

Physics

XI & XII

FORMULA SHEET
MADE WITH LOVE

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IIT KHARAGPUR ALUMNUS

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PHYSICAL CONSTANTS

Speed of Light $c = 3 \times 10^8 \text{ m/s}$

Plank constant $h = 6.63 \times 10^{-34} \text{ J.s}$ $hc = 1242 \text{ eV.nm}$

Gravitation constant $G = 6.67 \times 10^{-11} \text{ N.m}^2/\text{kg}^2$

Boltzmann constant $k = 1.38 \times 10^{-23} \text{ J/K}$

Molar gas constant $R = 8.314 \text{ J/mol.K}$

Avogadro's number $N_A = 6.023 \times 10^{23} / \text{mol}$

Charge of electron $e = 1.602 \times 10^{-19} \text{ C}$

Permeability of vacuum $\mu_0 = 4\pi \times 10^{-7} \text{ N/A}^2$

Permittivity of vacuum $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$

Coulomb constant $1/4\pi\epsilon_0 = 9 \times 10^9 \text{ N.m}^2/\text{C}^2$

Faraday constant $F = 96485 \text{ C/mol}$

Mass of electron $m_e = 9.1 \times 10^{-31} \text{ kg}$

Mass of proton $m_p = 1.6726 \times 10^{-27} \text{ kg}$

Mass of neutron $m_n = 1.6749 \times 10^{-27} \text{ kg}$

Atomic mass unit $u = 1.66 \times 10^{-27} \text{ kg}$

Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$

Rydberg constant $R_\infty = 1.097 \times 10^7 / \text{m}$

Bohr magnetron $\mu_B = 9.27 \times 10^{-24} \text{ J/T}$

Bohr radius $a_0 = 0.529 \times 10^{-10} \text{ m}$

Standard atmosphere $\text{atm} = 1.01325 \times 10^5 \text{ Pa}$

Wien displacement constant $b = 2.9 \times 10^{-3} \text{ mK}$



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VECTORS



$$\vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k} \quad |\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

DOT PRODUCT $\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$
 $= ab \cos \theta$



CROSS PRODUCT $\vec{a} \times \vec{b} = ab \sin \theta$



$$\vec{a} \times \vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix} = + (a_y b_z - b_y a_z) - (a_x b_z - b_x a_z) + (a_x b_y - b_x a_y)$$

DONT FORGET

KINEMATICS



$$\vec{v}_{inst} = d\vec{s}/dt$$

$$\vec{v}_{avg} = \Delta \vec{s} / \Delta t$$

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

$$v = u + at$$

$$\vec{a}_{inst} = d\vec{v}/dt$$

$$\vec{a}_{avg} = \Delta \vec{v} / \Delta t$$

$$v^2 = u^2 + 2as$$

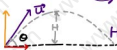
PROJECTILE MOTION

RELATIVE VELOCITY

$$\vec{v}_{A/B} = \vec{v}_A - \vec{v}_B$$

$$u_x = u \cos \theta$$

$$u_y = u \sin \theta$$



$$H = \frac{u^2 \sin^2 \theta}{2g}$$

$$\text{Time of Flight} = 2u_y/g \Rightarrow T = 2u \sin \theta / g$$

$$\text{Range} = u_x \cdot T \Rightarrow R = \frac{u^2 \sin 2\theta}{g}$$

$$y = \tan \theta \cdot x - \left(\frac{g}{2u^2 \cos^2 \theta} \right) \cdot x^2$$

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LAWS OF MOTION

INERTIA

$$F = d\vec{P}/dt = m\vec{a}$$

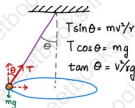
Action $\Rightarrow$ Reaction

$$f = \mu_s N$$



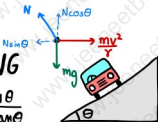
Centripetal force

$$\frac{mv^2}{r} = m\omega^2 r$$



CURVED BANKING

$$\frac{v^2}{rg} = \tan \theta \quad \frac{v^2}{rg} = \frac{\mu \pm \tan \theta}{1 \pm \mu \tan \theta}$$



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WORK, POWER & ENERGY

$$\text{Work} = \vec{F} \cdot \vec{s} = fs \cos \theta \\ = \int \vec{F} \cdot d\vec{s}$$

$$\text{KE}(K) = \frac{1}{2} mv^2$$

POTENTIAL ENERGY (U)

$$U_g = mgh$$

$$\vec{F} = -\frac{dU}{dx}$$

FOR
CONSERVATIVE
FORCES

$$U_{\text{spring}} = \frac{1}{2} kx^2$$

$$K + U = \text{Conserved}$$

$$\oint \vec{F} \cdot d\vec{s} = 0 \quad \left\{ \begin{array}{l} \text{work by Conservative} \\ \text{force in a closed path} \end{array} \right\}$$

$$\text{POWER} = dW/dt = \vec{F} \cdot \vec{v}$$

**WORK-ENERGY
THEOREM**

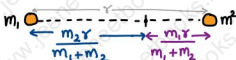
$$W_{\text{net}} = \Delta K$$



CENTER OF MASS

$$x_{cm} = \frac{\sum x_i m_i}{\sum m_i} = \frac{\int x dm}{\int dm}$$

$$\vec{V}_{cm} = \frac{\sum m_i \vec{V}_i}{\sum m_i} \quad \vec{F} = m \vec{a}_{cm}$$



HOLLOW CONE = $h/3$



SOLID CONE = $h/4$



HOLLOW



SOLID

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COLLISION



MOMENTUM CONSERVATION {Always}

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

ENERGY CONSERVATION {Elastic}

$$\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$



$$CoR = e = \frac{V_{SEPARATION}}{V_{APPROACH}} = \frac{v_2 - v_1}{u_1 - u_2}$$

$$m_1 \gg m_2$$

$m_1 \rightarrow$ undisturbed motion
Solve using CoR in m_1 frame

$$m_1 = m_2$$

Velocity Exchange
for Elastic



RIGID BODY DYNAMICS

$$\omega = \frac{\Delta \theta}{\Delta t} = \frac{d\theta}{dt} \quad \alpha = \frac{\Delta \omega}{\Delta t} = \frac{d\omega}{dt}$$

$$\vec{v} = \vec{\omega} \times \vec{r}$$

$$\vec{a}_{\text{tan}} = \vec{\alpha} \times \vec{r}$$

$$\vec{a}_{\text{centri}} = \omega^2 \vec{r}$$

$$\theta = \omega_0 t + \frac{1}{2} \alpha t^2$$

$$\omega = \omega_0 + \alpha t$$

$$\omega^2 = \omega_0^2 + 2\alpha\theta$$

$$\vec{L} = \vec{r} \times \vec{p} = m v r_{\perp}$$

$$\vec{\tau} = I \vec{\alpha} = d\vec{L}/dt$$

$$\vec{\tau} = \vec{r} \times \vec{F} = r_{\perp} F = r F \sin \theta$$

$$\text{EQUILIBRIUM : } F_{\text{net}} = 0 = \tau_{\text{net}}$$

$$\omega = 2\pi f \quad T = 1/f \quad \omega = v_{\perp}/r$$

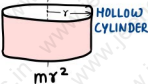
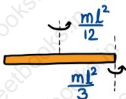
MOMENT OF INERTIA

$$I = \sum m_i r_i^2$$

$$I = \int r^2 dm$$

$$R_{\text{GYRATION}} \quad mk^2 = I$$





SOLID CYLINDER



$$\text{HOLLOW} = \frac{2}{3} m r^2$$

$$\text{SOLID} = \frac{2}{5} m r^2$$

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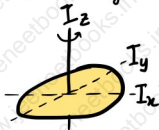
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AXIS THEOREMS

PERPENDICULAR

$$I_z = I_x + I_y$$



PARALLEL

$$I_{||} = I_{cm} + md^2$$



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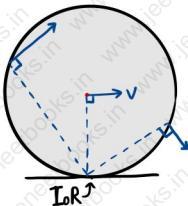
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IoR INSTANTANEOUS AXIS OF ROTATION

$$\vec{V} = \vec{\omega} \times \vec{r}$$



KINETIC ENERGY

$$K = \frac{1}{2} m v_c^2 + \frac{1}{2} I_c \omega^2$$

$$K = \frac{1}{2} I_H \omega^2 \left\{ \begin{array}{l} \text{About Hinge} \\ \text{or IoR} \end{array} \right\}$$

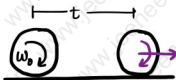
ROLLING MOTION

$v = \omega r$ (no slip condition)



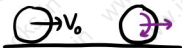
$$a = \frac{g \sin \theta}{\left[1 + \frac{I}{mr^2}\right]}$$

$$v = \sqrt{\frac{2gH}{1 + \frac{I}{mr^2}}}$$



Initial $\downarrow$

$$t = \frac{r\omega_0}{\mu g \left[1 + \frac{mr^2}{I}\right]}$$



$$t = \frac{v_0}{\mu g \left[1 + \frac{mr^2}{I}\right]}$$

GRAVITATION

$$F = G \frac{Mm}{R^2}$$

$$\text{POT. ENERGY (U)} = -GMm/R$$



$$V_{\text{ORBITAL}} = \sqrt{GM/R}$$

$$V_{\text{escape}} = \sqrt{2GM/R}$$

VARIATION OF g

$$g = G \frac{M}{R^2}$$

$$g' = g \left[1 - \frac{d}{R_e} \right]$$

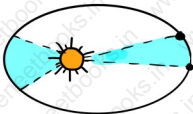
$$g' \approx g \left[1 - \frac{2h}{R_e} \right]$$



$$g' = g - \omega^2 R_e \cos^2 \theta$$



KEPLER'S LAWS



- 1st Elliptical Orbits, Sun @ foci
- 2nd Equal Area in Equal time ($\propto$)
- 3rd $T^2 \propto a^3$ [semi major axis]

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SHM

HOOKE'S LAW $F = -kx$

$$x = A \sin(\omega t + \phi)$$

$$v = A\omega \cos(\omega t + \phi)$$

$$a = -\omega^2 x = -k/m x$$

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{m/k}$$

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

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



$$E = K + U = \frac{1}{2}kA^2 = \frac{1}{2}m\omega^2A^2$$



$$T = 2\pi\sqrt{\frac{I}{mgL}}$$



$$\tau = k\theta$$

$$T = 2\pi\sqrt{\frac{I}{k}}$$

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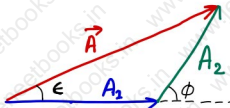
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$$x_1 = A_1 \sin(\omega t)$$

$$x_2 = A_2 \sin(\omega t + \phi)$$

$$x = x_1 + x_2 = A \sin(\omega t + \epsilon)$$

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos \phi}$$

$$\tan \epsilon = \frac{A_2 \sin \phi}{A_1 + A_2 \cos \phi}$$

SPRINGS



SERIES

$$\frac{1}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2}$$



PARALLEL

$$K_{eq} = K_1 + K_2$$



PROPERTIES OF MATTER

$$\text{YOUNG'S MODULUS } (Y) = \frac{F/A}{\Delta L/L}$$

$$\text{BULK MODULUS } (B) = -V \frac{\Delta P}{\Delta V}$$

$$\text{SHEAR MODULUS } (\eta) = \frac{F/A}{\tan \theta}$$

$$\text{COMPRESSIBILITY } (K) = \frac{1}{B} = -\frac{1}{V} \frac{\Delta V}{\Delta P}$$

$$\text{POISSON'S RATIO } (\sigma)$$

$$\frac{\text{LATERAL STRAIN}}{\text{LONGITUDINAL STRAIN}} = \frac{\Delta D/D}{\Delta L/L}$$

$$\text{ELASTIC ENERGY } (U)$$

$$\frac{1}{2} \text{ STRESS} \times \text{STRAIN} \times \text{VOLUME}$$

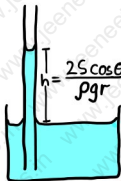
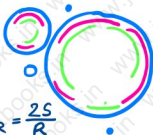


$$\text{SURFACE TENSION (S)} = F/l$$

$$\text{SURFACE ENERGY (U)} = S \cdot \text{AREA}$$

$$\Delta P_{\text{SOAP}} = \frac{4S}{R}$$

$$P_{\text{EXCESS}} = \Delta P_{\text{AIR}} = \frac{2S}{R}$$



$$P_{\text{HYDROSTATIC}} = \rho gh$$

$$F_{\text{BUOYANT}} = \rho gV$$



$$\text{CONTINUITY } A_1v_1 = A_2v_2$$

BERNOULLI'S

$$P + \rho gh + \frac{1}{2} \rho v^2 = \text{Const}$$



$$F_{\text{VISCOUS}} = -\eta A \frac{dv}{dx}$$

Area ↗

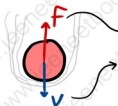
TORRICELLI'S

$$V_{\text{EFFLUX}} = \sqrt{2gH}$$



STOKE'S LAW

$$F = 6\pi\eta r v$$



V_{TERMINAL}

$$\frac{2r^2(\rho - \sigma)g}{9\eta}$$

POISEUILLI'S EQN



$$\frac{\text{VOLUME FLOW}}{\Delta t} = \frac{\pi p r^4}{8\eta L}$$

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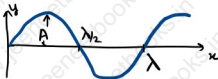
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WAVES



$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 y}{\partial t^2}$$



$$y = A \sin(kx - \omega t)$$
$$= A \sin\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right]$$

$$\text{WAVE NUMBER}(k) = \frac{2\pi}{\lambda}$$

$$T = \frac{1}{\nu} = \frac{2\pi}{\omega}$$

$$v = \nu \lambda$$

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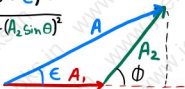
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$$Y_1 = A_1 \sin(kx - \omega t) \quad Y_2 = A_2 \sin(kx - \omega t + \phi)$$

$$Y = A \sin(kx - \omega t + \epsilon)$$

$$A^2 = \sqrt{(A_1 + A_2 \cos \phi)^2 + (A_2 \sin \phi)^2}$$

$$\tan \epsilon = \frac{A_2 \sin \phi}{A_1 + A_2 \cos \phi}$$



$\phi = 2n\pi$ (even) : Constructive
 $= (2n+1)\pi$ (odd) : destructive

$$P_{\text{avg}} = 2\pi^2 \mu \nu A v^2 \quad (\text{POWER})$$

$$v = \sqrt{\frac{T}{\mu}}$$



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STANDING WAVES

$$y_1 = A \sin(kx - \omega t)$$

$$y_2 = A \sin(kx + \omega t)$$

$$Y = 2A \cos kx \cdot \sin \omega t$$

Node if $\cos kx$ is zero $\Rightarrow x = (n + \frac{1}{2})\lambda$



$$L = n \cdot \frac{\lambda}{2} \quad v = \frac{n}{2L} \sqrt{\frac{T}{\mu}}$$

SONOMETER



$$L = (2n+1) \frac{\lambda}{4} \quad v = \frac{2n+1}{4L} \sqrt{\frac{T}{\mu}}$$

OPEN
 $\Rightarrow$ ANTI NODE

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SOUND WAVES

$$S = S_0 \sin[\omega(t - x/v)] \quad \left| \quad v_{\text{solid}} = \sqrt{Y/\rho}$$

$$P = P_0 \cos[\omega(t - x/v)] \quad \left| \quad v_{\text{liq}} = \sqrt{B/\rho}$$

$$P_0 = \left[\frac{B\omega}{v} \right] S_0 \quad \left| \quad v_{\text{gas}} = \sqrt{\gamma P/\rho}$$

$$I = \frac{2\pi^2 B}{v} S_0^2 v^2 = \frac{P_0^2 v}{2B} = \frac{P_0}{2\rho v}$$


STANDING LONGITUDINAL WAVES

$$P_1 = P_0 \sin[\omega(t - x/v)] \quad P_2 = P_0 \sin[\omega(t + x/v)]$$

$$P = P_1 + P_2 = 2P_0 \cos kx \sin \omega t$$

CLOSED ORGAN PIPE



$$L = (2n+1) \frac{\lambda}{4} \quad v = (2n+1) \frac{v}{4L}$$

OPEN ORGAN PIPE



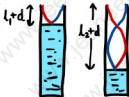
$$L = n \frac{\lambda}{2} \quad v = n \frac{v}{2L}$$



RESONANCE COLUMN

$$L_1 + d = \frac{\lambda}{2} \quad L_2 + d = \frac{3\lambda}{2}$$

$$v = 2(L_2 - L_1)v$$



BEATS (if $\omega_1 \approx \omega_2$)

$$P_1 = P_0 \sin \omega_1(t - x/v) \quad P_2 = P_0 \sin \omega_2(t - x/v)$$

$$P = 2P_0 \cos \Delta\omega(t - x/v) \sin \omega(t - x/v)$$

$$\omega = \left(\frac{\omega_1 + \omega_2}{2} \right)$$

$$\text{Beats} \rightarrow \Delta\omega = \omega_1 - \omega_2$$

DOPPLER

$$v = \frac{v + v_o}{v - v_s} v_o$$



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LIGHT WAVES



|||||→ PLANE WAVES

$$E = E_0 \sin \omega(t - x/v); I = I_0$$

SPHERICAL WAVES

$$E = \frac{a E_0}{r} \sin \omega(t - r/v); I = \frac{I_0}{r^2}$$



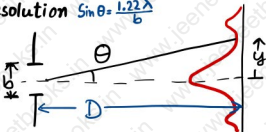
DIFFRACTION

$$\Delta x = b \sin \theta \approx b \theta$$

$$\theta \sim \tan \theta = y/D$$

Minima $b \theta = n \lambda$

Resolution $\sin \theta = \frac{1.22 \lambda}{b}$



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YOUNG'S DOUBLE SLIT EXPERIMENT

Path diff: $\Delta x = y \frac{d}{D}$

Phase diff: $\delta = \frac{2\pi}{\lambda} \Delta x$

CONSTRUCTIVE

$$\delta = 2n\pi; \Delta x = n\lambda$$

DESTRUCTIVE

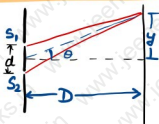
$$\delta = (2n+1)\pi; \Delta x = (n + \frac{1}{2})\lambda$$

$$\text{Intensity } I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \delta$$

$$I_{\text{max/min}} = (\sqrt{I_1} \pm \sqrt{I_2})^2$$

$$\text{Fringe Width } w = \lambda \frac{D}{d}$$

$$\text{Optical Path } \Delta x' = \mu \Delta x$$



$$\text{LAW of MALUS } I = I_0 \cos^2 \theta$$

INTERFERENCE THROUGH THIN FILM

$$\Delta x = 2\mu d = \begin{matrix} n\lambda \longrightarrow \text{Constructive} \\ (2n+1)\lambda/2 \longrightarrow \text{destructive} \end{matrix}$$

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OPTICS

REFLECTION

(ii) $\angle i = \angle r$

(i) i, r & normal in same plane

$f = R/2$

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

Magnification $m = -\frac{v}{u}$



REFRACTION

$\mu = \frac{c}{v} = \frac{\text{(vacuum)}}{\text{(medium)}}$

SNELL'S LAW $\mu_1 \sin i = \mu_2 \sin r$

APPARENT DEPTH $d' = d/\mu$

TIR CRITICAL ANGLE

$\mu \sin \theta_c = \sin 90^\circ = 1$



PRISM

$\delta = i + i' - A$

$\mu = \frac{\sin \left(\frac{A + \delta_{\min}}{2} \right)}{\sin \left(\frac{A}{2} \right)}$



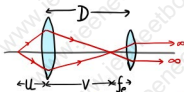
$\delta_{\min} = (\mu - 1)A$
For small 'A'

MICROSCOPE

Simple $m = D/f$

Compound

$m = \frac{v}{u} \frac{D}{f_e}$ Resolving Power $R = \frac{1}{\Delta d} = \frac{2\mu \sin \theta}{\lambda}$

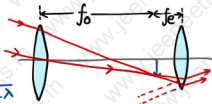


TELESCOPE

$$m = -f_o/f_e$$

$$L = f_o + f_e$$

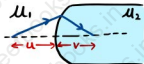
$$R = \frac{1}{\Delta\theta} = \frac{1}{1.22\lambda}$$



SPHERICAL SURFACE

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$m = \frac{\mu_1 v}{\mu_2 u}$$



LENS MAKER'S

$$\frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

LENS FORMULA

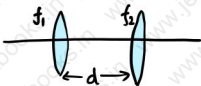
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}; m = \frac{v}{u}$$

POWER

$$P = \frac{1}{f}$$

THIN LENSES

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$



DISPERSION

Cauchy's $\mu = \mu_0 + A/\lambda^2$ $A > 0$

For small A & i

mean deviation $\delta_y = (\mu_y - 1)A$

Angular dispersion $\theta = (\mu_v - \mu_r)A$

Dispersive Power

$$\omega = \frac{\mu_v - \mu_r}{\mu_y - 1} \approx \frac{\theta}{\delta_y}$$



DISPERSION only

$$(\mu_y - 1)A + (\mu'_y - 1)A' = 0$$

DEVIATION only

$$(\mu_v - \mu_r)A = (\mu'_v - \mu'_r)A'$$

PHYSICS

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HEAT AND TEMP

$$F = 32 + \frac{9}{5}C$$

$$K = C + 273.16$$

Ideal Gas $\rightarrow PV = nRT$

van der Waals

$$\left(p + \frac{a}{V^2}\right)(V-b) = nRT$$

$$L = L_0(1 + \alpha \Delta T)$$

$$A = A_0(1 + 2\alpha \Delta T)$$

$$V = V_0(1 + 3\alpha \Delta T)$$

THERMAL STRESS

$$\frac{F}{A} = Y \frac{\Delta L}{L}$$

KINETIC THEORY

EQUIPARTITION OF ENERGY

$$K = \frac{1}{2} kT \text{ for each DoF}$$

$$K = \frac{f}{2} kT \text{ for } f \text{ Degrees of freedom}$$

$$\text{Internal Energy } U = \frac{f}{2} nRT$$

$$f = 3 \text{ (monatomic)}; 5 \text{ (diatomic)}$$



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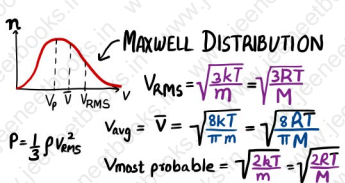
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SPECIFIC HEAT

Specific heat $S = \frac{Q}{m\Delta T}$

Latent heat $L = Q/m$

$$C_v = \frac{f}{2}R \quad C_p = C_v + R \quad \gamma = C_p/C_v$$

$$C_v = \frac{n_1 C_{v1} + n_2 C_{v2}}{n_1 + n_2} \quad \gamma = \frac{n_1 C_{p1} + n_2 C_{p2}}{n_1 C_{v1} + n_2 C_{v2}}$$



THERMODYNAMICS

IST LAW $\Delta Q = \Delta U + W$ $W = \int p \cdot dV$

ADIABATIC $W = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}$

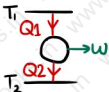
ISOTHERMAL $W = nRT \ln\left(\frac{V_2}{V_1}\right)$

ISOBARIC $W = p(V_2 - V_1)$

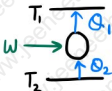
ADIABATIC: $\Delta Q = 0$; $PV^\gamma = \text{Const}$

IIND LAW ENTROPY $dS = \frac{dQ}{T}$

IIIRD LAW ENTROPY @ $T = 0K = 0$



$$\eta = \frac{W}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$$



$$\text{CoP} = \frac{Q_2}{W} = \frac{T_{\text{cold}}}{\Delta T}$$



HEAT TRANSFER

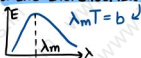
CONDUCTION $\frac{\Delta Q}{\Delta t} = -KA \frac{\Delta T}{x}$

Thermal Resistance = $\frac{x}{KA}$

 $R = R_1 + R_2 = \frac{x_1}{K_1 A_1} + \frac{x_2}{K_2 A_2}$
SERIES →

 $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$
PARALLEL →

WIEN'S DISPLACEMENT



STEFAN-BOLTZMANN

$$\Delta \theta / \Delta t = \sigma e A T^4$$

NEWTON'S COOLING

$$\frac{dT}{dt} = -bA(T - T_0)$$

KIRCHHOFF'S LAW

Emmision Power

Absorptive Power

$$= \frac{E_{\text{body}}}{a_{\text{body}}}$$

$$= E_{\text{black body}}$$



ELECTROSTATICS

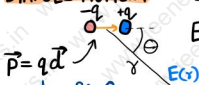
COULOMB'S LAW $F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$

$$\vec{E} = \vec{F}/q = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

POTENTIAL (V) = $\frac{1}{4\pi\epsilon_0} \frac{q}{r}$

PE (U) = $\frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$ $\vec{E} = -\frac{dV}{dr}$

DIAPOLE MOMENT



$\vec{p} = q\vec{d}$

$$\frac{1}{4\pi\epsilon_0} \cdot \frac{p \cos\theta}{r^2} = V(r)$$

$$E_r = \frac{1}{4\pi\epsilon_0} \cdot \frac{2p \cos\theta}{r^3}$$

$$E_\theta = \frac{1}{4\pi\epsilon_0} \cdot \frac{p \sin\theta}{r^3}$$

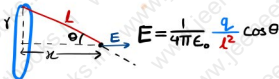
DIAPOLE $\vec{\tau} = \vec{p} \times \vec{E}$
IN FIELD $U = -\vec{p} \cdot \vec{E}$

GAUSS'S LAW

$\phi = q_{in}/\epsilon_0$

FLUX $\phi = \oint \vec{E} \cdot d\vec{s}$





UNIFORMLY CHARGED SPHERE



UNIFORM SHELL



LINE CHARGE $E = \frac{\lambda}{2\pi\epsilon_0 r}$

∞ -sheet $E = \frac{\sigma}{2\epsilon_0}$

$\vec{E}$ near
CONDUCTING SURFACE $E = \frac{\sigma}{\epsilon_0}$



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CAPACITORS

$$C = q/V \quad \text{---} \quad C = \epsilon_0 A/d$$



SPHERE

$$C = \frac{2\pi\epsilon_0 L}{\ln(r_2/r_1)}$$

$$C = 4\pi\epsilon_0 \frac{r_1 r_2}{r_2 - r_1}$$



PARALLEL $C_{eq} = C_1 + C_2$

SERIES $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$

WITH DIELECTRIC $C = \frac{\epsilon_0 K A}{d}$

Force b/w plates = $\frac{Q^2}{2A\epsilon_0}$

$$U = \frac{1}{2} CV^2 = \frac{Q^2}{2C} = \frac{1}{2} QV$$



CURRENT ELECTRICITY

$$\text{DENSITY } j = i/A = \sigma E$$

$$V_{\text{drift}} = \frac{1}{2} \frac{e E \hbar}{m} = \frac{i}{neA}$$

$$R_{\text{WIRE}} = \rho L/A \quad \rho = 1/\sigma$$

$$R = R_0 (1 + \alpha \Delta T)$$

$$\text{OHM'S LAW } V = iR$$



PARALLEL

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$



SERIES

$$R_{eq} = R_1 + R_2$$

KIRCHHOFF'S LAWS

$$\text{* JUNCTION LAW } \sum I_i = 0$$

Sum of all i towards a node = 0

$$\text{* LOOP LAW } \sum \Delta V = 0$$

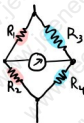
Sum of all ΔV in closed loop = 0



$$\text{POWER} = i^2 R = V^2/R = iV$$

BALANCED
WHEAT
STONE
BRIDGE

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$



GALVANOMETER

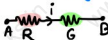
↳ **Ammeter**

$$i_g G = (i - i_g) S$$



↳ **Voltmeter**

$$V_{AB} = i_g (R + G)$$



CAPACITOR

Charging

$$q(t) = CV(1 - e^{-\frac{t}{RC}})$$

Discharging

$$q(t) = q_0 e^{-(t/RC)}$$



Time Constant $\tau = RC$

THOMSON EFFECT

$$\text{emf } e = \frac{\Delta H}{\Delta \theta} = \sigma \Delta T$$

PELTIER EFFECT

$$\text{emf } e = \frac{\Delta H}{\Delta \theta}$$

SEEBACK EFFECT

$$e = aT + \frac{1}{2}bT^2$$



FARADAY'S LAW OF ELECTROLYSIS

$$m = Zit = \frac{1}{F} E it$$

E = Chem equivalent

Z = Electro Chem eq

$$F = 96485 \text{ C/g}$$

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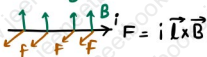
MAGNETISM

$$\vec{F}_{\text{LORENTZ}} = q\vec{v} \times \vec{B} + q\vec{E}$$



$$qvB = mv^2/r$$

$$T = \frac{2\pi m}{qB}$$



$$\vec{F} = i \vec{L} \times \vec{B}$$

BIOT-SAVART LAW

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i d\vec{L} \times \vec{r}}{r^3}$$



MAGNETIC DIPOLE

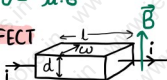


$$\vec{\mu} = i \text{Area} \quad \vec{B} = \vec{\mu} \times \vec{B}$$

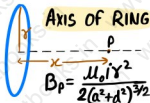
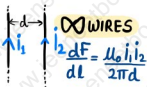
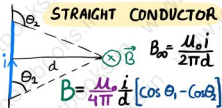
$$U = -\vec{\mu} \cdot \vec{B}$$

HALL EFFECT

$$V_H = \frac{Bi}{ned}$$



STRAIGHT CONDUCTOR



CENTER OF ARC

$B = \frac{\mu_0 i \theta}{4\pi r}$

$B = \mu_0 i / 2r$ (ring)

SOLENOID



$B = \mu_0 n i$ $n = N/L$



TOROID

$B = \mu_0 n i$
 $n = N/2\pi r$

AMPERE'S LAW

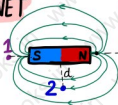
$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{in}$



BAR MAGNET

$$B_1 = \frac{\mu_0}{4\pi} \frac{2M}{d^3}$$

$$B_2 = \frac{\mu_0}{4\pi} \frac{M}{d^3}$$



ANGLE OF DIP

$$B_h = B \cos \delta$$



TANGENT GALVANOMETER

$$B_h \tan \theta = \mu_0 n i / 2r \quad | \quad i = K \tan \theta$$

MOVING COIL GALVANOMETER

$$n i A B = k \theta \quad ; \quad i = \frac{k}{n A B} \theta$$

PERMEABILITY

$$\vec{B} = \mu \vec{H}$$

MAGNETOMETER

$$T = 2\pi \sqrt{I / M B_h}$$



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ELECTROMAGNETIC INDUCTION

MAGNETIC FLUX $\Phi = \oint \vec{B} \cdot d\vec{s}$

FARADAY'S LAW $e = - \frac{d\Phi}{dt}$

LENZ'S LAW: Induced current produces $\vec{B}$ that opposes change in Φ



SELF INDUCTANCE

$$\Phi = Li \quad e = -L \frac{di}{dt}$$

SOLENOID $L = \mu_0 n^2 \pi r^2 l$

MUTUAL INDUCTANCE

$$\Phi = Mi, \quad e = -M \frac{di}{dt}$$



GROWTH

$$i = \frac{V}{R} [1 - e^{-\frac{t}{L/R}}]$$



DECAY

$$i = i_0 e^{-\frac{t}{L/R}}$$



Time Const. $\tau = L/R$

$$\text{ENERGY } U = \frac{1}{2} Li^2$$

ENERGY DENSITY OF B-FIELD

$$u = \frac{U}{V} = \frac{B^2}{2\mu_0}$$

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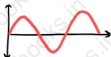


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ALTERNATING CURRENT


$$i = i_0 \sin(\omega t + \phi)$$
$$i_{rms} = i_0 / \sqrt{2}$$

$$POWER = i_{rms}^2 \cdot R$$

REACTANCE

CAPACITIVE $X_C = 1/\omega C$

INDUCTIVE $X_L = \omega L$

IMPEDANCE $Z = e_0 / i_0$

RC-CIRCUIT



$$\tan \phi = \frac{1}{\omega C R}$$

$$Z = \sqrt{R^2 + X_C^2}$$

$$X_C = \frac{1}{\omega C}$$

LR-CIRCUIT



$$\tan \phi = \frac{\omega L}{R}$$

$$Z = \sqrt{R^2 + X_L^2}$$

$$X_L = \omega L$$



LCR-CIRCUIT

$$\tan \phi = \frac{X_C - X_L}{R}$$



$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

$$\omega_{\text{RESONANCE}} = \frac{1}{2\pi\sqrt{LC}}$$

($X_C = X_L$)

$$P = e_{\text{rms}} i_{\text{rms}} \cos \phi$$

POWER
FACTOR ↗

ROTATING COIL $e = NAB\omega \sin \omega t$

TRANSFORMER $\frac{N_1}{N_2} = \frac{e_1}{e_2}$

$$C = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

Hey!



MODERN PHYSICS

$$E = h\nu = hc/\lambda \quad p = h/\lambda = E/c \quad E = mc^2$$

Ejected photo-electron $K_{\max} = h\nu - \phi$

THRESHOLD $\nu_0 = \phi/h$

STOPPING $V_0 = \frac{hc}{e} \left(\frac{1}{\lambda} \right) - \frac{\phi}{e}$



de Broglie $\lambda = h/p$

BOHR'S ATOM

$$E_n = -\frac{mZ^2e^4}{8\epsilon_0^2h^2n^2} = -\frac{13.6Z^2}{n^2} \text{ eV}$$

$$r_n = \frac{\epsilon_0 h^2 n^2}{\pi m Z e^2} = \frac{0.529 n^2 \text{ \AA}}{Z}$$

QUANTIZATION
OF ANGULAR
MOMENTUM

$$l = \frac{nh}{2\pi}$$

$$E_{\text{TRANSITION}} = 13.6 Z^2 \left(\frac{1}{n^2} - \frac{1}{m^2} \right) \text{ \AA}^0$$

HEISENBERG

$$\Delta x \Delta p \geq h/2\pi \quad \Delta E \cdot \Delta t \geq h/2\pi$$

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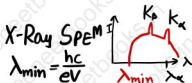
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MOSLEY'S LAW $\sqrt{\nu} = a(z - b)$

X-Ray DIFFRACTION $2d \sin \theta = n\lambda$



NUCLEUS

$$R = R_0 A^{1/3}; R_0 = 1.1 \times 10^{-15} \text{ m}$$

RADIOACTIVE DECAY

$$\frac{dN}{dt} = -\lambda N \quad N = N_0 e^{-\lambda t}$$

$$\text{HALF LIFE } t_{1/2} = 0.693/\lambda$$

$$\text{Avg LIFE } t_{\text{avg}} = 1/\lambda$$

Mass DEFECT

$$\Delta m = [Zm_p + (A-Z)m_n] - M$$

$$\text{BINDING } E = \Delta m \cdot c^2$$

$$\text{Q-VALUE } Q = U_i - U_f$$



SEMICONDUCTORS

HALF WAVE
RECTIFIER



FULL WAVE
RECTIFIER



TRIODE VALVE



TRIODE

Plate Resistance $r_p = \left. \frac{\Delta V_p}{\Delta i_p} \right|_{\Delta V_g = 0}$

Trans-conductance $g_m = \left. \frac{\Delta i_p}{\Delta V_g} \right|_{\Delta V_p = 0}$

Amplification $\mu = \left. \frac{-\Delta V_p}{\Delta V_g} \right|_{\Delta i_p = 0}$

$\mu = r_p \times g_m$

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TRANSISTOR

$$I_e = I_b + I_c$$

$$\alpha = \frac{I_c}{I_e} \quad \beta = \frac{I_c}{I_b} \quad \beta = \frac{\alpha}{1-\alpha}$$

Trans conductance $g_m = \frac{\Delta I_c}{\Delta V_{be}}$



LOGIC GATES



A	B	AB	A+B	$\overline{AB}$	$\overline{A+B}$	$\overline{AB} + \overline{AB}$
0	0	0	0	1	1	0
0	1	0	1	1	0	1
1	0	0	1	1	0	1
1	1	1	1	0	0	0





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