# Harold's Physics
# "Cheat Sheet"
3 May 2021

<table>
<tr><th></th><th>Mechanics: Linear Translation</th><th>Mechanics: Angular / Rotational Motion</th><th>Electricity / Magnetism</th><th>Fluid Mechanics / Thermo-dynamics</th><th>Atomic and Nuclear / Waves and Optics</th></tr>
<tr><td>Kinematics</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Position<br>(m)<br>(rad)</td><td>Horizontal / 1-D:<br>$\boldsymbol{x} = \boldsymbol{x}_0 + \boldsymbol{v}_{x0}t + \frac{1}{2}\boldsymbol{a}t^2$<br><br>Vertical:<br>$\boldsymbol{y} = \boldsymbol{y}_0 + \boldsymbol{v}_{y0}t - \frac{1}{2}\boldsymbol{g}t^2$<br><br>$\boldsymbol{x} = \boldsymbol{x}_0 + \boldsymbol{v}t$<br><br>$\boldsymbol{x} = \int \boldsymbol{v}\,dt$<br><br>$s = r\theta$</td><td>$\boldsymbol{\theta} = \boldsymbol{\theta}_0 + \boldsymbol{\omega}_0 t + \frac{1}{2}\boldsymbol{\alpha}t^2$<br><br>$\boldsymbol{\theta} = \boldsymbol{\theta}_0 + \boldsymbol{\omega}t$<br><br>$\boldsymbol{\theta} = \int \boldsymbol{\omega}\,dt$</td><td rowspan="2">$10^{-100}$<br>$= googolth$<br>$10^{-24} = yocto$<br>$10^{-21} = zepto$<br>$10^{-18} = atto$<br>$10^{-15} = femto$<br>$10^{-12} = pico$<br>$10^{-9} = nano$<br>$10^{-6} = micro$<br>$10^{-3} = milli$<br>$10^{-2} = centi$<br>$10^{-1} = deci$<br>$10^{0} = 1$<br>$10^{1} = deca$<br>$10^{2} = hecto$<br>$10^{3} = kilo$<br>$10^{6} = mega$<br>$10^{9} = giga$<br>$10^{12} = tera$<br>$10^{15} = peta$<br>$10^{18} = exa$<br>$10^{21} = zetta$<br>$10^{24} = yotta$<br>$10^{100} = googol$<br>$10^{1000}$<br>$= googolplex$</td><td rowspan="2"><u>Fluid Mechanics</u>:<br>$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$<br>(Conservation of Mass)<br><br>$\rho = \frac{m}{V}$<br><br>$\Delta\ell = \alpha\ell_0\Delta T$</td><td rowspan="2"><u>Waves</u>:<br>$f(x,t) = A\sin\left(2\pi\left(ft - \frac{x}{\lambda}\right) + \phi\right) + k$<br><br><u>Optics</u>:<br>$f = \frac{v}{\lambda}$<br><br>$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$<br><br>Refraction:<br>(bend)<br>$n = \frac{c}{v}$<br><br>Snell's Law:<br>$n_1 \sin\theta_1 = n_2 \sin\theta_2$<br><br>$\frac{n_1}{n_2} = \frac{v_2}{v_1}$<br><br>Diffraction:<br>(spread out)<br>$\Delta L = d\sin\theta$<br>$m\lambda = d\sin\theta$</td></tr>
<tr><td colspan="2">$\boldsymbol{x}(t) = A\cos(\boldsymbol{\omega}t + \phi)$<br><br>$\boldsymbol{x}(t) = A\cos(2\pi f t + \phi)$</td></tr>
</table>

| | Mechanics: Linear | Mechanics: Angular | Electricity / Magnetism | Fluid Mechanics / Thermo-dynamics | Atomic and Nuclear / Waves and Optics |
|---|---|---|---|---|---|
| **Velocity (m/s)**<br><br>Angular Velocity / Angular Frequency (rad/s) | $\boldsymbol{v} = \frac{d}{t} = \frac{\Delta \boldsymbol{x}}{\Delta t} = \frac{d\boldsymbol{x}}{dt}$<br>$\boldsymbol{v} = \boldsymbol{v}_0 + \boldsymbol{a}t$<br>$\boldsymbol{v}^2 = \boldsymbol{v}_0^2 + 2\boldsymbol{a}(x - x_0)$<br>$\overline{\boldsymbol{v}} = \frac{\boldsymbol{v}_0 + \boldsymbol{v}}{2}$<br>$\boldsymbol{v} = \int \boldsymbol{a}\, dt$<br>$f = \frac{1}{T}$ | $\boldsymbol{\omega} = \frac{\theta}{t} = \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$<br>$\boldsymbol{\omega} = \boldsymbol{\omega}_0 + \boldsymbol{\alpha}t$<br>$\boldsymbol{\omega}^2 = \boldsymbol{\omega}_0^2 + 2\boldsymbol{\alpha}(\theta - \theta_0)$<br>$\overline{\boldsymbol{\omega}} = \frac{\boldsymbol{\omega}_0 + \boldsymbol{\omega}}{2}$<br>$\boldsymbol{\omega} = \int \boldsymbol{\alpha}\, dt$<br>$\boldsymbol{\omega} = \frac{2\pi}{T} = 2\pi f$<br>$\boldsymbol{\omega} = \sqrt{\frac{k}{m}}$ *(spring)*<br>$\boldsymbol{\omega} = \sqrt{\frac{\boldsymbol{g}}{\ell}}$ *(pendulum)* | *Speed of Light:*<br>$c \approx 3.00 \times 10^8 \frac{m}{s}$ | ***Fluid Mechanics:***<br>$A_1 v_1 = A_2 v_2$<br>$v_{rms} = \sqrt{\frac{3RT}{M}}$<br>$v_{rms} = \sqrt{\frac{3k_B T}{\mu}}$ | ***Waves and Optics:***<br>$v = f\lambda$<br><br>***Reflection:***<br>*(throw back)*<br><br>*Critical angle:*<br>$\sin\theta_c = \frac{n_1}{n_2}$<br><br>*Maxima for a thin film:*<br>$2d = \frac{\lambda}{2n}, 3\frac{\lambda}{2n}, 5\frac{\lambda}{2n} \ldots$ |
| | $\boldsymbol{v} = \boldsymbol{\omega} r$<br>$\boldsymbol{v} = \boldsymbol{\omega} \times \boldsymbol{r}$<br>$\boldsymbol{v}(t) = -A\boldsymbol{\omega}\sin(\omega t + \phi)$<br>$\boldsymbol{v}(t) = -A\boldsymbol{\omega}\sin(2\pi f t + \phi)$ | | | | |

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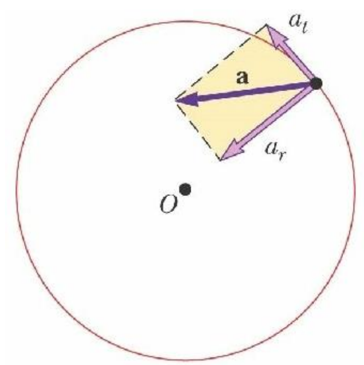
<tr><td rowspan="3">Acceleration<br>($\mathrm{m}/s^2$)<br>($\mathrm{rad}/s^2$)</td><td><u>Linear</u>:<br>$\boldsymbol{a} = \frac{\boldsymbol{v}}{t} = \frac{\Delta \boldsymbol{v}}{\Delta t} = \frac{d\boldsymbol{v}}{dt}$<br>$\boldsymbol{a} = \frac{\sum \boldsymbol{F}}{m} = \frac{\boldsymbol{F}_{net}}{m}$<br><u>Tangential (linear)</u>:<br>$\boldsymbol{a} = \boldsymbol{a}_t = \boldsymbol{\alpha}\, r$<br>Gravity ($\boldsymbol{g}$)</td><td><u>Angular</u>:<br>$\boldsymbol{\alpha} = \frac{\boldsymbol{\omega}}{t} = \frac{\Delta \boldsymbol{\omega}}{\Delta t} = \frac{d\boldsymbol{\omega}}{dt}$<br>$\boldsymbol{\alpha} = \frac{\sum \boldsymbol{\tau}}{I} = \frac{\boldsymbol{\tau}_{net}}{I}$<br><u>Centripetal (center)</u>:<br>$\boldsymbol{a}_c = \frac{\boldsymbol{v}^2}{r} = \boldsymbol{\omega}^2 r$</td><td colspan="3" rowspan="4">Constants:<br>Gravitational Constant $G = 6.67430 \times 10^{-11}\ \frac{Nm^2}{kg}$<br>Gravity Acceleration (Earth) $g = 9.80665\ \frac{m}{s^2} = 32.1740\ \frac{ft}{s^2}$<br>Speed of Light in Vacuum $c = 2.99792458 \times 10^{8}\ \frac{m}{s}$<br>Electron-Volt $1eV = 1.602176462 \times 10^{-19}\ J$<br>Charge of an Electron $e = -1.602176462 \times 10^{-19}\ C$<br>Mass of an Electron $m_e = 9.1093837015 \times 10^{-31}\ kg$<br>Mass of a Proton $m_p = 1.67262192369 \times 10^{-27}\ kg$<br>Mass of a Neutron $m_n = 1.67492749804 \times 10^{-27}\ kg$<br>Electric Permittivity $\varepsilon_0 = \frac{1}{\mu_0 c^2} = 8.85418782 \times 10^{-12}\ \frac{C^2}{Nm^2}$<br>Magnetic Permeability $\mu_0 = 4\pi \times 10^{-7}\ \frac{Tm}{A}$<br>Avogadro's Number $N_A = 6.02214076 \times 10^{23}\ \frac{1}{mol}$<br>Boltzmann Constant $k_B = 1.380649 \times 10^{-23}\ \frac{J}{K}$<br>Coulomb's Law Constant $k_e = \frac{1}{4\pi\varepsilon_0} = 8.987551 \times 10^{9}\ \frac{Nm^2}{C^2}$<br>Faraday Constant $F = 9.648533289 \times 10^{4}\ \frac{C}{mol}$<br>Planck's Constant $h = 6.6267004 \times 10^{-34}\ Js$</td></tr>
<tr><td colspan="2">

<u>Net</u>:<br>$\boldsymbol{a}_{net}^2 = \boldsymbol{a}_t^2 + \boldsymbol{a}_c^2$</td></tr>
<tr><td colspan="2">$\boldsymbol{a} = -A\boldsymbol{\omega}^2 \cos(\omega t + \phi)$<br>$\boldsymbol{a}(t) = -A\boldsymbol{\omega}^2 \cos(2\pi f t + \phi)$</td></tr>
<tr><td>Jerk (Jolt)<br>($\mathrm{m}/s^3$)<br>($\mathrm{rad}/s^3$)</td><td>$\vec{\boldsymbol{j}} = \frac{\boldsymbol{a}}{t} = \frac{\Delta \boldsymbol{a}}{\Delta t} = \frac{d\boldsymbol{a}}{dt}$</td><td>$\boldsymbol{\zeta} = \frac{\boldsymbol{\alpha}}{t} = \frac{\Delta \boldsymbol{\alpha}}{\Delta t} = \frac{d\boldsymbol{\alpha}}{dt}$</td></tr>
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| | Mechanics: Linear | Mechanics: Angular | Electricity / Magnetism | Fluid Mechanics / Thermo-dynamics | Atomic and Nuclear / Waves and Optics |
|---|---|---|---|---|---|
| **Dynamics** | | | | | |
| **Mass (kg)** / Moment of Inertia $(kg \bullet m^2)$ | $m$ = actual mass<br>$I$ = effective mass | $I = \sum mr^2$<br>$I = \int r^2\, dm$<br>$I = \int \boldsymbol{r} \bullet \boldsymbol{r}\, d\boldsymbol{m}$ | $m_p \approx m_n$ | *NA* | ***Magnification***:<br>$\lvert M \rvert = \left\lvert \frac{d_i}{d_o} \right\rvert = \left\lvert \frac{h_i}{h_o} \right\rvert$<br>$M_{Telescope} = -\frac{f_{objective\ lens}}{f_{eyepiece}}$ |
| **Momentum (kg•m/s)** $(kg \bullet m^2/s)$ | $\boldsymbol{p} = m\boldsymbol{v}$<br>$\Delta\boldsymbol{p} = m\Delta\boldsymbol{v}$<br>*Conservation of Linear Momentum:*<br>$\boldsymbol{p}_i = \boldsymbol{p}_f$<br>$\sum m\boldsymbol{v}_i = \sum m\boldsymbol{v}_f$<br>$\boldsymbol{p} = \boldsymbol{\omega} \times \boldsymbol{m}$<br>$\Delta\boldsymbol{p} = \boldsymbol{J} = \int_{t_1}^{t_2} \boldsymbol{F}\, dt$<br>*Elastic Collision = bounce off each other*<br>*Inelastic Collision = stick together* | $\boldsymbol{L} = I\boldsymbol{\omega}$<br>$\boldsymbol{L} = \boldsymbol{r}m\boldsymbol{v}$<br>*Conservation of Angular Momentum:*<br>$\boldsymbol{L}_i = \boldsymbol{L}_f$<br>$\sum I\boldsymbol{\omega}_i = \sum I\boldsymbol{\omega}_f$<br>$\boldsymbol{L} = \boldsymbol{r} \times \boldsymbol{p}$<br>$\boldsymbol{L} = m\boldsymbol{r} \times \boldsymbol{v}$<br>$L = \int \boldsymbol{r} \times \boldsymbol{v}\, dm$<br>$\Delta\boldsymbol{L} = \int \boldsymbol{\tau}\, dt$ | *NA* | *Fluid Mechanics*:<br>$\nabla\boldsymbol{p} = \rho\boldsymbol{g}$ | *Atomic and Nuclear*:<br>$\lambda = \frac{h}{p}$ |

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

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|---|---|---|---|---|---|
| **Energy** | | | | | |
| **Work (J = N•m)** | $W = Fd$<br>$W = F\,\Delta x\cos\theta$<br>$W = \int \boldsymbol{F} \bullet d\boldsymbol{r}$ | $W = \boldsymbol{\tau}\,\Delta\theta(\theta - \theta_0)$<br>$W = \tau\,\Delta\theta\cos\theta$<br>$W = \int \boldsymbol{\tau} \bullet d\boldsymbol{\theta}$ | $\boldsymbol{W} = \boldsymbol{Q}V$ | *Thermodynamics*:<br>$W = -P\,\Delta V$<br>$e = \left\lvert \frac{W}{Q_H} \right\rvert$<br>$e_c = \frac{T_H - T_C}{T_H}$ | $NA$ |
| **Kinetic Energy (J)** | *Translational:*<br>$K = KE = \frac{1}{2}m\boldsymbol{v}^2$ | *Rotational:*<br>$K = KE = \frac{1}{2}I\boldsymbol{\omega}^2$ | $1\ eV = 1.60 \times 10^{-19}\ J$ | *Fluid Mechanics*:<br>*Bernoulli's Equation:*<br>$P_1 + \rho g y_1 + \frac{1}{2}\rho {v_1}^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho {v_2}^2$<br>*Thermodynamics*:<br>$K_{avg} = \frac{3}{2}k_B T$ | *Atomic and Nuclear*:<br>$K_{max} = hf - \phi$ |
| **Potential Energy (J)** | $\Delta U_g = mgh$<br>$U_G = -\frac{Gm_1 m_2}{r}$<br>$G = 6.67 \times 10^{-11}\frac{Nm^2}{kg^2}$ | *Coiled Spring:*<br>$U_s = -\frac{1}{2}k\Delta x^2$ | $U_E = qV$<br>$U_E = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$<br>$U_c = \frac{1}{2}QV$<br>$U_c = \frac{1}{2}CV^2$<br>$U_L = \frac{1}{2}LI^2$ | *Fluid Mechanics*:<br>$P = P_0 + \rho g h$<br>*Continuity of Mass:*<br>$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$<br>*Continuity of Volume:*<br>$A_1 v_1 = A_2 v_2$<br>Thermodynamics:<br>$\Delta U = Q + W$ | *Atomic and Nuclear*:<br>$E = hf$<br>$E = mc^2$<br>$\Delta E = (\Delta m)c^2$<br>*Relativity:*<br>$E = mc^2\left(\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}\right)$ |

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|---|---|---|---|---|---|
| **Heat Energy (J)** | *Conservation of Energy:* $E_i = E_f$ <br> $\sum E_i = \sum E_f$ <br> $E = W + Q + K + \Delta U_g + U_G + U_s + U_E + U_c + U_L + \cdots = constant$ | | | *Thermodynamics:* <br> $H = \frac{kA\Delta T}{L}$ <br> $Q = mH_f$ <br> $Q = mH_v$ <br> $\Delta E = Q = mC\Delta T$ <br> $mC\Delta T = mC(T_f - T_i)$ <br> $C_{H_2O} = 4180\,J\,\frac{J}{kg\,°K}$ <br> $T_f = \frac{m_1C_1\Delta T_{1i} + m_2C_2\Delta T_2}{m_1C_1 + m_2C_2}$ | *NA* |
| **Power (W)** | $P = \frac{W}{t} = Fv$ <br> $P = \frac{\Delta E}{\Delta t} = \frac{dE}{dt}$ <br> $P = Fv\cos\theta$ <br> $P = \mathbf{F} \bullet \mathbf{v}$ | $P = \frac{W}{t} = \tau\omega$ <br> $P = \frac{\Delta W}{\Delta t} = \frac{dW}{dt}$ <br> $P = \tau\omega\cos\theta$ <br> $P = \boldsymbol{\tau} \bullet \boldsymbol{\omega}$ | $P = IV$ <br> $P = I^2R$ <br> $P = \frac{V^2}{R}$ | $P = pQ$ <br> *where:* <br> $P = pressure\left(\frac{N}{m^2}\right)$ <br> $Q = volumetric\ flow\ rate\left(\frac{m^3}{s}\right)$ | *NA* |

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| **Engineering Application** | | | | | |
| **Period / Frequency (Hz)** | $T = \frac{1}{f}$ <br> $f = \frac{1}{T}$ | $T = \frac{1}{f} = \frac{2\pi}{\omega}$ <br> $T_s = 2\pi\sqrt{\frac{m}{k}}$ <br> $T_p = 2\pi\sqrt{\frac{\ell}{g}}$ | $T = \frac{2\pi}{b}$ <br> *For:* <br> $y = sin(b\theta)$ <br> $y = cos(b\theta)$ | *NA* | *Waves and Optics:* <br> $f = \frac{v}{\lambda}$ <br> *Doppler Effect:* <br> $\boldsymbol{f_r} = \boldsymbol{f_s}\left(\frac{\boldsymbol{v} \pm \boldsymbol{v_r}}{\boldsymbol{v} \mp \boldsymbol{v_s}}\right)$ |
| **Center of Mass (m)** | $x_{CM} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$ <br> $x_{CM} = \frac{\sum m_i x_i}{\sum m_i}$ <br> $\bar{x} = \frac{1}{M}\int_0^M x\, dm$ <br> *where* $M = \int_0^M dm$ <br> *and* $dm = \rho\, dz\, dy\, dx$ | $\boldsymbol{r}_{CM} = \frac{\sum m\boldsymbol{r}}{\sum m}$ | *NA* | *NA* | *NA* |
| **Rigid Bodies** | $\sum F_y = \sum mg = 0$ <br> *(Down = '–')* | $\sum \tau = \sum F_y\, x_{CM} = 0$ <br> *(CW = '–')* | *Conservation of Charge* <br> $\sum Q_i = \sum Q_f$ <br> *(Circuits)* | *Conservation of Mass* <br> $\sum m_i = \sum m_f$ <br> *(Chemistry)* | *Conservation of Energy* <br> $\sum E_i = \sum E_f$ <br> *(Physics)* |

 

# Electricity

## Electricity

| | | | |
|---|---|---|---|
| **Electric Field (V/m) (N/C)** | $\boldsymbol{E} = \frac{\boldsymbol{F}}{q}$<br>$E_{avg} = -\frac{V}{d}$<br>$E = -\frac{\Delta V}{\Delta r} = -\frac{dV}{dr}$<br>*Gauss's Law:*<br>$\oint \boldsymbol{E} \bullet d\boldsymbol{A} = \frac{Q}{\epsilon_0}$<br>$\boldsymbol{E} = \rho \boldsymbol{J}$ | **Capacitance (F)** | $C = \frac{Q}{V}$<br>$C = \frac{\epsilon_0 A}{d}$<br>$C = \frac{\kappa \epsilon_0 A}{d}$<br>$C_p = \sum_i C_i$<br>$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$ |
| **Potential (V)** | $V = IR$<br>$V = \frac{Q}{C}$<br>$V = k \sum_i \frac{q_i}{r_i}$<br>$V = \frac{1}{4\pi\epsilon_0} \sum_i \frac{q_i}{r_i}$ | **Resistance (Ω)** | $R = \frac{V}{I}$<br>$R = \frac{\rho \ell}{A}$<br>$R_s = \sum_i R_i$<br>$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$ |
| **Current (A)** | $I = \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$<br>$I = \frac{V}{R}$<br>$I = Nev_d A$<br>$e = -1.602176462 \times 10^{-19}\ C$ | **Inductance (H)** | $L = N\frac{\Phi}{I}$<br>$L = \frac{V_L}{dI/dt}$<br>$L = \mu_0 \frac{N^2 A}{\ell}$<br>$L_s = \sum_i L_i$<br>$\frac{1}{L_p} = \sum_i \frac{1}{L_i}$ |

# Magnetism

| Magnetism | | | |
|---|---|---|---|
| **Magnetic Field (T)** | $B = \frac{\mu_0}{2\pi}\frac{I}{r}$ <br> *Solenoid:* <br> $B_s = \mu_0 nI$ <br> $where\ n = \frac{N}{\boldsymbol{\ell}}\ turns\ per\ meter$ <br> $\boldsymbol{B} = \frac{\mu_0}{4\pi}\frac{q\vec{\boldsymbol{v}} \times \vec{\boldsymbol{r}}}{r^3}$ <br> $\boldsymbol{B} = \frac{\mu_0}{4\pi}\frac{q\vec{\boldsymbol{v}} \times \hat{\boldsymbol{r}}}{r^2}$ <br> $\mu_0 = 4\pi \times 10^{-7}\frac{(T \bullet m)}{A}$ <br> *Ampere's Circuit Law:* <br> $\oint \boldsymbol{B} \bullet d\boldsymbol{\ell} = \mu_o I + \mu_0\varepsilon_0\frac{d\phi_E}{dt}$ <br> *Gauss's Law for Magnetism:* <br> $\oint \boldsymbol{B} \bullet d\boldsymbol{A} = 0$ <br> $dB = \frac{\mu_0}{4\pi}\frac{I\, d\boldsymbol{\ell} \times \vec{\boldsymbol{r}}}{r^3}$ | **EMF (V)** | *Faraday's Law of Induction:* <br> $\oint \boldsymbol{E} \bullet d\boldsymbol{\ell} = -\frac{\Delta\phi_B}{\Delta t}$ <br> $\varepsilon = -L\frac{dI}{dt}$ |
| **Magnetic Flux (Wb)** | $\phi_{\boldsymbol{B}} = BA\cos\theta$ <br> $\phi_B = \boldsymbol{B} \bullet \boldsymbol{A}$ <br> *Gauss's Law for Magnetism:* <br> $\phi_B = \int \boldsymbol{B} \bullet d\boldsymbol{A}$ | | |
| **EMF (V)** | $\varepsilon_{avg} = -\frac{\Delta\phi_B}{\Delta t}$ <br> $\boldsymbol{\varepsilon} = \oint \boldsymbol{E} \bullet d\boldsymbol{s} = -\frac{d\phi_B}{dt}$ <br> $\boldsymbol{\varepsilon} = \boldsymbol{B}lv$ | | |