5. WORK, ENERGY AND POWER

WORK

Work is said to be done when force produces displacement.

- $W = F\,s\cos\theta$,
- S.I unit is J (joule)

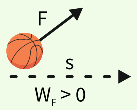
ENERGY

- Capacity to do work is defined as Energy.
- It is a scalar quantity.
- S.I. unit is J or Joule.

Work can be Positive, Negative or Zero

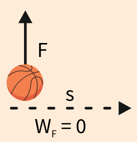
POSITIVE WORK

If force and displacement both are '+' and θ is acute.



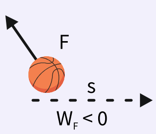
ZERO WORK

1) $W = 0$, if Force is perpendicular to the displacement.
2) Either Force or displacement is 0.



NEGATIVE WORK

If both force & displacement are '+' or '-' and θ is between 90° to 180°.



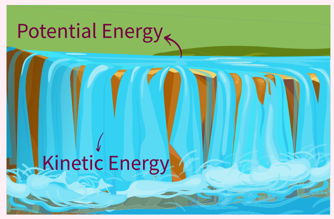
TYPES OF ENERGY

MECHANICAL ENERGY

Kinetic Energy + Potential Energy

KINETIC ENERGY

By virtue of velocity $K = \frac{1}{2}mv^2$



POTENTIAL ENERGY

By virtue of Position, height, stresses within its & Electrostatic Factors;

Gravitational Potential Energy = mgh

Electrostatic Potential energy = $\frac{kq_1q_2}{r}$

Various Forms of Energy

1) Heat energy
2) Chemical energy
3) Electrical energy
4) Nuclear energy
5) Mechanical Energy
6) Solar Energy etc.

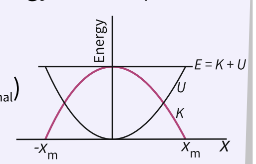
ENERGY IN SPRING MASS SYSTEM

1) Total mechanical energy at each point is constant.
2) $\Delta K + \Delta U = 0$

$(K_{initial} + U_{initial}) = (K_{final} + U_{final})$

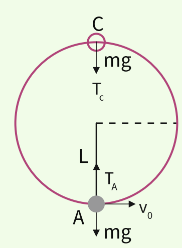
3) maximum Velocity

$$v_{max} = x_m\sqrt{\frac{k}{m}}$$



Mechanical Energy is Conserved

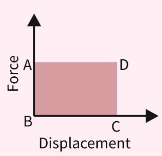
MOTION IN A VERTICAL CIRCLE



- In absence of dissipative forces, mechanical energy is conserved
  $v = \sqrt{5gl}$ i.e critical velocity at bottom to reach top
- $v = \sqrt{3gl}$ i.e critical velocity at the horizontal position.
- $v = \sqrt{gl}$ i.e critical velocity at the top.
- Tension at any point on circle, $T = \frac{mu^2}{r} - mg\,(2 - 3\cos\theta)$
- Velocity at any point on circle, $v^2 = u^2 - 2gl(1 - \cos\theta)$

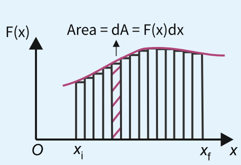
Work Done by a

Constant Force



- Area under F-S graph gives work done
- work done = Area under ABCD

Variable Force



If work is done by variable force, then $W_{total} = \int_{x_i}^{x_f} F(x)dx$

Work-Energy Theorem

1) Net Work done on an object by all forces will change in Kinetic energy of an object.
2) $W_{net} = \Delta K$
3) $W_{conservative} + W_{non-conservative} + W_{ext} = \Delta K$

$\int F(x).dx = \Delta K + \Delta U$

if variable force does work.

Work Done by Conservative & Non conservative Forces

CONSERVATIVE FORCES

1) Kx, mg and electrostatic forces are conservative forces.
2) Work done by these forces is stored in the form of Potential energy.
3) They are path independent.

NON CONSERVATIVE FORCES

1) Non – conservative forces are path dependent.
2) Friction is an example of non – conservative forces.

Formulae

1) $dW = \vec{F}.\vec{dr}$
2) $P = \frac{dw}{dt}$

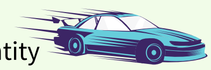
For small amount of work

Special Units

- $1\ hp = 746\ W$
- $1\ KWH = 3.6 \times 10^6\ J$

POWER

1) Time rate at which work is done.
2) It is a scalar quantity
3) S.I. Unit is watt (w).



INSTANTANEOUS POWER

Scalar product of force and instantaneous velocity (v) is instantaneous Power.

$$P_{inst} = F.\frac{ds}{dt} = F.V$$

AVERAGE POWER

Total Work done in time t is average power

$$P_{avg} = \frac{W_{total}}{t}$$

COLLISIONS

- ✦ An instance of one moving body striking with another.
- ✦ Collision of car with truck, collision of balls in snooker are examples.

Nature of Collisions

Value of coefficient of restitution defines nature of collision,

$$e = \frac{\text{relative velocity of separation}}{\text{relative velocity of approach}}$$

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

$e = 0$, $e = 1$, $0 < e < 1$

Defines nature of collisions

Conservation of Momentum

1) If net external force on system is zero then Linear momentum of system is conserved
2) $\Delta\vec{p} = 0$
3) $\vec{p}_i = \vec{p}_f$
4) $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

- ✦ In inelastic collision, momentum is conserved
- ✦ $0 < e < l$
- ✦ Bodies do not stick together after collision

- ✦ In perfectly inelastic collison momentum is conserved.
- ✦ $e = 0$
- ✦ Bodies sticks together after collision

- ✦ In elastic collision, momentum and K.E of system are conserved
- ✦ $e = 1$
- ✦ Bodies do not stick together after collision

TYPES OF COLLISIONS

1 - D COLLISION

1) $(\Delta p)_{sys} = 0$

2) $e = \frac{v_2 - v_1}{u_1 - u_2}$

3) $v_1 = \left(\frac{m_1 - em_2}{m_1 + m_2}\right) u_1 + \left(\frac{(1 + e)m_2}{m_1 + m_2}\right) u_2$

velocity of first particle after collision.

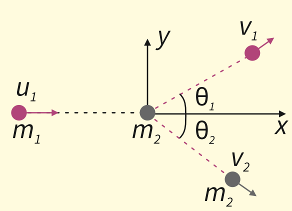
4) $v_2 = \left(\frac{m_1 - (1 + e)m_2}{m_1 + m_2}\right) u_1 + \left(\frac{m_2 - em_1}{m_1 + m_2}\right) u_2$

velocity of second particle after collision

5) Change in Kinetic energy,

$$\Delta K = \frac{1}{2}\frac{m_2 m_1}{m_1 + m_2}(u_1 - u_2)^2 (1 - e^2)$$

2 - D COLLISION



1) Bodies moving in a plane results in arbitrary collision in different directions is 2–D.

2) $\Delta\vec{p} = 0$

$\Delta p_x = 0$

$m_1 u_{1x} + m_2 u_{2x} = m_1 v_{1x} + m_2 v_{2x}$

$\Delta p_y = 0$

$m_1 u_{1y} + m_2 u_{2y} = m_1 v_{1y} + m_2 v_{2y}$

SPECIAL CASES

1) $h = e^{2n} h_0$

e = coefficient of restitution

$n = n^{th}$ collision,

h_0 = initial height,

h_n = height after n^{th} collision

2) $V_n = e^n V_0$,

$n = n^{th}$ collision,

V_0 = initial velocity,

v_n = velocity after n^{th} collision

3) $H = h_0 \frac{(1 + e^2)}{(1 - e^2)}$

H = total distance travelled before it stops

4) $T = \frac{(1 + e)}{(1 - e)}\sqrt{\frac{2h_0}{g}}$

T = time taken by ball to stop bouncing.