PHYSICAL CONSTANTS

Speed of Light $c = 3\times10^{8}\ m/s$

Plank constant $h = 6.63\times10^{-34}\ J s$ $hc = 1242\ eV\text{-}nm$

Gravitation constant $G = 6.67\times10^{-11}\ Nm^2/kg^2$

Boltzmann constant $k = 1.38\times10^{-23}\ J/K$

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

Avogadro's number $N_A = 6.023\times10^{23}/mol$

Charge of electron $e = 1.602\times10^{-19}\ C$

Permeability of vacuum $\mu_0 = 4\pi\times10^{-7}\ N/A^2$

Permitivity of vacuum $\epsilon_0 = 8.85\times10^{-12}\ F/m$

Coulomb constant $1/4\pi\epsilon_0 = 9\times10^{9}\ N m^2/C^2$

Faraday constant $F = 96485\ C/mol$

Mass of electron $m_e = 9.1\times10^{-31}\ kg$

Mass of proton $m_p = 1.6726\times10^{-27}\ kg$

Mass of neutron $m_n = 1.6749\times10^{-27}\ kg$

Atomic mass unit $u = 1.66\times10^{-27}\ kg$

Stefan-Boltzmann constant $\sigma = 5.67\times10^{-8}\ W/m^2K^4$

Rydberg constant $R_\infty = 1.097\times10^{7}/m$

Bohr magnetron $\mu_B = 9.27\times10^{-24}\ J/T$

Bohr radius $a_0 = 0.529\times10^{-10}\ m$

Standard atmosphere $atm = 1.01325\times10^{5}\ Pa$

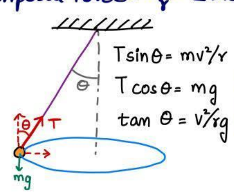
Wien displacement constant $b = 2.9\times10^{-3}\ mK$

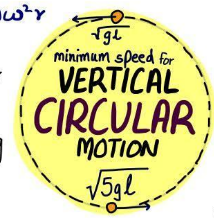
LAWS OF MOTION

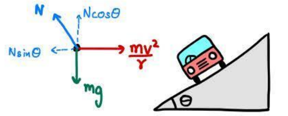
1st LAW: INERTIA 2nd LAW: $F = d\vec{P}/dt = ma$ 3rd LAW: Action ⇌ Reaction

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

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







CURVED BANKING

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

WORK, POWER & ENERGY

WORK $= \vec{F}.\vec{S} = FS\cos\theta$
$= \int \vec{F}.d\vec{s}$

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

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

WORK-ENERGY THEOREM
$W_{net} = \Delta K$

POTENTIAL ENERGY (U)

$U_g = mgh$ $\vec{F} = -\frac{dU}{dx}$ FOR CONSERVATIVE FORCES

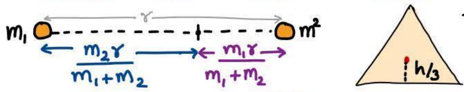
$U_{spring} = \frac{1}{2}kx^2$

K+U = Conserved

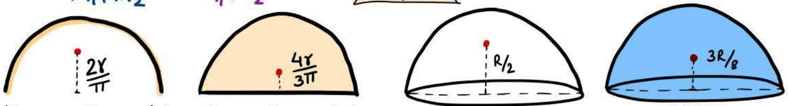
POWER $= dW/dt = \vec{F}.\vec{v}$

CENTER OF MASS

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

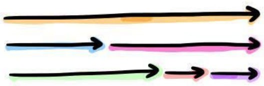


$\vec{V}_{cm} = \frac{\sum m_i \vec{v}_i}{\sum m_i}$ $\vec{F} = m\vec{a}_{cm}$



HOLLOW CONE = h/3 SOLID CONE = h/4 HOLLOW SOLID

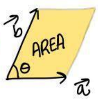
VECTORS



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

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

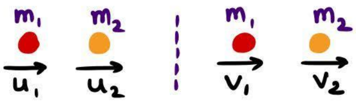
CROSS PRODUCT $\vec{a}\times\vec{b} = ab\sin\theta$

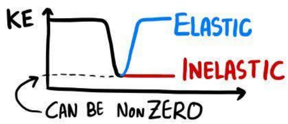


DONT FORGET

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

COLLISION





MOMENTUM CONSERVATION {Always}

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$CoR = e = \frac{V_{SEPARATION}}{V_{APPROACH}} = \frac{V_2 - V_1}{u_1 - u_2}$

ENERGY CONSERVATION {Elastic}

$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

$m_1 >> m_2$

$m_1 \rightarrow$ undisturbed motion

Solve using CoR in m_1 Frame

$m_1 = m_2$

Velocity Exchange for Elastic

KINEMATICS

$\vec{V}_{avg} = \Delta\vec{s}/\Delta t$ $\vec{V}_{inst} = d\vec{s}/dt$

$\vec{a}_{avg} = \Delta\vec{V}/\Delta t$ $\vec{a}_{inst} = d\vec{V}/dt$

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

$v = u + at$

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

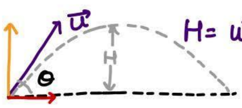
RELATIVE VELOCITY

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

PROJECTILE MOTION

$u_x = u\cos\theta$

$u_y = u\sin\theta$



$H = u^2\sin^2\theta/2g$

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

Range $= u_x.T \Rightarrow R = u^2\sin2\theta/g$

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

RIGID BODY DYNAMICS

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

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

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

$\omega = \omega_0 + \alpha t$

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

$\vec{L} = \vec{r}\times\vec{p} = mvr_\perp$

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

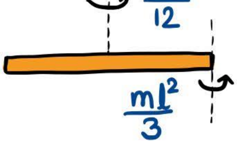
$\vec{\tau} = \vec{r}\times\vec{F} = r_\perp F = rF\sin\theta$

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

$\omega = 2\pi f$ $T = 1/f$

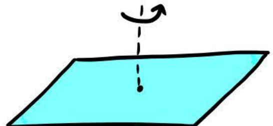
$\omega = V_\perp/r$

MOMENT OF INERTIA

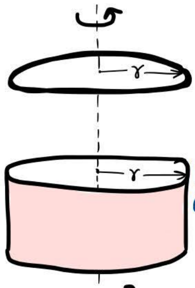


$\frac{ml^2}{12}$

$\frac{ml^2}{3}$



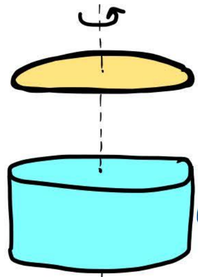
$\frac{m(a^2+b^2)}{12}$



RING

HOLLOW CYLINDER

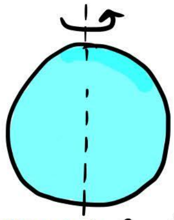
$m\gamma^2$



DISC

SOLID CYLINDER

$\frac{1}{2}m\gamma^2$



HOLLOW = $\frac{2}{3}m\gamma^2$

SOLID = $\frac{2}{5}m\gamma^2$

$I = \sum m_i r_i^2$

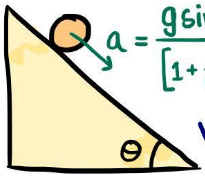
$I = \int r^2 dm$

$R_{GYRATION}$ $mk^2 = I$

KINETIC ENERGY

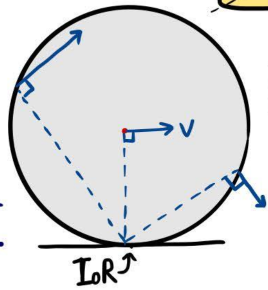
$K = \frac{1}{2}mv_c^2 + \frac{1}{2}I_c\omega^2$

$K = \frac{1}{2}I_H\omega^2$ {About Hinge or IoR}

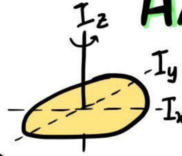


$a = \frac{g\sin\theta}{\left[1+\frac{I}{mr^2}\right]}$

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

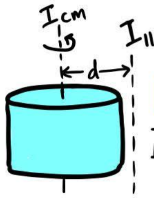


AXIS THEOREMS



PERPENDICULAR

$I_z = I_x + I_y$



PARALLEL

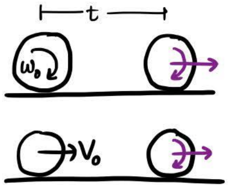
$I_{\parallel} = I_{cm} + md^2$

ROLLING MOTION

$V = \omega\gamma$ (no slip condition)

IoR INSTANTANEOUS AXIS OF ROTATION

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



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

$t = \frac{V_0}{\mu g\left[1+\frac{mr^2}{I}\right]}$

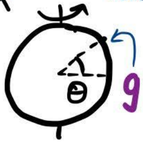
GRAVITATION

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

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

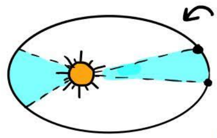
$F = G\frac{Mm}{R^2}$ POT. ENERGY (U) = $-GMm/R$

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



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

KEPLER'S LAWS



1st Elliptical Orbits, Sun @ foci

2nd Equal Area in Equal time ($\vec{L}$)

3rd $T^2 \propto a^3$ [semi major axis]

SHM

HOOKE'S LAW $F = -kx$

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

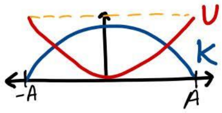
$v = A\omega\cos(\omega t + \phi)$

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

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

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

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



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

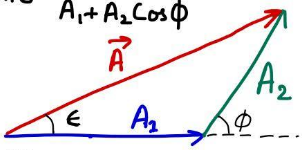
$x_1 = A_1\sin(\omega t)$

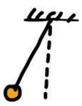
$x_2 = A_2\sin(\omega t + \phi)$

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

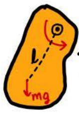
$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$

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





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



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

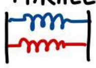
$\tau = k\theta$

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

SERIES

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

PARALLEL



$K_{eq} = K_1 + K_2$

PROPERTIES OF MATTER

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

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

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

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

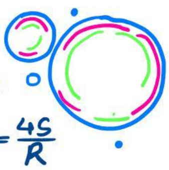
POISSON'S RATIO (σ) = $\frac{\text{LATERAL STRAIN}}{\text{LONGITUDINAL STRAIN}} = \frac{\Delta D/D}{\Delta l/l}$

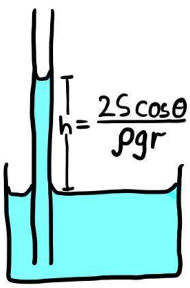
ELASTIC ENERGY (U) = $\frac{1}{2}$ STRESS × STRAIN × VOLUME

SURFACE TENSION (S) = F/l

SURFACE ENERGY (U) = S. AREA

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

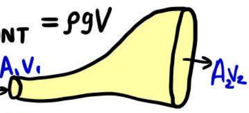




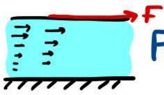
$h = \frac{2S\cos\theta}{\rho g r}$

$P_{HYDROSTATIC} = \rho gh$ $F_{BUOYANT} = \rho gV$

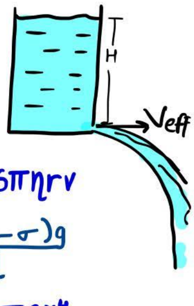
CONTINUITY $A_1V_1 = A_2V_2$



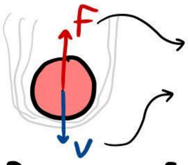
BERNOULLI'S $P + \rho gh + \frac{1}{2}\rho v^2 = Const$



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



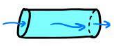
TORRICELLI'S $V_{EFFLUX} = \sqrt{2gH}$



STOKE'S LAW $F = 6\pi\eta rv$

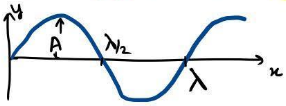
$V_{TERMINAL} = \frac{2r^2(\rho-\sigma)g}{9\eta}$

POISEUILLI'S EQN $\frac{\text{VOLUME FLOW}}{\Delta t} = \frac{\pi P\gamma^4}{8\eta L}$



WAVES

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



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

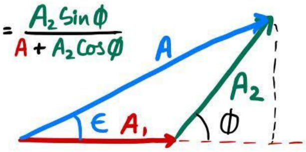
$T = \frac{1}{\nu} = \frac{2\pi}{\omega}$ $\quad v = \nu\lambda$ $\quad$ Wave Number $(k) = \frac{2\pi}{\lambda}$

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

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

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

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

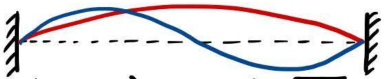


$P_{avg} = 2\pi^2\mu\nu A v^2$ $\quad$ Velocity $V = \sqrt{\frac{T}{\mu}}$

STANDING WAVES

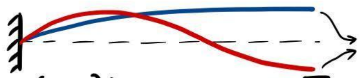
$y_1 = A\sin(kx - \omega t)$ $\quad y_2 = A\sin(kx + \omega t)$

$Y = 2A\cos kx \cdot \sin\omega t$ $\quad$ Node if $\cos kx$ is zero $\Rightarrow x = (n + \frac{1}{2})\lambda$



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

SONOMETER



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

SOUND WAVES

$S = S_0\sin[\omega(t - x/v)]$
$P = P_0\cos[\omega(t - x/v)]$
$P_0 = \left[\frac{B\omega}{V}\right]S_0$

$V_{solid} = \sqrt{Y/\rho}$
$V_{liq} = \sqrt{B/\rho}$
$V_{gas} = \sqrt{\gamma P/\rho}$

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

STANDING LONGITUDINAL WAVES

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

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

CLOSED ORGAN PIPE

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

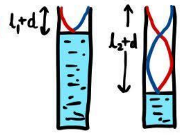
OPEN ORGAN PIPE

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

RESONANCE COLUMN

$l_1 + d = \frac{\lambda}{2}$ $\quad l_2 + d = \frac{3\lambda}{2}$

$V = 2(l_2 - l_1)\nu$



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

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

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

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

DOPPLER

$$\nu = \frac{V + V_0}{V - V_s}\nu_0$$

LIGHT WAVES

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

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

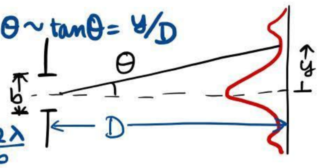
DIFFRACTION

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

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

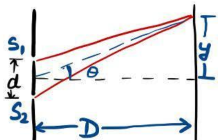
Minima $b\theta = n\lambda$

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



YOUNG'S DOUBLE SLIT EXPERIMENT

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



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

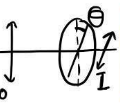
DESTRUCTIVE
$\delta = (2n+1)\lambda$; $\Delta x = (n + \frac{1}{2})\lambda$

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

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

LAW of MALUS

$I = I_0\cos^2\theta$



INTERFERENCE THROUGH THIN FILM

$\Delta x = 2\mu d = n\lambda \to$ constructive
$(2n+1)\lambda/2 \to$ destructive

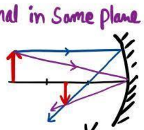
OPTICS

REFLECTION

(ii) $\angle i = \angle r$
(i) i, r & normal in same plane

$f = R/2$

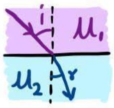
$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$



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

REFRACTION

$\mu = \frac{C}{V} = \frac{\text{(vacuum)}}{\text{(Medium)}}$

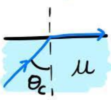


SNELL'S LAW $\mu_1\sin i = \mu_2\sin r$

APPARENT DEPTH $d' = d/\mu$

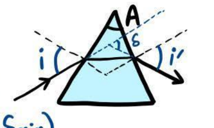
TIR CRITICAL ANGLE

$\mu\sin\theta_c = \cancel{\sin 90} 1$



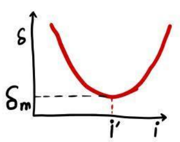
PRISM

$\delta = i + i' - A$



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

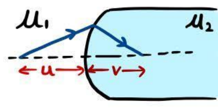
$\delta_{min} = (\mu - 1)A$
For small 'A'



SPHERICAL SURFACE

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

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

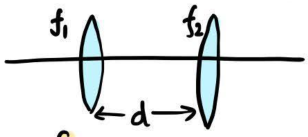


LENS MAKER'S $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

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

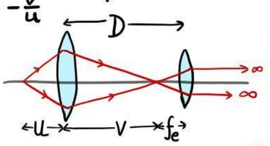
POWER $P = 1/f$

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



MICROSCOPE

Simple $m = D/f$



Compound

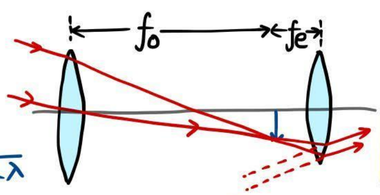
$m = \frac{v}{u}\frac{D}{fe}$ $\quad$ Resolving Pow $R = \frac{1}{\Delta d} = \frac{2\mu\sin\theta}{\lambda}$

TELESCOPE

$m = -f_o/f_e$

$L = f_o + f_e$

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



DISPERSION

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

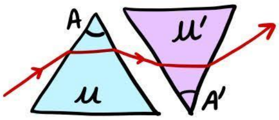
For small A & i

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

HEAT AND TEMP

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

$K = C + 273.16$

Ideal Gas → $PV = nRT$

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

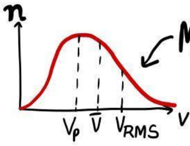
EQUIPARTITION OF ENERGY

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

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

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

$F = 3$ (monatomic) ; 5 (diatomic)



$V_{RMS} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$

$P = \frac{1}{3}\rho V_{rms}^2$

$V_{avg} = \bar{V} = \sqrt{\frac{8kT}{\pi m}} = \sqrt{\frac{8RT}{\pi M}}$

$V_{most\ probable} = \sqrt{\frac{2kT}{m}} = \sqrt{\frac{2RT}{M}}$

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

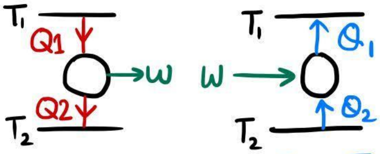
I^{st} LAW $\Delta Q = \Delta U + W \quad W = \int p\,dV$

ADIABATIC $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$

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

ISOBARIC $W = p(V_2 - V_1)$

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



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

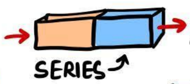
$CoP = \frac{Q_2}{W} = \frac{T_{cold}}{\Delta T}$

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

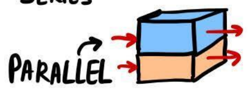
HEAT TRANSFER

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

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



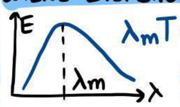
$R = R_1 + R_2 = \frac{x_1}{K_1A_1} + \frac{x_2}{K_2A_2}$



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

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

WIEN'S DISPLACEMENT



$\lambda_m T = b$

STEFAN-BOLTZMANN

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

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

ELECTROSTATICS

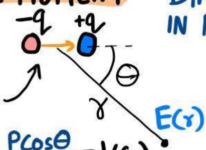
COULOMB'S LAW $F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}\hat{r}$

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

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

PE (U) $= \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r} \quad \vec{E} = -\frac{dV}{dr}$

DIAPOLE MOMENT



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

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

DIAPOLE IN FIELD

$\vec{\tau} = \vec{p} \times \vec{E}$

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

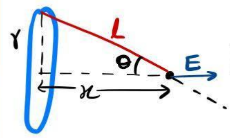
$E_r = \frac{1}{4\pi\epsilon_0}\cdot\frac{2p\cos\theta}{r^3}$

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

GAUSS'S LAW

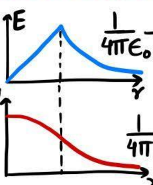
$\phi = q_{in}/\epsilon_0$

FLUX $\phi = \oint \vec{E}\cdot\vec{ds}$



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

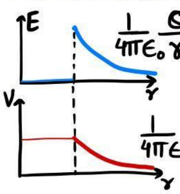
UNIFORMLY CHARGED SPHERE



$\frac{1}{4\pi\epsilon_0}\frac{Q}{R^3}\cdot r \qquad \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$

$\frac{1}{4\pi\epsilon_0}\cdot\frac{1}{2R}\left[3 - \frac{r^2}{R^2}\right] \qquad \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$

UNIFORM SHELL



$\frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$

$\frac{1}{4\pi\epsilon_0}\frac{Q}{r}$

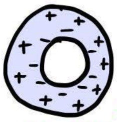
LINE CHARGE $E = \frac{\lambda}{2\pi\epsilon_0 r}$

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

$\vec{E}$ near conducting surface $E = \frac{\sigma}{\epsilon_0}$

CAPACITORS

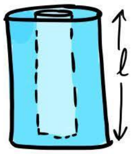
$C = q/V$ — $C = \epsilon_0 A/d$



$C = 4\pi\epsilon_0\frac{r_1r_2}{r_2 - r_1}$

SPHERE

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



PARALLEL $C_{eq} = C_1 + C_2$

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

WITH DIELECTRIC $C = \frac{\epsilon_0 KA}{d}$

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

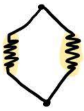
DENSITY $j = i/A = \sigma E$

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

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

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

OHM'S LAW $V = iR$



PARALLEL

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

SERIES

$R_{eq} = R_1 + R_2$

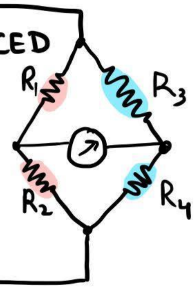
KIRCHHOF'S LAWS

* JUNCTION LAW $\Sigma I_i = 0$
  Sum of all i towards a node = 0
* LOOP LAW $\Sigma\Delta V = 0$
  Sum of all ΔV in closed loop = 0

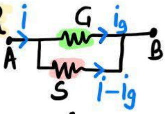
POWER $= i^2R = V^2/R = iV$

BALANCED WHEAT STONE BRIDGE

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

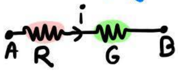


GALVANOMETER



↳ Ammeter
$i_g G = (i - i_g) S$

↳ Voltmeter



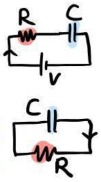
$V_{AB} = i_g(R+G)$

CAPACITOR

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

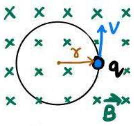
Discharging
$q(t) = q_0 e^{-(t/RC)}$

Time Constant $\tau = RC$



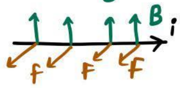
MAGNETISM

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



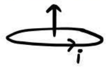
$qvB = mv^2/r$

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



$F = i\,\vec{l} \times \vec{B}$

MAGNETIC DIPOLE

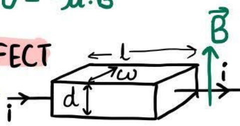


$\vec{\mu} = i\,Area$ $\quad \vec{\tau} = \vec{\mu} \times \vec{B}$

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

HALL EFFECT

$V_\omega = \dfrac{Bi}{ned}$



PELTIER EFFECT

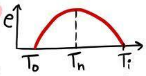
emf $e = \dfrac{\Delta H}{\Delta \theta}$

THOMSON EFFECT

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

SEEBACK EFFECT

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



$T_{neutral} = -a/b$ $\quad T_{inversion} = -2a/b$

FARADAY'S LAW OF ELECTROLYSIS

$m = Zit = \frac{1}{F} Eit$

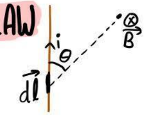
E = Chem equivalent

Z = Electro Chem eq

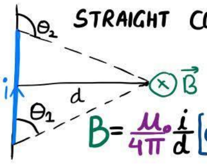
F = 96 485 C/g

BIOT-SAWART LAW

$d\vec{B} = \dfrac{\mu_0}{4\pi} \dfrac{i\, d\vec{l} \times \vec{r}}{r^3}$



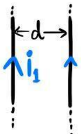
STRAIGHT CONDUCTOR



$B_\infty = \dfrac{\mu_0 i}{2\pi d}$

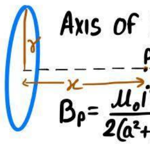
$B = \dfrac{\mu_0}{4\pi} \dfrac{i}{d} [\cos\theta_1 - \cos\theta_2]$

∞ WIRES



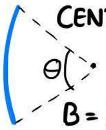
$\dfrac{dF}{dl} = \dfrac{\mu_0 i_1 i_2}{2\pi d}$

AXIS OF RING



$B_P = \dfrac{\mu_0 i r^2}{2(a^2+d^2)^{3/2}}$

CENTER OF ARC



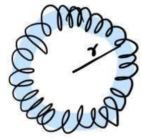
$B = \dfrac{\mu_0 i \theta}{4\pi r}$

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

SOLENOID

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

TOROID



$B = \mu_0 n i$

$n = N/2\pi r$

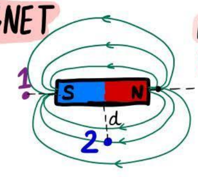
AMPERE'S LAW

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

BAR MAGNET

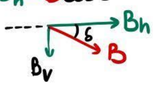
$B_1 = \dfrac{\mu_0}{4\pi} \dfrac{2M}{d^3}$

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



ANGLE OF DIP

$B_h = B\cos\delta$



TANGENT GALVANOMETER

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

MOVING COIL GALVANOMETER

$niAB = k\theta \;;\; i = \dfrac{k}{nAB}\theta$

PERMEABILITY

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

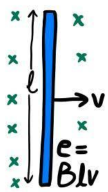
MAGNETOMETER

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

ELECTROMGNETIC INDUCTION

MAGNETIC FLUX $\phi = \oint \vec{B} \cdot d\vec{s}$ $\quad$ FARADAY'S LAW $e = -\dfrac{d\phi}{dt}$

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



$e = Blv$

SELF INDUCTANCE

$\phi = Li \quad e = -L\dfrac{di}{dt}$

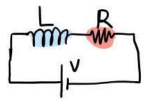
SOLENOID $L = \mu_0 n^2 \pi r^2 l$

MUTUAL INDUCTANCE

$\phi = Mi\,, \; e = -M\,di/dt$

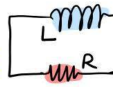
GROWTH

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



DECAY

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



Time Const. $\tau = L/R$

ENERGY $U = \frac{1}{2} L i^2$

ENERGY DENSITY OF B-FIELD

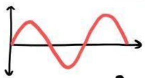
$u = \dfrac{U}{V} = \dfrac{B^2}{2\mu_0}$

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

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

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

ALTERNATING CURRENT



$i = i_0 \sin(\omega t + \phi)$

$i_{rms} = i_0/\sqrt{2}$

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

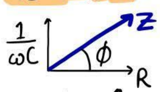
REACTANCE

CAPACITIVE $X_C = 1/\omega C$

INDUCTIVE $X_L = \omega L$

IMPEDANCE $Z = e_0/i_0$

RC-CIRCUIT

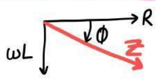


$\tan\phi = \dfrac{1}{\omega CR}$

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

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

LR-CIRCUIT

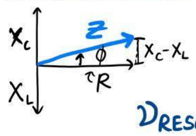


$\tan\phi = \dfrac{\omega L}{R}$

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

$X_L = \omega L$

LCR-CIRCUIT



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

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

$\nu_{RESONANCE} = \dfrac{1}{2\pi\sqrt{LC}}$

$(X_C = X_L)$

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

POWER FACTOR

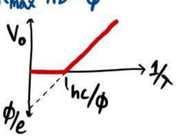
MODERN PHYSICS

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

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

THRESHOLD $\nu_0 = \phi/h$

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



de Broglie $\lambda = h/p$

BOHR'S ATOM

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

$r_n = \dfrac{\epsilon_0 h^2 n^2}{\pi m Z e^2} = \dfrac{0.529\, n^2}{Z} A^0$

QUNTIZATION OF ANGULAR MOMENTUM

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

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

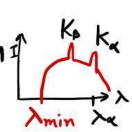
HEISENBERG $\Delta x \Delta p \geq h/2\pi \quad \Delta E \cdot \Delta t \geq h/2\pi$

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

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

X-Ray Spe[M]

$\lambda_{min} = \dfrac{hc}{eV}$



NUCLEUS

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

RADIOACTIVE DECAY

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

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

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

Mass DEFECT

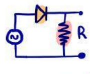
$\Delta m = [Zm_p + (A-Z)m_n] - M$

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

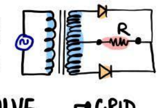
Q-VALUE $Q = U_i - U_f$

SEMICONDUCTORS

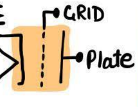
HALF WAVE RECTIFIER



FULL WAVE RECTIFIER



TRIODE VALVE



TRIODE

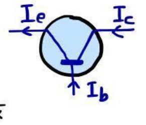
Plate Resistance $r_p = \dfrac{\Delta V_p}{\Delta i_p}\Big|_{\Delta V_g = 0}$

Trans-conductance $g_m = \dfrac{\Delta i_p}{\Delta V_g}\Big|_{\Delta V_p = 0}$

Amplification $\mu = \dfrac{-\Delta V_p}{\Delta V_g}\Big|_{\Delta i_p = 0}$

$\mu = r_p \times g_m$

TRANSISTOR

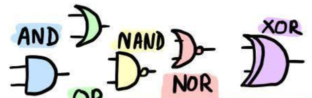


$I_e = I_b + I_c$

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

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

LOGIC GATES



A	B	AB	$A+B$	$\overline{AB}$	$\overline{A+B}$	$A\bar{B} + \bar{A}B$
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

NOW, YOU'RE ONE STEP CLOSER TO YOUR GOAL