CHAPTER 05

WORK, ENERGY & POWER

Energy is neither created nor destroyed. It just changes shape.

"SHERI REYNOLDS"

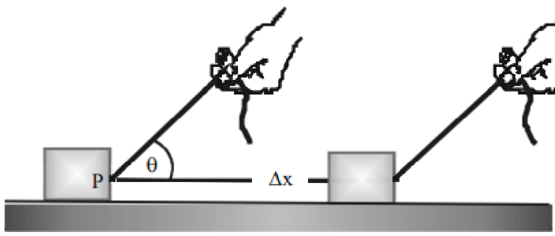
INTRODUCTION

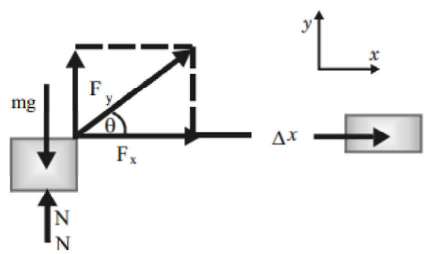
The terms 'work', 'energy' and 'power' are frequently used in everyday language. A farmer ploughing the field, a construction worker carrying bricks, a student studying for a competitive examination, an artist painting a beautiful landscape, all are said to be working. The capacity to do work is energy. We admire a long distance runner for her stamina or energy. The word 'power' is used in everday life with different shades of meaning. In karate or boxing we talk of 'powerful' punches. These are delivered at a great speed. The aim of this chapter is to develop an understanding of these three physical quantities. Before we proceed to this task, we need to develop a mathematical prerequisite, namely the scalar product of two vectors.

In physics, work is said to be done, if a force acting on a body is able to actually move it through some distance in the direction of the force. The watch-man of the office gate is not making any effort to move but is simply standing there i.e. both the force and displacement are zero and likewise no work is done by him. Again, when the coolie carrier load on his head, he exerts force along the vertical direction to support the load on his head. Since distance is covered along the horizontal i.e., no distance is covered in the direction of the force supplied along vertical, the work performed by the coolie is also zero.

Work done by Constant Force on a Body in Rectilinear Motion

To understand concept of work, consider a block being pulled with the help of a string on frictionless horizontal ground. Let pull $\vec{F}$ of the string on the box is constant in magnitude as well as direction the vertical component F_y of $\vec{F}$, the weight (mg) and the normal reaction N all act on the box in vertical direction but none of them can moves it unless F_y becomes greater than the weight (mg). Consider that is smaller than the weight of the box. Under this condition, the box moves along the plane only due to the horizontal components F_x of the force $\vec{F}$ the weight mg, the normal reaction. N from the ground and vertical component F_y all are perpendicular to the displacement therefore have no contribution in its displacement. Therefore, work is done on the box only by the horizontal component F_x of the force $\vec{F}$.





Here we must take car of one more point that is the box, which is a rigid body and undergoes translation motion therefore, displacement of every particle of the body including that on which the force is applied are equal. The particle of a body on which force acts is known as point of application of the force.

Now we observe that block is displaced & its speed is increase. And work W of the force $\vec{F}$ on the block is proportional to the product of its components in the direction of the displacement and the magnitude of the displacement Δx.

$$W \propto F_x . \Delta x = F \cos\theta . \Delta x$$

If we chose one unit of work as newton-meter, the constant of proportionality becomes unity and we have

$$W = F\cos\theta \ . \Delta x = \vec{F} . \Delta \vec{x}$$

The work W done by the force $\vec{F}$ is defined as scalar product of the force $\vec{F}$ and displacement $\Delta\vec{x}$ of point of application of the force.

ETOOS KEY POINTS

(i) If $\vec{F} = F_x = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$

$\vec{S} = \Delta_x\hat{i} + \Delta_y\hat{j} + \Delta_z\hat{k}$

then

$w = \vec{F}.\vec{S} = F_x(\Delta_x) + F_y(\Delta_y) + F_z(\Delta_z)$

(ii) Work done force is frame dependents as displacement is frame dependent.

(iii) Work can be positive or negative or zero. When a force speed up the practice, it does positive work. A force acting at 90° to the motion does no work. And when a force slow down the motion, it does negative work.

Etoos Tips & Formulas

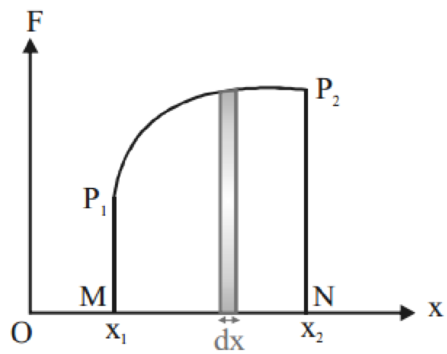
1. **Work done** $W = \int dW = \int \vec{F}.d\vec{r} = \int F dr \cos\theta$ [where θ is the angle between $\vec{F}$ & $d\vec{r}$]

   (a) For constant force $W = \vec{F}.\vec{d} = Fd\cos\theta$

   (b) For Unidirectional force

   $W = \int dW = \int F dx$ = Area between F -x curve and x- axis.

2. **Calculation of work done from force-displacement graph**



Total work done, $W = \sum_{x_1}^{x_2} dW = \sum_{r_1}^{r_2} F dx$ = Area of $P_1P_2NM = \int_{x_1}^{x_2} F dx$

3. **Nature of work done**

   Although work done is a scalar quantity, yet its value may be positive, negative or even zero

   (a) If $\vec{F}$ is a conservative force then $\vec{\nabla} \times \vec{F} = \vec{0}$ (i.e. curl of $\vec{F}$ is zero)

4. **Conservative Forces**

   (a) Work done does not depend upon path.

   (b) Work done in a round trip is zero.

   (c) Central forces, spring forces etc, are conservative forces

   (d) When only a conservative forces acts within a system, the kinetic energy and potential energy can change into each other. However, their sum the mechanical energy of the system, doesn`t change.

   (e) Work done is completely recoverable.

5. **Non-conservative Forces**

   (a) Work done depends upon path.

   (b) Work done in a round trip is not zero.

   (c) Force are velocity-dependent & retarding in nature e.g. friction, viscous force etc.

   (d) Work done against a non-conservative force may be dissipated as heat energy

   (e) Work done is not recoverable.

6. **Kinetic energy**

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

   $$K = \frac{1}{2}mv^2 = \frac{1}{2}m(\vec{v}.\vec{v})$$

   (b) Kinetic energy is a frame dependent quantity because velocity is a frame depends.

SOLVED EXAMPLE

Ex. 1 A box of mass m is initially at rest on a horizontal surface. A constant horizontal force of mg/2 is applied to the box directed to the right. The coefficient of friction of the surface changes with the distance pushed as $m = m_0x$ where x is the distance from the initial location. For what distance is the box pushed until it comes to rest again ?

(A) $\frac{2}{\mu_0}$ **(B)** $\frac{1}{\mu_0}$

(C) $\frac{1}{2\mu_0}$ **(D)** $\frac{1}{4\mu_0}$

Sol. Net change in kinetic energy = 0 $\Rightarrow$ net work W = 0

$$\int dW = \int F dx - \int \mu N dx = \frac{mg}{2}x - mg\mu_0\int_0^x x dx = 0$$

$$\Rightarrow x = \frac{1}{\mu_0}$$

Ex. 2 When a conservative force does positive work on a body, then

(A) its potential energy must increase.

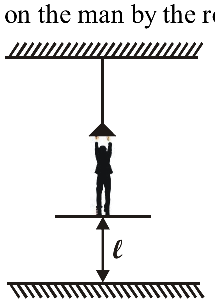
(B) its potential energy must decrease.

(C) its kinetic energy must increase.

(D) its total energy must decrease.

Sol. Work done by conservative force = – ΔU = positive $\Rightarrow \Delta U \downarrow$

Ex. 3 One end of a light rope is tied directly to the ceiling. A man of mass M initially at rest on the ground starts climbing the rope hand over upto a height ℓ. From the time he starts at rest on the ground to the time he is hanging at rest at a height ℓ, how much work done on the man by the rope ?



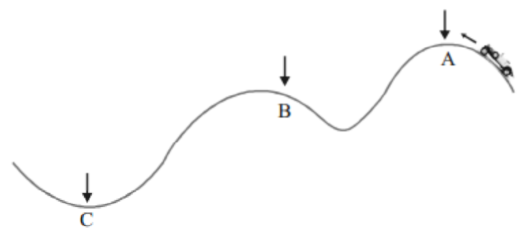
(A) 0 **(B)** Mgℓ

(C) –Mgℓ

(D) It depends on how fast the man goes up.

Sol. Total work done on man = 0 $\Rightarrow$ Work done by string = – work done by gravity = – (–Mgℓ) = Mgℓ

Ex. 4 A car is moving along a hilly road as shown (side view). The coefficient of static friction between the tyres and pavement is constant and the car maintains a steady speed. If, at one of the points shown the driver applies the brakes as hard as possible without making the tyres slip, the magnitude of the frictional force immediately after the brakes are applied will be maximum if the car was at



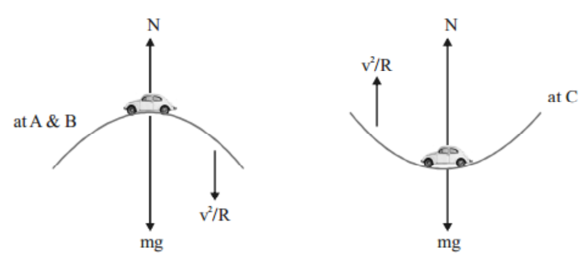
(A) point A **(B)** point B

(C) point C

(D) friction force dame for positions A, B and C

Sol. At A & B, N = mg – mv²/R & at C, N = mg + mv²/R

$\therefore$ $f_{max} = \mu_s N \rightarrow$ maximum for C



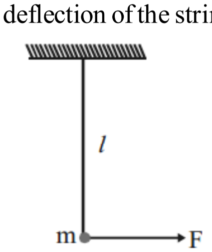
Ex. 5 A pendulum bob of mass m is suspended at rest. A constant horizontal force F = mg/2 starts acting on it. The maximum angular deflection of the string is

(A) 90°

(B) 53°

(C) 37°

(D) 60°



Exercise # 1 — SINGLE OBJECTIVE — NEET LEVEL

1. A body of m,ass 1 kg is thrown upwards with a velocity 20 m/s. It mementally comes to rest after attaining a height of 18 m. How much energy is lost due to air friction ($g = 10\ m/s^2$)
(A) 20 J (B) 30 J
(C) 40 J (D) 10 J

2. A block of mass 5kg is resting on a smooth surface. At what angle a force of 20N be acted on the body so that it will acquired a kinetic energy of 40 J after moving 4m
(A) 30° (B) 45°
(C) 60° (D) 120°

3. A man pushes a wall and fails to displace it. he does
(A) Negative work
(B) Positive but not maximum work
(C) No work at all
(D) Maximum work

4. Stopping distance of a moving vehicle is directly proportional to
(A) Square of the initial velocity
(B) Square of the initial acceleration
(C) The initial velocity
(D) The initial acceleration
(E) Mass of the vehicle

5. A body moves a distance of 10 m along a straight line under the action of a force of 5 N. If the work done is 25 joules, the angle which the force makes with the direction of motion of the body is
(A) 0° (B) 30°
(C) 60° (D) 90°

6. A cord is used to lower vertically a block of mass M by a distance d with constant downward acceleration $\frac{g}{4}$. Work done by the cord on the block is
(A) $Mg\frac{d}{4}$ (B) $3Mg\frac{d}{4}$
(C) $-3Mg\frac{d}{4}$ (D) Mgd

7. A body of mass 5 kg is placed at the origin, and can move only on the x-axis. A force of 10 N is acting on it in a direction making an angle of 60° with the x-axis and displaces it along the x-axis by 4 meters. The work done by the force is
(A) 2.5 J (B) 7.25 J
(C) 40 J (D) 20 J

8. If force and displacement of particle in direction of force are doubled. Wor would be
(A) Double (B) 4 times
(C) Half (D) 1/4 times

9. A force acts on a 30 g particle in such a way that the position of the particle as function of time is given by $x = 3t - 4t^2 + t^3$, where x is in meters and t is in seconds. The work done during the first 4 seconds is
(A) 5.28 J (B) 450 mJ
(C) 490 mJ (D) 530 mJ

10. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle, the motion of the particle takes place in a plane. It follows that
(A) Its velocity constant
(B) Its acceleration is constant
(C) Its kinetic energy is constant
(D) It moves in a straight line

11. A particle moves under the effect of a force F = Cx from $x = 0$ to $x = x_1$. The work done in the process is
(A) Cx_1^2 (B) $\frac{1}{2}Cx_1^2$
(C) Cx_1 (D) Zero

12. When a rubber-band is stretched by a distance x, it exerts a restoring force of magnitude $F = ax + bx^2$ where a and b are constant. The work done in stretching the unstretched rubber-band by L is
(A) $aL^2 + bL^3$ (B) $\frac{1}{2}(aL^2 + bL^3)$
(C) $\frac{aL^2}{2} + \frac{bL^3}{3}$ (D) $\frac{1}{2}\left(\frac{aL^2}{2} + \frac{bL^3}{3}\right)$

Exercise # 2 — SINGLE OBJECTIVE — AIIMS LEVEL

1. The work done by the frictional force on a pencil in drawing a complete circle of radius $r = 1/\pi$ metre on the surface by a pencil of negligible mass with a normal pressing force N = 5 N ($\mu = 0.5$) is :

(A) + 4J (B) –3 J
(C) – 2 J (D) – 5J

2. A person A of 50 kg rests on a swing of length 1m making an angle 37^{O} with the vertical. Another person B pushes him to swing on other side at 53^{O} with vertical. The work done by person B is : [$g = 10\ m/s^2$]

(A) 50 J (B) 9.8 J
(C) 100 J (D) 10 J

3. A rope is used to lower vertically a block of mass M by a distance x with a constant downward acceleration g/2. The work done by the rope on the block is :

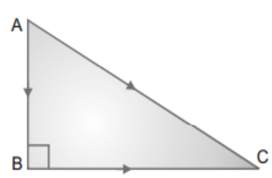
(A) Mgx (B) $\frac{1}{2}Mgx^2$
(C) $-\frac{1}{2}Mgx$ (D) Mgx^2

4. Work done in time t on a body of mass m which is accelerated from rest to a speed v in time t_1 as a function of time t is given by :

(A) $\frac{1}{2}m\frac{v}{t_1}t^2$ (B) $m\frac{v}{t_1}t^2$
(C) $\frac{1}{2}\left(\frac{mv}{t_1}t\right)^2 t^2$ (D) $\frac{1}{2}m\frac{v^2}{t_1^2}t^2$

5. The work done in moving a particle under the effect of a conservative force, from position A to B is 3 joule and from B to C is 4 joule. The work done in moving the particle from A to C is :

(A) 5 joule
(B) 7 joule
(C) 1 joule
(D) –1 joule



6. A block of mass m moving with speed v compresses a spring through distance x before its speed is halved. What is the value of spring constant ?

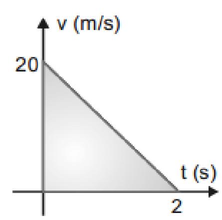
(A) $\frac{3mv^2}{4x^2}$ (B) $\frac{mv^2}{4x^2}$
(C) $\frac{mv^2}{2x^2}$ (D) $\frac{2mv^2}{x^2}$

7. A particle moves on a rough horizontal ground with some initial velocity say v_0. If $\frac{3}{4}$ of its kinetic energy is lost due to friction in time t_0 then coefficient of friction between the particle and the ground is :

(A) $\frac{v_0}{2gt_0}$ (B) $\frac{v_0}{4gt_0}$
(C) $\frac{3v_0}{4gt_0}$ (D) $\frac{v_0}{gt_0}$

8. Velocity–time graph of a particle of mass 2 kg moving in a straight line is as shown in figure. Work done by all the forces on the particle is :

(A) 400 J
(B) –400 J
(C) –200 J
(D) 200 J

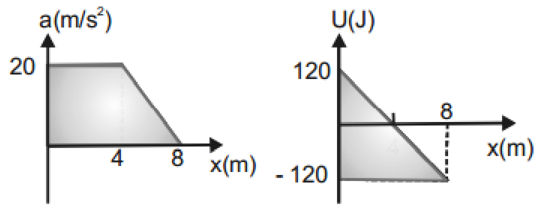


9. An engine can pull 4 coaches at a maximum speed of 20 m/s. Mass of the engine is twice the mass of every coach. Assuming resistive forces proportional to the weight, approximate maximum speeds of the engine when it pulls 12 and 6 coaches are :

(A) 8.5 m/s and 15 m/s respectively
(B) 6.5 m/s and 8 m/s respectively
(C) 8.5 m/s and 13 m/s respectively
(D) 10.5 m/s and 15 m/s respectively

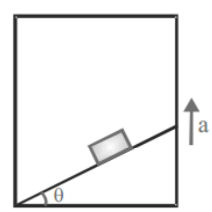
Exercise # 3 PART - 1 MATRIX MATCH COLUMN

1. Acceleration 'a' versus x and potential energy 'U' versus x graph of a particle moving along x–axis is as shown in figure. Mass of the particle is 1kg and velocity at x = 0 is 4 m/s. At x = 8 m :–



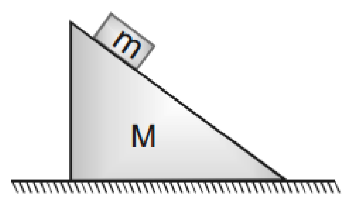
	Column I		Column II
(A)	Kinetic energy	(P)	120J
(B)	Work done by conservative forces	(Q)	240 J
(C)	Total work done	(R)	128 J
(D)	Work done by external forces	(S)	112 J
		(T)	–120 J

2. A block of mass m is stationary with respect to a rough wedge as shown in figure. Starting from rest, in time t work done on the block : (m = 1kg, $\theta = 30°$, a = 2m/s², t = 4s)



	Column I		Column II
(A)	By gravity	(P)	144 J
(B)	By normal reaction	(Q)	32 J
(C)	By friction	(R)	56 J
(D)	By all the forces	(S)	48 J
		(T)	None

3. A block of mass m lies on wedge of mass M. The wedge in turn lies on smooth



	Column I		Column II
(A)	Work done by normal reaction acting on the block is	(P)	Positive
(B)	Work done by normal reaction (exerted by block) acting on wedge is	(Q)	Negative
(C)	The sum of work done by normal reaction on block and work done by normal reaction (exerted by block) on wedge is	(R)	Zero
(D)	Net work done by all forces on block is	(S)	Less than mgh in magnitude

4. In vertical circular motion of a bob, match the entries of column–I with entries of column–II. Here v_0 is the velocity of bob at lowest point & T is tension in string.

	Column – I (Speed at lowest point)		Column–II (Possible situation)
(A)	$v_0 = \sqrt{5g\ell}$	(P)	$T_{lowest} - T_{highest} = 6mg$
(B)	$v_0 = \sqrt{g\ell}$	(Q)	String will slack for a finite time
(C)	$v_0 = 2\sqrt{g\ell}$	(R)	bob will oscillate
(D)	$v_0 = 3\sqrt{g\ell}$	(S)	bob will complete the circle

Exercise # 4 PART - 1 PREVIOUS YEAR (NEET/AIPMT)

1. A mass of 1 kg is thrown up with a velocity of 100 m/s. After 5 seconds, it explodes into two parts. One part of mass 400 g comes down with a velocity 25 m/s. The velocity of other part is (Take g = 10 ms^{-2})
(A) 40 m/s ↑ (B) 40 m/s ↓ [2000]
(C) 100 m/s ↑ (D) 60 m/s ↑

2. If $\vec{F} = (60\hat{i} + 15\hat{j} - 3\hat{k})$ N and $\vec{v} = (2\hat{i} - 4\hat{j} + 5\hat{k})$ m/s, then instantaneous power is [2000]
(A) 195 watt (B) 45 watt
(C) 75 watt (D) 100 watt

3. A particle is projected making an angle of 45° with horizontal having kinetic energy K. The kinetic energy at highest point will be [2001]
(A) $\frac{K}{\sqrt{2}}$ (B) $\frac{K}{2}$
(C) 2k (D) K

4. Two springs A and B having spring constant K_A and $K_B(K_A = 2K_B)$ are stretched by applying force of equal magnitude. If energy stored in spring A is E_A then energy stored in B will be [2001]
(A) $2E_A$ (B) $E_A/4$
(C) $E_A/2$ (D) $4E_A$

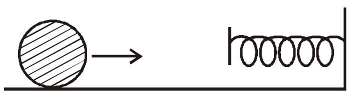
5. A child is sitting on a swing. Its minimum and maximum heights from the ground 0.75 m and 2 m respectively, its maximum speed will be [2001]
(A) 10 m/s (B) 5 m/s
(C) 8 m/s (D) 15 m/s

6. If kinetic energy of a body is increased by 300 % then percentage change in momentum will be
(A) 100% (B) 150% [2002]
(C) 265% (D) 73.2%

7. A stationary particle explodes into two particles of masses m_1 and m_2 which move in opposite directions with velocities v_1 and v_2. The ratio of their kinetic energies E_1/E_2 is [2003]
(A) m_2/m_1 (B) m_1/m_2
(C) 1 (D) m_1v_2/m_2v_1

8. When a long spring is stretched by 2 cm, its potential energy is U. If the spring is stretched by 10 cm, the potential energy stored in it will be [2003]
(A) U/5 (B) 5U
(C) 10U (D) 25U

9. A mass of 0.5 kg moving with a speed of 1.5 m/s on a horizontal smooth surface, collides with a nearly weightless spring of force constant k= 50 N/m. The maximum compression of the spring would be

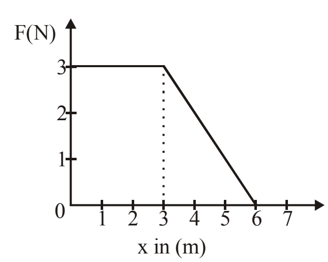


(A) 0.15 m (B) 0.12 m [2004]
(C) 1.5 m (D) 0.5 m

10. A ball of mass 2 kg and another of mass 4 kg are dropped together from a 60 feet tall building. After a fall of 30 feet each towards earth, their respective kinetic energies will be in the ratio of [2004]
(A) $\sqrt{2}:1$ (B) 1 : 4
(C) 1 : 2 (D) $1:\sqrt{2}$

11. A particle of mass m_1 is moving with a velocity v_1 and another particle of mass m_2 is moving with a velocity v_2. Both of them have the same momentum but their different kinetic energies are E_1 and E_2 respectively. If $m_1 > m_2$ then [2004]
(A) $E_1 < E_2$ (B) $\frac{E_1}{E_2} = \frac{m_1}{m_2}$
(C) $E_1 > E_2$ (D) $E_1 = E_2$

12. A force F acting on an object varies with distance x as shown here. The force is in N and x in m. The work done by the force in moving the object from x = 0 to x = 6 m is [2005]



MOCK TEST

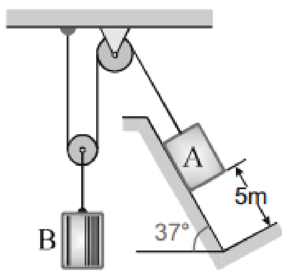
STRAIGHT OBJECTIVE TYPE

1. Work done by static friction on an object:
(A) may be positive (B) must be negative
(C) must be zero (D) none of these

2. A man places a chain (of mass 'm' and length 'ℓ') on a table slowly. Initially the lower end of the chain just touches the table. The man drops the chain when half of the chain is in vertical position. Then work done by the man in this process is :
(A) $-mg\dfrac{\ell}{2}$ (B) $-\dfrac{mg\ell}{4}$ (C) $-\dfrac{3mg\ell}{8}$ (D) $-\dfrac{mg\ell}{8}$

3. The potential energy of a particle of mass m free to move along x-axis is given by $U = \dfrac{1}{2}kx^2$ for $x < 0$ and $U = 0$ for $x \ge 0$ (x denotes the x-coordinate of the particle and k is a positive constant). If the total mechanical energy of the particle is E, then its speed at $x = -\sqrt{\dfrac{2E}{k}}$ is
(A) zero (B) $\sqrt{\dfrac{2E}{m}}$ (C) $\sqrt{\dfrac{E}{m}}$ (D) $\sqrt{\dfrac{E}{2m}}$

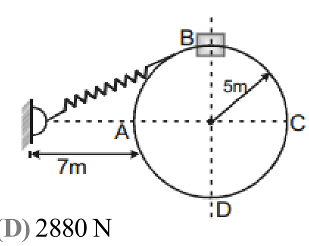
4. The blocks A and B shown in the figure have masses $M_A = 5$ kg and $M_B = 4$ kg. The system is released from rest. The speed of B after A has travelled a distance 1 m along the incline is



(A) $\dfrac{\sqrt{3}}{2}\sqrt{g}$ (B) $\dfrac{\sqrt{3}}{4}\sqrt{g}$ (C) $\dfrac{\sqrt{g}}{2\sqrt{3}}$ (D) $\dfrac{\sqrt{g}}{2}$

5. Of the sentences given
(i) Internal forces acting on the system cannot change $\dfrac{1}{2}mv_{cm}^2$, where m is the total mass of the system.
(ii) Internal forces acting on a system cannot change kinetic energy of system with respect to centre of mass
(A) both (i) and (ii) are correct (B) only (i) is correct
(C) only (ii) is correct (D) Both (i) and (ii) are wrong.

6. A collar 'B' of mass 2 kg is constrained to move along a horizontal smooth and fixed circular track of radius 5 m. The spring lying in the plane of the circular track and having spring constant 200 N/m is undeformed when the collar is at 'A'. If the collar starts from rest at 'B', the normal reaction exerted by the track on the collar when it passes through 'A' is :



(A) 360 N (B) 720 N (C) 1440 N (D) 2880 N

11th Class Modules Chapter Details

Physics
5
Modules

Chemistry
5
Modules

Mathematics
5
Modules

PHYSICS

Module-1

1. Physical World & Measurements
2. Basic Maths & Vector
3. Kinematics

Module-2

1. Law of Motion & Friction
2. Work, Energy & Power

Module-3

1. Motion of system of particles & Rigid Body
2. Gravitation

Module-4

1. Mechanical Properties of Matter
2. Thermal Properties of Matter

Module-5

1. Oscillations
2. Waves

CHEMISTRY

Module-1(PC)

1. Some Basic Conceps of Chemistry
2. Atomic Structure
3. Chemical Equilibrium
4. Ionic Equilibrium

Module-2(PC)

1. Thermodynamics & Thermochemistry
2. Redox Reaction
3. States Of Matter (Gaseous & Liquid)

Module-3(IC)

1. Periodic Table
2. Chemical Bonding
3. Hydrogen & Its Compounds
4. S-Block

Module-4(OC)

1. Nomenclature of Organic Compounds
2. Isomerism
3. General Organic Chemistry

Module-5(OC)

1. Reaction Mechanism
2. Hydrocarbon
3. Aromatic Hydrocarbon
4. Environmental Chemistry & Analysis Of Organic Compounds

BIOLOGY

Module-1

1. Diversity in the Living World
2. Plant Kingdom
3. Animal Kingdom

Module-2

1. Morphology in Flowering Plants
2. Anatomy of Flowering Plants
3. Structural Organization in Animals

Module-3

1. Cell: The Unit of Life
2. Biomolecules
3. Cell Cycle & Cell Division
4. Transport in Plants
5. Mineral Nutrition

Module-4

1. Photosynthesis in Higher Plants
2. Respiration in Plants
3. Plant Growth and Development
4. Digestion & Absorption
5. Breathing & Exchange of Gases

Module-5

1. Body Fluids & Its Circulation
2. Excretory Products & Their Elimination
3. Locomotion & Its Movement
4. Neural Control & Coordination
5. Chemical Coordination and Integration

12th Class Modules Chapter Details

Physics
5
Modules

Chemistry
5
Modules

Mathematics
5
Modules

PHYSICS

Module-1
1. Electrostatics
2. Capacitance

Module-2
1. Current Electricity
2. Magnetic Effect of Current and Magnetism

Module-3
1. Electromagnetic Induction
2. Alternating Current

Module-4
1. Geometrical Optics
2. Wave Optics

Module-5
1. Modern Physics
2. Nuclear Physics
3. Solids & Semiconductor Devices
4. Electromagnetic Waves

CHEMISTRY

Module-1(PC)
1. Solid State
2. Chemical Kinetics
3. Solutions and Colligative Properties

Module-2(PC)
1. Electrochemistry
2. Surface Chemistry

Module-3(IC)
1. P-Block Elements
2. Transition Elements (d & f block)
3. Co-ordination Compound
4. Metallurgy

Module-4(OC)
1. HaloAlkanes & HaloArenes
2. Alcohol, Phenol & Ether
3. Aldehyde, Ketone & Carboxylic Acid

Module-5(OC)
1. Nitrogen & Its Derivatives
2. Biomolecules & Polymers
3. Chemistry in Everyday Life

BIOLOGY

Module-1
1. Reproduction in Organisms
2. Sexual Reproduction in Flowering Plants
3. Human Reproduction
4. Reproductive Health

Module-2
1. Principles of Inheritance and Variation
2. Molecular Basis of Inheritance
3. Evolution

Module-3
1. Human Health and Disease
2. Strategies for Enhancement in Food Production
3. Microbes in Human Welfare

Module-4
1. Biotechnology: Principles and Processes
2. Biotechnology and Its Applications
3. Organisms and Populations

Module-5
1. Ecosystem
2. Biodiversity and Conservation
3. Environmental Issues