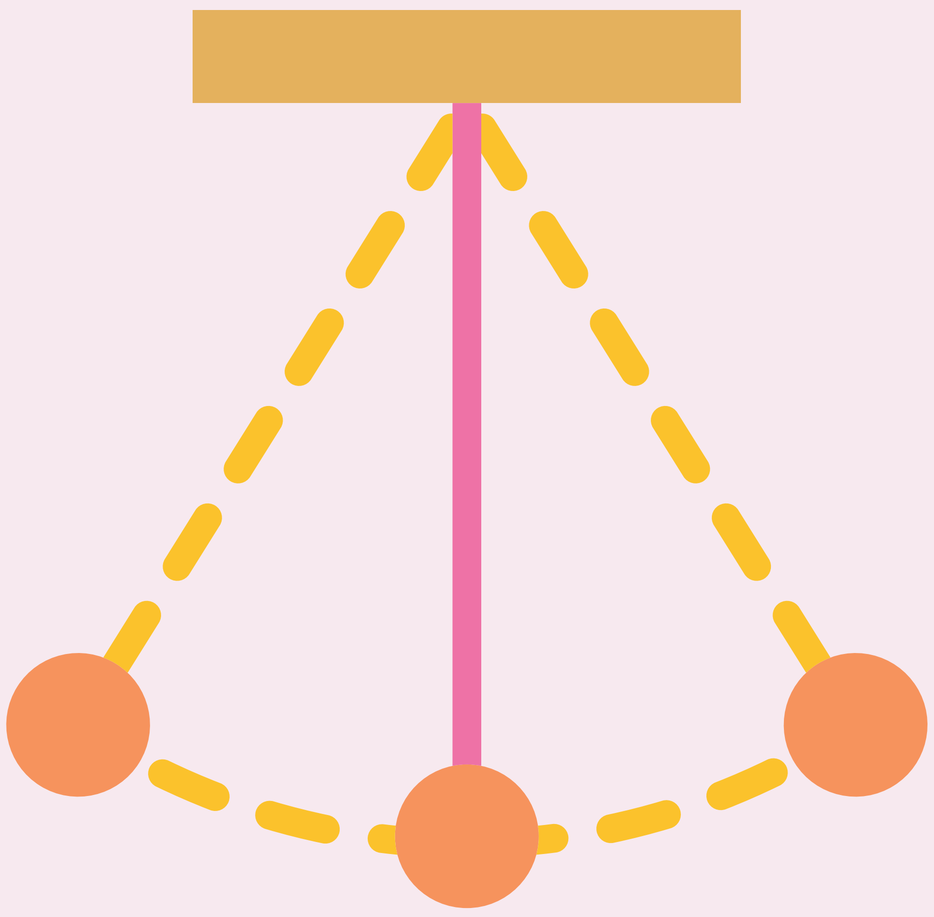
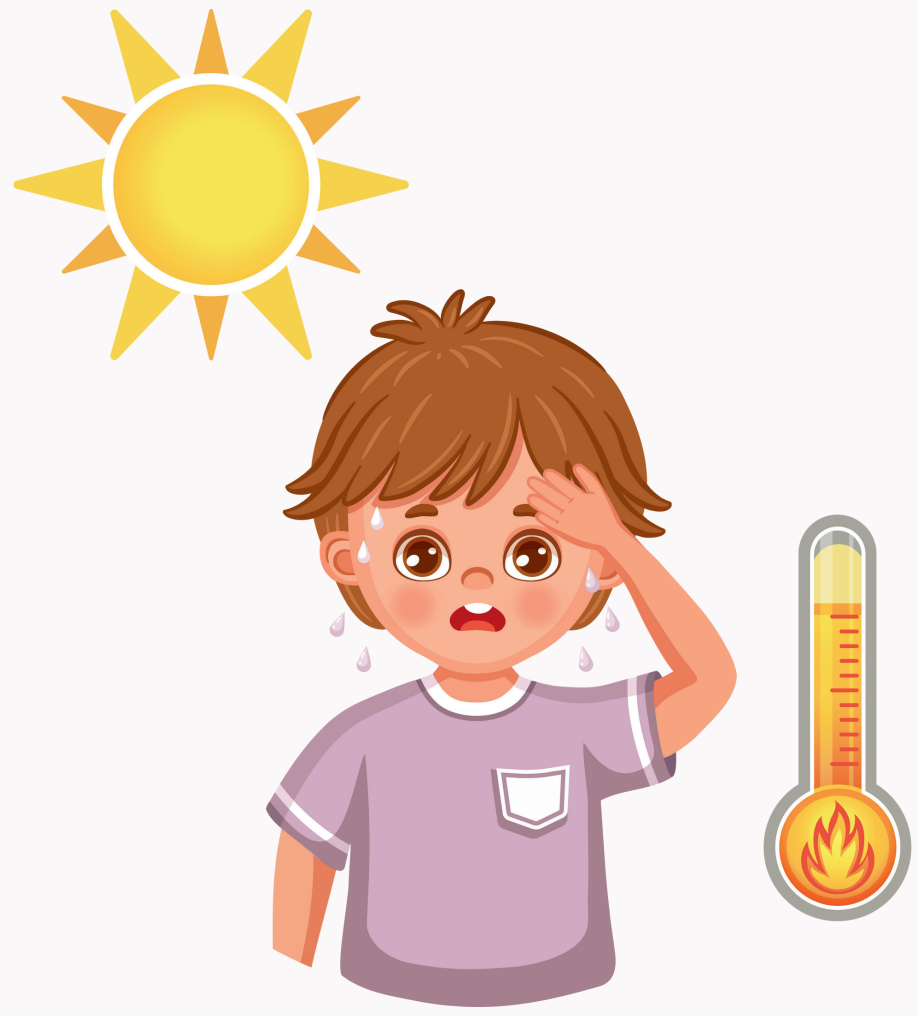
SP015 REFERENCE NOTES

MOTION



Oscillations
&
Waves

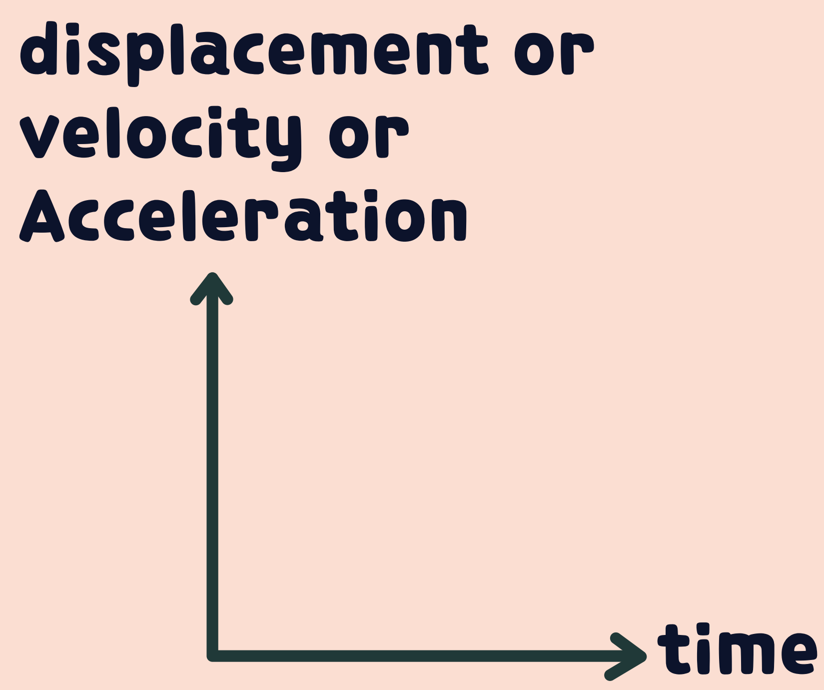


Heat

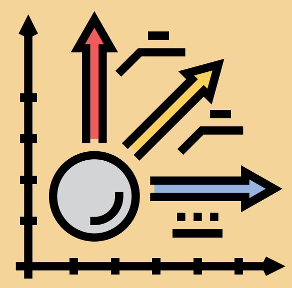
CHAPTER TWO

LINEAR MOTION

Average, Uniform, Instantaneous → velocity/ Acceleration



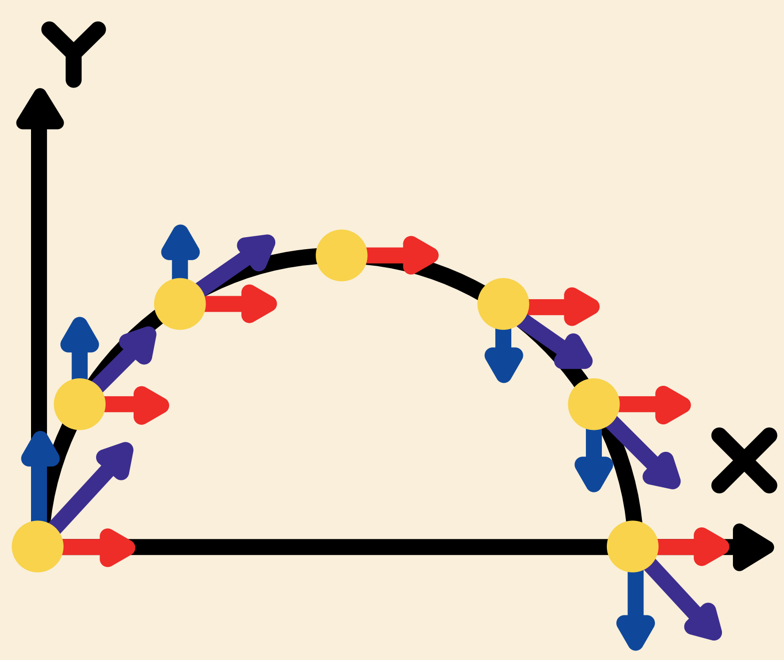
UNIFORMLY ACCELERATED MOTIONS



$$s = ut + \frac{1}{2}at^2 \qquad v^2 = u^2 + 2as$$

$$v = u + at \qquad s = \frac{1}{2}(u + v)t$$

PROJECTILE MOTION



$$u_x = u\cos\theta \qquad v_x = u_x$$

$$u_y = u\sin\theta \qquad v_y = u_y - gt$$

$$g = 9.81ms^{-2}$$

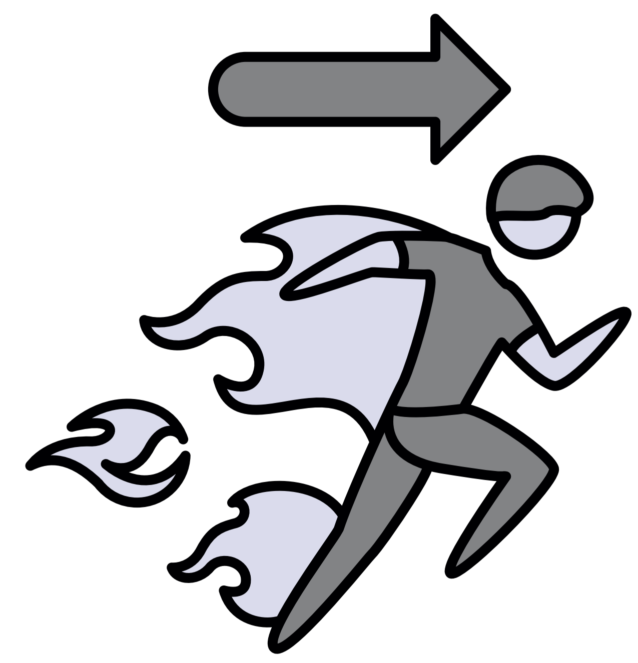
$$h_{max} = \frac{u^2\sin^2(\theta)}{2g} \qquad R = \frac{u^2\sin^2(2\theta)}{g}$$

Chapter Three

Momentum, Impulse & Newton's Law of Motion

Definitions

Momentum: $\vec{p} = m\vec{v}$



Impulse: $\vec{J} = \Delta\vec{p} = m\vec{v} - m\vec{u}$

Weight: $\vec{W} = m\vec{g}$

Friction: $\vec{f} = \mu\vec{N}$

Concepts

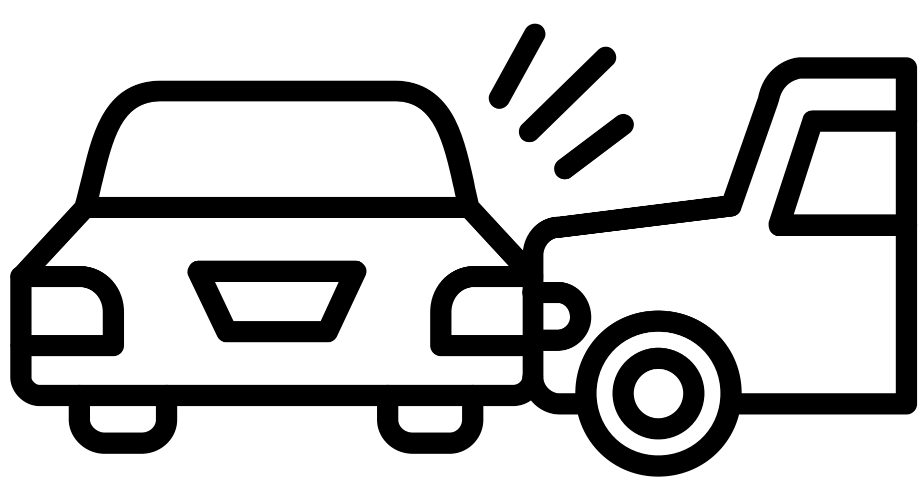
Conservation of Momentum: $\Delta\vec{p} = 0$

Newton's 1st Law: $\vec{F} = 0 \Rightarrow \vec{v} = 0$

Newton's 2nd Law: $\vec{F} = \frac{d\vec{p}}{dt}$

Elastic Collision: $\Delta K = 0$ ✓ $\Delta\vec{p} = 0$ ✓

Inelastic Collision: $\Delta K = 0$ ✓ $\Delta\vec{p} = 0$ ✗



CHAPTER 4: WORK, ENERGY & POWER

DEFINITIONS

Work: $W = \vec{F} \cdot \vec{s}$

Gravitational Potential Energy: $U_{gp} = mgh$

Kinetic Energy: $K = \frac{1}{2}mv^2$

Elastic Potential Energy: $U_{ep} = \frac{1}{2}kx^2$

Average Power: $P_{ave} = \frac{\Delta W}{\Delta t}$

Instantaneous Power: $P_{inst} = \vec{F} \cdot \vec{v}$

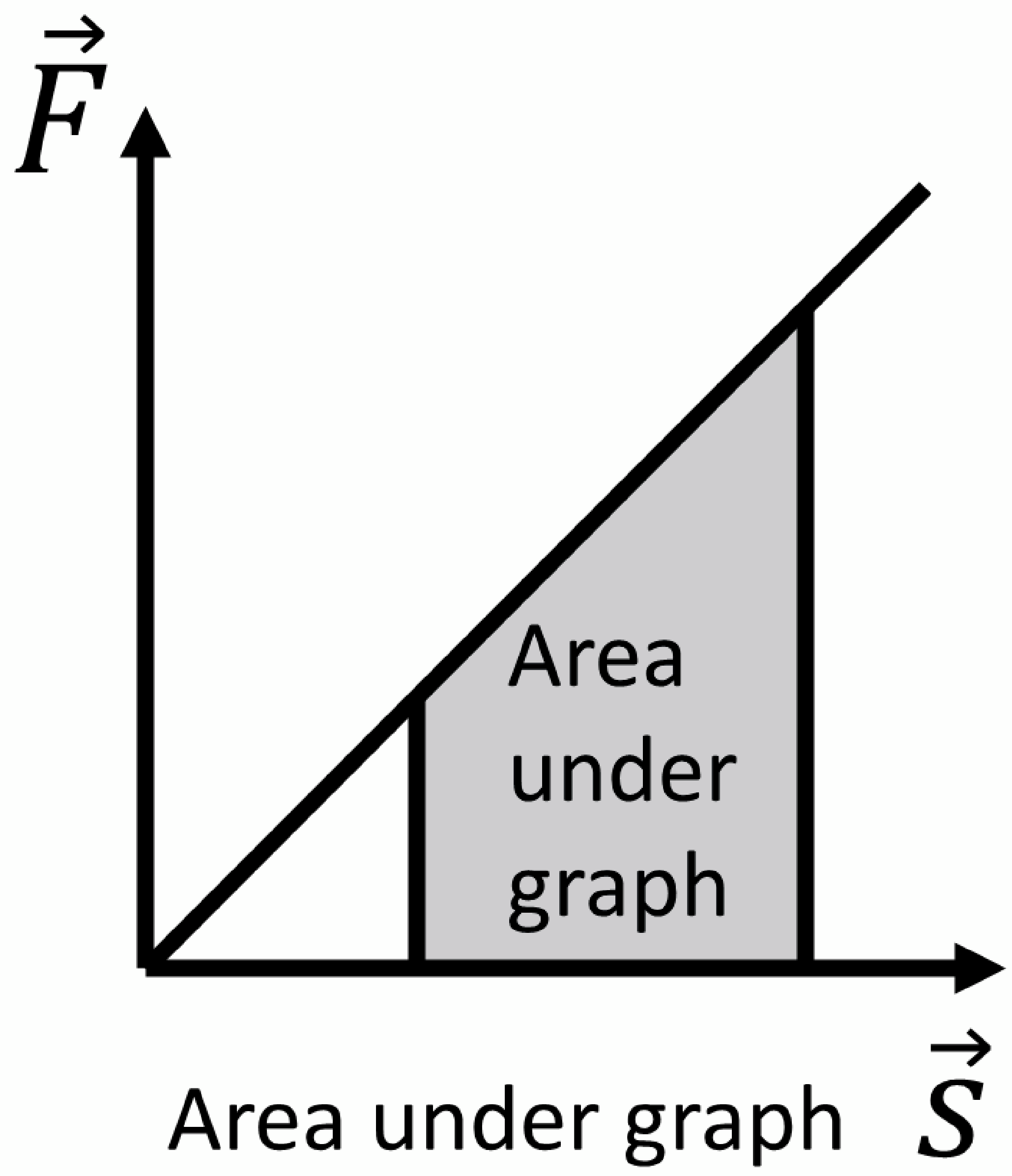
Work-Energy Theorem:

$$W = \Delta K$$

Conservation of Energy:

$$\Delta E = 0 \Rightarrow E_{final} = E_{initial}$$

CONCEPTS



Area under graph = Work done

CHAPTER 5: CIRCULAR MOTION

Definitions

Term	Definition
Angular Displacement	Angular displacement is the angle through which an object moves on a circular path. It is measured in **radians (rad)** and is given by the ratio of arc length to the radius of the circle.
Period	The period is the **time taken** for one complete revolution or cycle of circular motion. It is measured in **seconds (s)**.
Frequency	Frequency is the **number of complete revolutions or cycles** per unit time. It is measured in **hertz (Hz)** and is the reciprocal of the period: $$f = \frac{1}{T}$$
Angular Velocity	Angular velocity is the **rate of change of angular displacement** with respect to time. It is measured in **radians per second (rad/s)** and is given by: $$\omega = \frac{\theta}{t}$$
Uniform Circular Motion	Uniform circular motion is the motion of an object travelling in a **circular path at constant speed**. Although the speed remains constant, the velocity changes due to continuous change in direction, implying there is always **centripetal acceleration** directed toward the center.

Unit Conversion

$$2\pi\, rad = 1\, rev = 1\, rot = 360^o$$

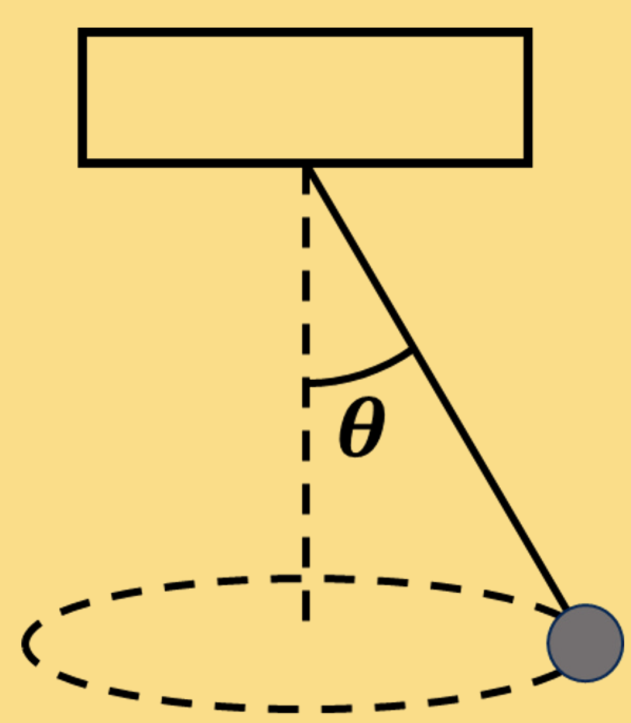
Centripetal Acceleration

$$a_c = \frac{v^2}{r} = r\omega^2$$

Centripetal Force

$$F_c = m\frac{v^2}{r} = m\, r\omega^2$$

CIRCULAR MOTION CASES
- HORIZONTAL
- VERTICAL
- CONICAL PENDULUM



CHAPTER 6: ROTATION OF RIGID BODY

LINEAR → ROTATIONAL

$$s = r\theta$$
$$v = r\omega$$
$$a_t = r\alpha$$
$$a_c = r\omega^2 = \frac{v^2}{r}$$

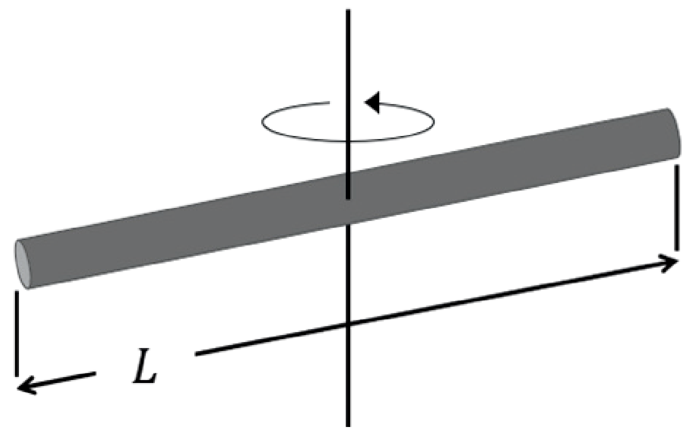
ROTATIONAL KINEMATICS

$$\omega = \omega_o + \alpha t$$
$$\theta = \omega_o t + \frac{1}{2}\alpha t^2$$
$$\omega^2 = \omega_o^2 + 2\alpha\theta$$
$$\theta = \frac{1}{2}(\omega_o + \omega)t$$

MOMENT OF INERTIA EQUATIONS

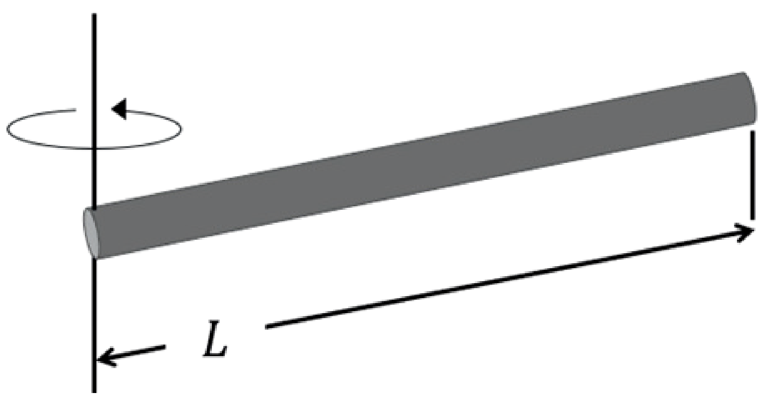
$$I = \Sigma m r^2 = \int_m r^2\, dm$$

Thin rod of mass M about its centre



$$I = \frac{1}{12}ML^2$$

Thin rod of mass M about its end



$$I = \frac{1}{3}ML^2$$

ROTATIONAL DYNAMICS

$$\vec{\tau} = \vec{r} \times \vec{F}$$

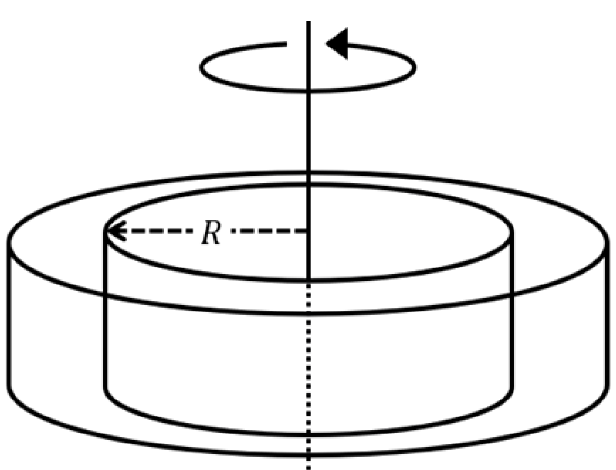
$$\vec{F} = m\vec{a} \Leftrightarrow \vec{\tau} = I\vec{\alpha}$$

Equilibrium:

$$\Sigma\vec{F} = 0 \Leftrightarrow \vec{\tau} = 0$$

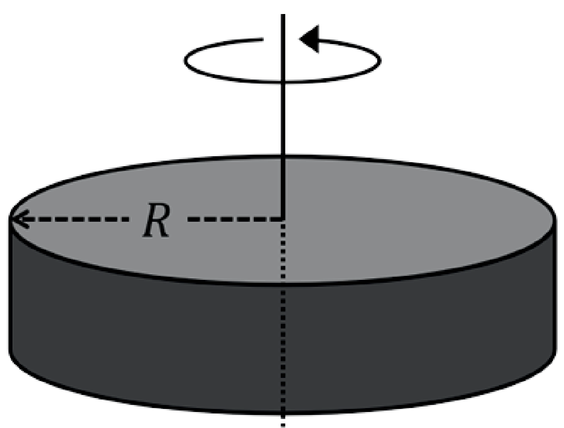
$$\vec{L} = I\vec{\omega}$$

Thin ring about its centre axis



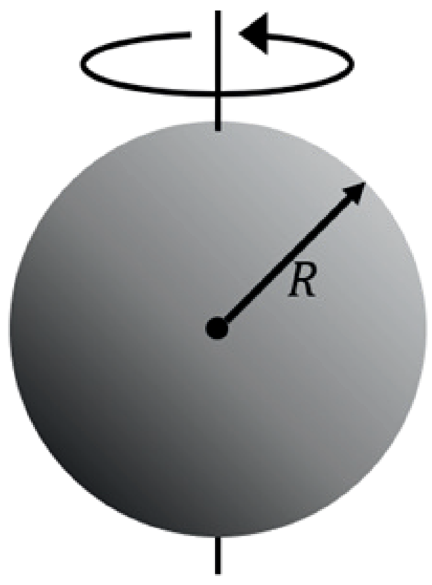
$$I = MR^2$$

cylinder about its



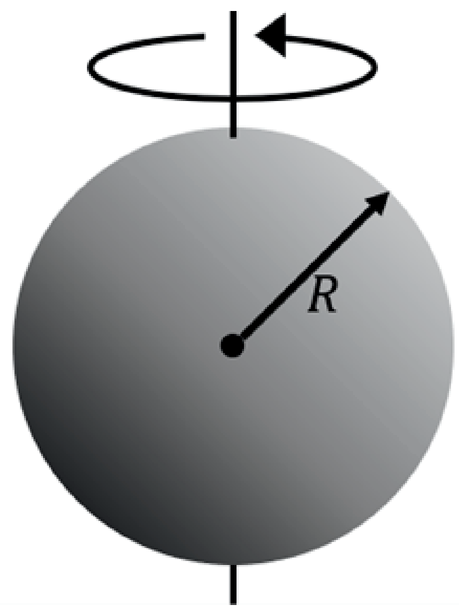
$$I = \frac{1}{2}MR^2$$

Solid Sphere



$$I = \frac{2}{5}MR^2$$

Hollow spherical shell



$$I = \frac{2}{3}MR^2$$

C7

SIMPLE HARMONIC MOTION

KINEMATICS

- Displacement Equation
- Equations as functions of time
- Equations as functions of displacement
- Graphs

$$y(t) = A\sin(\omega t)$$
$$v = \omega A\cos(\omega t) = \pm\omega\sqrt{A^2 - y^2}$$
$$a = -\omega^2 A\sin(\omega t) = -\omega^2 y$$
$$K = \frac{1}{2}m\omega^2 A^2\cos^2(\omega t) = \frac{1}{2}m\omega^2(A^2 - y^2)$$
$$U = \frac{1}{2}m\omega^2 A^2\sin^2(\omega t) = \frac{1}{2}m\omega^2 y^2$$
$$E_{total} = \frac{1}{2}m\omega^2 A^2$$

SIMPLE PENDULUM

- Period
- Angle <10 degrees
- Dependence on gravity & length

$$T_{sp} = 2\pi\sqrt{\frac{l}{g}}$$

MASS SPRING SYSTEM

- Period
- Dependence on spring constant & mass

$$T_{mss} = 2\pi\sqrt{\frac{m}{k}}$$

PROGRESSIVE WAVES

PROPERTIES

- Wavelength
- Equation of Progressive Waves
- Propagation vs vibrational speed
- Superposition of waves

$$k = \frac{2\pi}{\lambda};\ \omega = 2\pi f = \frac{2\pi}{T}$$
$$y(x,t) = A\sin(\omega t \pm kx)$$
$$v_{prop} = f\lambda$$
$$v_{vibrate} = \frac{dy}{dt}$$

DOPPLER EFFECT

- Ratio of frequencies
- Stationary/Moving?

$$\frac{f'}{f} = \frac{v \pm v_{obs}}{v \pm v_{source}}$$

STRETCHED STRING

- Node-to-node
- Fundamental Frequency
- Nth Overtones
- wave speed, tensions & mass density

$$v = \frac{\sqrt{T}}{\mu};\ f_n = \frac{nv}{2L}$$

CLOSED TUBE

- Node-to-Antinode
- Fundamental Frequency
- Nth overtones
- Only odd harmonics

$$f_n = \frac{nv_{sound}}{4L}$$

OPEN TUBE

- Antinode-to-antinode
- Fundamental Frequency
- Nth overtones

$$f_n = \frac{nv_{sound}}{2L}$$

Chapter 8: Physics of Matter

Young's Modulus

Stress

Stress is defined as the force per unit area acting on an object. It measures the internal resistance offered by the material to deformation.

$$\delta = \frac{F}{A}$$

Strain

Strain is the ratio of change in length to the original length of a material when subjected to stress. It is a measure of deformation and has no units.

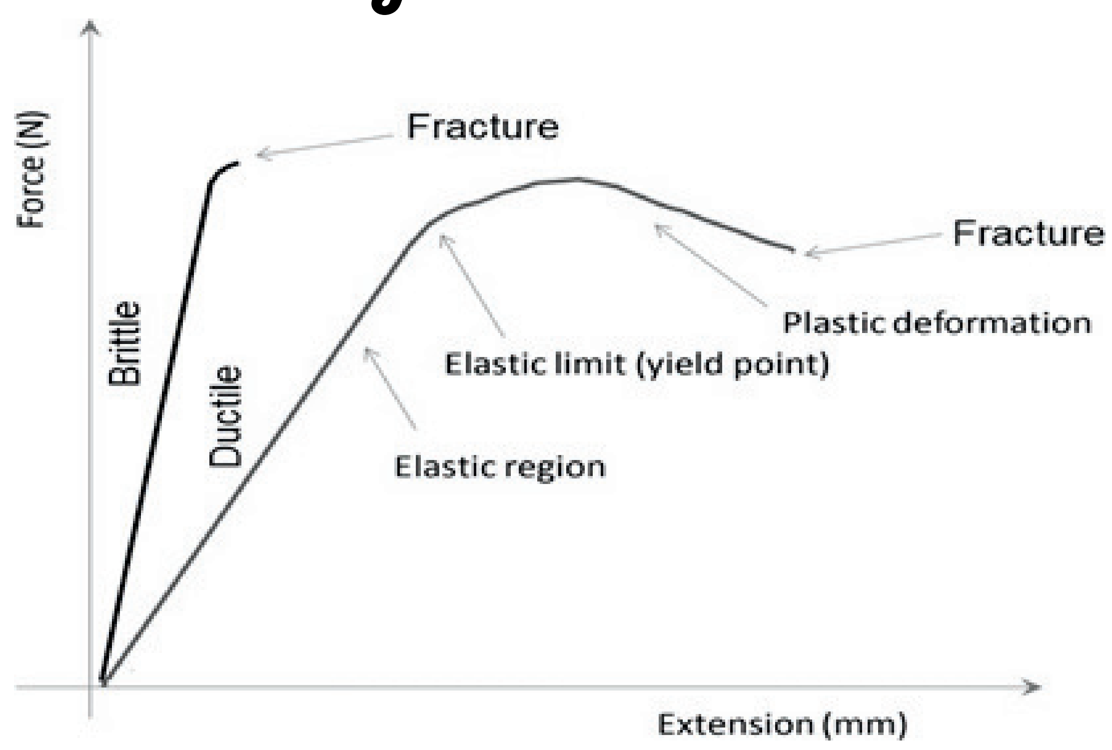
$$\varepsilon = \frac{\Delta L}{L_o}$$

Young's Modulus

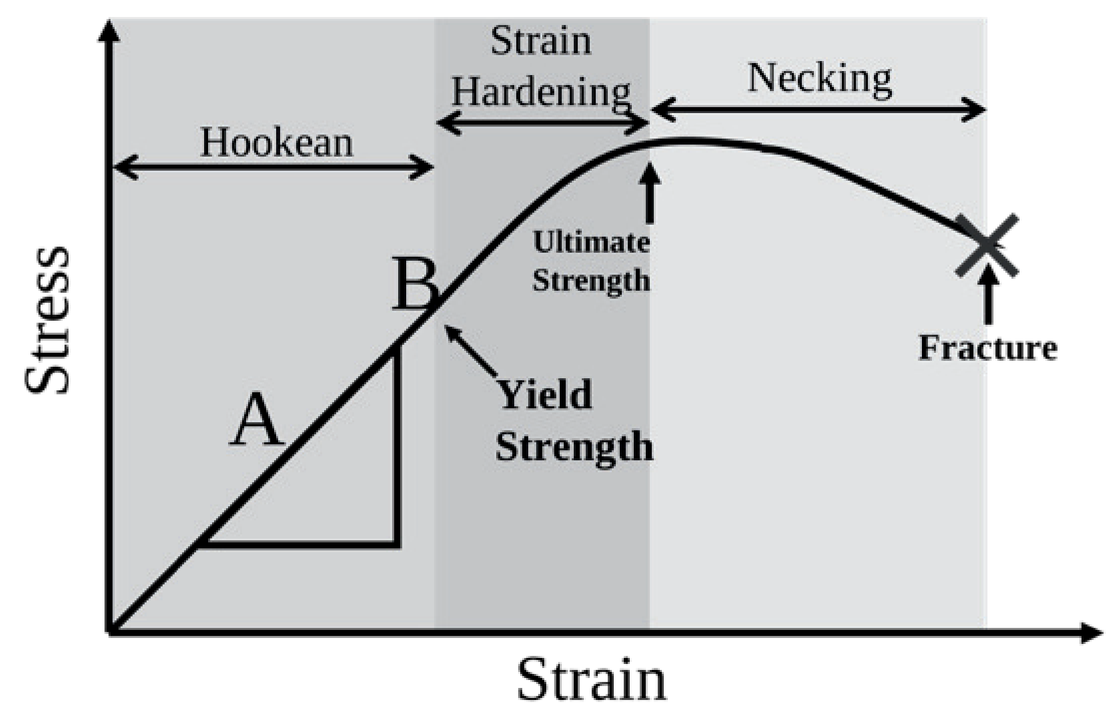
Young's Modulus is the ratio of stress to strain in a material within the elastic limit. It quantifies the stiffness of a material.

$$Y = \frac{\delta}{\varepsilon}$$

Force Elongation



Stress Strain GRaph



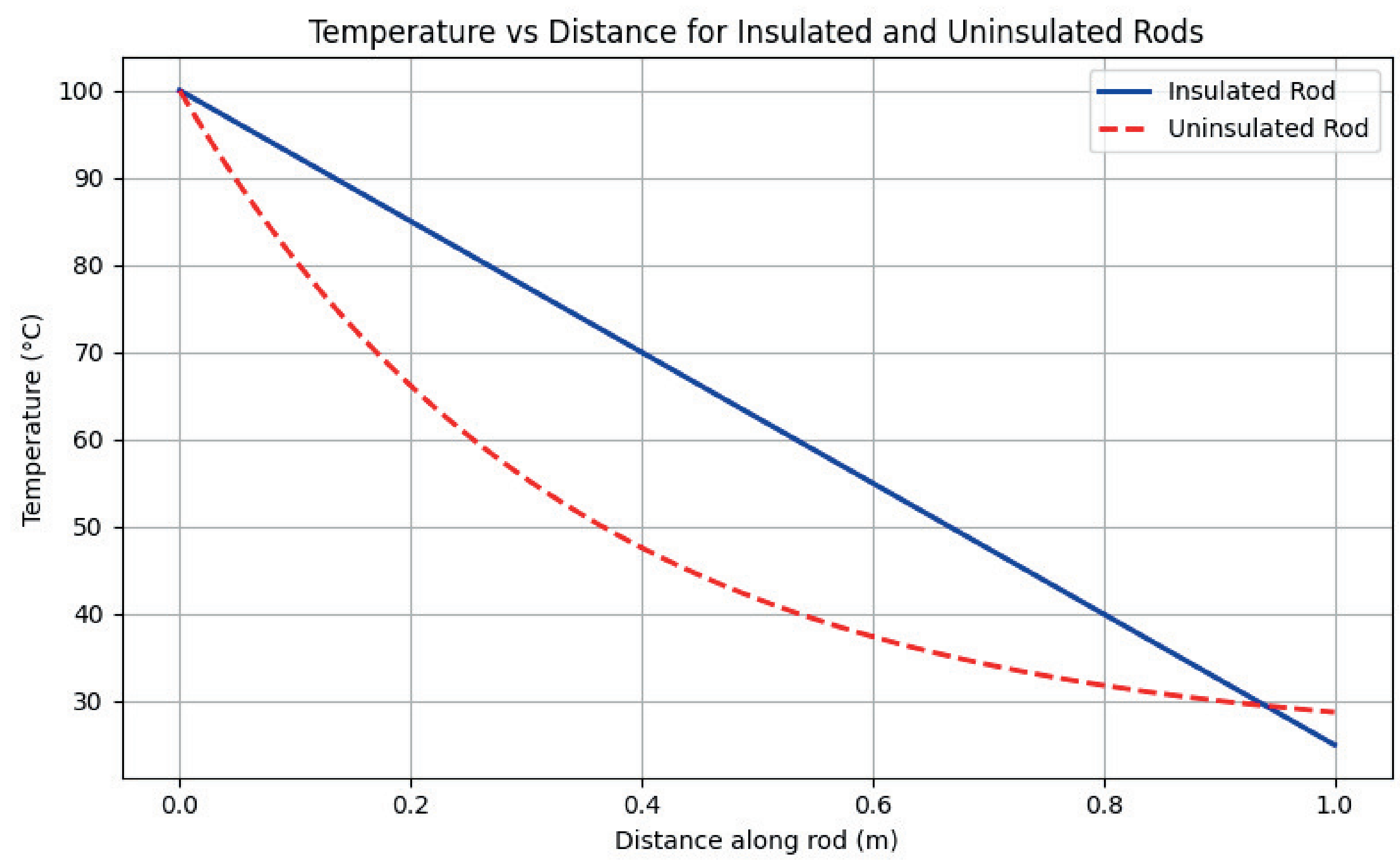
Heat Conduction

Rate of Heat Transfer

$$\frac{Q}{t} = -kA\left(\frac{\Delta T}{L}\right)$$

Steady-State

$$\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2$$



Chapter 8: Physics of Matter

Thermal Expansion

Linear Expansion

$$\Delta L = \alpha L_o \Delta T$$

Area Expansion

$$\Delta A = \beta A_o \Delta T$$

Volume Expansion

$$\Delta V = \gamma V_o \Delta T$$

Coefficient Relationship

$$\gamma = 3\alpha \qquad \beta = 2\alpha$$

CHAPTER 9

Kinetic Theory of Gases & Thermodynamics

Kinetic Theory of Gases

IMPORTANT

$1u = 1.660539 \times 10^{-27} kg$

$N_A = 6.022 \times 10^{23}$ particle per mol.

$pV = nRT = Nk_BT$

$$P = \frac{1}{3}\frac{\mathrm{Nm}}{\mathrm{V}}\mathrm{v}_{\mathrm{rms}}^2 = \frac{1}{3}\rho v_{rms}^2$$

$$U = \frac{f}{2}Nk_BT = \frac{f}{2}nRT$$

classical theorem of energy equipartition

At equilibrium, energy per molecule contributed for each degree of freedom is

$$\frac{1}{2}\boldsymbol{k_B T}$$

Translational Kinetic Energy

For all types of particles,

$$K_{tr} = \frac{3}{2}\boldsymbol{k_B T}$$

In general,

For particles of degree of freedom *f*,

$$U = \frac{f}{2}Nk_BT = \frac{f}{2}nRT$$

Total Translational Kinetic Energy

For monoatomic particles,

$$\Sigma K = \frac{3}{2}\boldsymbol{k_B T}$$

For diatomic particles,

$$\Sigma K = \frac{5}{2}\boldsymbol{k_B T}$$

CHAPTER 9

Kinetic Theory of Gases & Thermodynamics

Thermodynamics

First Law

$$\Delta U = \Delta Q - \Delta \mathrm{W_{by}}$$

TD Processes

Isothermal

$$\mathrm{W_{by}} = nRT\ ln\left(\frac{V_f}{V_i}\right)$$

$$\mathrm{W_{onto}} = -nRT\ ln\left(\frac{V_f}{V_i}\right)$$

isobaric

$$\mathrm{W_{by}} = p\Delta V$$

$$\mathrm{W_{onto}} = -p\Delta V$$

Isochoric

$$\mathrm{W_{by}} = -\mathrm{W_{onto}} = 0$$