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Q1. What is the work done by a person in holding a 15 kg suitcase, while waiting for a bus for 15 min.

Q2. What should be the angle between force and displacement so that no work is done?

Q3. No work is done against gravity, while moving a body along horizontal. Why?

Q4. A man rowing a boat upstream is at rest with respect to the bank. Is he doing work?

Q5. What is the amount of work done by a force? When a body moves in a circular path.

Q6. What is the work done by earth's gravitational force in keeping the moon in its orbit for its one revolution?

Q7. Define conservative force. Give its two examples.

Q8. Give one example each of conservative and non-conservative force.

Q9. What is the significance of the – ve sign in $W = mgd$?

Q10. A man raises a mass m to a height 'h' and then shifts it horizontally by a length 'x'. What is the work done against the force of gravity?

Q11. Give the conditions under which a force is called conservative force.

Q12. How will you find the work done when a variable force acts on a body?

Q13. A mass is moving in a circular path with constant speed. What is the work done?

Q14. It is necessary to do work a maintain a constant velocity with a body on a rough surface?

Q15. A man weighing 50 kgf climbs 10 m. Calculate the work done by gravity.

Q16. What is the dot product of $2\hat{i} + 4\hat{j} + 5\hat{k}$ and $3\hat{i} + 2\hat{j} + \hat{k}$?

Q17. A gardener moves a lawn roller through a distance of 50 m with a force of 100 N. if the force is acting at an angle of 60° to the direction of motion, find the work done.

Q18. The earth moving round the sun in circular orbit is acted upon by a force and hence work must be done on the earth by the force. Explain.

Q19. Does the work done raising a box on to a platform depends upon how fast it is raised up? If not why?

Q20. The sign of work done by a force on a body is important to understand. State carefully if the following quantities are positive or negative: work done by an applied force on a body moving on a rough horizontal plane with uniform velocity.

Q21. The sign of work done by a force on a body is important to understand. State carefully if the following quantities are positive or negative: work done by friction on a body sliding down an inclined plane.

Q22. The sign of work done by a force on a body is important to understand. State carefully if the following quantities are positive or negative: work done by gravitational force in the above case.

Q23. The sign of work done by a force on a body is important to understand. State carefully if the following quantities are positive or negative: work done by a man in lifting a bucket out of a well by means of a rope tied to the bucket.

Q24. Underline the correct alternative: When a conservative force does positive work on a body, the potential energy of the body increases/decreases/remains unaltered.

Q25. The sign of work done by a force on a body is important to understand. State carefully if the following quantities are positive or negative: work done by the resistive force of air on a vibrating pendulum in bringing it to rest.

Q26. Underline the correct alternative: The rate of change of total momentum of a many-particle system is proportional to the external force/sum of the internal forces on the system.

Q27. A man weighing 60 kg climbs up a stair case carrying a load of 20 kg on his head. The stair case has 20 steps each of height 0.2 m, find his work.

Q28. Establish that work done is the product of the displacement and the force in the direction of displacement.

Q29. Prove that the work done in a frictional surface is non-zero in a closed path.

Q30. What are conservative forces? Distinguish the conservative and non-conservative forces among the following:

(a) Gravitational force (b) Frictional force (c) Air resistance (d) Electrostatic force

Q31. "The earth moving round the sun in a circular orbit is acted upon by a force and hence work must be done on the earth by the force." Do you agree with this statement?

Q32. Define positive, negative and zero work.

Q33. A man weighing 80 kgf carries a stone of weight 20 kgf to the top of the building 30 m high. Calculate the work done by him. Given, $g = 9.8\ ms^{-2}$.

Q34. A force $\vec{F} = (2\hat{i} - 6\hat{j})$ N is applied on a body, which is sliding over a floor. If the body is displaced through $(-3\hat{j})$ m, how much work is done by the force?

Q35. Show that the vectors:

$\vec{A} = 3\hat{i} + \hat{j} + \hat{k}$ and $\vec{B} = \hat{i} + 2\hat{j} - 5\hat{k}$ are perpendicular to each other.

Q36. What is the amount of work done by.

(a) a weight-lifter is holding a weight of 100 kg on his shoulder for 40 s?

(b) The earth's gravitational force in keeping the moon in its orbit (assumed perfectly circular)?

(c) a locomotive against gravity, if it is travelling on a level plane?

(d) an electron moving with half the speeds of light in empty space free of electromagnetic fields and far from all matter?

Q37. Prove the following:

$$(2\vec{A} + 3\vec{B}).(\vec{A} - 7\vec{B}) = 2A^2 - 21B^2 - 11AB\cos\theta$$

Q38. What is the work done by a man in carrying a suitcase weighting 30 kg over his head, when he travels a distance of 10 min the (a) vertical direction, (b) horizontal direction.

Q39. A body constrained to move along the constant force F given by $F = \hat{i} + 2\hat{j} + 3\hat{k}\ N$ Where $\hat{i} + \hat{j} + \hat{k}$ are unit vectors along the x, y and z-axis of the system respectively. What is the work done by this force in moving the body a distance of 4 m along the z-axis?

Q40. Find the angle between force $F = (3\hat{i} + 4\hat{j} - 5\hat{k})$ unit and displacement $d = \hat{}\ (5\hat{i} + 4\hat{j} + 3\hat{k})$ unit. Also find the projection of F on d.

Q41. Two springs A and B with constants k_A and k_B ($k_A > k_B$) are given. In which of the springs more work is to be done if,
(a) they are stretched by the same amount, (b) they are stretched by same force.

Q42. Find the work done, if a weight of 25 kgf is lifted through a vertical height of 2 m from the ground and also if it is raised to same place by pushing up on an inclined plane making an angle of 30° with the ground. Neglect friction.

Q43. Define the dot product with example, find the angle between the vectors $\vec{A} = \hat{i} - 2\hat{j} - 5\hat{k}$ and $\vec{B} = 2\hat{i} + \hat{j} - 4\hat{k}$.

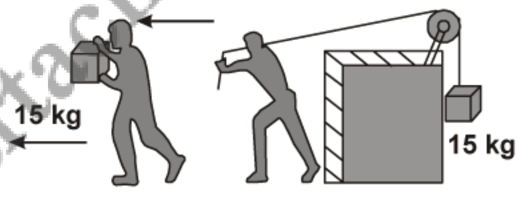
Q44. If $\vec{A} = 4\hat{i} + 6\hat{j} - 3\hat{k}$ and $\vec{B} = -2\hat{i} - 5\hat{j} - 7\hat{k}$, find the angle between the vectors $\vec{A}$ and $\vec{B}$.

Q45. A cyclist comes to a skidding stop in 5 m. During this process, the force on the cycle due to the road is 250 N and is directly opposed to the motion.
(a) How much work does the road do on the cycle?
(b) How much work does the cycle do on the road?

Q46. (a) 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?

(b) Comets move around the sun in highly elliptical orbits. The gravitational force on the comet due to the sun is not normal to the comet's velocity in general. Yet the work done by the gravitational force over every complete orbit of the comet is zero. Why?

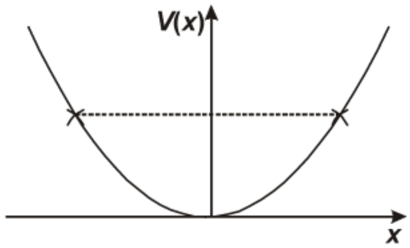
(c) An artificial satellite orbiting the earth in very thin atmosphere loses its energy gradually due to dissipation against atmospheric resistance, however small. Why then does is speed increase progressively as it comes closer and closer to the earth?



(i) (ii)

(d) In Figure the man walks 2 m carrying a mass of 15 kg on his hands. In figure (ii), he walks the same distance pulling the rope behind him. The rope goes over a pulley, and a mass of 15 kg hangs at its other end. In which case is the work done greater?

Q47. The potential energy function for a particle executing linear simple harmonic motion is given by $V(x) = kx^2/2$, where k is the force constant of the oscillator. For $k = 0.5\ \text{N m}^{-1}$, the graph of $V(x)$ versus x is shown in figure.
Show that a particle of total energy 1 J moving under this potential must 'turn back' when it reaches $x = \pm 2$ m.

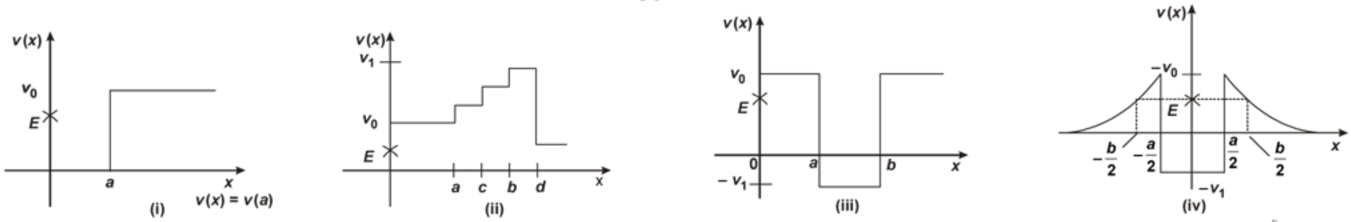


Q48. Work done by a force is given by $W = F.S$ where F is the force and S is the displacement Show that:

(a) Work done is also equal to change in K.E.

(b) Work done is also equal to change in potential energy using this expression.

Q49. Given in the Figure are examples of some potential energy functions in one dimension. The total energy of the particle is indicated by a cross on the ordinate axis. In each case, specify the regions, if any, in which the particle cannot be found for the give Also, indicate the minimum total energy the particle must have in each case. Think of simple physical contexts for which these potential energy shapes are relevant.



Q50. A body of mass 2 kg initially at rest moves under the action of an applied horizontal force of 7 N on a table with coefficient of kinetic friction = 0.1. Compute the work done by the applied force in 10 s, work done by friction in 10 s, work done by the net force on the body in 10 s, change in kinetic energy of the body in 10 s, and interpret your results.

Q51. A body of mass 5 kg is moved alone a straight line and its displacement (x) varies with time (t) according to the relation

$t = \sqrt{x} + 1$ Find the work done in moving the body for first 10 s.

Q52. Find the magnitude and direction of (a) $\hat{i} + \hat{j}$ and (b) $\hat{i} - \hat{j}$.

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S1. It is zero. It is because, the displacement is zero.

S2. Given, $W = 0$

New $W = F\,S \cos\theta$

$\Rightarrow$ $FS \cos\theta = 0$

$\cos\theta = 0$

$\Rightarrow$ $\theta = 90°$

S3. It is because, the gravity and the displacement are perpendicular to each other. Therefore,

$$W = FS \cos 90° = 0$$

S4. The man applies force for rowing the boat upstream. Since he is at rest w.r.t. the bank, the displacement is zero. Likewise, the work done is also zero.

S5. Zero. It is because, the centripetal force needed to revolve the body is always perpendicular to the circular path.

S6. Zero. It is because the gravitational force (conservative force) is always perpendicular to the displacement.

S7. A force is said to be conservative, if work done by the force over a closed path is zero.

Examples: Gravitational and electrostatic force.

S8. Gravity is a conservative force, while friction is a non-conservative force.

S9. Negative sign indicates that the work is done against the force.

S10. Work done against force of gravity is *mgh* since no work is done in the horizontal displacement.

S11. Any force is conservative if,

(a) Work done against is independent of path.

(b) Work done in a closed path is zero.

S12. For variable force, $W = \int_{x_i}^{x_f} F\,dx$ where F is the force shifting the mass from x_i to x_f.

S13. Since centripetal force and displacement are perpendicular, work done is zero.

S14. Yes, to overcome the frictional force of rough surface.

S15. Here, $F = 50 \text{ kgf} = 50 \times 9.8 \text{ N}$ (downwards);

$S = 10 \text{ m}$ (upward)

Now, $W = FS\cos\theta = 50 \times 9.8 \times 10 \times \cos 180°$ $(\because \theta = 180°)$

$= 50 \times 9.8 \times 10(-1) = \mathbf{-4{,}900\ J}$.

S16. Let, $\vec{A} = 2\hat{i} + 4\hat{j} + 5\hat{k}$

$\vec{B} = 3\hat{i} + 2\hat{j} + \hat{k}$

$\vec{A} \cdot \vec{B} = (2\hat{i} + 4\hat{j} + 5\hat{k})(3\hat{i} + 2\hat{j} + \hat{k})$

$= 6 + 8 + 5 = \mathbf{19}$.

S17. Work done $= Fd\cos\theta$

$= 100 \times 50 \times \cos 60°$

$= 5000 \times \frac{1}{2} = 2500 \text{ J}$

S18. It is wrong. Since force and displacement are perpendicular to each other work done is zero.

S19. No. Work done against gravity depends only on the initial and final points The change in energy is same as the work done.

S20. Positive.

Here the body is moving on a rough horizontal plane. Frictional force opposes the motion of the body. Therefore, in order to maintain a uniform velocity, a uniform force must be applied to the body. Since the applied force acts in the direction of motion of the body, the work done is positive.

S21. Negative.

Since the direction of frictional force is opposite to the direction of motion, the work done by frictional force is negative in this case.

S22. Negative.

In the given case, the direction of gravitational force is vertically downward and displacement (vertically upward) are opposite to each other. Hence, the sign of work done is negative.

S23. Positive.

In the given case, force and displacement are in the same direction. Hence, the sign of work done is positive. In this case, the work is done on the bucket.

S24. Decreases.

Explanation: A conservative force does a positive work on a body when it displaces the body in the direction of force. As a result, the body advances toward the centre of force. It decreases the separation between the two, thereby decreasing the potential energy of the body.

S25. Negative.

The resistive force of air acts in the direction opposite to the direction of motion of the pendulum. Hence, the work done is negative in this case.

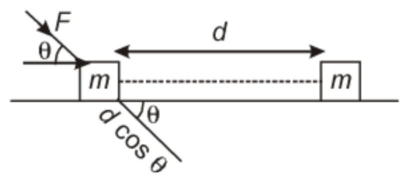
S26. External force.

Explanation: Internal forces, irrespective of their direction, cannot produce any change in the total momentum of a body, since they will cancel each other. Hence, the total momentum of a many- particle system is proportional to the external forces acting on the system.

S27. Here $m = 60 + 20 = 80$ kg, $h = 20 \times 0.2 = 4$ m, $g = 9.8$ ms^{-2}

$\therefore$ Work done $= mgh = 80 \times 9.8 \times 4 = 3136$ J.

S28. Work done = $\vec{F}.\vec{d} = F(d \cos\theta)$ or is the component of displacement in the component of force



and $F \cos\theta$ is the component of force and $F \cos\theta$ is the component of force in the direction of displacement. Therefore work done is the product of the component of force and displacement with the displacement and force in the direction.

S29. Let F_f be the force of friction in a surface. The work done to carry a mass m from a point A to another point B is, $-F_f AB$. In the return path B to A also, the work done is $-F_f AB$, since the F_f acts against the motion. The net work done is therefore, $-2F_f(AB)$. Since friction is dependent on the nature of the surface it is dependent on path.

S30. Conservative forces those forces in which work done

(a) in a closed path is zero and

(b) is independent of path.

Conservative forces: Gravitational and Electrostatic force.

Non-Conservative forces: Frictional force and air resistance.

S31. The gravitational force on the earth due to the sun is a conservative force. Since the work done by a conservative force over a closed path is always zero (irrespective of the nature of path), the work done by the gravitational force over every complete orbit of the earth is zero.

S32. Work done is given by

$$W = \vec{F} \cdot \vec{S}$$

Therefore, work done will be ***positive***, ***negative*** or ***zero*** depending on whether the angle between $\vec{F}$ and $\vec{S}$ is ***acute***, ***obtuse*** or is 90°. Also the work done is zero, when either $\vec{F}$ or $\vec{S}$ or both $\vec{F}$ and $\vec{S}$ are zero.

S33. Here, Weight of the man = 80 kgf;

Weight of the stone = 20 kgf

Force applied to carry the total weight up,

$$F = 80 + 20 = 100 \text{ kgf} = 100 \times 9.8 = 980 \text{ N}$$

Height through which the weight is carried,

$$S = 30 \text{ m}$$

Therefore, work done,

$$W = FS = 980 \times 30 = \mathbf{29{,}400\ J}.$$

S34. Here, $\vec{F} = (2\hat{i} - 6\hat{j})$ and $\vec{S} = (-3\hat{j})$

Now, $W = \vec{F} \cdot \vec{S} = (2\hat{i} - 6\hat{j}) \cdot (-3\hat{j}) = \mathbf{18\ J}.$

S35. The vectors $\vec{A}$ and $\vec{B}$ are perpendicular, if

$$\vec{A} \cdot \vec{B} = 0$$

Now, $\vec{A} \cdot \vec{B} = (3\hat{i} + \hat{j} + \hat{k}) \cdot (\hat{i} + 2\hat{j} - 5\hat{k}) = (3 + 2 - 5) = 0$

Hence, the vectors $\vec{A}$ and $\vec{B}$ are perpendicular to each other.

S36. (a) Zero (b) Zero (c) Zero (d) Zero.

S37. Now, L.H.S. $= (2\vec{A} + 3\vec{B}) \cdot (\vec{A} - 7\vec{B})$

$$= 2\vec{A} \cdot \vec{A} + 3\vec{B} \cdot \vec{A} - 14\vec{A} \cdot \vec{B} - 21\vec{B} \cdot \vec{B}$$

$$= 2A^2 + 3AB\cos\theta - 14AB\cos\theta - 21B^2$$

$$= 2A^2 - 21B^2 - 11\text{AB}\cos\theta$$

Hence, $(2\vec{A} + 3\text{B}) \cdot (\vec{A} - 7\text{B})$

$$= 2A^2 - 21B^2 - 11AB\cos\theta$$

S38. To carry the suitcase, the man has to apply a force equal to the weight of the suitcase in upward direction *i.e.*,

(a) Here, $F = 30 \text{ kgf} = 30 \times 9.8 \text{ N}$ (vertically upwards)

Now, $S = 10 \text{ m}; \quad \theta = 0°$

$$W = FS\cos\theta = 30 \times 9.8 \times 10 \times \cos 0° = \mathbf{2{,}940\ J}.$$

(b) Here, $S = 10 \text{ m}; \quad \theta = 90°$

Now, $W = FS\cos\theta = 30 \times 9.8 \times 10 \times \cos 90° = 0.$

S39. Force exerted on the body, $F = -\hat{i} + 2\hat{j} + 3\hat{k}$

Displacement, $S = 4\hat{k}$ m

Work done, $W = F \cdot S$

$$= \left(-\hat{i} + 2\hat{j} + 3\hat{k}\right).\left(4\hat{k}\right)$$

$$= 0 + 0 + 3 \times 4$$

$$= 12 \text{ J}$$

Hence, 12J of work is done by the force on the body.

S40.

$$F \cdot d = F_x d_x + F_y d_y + F_z d_z$$
$$= 3(5) + 4(4) + (-5)(3)$$
$$= 16 \text{ unit}$$

Hence, $F \cdot d = Fd \cos\theta = 16$ unit

Now, $F \cdot F = F^2 = F_x^2 + F_y^2 + F_z^2$

$$= 9 + 16 + 25$$
$$= 50 \text{ unit}$$

and $d \cdot d = d^2 = d_x^2 + d_y^2 + d_z^2$

$$= 25 + 16 + 9$$
$$= 50 \text{ unit}$$

$$\cos\theta = \frac{16}{\sqrt{50}\sqrt{50}} = \frac{16}{50} = 0.32$$

$$\theta = \cos^{-1} 0.32$$

S41. We have, $F = -kx$ and W = Energy = $\frac{1}{2}kx^2$.

(a) For same stretch, $\frac{W_A}{W_B} = \frac{k_A}{k_B}$

$\therefore$ $k_A > k_B$, $W_A > W_B$.

(b) For same force, $\frac{W_A}{W_B} = \frac{F^2}{2k_A} \cdot \frac{2k_B}{F^2}, \frac{W_A}{W_B} = \frac{k_B}{k_A}$

$\therefore$ $W_A < W_B$.

S42. ***When weight is lifted vertically upwards:***

Since $F = 25$ kgf $= 25 \times 9.8$ N, $S = 2\,m$ and $\theta = 0°$

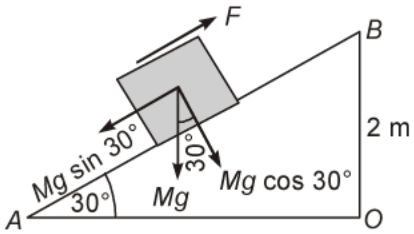
$W = FS \cos\theta = 25 \times 9.8 \times 2 \times \cos 0° =$ **490 J**.

When weight is lifted alone inclined plane:

In order to lift the weight through a vertical height OB by moving it along an inclined plane [as show in the figure], a force F equal to $Mg \sin 30°$ has to be applied through a distance AB.

$$W = F \times AB = Mg \sin 30° \times AB$$

$$= Mg \times \frac{OB}{AB} \times AB = Mg \times OB$$



Here, $Mg = 25 \text{ kgf} = 25 \times 9.8 \text{ N}$ and $OB = 2\text{m}$

$$W = 25 \times 9.8 \times 2 = \mathbf{490\ J}.$$

S43. The scalar product of the two $\vec{A}$ and $\vec{B}$ is defined as the product of the magnitudes of the vectors $\vec{A}$ and $\vec{B}$ and the cosine of the angle between them.

Work is a example of dot product.

$$W = \vec{F}.\vec{S}$$

Here, $\vec{A} = \hat{i} - 2\hat{j} - 5\hat{k}$; $\vec{B} = 2\hat{i} + \hat{j} - 4\hat{k}$

We know, $\vec{A}.\vec{B} = AB \cos\theta$

or $\cos\theta = \frac{\vec{A}.\vec{B}}{AB}$

Now, $A = \sqrt{1^2 + (-2)^2 + (-5)^2} = \sqrt{1+4+25} = \sqrt{30}$

$B = \sqrt{2^2 + 1^2 + (-4)^2} = \sqrt{4+1+16} = \sqrt{21}$

and $\vec{A}.\vec{B} = (\hat{i} - 2\hat{j} - 5\hat{k})\ (2\hat{i} + \hat{j} - 4\hat{k})$

$= 1 \times 2 + (-2) \times 1 + (-5) \times (-4)$

$= 2 - 2 + 20 = 20$

$\therefore$ $\cos\theta = \frac{20}{\sqrt{30} \times \sqrt{21}} = 0.7968$

or $\theta = \mathbf{37.2°}$.

S44. Here, $\vec{A} = 4\hat{i} + 6\hat{j} - 3\hat{k}$ and $\vec{B} = -2\hat{i} - 5\hat{j} + 7\hat{k}$

Let θ be the angle between the vectors $\vec{A}$ and $\vec{B}$.

Now, $\vec{A}.\vec{B} = |A||B| \cos\theta$

or $\cos\theta = \frac{\vec{A}.\vec{B}}{|A||B|}$ ... (i)

Now, $\vec{A}.\vec{B} = (4\hat{i} + 6\hat{j} - 3\hat{k}).(-2\hat{i} - 5\hat{j} + 7\hat{k})$

$$= -8 - 30 - 21 = -59$$

Also, $$|\vec{A}| = \sqrt{4^2 + 6^2 + (-3)^2} = \sqrt{16 + 36 + 9} = \sqrt{61}$$

and $$|\vec{B}| = \sqrt{(-2)^2 + (-5)^2 + 7^2} = \sqrt{4 + 25 + 49} = \sqrt{78}$$

In the Eqn. (i), substituting for $\vec{A} \cdot \vec{B}$, A and B, we have

$$\cos\theta = \frac{-59}{\sqrt{61}\sqrt{78}} = -0.8553$$

or $$\theta = \mathbf{148.8^\circ}.$$

S45. (a) the motion of the cycle is opposed by the force of friction between the cycle and the road. As the force of friction acts in a direction opposite to the motion, it makes an angle of 180° with the displacement. Therefore, work done by the road on the cycle,

$$W = FS\cos\theta = 250 \times 5 \times \cos 180^\circ = 250 \times 5 \times (-1)$$

$$= \mathbf{-1{,}250\ J}.$$

(b) An equal and opposite force acts on the road due to the cycle but the displacement of the road is zero. Therefore, work done by the cycle on the road.

$$W = FS\cos\theta = 250 \times 0 \times \cos 0^\circ = \mathbf{0}.$$

S46. (a) **Rocket:** The burning of the casing of a rocket in flight (due to friction) results in the reduction of the mass of the rocket.

According to the conservation of energy:

Total Energy (T. E.) = Potential energy (P.E.) + Kinetic energy (K.E.)

The reduction in the rocket's mass causes a drop in the total energy. Therefore, the heat energy required for the burning is obtained from the rocket.

(b) Gravitational force is a conservative force. Since the work done by a conservative force over a closed path is zero, the work done by the gravitational force over every complete orbit of a comet is zero.

(c) When an artificial satellite, orbiting around earth, moves closer to earth, its potential energy decreases because of the reduction in the height. Since the total energy of the system remains constant, the reduction in P.E. results in an increase in K.E. Hence, the velocity of the satellite increases. However, due to atmospheric friction, the total energy of the satellite decreases by a small amount.

In the second case

Case I: Mass, $m = 15$ kg

Displacement, $S = 2$ m

Work done, $W = Fs\cos\theta$

Where, θ = Angle between force and displacement = 90°

$= mgS \cos\theta = 15 \times 2 \times 9.8 \cos 90°$

$= 0$ $(\because \cos 90° = 0)$

Case II: Mass, $m = 15$ kg

Displacement, $S = 2$ m

(d) Here, the direction of the force applied on the rope and the direction of the displacement of the rope are same.

Therefore, the angle between them, $\theta = 0°$

Since $\cos 0° = 1$

Work done, $W = FS\cos\theta = mgs$

$= 15 \times 9.8 \times 2 = 294$ J

Hence, more work is done in the second case.

S47. Total energy of the particle, $E = 1$ J

Force constant, $k = 0.5$ N m^{-1}

Kinetic energy of the particle, $K = \frac{1}{2}mv^2$

According to the conservation law:

$$E = V + K$$

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

At the moment of 'turn back', velocity (and hence K) becomes zero.

$$\therefore \quad 1 = \frac{1}{2}kx^2$$

$$\frac{1}{2} \times 0.5x^2 = 1$$

$$x^2 = 4$$

$$x = \pm 2$$

Hence, the particle turns back when it reaches $x = \pm 2$ m.

S48. (a) M = mass of body at rest

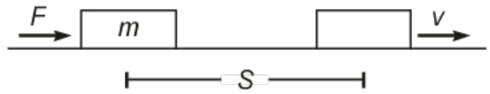
$\vec{dS}$ = small displacement in the direction of force.

Small amount of work done by force

$$dW = \vec{F}.\vec{dS} = FdS\cos 0° = FdS$$

If is acceleration produced in the body, then

$$\vec{F} = m\vec{a} = m\frac{dv}{dt}$$



$$dW = \left(m\frac{dv}{dt}\right).dS = m\left(\frac{dS}{dt}\right)dv$$

$$= mv\,dv.$$

Total work done by the force

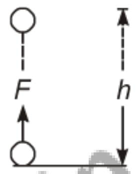
$$W = \int_0^v mv\,dv$$

$$= m\int_0^v v\,dv = m\left[\frac{v^2}{2}\right]_0^v$$

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

(b) $F = mg$

As the distance is moved in the direction of force applied



Work done = Force × distance

$W = F \times h = mgh.$ [$\theta = 0^\circ$ therefore $\cos\theta = 1$]

S49. Case I: $x > a$; 0

Total energy of a system is given by the relation:

$$E = P.E. + K.E.$$

$\therefore$ $K.E. = E - P.E.$

Kinetic energy of a body is a positive quantity. It cannot be negative. Therefore, the particle will not exist in a region where K.E. becomes negative.

Case II: In the given case, the potential energy (v_0) of the particle becomes greater than total energy (E) for $x > a$. Hence, kinetic energy becomes negative in this region. Therefore, the particle will not exist is this region. The minimum total energy of the particle is zero.

Case III: All regions

In the given case, the potential energy (v_0) is greater than total energy (E) in all regions. Hence, the particle will not exist in this region.

$x > a$ and $x < b$; $-v_1$

In the given case, the condition regarding the positivity of K.E. is satisfied only in the region between $x > a$ and $x < b$.

Case IV: The minimum potential energy in this case is $-v_1$. Therefore, K.E. = $E - (-v_1) = E + v_1$. Therefore, for the positivity of the kinetic energy, the total energy of the particle must be greater than $-v_1$. So, the minimum total energy the particle must have is $-v_1$.

$$-\frac{b}{2} < x < \frac{a}{2}; \frac{a}{2} < x < \frac{b}{2}; -v_1$$

In the given case, the potential energy (v_0) of the particle becomes greater than the total energy (E) for $-\frac{b}{2} < x < \frac{b}{2}$ and $-\frac{a}{2} < x < \frac{a}{2}$. regions.

The minimum potential energy in this case is $-v_1$. Therefore, K.E. = E – (v_1) = $E + v_1$. Therefore, for the positivity of the kinetic energy, the total energy of the particle must be greater than $-v_1$. So, the minimum total energy the particle must have is $-v_1$.

S50. Given,

Mass of the body,		$m = 2$ kg
Applied force,		$F = 7$ N
Coefficient of kinetic friction,		$\mu = 0.1$
Initial velocity,		$u = 0$
Time,		$t = 10$ s

The acceleration produced in the body by the applied force is given by Newton's second law of motion as:

$$a' = \frac{F}{m} = \frac{7}{2} = 3.5 \text{ m/s}^2$$

Frictional force is given as: $f = \mu mg$

$$= 0.1 \times 2 \times 9.8 = -1.96 \text{ N}$$

The acceleration produced by the frictional force:

$$a'' = -\frac{1.96}{2} = -0.98 \text{ m/s}^2$$

Total acceleration of the body: $a = a' + a''$

$$= 3.5 + (-0.98) = 2.52 \text{ m/s}^2$$

The distance travelled by the body is given by the equation of motion:

$$s = ut + \frac{1}{2}at^2$$

$$= 0 + \frac{1}{2} \times 2.52 \times (10)^2 = 126 \text{ m}$$

Work done by the applied force, $W_a = F \times s = 7 \times 126 = 882$ J

Work done by the frictional force, $W_f = F \times s = -1.96 \times 126 = -247$ J

Net force = 7 + (–1.96) = 5.04 N

Work done by the net force, $W_{net} = 5.04 \times 126 = 635$ J

From the first equation of motion, final velocity can be calculated as:

$$v = u + at$$

$$= 0 + 2.52 \times 10 = 25.2 \text{ m/s}$$

$$\text{Change in kinetic energy} = \text{Work done by the net force} = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$= \frac{1}{2} \times 2(v^2 - u^2) = (25.2)^2 - 0^2 = 635 \text{ J}$$

S51. Here, $t = \sqrt{x} + 1$

or $\sqrt{x} = t - 1$

or $x = (t^2 - 2t + 1)\ m$

Differentiating both sides w.r.t. t, we have

$$\frac{dx}{dt} = 2t - 2 + 0$$

or $v = (2t - 2)\ \text{ms}^{-1}$

Again, differentiating both sides w.r.t. t, we have

$$\frac{dv}{dt} = 2 - 0$$

or $a = 2\ \text{ms}^{-2}$

Therefore, force applied on the body,

$$F = Ma = 5 \times 2 = 10 \text{ N}$$

Now, initial displacement of the body,

$$x_0 = 0^2 - 2 \times 0 + 1 = 1 \text{ m}$$

Displacement of the body during 10 s,

$$x_{10} = 10^2 - 2 \times 10 + 1 = 81 \text{ m}$$

Therefore, displacement of the body in first 10 s,

$$S = x_{10} - x_0 = 81 - 1 = 80 \text{ m}$$

Hence, work done in moving the body for first 10 s,

$$W = FS = 10 \times 80 = \mathbf{800\ J}.$$

S52. (a) the magnitude of the vector $|\hat{i} + \hat{j}|$ is given by

$$|\hat{i} + \hat{j}| = [(1)^2 + (1)^2]^{1/2} = \sqrt{2}$$

Suppose that the vector $\hat{i} + \hat{j}$ makes an angle θ_1 with the X-axis (*i.e.*, with the direction of unit vector $\hat{i}$). Then,

$$(\hat{i}+\hat{j})\cdot\hat{i} = |\hat{i}+\hat{j}\,||\hat{i}|\cos\theta_1 \qquad (\because\ \vec{A}\cdot\vec{B} = AB\cos\theta)$$

or $$\hat{i}\cdot\hat{i}+\hat{j}\cdot\hat{i} = (\sqrt{2})(1)\cos\theta_1$$

or $$1 + 0 = \sqrt{2}\cos\theta_1$$

or $$\cos\theta_1 = \frac{1}{\sqrt{2}}$$

or $$\theta_1 = 45°$$

(b) The magnitude of the vector $|\hat{i}-\hat{j}|$ is given by

$$|\hat{i}-\hat{j}| = [(1)^2 + (-1)^2]^{1/2} = \theta_2$$

If the vector $\hat{i}-\hat{j}$ makes an angle θ_2 with X-axis *i.e.*, with $\hat{i}$, then

$$(\hat{i}-\hat{j})\cdot\hat{i} = |\hat{i}-\hat{j}||\hat{i}|\cos\theta_2$$

or $$\hat{i}\cdot\hat{i}-\hat{j}\cdot\hat{i} = (\sqrt{2})(1)\cos\theta_2$$

or $$1 - 0 = \sqrt{2}\cos\theta_2$$

or $$\cos\theta_2 = \frac{1}{\sqrt{2}}$$

or $$\theta_2 = 45°$$

Note: $\cos\theta = \frac{1}{\sqrt{2}}$ also gives $\theta = -45°$.

From their graphical representation, it can be easily seen that in fact the vectors $\hat{i}+\hat{j}$ and $\hat{i}-\hat{j}$ make angles of $\theta_1 = 45°$ and $\theta_2 = -45°$ respectively with the X-axis.

Date: 13/10/2021

Q1. Is It possible to have a collision in which all kinetic energy is lost? Give example.

Q2. A planet moving around the sun is a good illustration of the law of conservation of energy. Explain.

Q3. A light body and heavy body have the same momentum. Which one will have greater kinetic energy?

Q4. Draw the variation of potential energy stored in a spring as a function of extension.

Q5. Two bodies m_1 and m_2 ($m_1 > m_2$) have equal kinetic energies. Which will have more momentum?

Q6. What is the elastic potential energy storage in a spring?

Q7. What is the unit for spring of force constant?

Q8. State the law of conservation of energy.

Q9. What type of energy is stored in the spring of a watch?

Q10. How many joules are in 1 MeV?

Q11. Define one kilowatt hour.

Q12. State work-energy theorem.

Q13. What is potential energy?

Q14. What is kinetic energy, write its dimension?

Q15. State if the following statements is true or false. Give reasons for your answer: In an elastic collision of two bodies, the momentum and energy of each body is conserved.

Q16. Underline the correct alternative: In an inelastic collision of two bodies, the quantities which do not change after the collision are the total kinetic energy/total linear momentum/ total energy of the system of two bodies.

Q17. Underline the correct alternative: Work done by a body against friction always results in a loss of its kinetic/potential energy.

Q18. A body falling from a height of 10 m rebounds from a hard floor. It loses 20 % of its energy in impact. What is the height to which it would rise after the impact?

Q19. The energy supplied to Kolkata by the State Electricity Board during an average November weekday was 40×10^6 kWh. If this energy could be obtained by the conversion of matter, how much mass would have to be annihilated?

Q20. What is meant by mass energy equivalence? Discuss its significance in physics.

Q21. Does a single external force acting on a particle necessarily change its kinetic energy? Explain.

Q22. State if the following statements is true or false. Give reasons for your answer: In an inelastic collision, the final kinetic energy is always less than the initial kinetic energy of the system.

Q23. State if the following statements is true or false. Give reasons for your answer: Total energy of a system is always conserved, no matter what internal and external forces on the body are present.

Q24. State if the following statements is true or false. Give reasons for your answer: Work done in the motion of a body over a closed loop is zero for every force in nature.

O25. Define conservative and non-conservative force.

Q26. When is potential energy of a body said to be positive or negative.

Q27. Explain the work energy theorem.

Q28. Discuss the variation of mass with velocity.

Q29. A lorry and a car moving with the same kinetic energy are brought to rest by the application of brakes, which provide equal retarding forces. This of them will come to rest in a shorter time.

Q30. Draw a graph showing the variation of potential energy and kinetic energy with respect to height of a free fall under gravitational force.

Q31. How high must a body be lifted to gain an amount of potential energy equal to the kinetic energy equal to at speed 20 ms^{-1}. The value of acceleration due to gravity at that place is $g = 9.8\ ms^{-2}$.

Q32. A body of mass 'M' at rest is struck by a body of mass 'm'. Show that the fraction of K.E. of mass m transferred to the struck particle is $\frac{4mM}{(m+M)^2}$.

Q33. A body of mass 4 kg initially at rest is subject to a force 16 N. What is the kinetic energy acquired by the body at the end of 10 s?

Q34. A body of mass 5kg initially at rest is subjected a force of 20 N. What is the kinetic energy acquired by the body at the end of 10 s?

Q35. Calculate the energy in MeV equivalent to the mass of electron at rest. Given that the mass of electron at rest $m_0 = 9.1 \times 10^{-31}$ kg, 1 MeV = 1.6×10^{-13} J and velocity of light = $3 \times 10^8\ ms^{-1}$.

Q36. The momentum of a body is doubled. By what percentage does its kinetic energy increase?

Q37. 230 joule were spent in lifting a 10 kg weight to a height of 2 m. Calculate the acceleration with which it was raised. Take $g = 10\ ms^{-2}$.

Q38. A spring is cut into two equal halves. What is the spring constant of each portion?

Q39. It is well known that a raindrop falls under the influence of the downward gravitational force and the opposing resistive force. The latter is known to be proportional to the speed of the drop but is otherwise undetermined. Consider a drop of mass 1.00 g falling from a height 1.00 km. It hits the ground with a speed of 50.0 $m\,s^{-1}$. (a) What is the work done by the gravitational force? What is the work done by the unknown resistive force?

Q40. A trolley of mass 300 kg carrying a sandbag of 25 kg is moving uniformly with a speed of 27 km/h on a frictionless track. After a while, sand starts leaking out of a hole on the floor of the trolley at the rate of 0.05 kgs^{-1} sand bag is empty. what would be the speed of trolley?

Q41. What power must be developed by an aircraft engine to raise it to an altitude of 1 km, if the aircraft weight 3,000 kgf and the time of ascent is 1 min?

Q42. In a ballistics demonstration a police officer fires a bullet of mass 50.0 g with speed 200 $m\,s^{-1}$ (see Table 6.2) 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?

Q43. A cyclist comes to a skidding stop in 10 m. During this process, the force on the cycle due to the road is 200 N and is directly opposed to the motion. (a) How much work does the road do on the cycle? (b) How much work does the cycle do on the road?

Q44. A woman pushes a trunk on a railway platform which has a rough surface. She applies a force of 100 N over a distance of 10 m. Thereafter, she gets progressively tired and her applied force reduces linearly with distance to 50 N. The total distance through which the trunk has been moved is 20 m. Plot the force applied by the woman and the frictional force, which is 50 N versus displacement. Calculate the work done by the two forces over 20 m.

Q45. Examine Tables 6.1-6.3 (NCERT) and express (a) The energy required to break one bond in DNA in eV; (b) The kinetic energy of an air molecule (10^{-21} J) in eV; (c) The daily intake of a human adult in kilocalories.

Q46. A block of mass $m = 1$ kg, moving on a horizontal surface with speed $v_i = 2\,m\,s^{-1}$ enters a rough patch ranging from $x = 0.10$ m to $x = 2.01$ m. The retarding force F_r on the block in this range is inversely proportional to x over this range,

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

$$= 0 \quad \text{for} \quad x < 0.1 \text{ m} \quad \text{and} \quad x > 2.01 \text{ m}$$

where $k = 0.5$ J. What is the final kinetic energy and speed v_f of the block as it crosses this patch?

Q47. An elevator can carry a maximum load of 1800 kg (elevator + passengers) is moving up with a constant speed of 2 $m\,s^{-1}$. The frictional force opposing the motion is 4000 N. Determine the minimum power delivered by the motor to the elevator in watts as well as in horse power.

Q48. Prove that the total mechanical energy remains constant for a ball of mass m dropped from a tower of height h.

Q49. An elastic spring of spring constant 'k' is compressed by an amount x. Show that its potential energy is $\frac{1}{2}kx^2$.

Q50. A body of mass 2 kg is resting on a rough horizontal surface. A force of 20 N is now applied to it for 10 seconds parallel to the surface. If the coefficient of kinetic friction between the surfaces in contact is 0.2, calculate: Take $g = 10$ m/s^2.

(a) Work done by the applied force in 10 seconds.

(b) Change in kinetic energy of the object in 10 seconds.

Q51. A bullet weighing 10 g is fired with a velocity of 800 m s^{-1}. After passing through a mud wall 1 m thick, its velocity decreases to 100 m s^{-1}. Find the average resistance offered by the mud wall.

Q52. In a ballistic demonstration, a police officer fires a bullet of mass 50 g with a speed of 300 m s^{-1} on soft plywood. The bullet emerges with 20% of its initial kinetic energy. What is the emergent speed of the bullet?

Q53. It is well known that a raindrop falls under the influence of the gravitational force and the opposing resistive force. The latter is known to be proportional to the speed of the drop but is otherwise undetermined. Consider a drop of mass 1 g falling from a height of 1 km. It hits the ground with a speed of 50 ms^{-1}.

(a) What is the work done by the gravitational force?

(b) What is the work done by the unknown resistive force?

Q54. (a) A spherical of mass 20 kg is stationary at the top of a hill of height 100 m. It rolls down a smooth surface to the ground, then climbs up another hill of height 30 m and finally rolls down to a horizontal base at a height of 20 m above the ground. Find the velocity possessed by the ball at its final position. Given that g = 10 ms^{-1}.

(b) A light body and heavy body have same momentum. Which is having more kinetic energy and why?

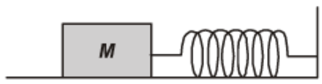
Q55. Calculate the velocity of the bob of a simple pendulum at its mean position, if it is able to rise to a vertical height of 10 cm. Given, g = 980 cm s^{-2}.

Q56. A ball bounces to 80% of its original height. What fraction of its mechanical energy is lost in each bounce? Where does this energy go?

Q57. The absolute value of potential energy (and therefore total energy) has no physical significance. It is the difference of potential energies that matters. One can, therefore, add or subtract a constant to the potential energy provided we do it to potential energy at every position for a given force, without any change in the physical situation. By convention, for force which fall off to zero at large distances, the potential energy positive or negative or (a) electron-positron bound state, (b) planet-satellite system (c) electron-electron system?

Q58. Kinetic energy of a body is increase by 300%. Find the percentage in momentum.

Q59. The block of mass M moving on the frictionless horizontal surface collides with the spring of spring constant k and compresses it by length L [as shown in the figure]. Find the maximum momentum of the block after collision.



Q60. A body of mass 10 kg moving with a speed of 2 ms^{-1} on a frictionless table impinges a mounted spring of force constant 4×10^5 Nm^{-1}. What is the compression of the springs, when the body comes to rest?

Q61. A spring obeys Hooke's law. It requires 20 J of work to stretch it through 0.1 m. Find the force constant of the spring. Also calculate the work done to stretch it further through 0.1 m.

Q62. When a block of mass 0.5 kg is suspended from the end of a spring, it stretches by 0.02 m. (a) Find the force constant of the spring. (b) The block is given a sharp impulse, so that it moves upwards with a velocity of $\sqrt{20}$ ms^{-1}. How high will it rise? Given, g = 10m s^{-2}.

Q63. A person trying to lose weight (dieter) lifts a 10 kg mass, one thousand times, to a height of 0.5 m each time. Assume that the potential energy lost each time she lowers the mass is dissipated. (a) How much work does she do against the gravitational force? (b) Fat supplies 3.8×10^7 J of energy per kilogram which is converted to mechanical energy with a 20% efficiency rate. How much fat will the dieter use up?

Q64. (a) Show that in case of one dimensional elastic collision of two bodies, the relative velocity of separation after the collision is equal to the relative velocity of approach before the collision.

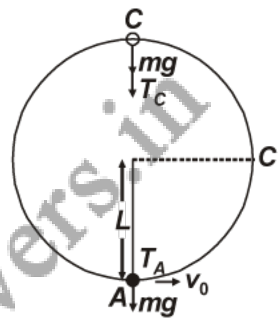
(b) A bolt of mass 0.3 kg falls from the ceiling of an elevator moving down with an uniform speed of 7 m s^{-1}. It hits the floor of the elevator (length of the elevator = 3 m) and does not rebound. What is the heat produced by the impact? Would your answer be different if the elevator were stationary?

Q65. (a) Define kinetic energy. Prove that K.E. associated with a mass '*m*' moving with velocity *v* is $\frac{1}{2} mv^2$.

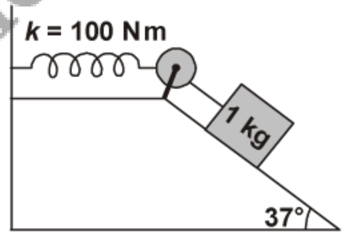
(b) How high must a body be lifted 1 to gain an amount of potential energy equal to the kinetic energy equal to at speed 20 ms^{-1}. The value of acceleration due to gravity at that place is $g = 9.8\ ms^{-2}$.

Q66. The mass of a pendulum bob is 0.1 kg and the string is 1 m long. The bob is held, so that the string is horizontal and it is then allowed to fall. Find its kinetic energy, when the string makes an angles of (a) 0° and (b) 30° with the vertical.

Q67. A bob of mass *m* is suspended by a light string of length *L*. It is imparted a horizontal velocity v_0 at the lowest point *A* such that it completes a semi-circular trajectory in the vertical plane with the string becoming slack only on reaching the topmost point, *C*. This is shown in figure. Obtain an expression for (a) v_0; (b) the speeds at points *B* and *C*; (c) the ratio of the kinetic energies (K_B/K_C) at *B* and *C*. Comment on the nature of the trajectory of the bob after it reaches the point *C*.



Q68. A 1 kg block situated on a rough incline is connected to a spring of spring constant 100 N m^{-1} as shown in figure. The block is released from rest with the spring in the unstretched position. The block moves 10 cm down the incline before coming to rest. Find the coefficient of friction between the block and the incline. Assume that the spring has a negligible mass and the pulley is frictionless.



Q69. A 75 kg box is dropped from the top of a tower. The height of the tower is 35 m. Calculate

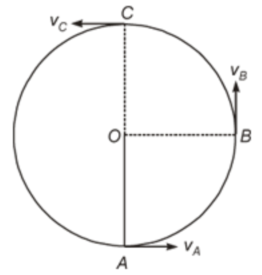
(a) The initial potential energy of the box,

(b) Its potential energy 15 m above the ground,

(c) The maximum value of its kinetic energy and

(d) Its kinetic energy 20 m below the top of the tower.

Q70. A bob of mass M is suspended by a light string of length L. It is imparted a horizontal velocity v_A at the lowest point A, such that it completes a semi-circular trajectory in the vertical plan with the string becoming slack only on reaching the topmost point C [as shown in figure].

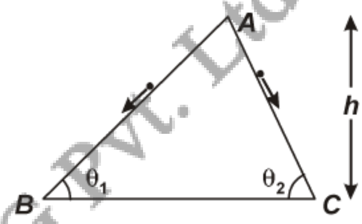


Obtain an expression for (a) v_A, v_B and v_C, the speeds at the points A, B and C and (b) the ratio of kinetic energies at B and C. Comment on the nature of the trajectory of the bob, after it reaches the point C.

Q71. A running man has half the kinetic energy that a boy of half his mass has. The man speeds up by 1 ms^{-1} and then has the same kinetic energy as the boy. What were the original speeds of the man and the boy.

Q72. A particle of mass m moves in a straight line with retardation proportional to its displacement. Find the expression for loss of kinetic energy for any displacement x.

Q73. Two inclined frictionless tracks, one gradual and the other steep meet at A from where two stones are allowed to slide down from rest, one on each track (as shown in figure). Will the stones reach the bottom at the same time? Will they reach there with the same speed? Explain. Given $\theta_1 = 30°$, $\theta_2 = 60°$, and $h = 10$ m, what are the speed and times taken by the two stone the two stones?



Q74. A rain drop of radius 2 mm falls from a height of 500 m above the ground. It falls with decreasing acceleration (due to viscous resistance of the air) until at half its original height, it attains its maximum (terminal) speed, and moves with uniform speed What is the work done by the gravitational force on the drop in the first and second half of its journey? What is the work done by the resistive force in the entire journey if its speed on reaching the ground is 10 ms^{-1}.

Q75. What is Einstein's energy-mass equivalence? Explain the energy output of a mass on the basis of this relationship. Give two situations where this relationship can be employed. Also calculate energy released from complete annihilation of 1 g matter.

Date: 13/10/2021

S1. Consider two particles having momentum m_1u_1 and m_2u_2 colliding perfectly inelastically to form single mass $(m_1 + m_2)$ moving with velocity v. For *K.E.* to be completely lost

$$\frac{1}{2}(m_1 + m_2)v^2 = 0 \quad \text{or} \quad v = 0$$

i.e.,
$$\frac{m_1u_1 + m_2u_2}{m_1 + m_2} = 0$$

$$m_1u_1 = -m_2u_2$$

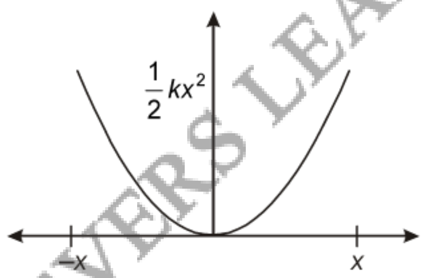
i.e., the two particles should have equal opposite momentum for K.E. to be completely lost.

S2. At all stages during motion of the planet around sun, the sum of kinetic and potential energies is constant. When the planet is farthest from the sun, it is slowest. In other words, it has minimum kinetic energy and words, it has minimum kinetic energy and hence maximum potential energy.

S3. As
$$K = \frac{p^2}{2m},$$

Since p is same for both bodies $K \propto \frac{1}{m}$, *i.e.*, lighter body has more K.E. than the heavier body.

S4.



S5.
$$E = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mE}$$

Heavier the mass, more the momentum. So m_1 will have more momentum than m_2

S6. Energy stored in a spring is $\frac{1}{2}kx^2$.

S7. S.I. unit for spring constant is Nm^{-1}.

S8. Energy can neither be created nor destroyed, but only can be transformed from one form to another.

S9. Potential energy.

S10. 1 MeV = 1.6×10^{-13} J.

S11. It is the energy consumed by an application of power one kilowatt in one hour.

S12. It states that work done by a force acting on a body is equal to the change produced in the kinetic energy of the body.

$$W = \frac{1}{2}M\,v^2 - \frac{1}{2}M\,u^2.$$

S13. It is the energy possessed by a body by virtue of its position of configuration (shape or size).

$$PE = Mgh$$

Its dimension $[ML^2T^{-2}]$.

S14. The energy possessed by a body by virtue of its motion is called kinetic energy.

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

Its dimension $[ML^2T^{-2}]$.

S15. False.

Explanation: In an elastic collision, the total energy and momentum of both the bodies, and not of each individual body, is conserved.

S16. Total linear momentum.

Explanation: The total linear momentum always remains conserved whether it is an elastic collision or an inelastic collision.

S17. Kinetic energy.

Explanation: The work done against the direction of friction reduces the velocity of a body. Hence, there is a loss of kinetic energy of the body.

S18.

$$\frac{80}{100}mgh = mgh'$$

$$h' = \frac{4}{5}h = \frac{4}{5} \times 10\text{ m} = \mathbf{8\ cm}.$$

S19. Given: $E = 40 \times 10^6$ kWh $= 40 \times 10^6 \times 10^3 \times 3{,}600$

If M is the mass to be annihilated, then

$$M = \frac{E}{c^2} = \frac{40 \times 10^6 \times 10^3 \times 3{,}600}{(3 \times 10^8)^2}$$

$$= \mathbf{1.6 \times 10^{-3}\ kg}.$$

S20. Energy and non-mass are inter convertible. In Physics, it gives explanation for the energy released in nuclear reactions.

S21. Yes. A single force cannot keep a body at equilibrium. It will change its kinetic energy.

S22. True

Explanation: In an inelastic collision, the final kinetic energy is always less than the initial kinetic energy of the system. This is because in such collisions, there is always a loss of energy in the form of heat, sound, etc.

S23. False

Explanation: Although internal forces are balanced, they cause no work to be done on a body. It is the external forces that have the ability to do work. Hence, external forces are able to change the energy of a system.

S24. False

Explanation: The work done in the motion of a body over a closed loop is zero for a conservation force only.

S25. A force is said to be conservative, if the work by the force in moving a body between any two points is independent of the path followed.

If the work done by a force in moving a body over a closed path is non-zero, the force is said to be a non-conservative force.

S26. The potential energy of a body is said to positive, if they are held at some distance against the force repulsion. On the other hand, the potential energy is said to be negative, if the bodies are held against the force of attraction.

S27. It states that work done by a force acting on a body is equal to the change produced in the kinetic energy of the body.

Suppose that a body is initially at rest and the force $\vec{F}$ is applied on the body to displace it through $\overrightarrow{dS}$ along the direction of the force. Then, the small work done

$$dW = \vec{F}.\overrightarrow{dS} = F\,dS \qquad (\because \quad \theta = 0°)$$

According to Newton's second law of motion,

$$F = M\,a,$$

where a is acceleration produced (in the direction of force) on applying the force.

$$\therefore \qquad dW = M\,a\,dS = M\frac{dv}{dt}dS \qquad \left(\because\ a = \frac{dv}{dt}\right)$$

or

$$dW = M\,\frac{dS}{dt}\,dv = M\,v\,dv \qquad \left(\because\ a = \frac{dS}{dt} = v\right)$$

Therefore, work done by the force in order to increase its velocity from u (initial velocity) to v (final velocity) is given by

$$W = \int_u^v M\,v\,d\,v = M\int_u^v v\,d\,v = M\left|\frac{v^2}{2}\right|_u^v$$

or $$W = \frac{1}{2}Mv^2 - \frac{1}{2}Mu^2$$

Hence, work done on a body by a force is equal to the change in its kinetic energy.

S28. By Einstein's theory of relativity,

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

$\Rightarrow$ mass of moving body increases with velocity, because if v is increases with velocity, because if v is increased $\Rightarrow \frac{v^2}{c^2}$ is increased.

$\Rightarrow$ $1-\frac{v^2}{c^2}$ is decreased $\Rightarrow \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ in increased. If v is zero then $m = m_{0.}$

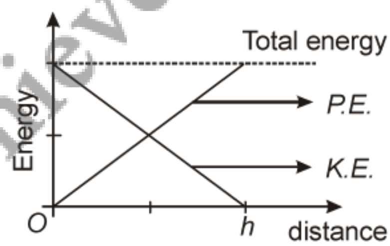
S29. Let T be K.E. of a vehicle. If the vehicle comes to rest in a distance S on applying a retarding force F, then work done by the retarding force has to be just equal to the kinetic energy of the vehicle *i.e.*,

$$FS = T$$

or $$S = \frac{T}{F}$$

Since for both the vehicles, the values of T and F are same, they will come to rest in the ***same distance*** and hence in the same time.

S30. The total energy associated with a mass 'm' at any height 'h' is mgh. The variation of potential and kinetic energy from ground to height 'h' is mgh. The variation of potential and kinetic energy from ground to height 'h' is given as:



S31. According to the law of conservation of energy.

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

$$9.8\,h = \frac{1}{2} \times 20 \times 20$$

$$h = \frac{200}{9.8} = 20.4 \text{ m}.$$

S32. Given

$m_1 = m \quad u_1 = u$

$m_2 = M \quad u_2 = 0,\ v_2 = ?$

$$v_2 = \frac{2m_1u_1}{m_1 + m_2} + \frac{(m_2 - m_1)\,u_2}{m_1 + m_2}$$

$$= \frac{2mu}{m + M} + 0 = \frac{2mu}{m + M}$$

K.E of body stuck after collision,

$$E_2 = \frac{1}{2}m_2v_2^2 = \frac{1}{2}M\left(\frac{2mu}{m+M}\right)^2$$

$$= \frac{2Mm^2u^2}{(m+M)^2}$$

Initial K.E.,

$$E_1 = \frac{1}{2}m_1u_1^2 = \frac{1}{2}mu^2$$

$\therefore$ fraction of initial K.E. transferred

$$\frac{E_2}{E_1} = \frac{2Mm^2u^2}{(m+M)^2\left(\frac{1}{2}mu^2\right)}$$

$$= \frac{4mM}{(m+M)^2}$$

S33. Given

$m = 4$ kg, $u = 0$,

$F = 16$ N, $t = 10$ sec

$F = ma \Rightarrow 16 = 4a \Rightarrow a = 4\ \text{m/s}^2$

$v = u + at = 0 + 4(10)$

$v = 40$ m/s

K.E. of the body at the end of 10 sec.

$$E = \frac{1}{2}mv^2 = \frac{1}{2} \times 4 \times (40)^2$$

$= 3200$ J.

S34. Here, $M = 5$kg; $F = 20$ N; $u = 0$ and $t = 10$ s

Now, acceleration produced

$$a = \frac{F}{M} = \frac{20}{5} = 4\ \text{ms}^{-2}$$

Let v be the velocity attained by the body at the end of 10 s

From the relation: $v = u + at$, we have

$$v = 0 + 4 \times 10 = 40 \text{ ms}^{-1}$$

Hence, the kinetic energy acquired by the body,

$$\text{K.E.} = \frac{1}{2} Mv^2 = \frac{1}{2} \times 5 \times 40^2 = \mathbf{4,000\ J}.$$

S35. Given: Mass of the electron, $m_0 = 9.1 \times 10^{-31}$ kg

Velocity of light = $3 \times 10^8 \text{ ms}^{-1}$

$$\therefore \quad E = m_0 c^2 = 9.1 \times 10^{-31} \times (3 \times 10^8)^2 = 81.9 \times 10^{-15} \text{ J}$$

$$= \frac{81.9 \times 10^{-15}}{1.6 \times 10^{-13}} = \mathbf{0.512\ MeV}.$$

S36. If a body possesses momentum p, then its kinetic energy is give by

$$T = \frac{p^2}{2m}$$

If the momentum of the body is doubled, then its kinetic energy will become

$$T' = \frac{(2p)^2}{2m} = \frac{4p^2}{2m}$$

Now, change in the kinetic energy of the body,

$$T' - T = \frac{4p^2}{2m} - \frac{p^2}{2m} = \frac{3p^2}{2m}$$

% change in the kinetic energy of the body,

$$\frac{T' - T}{T} \times 100 = \frac{3p^2}{2m} \times \frac{2m}{p^2} \times 100 = \mathbf{300\%}.$$

S37. When a mass M is raised through a height h with acceleration a, then work done,

$$W = M(g + a)h \quad \ldots \text{(i)}$$

Setting the values $W = 230$ J; $M = 10$ kg;

$h = 2$m and g = 10 ms^2

$$\therefore \quad 230 = 10 \times (10 + a) \times 2 \quad \text{or} \quad 10 + a = 11.5$$

or $a = \mathbf{1.5\ ms^{-2}}$.

S38. Suppose that when a spring having spring constant k is applied a deforming force, its length increases by x. Then,

$$F = -kx \quad \ldots \text{(i)}$$

Here, F is the restoring force set up in the spring and it is equal and opposite to the applied deforming force. When the spring is cut into two halves and the same deforming force is applied to each half, the increase in length will be $x/2$. If k' is spring constant of the each portion of the spring, then

$$F = -k' (x/2) \quad \dots \text{(ii)}$$

From the Eqns (i) and (ii), it follows that

$$K' = \mathbf{2k}.$$

S39. (a) The change in kinetic energy of the drop is

$$\Delta K = \frac{1}{2} m v^2 - 0 \qquad \left[\frac{1}{2} mv^2 = \text{Final kinetic energy}\right]$$

$$= \frac{1}{2} \times 10^{-3} \times 50 \times 50$$

$$= 1.25 \text{ J}$$

where we have assumed that the drop is initially at rest.

Assuming that g is a constant with a value 10 m/s^2, the work done by the gravitational force is,

$$W_g = mgh$$

$$= 10^{-3} \times 10 \times 10^3$$

$$= 10.0 \text{ J}$$

(b) From the work-energy theorem

$$\Delta K = W_g + W_r$$

where W_r is the work done by the resistive force on the raindrop. Thus

$$W_r = \Delta K - W_g$$

$$= 1.25 - 10$$

$$= -8.75 \text{ J}$$

is negative.

S40. The sand bag is placed on a trolley that is moving with a uniform speed of 27 km/h. The external forces acting on the system of the sandbag and the trolley is zero. When the sand starts leaking from the bag, there will be no change because the leaking action does not produce any external force on the system. This is in accordance with Newton's first law of motion. Hence, the speed of the trolley will remain 27 km/h.

S41. Given, Mg = 3000 kgf = 3000 × 9.8 N; H = 1 km = 10^3 m; t = 1 min = 60 s

Total work done by the aircraft,

$$W = Mgh = 3000 \times 9.8 \times 10^3 \text{ J}$$

Hence, power developed by the aircraft,

$$P = \frac{W}{t} = \frac{3,000 \times 9.8 \times 10^3}{60} = 490 \times 10^3 \text{ W} = \textbf{490 KW}.$$

S42. The initial kinetic energy of the bullet is $mv^2/2 = 1000$ J. It has a final kinetic energy of $0.1 \times 1000 = 100$ J. If v_f is the emergent speed of the bullet,

$$\frac{1}{2} m v_f^2 = 100 \text{ J}$$

$$v_f = \sqrt{\frac{2 \times 100 \text{ J}}{0.05 \text{ kg}}} = 63.2 \text{ m s}^{-1}$$

The speed is reduced by approximately 68%.

S43. Work done on the cycle by the road is the work done by the stopping (frictional) force on the cycle due to the road.

(a) The stopping force and the displacement make an angle of 180° (π rad) with each other. Thus, work done by the road,

$$Wr = Fd \cos \theta$$

$$= 200 \times 10 \times \cos \pi$$

$$= -2000 \text{ J}$$

It is this negative work that brings the cycle to a halt in accordance with WE theorem.

(b) From Newton's Third Law an equal and opposite force acts on the road due to the cycle. Its magnitude is 200 N. However, the road undergoes no displacement. Thus, work done by cycle on the road is zero.

S44. The plot of the applied force is shown in figure. At $x = 20$ m, $F = 50$ N ($\neq 0$). We are given that the frictional force f is $|f| = 50$ N. It opposes motion and acts in a direction opposite to F. It is therefore, shown on the negative side of the force axis.

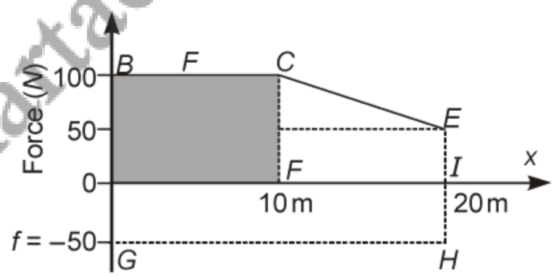
The work done by the woman is

$W_F \rightarrow$ area of the rectangle *ABCD*

+ area of the trapezium *CEID*

$$W_F = 00 \times 10 + \frac{1}{2}(100 + 50) \times 10$$

$$= 1000 + 750 = 1750 \text{ J}$$



The work done by the frictional force is

$W_f \rightarrow$ area of the rectangle *AGHI*

$$W_f = (-50) \times 20 = -1000 \text{ J}$$

The area on the negative side of the force axis has a negative sign.

S45. (a) Energy required to break one bond of DNA is

$$\frac{10^{-20}\text{ J}}{1.6\times10^{-19}\text{ J/eV}} \simeq 0.06\text{ eV}$$

Note 0.1 eV = 100 meV (100 millielectron volt).

(b) The kinetic energy of an air molecule is

$$\frac{10^{-21}\text{ J}}{1.6\times10^{-19}\text{ J/eV}} \simeq 0.0062\text{ eV}$$

This is the same as 6.2 meV.

(c) The average human consumption in a day is

$$\frac{10^{7}\text{ J}}{4.2\times10^{3}\text{ J/kcal}} \simeq 2400\text{ kcal}$$

We point out a common misconception created by newspapers and magazines. They mention food values in calories and urge us to restrict diet intake to below 2400 calories. What they should be saying is kilocalories (kcal) and not calories. A person consuming 2400 calories a day will soon starve to death! 1 food calorie is 1 kcal.

S46. From Eq. (6.8a)

$$K_f = K_i + \int_{0.1}^{2.01}\left(\frac{-k}{x}\right)dx$$

$$= \frac{1}{2}mv_i^2 - k\ln(x)\Big|_{0.1}^{2.01}$$

$$= \frac{1}{2}mv_i^2 - k\ln(2.01/0.1)$$

$$= 2 - 0.5\ln(20.1)$$

$$= 2 - 1.5 = 0.5\text{ J}$$

$$v_f = \sqrt{2K_f/m} = 1\text{ m s}^{-1}$$

Here, note that ln is a symbol for the natural logarithm to the base e and not the logarithm to the base 10 [$\ln X = \log_e X = 2.303\log_{10}X$].

S47. The downward force on the elevator is

$$F = mg + F_f = (1800\times10) + 4000 = 22000\text{ N}$$

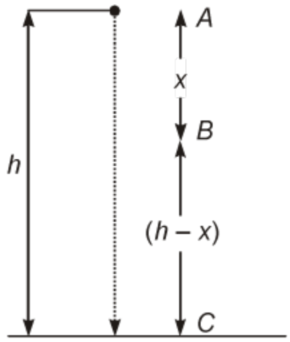
The motor must supply enough power to balance this force. Hence,

$$P = \boldsymbol{F}.\boldsymbol{v} = 22000\times2 = 44000\text{ W} = 59\text{ hp.}\qquad[1\text{ hp} = 746\text{ watts}]$$

S48. **At *A*:** P.E. = mgh

P.E. K.E. = 0

Total energy = P.E. + K.E. = mgh



At *B*:

Velocity $v = \sqrt{2gx}$ [$V^2 - U^2 = 2as$]

$$\text{K.E.} = \frac{1}{2}mv^2 = \frac{1}{2}m \cdot 2gx = mgx$$

$$\text{P.E.} = mg(h - X)$$

$$\text{Total energy} = mg(h - X) + mgx$$

$$= mgh$$

At *C*:

Velocity $v = \sqrt{2gh}$.

$$\text{K.E.} = \frac{1}{2}mv^2 = \frac{1}{2}m \cdot 2gh = mgh$$

$$\text{P.E.} = 0$$

∴ total energy = mgh.

Total mechanical energy is therefore mgh at all states as a body is dropped.

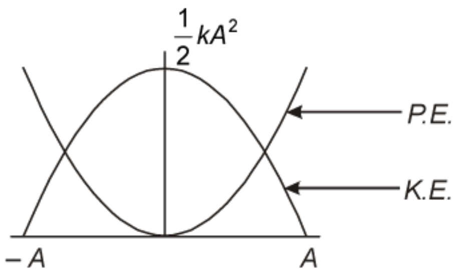
S49. Consider a particle of mass m attached to a spring is compressed through small distance x then restoring force comes into play

$$F = -kx \quad \text{... (i)}$$

This force brings the body back to its mean position and hence it starts oscillating. If $\frac{d^2x}{dt^2}$ is acceleration produced,

$$F = \frac{md^2x}{dt^2} \quad \text{... (ii)}$$

From (i) and (ii)



$$\frac{md^2x}{dt^2} = -kx$$

⇒ $$\frac{d^2x}{dt^2} = \frac{-k}{m}x$$

$$= \frac{d^2x}{dt^2} + \omega^2 x$$

$$= 0 \qquad \left(\omega^2 = \frac{k}{m}\right)$$

New potential energy

$$U = \frac{1}{2}m\omega^2 x^2$$

Putting value of ω^2, we have $U = \frac{1}{2}kx^2$

Alternatively, $U = W = \int F dx$

$$= \int kx\, dx = \frac{1}{2}kx^2$$

As position x changes from O to $\pm$A. The potential energy increases causing decrease in K.E. of the attached mass. It can be shown in figure.

S50. Force of kinetic friction

$$F_k = \mu \text{ mg}$$
$$= (0.2)\ (2\text{ kg})\ (10\text{ m/s}^2)$$
$$= 4\text{ N}.$$

Net external force on the body

$$F_{\text{net}} = 20\text{ N} - 4\text{ N} = 16\text{ N}$$

Acceleration $a = \frac{F_{\text{net}}}{m} = \frac{16\,N}{2\,kg} = 8\,m/s^2$

Displacement of the body in 10 sec.

$$S = \text{ut} + \frac{1}{2}at^2 = \frac{1}{2}at^2$$
$$= \frac{1}{2} \times (8)(10)^2 = \mathbf{400\ m}.$$

(a) Work done by applied force

$$W = F \times S$$
$$= 20 \times 400$$
$$= \mathbf{8{,}000\ J}.$$

(b) Change in K.E.

= Work done by net force

$$= F_{\text{net}} \times S$$
$$= 16 \times 400 = \mathbf{6{,}400\ J}.$$

S51. Here, mass of the bullet,

$$M = 10 \text{ g} = \frac{10}{1{,}000} = 0.01 \text{ kg};$$

Velocity of the bullet before entering the mud wall,

$$u = 800 \text{ ms}^{-1};$$

Velocity of the bullet on leaving the mud wall,

$$v = 100 \text{ ms}^{-1};$$

and distance covered by the bullet,

$$S = 1 \text{ m}$$

Let F be the average resistance offered by the wall. Then, according to work-energy theorem,

Work done against resistance offered by the mud wall

= change in kinetic energy of the bullet

i.e., $$-FS = \frac{1}{2}Mv^2 - \frac{1}{2}Mu^2$$

or $$F = \frac{M(u^2 - v^2)}{2S} = \frac{0.01 \times [(800)^2 - (100)^2]}{2 \times 1}$$

$$= \mathbf{3{,}150\ N}.$$

S52. Here, $M = 50 \text{ g} = 0.05 \text{ kg}$; $v_i = 300 \text{ ms}^{-1}$

Therefore, initial kinetic energy of the bullet,

$$K_i = \frac{1}{2}Mv_i^2 = \frac{1}{2} \times 0.05 \times 300^2 = 2{,}250 \text{ J}$$

Final kinetic energy of the bullet after emerging from plywood,

$$k_f = 2{,}250 \times \frac{20}{100} = \mathbf{450\ J}$$

If V' is the final velocity of the bullet, then

$$k_f = \frac{1}{2}Mv_f^2 = 450$$

or $$v_f = \sqrt{\frac{2 \times 450}{M}} = \sqrt{\frac{2 \times 450}{0.05}} = \mathbf{134.16\ m\ s^{-1}}.$$

S53. (a) Here, $M = 1\text{g} = 0.001 \text{ kg}$; $h = 1 \text{ km} = 1{,}000 \text{ m}$

and $v = 50 \text{ ms}^{-1}$

Therefore, work done by the gravitational force,

$$W = Mgh = 0.001 \times 9.8 \times 1{,}000 = \mathbf{9.8\ J}$$

(b) If W' is work done by the unknown resistive force, then according to work-energy theorem,

$$W + W' = \frac{1}{2} Mv^2 - \frac{1}{2} \text{Mu}^2$$

or

$$W' = \frac{1}{2} Mv^2 - \frac{1}{2} Mu^2 - W$$

$$= \frac{1}{2} \times 0.001 \times 50^2 - \frac{1}{2} \times 0.001 \times 0^2 - 9.8$$

$$= 1.25 - 0 - 9.8 = \mathbf{-8.55\ J}.$$

S54. (a) Given, initial height of the ball, $h_i = 100$ m,

Initial velocity of the ball, $v_i = 0$.

Final height of the ball, $h_f = 20$ m

Let v_f be the velocity acquired by the ball on attaining height h_f. Then, according to the law of conservation of energy,

$$Mgh_i + \frac{1}{2} Mv_i^2 = Mgh_f + \frac{1}{2} Mv_f^2$$

Since $v_i = 0$, we have

$$v_f = \sqrt{2g(h_i - h_f)} = \sqrt{2 \times 10 \times (100 - 20)}$$

$$= \mathbf{40\ m\ s^{-1}}.$$

(b) Let m_1 and m_2 be the masses of the lighter and heavier body and v_1 and v_2 be their respective velocity. Since they possess same momentum,

$$M_1 v_1 = m_2 v_2$$

K.E. of the lighter body, $T_1 = \frac{1}{2} m_1 v_1^2;$

K.E. of the heavier body, $T_2 = \frac{1}{2} m_2 v_2^2$

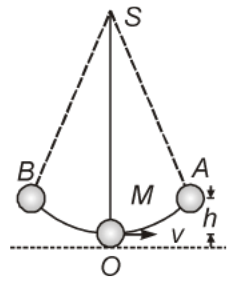
$$\frac{T_1}{T_2} = \frac{\frac{1}{2} m_1 v_1^2}{\frac{1}{2} m_2 v_2^2} = \frac{(m_1 v_1)^2}{(m_2 v_2)^2} x \frac{m_2}{m_1}$$

or $\frac{T_1}{T_2} = \frac{m_2}{m_1}$ $[\because\ m_1 v_1 = m_2 v_2]$

As $m_1 < m_2$, therefore, $E_1 > E_2$ *i.e.*, the lighter body has more kinetic energy.

S55. Consider that the bob of a simple pendulum of mass M has velocity v at its mean position O. When the bob of the pendulum moves from its mean position to the extreme position, say A, it rises through a height h above the ground as shown in figure.

In doing so, its kinetic energy at the mean position. O changes into potential energy at the extreme position. At the point A, the energy of the bob is wholly potential (Mgh), while at the point O, the energy is wholly kinetic ($\frac{1}{2}Mv^2$).



According to the principle of conservation of energy,

i.e kinetic energy at mean position = potential energy at extreme position.

$$\frac{1}{2}Mv^2 = Mgh$$

or $$v = \sqrt{2gh}$$

Here, $$h = 10 \text{ cm}; \quad g = 980 \text{ cm s}^{-2}$$

$$V = \sqrt{2 \times 980 \times 10} = \mathbf{140\ cm s^{-1}}.$$

S56. Suppose that the ball is dropped from a height h.

If M is mass of the ball, then initial potential energy possessed by the ball = Mgh

The ball bounces to 80% of its original height. Therefore,

$$\text{height attained after the bounce} = \frac{80}{100} \times h = 0.8h$$

Potential energy of the ball after the bounce

$$= Mg \times 0.8h = 0.8\,Mgh$$

Therefore, decrease in potential energy

$$= Mgh - 0.8\,Mgh = 0.2\,Mgh$$

Fraction of the energy lost in the bounce

$$= \frac{0.2\,Mgh}{Mgh} = \frac{1}{5}.$$

The energy is dissipated as heat during the bounce.

S57. By conservation, for the force which fall off to zero at large distance, the potential energy at infinity is taken to be zero. Now, such a force between two particles (or bodies) may be attractive or repulsive. When the two particles are or positive, accordingly as the force between the two particles is attractive or repulsive.

(a) For the electron-positron bound state, the potential energy is negative. It is because, force between electron and positron is attractive.

(b) For the reason stated in (a); for the planet-satellite system, the potential energy is negative.

(c) For the electron-electron system, the potential energy is positive, as the force between two electrons is repulsive in nature.

S58. Consider that a body of mass M is moving with a velocity. Then,

Kinetic energy,

$$T = \frac{1}{2}Mv^2; \quad \text{momentum, } p = Mv$$

When the kinetic energy of body is increased by 300%, *i.e.*, by $3T$, its kinetic energy will become,

$$T' = T + 3T = 4T = 4 \times \frac{1}{2}Mv^2 = 2Mv^2$$

If v' is velocity of the body, then

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

or $$v' = 2v$$

Therefore, momentum of the body will become,

$$p' = Mv' = M \times 2v = 2Mv$$

Hence, percentage increase in momentum of the body,

$$= \frac{2Mv - Mv}{Mv} \times 100 = \mathbf{100\%}.$$

S59. When the spring of spring constant k gets compressed by a length L, potential energy stored in the spring,

$$U = \frac{1}{2}kL^2$$

If v is velocity imparted to the block, then

Kinetic energy of the block = U

or $$\frac{1}{2}Mv^2 = \frac{1}{2}kL^2.$$

or $$v = \sqrt{\frac{k}{M}}L$$

If no energy is lost during collision, the above gives the maximum velocity imparted to the block. Hence, maximum momentum of the block,

$$p = Mv = M \times \sqrt{\frac{k}{M}}L$$

$$= \sqrt{Mk}\,L.$$

S60. When the body impinges on the spring, say with a velocity v, let x be the compression produced.

Then, potential energy stored in the spring,

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

Since the body comes to rest after impinging on the spring, the loss in kinetic energy of the body,

$$T = \frac{1}{2}Mv^2$$

According to the principle of conservation of energy,

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

or $$x = \sqrt{\frac{M}{k}}\,v$$

setting the values, $M = 10$ kg; $v = 2$ ms^{-1} and $k = 4 \times 10^5$ Nm^{-1}

∴ $$x = \sqrt{\frac{10}{4 \times 10^5}} \times 2 = 10^{-2}\text{m} = \mathbf{1\ cm}.$$

S61. Let k be the force constant of the spring.

Work done to stretch the spring through length x,

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

or $$k = \frac{2W}{x^2}$$

Here, $W = 20$ J and $x = 0.1$ m

∴ $$k = \frac{2 \times 20}{(0.1)^2} = \mathbf{4{,}000\ Nm^{-1}}$$

Now, total extension, $x' = 0.1 + 0.1 = 0.2$ m.

Therefore, work done to stretch the spring through 0.2 m,

$$W' = \frac{1}{2}kx'^2 = \frac{1}{2} \times 4{,}000 \times (0.2)^2 = 80\text{ J}$$

Therefore, work required to stretch the spring through additional 0.1 m

$$= W' - W = 80 - 20 = \mathbf{60\ J}.$$

S62. (a) Let k be the force constant of the spring.

Now, $$k = \frac{F}{x} = \frac{Mg}{x}$$

setting, $M = 0.5$ kg; $g = 10$ ms^{-2} and $x = 0.02$ m

$\therefore$ $$k = \frac{0.5 \times 10}{0.02} = \mathbf{250\ Nm^{-1}}$$

(b) Suppose that when block is given a sharp impulse, the spring extends in length by an amount x. If the block moves upwards with a velocity v, then

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

or $$x = \sqrt{\frac{M}{k}}\,v$$

Here, $$v = \sqrt{20}\ \text{ms}^{-1}$$

$\therefore$ $$x = \sqrt{\frac{0.5}{250}} \times \sqrt{20} = \mathbf{0.2\ m}.$$

S63. Mass of the weight, $m = 10$ kg

Height to which the person lifts the weight,

$h = 0.5$ m

Number of times the weight is lifted, $n = 1000$

(a) For work done against gravitational force:

$$= n(mgh)$$

$$= 1000 \times 10 \times 9.8 \times 0.5 = 49 \times 10^3\text{J} = 49\text{ kJ}$$

Energy equivalent of 1 kg of fat = 3.8×10^7 J

Efficiency rate = 20%

Mechanical energy supplied by the person's body:

$$= \frac{20}{100} \times 3.8 \times 10^7\text{J}$$

$$= \frac{1}{5} \times 3.8 \times 10^7$$

(b) Equivalent mass of fat lost by the dieter:

$$= \frac{1}{\frac{1}{5} \times 3.8 \times 10^7} \times 49 \times 10^3$$

$$= \frac{245}{3.8} \times 10^{-4}$$

$$= 6.45 \times 10^{-3}\text{ kg}.$$

S64. (a) Conservation of momentum

$$m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2 \quad \text{... (i)}$$

Conservation of energy

$$\frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 \quad \text{... (ii)}$$

Solving the Eq. (i) and Eq. (ii), we get

$$v_2 - v_1 = u_1 - u_2.$$

(b) Mass of the bolt, $m = 0.3$ kg

Speed of the elevator = 7 m/s

Height, $h = 3$ m

Since the relative velocity of the bolt with respect to the lift is zero, at the time of impact, potential energy gets converted into heat energy.

Heat produced = Loss of potential energy

$$= mgh = 0.3 \times 9.8 \times 3$$

$$= 8.82 \text{ J}$$

The heat produced will remain the same even if the lift is stationary. This is because of the fact that the relative velocity of the bolt with respect to the lift will remain zero.

S65. (a) Kinetic energy is defined as the energy associated with a body under motion.

$$W = \int F dx = \int m \frac{dv}{dt} dx = \int mv\, dv = \frac{1}{2} mv^2.$$

The work done is transformed as kinetic energy for anybody capable of moving.

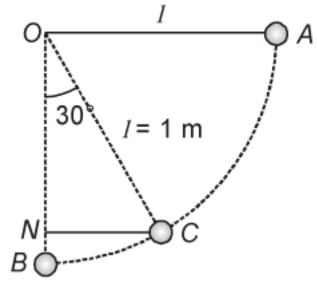
(b) Now energy equation

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

$$9.8\, h = \frac{1}{2} \times 20 \times 20$$

$$h = \frac{200}{9.8} = 20.4 \text{ m}.$$

S66. The pendulum is initially held in the position OA as shown in figure



(a) When the bob reaches the point B, the string makes an angle of 0° with the vertical. It follows that

K.E. of the bob at the point B,

= P.E. of bob at the point A

$= Mg \times l = 0.1 \times 9.8 \times 1 =$ **0.98 J**.

(b) When the bob reaches the point C, the string makes an angle of 30° with the vertical.

P.E. of the bob at the point C

$$= Mg \times BN = Mg \times (OB - ON)$$

$$= Mg \times (l - l\cos 30°)$$

$$= Mgl(1 - \cos 30°)$$

$$= 0.1 \times 9.8 \times 1 \times (1 - 0.866) = 0.131 \text{ J}$$

Therefore, K.E. of bob at the point C

$$= 0.98 - 0.131 = \mathbf{0.849\ J}.$$

S67. (a) There are two external forces on the bob : gravity and the tension (T) in the string. The latter does no work since the displacement of the bob is always normal to the string. The potential energy of the bob is thus associated with the gravitational force only. The total mechanical energy E of the system is conserved. We take the potential energy of the system to be zero at the lowest point A. Thus, at A:

$$E = \frac{1}{2} m v_0^2 \quad \text{... (i)}$$

$$T_A - mg = \frac{m v_0^2}{L} \quad \text{[Newton's Second Law]}$$

where T_A is the tension in the string at A. At the highest point C, the string slackens, as the tension in the string (T_C) becomes zero.

Thus, at C

$$E = \frac{1}{2} m v_C^2 + 2mgL \quad \text{[E = Energy]... (ii)}$$

$$mg = \frac{m v_C^2}{L} \quad \text{[Newton's Second Law] ... (iii)}$$

where v_C is the speed at C. From Eqs. (ii) and (iii)

$$E = \frac{5}{2} mgL$$

Equating this to the energy at A

$$\frac{5}{2} mgL = \frac{m}{2} v_0^2$$

or,

$$v_0 = \sqrt{5gL}$$

It is clear from Eq. (iii)

$$v_C = \sqrt{gL}$$

At B, the energy is

$$E = \frac{1}{2} m v_B^2 + mgL$$

Equating this to the energy at A and employing the result from (i), namely $v_0^2 = 5gL$,

$$\frac{1}{2}mv_B^2 + mgL = \frac{1}{2}mv_0^2$$

$$= \frac{5}{2}mgL$$

$$\therefore \quad v_B = \sqrt{3gL}$$

The ratio of the kinetic energies at B and C is:

$$\frac{K_B}{K_C} = \frac{\frac{1}{2}mv_B^2}{\frac{1}{2}mv_C^2} = \frac{3}{1}$$

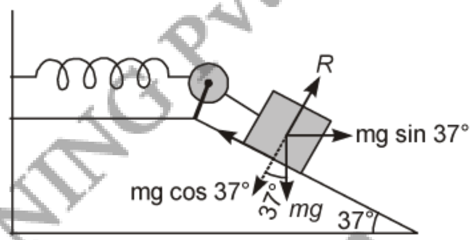
At point C, the string becomes slack and the velocity of the bob is horizontal and to the left. If the connecting string is cut at this instant, the bob will execute a projectile motion with horizontal projection akin to a rock kicked horizontally from the edge of a cliff. Otherwise the bob will continue on its circular path and complete the revolution.

S68. Mass of the block, $m = 1$ kg

Spring constant, $k = 100 \text{ N m}^{-1}$

Displacement in the block, $x = 10 \text{ cm} = 0.1 \text{ m}$

The given situation can be shown as in the following figure.



At equilibrium:

Normal reaction, $R = mg\cos 37°$

Frictional force, $f = \mu R = mg\sin 37°$

Where, μ is the coefficient of friction

$$\text{Net force acting on the block} = mg\sin 37° - f$$

$$= mg\sin 37° - \mu\, mg\cos 37°$$

$$= mg(\sin 37° - \mu\cos 37°)$$

At equilibrium, the work done by the block is equal to the potential energy of the spring, *i.e.*,

$$mg(\sin 37° - \mu\cos 37°)\,x = \frac{1}{2}kx^2$$

$$1 \times 9.8(\sin 37° - \mu\cos 37°) = \frac{1}{2} \times 100 \times 0.1$$

$$0.602 - \mu \times 0.799 = 0.510$$

$$\therefore \quad \mu = \frac{0.092}{0.799} = 0.115$$

S69. Given, $M = 75$ kg; $h = 35$ m

(a) Initial potential energy = $75 \times 9.8 \times 35$ = **25,725 J**.

(b) Potential energy at a height of 15 m = $75 \times 9.8 \times 15$ = **11,025 J**.

(c) The kinetic energy will be maximum, when the box reaches the ground and it will be equal to initial potential energy *i.e.*, **25,725 J**.

(d) As obtained in part (b), potential energy of the box at a height 15 m above the ground or 20 m below the top of the tower = 11,025 J.

Therefore, 20 m below the top of the tower,

Kinetic energy = 25,725 – 11,025 = **14,700 J**.

S70. (a) As the string slacks at the topmost point C, the tension in the string at that point will be zero.

It can be proved that the velocity of the bob at the lowest point A,

$$v_A = \sqrt{5gL}$$

The velocity of the bob at the topmost point C,

$$v_C = \sqrt{gL}$$

To find the velocity of the bob at the point B, let us apply the principle of conservation of energy.

Now, sum of potential and kinetic energies at point B

= kinetic energy at point A

or $$MgL + \frac{1}{2}Mv_B^2 = \frac{1}{2}Mv_A^2$$

$$= \frac{1}{2}M \times (\sqrt{5gL})^2 = \frac{5}{2}MgL$$

$\therefore$ $$\frac{1}{2}Mv_B^2 = \frac{5}{2}MgL - MgL = \frac{3}{2}MgL$$

or $$v_B = \sqrt{3gL}$$

(b) Now, ration of kinetic energies at the points B and C

$$\frac{T_B}{T_C} = \frac{\frac{1}{2}Mv_B^2}{\frac{1}{2}Mv_C^2} = \frac{v_B^2}{v_C^2} = \frac{(\sqrt{3gL})^2}{(\sqrt{gL})^2} = \mathbf{3}.$$

S71. Let M be the mass of the man. Then,

$$\text{Mass of the boy} = \frac{M}{2}$$

Let v_m and v_b be the speeds of the man and the boy respectively.

Then, K.E. of the man = $\frac{1}{2}Mv_m^2$

and K.E. of the boy = $\frac{1}{2}\left(\frac{M}{2}\right)v_b^2 = \frac{1}{4}Mv_b^2$

According to statement of the problem,

$$\frac{1}{2}Mv_b^2 = \frac{1}{2}\times\frac{1}{4}Mv_m^2$$

or $$v_b = 2v_m$$

When the man speeds up by 1 ms^{-1}, their kinetic energies become the same, Therefore,

$$\frac{1}{2}M(v_m + 1)^2 = \frac{1}{2}\left(\frac{M}{2}\right)v_b^2$$

or $$\frac{1}{2}M(v_m + 1)^2 = \frac{1}{2}\left(\frac{M}{2}\right)v_b^2$$

or $$(v_m + 1)^2 = 2v_m^2$$

or $$v_m + 1 = \pm\sqrt{2}\,v_m$$

The negative sign in the above equation gives

$$v_m + 1 = \sqrt{2}\,v_m$$

or $$(\sqrt{2} - 1)\,v_m = 1$$

or $$v_m = \frac{1}{\sqrt{2}-1} = 2.415\ ms^{-1}$$

Also, $$v_b = 2\times 2.415 = \mathbf{4.83\ ms^{-1}}.$$

S72. Here, $a \propto x$

or $$a = -kx, \quad \dots\text{(i)}$$

where negative sign shows that a is retardation.

Now, $$a = \frac{dv}{dt}$$

$$= \frac{dv}{dx}\times\frac{dx}{dt}$$

or $$a = v\frac{dv}{dx} \quad \dots\text{(ii)}$$

From the Eqns. (i) and (ii), we have

$$v\frac{dv}{dx} = -kx$$

or $$v\,dv = kx\,dx$$

Integrating both sides within proper limits, we have

$$\int_u^v v\,dv = k\int_0^x x\,dx$$

or $$\left|\frac{v^2}{2}\right|_v^u = -k\left|\frac{x^2}{2}\right|_0^x$$

or $$\frac{1}{2}v^2 - \frac{1}{2}u^2 = -\frac{1}{2}kx^2$$

or $$\frac{1}{2}u^2 - \frac{1}{2}v^2 = \frac{1}{2}kx^2$$

Therefore, loss in kinetic energy,

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

S73. No; the stone moving down the steep plane will reach the bottom first

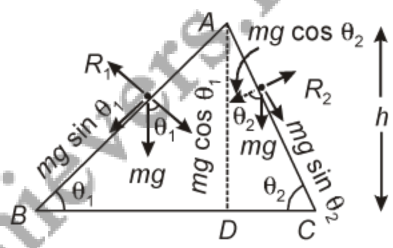
Yes; the stones will reach the bottom with the same speed

$$v_B = v_C = 14 \text{ m/s}$$

$$t_1 = 2.86 \text{ s};\ t_2 = 1.65 \text{ s}$$

– Kinetic energy of the system

The given situation can be shown as in the following figure:



Here, the initial height (AD) for both the stones is the same (h). Hence, both will have the same potential energy at point A.

As per the law of conservation of energy, the kinetic energy of the stones at points B and C will also be the same, *i.e.*,

$$\frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2$$

$$v_1 = v_2 = v, \text{ say}$$

Where, m = Mass of each stone

v = Speed of each stone at points B and C

Hence, both stones will reach the bottom with the same speed, v.

For stone I: Net force acting on this stone is given by:

$$F_{net} = ma_1 = mg \sin \theta_1$$

$$a_1 = g \sin \theta_1$$

For stone II: $a_2 = g \sin \theta_2$

$\because$ $\theta_2 > \theta_1$

$\therefore$ $\sin \theta_2 > \sin \theta_1$

$\therefore$ $a_2 > a_1$

Using the first equation of motion, the time of slide can be obtained as:

$$v = u + at$$

$\therefore$ $t = \dfrac{v}{a}$ $(\because u = 0)$

For stone I: $t_1 = \dfrac{v}{a_1}$

For stone II: $t_2 = \dfrac{v}{a_2}$

$\because$ $a_2 = \dfrac{v}{t_2}$

Hence, the stone moving down the steep plane will reach the bottom first.

The speed (v) of each stone at points B and C is given by the relation obtained from the law of conservation of energy.

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

$\therefore$ $v = \sqrt{2gh}$

$$= \sqrt{2 \times 9.8 \times 10}$$

$$= \sqrt{196} = 14 \text{ m/s}$$

The times are given as:

$$t_1 = \frac{v}{a_1} = \frac{v}{g \sin\theta_1} = \frac{14}{9.8 \times \sin 30} = \frac{14}{9.8 \times \frac{1}{2}} = 2.86 \text{ s}$$

$$t_2 = \frac{v}{a_2} = \frac{v}{g \sin\theta_1} = \frac{14}{9.8 \times \sin 60} = \frac{14}{9.8 \times \frac{1}{2}} = 1.65 \text{ s}$$

S74. Radius of the rain drop, $r = 2\text{ mm} = 2 \times 10^{-3}\text{ m}$

Volume of the rain drop, $V = \frac{4}{3}\pi r^3$

$$= \frac{4}{3} \times 3.14 \times (2 \times 10^{-3})^3$$

Density of water, $\rho = 10^3\text{ kg m}^{-3}$

Mass of the rain drop, $m = \rho V$

$$= \frac{4}{3} \times 3.14 \times (2 \times 10^{-3})^3 \times 10^3$$

The work done by the gravitational force on the drop in the first half of its journey:

$$W_I = mgh$$

$$= \frac{4}{3} \times 3.14 \times (2 \times 10^{-3})^3 \times 10^3 \times 9.8 \times 250$$

$$= 0.082\text{J}$$

This amount of work is equal to the work done by the gravitational force on the drop in the second half of its journey, i.e., W_{II}, = 0.082 J

As per the law of conservation of energy, if no resistive force is present, then the total energy of the rain drop will remain the same.

∴ Total energy at the top:

$$E_T = mgh + 0$$

$$= \frac{4}{3} \times 3.14 \times (2 \times 10^{-3})^3 \times 9.8 \times 500$$

$$= 0.164\text{ J}$$

Due to the presence of a resistive force, the drop hits the ground with a velocity of 10 m/s.

∴ Total energy at the ground:

$$E_G = \frac{1}{2}mv^2 + 0$$

$$= \frac{1}{2} \times \frac{4}{3} \times 3.14 \times \left(2 \times 10^{-3}\right)^3 \times (10)^2$$

$$= 1.675 \times 10^{-3}\text{J}$$

∴ Work done by Resistive force = $E_G - E_T = -0.162$ J.

S75. Einstein's energy mass equivalence relationship states that mass and energy are equivalent. The equivalence relation is given by $E = mc^2$ where 'm' is the mass that disappears.

In the case of sun, four hydrogen (lighter) nuclei fuse to from a helium nucleus whose mass is less than the sum of masses of four hydrogen nuclei. This mass difference, called the mass defect Δm, it is the source of energy which is released by the sun.

Two other examples are

(a) Atom bomb based on uncontrolled nuclear power plant by controlled nuclear fission process.

(b) To provided electrical as in nuclear power plant by controlled nuclear fission process.

(c) In chemical reactions. (*Any two*)

Annihilation of 1 g of matter is

$$E = mc^2$$
$$= (10^{-3}) \times (3 \times 10^8)^2$$
$$= 9 \times 10^{13}\ \text{J}.$$

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Q1. Power of electrical appliances such as electric bulbs, electric heaters, fans, electric motor and dynamos what is units?

Q2. In a tug of war, one team is slowly giving way to the other. What work is being done and by whom?

Q3. An engine pumps out 40 kg of water per second. If water comes out with a velocity of 3 m s^{-1}, then what is the power of the engine?

Q4. Can a body have energy without having momentum and have momentum without having energy? Explain.

Q5. Define power. Obtain an expression for it in terms of force and velocity.

Q6. Define the term watt, and kilo-watt hour.

Q7. A shell explodes while at rest. Discuss the momentum and energy conservation in the explosion.

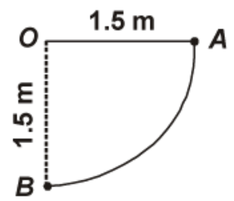
Q8. What is the difference between head-on collision and glancing collision? Define coefficient of restitution.

Q9. An aeroplane's velocity is doubled. What happens to its momentum and kinetic energy?

Q10. An elevator can carry a maximum load of 1,600 kg (elevator + passengers) is moving up with a constant speed of 2 ms^{-1}. The frictional force opposing the motion is 3320 N. Determine the maximum power delivered by the motor to the elevator (in watts as well as in horse power).

Q11. A man pulls a lawn roller with a force of 20kgf. He applies the force at an angle 60° with the ground. Calculate the work done in pulling the roller through 10 m. If he takes 1 minute in doing so, calculate the power developed. Take g = 10 ms^{-2}.

Q12. The bob of a pendulum is released from a horizontal *A* as shown. If the length of the pendulum is 1.5 m, what is the speed with which the bob arrives at the lowermost point *B*, given that it dissipates 5% of its initial energy against air resistance?



Q13. Consider Example 6.8 taking the coefficient of friction, μ, to be 0.5 and calculate the maximum compression of the spring.

Q14. To simulate car accidents, auto manufacturers study the collisions of moving cars with mounted springs of different spring constants. Consider a typical simulation with a car of mass 1000 kg moving with a speed 18.0 km/h on a smooth road and colliding with a horizontally mounted spring of spring constant 6.25×10^3 N m^{-1}. What is the maximum compression of the spring?

Q15. A pump on the ground floor of a building can pump up water to fill a tank of volume 30 m^3 in 15 min. If the tank is 40 m above the ground, and the efficiency of the pump is 30%, how much electric power is consumed by the pump?

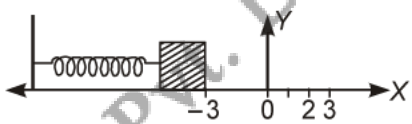
Q16. A particle of mass 4 m which is at rest explodes into three fragments. Two of these fragments each of mass *m*, are found to move with a speed of *v*, each in mutually perpendicular direction. what is the total energy released in this process?

Q17. One coolie takes one minute to raise a box through a height of 2 metre. Another one take 30 second for the same job and does the same amount of work. Which one of the two has greater power and which one uses greater energy?

Q18. A neutron (*u* m/s) collides with a nucleus at rest of mass number A. How much energy is transferred to the nucleus by the neutron?

Q19. A man weighing 60 kg climbs up a stair case carrying a load of 20 kg on his head. The stair case has 20 steps each of height 0.2 m. If he takes 10 sec to climb, find his work.

Q20. For three situations, the initial and final positions respectively, along x-axis for the block in fig. are (a) – 3 cm, 2 cm and (b) 2 cm, 3 cm. (c) 3 cm, 3 cm
In each situation, is the work done by the spring force on the block positive, negative or zero?



Q21. The heart rate (number of heart beats per minute) scales as $\frac{1}{L}$ where *L* is the characteristic length of the mammal. Can you explain this?
If the scale factor of a human relative to a rhesus monkey is about 2.5, what is the monkey's heart rate?

Q22. A car of mass 2,000 kg is lifted up a distance of 30 m by a crane in 1 minute. A second crane does the same job in 2 minutes. Do the cranes consume the same or different amounts of fuels? What is the power supplied by each crane? Neglect power dissipation against friction.

Q23. A man cycles up a hill, whose slope is 1 in 20 with velocity of 6.4 km/h along the hill. The weight of the man and the cycle is 98 kg. What work per minutes is he doing? What is his horse power?

Q24. A water pumps out 2,400 kg of water per minute.(a) If water is coming out with a velocity of 3 ms^{-1}, what is power of the pump? (b) How much work is done, if the pump runs for 10 hours?

Q25. The mass of an aeroplane is 480 quintal. It starts from rest and develops a speed of 42 ms^{-1} just before takeoff. If the length of the runway is 2 km, calculate the power developed.

Q26. An engine pumps up 1,000 kg of water through a height of 10 m in 5 s. If the efficiency of the engine 60%, calculate the power of the engine in kilowatt. Take $g = 10\ ms^{-2}$.

Q27. An automobile is moving at 100 $km\,h^{-1}$ and is exerting a attractive force of 400 kgf. What horse power must the engine develop, if 20% of the power developed is wasted?

Q28. A body is initially at rest. It undergoes one-dimensional motion with constant acceleration. What power delivered to it at time?

Q29. A body of mass 0.5 kg travels in a straight line with velocity $v = ax^{3/2}$ where a = $5\,m^{-1/2}s^{-1}$. What is the work done by the net force during its displacement from $x = 0$ to $x = 2$ m?

Q30. The blades of a windmill sweep out a circle of area A.

(a) If the wind flows at a velocity v perpendicular to the circle, what is the mass of the air passing through it in time t?

(b) What is the kinetic energy of the air?

(c) Assume that the windmill converts 25% of the wind's energy into electrical energy, and that $A = 30\ m^2$, $v = 36$ km/h and the density of air is $1.2\ kg\ m^{-3}$. What is the electrical power produced?

Q31. A family uses 8 kW of power. (a) Direct solar energy is incident on the horizontal surface at an average rate of 200 W per square meter. If 20% of this energy can be converted to useful electrical energy, how large an area is needed to supply 8 kW? (b) compare this area to that of the roof of a typical house.

Q32. A bolt of mass 0.3 kg falls from the ceiling of an elevator moving down with an uniform speed of $7\ m\,s^{-1}$. It hits the floor of the elevator (length of the elevator = 3 m) and does not rebound. What is the heat produced by the impact? Would your answer be different if the elevator were stationary?

Q33. A body is moving unidirectional under the influence of a source of constant power. What is the relation between displacement and time 't'? (F will also be a constant.)

Q34. (a) A moving car encounter air resistance which is proportional to the square of the speed of the car. What is the ratio that required at $80\ kmh^{-1}$ with the same braking force?

(b) An engine of 150 kW power is drawing a train of total mass 15×10^4 kg up an inclination of 1 in 50. The frictional resistance is 4 kg wt/1000 kg. Calculate the maximum speed. Given : $g = 10\ m\ s^{-2}$.

Q35. (a) The potential energy of a spring when stretched through a distance x is 25 J. What is the amount of work done on the same spring so as to stretch it by an additional distance $5x$?

(b) The heart of a man pumps 4 liter blood per minute at a pressure of 130 mm of mercury. If density of mercury is $13.6\ g\ cm^{-3}$, then calculate the power of the heart.

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S1. Watt or kilowatt.

S2. The winning team is performing work over losing team.

S3. Given, $m = 40$ kg, $v = 3\ \text{ms}^{-1}$

K.E. of water coming out in 1 second = $\frac{1}{2}mv^2$

$$= \frac{1}{2} \times 40 \times 3 \times 3 \text{ watt} = 180 \text{ watt}$$

$\therefore$ Power of the engine = 180 watt.

S4. Yes, a body at rest has no momentum. *i.e.*, $mv = 0$ also $K.E. = \frac{1}{2}mv^2 = 0$. But it has potential energy. Therefore it possesses energy (K.E. + P.E.), = – P.E. then total energy is zero but momentum is still there, e.g., an electron in an atom has momentum but negative total energy.

S5. **Power:** The rate of doing work is called power.

$$P = \underset{\Delta t \to 0}{Lt} \frac{\Delta W}{\Delta t} = \frac{dW}{dt}$$

$$= \frac{d}{dt}(\vec{F}.\vec{s}) = \vec{F}.\frac{\vec{ds}}{dt}$$

$$P = \vec{F}.\vec{v}$$

$\Rightarrow$ $P = Fv$

S6. **Watt:** Power is said to be one watt if it can work at the rate of 1 joule per second

1 watt = 1 joule/sec.

Kilowatt hour (kWh) = 1 kWh is work done in 1 hour at a constant rate of 1 kilowatt.

$1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$

S7. As the shell explodes, while being at rest, the momentum after explosion should also be zero. The internal energy with the shell will provide kinetic energy to the pieces into which it is broken. Therefore, there is increase in kinetic energy at the loss of internal energy.

S8. **Head on collision:** If the bodies move along the same straight line before and after collision it is called head-on collision.

Glancing collision: If the bodies do not move along the same straight line after the collision it is called glancing collision.

Coefficient of restitution: It is the measure of degree of elasticity of a collision and is defined as

$$e = \frac{\text{relative speed of separation after collision}}{\text{relative speed of approach before collision}}$$

S9. (a) When the velocity (v) of an aeroplane is doubled its momentum is also doubled when the velocity of the aeroplane is increased in forward direction, the velocity of exhaust gases also increase but in backward direction due to action of its engines. Taking forward direction as positive and backward direction as negative, thus total momentum remains same.

(b) The kinetic energy of aeroplane $\frac{1}{2}mv^2$ becomes four times its previous value, when its value is doubled. The additional kinetic energy comes from chemical energy of the fuel of engine.

S10. Here, Frictional force = 3,320 N; $v = 2\ \text{ms}^{-1}$

Now, weight of the elevator + passengers,

$$Mg = 1{,}600 \times 9.8 = 15{,}680\ \text{N}$$

Therefore force to be applied by the motor,

$$F = Mg + \text{frictional force}$$

$$= 15{,}680 + 3{,}320 = 19{,}000\ \text{N}$$

Hence, power delivered by the motor to the elevator,

$$P = Fv = 19{,}000 \times 2$$

$$= 38{,}000\ \text{W}$$

$$= \frac{38{,}000}{746} = 50.93\ \text{hp.} \qquad \textbf{[1 hp = 746 watt]}$$

S11. Given $F = 20\ \text{k}gf = 20 \times 10 = 200\ \text{N}$ $[\because\ g = 10\ \text{ms}^{-2})$

$S = 0$ m; $\theta = 60°$; $t = 1$ min = 60 s

Now, $W = FS\cos\theta = 200 \times 10 \times \cos 60°$

$$= 200 \times 10 \times 0.5 = \mathbf{1{,}000\ J}$$

Hence, power developed,

$$P = \frac{W}{t} = \frac{1{,}000}{60} = \mathbf{16.67\ W}.$$

S12. Gravitational potential energy at A

$$= mg \times 1.5\ \text{J}$$

Kinetic energy at B

$$= \left[mg \times 1.5 - \frac{5}{100} \times mg \times 1.5 \right] J$$

$$= mg \times 1.5 \times \frac{95}{100} J$$

$\because$ $(P.E.)_A = (K.E.)_B$ = and 5% of initial energy is dissipated against air resistance.

$\therefore$ $$\frac{1}{2}mv^2 = mg \times 1.5 \times \frac{95}{100}$$

or $$v^2 = \frac{2 \times 9.8 \times 1.5 \times 95}{100}$$

or $$v = 5.285 \text{ ms}^{-1}$$

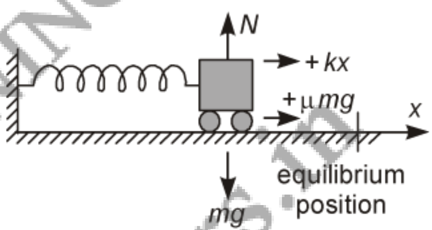
S13. In presence of friction, both the spring force and the frictional force act so as to oppose the compression of the spring as shown in figure.

We invoke the work-energy theorem, rather than the conservation of mechanical energy.

According to work energy theorem

$$\Delta K.E. = \text{Work done by net force}$$

The change in kinetic energy is



$$\Delta K = K_f - K_i = 0 - \frac{1}{2}mv^2$$

The work done by the net force is

$$W = -\frac{1}{2}kx_m^2 - \mu mgx_m$$

Equating we have

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

Now $\mu mg = 0.5 \times 10^3 \times 10 = 5 \times 10^3$ N (taking g =10.0 m s^{-2}). After rearranging the above equation we obtain the following quadratic equation in the unknown x_m.

$$kx_m^2 + 2\mu mgx_m - mv^2 = 0$$

$$x_m = \frac{-\mu mg + [\mu^2 m^2 g^2 + mkv^2]^{1/2}}{k}$$

where we take the positive square root since x_m is positive. Putting in numerical values we obtain

$$x_m = 1.35 \text{ m}$$

which, as expected, is less than the result in Example 6.8.

If the two forces on the body consist of a conservative force F_c and a non-conservative force F_{nc}, the conservation of mechanical energy formula will have to be modified. By the *WE* theorem

$$(F_c + F_{nc})\Delta x = \Delta K$$

But $F_c \Delta x = -\Delta V$

Hence, $\Delta (K + V) = Fn_c \Delta x$

$$\Delta E = Fn_c \Delta x$$

where E is the total mechanical energy. Over the path this assumes the form

$$E_f - E_i = W_{nc}$$

Where W_{nc} is the total work done by the non-conservative forces over the path. Note that unlike the conservative force, W_{nc} depends on the particular path i to f.

S14. At maximum compression the kinetic energy of the car is converted entirely into the potential energy of the spring.

The kinetic energy of the moving car is

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

$$= \frac{1}{2} \times 10^3 \times 5 \times 5$$

$$K = 1.25 \times 10^4 \text{ J}$$

where we have converted 18 km h^{-1} to 5 m s^{-1} [**It is useful to remember that 36 km h^{-1} = 10 m s^{-1}**]. At maximum compression x_m, the potential energy V of the spring is equal to the kinetic energy K of the moving car from the principle of conservation of mechanical energy.

$$V = \frac{1}{2} k x_m^2 = 1.25 \times 10^4 \text{ J}$$

We obtain

$$x_m = 2.00 \text{ m}$$

We note that we have idealised the situation. The spring is considered to be massless. The surface has been considered to possess negligible friction.

S15. Volume of the tank, $V = 30 \text{ m}^3$

Time of operation, $t = 15 \text{ min} = 15 \times 60 = 900 \text{ s}$

Height of the tank, $h = 40 \text{ m}$

Efficiency of the pump, $\eta = 30\%$

Density of water, $\rho = 10^3 \text{ kg/m}^3$

Mass of water, $m = \rho V = 30 \times 10^3 \text{ kg}$

Output power can be obtained as:

$$P_0 = \frac{\text{Work done}}{\text{Time}} = \frac{mgh}{t}$$

$$= \frac{30 \times 10^3 \times 9.8 \times 40}{900} = 13.067 \times 10^3 \text{ W}$$

For input power P_i, efficiency η, is given by the relation:

$$\eta = \frac{P_0}{P_i} = 30\%$$

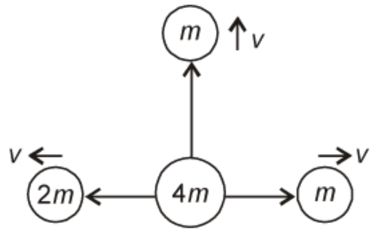
$$P_i = \frac{13.067}{30} \times 100 \times 10^3$$

$$= 0.436 \times 10^3 \text{ W} = 43.6 \text{ kW}$$

S16. (a)

$$\sqrt{2}\, mv = (2\,m)\,V$$

$$V = \frac{v}{\sqrt{2}}$$



$$\text{Total } K.E. = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}(2\,m)\frac{v^2}{2}$$

$$= \frac{3}{2}mv^2$$

S17.

$$\text{Power of first coolie} = \frac{\text{Work}}{\text{Time}} = \frac{M \times g \times S}{t} = \frac{M \times 9.8 \times 2}{60} \text{Js}^{-1}$$

$$\text{Power of second coolie} = \frac{M \times 9.8 \times 2}{30} J\,s^{-1} = 2\left(\frac{M \times 9.8 \times 2}{60}\right)\text{Js}^{-1}$$

$$= 2 \times \text{Power of first coolie}$$

So, the power of the second coolie is double that of the first. Both the coolies spend the same amount of energy.

S18. Let neutron's mass be m

The mass of nucleus of mass number A is mA.

Applying conservation of momentum, (v_1 – velocity of neutron, v_2 – velocity of nucleus after collision)

$$mu = mv_1 + mAv_2 \quad \Rightarrow \quad u = v_1 + Av_2 \qquad \dots \text{(i)}$$

Also, $v_1 - v_2 = -\,e(u - 0)$,

but $e = 1$ (e is coefficient of restitution)

$$\therefore \qquad v_1 - v_2 = -u \qquad \dots \text{(ii)}$$

Solving (i) and (ii) we get

$$v_2 = \frac{2u}{1+A} \text{ and } v_1 = \frac{u(1-A)}{(1+A)}$$

Energy transferred to the nucleus

$$= \frac{1}{2}mu^2 - \frac{1}{2}mv_1^2$$

$$= \frac{1}{2}mu^2\left[1-\left(\frac{1-A}{1+A}\right)^2\right] = \frac{4AE}{(1+A)^2}$$

Where E is the initial energy of neutron.

S19. Here $m = 60 + 20 = 80$ kg, $h = 20 \times 0.2 = 4$ m, $g = 9.8$ ms^{-2}

$\therefore$ Work done = $mgh = 80 \times 9.8 \times 4 = 3136$ J

or $$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{3136}{10} = 313.6 \text{ Js}^{-1} = 313.6 \text{ W}$$

S20. (a) Since $\Delta U = \frac{1}{2}k\left(x_2^2 - x_1^2\right)$, energy decreases, so work done by external force negative. Therefore, work done by spring force is positive.

(b) Since, $\Delta U = \frac{1}{2}k\left(x_2^2 - x_1^2\right)$, energy increases, so work done by external force is positive. Therefore, work done by spring force is negative.

(c) Since, $\Delta U = \frac{1}{2}k\left(x_2^2 - x_1^2\right)$, energy zero.

S21. In case of mammals, greater the length or heights, lower is the heart rate. So ratio of the rate of heart beat is the inverse ratio of their characteristic lengths.

For a human, there are 70 beats per minute. Since scale factor is 2.5, number of beats for a monkey will be $70 \times 2.5 = 175$ beats per minute.

S22. Here, $M = 2{,}000$ kg; $h = 30$m;

Therefore, work done in lifting the car,

$$W = Mgh = 2{,}000 \times 9.8 \times 30 = 5.88 \times 10^5 \text{ J}$$

From the principle of conservation of energy, both the cranes will consume fuel equivalent to 5.88×10^5 J *i.e.*, two cranes consume ***same amount of fuel***.

For the first cranes:

$W = 5.88 \times 10^5$ J; time, t_1 =1 min = 60 s

Therefore, power of the first cranes,

$$P_1 = \frac{W}{t_1} = \frac{5.88 \times 10^5}{60} = \mathbf{9{,}800 \text{ W}}$$

For second cranes:

$W = 5.88 \times 10^5$ J, time; t_2 = 2 min = 120 s

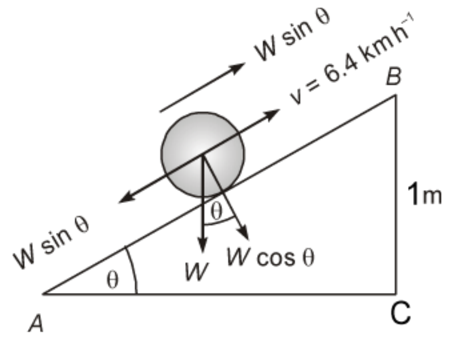
Therefore, power of the second crane,

$$P_2 = \frac{W}{t_2} = \frac{5.88 \times 10^5}{120} = \mathbf{4{,}900 \text{ W}}.$$

S23. The figure shows that, the slope of 1 in 20 implies that if $BC = 1$, Then $AB = 20$.

If the inclination of the hill with the horizontal is θ, then

$$\sin\theta = 1/20$$



The weight W of the man and cycle can be resolved into two components. Since the component of the weight alone the hill is $W\sin\theta$, in order to cycle up, the force equal to $W\sin\theta$ has to be applied in the ward direction as shown in the figure.

Thus, force applied by the man,

$$F = W\sin\theta$$

$$= 98 \times \frac{1}{20} = 4.9\,\text{k}\,gf = 4.9 \times 9.8\,\text{N}$$

Velocity of the man,

$$v = 6.4 \text{ km h}^{-1} = \frac{16}{9} \text{ ms}^{-1}$$

Now, power of the man,

$$P = Fv = 4.9 \times 9.8 \times \frac{16}{9} \text{ W}$$

$$= 4.9 \times 9.8 \times \frac{16}{9} \times \frac{1}{746} = \mathbf{0.1144\ hp}$$

Also, work done in 1 minute,

$$W = P \times t = 4.9 \times 9.8 \times \frac{16}{9} \times 60 = \mathbf{5{,}122.13\ J}.$$

S24. (a) Here, mass of the water pumped out,

$M = 2{,}400$ kg time taken, $t = 1$ min $= 60$ s

Velocity of the pumped out water,

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

From work-energy theorem,

Work done to pump out the water

= change in kinetic energy of the water

or $$W = \frac{1}{2}Mv^2 - \frac{1}{2}Mu^2 = \frac{1}{2}M(v^2 - u^2)$$

$$= \frac{1}{2} \times 2{,}400 \times (3^2 - 0^2) = 10{,}800 \text{ J}$$

Therefore, power of the water pump,

$$P = \frac{W}{t} = \frac{10{,}800}{60} = 180 \text{ W}$$

(b) Time for which the pump is run,

$$t = 10 \text{ h} = 10 \times 3{,}600 \text{ s}$$

Therefore, total work done by the pump,

$$W = P \times t = 180 \times 10 \times 3{,}600 = \mathbf{6.48 \times 10^6 \ J}.$$

S25. Here, $u = 0$; $v = 42 \text{ ms}^{-1}$ and $S = 2 \text{ km} = 2{,}000 \text{ m}$

Now, $v^2 - u^2 = 2aS$

$$42^2 - 0^2 = 2 \times a \times 2{,}000$$

or $a = 0.441 \text{ ms}^{-2}$

Mass of the aeroplane, $M = 480$ quintal $= 48{,}000$ kg

Therefore, force developed by the aeroplane,

$$F = Ma = 48{,}000 \times 0.441 = 21{,}168 \text{ N}$$

Power developed by the aeroplane at the time of take off,

$$P = Fv = 21{,}168 \times 42 = \mathbf{8{,}89{,}056 \ W}.$$

Note: The average power developed by the aero plane will be equal to one half of the power developed just before the take off.

S26. Given $M = 1{,}000$ kg; $h = 10$ m; $t = 5$ s; $g = 10 \text{ ms}^{-2}$ and $\eta = 60\% = 0.6$

Total work done by the engine,

$$W = Mgh = 1{,}000 \times 10 \times 10 = 10^5 \text{ J}$$

Output power of the engine,

$$P_{out} = \frac{W}{t} = \frac{10^5}{5} = 20{,}000 \text{ W} = 20 \text{ kW}$$

Let P_{in} be the power of the engine. Then,

$$\eta = \frac{P_{out}}{P_{in}}$$

or $$P_{in} = \frac{P_{out}}{\eta} = \frac{20}{0.6} = \mathbf{33.33 \ kW}.$$

S27. Here, force exerted, $F = 400\text{ kgf} = 400 \times 9.8\text{ N};$

$$v = 100\text{ km h}^{-1} = 27.78\text{ ms}^{-1}$$

Since 20% of the power developed is wasted, efficiency of the automobile, $\eta = 80\% = 0.8$

$$\therefore \qquad P_{in} = \frac{P_{out}}{\eta} = \frac{400 \times 9.8 \times 27.78}{0.8} = 1{,}36{,}122\text{ W}$$

$$= \frac{1{,}36{,}122}{746} = \mathbf{182.5\ h.p.}$$

S28. Let, Mass of the body = m

Acceleration of the body = a

Using Newton's second law of motion, the force experienced by the body is given by the equation:

$$F = ma$$

Both m and a are constants. Hence, force F will also be a constant

$$F = ma = \text{Constant} \qquad \dots \text{(i)}$$

For velocity v, acceleration is given as,

$$a = \frac{dv}{dt} = \text{Constant}$$

$$dv = \text{Constant} \times dt$$

$$v = \alpha t \qquad \dots \text{(ii)}$$

Where, α is another constant

$$v \propto t \qquad \dots \text{(iii)}$$

Power is given by the relation:

$$P = F.v$$

Using equations (i) and (iii), we have:

$$P \propto t$$

Hence, power is directly proportional to time.

S29. Mass of the body, $m = 0.5$ kg

Velocity of the body is governed by the equation, $v = a\,x^{3/2}$ with a = $v = 5\,m^{-1/2}s^{-1}$

Initial velocity, u (at x = 0) = 0

Final velocity v (at x = 2 m) = $10\sqrt{2}$ m/s

Work done, W = Change in kinetic energy

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

$$= \frac{1}{2} m (v^2 - u^2)$$

$$= \frac{1}{2} \times 0.5 \left[\left(10\sqrt{2}\right)^2 - (0)^2 \right]$$

$$= \frac{1}{2} \times 0.5 \times 10 \times 10 \times 2$$

$$= 50 \text{ J}$$

S30. Area of the circle swept by the windmill = A

Velocity of the wind = v

Density of air = ρ

Volume of the wind flowing through the windmill per sec = Av

(a) Mass of the wind flowing through the windmill per sec = ρAv

Mass m, of the wind flowing through the windmill in time $t = \rho Avt$

(b) Kinetic energy of air = $\frac{1}{2} mv^2$

$$= \frac{1}{2} (\rho Avt) v^2 = \frac{1}{2} \rho A v^3 t$$

Area of the circle swept by the windmill (A) = 30 m^2

Velocity of the wind (v) = 36 km/h

Density of air, (ρ) = 1.2 kg m^{-3}

Electric energy produced = 25% of the wind energy

$$= \frac{25}{100} \times \text{Kinetic energy of air}$$

$$= \frac{1}{8} \rho A v^3 t$$

(c) Electrical power = $\frac{\text{Electrical energy}}{\text{Time}}$

$$= \frac{1}{8} \frac{\rho A v^3 t}{t} = \frac{1}{8} \rho A v^3$$

$$= \frac{1}{8} \times 1.2 \times 30 \times (10)^3$$

$$= 4.5 \times 10^3 \text{ W} = 4.5 \text{ kW}$$

S31. (a) Power used by the family, $P = 8$ kW $= 8 \times 10^3$ W

Solar energy received per square metre = 200 W

Efficiency of conversion from solar to electricity energy = 20%

Area required to generate the desired electricity = A

As per the information given in the question, we have:

$$8 \times 10^3 = 20\% \times (A \times 200)$$

$$= \frac{20}{100} \times A \times 200$$

$$\because \qquad A = \frac{8 \times 10^3}{40} = 200 \text{ m}^2$$

(b) The area of a solar plate required to generate 8 kW of electricity is almost equivalent to the area of the roof of a building having dimensions 14 m $\times$ 14m.

S32. Mass of the bolt, $m = 0.3$ kg

Speed of the elevator $= 7$ m/s

Height, $h = 3$ m

Since the relative velocity of the bolt with respect to the lift is zero, at the time of impact, potential energy gets converted into heat energy.

Heat produced = Loss of potential energy

$= mgh = 0.3 \times 9.8 \times 3$

$= 8.82$ J

The heat produced will remain the same even if the lift is stationary. This is because of the fact that the relative velocity of the bolt with respect to the lift will remain zero.

Initial momentum = Final momentum

$2200 = 220v' - 80$

$$\therefore \qquad v' = \frac{2280}{220} = 10.36 \text{ m/s}$$

Length of the trolley, $l = 10$ m

Speed of the boy, $v'' = 4$ m/s

Time taken by the boy to run, $t = \frac{10}{4} = 2.5$ s

$\therefore$ Distance moved by the trolley $= v'' \times t = 10.36 \times 2.5 = 25.9$ m.

S33. Power is given by the relation:

$$P = Fv \quad \textbf{and} \quad F = ma$$

$$= mav = mv\frac{dv}{dt} = \text{Constant (say, } k)$$

$\therefore$ $$vdv = \frac{k}{m}dt$$

Integrating both sides:

$$\frac{v^2}{2} = \frac{k}{m}t$$

$$v = \sqrt{\frac{2kt}{m}}$$

For displacement x of the body, we have:

$$v = \frac{dx}{dt} = \sqrt{\frac{2k}{m}t}$$

$$dx = k't^{\frac{1}{2}}dt$$

where $k' = \sqrt{\frac{2k}{m}}$ = New constant

On integrating both sides, we get:

$$x = \frac{2}{3}k't^{\frac{3}{2}}$$

$\therefore$ $$x \propto t^{\frac{3}{2}}.$$

S34. (a) $F \propto v^2$ also $P = Fv$

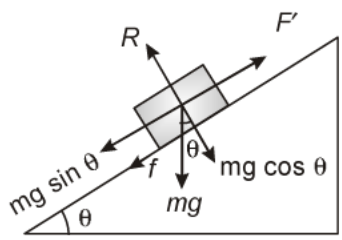
$\Rightarrow$ $$\frac{P_1}{P_2} = \frac{v_1^3}{v_2^3}$$

$$= \frac{40 \times 40 \times 40}{80 \times 80 \times 80} = \frac{1}{8}$$

(b) Power, $P = 150 \text{ kW} = 150 \times 10^3 \text{ W}$

Mass, $m = 15 \times 10^4$ kg ;

$$\sin\theta = \frac{1}{50}$$



Applied force, $F' = mg\sin\theta + f$ **(f = Frictional force)** or $$F' = \left(15\times10^4\times\frac{1}{50}+\frac{4}{1000}\times15\times10^4\times10\right)\text{N}$$

$$= (3\times10^4 + 6\times103)\text{ N} = 360000\text{ N}$$

We know that $P = F'v\cos\theta$

In this case, both the force and the velocity act in the same direction.

S35. (a) $$P.E. = \frac{1}{2}kx^2 = 25\text{ J}$$

Additional distance of 5*x* means *x* becomes 6*x*

$$P.E. = \frac{1}{2}k[6x]^2 = \frac{1}{2}k\,36x^2 = 25\times36$$

$$= 900\text{ J}$$

Additional work done = 900 – 25

= 875 J

(b) Height of liquid column, h = 130 mm = 13 cm = 0.13 m

Density of mercury, $\rho = 13.6\ g\text{ cm}^{-3} = \frac{13.6}{10^3}\times10^6\text{kg m}^{-3}$

$= 13.6\times10^3\text{ kg m}^{-3}$

Acceleration due to gravity, $g = 9.8\text{ m s}^{-2}$

Volume of blood, $V = 4\text{ liter} = 4\times10^3\text{ cm}^3$

$= 4\times10^3\times10^{-6}\text{ m}^3 = 4\times10^{-3}\text{ m}^3$

Time, t = 1 minute = 60 second

Work done, W = force × distance

= pressure × area × distance

= pressure × volume = $h\rho gV$

Power, $$P = \frac{W}{t} = \frac{h\rho g V}{t}$$

$$= \frac{0.13\times13.6\times10^3\times9.8\times4\times10^{-3}}{60}\text{ W} = 1.155\text{ W}$$

Date: 13/10/2021

Q1. Answer carefully, with reasons: Is the total linear momentum conserved during the short time of an elastic collision of two balls? When they are in contact.

Q2. In an elastic collision of two billiard balls, is the total kinetic energy conserved during the short time of collision of the balls (*i.e.*, when they are in contact). Why?

Q3. Two equal masses, one at rest and another moving undergo elastic a oblique collision. If one mass goes at an angle $\frac{\pi}{3}$ with its original direction of motion, what is the direction of motion of the other?

Q4. Write the two characteristics of inelastic collision?

Q5. Write the two characteristics of elastic collision?

Q6. What are perfectly inelastic collisions?

Q7. If one of the two colliding particles is initially at rest, is it possible for both of the particles to be at rest after collision?

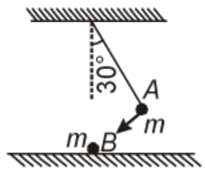
Q8. Ten identical balls are placed in contact on a smooth surface. If an eleventh identical ball moving with a speed '*u*' collides on the first, what will you notice?

Q9. Answer carefully, with reasons: If the potential energy of two billiard balls depends only on the separation distance between their centres, is the collision elastic or inelastic? (Note, we are talking here of potential energy corresponding to the force during collision, not gravitational potential energy).

Q10. Define the terms elastic collision and inelastic collision. What is the difference between inelastic collision and a completely inelastic collision?

Q11. A molecule in a gas container hits a horizontal wall with speed 200 m s^{-1} and angle 30° with the normal, and rebounds with the same speed. Is momentum conserved in the collision? Is the collision elastic or inelastic?

Q12. The bob A of a pendulum released from 30° to the vertical hits another bob *B* of the same mass at rest on a table as shown in figure. How high does the bob *A* rise after the collision? Neglect the size of the bobs.



Q13. A 20 g bullet is fired horizontally into a 5 kg block of wood suspended by a long string. The bullet gets embedded in the block and the block as a whole swings 15 cm above its initial level. Calculate the velocity of the bullet.

Q14. A ball of mass 0.1 kg makes and elastic head-on collision with a ball of unknown mass, initially at rest. If the 0.1 kg ball rebounds at one third of its original speed, what is the mass of the other ball?

Q15. A spherical metal ball of mass 0.5 kg moving with a speed of 0.5 m s^{-1} on a smooth linear horizontal track collides head on with another ball *B* of same mass at rest. Assuming the collision to be perfectly elastic, what are the speeds of *A* and *B* after collision?

Q16. In a nuclear reactor, fast neutrons collide with the atoms of the moderator and lose energy. Explain this collision.

Q17. What happens when a light sphere collides head-on with a more massive sphere initially at rest?

Q18. A trolley of mass 200 kg moves with a uniform speed of 36 km/h on a frictionless track. A child of mass 20 kg runs on the trolley from one end to the other (10 m away) with a speed of 4 m s^{-1} relative to the trolley in a direction opposite to the its motion, and jumps out of the trolley. What is the final speed of the trolley? How much has the trolley moved from the time the child begins to run?

Q19. A sphere of mass 500 g moving with velocity 200 cm s^{-1} collision centrally with another sphere of mass 100 g moving with a velocity 100 cm s^{-1} towards it. After the collision, the two spheres stick together. Find the final velocities of the two spheres and loss in kinetic energy of the system.

Q20. A bullet is fired into a block of wood. If it gets totally embedded in it and the system moves together as one entity, then state what happens to the initial kinetic energy and linear momentum of the bullet?

Q21. Two spheres moving in the same direction collide. Their masses are 5 kg and 2 kg and velocities are 10 m s^{-1} and 5 m s^{-1} respectively. If the coefficient of restitution is 0.6, find their velocities after collision. Also calculate the loss in kinetic energy.

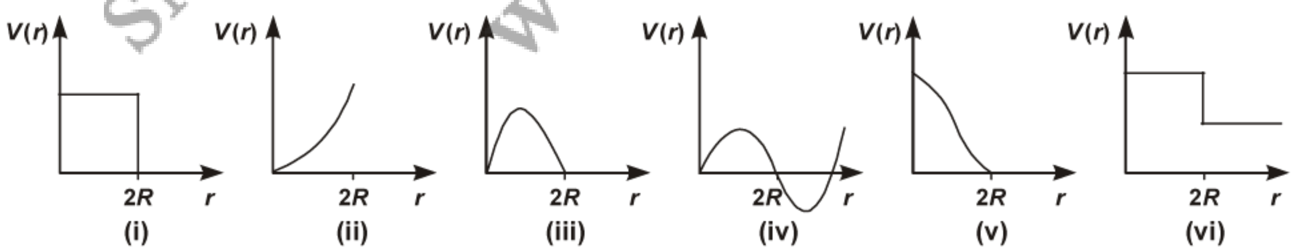
Q22. A railway carriage of mass 10,000 kg moving with a speed of 54 km h^{-1} strikes a stationary carriage of the same mass. After the collision, the carriage get coupled and move together. What is their common speed after the collision? If the collision elastic?

Q23. What are elastic collisions? A body of mass M at rest is struck by a moving body of mass m. Prove that fraction of the initial K.E. of the mass m transferred to the struck body is $4\,m\,M/(M+m)^2$ in an elastic collision.

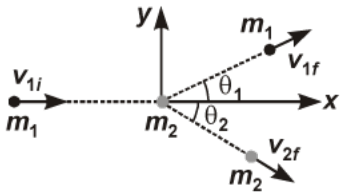
Q24. Define elastic collisions? Two balls each of mass M moving in opposite with equal speeds v undergo a head-on collision. Calculate the velocity of the two balls after collision.

Q25. Slowing down of neutrons: In a nuclear reactor a neutron of high speed (typically 10^7 m s^{-1}) must be slowed to 10^3 m s^{-1} so that it can have a high probability of interacting with isotope $^{235}_{92}U$ and causing it to fission. Show that a neutron can lose most of its kinetic energy in an elastic collision with a light nuclei like deuterium or carbon which has a mass of only a few times the neutron mass. The material making up the light nuclei, usually heavy water (D_2O) or graphite, is called a moderator.

Q26. Which of the following potential energy curves in figure cannot possibly describe the elastic collision of two billiard balls? Here r is the distance between centres of the balls.



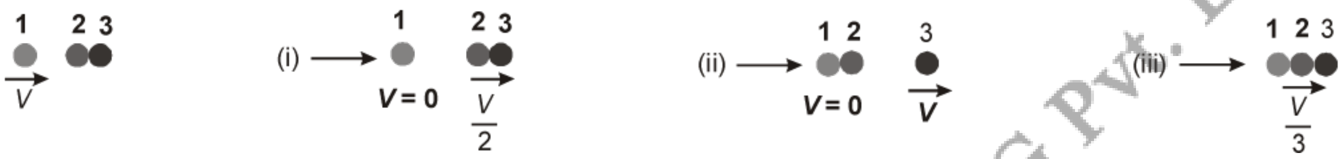
Q27. Consider the collision depicted in figure to be between two billiard balls with equal masses $m_1 = m_2$. The first ball is called the cue while the second ball is called the target. The billiard player wants to 'sink' the target ball in a corner pocket, which is at an angle $\theta_2 = 37°$. Assume that the collision is elastic and that friction and rotational motion are not important. Obtain θ_1.



Q28. Derive an expression for the velocity of the two masses m_1 and m_2 moving with speeds u_1 and u_2 undergoing elastic collision in one dimension.

Q29. A body *A* of mass *M* moving eastward with a velocity *v* collision with another identical body *B* moving northward with the same velocity. On collision, the two bodies coalesce to form a single body *C* of mass 2 *M*. Prove that the combined mass moves with velocity $v/\sqrt{2}$ in *NE*-direction.

Q30. Two identical ball bearings in contact with each other and resting on a frictionless table are hit head-on by another ball bearing of the same mass moving initially with a speed *V*. If the collision is elastic, which of the following



Q31. An electron and a proton are detected in a cosmic ray experiment, the first with kinetic energy 10 keV, and the second with 100 keV. Which is faster, the electron or the proton? Obtain the ratio of their speeds. (electron mass = 9.11×10^{-31} kg, proton mass = 1.67×10^{-27} kg, 1 eV = 1.60×10^{-19} J).

Q32. A bullet of mass 0.012 kg and horizontal speed 70 m s^{-1} strikes a block of mass 0.4 kg and instantly comes to rest with respect to the block. The block is suspended from the ceiling by means of thin wires. Calculate the height to which the block rises. Also, estimate the amount of heat produced in the block.

Date: 13/10/2021

S1. No.

S2. Total K.E. is not conserved because a part of K.E. is used in deforming the balls during that short interval.

S3. The direction of the other mass is at an angle $\left(\frac{\pi}{2}-\frac{\pi}{3}\right)$, *i.e.*, $\frac{\pi}{6}$ or 30°.

S4. (a) The momentum is conserved.

(b) The total energy is conserved

S5. (a) The momentum is conserved.

(b) The total energy is conserved.

S6. The collision, in which momentum is conserved with some loss in kinetic energy and the colliding bodies stick together and continue to move as a single body along the same straight line after the collision, is called a perfectly inelastic collision.

S7. This is not possible as law of conservation of momentum will not be obeyed.

S8. When the eleventh ball hits the first ball, the tenth will start moving with the same speed due to transfer of momentum of equal proportion.

S9. In the given case, the forces involved are conservation. This is because they depend on the separation between the centres of the billiard balls. Hence, the collision is elastic.

S10. Elastic collisions are those collisions in which the momentum and kinetic energy will be conserved. In inelastic collision only momentum will remain conserved.

In inelastic collision, loss in K.E. of moving body may not be 100% but in complete or perfect inelastic collision, the K.E. of moving body is lost so that the bodies move together after collision.

S11. Yes; Collision is elastic. The momentum of the gas molecule remains conserved whether the collision inelastic. The gas molecule moves with a velocity of 200 m/s and strikes the stationary wall of the container, rebounding with the same speed. It shows that the rebound velocity of the wall remains zero. Hence, the total kinetic energy of the molecule remains conserved during the collision. The given collision is an example of an elastic collision.

S12. Bob A will not rise at all In an elastic collision between two equal masses in which one is stationary, while the other is moving with some velocity, the stationary mass acquires the same velocity, while the moving mass immediately comes to rest after collision. In this case, a complete transfer of momentum takes place from the moving mass to the stationary mass. Hence, bob *A* of mass *m*, after colliding with bob *B* of equal mass, will come to rest, while bob *B* will move with the velocity of bob *A* at the instant of collision.

S13. Here, $m = 20$ g = 0.02 kg; $M = 5$ kg and $h = 15$ cm = 0.15 m

The velocity of bullet,

$$v = \frac{M+m}{m} \times \sqrt{2gh}$$

$$= \frac{5+0.02}{0.02} \times \sqrt{2 \times 9.8 \times 0.15} = \mathbf{430.4\ cm\ s^{-1}}.$$

S14. Given: $M_1 = 0.1$ kg; $u_2 = 0$; $v_1 = -\frac{u_1}{3}$

Now, $$v_1 = \frac{(M_1 - M_2)u_1 + 2M_2u_2}{M_1 + M_2}$$

$\therefore$ $$-\frac{u_1}{3} = \frac{(0.1 - M_2)\,u_1 + 2M_2 \times 0}{0.1 + M_2}$$

or $$-\frac{u_1}{3}\,(0.1 + M_2) = (0.1 + M_2)\,u_1$$

or $$-(0.1 + M_2) = 3\,(0.1 + M_2)$$

or $$M_2 = \mathbf{0.2\ kg}.$$

S15. Given: $M_1 = M_2 = 0.5$ kg; $u_1 = 0.5$ ms^{-1}; $u_2 = 0$

Now, $$v_1 = \frac{(M_1 - M_2)u_1 + 2M_2u_2}{M_1 + M_2}$$

$$= \frac{(0.5 - 0.5) \times 0.5 + 2 \times 0.5 \times 0}{0.5 + 0.5} = \mathbf{0}$$

and $$v_2 = \frac{(M_2 - M_1)u_2 + 2M_1u_1}{M_1 + M_2}$$

$$= \frac{(0.5 - 0.5)\,0 + 2 \times 0.5 \times 0.5}{0.5 + 0.5} = \mathbf{0.5\ ms^{-1}}.$$

S16. The mass of neutrons and protons are comparable. So when a fast neutron collides on a proton at rest, it transfers its energy to on a proton at rest, it transfers its energy to the proton and comes to rest. Heavy water (D_2O) has large availability of protons.

S17. Let the sphere A be of mass m_1 moving with velocity v_1 collide head-on with another sphere B of mass m_2 at rest. If v_1 and v_2 are the velocities of spheres after head-on collision,

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 \qquad \dots \text{(i)}$$

and $$v_2 = \left(\frac{2m_1}{m_1 + m_2}\right)u_1 \qquad \dots \text{(ii)}$$

Since $m_1 << m_2$ from (a) we have $v_1 = -u_1$ and from (b) v_2 is very small almost zero. In other words light sphere rebounds with nearly the same velocity whereas massive sphere remains stationary.

S18. Given Mass of the trolley, $M = 200$ kg

Speed of the trolley, $v = 36$ km/h = 10 m/s

Mass of the boy, $m = 20$ kg

Initial momentum of the system of the boy and the trolley

$$= (M + m)\,v$$

$$= (200 + 20) \times 10$$

$$= 2200 \text{ kg m/s}$$

Let v' be the final velocity of the trolley with respect to the ground.

Final velocity of the boy with respect to the ground = $v' - 4$

Final momentum = $Mv' + m(v' - 4)$

$$= 200v' + 20v' - 80$$

$$= 220v' - 80$$

As per the law of conservation of momentum:

$$\text{Initial momentum} = \text{Final momentum}$$

$$2200 = 220v' - 80$$

$$2280 = 220\,v'$$

$$v' = \frac{2280}{220} = 10.36 \text{ ms}^{-1}$$

Length of the trolley, $l = 10$ m

Speed of the boy, $v'' = 4$ m/s

Time taken by the boy to run, $t = \frac{10}{4} = 2.5\ s$

$\therefore$ Distance moved by the trolley = $v' \times t = 10.36 \times 2.5 = 25.9$ m.

S19. Given, $M_1 = 500$ g; $M_2 = 100$ g;

$u_1 = 200 \text{ cm s}^{-1}$ and $u_2 = -100 \text{ cm s}^{-1}$

Now, $$v = \frac{M_1 u_1 + M_2 u_2}{M_1 + M_2} = \frac{500 \times 200 + 100 \times (-100)}{500 + 100}$$

$$= \mathbf{150\ cm\,s^{-1}}.$$

S20. Consider two particles A and B of masses m_1 and m_2 moving with initial. Velocities u_1 and u_2 along x-axis. They collide and move as one entity. Let V be the common velocity when they move as single mass.

m_1 = Mass of bullet.

u_1 = Initial velocity of bullet

m_2 = mass of wood.

u_2 = Initial velocity of wood

= 0

According to conservation of momentum.

$$m_1 u_1 + m_2 u_2 = (m_1 + m_2) V$$

$$u_* = 0$$

$$V = \frac{m_1 u_1}{m_1 + m_2} \quad \dots \text{(i)}$$

Initial K.E., $K_i = \frac{1}{2} m_1 u_1^2$

Final K.E., $K_f = \frac{1}{2} (m_1 + m_2) V^2$

$$\frac{K_f}{K_i} = \frac{\frac{1}{2}(m_1 + m_2)V^2}{\frac{1}{2} m_1 u_1^2} = \left(\frac{m_1 + m_2}{m_1}\right)\frac{V^2}{u_1^2} \quad \dots \text{(ii)}$$

From Eq. (i) and (ii), we get

$$\frac{K_f}{K_i} = \left(\frac{m_1 + m_2}{m_1}\right)\left(\frac{m_1}{m_1 + m_2}\right)^2 = \frac{m_1}{m_1 + m_2}$$

When, $K_f < K_i$ there is loss in K.E.

S21. Here, $M_1 = 5$ kg; $M_2 = 2$ kg ;

$u_1 = 10 \text{ m s}^{-1}$; $u_2 = 5 \text{ m s}^{-1}$ and $e = 0.6$

Now, $$v_1 = \frac{(M_1^2 - eM_2) u_1 + (1 + e) M_2 u_2}{M_1 + M_2}$$

$$= \frac{(5 - 0.6 \times 2) \times 10 + (1 + 0.6) \times 2 \times 5}{5 + 2}$$

$$= 7.7 \text{ m s}^{-1}$$

and $$v_2 = \frac{(M_2 - eM_1) u_2 + (1 + e) M_1 u_1}{M_1 + M_2}$$

$$= \frac{(2 - 0.6 \times 5) \times 5 + (1 + 0.6) \times 5 \times 10}{5 + 2}$$

$$= 10.7 \text{ m s}^{-1}$$

Also loss in kinetic energy,

$$\Delta T = \frac{(1 - e^2) M_1 M_2}{2(M_1 + M_2)} (u_1 - u_2)^2$$

$$= \frac{[(1)^2 - (0.6)^2] \times 5 \times 2}{2(5 + 2)} (10 - 5)^2 = 11.43 \text{ J}.$$

S22. Given, $M_1 = M_2 = 10{,}000$ kg; $u_1 = 54$ km h^{-1} = 15 ms^{-1}

and $u_2 = 0$

After the collision, the two carriages get coupled. Let v be the velocity of the two coupled carriages.

According to the principle of conservation of momentum,

$$M_1 u_1 + M_2 u_2 = (M_1 + M_2) v$$

$\therefore$ $10{,}000 \times 15 + 10{,}000 \times 0 = (10{,}000 + 10{,}000) v$

or $v = 7.5$ m s^{-1}

Initial K.E. of the two carriages,

$$\frac{1}{2} M_1 u_1^2 + \frac{1}{2} M_2 u_2^2 = \frac{1}{2} \times 10{,}000 \times 15^2 + \frac{1}{2} \times 10{,}000 \times 0^2$$

$$= 1.125 \times 10^6 \text{ J}$$

Final K.E. of the two carriages,

$$\frac{1}{2}(M_1 + M_2) v^2 = \frac{1}{2}(10{,}000 + 10{,}000) \times (7.5)^2$$

$$= 5.625 \times 10^5 \text{J}$$

Since energy of the system after the collision decreases (not conserved), the collision is inelastic in nature.

S23. The collision, in which both the momentum and kinetic energy are conserved and the colliding bodies continue to move along the same straight line after the collision, is called an elastic collision in one dimension.

Here, $M_1 = m$; $M_2 = M$; $u_2 = 0$

Suppose that $u_1 = u$.

Initial K.E. of the moving body, $T_1 = \frac{1}{2} m u^2$

Initial K.E. of the struck body, $T_2 = 0$

Now,
$$v_2 = \frac{(M_2 - M_1)u_2 + 2\,M_1u_1}{M_1 + M_2}$$

$$= \frac{(M - m)\times 0 + 2\,m\,u}{M + m} = \frac{2\,m\,u}{M + m}$$

K.E. of the struck body after collision,

$$T_2' = \frac{1}{2}Mv_2^2 = \frac{1}{2}M \times \left(\frac{2\,m\,u}{M + m}\right)^2$$

or
$$T_2' = \frac{2\,Mm^2\,u^2}{(M + m)^2}$$

Therefore, K.E. transferred to the struck body,

$$T_2' - T_2 = \frac{2\,M\,m^2\,u^2}{(M + m)^2} - 0 = \frac{2M\,m^2u^2}{(M + m)^2}$$

Hence, fraction of the initial K.E. of the mass m transferred to the struck body,

$$\frac{T_2' - T_2}{T_1} = \frac{2\,M\,m^2u^2}{(M + m)^2} \times \frac{1}{\frac{1}{2}m\,u^2}$$

$$= \frac{4\,m\,M}{(M + m)^2}.$$

S24. The collision, in which both the momentum and kinetic energy are conserved and the colliding bodies continue to move along the same straight line after the collision, is called an elastic collision in one dimension.

Here, $M_1 = M_2 = M;\ u_1 = v$ and $u_2 = -v$

Now,
$$v_1 = \frac{(M_1 - M_1)\,u_1 + 2\,M_2\,u_2}{M_1 + M_2}$$

$$= \frac{(M - M)\,v + 2\,M(-v)}{M + M} = \frac{0 - 2\,Mv}{2\,M}$$

or
$$v_1 = -v$$

Also,
$$v_2 = \frac{(M_2 - M_1)\,u_2 + 2\,M_1\,u_1}{M_1 + M_2}$$

$$= \frac{(M-M)(-v)+2Mv}{M+M} = \frac{0+2Mv}{2M}$$

or $v_2 = v.$

Thus, after the collision, the two balls bounce back with equal speeds v.

S25. The initial kinetic energy of the neutron is

$$K_{1i} = \frac{1}{2} m_1 v_{1i}^2$$

while its final kinetic energy from Eq. (6.27)

$$K_{1f} = \frac{1}{2} m_1 v_{1f}^2 = \frac{1}{2} m_1 \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 v_{1i}^2$$

The fractional kinetic energy lost is

$$f_1 = \frac{K_{1f}}{K_{1i}} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2$$

while the fractional kinetic energy gained by the moderating nuclei K_{2f}/K_{1i} is

$$f_2 = 1 - f_1 \text{ (elastic collision)}$$

$$= \frac{4 m_1 m_2}{(m_1 + m_2)^2}$$

One can also verify this result by substituting from Eq. (6.28).

For deuterium $m_2 = 2m_1$ and we obtain $f_1 = 1/9$ while $f_2 = 8/9$. Almost 90% of the neutron's energy is transferred to deuterium. For carbon $f_1 = 71.6\%$ and $f_2 = 28.4\%$. In practice, however, this number is smaller since head-on collisions are rare.

S26. (i), (ii), (iii), (iv), and (vi)

The potential energy of a system of two masses is inversely proportional to the separation between them. In the given case, the potential energy of the system of the two balls will decrease as they come closer to each other. It will become zero (*i.e.*, $V(r) = 0$) when the two balls touch each other, *i.e.*, at $r = 2R$, where R is the radius of each billiard ball. The potential energy curves given in figures (i), (ii), (iii), (iv), and (vi) do not satisfy these two conditions. Hence, they do not describe the elastic collisions between them.

S27. From momentum conservation, since the masses are equal

$$\mathbf{v}_{1i} = \mathbf{v}_{1f} + \mathbf{v}_{2f}$$

or

$$v_{1i}^2 = (\mathbf{v}_{1f} + \mathbf{v}_{2f}) \cdot (\mathbf{v}_{1f} + \mathbf{v}_{2f})$$

$$= v_{1f}^2 + v_{2f}^2 + 2\mathbf{v}_{1f} \cdot \mathbf{v}_{2f}$$

$$= \{v_{1f}^2 + v_{2f}^2 + 2v_{1f}v_{2f} \cos(\theta_1 + 37°)\} \quad \text{... (i)}$$

Since the collision is elastic and $m_1 = m_2$ it follows from conservation of kinetic energy that

$$v_{1i}^2 = v_{1f}^2 + v_{2f}^2 \quad \text{... (ii)}$$

Comparing Eqs. (i) and (ii), we get

$$\cos(\theta_1 + 37°) = 0$$

or $$\theta_1 + 37° = 90°$$

Thus, $$\theta_1 = 53°$$

This proves the following result: when two equal masses undergo a glancing elastic collision with one of them at rest, after the collision, they will move at right angles to each other.

S28. One dimensional elastic collision is one in which both momentum and K.E. are conserved and the body moves in the same line of motion even after the collision.

If m_1, m_2 are the masses u_1, u_2 are the initial velocities and v_1, v_2 are the final velocities, then

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2 \quad \text{... (i)}$$

$$\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 \quad \text{... (ii)}$$

(*i.e.*) $$m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2) \quad \text{from (ii)}$$

$$m_2(u_1 - v_1) = m_2(v_2 - u_2) \quad \text{from (i)}$$

Dividing both sides

$$v_1 + u_1 = v_2 + u_2$$

$$v_1 = v_2 + u_2 - u_*$$

Substituting in Eq. (i), we have

$$m_1 u_1 + m_2 u_2 = m_1(v_2 + u_2 - u_1) + m_2 v_2$$

$$2 m_1 u_1 + u_2(m_2 - m_1) = v_2(m_1 + m_2)$$

$\therefore$ $$v_2 = \frac{u_2(m_2 - m_1) + 2m_1u_1}{(m_1 + m_2)}$$

Similarly,

$$v_1 = \frac{u_1(m_1 - m_2) + 2m_2u_2}{(m_1 + m_2)}.$$

S29. Suppose that the single body *C* formed on collision of the bodies *A* and *B* moves with velocity *V* and in a direction making angle θ north of east [as shown in the figure].

Applying the law of conservation of linear momentum along *WE*-direction (*X*-axis), we have

$$Mv + M \times 0 = 2M \times V\cos\theta$$

or $$V\cos\theta = v/2 \quad \text{... (i)}$$

Applying the law of conservation of linear momentum alone NS- direction (Y – axis), we have

$$M \times 0 + Mv = 2M \times V \sin\theta$$

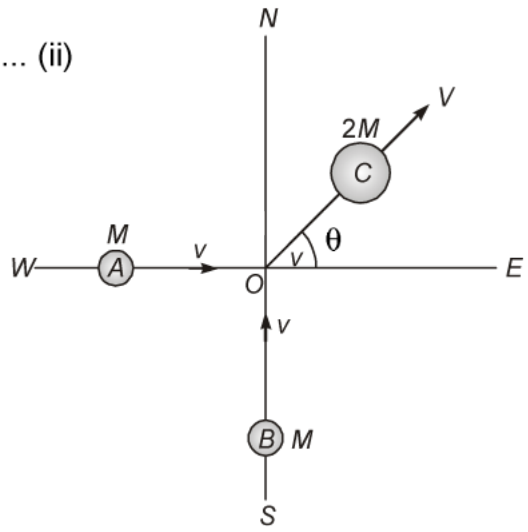
or $$V \sin\theta = v/2 \quad \text{... (ii)}$$

Squaring and adding the Eqns. (i) and (ii), we get

$$(V \cos\theta)^2 + (V \sin\theta)^2 = (v/2)^2 + (v/2)^2$$

or $$V^2(\cos^2\theta + \sin^2\theta) = v^2/2$$

or $$V = v/\sqrt{2}$$



Dividing the equation (ii) by (i), we get

$$\frac{V \sin\theta}{V \cos\theta} = \frac{v/\sqrt{2}}{v/\sqrt{2}} \quad \text{or} \quad \tan\theta = 1$$

or $$\theta = 45°$$

Hence, the combined mass moves with velocity $v/\sqrt{2}$ in ***NE-direction***.

S30. It can be observed that the total momentum before and after collision in each case is constant.

For an elastic collision, the total kinetic energy of a system remains conserved before and after collision.

Case I: Total kinetic energy of the system after collision:

$$= \frac{1}{2} m \times 0 + \frac{1}{2}(2m)\left(\frac{V}{2}\right)^2$$

$$= \frac{1}{4} mV^2$$

Hence, the kinetic energy of the system is not conserved in case (i).

Case II: Total kinetic energy of the system after collision:

$$= \frac{1}{2}(2m) \times 0 + \frac{1}{2} mV^2$$

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

Hence, the kinetic energy of the system is conserved in case (ii).

Case III: Total kinetic energy of the system after collision:

$$= \frac{1}{2}(2m)\left(\frac{V}{3}\right)^2$$

$$= \frac{1}{6} mV^2$$

Hence, the kinetic energy of the system is not conserved in case (iii).

S31. Given, Mass of the electron, $m_e = 9.11 \times 10^{-31}$ kg

Mass of the proton, $m_p = 1.67 \times 10^{-27}$ kg

Kinetic energy of the electron, $E_{Ke} = 10 \text{ keV} = 10^4 \text{ eV}$

$= 10^4 \times 1.60 \times 10^{-19}$

$= 1.60 \times 10^{-15}$ J

Kinetic energy of the proton, $E_{Kp} = 100 \text{ keV} = 10^5 \text{ eV}$

$= 1.6 \times 10^{-19}$ J.

For the velocity of an electron v_e, its kinetic energy is given by the relation:

$$E_{ke} = \frac{1}{2} m_e v_e^2$$

$$\therefore \quad v_c = \sqrt{\frac{2 \times E_{ke}}{m_e}}$$

$$\therefore \quad = \sqrt{\frac{2 \times 1.60 \times 10^{-15}}{9.11 \times 10^{-31}}} = 5.93 \times 10^7 \text{ m/s}$$

For the velocity of a proton v_p, its kinetic energy is given by the relation:

$$E_{kp} = \frac{1}{2} m_p v_p^2$$

$$v_p = \sqrt{\frac{2 \times E_{K_p}}{m_p}}$$

$$\therefore \quad v_p = \sqrt{\frac{2 \times 1.6 \times 10^{-14}}{1.67 \times 10^{-27}}} = 4.38 \times 10^6 \text{ m/s}$$

Hence, the electron is moving faster than the proton.

The ratio of their speeds:

$$\frac{v_e}{v_p} = \frac{5.93 \times 10^7}{4.38 \times 10^6} = 13.54 : 1$$

S32. Mass of the bullet, $m = 0.012$ kg

Initial speed of the bullet, $u_b = 70$ m/s

Mass of the wooden block, $M = 0.4$ kg

Initial speed of the wooden block, $u_B = 0$

Final speed of the system of the bullet and the block = v

Applying the law of conservation of momentum:

$$mu_b + Mu_B = (m + M)\, v$$

$\therefore$ $$v = \frac{0.84}{0.412} = 2.04 \text{ m/s}$$

For the system of the bullet and the wooden block:

Mass of the system, $m' = 0.412$ kg

Velocity of the system = 2.04 m/s

Height up to which the system rises = h

Applying the law of conservation of energy to this system:

Potential energy at the highest point = Kinetic energy at the lowest point

$$m'gh = \frac{1}{2} m'v^2$$

$\therefore$ $$h = \frac{1}{2}\left(\frac{v^2}{g}\right)$$

$$= \frac{1}{2}\left(\frac{v^2}{g}\right)$$

$$= \frac{1}{2} \times \frac{(2.04)^2}{9.8}$$

The wooden block will rise to a height of 0.2123 m.

Heat produced = Kinetic energy of the bullet

$$= \frac{1}{2} mu^2 - \frac{1}{2} m'v^2$$

$$= \frac{1}{2} \times 0.012 \times (70)^2 - \frac{1}{2} \times 0.412 \times (2.04)^2$$

$$= 29.4 - 0.857 = 28.54 \text{ J.}$$