6

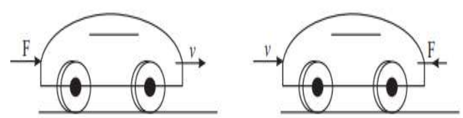
Work, Energy and power

Work

- The work done by a force is the product of the magnitude of a force component in the direction of the displacement and displacement of this object
- If force **F** is acting at angle θ with respect to displacement **d** of the object
- W =Fcosθ.d or **W** =**F.d**
- Dimension formula
  W = force * displacement
  = Mass * Acceleration* distance
  = $[M][LT^{-2}][L]$
  = $[ML^2T^{-2}]$
- SI unit Joule
- 1kWh = $3.6*10^6$J

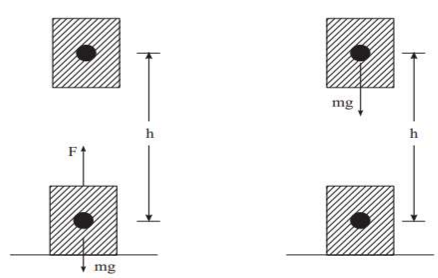
Positive work and negative work

Positive work	**Negative work**
Force and displacement is parallel to each other.	Force is opposite to displacement
$0 \le \theta \le 90$	90< θ≤ 180
W = $Fdcos0^0$	W = $Fdcos180^0$
W = F d	W = -F d
External force favour the motion of the body.	Force oppose the motion of the body.



Work done by Force of Gravity

- The work done against the force mg and the displacement is upward
  W = Fd cos 180^0
  = -mgh
- The force and displacement d are in the same direction
  W =Fd cos 0^0
  = mgh



- When the object is lifted up,the work done by the gravitational force is negative but the work done by the person lifting the object is positive
- When the object is being lowered the work done by the gravitational force is positive but the work done by the person lowering the object is negative.

Work done by a variable force

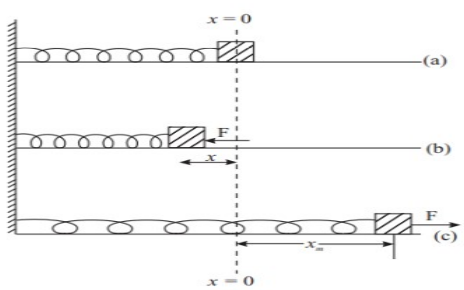
- magnitude and direction of a force varies with position, the work done by such a force for an infinitesimal displacement is given by

$$\Delta \boldsymbol{W} = \boldsymbol{F}(\boldsymbol{x})\Delta \boldsymbol{x}$$

$$\boldsymbol{W} = \sum_{lim\ \Delta x \to 0} \boldsymbol{F}(\boldsymbol{x})\Delta \boldsymbol{x}$$

Work done by a spring

F =-kx (Hook's Law)



Where k is spring constant

Power

- The rate at which work is done is called power.
- Average power = work done/ time taken
- Unit of power = joule/second = watt
- Dimension of power $[ML^2T^{-3}]$
- 1k W h = 3.6 MJ(mega joule)

Work and Kinetic Energy

- **Kinetic energy**
  The energy possessed by a body by virtue of its motion is called kinetic energy. Let m = mass of the body, v = velocity of the body then K.E. = ½ m v^2

Work energy theorem

- The work energy theorem states that the work done by the resultant of all forces acting on a body is equal to the change in kinetic energy of the body.

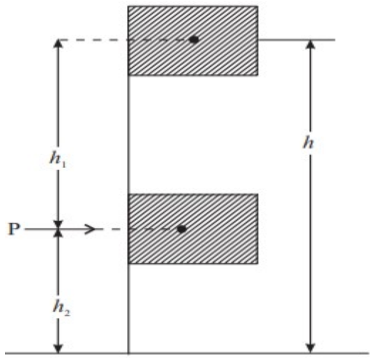
Potential energy

- Object possess another kind of energy due to their position in space. This energy is known as Potential Energy.
  Work = force * distance

Conservation of Energy

- The total energy of an isolated system always remain constant.
- The energy may change its form.

Conservation of mechanical energy during the freefall of a body



$V^2 = u^2 + 2gs$

$U = 0$, $s = h_1$

$V^2 = 2gh_1$

K.E. = $\frac{1}{2} mv^2$

$= (m/2)\, 2gh_1$

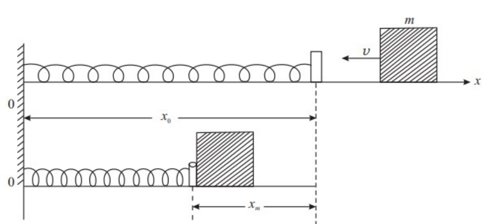
$= mgh_1$

K.E. + P.E. = $mgh_1 + mgh_2$

= mgh

Total energy is conserved.

Conservation of mechanical energy for a mass oscillating on a spring



$\frac{1}{2} k x_m^2 = \frac{1}{2} m v^2$

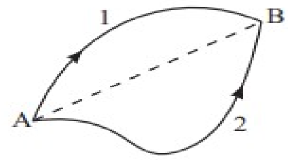
K.E. + P.E. (before collision) = K.E. + P.E. (after collision)

The total energy is conserved.

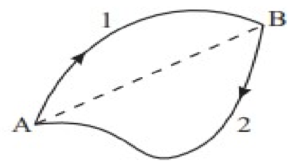
Conservative and Dissipative Forces

Conservative forces

- **When the force is independent of path followed by the object known as conservative force.**



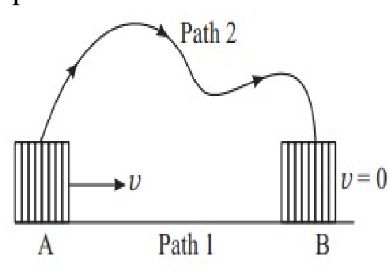
(a)



- A conservative force has a property that the work done by a conservative force is independent of the path.
  W_{AB}(along 1) = $-W_{BA}$(along 2)
  $W_{AB} + W_{BA} = 0$
- The work done by the conservative force on an object is zero when the object moves around a closed path and return back to its starting point.

Non conservative force

- A non-conservative force has a property that the work done by a conservative force is dependent of the path.



Elastic and Inelastic collision

- When two bodies interact, it is termed as collision.
- Collision is an isolated event in which a strong force acts between two or more bodies for

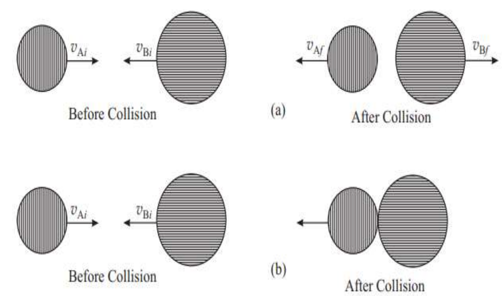
a short time as a result of which the energy and momentum of the interacting particle change.

- Types of collision : on the basis of kinetic energy

Perfectly elastic collision	**Perfectly Inelastic collision**
If the forces of interaction between the two bodies are conservative, the total kinetic energy is conserved	When two colliding bodies stick together after the collision and move as one single unit, it is termed as perfectly inelastic collision
If in a collision, kinetic energy after collision is equal to kinetic energy before collision, the collision is said to be perfectly elastic.	If in a collision two bodies stick together or move with same velocity after the collision, the collision is said to be perfectly inelastic
Coefficient of restitution e = 1	Coefficient of restitution e = 0
Examples : (1) Collision between atomic particles (2) Bouncing of ball with same velocity after the collision with earth.	Example : Collision between a bullet and a block of wood into which it is fired. When the bullet remains embeded in the block.

Elastic Collision (Head on)

For conservation of momentum



$$\boldsymbol{m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}}$$

For conservation of kinetic energy

$$\frac{1}{2}m_A v_{Ai}^2 + \frac{1}{2}m_B v_{Bi}^2 = \frac{1}{2}m_A v_{Af}^2 + \frac{1}{2}m_B v_{Bf}^2$$

$$v_{Af} = \frac{2m_B v_{Bi}}{m_A + m_B} + \frac{v_{Ai}(m_A - m_B)}{m_A + m_B}$$

$$v_{Bf} = -\frac{2m_A v_{Ai}}{m_A + m_B} + \frac{v_{Bi}(m_B - m_A)}{m_A + m_B}$$

Check Your Progress

1. Which one of the following is correct
   a) K.E. = $P^2/2m$
   b) P/2m
   c) $P/2m^2$
   d) $(P/2m)^2$
2. For perfectly inelastic collision, value of coefficient for restitution e is
   a) E=1
   b) E<1
   c) E=0

d) E>1

3. If $\boldsymbol{A} = \hat{\imath} + 2\hat{\jmath} - \hat{k}$ and $\boldsymbol{B} = -\hat{\imath} - \widehat{2\jmath} - \widehat{2k}$ the value of **A.B**
    A. -2
    B. -4
    C. 3
    D. -3
4. The slope of the K.E versus position for gives the ratio of change of
    A. Work
    B. Momentum
    C. Force
    D. power
5. If two masses m_1 and m_2 collide , the ratio of changes in their respective velocity is proportional to
    a) m_1/m_2
    b) $\sqrt{{m2}/{m1}}$
    c) $m_{2/m1}$
    d) $\sqrt{{m1}/{m2}}$

Stretch Yourself

1. When an air bubble raise in water. What happen to its potential energy
2. A body of mass 50 kg has a momentum of 100 $kgms^{-1}$ calculate its K.E.
3. What is meant by zero work? State the condition under which a force does no work give example
4. State and explain work energy principles.
5. What is meant by collision?

Answer to Check Yourself

1A) 2C) 3D) 4B) 5 C)