Work and Energy

OBJECTIVE TYPE QUESTIONS

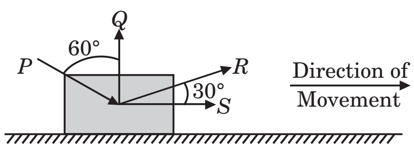
Multiple Choice Questions (MCQs)

1. Which of the following statements is true about work done?

(i) Work done by a force is always positive.
(ii) SI unit of work is joule.
(iii) Work has both, magnitude and direction.
(iv) Work is said to be done if an object is displaced when a force acts on it.

(a) (i) and (ii) (b) (ii) and (iii)
(c) (ii) and (iv) (d) (i), (ii), (iii) and (iv)

2. Four forces of equal magnitude are acting on an object as shown in figure. Which of the following forces does the least work?



(a) P (b) Q
(c) R (d) S

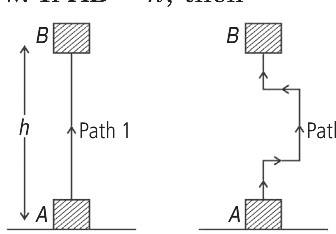
3. Two bodies have their masses $m_1/m_2 = 3$ and their kinetic energies $\frac{K.E_1}{K.E_2} = \frac{1}{3}$. The ratio of their velocities are

(a) 1 : 1 (b) 1 : 2
(c) 1 : 3 (d) 2 : 3

4. A man of weight 60 kg wt takes a body of mass 15 kg at a height 10 m on a building in 3 minutes. The efficiency of man is

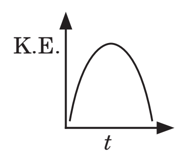
(a) 10% (b) 20%
(c) 30% (d) 40%

5. A block is raised from position A to B by taking two different paths as shown in the figure given below. If $AB = h$, then



(a) the work done on the block is greater in case of path 1 than in case of path 2
(b) the work done on the block is greater in case of path 2 than in case of path 1
(c) the work done on the block is same for both paths
(d) the work done cannot be determined.

6. A cricket ball is projected vertically upward such that it returns back to the thrower. The variation in kinetic energy with time is best represented by

(a)


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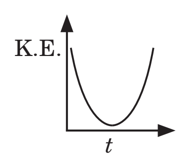

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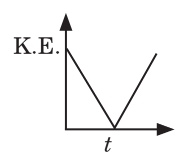

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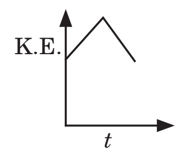
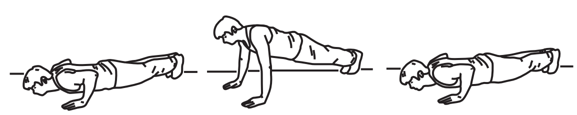


7. An athlete keeps fit by doing press-ups.



He applies a force of 300 N as he pushes up a distance of 0.5 m. He does 10 press-ups in 30 s. What is his average power output in 30 s?

(a) 5 W (b) 50 W
(c) 150 W (d) 1500 W

8. When an ideal simple pendulum oscillates between the extreme points P and Q, there is continuous (i) of potential energy and kinetic energy. The potential energy depends on the choice of (ii). Force acting on the bob of the pendulum is maximum at (iii) , and minimum at (iv).

	(i)	(ii)	(iii)	(iv)
(a)	Dissipation	reference level	mid point	extremes
(b)	Dissipation	mass	mid point	extremes
(c)	Exchange	reference level	extremes	mid point
(d)	Exchange	velocity	extremes	mid point

9. Which of the following statements is/are incorrect?

(i) Work and energy have different units.

(ii) Two bodies of unequal masses have equal acceleration at any instant of time when they are dropped from a cliff.

(iii) When an aeroplane takes off, the work done by its weight is positive.

(iv) When the speed of a particle is doubled, the ratio of its momentum and kinetic energy gets halved.

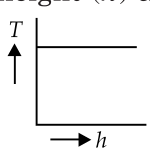
(a) (ii) only (b) (i) and (iii) only
(c) (i), (ii) and (iv) only (d) (i), (ii), (iii) and (iv)

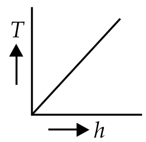
10.

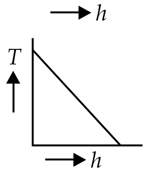
Column-I	Column-II
(P) Force	1. kg m^2s^{-2}
(Q) Work	2. kg m s^{-1}
(R) Momentum	3. kg m^2 s^{-3}
(S) Power	4. kg m s^{-2}

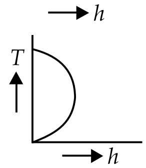
(a) P-4, Q-1, R-2, S-3 (b) P-3, Q-2, R-4, S-1
(c) P-3, Q-4, R-2, S-1 (d) P-1, Q-4, R-3, S-2

11. Which of the following graph best represents the total energy (T) of a freely falling body and its height (h) above the ground?

(a) 

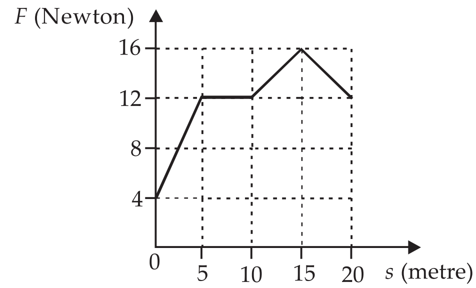
(b) 

(c) 

(d) 

12. A body rolls down on inclined plane, it has
(a) only kinetic energy
(b) only potential energy
(c) both kinetic energy and potential energy
(d) neither kinetic energy nor potential energy

13. Figure shows the frictional force versus displacement for a particle in motion. The loss of kinetic energy (work done against friction) in travelling over s = 0 to s = 20 m will be



(a) 80 J (b) 160 J
(c) 240 J (d) 24 J

14. When the momentum of a body is increased by 100%, its K.E. increases by
(a) 100% (b) 200%
(c) 300% (d) 400%

15. A rocket rises up in air due to the force generated by the fuel. The work done by the
(a) fuel is negative work and by force of gravity is positive work
(b) fuel is positive work and by force of gravity is negative work
(c) both fuel and force of gravity do positive work
(d) both fuel and force of gravity do negative work.

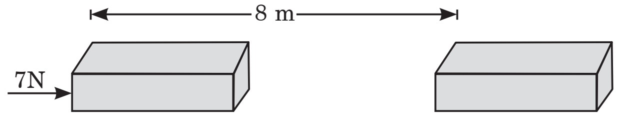
16. Two masses of 1 g and 4 g are moving with equal linear momenta. The ratio of their kinetic energies is :
(a) 4 : 1 (b) $\sqrt{2}:1$
(c) 1 : 2 (d) 1 : 16

17. At sea level, a nitrogen molecule in air has an average translational kinetic energy of 6.2×10^{-21} J. Its mass is 4.7×10^{-26} kg. If the molecule shoots up straight without resistance, it will rise to a height of
(a) 1.35 km (b) 13.5 km
(c) 135 km (d) 1350 km

18. A rod of mass m and length l is lying on a horizontal table. Work done in making it stand on one end will be
(a) mgl (b) $mgl/2$
(c) $mgl/4$ (d) $2mgl$

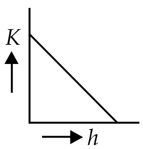
19. The power of a water pump is 2 kW. If g = 10 m/s^2, the amount of water it can raise in 1 min to a height of 10 m is
(a) 2000 litre (b) 1000 litre
(c) 100 litre (d) 1200 litre

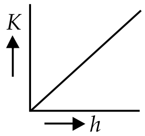
20. A force of 7 N acts on an object. The displacement is, say 8 m, in the direction of the force. Let us take it that the force acts on the object throughout the displacement. What is the work done in this case?

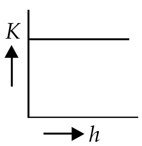


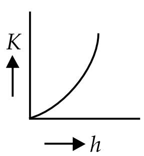
(a) 56 J (b) 80 J
(c) 90 J (d) 100 J

21. Which of the following graph best represents the kinetic energy (K.E) of a freely falling body and its height h above the ground?

(a) 

(b) 

(c) 

(d) 

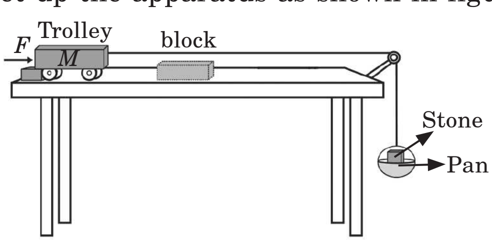
22. In which of the following cases is the potential energy of a spring minimum?
(a) When it is compressed.
(b) When it is extended.
(c) When it is at its natural length.
(d) When it is at its natural length but is kept at a height h above the ground.

23.

Column-I		**Column-II**
(P) Kinetic energy	1.	mgh
(Q) Power	2.	$\frac{1}{2}mv^2$
(R) Potential energy	3.	mv
(S) Momentum	4.	W/t

(a) P-2, Q-4, R-1, S-3 (b) P-3, Q-2, R-4, S-1
(c) P-3, Q-4, R-2, S-1 (d) P-1, Q-4, R-3, S-2

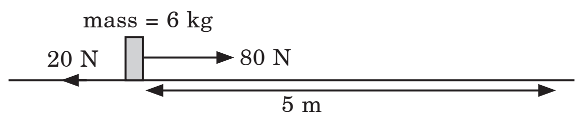
24. Set up the apparatus as shown in figure.



When stone is placed in the pan, trolley moves forward. If you have two stones of masses 10 kg and 5 kg, then in which of the following cases, the block placed in path of trolley suffers maximum displacement?
(Assume that trolley stops after hitting the block.)
(a) When stone of 5 kg is placed in the pan.
(b) When stone of 10 kg is placed in the pan.
(c) When both the stone are placed in the pan.
(d) When the pan is empty.

25. The speed of a motor bike decreases by 4 times. Its kinetic energy will decrease by
(a) four times (b) eight times
(c) sixteen times (d) thirty two times.

26. A man exerts a 80 N force on a load of mass 6 kg along a rough surface. The frictional force acting on the load is 20 N.



Given that the mass moves 5 m horizontally in 30 s, what is the useful power developed by the man?
(a) 10 W (b) 13 W
(c) 78 W (d) 300 W

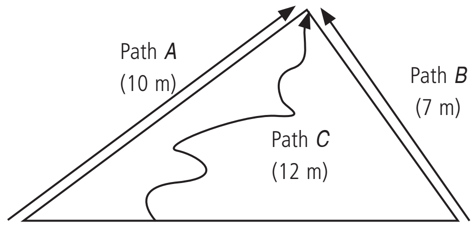
27. The work required to be done to stop a car of 2500 kg moving at a velocity of 90 km h^{-1} is
(a) –781.25 kJ (b) 781.25 kJ
(c) 2250 kJ (d) –2250 kJ.

28. A rocket rises up vertically. What happens to its potential energy?
(a) It increases.
(b) It initially increases then decreases.
(c) It initially decreases then increases.
(d) It increases, till it becomes maximum.

29. A car is accelerating up a slope. What are the changes in its kinetic energy and potential energy as it is moving up the slope?

	Kinetic energy	**Potential energy**
(a)	decrease	decrease
(b)	decrease	increase
(c)	increase	increase
(d)	increase	decrease

30. There are three paths A, B and C leading to the top of the hill as shown. Assuming that the friction of the ground is negligible, which of the following statements is true?

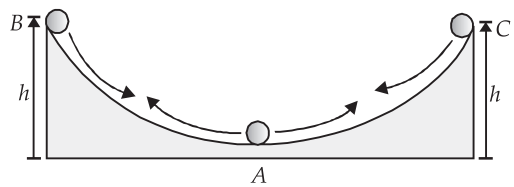


(a) All three paths require the same amount of energy to reach the top.
(b) Path B requires the least energy to reach the top.
(c) Path C requires most energy to reach the top.
(d) Path B requires more energy than path A to reach the top.

Case Based MCQs

Case I : Read the passage given below and answer the following questions from 31 to 33.

Figure shows a watch glass embedded in clay. A tiny spherical ball is placed at the edge B at a height h above the centre A.



31. The kinetic energy of ball, when it reaches at point A is
(a) zero
(b) maximum
(c) minimum
(d) can't say.

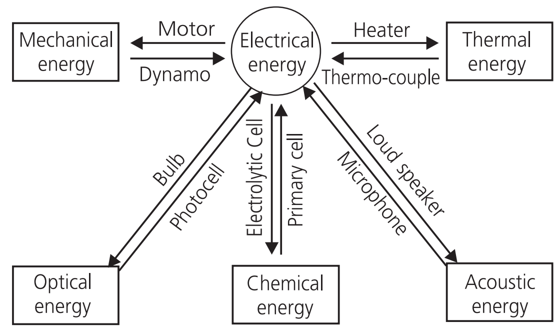
32. The ball comes to rest because of
(a) frictional force
(b) gravitational force
(c) both (a) and (b)
(d) none of these.

33. The energy possessed by ball at point C is
(a) potential energy
(b) kinetic energy
(c) both potential and kinetic energy
(d) heat energy.

Case II : Read the passage given below and answer the following questions from 34 to 37.

The principle of conservation of energy states that the energy in a system can neither be created nor be destroyed. It can only be transformed from one form to another, but total energy of the system remains constant.

Conservation of electrical energy to various forms or vice versa along with devices is illustrated in the figure given below.



34. Water stored in a dam possesses
(a) no energy
(b) electrical energy
(c) kinetic energy
(d) potential energy.

35. A battery lights a bulb. Describe the energy changes involved in the process.
(a) Chemical energy $\rightarrow$ Light energy $\rightarrow$ Electrical energy
(b) Electrical energy $\rightarrow$ Chemical energy $\rightarrow$ Electrical energy
(c) Chemical energy $\rightarrow$ Electrical energy $\rightarrow$ Light energy
(d) None of these.

36. Name a machine that transforms muscular energy into useful mechanical work.
(a) Amicrophone
(b) Bicycle
(c) Electric torch
(d) An electric bell

37. A body is falling from a height h. After it has fallen a height $\frac{h}{2}$, it will possess
(a) only potential energy
(b) only kinetic energy
(c) half potential and half kinetic energy
(d) more kinetic and less potential energy.

Case III : Read the passage given below and answer the following questions from 38 to 40.

An elevator weighing 500 kg is to be lifted up at a constant velocity of 0.4 m s^{-1}. For this purpose a motor of required horse power is used.

38. The power of motor is

(a) 1940 W (b) 1950 W

(c) 1960 W (d) 1970 W

39. The acceleration due to gravity in case of upward motion is

(a) 9.8 m s^{-2} (b) –9.8 m s^{-2}

(c) 8.9 m s^{-2} (d) –8.9 m s^{-2}

40. The power of motor in hp is

(a) 2.33 (b) 2.43

(c) 2.53 (d) 2.63

Assertion & Reasoning Based MCQs

For question numbers 41-50, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Both assertion and reason are true, and reason is correct explanation of the assertion.

(b) Both assertion and reason are true, but reason is not the correct explanation of the assertion.

(c) Assertion is true, but reason is false.

(d) Assertion is false, but reason is true.

41. Assertion : Work done by or against gravitational force in moving a body from one point to another is independent of the actual path followed between the two points.

Reason : Gravitational forces are conservative forces.

42. Assertion : *A* crane *P* lifts a car upto a certain height in 1 min. Another crane *Q* lifts the same car upto the same height in 2 min. Then crane *P* consumes two times more fuel than crane *Q*.

Reason : Crane *P* supplies two times more power than crane *Q*.

43. Assertion : No work is done when a woman carrying a load on her head, walks on a level road with a uniform velocity.

Reason : No work is done if force is perpendicular to the direction of displacement.

44. Assertion : Distance covered in stopping a moving body is equal to kinetic energy/force applied.

Reason : Work done in brining a body to just stop must be equal to the kinetic energy of the body.

45. Assertion : Work done by the gravitational force through a certain distance is constant irrespective of the fact that the body has a uniform or accelerated motion.

Reason : Gravitational force is a conservative force.

46. Assertion : According to law of conservation of mechanical energy, change in potential energy is equal and opposite to the change in kinetic energy.

Reason : Mechanical energy is not a conserved quantity.

47. Assertion : Graph between potential energy of a spring versus the extension or compression of the spring is a straight line.

Reason : Potential energy of a stretched or compressed spring, is directly proportional to square of extension or compression.

48. Assertion : The kinetic energy, with any reference, must be positive.

Reason : It is because, in the expression for kinetic energy, the velocity appears with power 2 and mass is a scalar quantity.

49. Assertion : The change in kinetic energy of a particle is equal to the work done on it by the net force.

Reason : Change in kinetic energy of particle is equal to the work done only in case of a system of one particle.

50. Assertion : Work done against or by the force of friction in moving a body around a closed loop is zero.

Reason : Work done depends upon the nature of force.

SUBJECTIVE TYPE QUESTIONS

Very Short Answer Type Questions (VSA)

1. By how much will the kinetic energy of a body increase if its speed is doubled?

2. How is energy stored in a clock?

3. Explain by an example that a body may possess energy when it is not in motion.

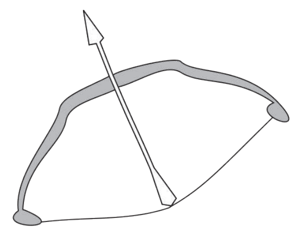
4. What is the difference between potential energy and kinetic energy?

5. A cell converts one form of energy into another. Name the two forms.

6. Define the commercial unit of energy.

7. A student pushes against a wall with a force of 200 N. How much work does he do in 10 minutes?

8. In the figure given below, when the arrow is released from a stretched bow, the arrow moves in air from where does the arrow receive kinetic energy?



9. Mention a situation in which an object gets displaced in the absence of a force acting on it.

10. A porter carrying load on his head moves up a stair. Is he doing work? Explain.

Short Answer Type Questions (SA-I)

11. A nail becomes warm it is hammered into a plank. Explain why?

12. Why do some engines require fuels like petrol and diesel?

13. A force acts on a body of mass 10 kg. If the velocity of the body changes from 5 m s^{-1} to 3 m s^{-1}, then what is the work done by the force on the body?

14. A saw becomes warm when it is used to cut a log of wood. Why?

15. What is gravitational potential energy?

16. The casing of a rocket in flight burns up due to friction. At whose expense is the heat energy required for burning obtained? The rocket or the atmosphere?

17. When a constant force is applied to a body moving with constant acceleration, is the power of the force constant? If not, how would force have to vary with speed for the power to be constant?

18. A pendulum, swinging back and forth, rises at the end of its swing to a position 15 cm higher than its lowest point. How fast is it going at the lowest point?

19. If an electric iron of 1200 W is used for 30 minutes everyday, find electric energy consumed in the month of April.

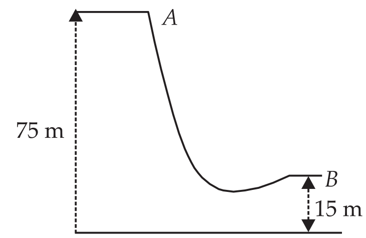
20. In a tug of war, one team wins and the other team loses. Which team does positive work and which one does negative work? Justify your answer.

Short Answer Type Questions (SA-II)

21. A pump is required to lift 1000 kg of water per minute from a well 12 m deep and eject it with a speed of 20 m s^{-1}. How much work is done per second in lifting the water and what must be, the power output of the pump?

22. A child pulls a toy car through a distance of 10 metres on a horizontal floor. The string held in child's hand makes an angle of 60° with the horizontal surface. If the force applied by the child be 10 N, calculate the work done by the child in pulling the toy car.

23. The diagram shows a ski jump. A skier weighing 60 kg f stands at A. He moves from A to B and takes off for his jump at B.

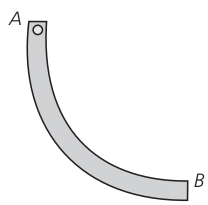


(a) Calculate the change in the gravitational potential energy of the skier between A and B.

(b) If 75% of the energy in part (a) becomes kinetic energy at B, calculate the speed at which the skier arrives at B.

24. Ram weighs 40 kg and takes 60 seconds to climb a hill 50 m high. Shyam also weighs 40 kg and takes 50 seconds to climb the same hill. Who is more powerful? (g = 10 m s^{-2}).

25. A ball moves along a curved path of radius 5 m as shown in figure. It starts from point A and reaches the point B. Calculate the normal force that acts on the ball at B assuming that there is no friction between the ball and the surface of contact.



26. Four men lift a 250 kg box to a height of 1 m and hold it without raising or lowering it.

(a) How much work is done by the men in lifting the box?

(b) How much work do they do in just holding it?

(c) Why do they get tired while holding it? (g = 10 m s^{-2})

27. A bullet loses $\frac{1}{10}$th of its speed in passing through a wooden plank. Find the least number of such planks required to stop the bullet.

28. If an electric bulb of 100 watt is lighted for 2 hours daily, how much electrical energy would be consumed per day? Also find the cost if cost per unit is Rs. 2.

29. A ball is dropped from a height of 10 m. If the energy of the ball reduces by 40% after striking the ground, how much high can the ball bounce back? (g = 10 m/s^2)

30. Is it possible that an object is in the state of accelerated motion due to external force acting on it, but no work is being done by the force. Explain it with an example.

31. A boy is moving on a straight road against a frictional force of 5 N. After travelling a distance of 1.5 km, he forgot the correct path at a round about, figure of radius 100 m. However, he moves on the circular path for one and half cycle and then he moves forward upto 2.0 km. Calculate the work done by him.

Long Answer Type Questions (LA)

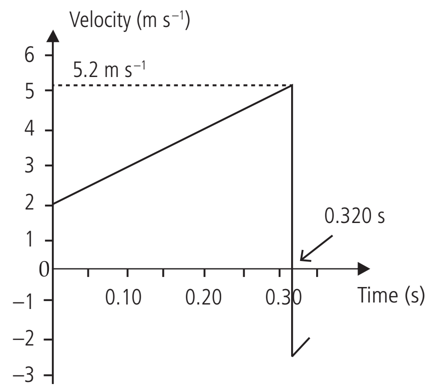
32. An object of mass 20 kg is dropped from a height of 4 m. Fill in the blanks in the following table by computing the potential energy and kinetic energy in each case. Use g = 10 m/s^2.

S. No.	Height at which object is located (m)	Potential energy, E_P (J)	Kinetic energy, E_K (J)	Total mechanical energy, (J)
(i)	4	- - - -	- - - -	- - - -
(ii)	3	- - - -	- - - -	- - - -
(iii)	2	- - - -	- - - -	- - - -
(iv)	1	- - - -	- - - -	- - - -
(v)	Just above the ground	- - - -	- - - -	- - - -

Also discuss the observation made from the data entered in table.

33. Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?

34. A ball is thrown down from a certain height and allowed to fall downward. Figure shows how the velocity of the ball varies with time t. Air resistance may be ignored.



The ball has mass 0.23 kg and leaves the thrower's hand at t = 0. It hits the ground at t = 0.320 s and rebounds with 50% of the speed with which it hit the ground.

(a) State the maximum velocity of the ball.

(b) Show that the acceleration of free fall is 10 m s^{-2}.

(c) Determine the velocity of the ball just after it rebounds.

(d) Calculate the loss of kinetic energy of the ball as it hits the ground and rebounds.

35. Prove that mechanical energy of a freely falling body is conserved.

36. A running man has half the kinetic energy that a boy of half his mass has. The man speeds up by 1 m s^{-1} and then has the same kinetic energy as that of boy. What were the original speeds of the man and boy?

ANSWERS

OBJECTIVE TYPE QUESTIONS

1. (c) : Work done by a force can be negative, positive or zero, depending upon the direction of force applied.

Work is a scalar quantity. It has magnitude but no direction.

2. (b) : There is no work done when the force and the displacement are perpendicular to each other.

The maximum work is done when the force applied is parallel to the direction of movement.

3. (c) : As $\frac{K.E._1}{K.E._2} = \frac{1}{3}$ or $\frac{1}{3} = \frac{\frac{1}{2}m_1v_1^2}{\frac{1}{2}m_2v_2^2}$ $\quad (\because K.E. = \frac{1}{2}mv^2)$

or $\left(\frac{m_1}{m_2}\right)\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{3}$

Since $m_1/m_2 = 3$, we have $3\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{3}$

or $\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{9}$ or $\frac{v_1}{v_2} = \frac{1}{3} = 1:3$

4. (b) : Efficiency, $\eta = \frac{\text{Useful work}}{\text{Total work}} = \frac{15gh}{(15+60)gh}$

$$= \frac{15}{75} = \frac{1}{5} = 20\%$$

5. (c) : Work done by gravity in moving an object from one place to another depends only on the initial and final positions, not on the path taken. In both the situations, work done on the block is same *i.e.*, mgh.

6. (c) : When the ball rises up its K.E. decreases, till it becomes zero. On falling down its K.E. increases.

7. (b) : Average power, $P = \frac{W}{t}$

$P = \frac{300\text{ N} \times 0.5\text{ m} \times 10}{30\text{ s}} = 50\text{ W}$

8. (c)

9. (b) : (i) Work and energy have same units *i.e.*, joule.

(ii) Yes, they have equal acceleration *i.e.*, acceleration due to gravity.

(iii) When an aeroplane takes off weight is acting downwards and displacement is upward so negative work is done by its weight.

(iv) Ratio of momentum (p) and kinetic energy (K)

$$\frac{p}{K} = \frac{mv}{\left(\frac{1}{2}mv^2\right)} = \frac{2}{v}$$

$\Rightarrow \frac{p}{K} \propto \frac{1}{v}$

i.e., when the speed gets doubled, this ratio becomes half.

10. (a) : P – 4, Q – 1, R – 2, S – 3

11. (a) : Total energy remains the same.

12. (c)

13. (c) : Work done = total area enclosed by *F-s* graph on *s*-axis.

Work done = $\frac{1}{2}(5)(4+12)+(5)(12)+\frac{1}{2}(5)(12+16)$
$+\frac{1}{2}(5)(16+12)=240\text{J}$

14. (c) : $\text{K.E.}=\frac{p^2}{2m}$

p is increased by 100% *i.e.*, $2p$

$\text{K.E.}=\frac{(2p)^2}{2m}=\frac{p^2}{2m}\times 4$

∴ K.E. increases by 300%

15. (b) : As the rocket moves in the direction of force generated by fuel, therefore it is positive work. As the force of gravity acts in the direction opposite to the displacement, therefore, it is negative work.

16. (a) : As $\frac{K_1}{K_2}=\frac{p^2/2m_1}{p^2/2m_2}=\frac{m_2}{m_1}=\frac{4}{1}, K_1:K_2=4:1$

17. (b) : KE of the molecule is converted into its PE, *i.e.*, $mgh = 6.2\times 10^{-21}$ J

or $h=\frac{6.2\times 10^{-21}}{(4.7\times 10^{-26})\times 9.8}=13.5$ km

18. (b) : Work done = final PE. – initial PE.
$= mg\,(l/2) - 0 = mgl/2$

(as when the rod is standing on one end, its centre of gravity is at a distance $l/2$ from the table and when it is lying on the table, its CG is on the table, *i.e.*, at zero distance from the table)

19. (d) : $P=\frac{W}{t}=\frac{mgh}{t}$ or $m=\frac{Pt}{gh}=\frac{(2000\text{ W})\times(60\text{ s})}{(10\text{ m/s}^2)(10\text{ m})}$

= 1200 kg = 1200 litre (as mass of 1 litre of water is kg)

20. (a) : Here, force acting on the object, $F = 7$ N
displacement in the direction of the force, $s = 8$ m
Since F acts on the object throughout the displacement, it is constant.
Work done by the force, *i.e.*,
$W = F\times s = 7\text{ N}\times 8\text{ m} = 56$ J

21. (a) : $mgh = K + mgh'$

$\Rightarrow h' = h - \frac{K}{mg}$

22. (c)

23. (a) : P – 2, Q – 4, R – 1, S – 3

24. (c) : When you place stone in the pan, it exerts a forward pull on the trolley by virtue of its height. The trolley moves forward and hits the block. During collision, the trolley transfer its momentum to the block and block gets displaced. Note that the energy in the system is provided by the mass hanging in the pan. As we knows, total energy of the system is conserved.
Loss of P.E. of the stone in pan = Gain in K.E. of the trolley

$mgh = \frac{1}{2}Mv'^2$

Here, m is the mass of stone and M is the mass of trolley.

And also, $\frac{1}{2}Mv^2$ = Work done by the block
= Force × displacement

∵ Displacement of block ∝ mass of stone in the pan.
Hence, option (c) is correct.

25. (c) : Say the speed of motor bike of mass m is v.

So, its kinetic energy $\text{K.E.}_1=\frac{1}{2}mv^2$

When its speed is decreased by 4 times then its kinetic energy K.E._2

$=\frac{1}{2}m\left(\frac{v}{4}\right)^2=\frac{1}{16}\left(\frac{1}{2}mv^2\right)=\frac{1}{16}\text{K.E.}_1$

∴ Its kinetic energy will decrease by sixteen times.

26. (a) : Total displacement of the load = 5 m
Work done by man on the load, $W_1 = 80\times 5$ N m
= 400 J
Work done by friction on the load, $W_2 = -20\times 5$ N m
= –100 J
(since frictional force acts in opposite direction of motion).
Useful work done by man, $W = W_1 + W_2$
= (400 – 100) J = 300 J

Useful power developed by man, $P=\frac{W}{t}=\frac{300}{30}\text{W} = 10$ W

27. (a) : Here, mass of the car, $m = 2500$ kg
Initial velocity of the car, $u = 90$ km h^{-1}

$=\left(90\times\frac{5}{18}\right)\text{m s}^{-1} = 25\text{ m s}^{-1}$

Initial kinetic energy, $\text{K.E.}_i=\frac{1}{2}mu^2$

$=\frac{1}{2}\times 2500\times(25)^2$

= 781,250 J = 781.25 kJ

Final kinetic energy, $K.E._f = \frac{1}{2}mv^2 = 0$ $(\because v = 0)$

Work required to stop the car

$= $ change in kinetic energy of car

$= K.E._f - K.E._i = 0 - 781.25$ kJ

$= -781.25$ kJ

28. (d) : P.E. goes on increasing till the rocket stops rising.

29. (c) : The key words in this question are "accelerating" and "up a slope". "Accelerating" indicates that the car is increasing speed and thus the KE must increase. "Up a slope" indicates that the car is increasing height and thus the PE must increase. The energy to increase KE and PE come from the fuel used in the car to accelerate. It is important to note that here work is done by the external agent, *i.e.*, energy is supplied to the system continuously.

30. (a) : The work done to reach the top of the hill is the same for all three routes when there is no friction along the ways. The height achieved by the three routes is the same.

31. (b) : When the ball reaches at A, its entire potential energy will be converted into kinetic energy, since height is zero.

32. (c) : The forces which oppose the motion of ball are frictional and gravitational.

33. (a) : The energy possessed by the ball at point C is potential energy, because of its height h from ground.

34. (d) : Water stored in a dam possesses potential energy as it is stored at a certain height from the ground level.

35. (c) : A battery converts chemical energy into electrical energy. This electrical energy is converted into light energy as the bulb is lighted up, *i.e.*, the sequence of energy changes is as follows :

Chemical energy $\rightarrow$ Electrical energy $\rightarrow$ Light energy.

36. (b) : Bicycle form molecular energy into mechanical work.

37. (c) : At a height h, PE = mgh

At a height $h/2$, PE = $mg\left(\frac{h}{2}\right) = \frac{1}{2}mgh$

The rest $\left(\frac{1}{2}mgh\right)$ of the PE is converted into KE. Thus, at a height $(h/2)$, PE = KE = $\frac{1}{2}mgh$.

38. (c) : Here, $m = 500$ kg

$v = 0.4$ m s^{-1}

$\therefore$ Power = Force $\times$ Velocity = $m \times g \times v$

$= 500 \times 9.8 \times 0.4 = 1960$ Watt

39. (b) : Since the lift is moving in upward direction, the value of acceleration due to gravity will be taken as negative.

40. (d) : 1 hp = 746 W

So, power $= \frac{1960}{746} = 2.63$ hp

41. (a) : From, definition, work done in moving a body against a conservative force is independent of the path followed.

42. (a) : Since, power is inversely proportional to time, crane P supplies more power.

43. (a) : Work done, $W = \vec{F}\cdot d\vec{s} = F\,ds\cos\theta = 0$, when $\theta = 90°$. No work is done when force is normal to the displacement.

44. (a) : Under ideal situation when no energy is dissipated due to friction etc., total energy is used to stop the body. Thus work done = force $\times$ distance and

distance = kinetic energy/force.

45. (b) : Work done by the gravitational force is mgh.

46. (c) : For conservative forces the sum of kinetic and potential energies at any point remains constant throughout the motion. It does not depend upon time. This is known as law of conservation of mechanical energy.

According to this rule, Kinetic energy + Potential energy = E = constant

47. (d) : Potential energy, $(U) = \frac{1}{2}kx^2$ *i.e.* $U \propto x^2$

This is an equation of parabola, so graph between U and x is a parabola, not straight line.

48. (a)

49. (c) : Thus work done by a force acting on a body is equal to change in kinetic energy of the body. This is true for a system containing any number of particles.

50. (d) : Work done W during the motion of a body over a closed path depends upon whether the force doing work is conservative or non-conservative in nature. For conservative forces such as gravitational or electrostatic force, W is zero. For non-conservative forces such as frictional force, some work is done and thus $W \neq 0$.

SUBJECTIVE TYPE QUESTIONS

1. The kinetic energy (E_k) of the body will become four times as $E_k = \frac{1}{2}mv^2$ or $E_k \propto v^2$.

2. The energy stored in the clock is in the form of elastic potential energy of its coiled spring. The spring is coiled by winding the clock.

3. A body resting at a height h from the ground possesses gravitational potential energy (E_p) which is given by $E_p = mgh$ where mg is the weight of the body.

4. Potential energy of a body is by virtue of its position or shape whereas kinetic energy of a body is by virtue of its motion.

5. A cell converts chemical energy into electrical energy.

6. The commercial unit of energy is kW h (kilowatt hour). 1 kW h is the energy used in one hour at the rate of 1000 J s^{-1}.
1 kW h = 1kW × 1 h

7. No work is done as there is no displacement.

i.e., $W = F \times s$

$W = 200 \text{ N} \times 0 \Rightarrow W = 0$

8. The potential energy of a stretched bow is converted into the kinetic energy of the arrow.

9. When the object moves with a uniform velocity, it will suffer displacement even in the absence of a force.

10. Yes, he does work against gravity because the porter lifts the load vertically to the upstairs. Force has to be applied on the load against the force of gravitation.

11. The potential energy of the hammer is transferred to the nail. A major part of this energy is changed into kinetic energy as the nail moves into the plank and the rest is converted into heat. It is due to this heat that the nail becomes warm.

12. Internal combustion heat engines use the chemical energy of fossil fuels (petrol and diesel) for their operation. These engines first convert the chemical energy of the fuels into heat energy which is later on converted into mechanical energy.

13. Here, mass, $m = 10$ kg

Initial velocity, $u = 5 \text{ m s}^{-1}$

Final velocity, $v = 3 \text{ m s}^{-1}$

∴ Work done on the body = Change in kinetic energy

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

$$= \frac{1}{2}m(v^2 - u^2) = \frac{1}{2} \times 10(9 - 25) = -80 \text{ J}$$

14. A part of the kinetic energy of the saw is converted into heat as it cuts the log of wood. It is due to this heat that saw becomes warm. Thus, kinetic energy of saw changes into heat.

15. The gravitational potential energy of an object at a point above the ground is defined as the work done in raising the object from the ground to that point against gravity.

16. When the casing burn up, its mass decreases due to this total energy of the rocket decreases because total energy of rocket in flight depends on its mass. Hence, heat energy required for burning is obtained from the rocket itself and not from the atmosphere.

17. We know that power (P) = force (F) × velocity (v). Since the body is moving with acceleration, v changes and as a result of that P also changes, F being constant. For P to be constant, Fv = constant or $F \propto 1/v$. Thus, as v increases, F should decrease to keep P constant.

18. The gravitational potential energy it loses turns into kinetic energy, so

$(E_g)_{top} = (E_k)_{bottom}$

$$mgh_{top} = \frac{1}{2}mv^2_{bottom}$$

$$v_{bottom} = \sqrt{2gh} = \sqrt{2(9.8 \text{ m s}^{-2})(0.15 \text{ m})} = 1.7 \text{ m s}^{-1}$$

19. We are given that power of the electric iron,

$P = 1200 \text{ W} = 1.2$ kW

Total time for which the electric iron is used in the month of April (30 days) = (30 min/day) (30 day)

$$= \left(\frac{1}{2}\text{h/day}\right)(30 \text{ day}) = 15 \text{ h}$$

Energy consumed, $E = Pt$ = (1.2 kW) (15 h) = 18 kWh

(as P = work done/time = E/t)

20. Winning team does positive work on the rope because the force applied by the team on the rope acts in the direction of the displacement of the rope. On the other hand, losing team does negative work as the force applied by the team on the rope acts in the direction opposite to the direction of the displacement of the rope.

21. When 1000 kg of water is lifted from a 12.0 m deep well

Work required per minute is = mgh

$= 1.2 \times 10^5 \text{ J min}^{-1}$

Work required per second is

$$= \frac{1.2 \times 10^5}{60} = 2000 \text{ J s}^{-1}$$

Kinetic energy gained by the water per second is

$$=\frac{1}{2}mv^2=\frac{1}{2}\times\frac{1000}{60}\times(20)^2=3333.33\ \text{J s}^{-1}$$

Total work required per second by the pump or power output of pump is

$= 2000 + 3333.33 = 5333.33\ \text{J s}^{-1}$

22. In this case, as the applied force and the displacement are not in same direction the work done is given by the formula.

$W = Fs\cos\theta$

Here, force $F = 10$ N

Magnitude of the displacement, $s = 10$ m

$\theta = 60°$

So substituting these values in the given formula, we get

$W = 10 \times 10 \cos 60°$

$$W=10\times10\times\frac{1}{2}=50\ \text{joule}\quad\left(\because\ \cos60°=\frac{1}{2}\right)$$

23. (a) Change in gravitational potential energy

$= 60\ \text{kg} \times 10\ \text{m s}^{-2} \times (75\ \text{m} - 15\ \text{m})$

$= 600 \times 60\ \text{J} = 36000\ \text{J}$

(b) Kinetic energy at $B=\frac{75}{100}\times36000\ \text{J}=27000\ \text{J}$

Thus, $\frac{1}{2}mv^2=27000\ \text{J}$

$$v=\sqrt{\frac{2\times27000\ \text{J}}{m}}$$

$$=\sqrt{\frac{2\times27000\ \text{kg m}^2\ \text{s}^{-2}}{60\ \text{kg}}}$$

$$=\sqrt{900\ \text{m}^2\ \text{s}^{-2}}=30\ \text{m s}^{-1}$$

24. Mass of Ram, $m = 40$ kg

$\therefore$ Weight of Ram $= mg = 40\ \text{kg} \times 10\ \text{m s}^{-2} = 400$ N

Distance travelled, $h = 50$ m

$\therefore$ Work done by Ram,

$W = mgh = 400\ \text{N} \times 50\ \text{m} = 20{,}000$ J

Time taken by Ram, $t = 60$ s

$$\therefore\ \text{Power of Ram}=\frac{W}{t}=\frac{20{,}000\ \text{J}}{60\ \text{s}}=333.33\ \text{W}$$

Weight of Shyam $= mg = 40\ \text{kg} \times 10\ \text{m s}^{-2} = 400$ N

Distance travelled, $h = 50$ m

$\therefore$ Work done by Shyam,

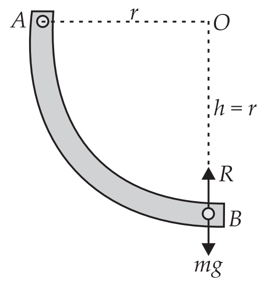
$W = mgh = 400\ \text{N} \times 50\ \text{m} = 20{,}000$ J

Time taken, $t = 50$ s

$$\therefore\ \text{Power of Shyam}=\frac{W}{t}=\frac{20{,}000\ \text{J}}{50\ \text{s}}=400\ \text{W}$$

Shyam is more powerful than Ram.

25. As it is clear from figure.



P.E. of ball at A = K.E. of ball at B

$$mgh=\frac{1}{2}mv^2\quad\Rightarrow\quad v^2=2gh=2gr$$

Centripetal force on the ball at B

$$F=\frac{mv^2}{r}=\frac{m}{r}(2gr)=2mg$$

If R is normal force of reaction acting on the ball in the upward direction at B, then

$F = R - W$ or $R = F + W = 2mg + mg = 3mg$

26. Mass of the box, $m = 250$ kg

Height upto which it is raised, $h = 1$ m

(a) Work done by the men in lifting the box

$= F \times s = 250 \times 10 \times 1$ J (Here $F = mg$, $s = h$)

$= 2500$ J

(b) In just holding the box, there is no displacement, so no work is done.

(c) In order to hold the box at a certain height, men are applying a force which is equal and opposite to the gravitational force acting on the box. While applying the force, muscular effort is involved. So, men get tired while holding it.

27. Let u be the initial velocity of the bullet and let s be the thickness of one plank. The velocity of the bullet when it leaves the plank is $9u/10$. Hence

$$\left(\frac{9u}{10}\right)^2-u^2=2as\quad\text{or}\quad 2as=-\frac{19}{100}u^2\qquad\ldots\text{(i)}$$

If n is the number of planks required to stop the bullet, then (since $v = 0$) we have

$0 - u^2 = (2as)n$

or $$=-\frac{u^2}{2as}=\frac{100}{19}=5.3\qquad\text{(using eqn. (i))}$$

At least six planks are required to stop the bullet.

28. Power of electric bulb (P) = 100 W

Duration of time used for (t) = 2 h

Electrical energy consumed (E) = ?

We know, $P = \frac{E}{t}$ or $E = P \times t$

Putting the given values in the above formula, we get

E = 100 W × 2 h = 200 W h

= 0.2 kW h = 0.2 unit (∵ 1 kW h = 1 unit)

Cost of 1 unit = Rs. 2

∴ Cost of 0.2 unit = Rs. 2 × 0.2 = Rs. 0.40 or 40 paise.

Thus, the cost of using 100 W electric bulb for 2 hours is Rs. 0.40 or 40 paise.

29. Initial (potential) energy of the ball

$= mgh = m \times 10 \times 10 = 100\ m$

Since the energy of the ball reduces by 40% on striking the ground, energy left with the ball

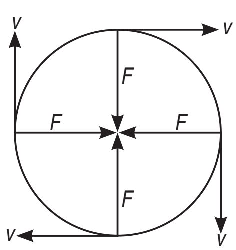
$= \left(\frac{60}{100}\right)(100\ m) = 60\ m$

It is this energy (60 m) which enables the ball to bounce back to a height h'. Clearly.

$mgh' = (60\ m)$

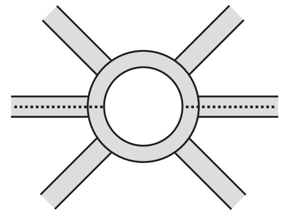
or $h' = \frac{60\ m}{mg} = \frac{60\ m}{m \times 10} = 6$ m

30. Yes, this is possible if the external force (F) and the displacement of the object in a state of constant acceleration are perpendicular to each other.



Example : An object moves with uniform speed (v) in a circular path of radius (r), due to a force (called centripetal force, F) acting on it along its radius towards the centre. The object has a constant acceleration (v^2/r) which also acts along the radius towards the centre. In this case, F and displacement (which is in the direction v) are always perpendicular to each other as shown in figure. In short, centripetal force (due to which an object is in a state of constant acceleration towards the centre while moving in a circular path) does no work.

31. Frictional force, F = 5 N



Total distance covered by the body,

s = 1.5 km + (2π × 100 m + π × 100 m) + 2.0 km

= 1500 m + 942 m + 2000 m = 4442 m

Work done, $W = Fs$ = (5 N) (4442 m) = 22210 J

Note : We should take the distance covered while moving in the circular path as 1.5 times its circumference (2π r) and not its diameter since work is done against friction for the entire one and a half cycle.

32. (i) When h = 4 m, E_p = (20 kg) (10 m/s^2) (4 m) = 800 J

$E_k = 0$

(ii) When h = 3 m, E_p = (20 kg) (10 m/s^2) (3 m) = 600 J

$E_k = \frac{1}{2} mv^2$

From $v^2 - u^2 = 2as$, $v^2 = 2gs$ as $u = 0$, $a = g$ and s is the distance through which object moves. Clearly,

$E_k = \frac{1}{2} mv^2 = \frac{1}{2}$ m (2 gs) = mgs.

In this case, s = 4 m – 3 m =1 m)

= (20 kg) (10 m/s^2) (1 m) = 200 J

(iii) When h = 2 m, E_p = (20 kg) (10 m/s^2) (2 m) = 400 J

$E_k = \frac{1}{2} mv^2 = mgs$ = (20 kg) (10 m/s^2) (2 m) = 400 J

(iv) When h = 1 m, E_p = (20 kg) (10 m/s^2) (1 m) = 200 J

$E_k = \frac{1}{2} mv^2 = mgs$

= (20 kg) (10 m/s^2) (3 m) = 600 J

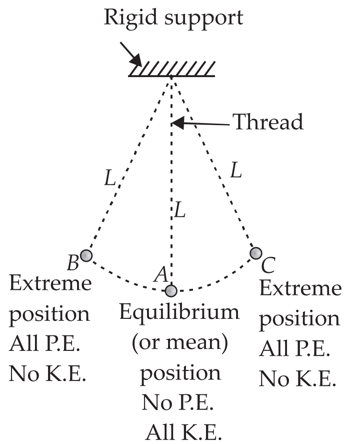
(v) Just above the ground, $E_p = 0$

$E_k = \frac{1}{2} mv^2 = mgs$

= (20 kg) (10 m/s^2) (4 m) = 800 J

Thus, we observe that as the object falls, E_p goes on decreasing and E_k goes on increasing, *i.e.*, potential energy changes into kinetic energy in case a freely falling object. Further, as $E_p + E_k$ = constant, the law of conservation of energy is established.

33. A small metallic ball (called bob) suspended by a light string (thread) from a frictionless, rigid support is called a simple pendulum. A simple pendulum is shown in figure.



The bob of a simple pendulum swings from one extreme position to the other through its mean position.

The bob is at its highest position at the extreme positions and at lowest at its mean position.

The energy changes which occur during the motion of the bob are shown in figure. So, when a pendulum swings to and fro, its energy changes constantly in the following sequence.

Extreme right position-All P.E. No K.E.

↓

Mean position-No P.E. All K.E.

↓

Extreme left position-All P.E. No K.E.

↓

Mean position-No P.E. All K.E.

↓

Extreme right position-All P.E. No K.E.

Bob eventually comes to rest due to friction of air which converts its mechanical energy into heat energy. It does not violate the law of conservation of energy has been changed from one form to another form.

34. (a) From the graph, the maximum velocity of the ball is 5.2 m s^{-1}.

(b) From the graph, change in velocity from $t = 0$ to $t = 0.320$ s = (5.2 – 2.0) = 3.2 m s^{-1}

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$= \frac{3.2}{0.320} = 10\,\text{m s}^{-2}$$

Since the ball is falling freely in downward direction, the acceleration of free fall is the acceleration of the ball, 10 m s^{-2}.

(c) The ball would have maximum velocity just before it hits the ground. Since it rebounds with 50% of the speed, the speed of the ball after it rebounds is $\frac{5.2}{2} = 2.6\,\text{m s}^{-1}$.

The velocity after it rebounds is, therefore, –2.6 m s^{-1}.

(d) Kinetic energy of the ball just before hitting the ground

$$= \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 0.23 \times 5.2 \times 5.2 = 3.109\text{ J}$$

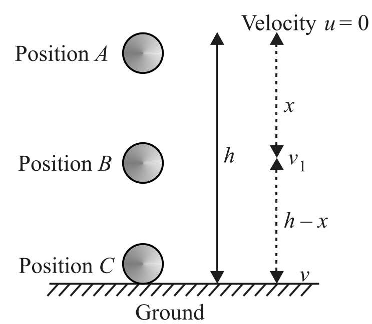
Kinetic energy of the ball just after rebound

$$= \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 0.23 \times (-2.6) \times (-2.6) = 0.777\text{ J}$$

Loss in kinetic energy = 3.109 – 0.777
= 2.332 J

35. Let m be the mass of a body held at a position A and at a height h above the ground.



At position A

Kinetic energy of the body, K.E. = 0

(∵ the body is at rest at A)

Potential energy of the body P.E. = mgh

(∵ the body is at a height h)

∴ Total mechanical energy at A,

$M.E_A$ = K.E. + P.E. = 0 + mgh = mgh

∴ $M.E_A = mgh$

Let the body be allowed to fall freely under the action of gravity. In free fall, let the body reach the point B with a velocity v_1 where $AB = x$.

At position B,

From the equation of motion,

$v^2 - u^2 = 2as$

$v_1^2 - 0 = 2gx$

$v_1^2 = 2gx$ …(i)

Kinetic energy of the body, K.E. = $\frac{1}{2}mv_1^2$ ...(ii)

Substituting the value of $v_1{}^2$ from eqn. (i) in eqn. (ii), we get

$$\text{K.E.} = \frac{1}{2}m(2gx) = mgx$$

Height of the body at B above the ground = $CB = (h - x)$

Total mechanical energy at B,

$$(M.E_B) = \text{K.E.} + \text{P.E.}$$
$$= mgx + mg(h - x)$$
$$= mgx + mgh - mgx$$

$\therefore$ $\text{M.E}_B = mgh$

Let the body be allowed to fall freely under gravity, when it strikes the ground at C with a velocity v.

At position C,

From, $v^2 - u^2 = 2as$

$v^2 - 0 = 2gh$

$v^2 = 2gh$ ...(iii)

Kinetic energy of the body, K.E. $= \frac{1}{2}mv^2$ ...(iv)

Substituting the value of v^2 from eqn. (iii) in eqn. (iv), we get

$$\text{K.E.} = \frac{1}{2}m(2gh) = mgh$$

Potential energy of the body at C, P.E. = $mgh = mg(0) = 0$

($\because$ the body is on the ground, *i.e.*, $h = 0$)

Total mechanical energy at C (M.E_C) = K.E. + P.E.

$= mgh + 0 = mgh$

$\therefore$ $\text{M.E}_C = mgh$

Hence, $\text{M.E}_A = \text{M.E}_B = \text{M.E}_C = mgh$

$\therefore$ total mechanical energy of freely falling object is conserved.

36. Let M be the mass of man and m be the mass of boy.

Then $m = \frac{M}{2}$ (given)

If v_1 and v_2 are the original speeds of the man and boy, then

$$\text{K.E. of boy} = \frac{1}{2}mv_2^2 = \frac{1}{2}\left(\frac{M}{2}\right)v_2^2$$

$$\text{Given K.E. of man} = \frac{1}{2} \times \text{K.E. of boy}$$

$$\therefore \ \frac{1}{2}Mv_1^2 = \frac{1}{2} \times \frac{1}{2}\left(\frac{M}{2}\right)v_2^2 \quad i.e. \ v_1^2 = \frac{v_2^2}{4}$$

or $v_1 = \frac{v_2}{2}$ ...(i)

When the man speeds up by 1.0 m s^{-1},

the speed of man = $(v_1 + 1)$ m s^{-1}

$$\text{K.E. of man} = \frac{1}{2}M(v_1 + 1)^2$$

According to question,

$$\frac{1}{2}M(v_1 + 1)^2 = \frac{1}{2}\left(\frac{M}{2}\right)v_2^2$$

i.e., $(v_1 + 1)^2 = \frac{v_2^2}{2}$ ...(ii)

Solving (i) and (ii), we get

$v_1 = 2.41$ m s^{-1} and $v_2 = 4.82$ m s^{-1}

☺☺☺