

PHYSICAL CONSTANTS

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

Plank constant $\hbar = 6.63 \times 10^{-34} \text{ Js}$ $hc = 1242 \text{ eV-nm}$

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

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

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

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

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

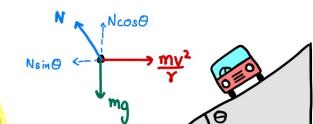
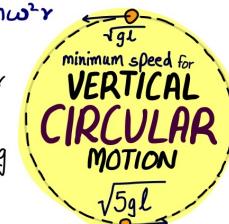
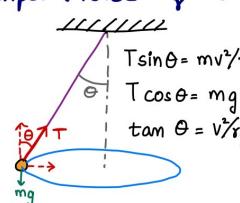


LAWS OF MOTION

1st LAW: INERTIA 2nd LAW: $F = d\vec{P}/dt = ma$ 3rd LAW: Action \Rightarrow Reaction

Friction: $f_{\text{static, maximum}} = \mu_s N$ $f_{\text{kinetic}} = \mu_k N$

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



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

WORK, POWER & ENERGY

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

$\oint \vec{F} \cdot d\vec{s} = 0$ {Work by Conservative force in a closed path}

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

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

(K)

POTENTIAL ENERGY (U)

$$U_g = mgh \quad \vec{F} = -\frac{dU}{dx}$$

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

FOR CONSERVATIVE FORCES

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

K + U = Conserved

VECTORS

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

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

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

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

DON'T FORGET

CENTER OF MASS

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

$$m_1 \xrightarrow{\frac{m_2 r}{m_1 + m_2}} \quad m_2 \xleftarrow{\frac{m_1 r}{m_1 + m_2}}$$

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

$$\text{HOLLOW CONE} = h/3 \quad \text{SOLID CONE} = h/4 \quad \text{HOLLOW} \quad \text{SOLID}$$

KINEMATICS

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

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

$$s = ut + \frac{1}{2} at^2 \quad \text{RELATIVE VELOCITY}$$

$$v = u + at$$

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

$$v_{A/B} = V_A - V_B$$

PROJECTILE MOTION

$$u_x = u \cos \theta \quad u_y = u \sin \theta$$

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

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

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

RIGID BODY DYNAMICS

$$\omega = \frac{\Delta \theta}{\Delta t} = \frac{d\theta}{dt} \quad \alpha = \frac{\Delta \omega}{\Delta t} = \frac{d\omega}{dt} \quad \vec{v} = \vec{\omega} \times \vec{r} \quad \vec{a}_{\text{tan}} = \vec{\omega} \times \vec{v}$$

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

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

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

$$\vec{l} = \vec{r} \times \vec{p} = mv \vec{\gamma}$$

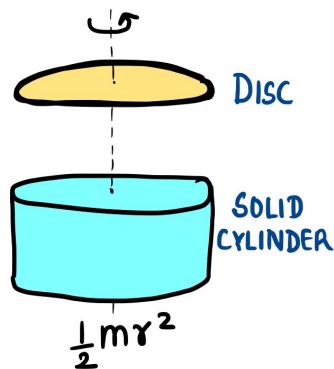
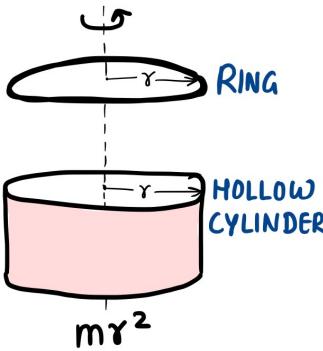
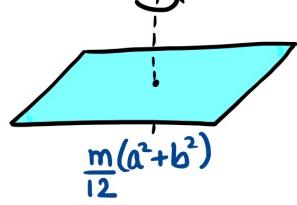
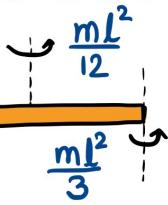
$$\vec{z} = I\alpha = d\vec{l}/dt$$

$$\vec{f} = \vec{r} \times \vec{F} = \gamma F = \gamma F \sin \theta$$

$$\text{EQUILIBRIUM : } F_{\text{net}} = 0 = Z_{\text{net}} \quad \omega = 2\pi f \quad T = 1/f$$

$$\omega = V_1/\gamma$$

MOMENT OF INERTIA



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

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

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

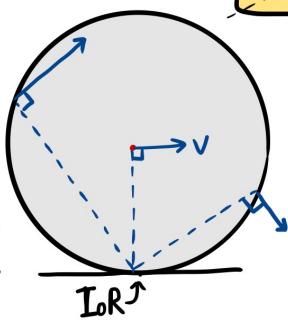
$$R_{\text{ROTATION}} \quad mk^2 = I$$

KINETIC ENERGY

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

$$K = \frac{1}{2} I_H \omega^2 \quad \begin{cases} \text{About Hinge} \\ \text{or IoR} \end{cases}$$

$$a = \frac{g \sin \theta}{[1 + \frac{I}{m r^2}]} \quad v = \sqrt{\frac{2gH}{1 + \frac{I}{m r^2}}}$$



AXIS THEOREMS

PERPENDICULAR

$$I_z = I_x + I_y$$

$$I_z = I_x + I_y$$

$$I_{\parallel} = I_{cm} + md^2$$

PARALLEL

$$t = \frac{\pi \omega_0}{\mu g [1 + \frac{I}{m r^2}]} \quad t = \frac{v_0}{\mu g [1 + \frac{I}{m r^2}]}$$

ROLLING MOTION

$$V = \omega r \quad (\text{no slip condition})$$

IoR INSTANTANEOUS
AXIS OF ROTATION
 $\vec{V} = \vec{\omega} \times \vec{r}$

GRAVITATION

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

$$\text{POTENTIAL ENERGY (U)} = -G Mm/R$$

$$g = G \frac{M}{R^2} \quad g' = g \left[1 - \frac{d}{R_e} \right] \quad g' \approx g \left[1 - \frac{2h}{R_e} \right]$$

$$V_{\text{ORBITAL}} = \sqrt{GM/R} \quad V_{\text{ESCAPE}} = \sqrt{2GM/R}$$

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

KEPLER'S LAWS

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

SIM
HOOTKE'S LAW $F = -kx$
 $x = A \sin(\omega t + \phi)$
 $v = Aw \cos(\omega t + \phi)$
 $a = -\omega^2 x = -k/m x$
 $T = \frac{2\pi}{\omega} = 2\pi \sqrt{m/k}$

$$K = \frac{1}{2} mv^2 \quad U = \frac{1}{2} kx^2 \quad E = K + U = \frac{1}{2} KA^2 = \frac{1}{2} m \omega^2 A^2$$

$$T = 2\pi \sqrt{l/g}$$

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

$$Z = k\theta \quad T = 2\pi \sqrt{\frac{I}{K}}$$

$$x_1 = A_1 \sin(\omega t) \quad x_2 = A_2 \sin(\omega t + \phi) \quad x = x_1 + x_2 = A \sin(\omega t + \epsilon)$$

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

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

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

PARALLEL $K_{eq} = K_1 + K_2$

PROPERTIES OF MATTER

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

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

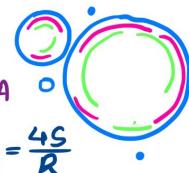
$$\text{POISSON'S RATIO} (\sigma) = \frac{\text{LATERAL STRAIN}}{\text{LONGITUDINAL STRAIN}} = \frac{\Delta D/D}{\Delta L/L}$$

$$\text{ELASTIC ENERGY (U)} = \frac{1}{2} \text{STRESS} \times \text{STRAIN} \times \text{VOLUME}$$

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

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

$$P_{\text{EXCESS}} = \Delta P_{\text{AIR}} = \frac{2S}{R} \quad \Delta P_{\text{SOAP}} = \frac{4S}{R}$$



$$h = \frac{2S \cos \theta}{\rho g r}$$

$$P_{\text{HYDROSTATIC}} = \rho gh \quad F_{\text{BUOYANT}} = \rho g V$$

$$\text{CONTINUITY } A_1 V_1 = A_2 V_2 \rightarrow \frac{A_1}{A_2} = \frac{V_1}{V_2}$$

$$\text{BERNOULLI'S } P + \rho gh + \frac{1}{2} \rho V^2 = \text{Const}$$

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

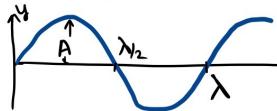
$$\text{TORRICELLI'S } V_{\text{EFFLUX}} = \sqrt{2gh}$$

$$\text{STOKE'S LAW } F = 6\pi \eta r v$$

$$V_{\text{TERMINAL}} = \frac{2r^2(p-\sigma)g}{9\eta}$$

$$\text{POISEUILLE'S EQN } \frac{\text{VOLUME FLOW}}{\Delta t} = \frac{\pi p r^4}{8\eta L}$$

WAVES



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

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

$$T = \frac{1}{v} = \frac{2\pi}{\omega} \quad v = \lambda f \quad \text{WAVE NUMBER } (k) = \frac{2\pi}{\lambda}$$

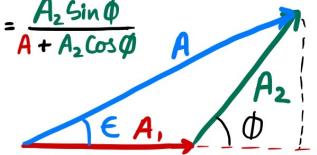


$$Y_1 = A_1 \sin(kx - \omega t) \quad Y_2 = A_2 \sin(kx - \omega t + \phi)$$

$$Y = A \sin(kx - \omega t + \phi) \quad A^2 = \sqrt{(A_1 + A_2 \cos \phi)^2 + (A_2 \sin \phi)^2}$$

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

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



STANDING WAVES

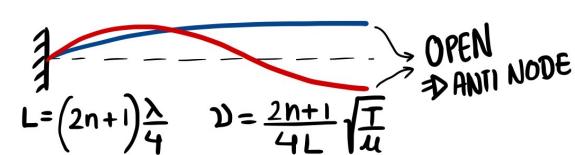
$$y_1 = A \sin(kx - \omega t) \quad y_2 = A \sin(kx + \omega t)$$

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

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



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



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

OPEN \Rightarrow ANTI NODE

SOUND WAVES

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

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

$$P_0 = \left[\frac{B\omega}{V} \right] S_0 \quad V_{\text{gas}} = \sqrt{R P / \rho}$$

$$I = \frac{2\pi^2 B}{V} S_0 V^2 = \frac{P_0^2 V}{2B} = \frac{P_0}{2\rho V} \quad \text{Intensity}$$

STANDING LONGITUDINAL WAVES

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

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

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

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

$$P = 2P_0 \cos \Delta\omega(t - x/v) \sin \omega_1(t - x/v)$$

$$\omega = \frac{(\omega_1 + \omega_2)}{2} \quad \text{Beats} \rightarrow \Delta\omega = \omega_1 - \omega_2$$

$$\text{DOPPLER} \quad v = \frac{V + V_0}{V - V_s} v_0$$

LIGHT WAVES

$$\text{PLANE WAVES} \quad E = E_0 \sin \omega(t - x/v); I = I_0$$

$$\text{SPHERICAL WAVES} \quad E = \frac{aE_0}{r} \sin \omega(t - r/v); I = \frac{I_0}{r}$$

DIFFRACTION

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

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

$$\text{Minima } b\theta = n\lambda$$

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

$$\text{Diffraction Pattern } I = I_0 \cos^2 \theta$$

YOUNG'S DOUBLE SLIT EXPERIMENT

$$\text{Path diff: } \Delta x = y \frac{d}{D} \quad \text{Phase diff: } \delta = \frac{2\pi}{\lambda} \Delta x$$

CONSTRUCTIVE | DESTRUCTIVE

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

$$\text{Intensity } I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \delta \quad I_{\text{max/min}} = (\sqrt{I_1} \pm \sqrt{I_2})^2$$

$$\text{Fringe Width } \omega = \lambda \frac{D}{a} \quad \text{Optical Path } \Delta x' = \omega \Delta x$$

LAW OF MALUS

$$I = I_0 \cos^2 \theta$$

INTERFERENCE THROUGH THIN FILM

$$\Delta x = 2nd = \frac{n\lambda}{(2n+1)\lambda/2} \rightarrow \text{constructive/destructive}$$

OPTICS

REFLECTION



$$(ii) i = r$$

(i) i, r & normal in same plane

$$f = R/2$$

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

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

MICROSCOPE

$$\text{Simple } m = D/f$$



Compound

$$m = \frac{v}{u} \frac{D}{f_e}$$

$$\text{Resolving Power } R = \frac{1}{\Delta d} = \frac{2 \mu \sin \theta}{\lambda}$$

DISPERSION

$$\text{Cauchy's } \mu = \mu_0 + A/x \quad A > 0$$

For small A & i

$$\text{mean deviation } S_y = (\mu_y - 1)A$$

$$\text{Angular dispersion } \Theta = (\mu_y - \mu_r)A$$

Dispersive Power

$$\omega = \frac{\mu_r - \mu_v}{\mu_y - 1} \approx \frac{\Theta}{S_y}$$

REFRACTION

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

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

$$\text{APPARENT DEPTH } d' = d/u$$

$$\text{TIR CRITICAL ANGLE } \mu \sin \theta_c = \sin 90^\circ = 1$$

$$\mu \sin \theta_c = \frac{1}{\mu_c}$$

PRISM

$$S = i + i' - A$$

$$\mu = \frac{\sin \frac{(A + S_{\min})}{2}}{\sin \frac{A}{2}}$$

$$S_{\min} = (\mu - 1)A$$

For small 'A'

$$S_m = \frac{1}{2} \mu A$$

SPHERICAL SURFACE

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

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

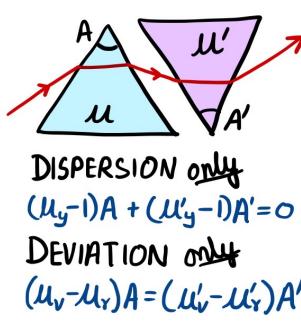
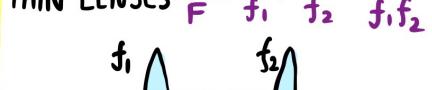
LENS MAKER'S

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

$$\text{LENS FORMULA } \frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

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

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



DISPERSION ONLY

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

DEVIATION ONLY

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

PHYSICS

HEAT AND TEMP

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

$$K = C + 273.16$$

$$\text{Ideal Gas} \rightarrow PV = nRT$$

van der Waals

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

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

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

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

THERMAL STRESS

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

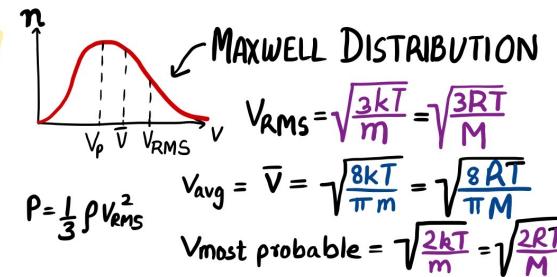
KINETIC THEORY

EQUIPARTITION OF ENERGY

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

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

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



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

SPECIFIC HEAT

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

$$\text{Latent heat } L = Q/m$$

$$C_v = \frac{F}{2} R \quad C_p = C_v + R \quad r = \frac{C_p}{C_v}$$

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

THERMODYNAMICS

$$\text{I}^{\text{ST}} \text{ LAW } \Delta Q = \Delta U + W \quad W = \int p.dV$$

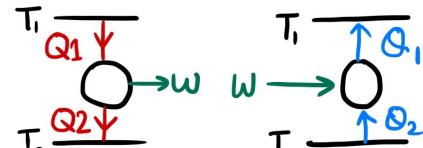
$$\text{ADIABATIC } W = \frac{p_1 V_1 - p_2 V_2}{r-1}$$

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

$$\text{ISOBARIC } W = p(V_2 - V_1)$$

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

$$\text{II}^{\text{ND}} \text{ LAW } \text{ENTROPY } dS = \frac{dQ}{T}$$



$$n = \frac{W}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1} \quad \text{CoP} = \frac{Q_2}{W} = \frac{T_{cold}}{\Delta T}$$

HEAT TRANSFER

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

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

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

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

$$\text{KIRCHHOFF'S LAW } \frac{\text{Emmisive Power}}{\text{Absorptive Power}} = \frac{E_{body}}{a_{body}} = E_{blackbody}$$

$$\text{WIEN'S DISPLACEMENT } \lambda_m T = b \quad \text{STEFAN-BOLTZMANN } \Delta \theta / \Delta t = \sigma e A T^4$$

$$\text{NEWTON'S COOLING } \frac{dT}{dt} = -bA(T - T_0)$$

ELECTROSTATICS

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

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

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

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

DIPOLE MOMENT

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

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

DIPOLE IN FIELD

$$\vec{p} = \vec{p}_0 \vec{E}$$

$$U = -\vec{p} \cdot \vec{E}$$

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

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

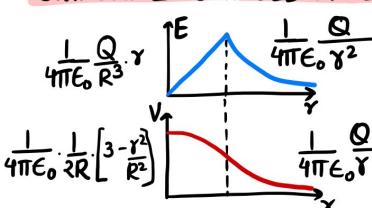
GAUSS'S LAW

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

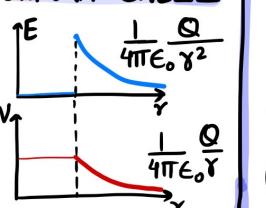
$$\text{FLUX } \phi = \oint \vec{E} \cdot d\vec{s}$$

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \cos \theta$$

UNIFORMLY CHARGED SPHERE



UNIFORM SHELL



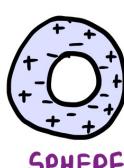
$$\text{LINE CHARGE } E = \frac{\lambda}{2\pi\epsilon_0 r}$$

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

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

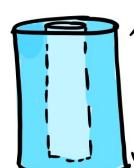
CAPACITORS

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



$$C = \frac{2\pi\epsilon_0 L}{\ln(Y_2/Y_1)}$$

$$C = 4\pi\epsilon_0 \frac{Y_1 Y_2}{Y_2 - Y_1}$$



$$\text{PARALLEL } C_{eq} = C_1 + C_2$$

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

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

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

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

CURRENT ELECTRICITY

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

$$V_{drift} = \frac{1}{2} \frac{eE\tau}{m} = \frac{i}{neA}$$

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

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

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

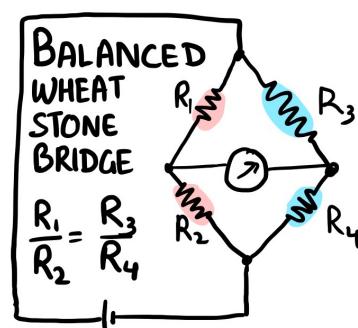
$$\text{SERIES } R_{eq} = R_1 + R_2$$

KIRCHHOFF'S LAWS

$$*\text{ JUNCTION LAW } \sum I_i = 0 \quad \text{Sum of all } i \text{ towards a node} = 0$$

$$*\text{ LOOP LAW } \sum \Delta V = 0 \quad \text{Sum of all } \Delta V \text{ in closed loop} = 0$$

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



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

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

CAPACITOR
Charging
 $q(t) = CV(i - e^{-\frac{t}{RC}})$
Discharging
 $q(t) = q_0 e^{-(t/RC)}$
Time Constant $\tau = RC$

PELTIER EFFECT
 $\text{emf } e = \frac{\Delta H}{\Delta T}$

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

SEEBACK EFFECT

$e = aT + \frac{1}{2}bT^2$
 $T_{\text{neutral}} = -a/b$ $T_{\text{inversion}} = -2a/b$

FARADAY'S LAW OF ELECTROLYSIS

$m = Zit = \frac{1}{F} Eit$
 $E = \text{Chem equivalent}$
 $Z = \text{ElectroChem eq}$
 $F = 96485 \text{ C/g}$

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-SAWART LAW
 $d\vec{B} = \frac{\mu_0}{4\pi} i \vec{l} \times \vec{r}$

MAGNETIC DIPOLE
 $\vec{\mu} = i \text{Area}$ $\vec{B} = \vec{\mu} / \vec{r}$

HALL EFFECT
 $V_w = \frac{Bi}{ned}$

STRAIGHT CONDUCTOR
 $B_{\infty} = \frac{\mu_0 i}{2\pi d}$
 $B = \frac{\mu_0 i}{4\pi d} [\cos \theta_1 - \cos \theta_2]$

WIRE
 i_1 i_2 $\frac{dF}{dl} = \frac{\mu_0 i_1 i_2}{2\pi d}$

AXIS OF RING
 $B_p = \frac{\mu_0 i Y^2}{2(a^2 + d^2)^{3/2}}$

CENTER OF ARC
 $B = \frac{\mu_0 i \theta}{4\pi r}$
 $B = \mu_0 i / 2r \text{ (ring)}$

SOLENOID
 $M = \mu_0 n I$
 $B = \mu_0 n I / L$

TOROID
 $B = \mu_0 n i$
 $n = N / 2\pi R$

AMPERE'S LAW
 $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{in}}$

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
 $B_h = B \cos \delta$
 $B_v = B \sin \delta$

TANGENT GALVANOMETER
 $B_h \tan \theta = \mu_0 n i / 2r$ $i = k \tan \theta$

MOVING COIL GALVANOMETER
 $niAB = k\theta$; $i = \frac{k}{nAB} \theta$

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

MAGNETOMETER
 $T = 2\pi \sqrt{I / MB_h}$

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

ALTERNATING CURRENT

$i = i_0 \sin(\omega t + \phi)$
 $i_{\text{rms}} = i_0 / \sqrt{2}$
POWER = $i_{\text{rms}}^2 \cdot R$

REACTANCE

CAPACITIVE $X_C = 1/\omega C$
INDUCTIVE $X_L = \omega L$
IMPEDANCE $Z = \sqrt{R^2 + X^2}$

RC-CIRCUIT

$\frac{1}{\omega C} \rightarrow Z$
 $\tan \phi = \frac{1}{\omega CR}$
 $Z = \sqrt{R^2 + X_C^2}$
 $X_C = \frac{1}{\omega C}$

LR-CIRCUIT

$wL \rightarrow Z$
 $\tan \phi = \frac{wL}{R}$
 $Z = \sqrt{R^2 + X_L^2}$
 $X_L = \omega L$

LCR-CIRCUIT

$\tan \phi = \frac{X_C - X_L}{R}$
 $Z = \sqrt{R^2 + (X_C - X_L)^2}$
 $D_{\text{RESONANCE}} = \frac{1}{2\pi \sqrt{LC}}$
 $P = E_{\text{rms}} i_{\text{rms}} \cos \phi$
 $(X_C = X_L)$

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

SOLENOID $L = \mu_0 n^2 \pi r^2 L$
MUTUAL INDUCTANCE $\Phi = M_i$, $e = -M \frac{di}{dt}$

GROWTH
 $i = \frac{V}{RL} [1 - e^{-\frac{t}{RL}}]$

DECAY
 $i = i_0 e^{-\frac{t}{RL}}$

TIME CONST. $\beta = L/R$
ENERGY $U = \frac{1}{2} L i^2$

ENERGY DENSITY OF B-FIELD
 $u = \frac{U}{V} = \frac{B^2}{2\mu_0}$

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

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

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

MODERN PHYSICS

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

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

THRESHOLD $\nu_0 = \phi/h$

STOPPING $V_0 = \frac{hc(1-\phi)}{e(\lambda)} - \frac{\phi}{e}$
de Broglie $\lambda = h/p$

BOHR'S ATOM

$E_n = -\frac{mZ^2 e^4}{8\epsilon^2 h^2 n^2} = -\frac{13.6 Z^2 \text{ eV}}{n^2}$
 $\gamma_n = \frac{E_h c^2 n^2}{\pi m Z^2 e^2} = \frac{0.529 n^2 A^2}{Z}$

$E_{\text{TRANSITION}} = 13.6 Z^2 \left(\frac{1}{n^2} - \frac{1}{m^2} \right) A^0$
 $\Delta E \cdot \Delta t \geq \hbar/2\pi$

HEISENBERG $\Delta x \Delta p \geq \hbar/2\pi$

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

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

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

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

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

MASS DEFECT

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

BINDING E = $\Delta m \cdot c^2$

Q-VALUE $Q = U_i - U_f$

SEMICONDUCTORS

HALF WAVE RECTIFIER

FULL WAVE RECTIFIER

TRIODE VALVE

TRIODE

Plate Resistance $r_p = \frac{\Delta V_p}{\Delta I_p}$

Transconductance $g_m = \frac{\Delta I_p}{\Delta V_p}$

Amplification $A = -\frac{\Delta V_p}{\Delta V_g}$

$\mu = r_p \times g_m$

TRANSISTOR

$I_e = I_b + I_c$

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

Transconductance $g_m = \frac{\Delta I_c}{\Delta V_{be}}$

LOGIC GATES

AND	NAND	OR	NOR	XOR
0 0 0 0	1 1 1 0	1 1 0 1	0 0 1 1	1 0 0 1
0 1 0 1	1 0 1 0	1 0 1 1	0 1 0 1	1 1 1 0
1 0 0 1	0 1 1 1	0 1 1 0	1 0 0 1	0 1 0 1
1 1 1 0	0 0 0 1	0 0 1 1	1 1 1 1	1 0 1 1

NOW, YOU'RE ONE STEP

CLOSER TO YOUR GOAL