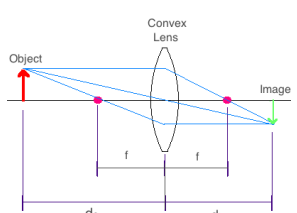


Harold's Physics Formulas

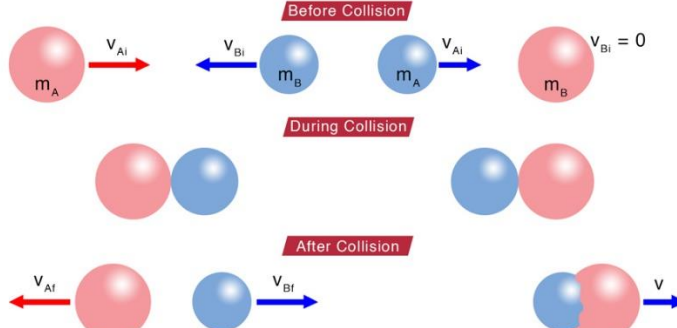
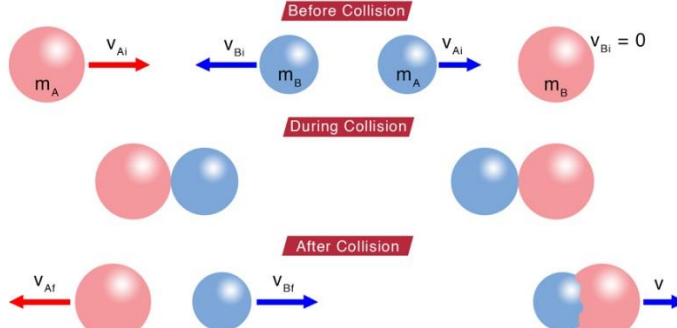
Cheat Sheet

30 April 2024

	Mechanics: Linear Translation	Mechanics: Angular / Rotational Motion	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Kinematics					
Position (m) (rad)	<p><i>Horizontal / 1-D:</i></p> $x = x_0 + v_{x0}t + \frac{1}{2}at^2$ <p><i>Vertical:</i></p> $y = y_0 + v_{y0}t - \frac{1}{2}gt^2$ $x = x_0 + vt$ $x = \int v dt$ $s = r\theta$	$\theta = \theta_0 + \omega_0t + \frac{1}{2}\alpha t^2$ $\theta = \theta_0 + \omega t$ $\theta = \int \omega dt$	10^{-100} = googolth 10^{-24} = yocto- 10^{-21} = zepto- 10^{-18} = atto- 10^{-15} = femto- 10^{-12} = pico- 10^{-9} = nano- 10^{-6} = micro- 10^{-3} = milli- 10^{-2} = centi- 10^{-1} = deci- 10^0 = 1 10^1 = deca- 10^2 = hecto- 10^3 = kilo- 10^6 = mega- 10^9 = giga- 10^{12} = tera- 10^{15} = peta- 10^{18} = exa- 10^{21} = zetta- 10^{24} = yotta- 10^{100} = googol 10^{1000} = googolplex	<p><i>Fluid Mechanics:</i></p> $P_1 + \rho gy_1 + \frac{1}{2}\rho v_1^2$ $= P_2 + \rho gy_2 + \frac{1}{2}\rho v_2^2$ <p>(Conservation of Mass)</p> $\rho = \frac{m}{V}$ $\Delta \ell = \alpha \ell_0 \Delta T$	<p><i>Waves:</i></p> $f(x, t) = A \sin \left(2\pi \left(ft - \frac{x}{\lambda} \right) + \phi \right) + k$ <p><i>Optics:</i></p> $f = \frac{v}{\lambda}$ $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ <p>Refraction: (bend)</p> $n = \frac{c}{v}$ <p>Snell's Law:</p> $n_1 \sin \theta_1 = n_2 \sin \theta_2$ $\frac{n_1}{v_1} = \frac{n_2}{v_2}$ <p>Diffraction: (spread out)</p> $\Delta L = d \sin \theta$ $m\lambda = d \sin \theta$
		$x(t) = A \cos(\omega t + \phi)$ $x(t) = A \cos(2\pi f t + \phi)$			<p>Optics:</p> 

	Mechanics: Linear	Mechanics: Angular	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Velocity (m/s) Angular Velocity / Angular Frequency (rad/s)	$v = \frac{d}{t} = \frac{\Delta x}{\Delta t} \rightarrow \frac{dx}{dt}$ $v = v_0 + at$ $v^2 = v_0^2 + 2a(x - x_0)$ $\bar{v} = \frac{v_0 + v}{2}$ $v = \int a dt$ $f = \frac{1}{T}$	$\omega = \frac{\theta}{t} = \frac{\Delta \theta}{\Delta t} \rightarrow \frac{d\theta}{dt}$ $\omega = \omega_0 + \alpha t$ $\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$ $\bar{\omega} = \frac{\omega_0 + \omega}{2}$ $\omega = \int \alpha dt$ $\omega = \frac{2\pi}{T} = 2\pi f$ $\omega = \sqrt{\frac{k}{m}} \text{ (spring)}$ $\omega = \sqrt{\frac{g}{\ell}} \text{ (pendulum)}$	<i>Speed of Light:</i> $c \approx 3.00 \times 10^8 \frac{m}{s}$	<i>Fluid Mechanics:</i> $A_1 v_1 = A_2 v_2$ $v_{rms} = \sqrt{\frac{3RT}{M}}$ $v_{rms} = \sqrt{\frac{3k_B T}{\mu}}$	<i>Waves and Optics:</i> $v = f\lambda$ Reflection: <i>(throw back)</i> <i>Critical angle:</i> $\sin \theta_c = \frac{n_1}{n_2}$ <i>Maxima for a thin film:</i> $2d = \frac{\lambda}{2n}, 3\frac{\lambda}{2n}, 5\frac{\lambda}{2n} \dots$
	$v = \omega r$ $v = \omega \times r$ $v(t) = -A\omega \sin(\omega t + \phi)$ $v(t) = -A(2\pi f) \sin(2\pi f t + \phi)$				

	Mechanics: Linear	Mechanics: Angular	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Acceleration (m/s ²) (rad/s ²)	<u>Linear:</u> $\mathbf{a} = \frac{\mathbf{v}}{t} = \frac{\Delta \mathbf{v}}{\Delta t} \rightarrow \frac{d\mathbf{v}}{dt}$ $\mathbf{a} = \frac{\sum \mathbf{F}}{m} = \frac{\mathbf{F}_{net}}{m}$ <u>Tangential (linear):</u> $\mathbf{a} = \mathbf{a}_t = \alpha r$ Gravity (g)	<u>Angular:</u> $\alpha = \frac{\omega}{t} = \frac{\Delta \omega}{\Delta t} \rightarrow \frac{d\omega}{dt}$ $\alpha = \frac{\sum \tau}{I} = \frac{\tau_{net}}{I}$ <u>Centripetal (center):</u> $\mathbf{a}_c = \frac{v^2}{r} = \omega^2 r$	Constants: Gravitational Constant $G = 6.67430 \times 10^{-11} \frac{Nm^2}{kg}$ Gravity Acceleration (Earth) $g = 9.80665 \frac{m}{s^2} = 32.1740 \frac{ft}{s^2}$ Speed of Light in Vacuum $c = 2.99792458 \times 10^8 \frac{m}{s}$ Electron-Volt $1eV = 1.602176634 \times 10^{-19} J$ Charge of an Electron $e = -1.602176634 \times 10^{-19} C$ Mass of an Electron $m_e = 9.1093837015(28) \times 10^{-31} kg$ Mass of a Proton $m_p = 1.67262192369(51) \times 10^{-27} kg$ Mass of a Neutron $m_n = 1.67492749804(95) \times 10^{-27} kg$ Electric Permittivity $\epsilon_0 = \frac{1}{\mu_0 c^2} = 8.8541878128 \times 10^{-12} \frac{C^2}{Nm^2}$ Magnetic Permeability $\mu_0 = 4\pi \times 10^{-7} \frac{Tm}{A}$ Avogadro's Number $N_A = 6.02214076 \times 10^{23} \frac{1}{mol}$ Boltzmann Constant $k_B = 1.380649 \times 10^{-23} \frac{J}{K}$ Coulomb Constant $k_e = \frac{1}{4\pi\epsilon_0} = 8.9875517923 \times 10^9 \frac{Nm^2}{C^2}$ Faraday Constant $F = 9.64853321233100184 \times 10^4 \frac{C}{mol}$ Planck's Constant $h = 6.6267015 \times 10^{-34} Js$ Avogadro's Number $N_A = 6.02214076 \times 10^{23} / mole$ pi $\pi = 3.14159265358979323846...$		
	<p style="text-align: center;"><u>Net:</u> $\mathbf{a}_{net}^2 = \mathbf{a}_t^2 + \mathbf{a}_c^2$</p>				
	$\mathbf{a}(t) = -A\omega^2 \cos(\omega t + \phi)$ $\mathbf{a}(t) = -A(2\pi f)^2 \cos(2\pi f t + \phi)$				
Jerk (Jolt) (m/s ³) (rad/s ³)	$\vec{j} = \frac{\mathbf{a}}{t} = \frac{\Delta \mathbf{a}}{\Delta t} \rightarrow \frac{d\mathbf{a}}{dt}$	$\zeta = \frac{\alpha}{t} = \frac{\Delta \alpha}{\Delta t} \rightarrow \frac{d\alpha}{dt}$			

	Mechanics: Linear	Mechanics: Angular	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Dynamics					
Mass (kg) / Moment of Inertia (kg • m²)	$m = \text{actual mass}$ $I = \text{effective mass}$	$I = \sum mr^2$ $I = \int r^2 dm$ $I = \int \mathbf{r} \cdot \mathbf{r} dm$	$m_p \approx m_n$	NA	Magnification: $ M = \left \frac{d_i}{d_o} \right = \left \frac{h_i}{h_o} \right $ $M_{\text{Telescope}} = - \frac{f_{\text{objective lens}}}{f_{\text{eyepiece}}}$
Momentum (kg•m/s) (kg • m ² /s)	$\mathbf{p} = m\mathbf{v}$ $\Delta\mathbf{p} = m\Delta\mathbf{v}$ Conservation of Linear Momentum: $\mathbf{p}_i = \mathbf{p}_f$ $\sum m\mathbf{v}_i = \sum m\mathbf{v}_f$ $\mathbf{p} = \boldsymbol{\omega} \times \mathbf{m}$ $\Delta\mathbf{p} = \mathbf{J} = \int_{t_1}^{t_2} \mathbf{F} dt$ Elastic Collision = bounce off Inelastic Collision = stick together	$\mathbf{L} = I\boldsymbol{\omega}$ $\mathbf{L} = \mathbf{r}m\mathbf{v}$ Conservation of Angular Momentum: $\mathbf{L}_i = \mathbf{L}_f$ $\sum I\boldsymbol{\omega}_i = \sum I\boldsymbol{\omega}_f$ $\mathbf{L} = \mathbf{r} \times \mathbf{p}$ $\mathbf{L} = m\mathbf{r} \times \mathbf{v}$ $\mathbf{L} = \int \mathbf{r} \times \mathbf{v} dm$ $\Delta\mathbf{L} = \int \boldsymbol{\tau} dt$	NA	Fluid Mechanics: $\nabla\mathbf{p} = \rho\mathbf{g}$	Atomic and Nuclear: $\lambda = \frac{h}{p}$
			<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <div style="background-color: #28a745; color: white; padding: 2px; border-radius: 5px; display: inline-block;">Elastic Collision</div> <div style="font-size: 2em; margin: 0 5px;">vs.</div> <div style="background-color: #007bff; color: white; padding: 2px; border-radius: 5px; display: inline-block;">Inelastic Collision</div> </div> <div style="text-align: center;"> <p><small>Kinetic energy and momentum are conserved</small></p>  </div> <div style="text-align: center;"> <p><small>Kinetic energy is not conserved, but momentum is conserved</small></p>  </div> </div>		

	Mechanics: Linear	Mechanics: Angular	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Force (N = kg•m/s ²) / Torque (J = N•m)	$\mathbf{F} = m\mathbf{a}$ $\mathbf{F}_g = m\mathbf{g}$ $\sum \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$ $\mathbf{F} = \frac{\mathbf{p}}{t} = \frac{\Delta\mathbf{p}}{\Delta t}$ $\mathbf{F} = \frac{d\mathbf{p}}{dt} = \frac{d}{dt}(m\mathbf{v})$ $\mathbf{F}_f \leq \mu N$ <p>Hooke's Law:</p> $\mathbf{F}_s = -k\Delta\mathbf{x}$ $\mathbf{F}_G = -\frac{Gm_1m_2}{r^2}$ $\mathbf{F}_G = -\frac{Gm_1m_2}{r^2} \hat{\mathbf{r}}$	$\tau = rF \sin \theta$ $\sum \tau = \tau_{net} = I\alpha$ $\tau = rF = I\alpha$ $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$ $\boldsymbol{\tau} = \frac{d\mathbf{L}}{dt} = I \frac{d\boldsymbol{\omega}}{dt}$ $\mathbf{F} = m\mathbf{a}_c$ $\mathbf{F} = \frac{m\mathbf{v}^2}{r}$ $\mathbf{F} = m\mathbf{r}\omega^2$	<p><u>Electricity:</u></p> <p>Coulomb's Law:</p> $\mathbf{F} = k \frac{q_1q_2}{r^2}$ $\mathbf{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r^2}$ $\mathbf{F} = \mathbf{E} q$ <p><u>Magnetism:</u></p> $\mathbf{F}_B = qvB \sin \theta$ $\mathbf{F}_B = BI\ell \sin \theta$ $\mathbf{F}_B = q\mathbf{v} \times \mathbf{B}$ $\mathbf{F}_B = I\boldsymbol{\ell} \times \mathbf{B}$ $\mathbf{F} = \int I d\boldsymbol{\ell} \times \mathbf{B}$	<p><u>Fluid Mechanics:</u></p> $F = PA$ $P = \frac{F}{A} = \rho hg$ $F_{buoy} = \rho Vg$ $PV = nRT = Nk_B T$ $R = 8.31 \frac{J}{(mol \cdot K)}$ $k_B = 1.38 \times 10^{-23} \frac{J}{K}$	NA
Impulse (N•s) (N•m•s)	$\mathbf{J} = \mathbf{F} \Delta t = \Delta\mathbf{p} = m \Delta\mathbf{v}$ $\mathbf{J} = \Delta\mathbf{p} = \int \mathbf{F} dt$	$\mathbf{H} = \boldsymbol{\tau} \Delta t = \Delta\mathbf{L} = I \Delta\boldsymbol{\omega}$ $\mathbf{H} = \Delta\mathbf{L} = \int \boldsymbol{\tau} dt$	NA	NA	NA
Yank (N/s ²) / Rotatum (J/s)	$\mathbf{Y} = m\mathbf{J}$ $\mathbf{Y} = \frac{\mathbf{F}}{t} = \frac{\Delta\mathbf{F}}{\Delta t} \rightarrow \frac{d\mathbf{F}}{dt}$	$\mathbf{P} = I\boldsymbol{\zeta}$ $\mathbf{P} = \mathbf{r} \times \mathbf{Y}$ $\mathbf{P} = \frac{\boldsymbol{\tau}}{t} = \frac{\Delta\boldsymbol{\tau}}{\Delta t} \rightarrow \frac{d\boldsymbol{\tau}}{dt} = I\boldsymbol{\zeta}$	NA	NA	NA

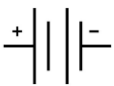
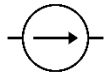

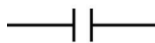

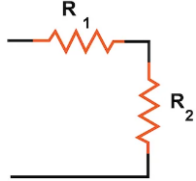
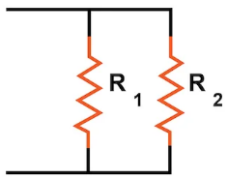
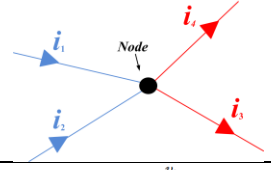
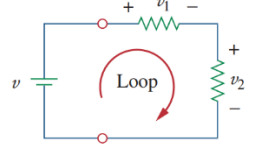
	Mechanics: Linear	Mechanics: Angular	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Energy					
Work (J = N•m)	$W = Fd$ $W = F \Delta x \cos \theta$ $W = \int \mathbf{F} \cdot d\mathbf{r}$	$W = \tau \Delta\theta(\theta - \theta_0)$ $W = \tau \Delta\theta \cos \theta$ $W = \int \tau \cdot d\theta$	$W = QV$	<u>Thermodynamics:</u> $W = -P \Delta V$ $e = \left \frac{W}{Q_H} \right $ $e_c = \frac{T_H - T_C}{T_H}$	NA
Kinetic Energy (J)	<u>Translational:</u> $K = KE = \frac{1}{2}mv^2$	<u>Rotational:</u> $K = KE = \frac{1}{2}I\omega^2$	1 eV $= 1.60 \times 10^{-19} \text{ J}$	<u>Fluid Mechanics:</u> <u>Bernoulli's Equation:</u> $P_1 + \rho gy_1 + \frac{1}{2}\rho v_1^2$ $= P_2 + \rho gy_2 + \frac{1}{2}\rho v_2^2$ <u>Thermodynamics:</u> $K_{avg} = \frac{3}{2}k_B T$	<u>Atomic and Nuclear:</u> $K_{max} = hf - \phi$
Potential Energy (J)	$\Delta U_g = mgh$ $U_G = -\frac{Gm_1m_2}{r}$ $G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$	<u>Coiled Spring:</u> $U_s = -\frac{1}{2}k\Delta x^2$	$U_E = qV$ $U_E = \frac{1}{4\pi\epsilon_0} \frac{q_1q_2}{r}$ $U_c = \frac{1}{2}QV$ $U_c = \frac{1}{2}CV^2$ $U_L = \frac{1}{2}LI^2$	<u>Fluid Mechanics:</u> $P = P_0 + \rho gh$ <u>Continuity of Mass:</u> $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$ <u>Continuity of Volume:</u> $A_1 v_1 = A_2 v_2$ <u>Thermodynamics:</u> $\Delta U = Q + W$	<u>Atomic and Nuclear:</u> $E = hf$ $E = mc^2$ $\Delta E = (\Delta m)c^2$ <u>Relativity:</u> $E = mc^2 \left(\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \right)$

	Mechanics: Linear	Mechanics: Angular	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Heat Energy (J)	<p>Conservation of Energy: $E_i = E_f$</p> $\sum E_i = \sum E_f$ $E = W + Q + K + \Delta U_g + U_G + U_s + U_E + U_c + U_L + \dots = \text{constant}$			<p><u>Thermodynamics:</u></p> $H = \frac{kA\Delta T}{L}$ $Q = mH_f$ $Q = mH_v$ $\Delta E = Q = mC\Delta T$ $mC\Delta T = mC(T_f - T_i)$ $C_{H_2O} = 4180 \frac{J}{kg^\circ K}$ $T_f = \frac{m_1 C_1 \Delta T_{1i} + m_2 C_2 \Delta T_2}{m_1 C_1 + m_2 C_2}$	NA
Power (W)	$P = \frac{W}{t} = Fv$ $P = \frac{\Delta E}{\Delta t} \rightarrow \frac{dE}{dt}$ $P = Fv \cos \theta$ $P = \mathbf{F} \cdot \mathbf{v}$	$P = \frac{W}{t} = \tau\omega$ $P = \frac{\Delta W}{\Delta t} \rightarrow \frac{dW}{dt}$ $P = \tau\omega \cos \theta$ $P = \mathbf{\tau} \cdot \mathbf{\omega}$	$P = IV$ $P = I^2 R$ $P = \frac{V^2}{R}$	$P = pQ$ <p>where:</p> $P = \text{pressure} \left(\frac{N}{m^2} \right)$ $Q = \text{volumetric flow rate} \left(\frac{m^3}{s} \right)$	NA

	Mechanics: Linear	Mechanics: Angular	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Engineering Application					
Period / Frequency (Hz)	$T = \frac{1}{f}$ $f = \frac{1}{T}$ <p>Kepler's Third Law:</p> $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$	$T = \frac{1}{f} = \frac{2\pi}{\omega}$ $T_s = 2\pi\sqrt{\frac{m}{k}}$ $T_p = 2\pi\sqrt{\frac{\ell}{g}}$	$T = \frac{2\pi}{b}$ <p>For:</p> $y = \sin(b\theta)$ $y = \cos(b\theta)$	NA	<p><u>Waves and Optics:</u></p> $f = \frac{v}{\lambda}$ <p>Doppler Effect:</p> $f_r = f_s \left(\frac{v \pm v_r}{v \mp v_s}\right)$
Center of Mass (m)	$x_{CM} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$ $x_{CM} = \frac{\sum m_i x_i}{\sum m_i}$ $\bar{x} = \frac{1}{M} \int_0^M x \, dm$ <p>where $M = \int_0^M dm$ and $dm = \rho \, dz \, dy \, dx$</p>	$r_{CM} = \frac{\sum mr}{\sum m}$	NA	NA	NA
Rigid Bodies	$\sum F_y = \sum mg = 0$ <p>(Down = '-')</p>	$\sum \tau = \sum F_y x_{CM} = 0$ <p>(CW = '-')</p>	NA	NA	NA

	Mechanics: Linear	Mechanics: Angular	Electricity / Magnetism	Fluid Mechanics / Thermodynamics	Atomic and Nuclear / Waves and Optics
Conservation Laws	<p><i>Conservation of Linear Momentum</i></p> $\sum p_i = \sum p_f$ $\sum mv_i = \sum mv_f$ <p>(Physics)</p>	<p><i>Conservation of Angular Momentum</i></p> $\sum L_i = \sum L_f$ $\sum I\omega_i = \sum I\omega_f$ <p>(Physics)</p>	<p><i>Conservation of Electric Charge</i></p> $\sum Q_i = \sum Q_f$ <p>(Circuits)</p>	<p><i>Conservation of Mass (or Matter)</i></p> $\sum m_i = \sum m_f$ <p>(Chemistry)</p> <p><i>Bernoulli's Equation:</i></p> $P_1 + \rho gy_1 + \frac{1}{2}\rho v_1^2$ $= P_2 + \rho gy_2 + \frac{1}{2}\rho v_2^2$ <p>(Fluid Mechanics / Pressure)</p>	<p><i>Conservation of Energy</i></p> $\sum E_i = \sum E_f$ E $= W + Q + K + \Delta U_g$ $+ U_G + U_s + U_E + U_c$ $+ U_L + \dots = \text{constant}$ <p>(Physics)</p>

Electricity

Terms	Formulas		
Electric Field (V/m or N/C)	$E = \frac{F}{q}$ $E_{avg} = -\frac{V}{d}$ $E = -\frac{\Delta V}{\Delta r}$	$E = \rho J$ $E = -\frac{dV}{dr}$	<i>Gauss's Law:</i> $\oint E \cdot dA = \frac{Q}{\epsilon_0}$
Potential / Voltage (V)	$V = IR$ $V = \frac{Q}{C}$	$V = k \sum_i \frac{q_i}{r_i} = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i}$	
Current (A)	$I = \frac{\Delta Q}{\Delta t}$ $I = \frac{V}{R}$	$I = \frac{dQ}{dt}$ $I = nev_d A$	
Circuits		Series	Parallel
Circuit Terms	 Resistor  Capacitor  Inductor		
Resistance (Ω)	$R = \frac{V}{I}$ $R = \frac{\rho \ell}{A}$	$R_s = \sum_i R_i$	$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$ $R_p = \frac{R_1 R_2}{R_1 + R_2}$
Inductance (H)	$L = N \frac{\Phi}{I}$ $L = \frac{V_L}{dI/dt}$ $L = \mu_0 \frac{N^2 A}{\ell}$	$L_s = \sum_i L_i$	$\frac{1}{L_p} = \sum_i \frac{1}{L_i}$
Capacitance (F)	$C = \frac{Q}{V}$ $C = \frac{\epsilon_0 A}{d}$ $C = \frac{\kappa \epsilon_0 A}{d}$	$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$	$C_p = \sum_i C_i$
Kirchhoff's Current Law (KCL)	$\sum_{i=1}^n I_i = 0$ <p>The algebraic sum of currents in a network of conductors meeting at a point (node) is zero.</p>		
Kirchhoff's Voltage Law (KVL)	$\sum_{i=1}^n V_i = 0$ <p>The directed sum of the potential differences (voltages) around any closed loop is zero.</p>		 KVL: $-v + v_1 + v_2 = 0$

Magnetism

Term	Formulas	Laws
Magnetic Field (T)	$B = \frac{\mu_0 I}{2\pi r}$ <p>Solenoid: $B_s = \mu_0 n I$ where $n = \frac{N}{\ell}$ turns per meter</p> $\mathbf{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \vec{r}}{r^3}$ $\mathbf{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$ $\mu_0 = 4\pi \times 10^{-7} \frac{(T \cdot m)}{A}$	<p>Ampere's Circuit Law:</p> $\oint \mathbf{B} \cdot d\boldsymbol{\ell} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\phi_E}{dt}$ <p>Gauss's Law for Magnetism:</p> $\oint \mathbf{B} \cdot d\mathbf{A} = 0$ $d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{I d\boldsymbol{\ell} \times \vec{r}}{r^3}$
Magnetic Flux (Wb)	$\phi_B = BA \cos \theta$ $\phi_B = \mathbf{B} \cdot \mathbf{A}$	<p>Gauss's Law for Magnetism:</p> $\phi_B = \int \mathbf{B} \cdot d\mathbf{A}$
EMF (V)	$\epsilon_{avg} = - \frac{\Delta\phi_B}{\Delta t}$ $\epsilon = \oint \mathbf{E} \cdot d\mathbf{s} = - \frac{d\phi_B}{dt}$ $\epsilon = Blv$	<p>Faraday's Law of Induction:</p> $\oint \mathbf{E} \cdot d\boldsymbol{\ell} = - \frac{\Delta\phi_B}{\Delta t}$ $\epsilon = -L \frac{dI}{dt}$