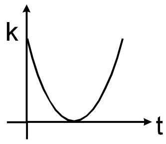


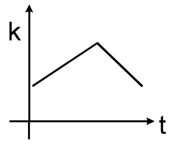
(A) 5 cm (B) 2.5 cm (C) 8 cm (D) 10 cm

20. In a projectile motion, KE varies with time as in graph :

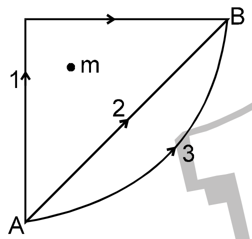
(A) 

(B) 

(C) 

(D) 

21. If W_1, W_2 and W_3 represent the work done in moving a particle from A to B along three different paths 1, 2, 3 respectively (as shown) in the gravitational field of a point mass m, find the correct relation between W_1, W_2 and W_3



(A) $W_1 > W_2 > W_3$ (B) $W_1 = W_2 = W_3$ (C) $W_1 < W_2 < W_3$ (D) $W_2 > W_1 > W_3$

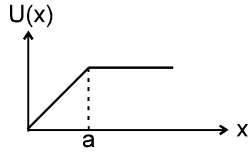
22. A lorry and a car moving with the same K.E. are brought to rest by applying the same retarding force, then
(A) Lorry will come to rest in a shortest distance (B) Car will come to rest in a shorter distance
(C) Both come to rest in a same distance (D) None of the above

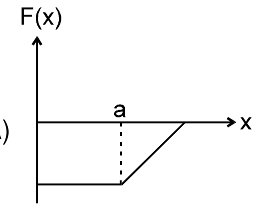
23. An open knife edge of mass 'm' is dropped from a height 'h' on a wooden floor. If the blade penetrates upto depth 'd' into the wood, the average resistance offered by the wood to the knife edge is

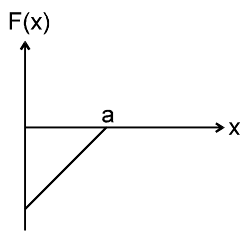
(A) mg (B) $mg\left(1-\frac{h}{d}\right)$ (C) $mg\left(1+\frac{h}{d}\right)$ (D) $mg\left(1+\frac{h}{d}\right)^2$

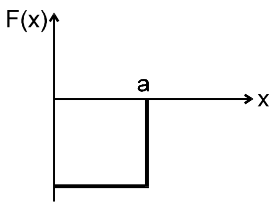
24. A body is moved along a straight line by a machine delivering constant power. The distance moved by the body in time t is proportional to
(A) $t^{1/2}$ (B) $t^{3/4}$ (C) $t^{3/2}$ (D) t^2

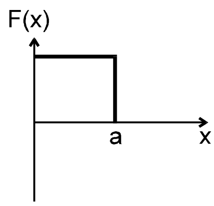
25. The potential energy of a system is represented in the first figure, the force acting on the system will be represented by



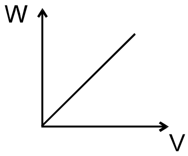
(A) 

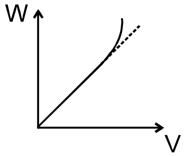
(B) 

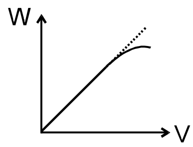
(C) 

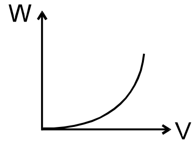
(D) 

26. A particle, initially at rest on a frictionless horizontal surface, is acted upon by a horizontal force which is constant in size and direction. A graph is plotted between the work done (W) on the particle, against the speed of the particle, (v). If there are no other horizontal forces acting on the particle the graph would look like

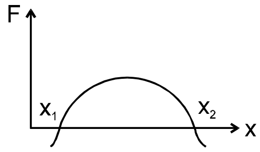
(A) 

(B) 

(C) 

(D) 

27. The force acting on a body moving along x-axis varies with the position of the particle as shown in the figure.



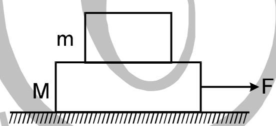
The body is in stable equilibrium at

(A) $x = x_1$ (B) $x = x_2$ (C) both x_1 and x_2 (D) neither x_1 nor x_2

EXERCISE-4

SECTION (A) : SUBJECTIVE QUESTIONS

1. A block of mass m is kept over another block of mass M and the system rests on a horizontal surface (figure). A constant horizontal force F acting on the lower block produces an acceleration $\frac{F}{2(m+M)}$ in the system, the two blocks always move together. (a) Find the coefficient of kinetic friction between the bigger block and the horizontal surface. (b) Find the frictional force acting on the smaller block. (c) Find the work done by the force of friction on the smaller block by the bigger block during a displacement *d* of the system.

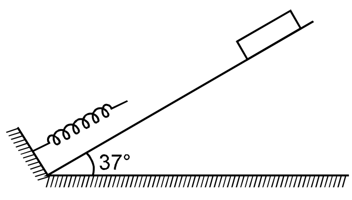


2. A box weighing 2000 N is to be slowly slid through 20 m on a straight track having friction coefficient 0.2 with the box. (a) Find the work done by the person pulling the box with a chain at an angle θ with the horizontal. (b) Find the work when the person has chosen a value of θ which ensures him the minimum magnitude of the force.

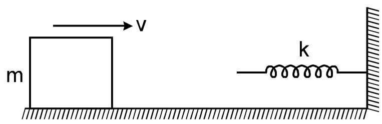
3. A particle of mass m moves on a straight line with its velocity varying with the distance travelled according to the equation $v = a\sqrt{x}$, where a is a constant. Find total work done by all the forces during a displacement from x = 0 to x = d.

4. The US athlete Florence Griffith-Joyner won the 100 m sprint gold medal at Seol Olympic 1988 setting a new Olympic record of 10.54 s. Assume that she achieved her maximum speed in a very short time and then ran the race with that speed till she crossed the line. Take her mass to be 50 kg. (a) Calculate the kinetic energy of Griffith-Joyner at her full speed. (b) Assuming that the track, the wind etc. offered an average resistance of one tenth of her weight, calculate the work done by the resistance during the run. (c) What power Griffith-Joyner had to exert to maintain uniform speed ?

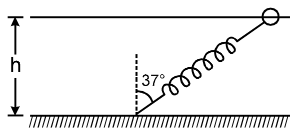
5. Figure shows a spring fixed at the bottom end of an incline of inclination 37°. A small block of mass 2 kg starts slipping down the incline from a point 4.8 m away from the spring. The block compresses the spring by 20 cm, stops momentarily and then rebounds through a distance of 1 m up the incline. Find (a) The friction coefficient between the plane and the block and (b) the spring constant of the spring. Take g = 10 m/s².



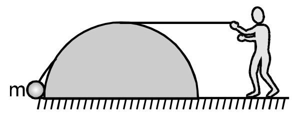
6. A block of mass m sliding on a smooth horizontal surface with a velocity $\vec{v}$ meets a long horizontal spring fixed at one end and having spring constant k as shown in figure. Find the maximum compression of the spring. Will the velocity of the block be the same as $\vec{v}$ when it comes back to the original position shown?



7. One end of a spring of natural length h and spring constant k is fixed at the ground and the other is fitted with a smooth ring of mass m which is allowed to slide on a horizontal rod fixed at a height h (figure). Initially, the spring makes an angle of 37° with the vertical when the system is released from rest. Find the speed of the ring when the spring becomes vertical.



8. As shown in the figure a person is pulling a mass 'm' from ground on a fixed rough hemispherical surface upto the top of the hemisphere with the help of a light inextensible string. Find the work done by tension in the string if radius of hemisphere is R and friction coefficient is μ. Assume that the block is pulled with negligible velocity.



9. Two blocks of masses m_1 and m_2 are connected by a spring of stiffness k. The coefficient of friction between the blocks and the surface is μ. Find the minimum constant force F to be applied to m_1 in order to slide the mass m_2.

10*. A particle of mass m approaches a region of force starting from $r = +\infty$. The potential energy function in terms of distance r from the origin is given by,

$$U(r) = \frac{K}{2a^3}(3a^2 - r^2) \quad \text{for} \quad , 0 \le r \le a$$

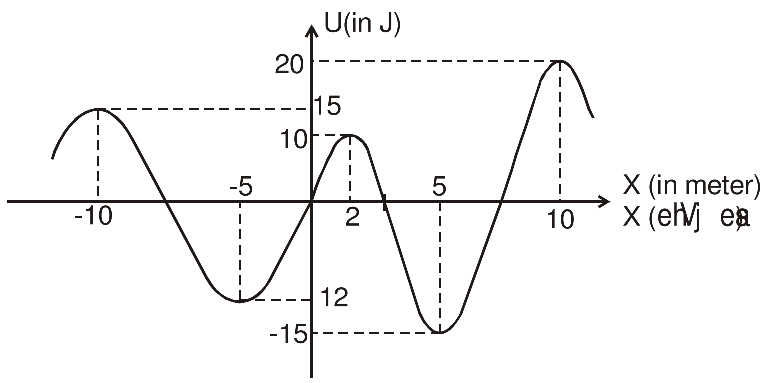
$$= K/r \quad \text{for} \quad , r \ge a$$

(a) Derive the force F (r) and determine whether it is repulsive or attractive.

(b) With what velocity should the particle start at $r = \infty$ to cross over to r = on the other side of the origin.

(c) If the velocity of the particle at $r = \infty$ is $\sqrt{\frac{2K}{am}}$, towards the origin describe the motion.

11. In the figure the variation of potential energy of a particle of mass m = 2kg is represented w.r.t. its x-coordinate. The particle moves under the effect of this conservative force along the x-axis. Which of the following statements is incorrect about the particle is true :

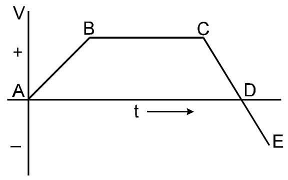


1. If it is released at the origin it will move in negative x-axis.
2. If it is released at $x = 2 + \Delta$ where $\Delta \to 0$ then its maximum speed will be 5 m/s and it will perform oscillatory motion
3. If initially $x = -10$ and $\vec{u} = \sqrt{6}\,\hat{i}$ then it will cross x = 10
4. x = – 5 and x = + 5 are unstable equilibrium positions of the particle

SECTION (B) : QUESTIONS FOR SHORT ANSWER

12. Can kinetic energy of a system be increased or decreased without applying any external force on the system?

13. A single force acts on a particle in rectilinear motion. A plot of velocity versus time for the particle is shown in figure. Find the sign (positive or negative) of the work done by the force on the particle in each of the intervals AB, BC, CD and DE.



14. An elevator is moved by its cables at constant speed. Is the total work done on the elevator positive, negative, or zero?

15. A rope tied to a body is pulled, causing the body to accelerate. But according to Newton's Third law the body pulls back on the rope with an equal and opposite force. Is the total work done then zero? If so, how can the body's kinetic energy change?

16. Are there any cases where a frictional force can increase the mechanical energy of a system.

17. Does the work-energy theorem hold if friction acts on an object?

18. Does the power needed to raise a box onto a platform depend on how fast it is raised?

19. Suppose that the earth revolves around the sun in a perfectly circular orbit. Does the sun do any work on the earth?

20. State the net workdone in the following situations :
(a) A laborer carrying bricks on his head on a level road from one place to another.
(b) A man rowing a boat upstream at rest with respect to shore.
(c) When a body of mass m moves with a uniform speed v in a circle.
(d) When a car moves with a uniform speed on a smooth level road, neglecting the air resistance.

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

SECTION (C) : ASSERTION AND REASONING

In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements,mark the correct answer as
(A) If both assertion and reason are true and reason is the correct explanation of assertion.
(B) If both assertion and reason are true but reason is not the correct explanation of assertion.
(C) If assertion is true but reason is false
(D) If assertion is false but reason is true.
(E) If both assertion and reason are false.

22. **Assertion :** The total work done during a round trip is always zero.
Reason : No force is required to move a body in its round trip.

23. **Assertion :** Work done by friction on a body sliding down an inclined plane is positive.
Reason : Work done is greater than zero, if angle between force and displacement is acute or both are in same direction.

24. **Assertion :** The instantaneous power of an agent is measured as the dot product of instantaneous velocity and the force acting on it at that instant.
Reason : The unit of instantaneous power is watt.

SECTION (D) : STATE TRUE OR FALSE

25. A light and a heavy particle having equal momenta have equal kinetic energies.

Teko Classes, Maths : Suhag R. Kariya (S. R. K. Sir), Bhopal Phone : 0 903 903 7779, 0 98930 58881.

26. Total mechanical energy of a body cannot be negative.

27. A man rowing a boat upstream is at rest with respect to the shore. He is doing no work.

28. A body cannot have momentum, when its kinetic energy is zero.

SECTION (E) : FILL IN THE BLANKS

29. When a proton and an electron are brought nearer, potential energy of the system _____ .

30. The linear momentum of a body increases by 50%. The corresponding increase in its K.E. is ________.

EXERCISE-5

1. A force $\vec{F} = -K(y\,\hat{i} + x\,\hat{j})$ where K is a positive constant, acts on a particle moving in the x-y plane. Starting from the origin, the particle is taken along the positive x-axis to the point (a,0) and then parallel to the y-axis to the point (a,a). The total work done by the force $\vec{F}$ on the particle is **[JEE 1998]**

(A) $-2Ka^2$ (B) $2Ka^2$ (C) $-Ka^2$ (D) Ka^2

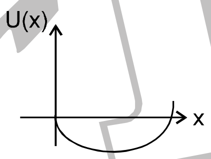
2. A pump motor is used to deliver water at a certain rate from a given pipe. To obtain "n" times water from the same pipe in the same time, the amount by which the power of the motor should be increased is: **[REE 1998]**

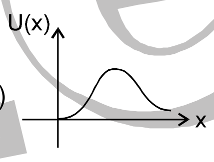
(A) n^2 (B) n^3 (C) n^4 (D) $n^{1/2}$

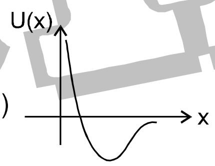
3. A wind-powered generator converts wind energy into electrical energy. Assume that the generator converts a fixed fraction of the wind energy intercepted by its blades into electrical energy. For wind speed v, the electrical power output will be proportional to- **[JEE2000]**

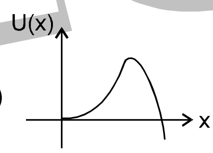
(A) v (B) v^2 (C) v^3 (D) v^4

4. A particle, which is constrained to move along the x-axis, is subjected to a force in the same direction which varies with the distance x of the particle from the origin as $F(x) = -kx + ax^3$. Here k and a are positive constants. For $x \geq 0$, the functional form of the potential energy U(x) of the particle is **[JEE 2002]**

(A) 

(B) 

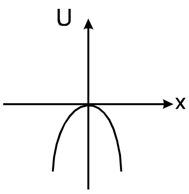
(C) 

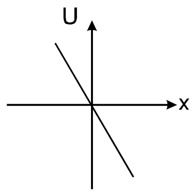
(D) 

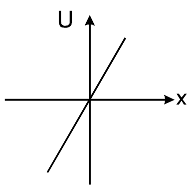
5. An ideal spring with spring-constant k is hung from the ceiling and a block of mass M is attached to its lower end. The mass is released with the spring initially unstreched. Then the maximum extension in the spring is **[JEE 2002]**

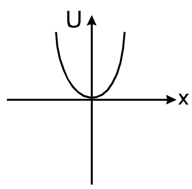
(A) 4 Mg/k (B) 2 Mg/k (C) Mg/k (D) Mg/2k

6. A particle moves under the influence of a force F = kx in one dimensions (k is a positive constant and x is the distance of the particle from the origin). Assume that the potential energy of the particle at the origin is zero, the schematic diagram of the potential energy U as a function of x is given by **[JEE 2004]**

(A) 

(B) 

(C) 

(D) 

ANSWER

EXERCISE # 1

SECTION (A) : WORK DONE BY CONSTANT FORCE

A 1. (i) Zero (ii) 500J

A 2. 1.96×10^{11} J

SECTION (B) : WORK DONE BY A VARIABLE FORCE

B 1. 135 J. **B 2.** $\frac{mg\ell}{2}$

SECTION (C) : WORK ENERGY THEOREM

C 1. $v_f = 63.2\ ms^{-1}$ **C 2.** – 8.75 J

C 3. 80 kg **C 4.** $\frac{3mv^2}{4x^2}$

C 5. 2mg/k

C 6. (a) Since the gravitational force is a conservative force therefore the work done in round trip is zero.
(b) 18.5 J (c) –7.6 J
(d) 10.9 J.

C 7. 0.12

C 8. **(a)** $a_1 = F/m$, so $v_1 = a_1t = Ft/m$.
(b) Since velocities add, $v = v_c + v_1 = v_c + Ft/m$
(c) $\Delta K_1 = m(v_1)^2/2 = F^2t^2/2m$
(d) $\Delta K = m\,(v_c + v_1)^2/2 - mv_c^2/2$
(e) s_1 is $a_1t^2/2 = Ft^2/2m$
(f) $s_1 + v_ct$
(h) Compare W and W_1 and ΔK and ΔK_1, they are respectively equal.
(i) The work - energy theorem holds for moving observers.

SECTION (D) : POTENTIAL ENERGY AND MECHANICAL ENERGY CONSERVATION

D 1. 6 m s^{-1} .

D 2. (a) 5×10^4 (b) 6.25×10^{-3} kg

D 3. 0.13

D 4. $\vec{F} = -(4\hat{i} + 36\hat{j} + 2\hat{k})N$

D 5. $\vec{F} = -[2y\hat{i} + (2x+z)\hat{j} + y\hat{k}]$

D 6. (i) U(x, y, z) = (–2x – 3y)
(ii) U(x, y, z) = – $(x^2 + y^2)$
(iii) U(x, y, z) = – xy.

SECTION (E) : POWER

E 1. $\frac{8}{3}$ hp **E 2.** 320 hp

E 3. 50 W **E 4.** 49 kW

E 5. 1568 W **E 6.** 686 W

EXERCISE # 2

SECTION : (A) WORK DONE BY CONSTANT FORCE

A 1. C **A 2.** D **A 3.** C

A 4. A **A 5.** A

SECTION (B) : WORK DONE BY A VARIABLE FORCE

B 1. B **B 2.** C **B 3.** D

B 4. D **B 5.** B

SECTION (C) : WORK ENERGY THEOREM

C 1. A **C 2.** A **C 3.** D

C 4. B **C 5.** B **C 6.** A

C 7. A

SECTION (D) : MECHANICAL ENERGY CONSERVATION

D 1. C **D 2.** C **D 3.** C

D 4. C **D 5.** A **D 6.** B

D 7. C **D 8.** A **D 9.** C

D 10. C

SECTION (E) : POWER

E 1. C **E 2.** C **E 3.** B

E 4. B

SECTION (F) : CONSERVATIVE & NONCONSERVATIVE FORCES AND EQUILIBRIUM

F 1. C **F 2.** B **F 3.** C

F 4. A **F 5.** A

F 6. (b) $W_{ABC} = W_{ADC} = \frac{a^5}{3}$ (J), $W_{AC} = \frac{2a^5}{5}$ (J)]

F 7. **(a)** $F = -\frac{dU}{dy} = \omega$

(b) $F = -\frac{dU}{dy} = -3ay^2 + 2by$

(c) $F = -\frac{dU}{dy} = -\beta U_0 \cos\beta y$]

F 8. A

F 9. ABC

EXERCISE # 3

1. A **2.** C **3*.** AB

4. A **5*.** CD **6.** D

7*. ABD **8*.** ACD **9*.** BD

10*. AB **11.** B **12*.** ABC

13*. ABC **14*.** BC **15*.** BD

16*. ABC **17.** C **18.** A

19. B **20.** B **21.** B

22. C **23.** C **24.** C

25. C **26.** D **27.** B

EXERCISE # 4

SECTION (A) : SUBJECTIVE QUESTIONS

1. (a) $\frac{F}{2(M+m)g}$ (b) $\frac{mF}{2(M+m)}$ (c) $\frac{mFd}{2(M+m)}$

2. (a) $\frac{40000}{5+\tan\theta}$J (b) 7690 J

3. $ma^2d/2$

4. (a) 2250 J (b) – 4900 J (c) 465 W

5. (a) 0.5 (b) 1000 N/m

6. $v\sqrt{m/k}$, No **7.** $\frac{h}{4}\sqrt{k/m}$

8. $W = (\mu + 1)\, mgR$ **9.** $\mu m_1 g + \frac{\mu m_2 g}{2}$

10*. (a) repulsive (b) $\sqrt{\frac{3k}{am}}$

11. 1, 2, 3

Sol. If the particle is released at the origin, it will try to go in the direction of force. Here $\frac{du}{dx}$ is positive and hence force is negative, as a result it will move towards – ve x-axis.

When the particle is released at $x = 2 + \Delta$; it will reach the point of least possible potential energy (–15 J) where it will have maximum kinetic energy.

$\therefore \quad \frac{1}{2} m v_{max}^2 = 25$

$\Rightarrow \quad v_{max} = 5$ m/s

The particle will now perform oscillatory motion between $-15 \le U \le 15$, because reaching U = + 15 J, the kinetic energy and hence speed becomes zero.

In (C); $E_i = U_i + k_i = 15 + 6 = 21$ J

At x = 10; $U_f = 20 \quad \Rightarrow k_f = 1 \neq 0$

$\Rightarrow$ The particle cross x = 10.

SECTION (B) : QUESTIONS FOR SHORT ANSWER

12. Yes (eg: by means of internal forces as in the case of explosen of bomb)

13. AB → (positive), BC → zero, CD → (negative), DE → (positive),

14. zero

15. No, the workdone is not zero. Isolate the system on which force is applied.

16. Yes, (two block problem).

17. Yes, ($\because$ workdone by all forces, conservative or nonconserveative equals to change in kinetic energy).

18. Yes, ($\because$ workdone is same but time taken is different).

19. No, ($\because$ the force of gravitation is always perpendicular to the displacement).

20. All zero

21. Heavier body ($\frac{p_L^2}{2m_L} = \frac{p_H^2}{2m_H}$

$\Rightarrow \quad p_H > p_L$).

SECTION (C) : ASSERTION AND REASONING

22. E **23.** D

24. B

SECTION (D) : STATE TRUE OR FALSE

25. False **26.** False

27. True **28.** True

SECTION (E) : FILL IN THE BLANKS

29. Decreases **30.** 125 %

EXERCISE # 5

1. C **2.** B **3.** C

4. D **5.** B **6.** A

