# Formula Sheet



## General Waves

$$y(x,t) = y_m \sin(kx - \omega t + \phi_0)$$
$$k = \frac{2\pi}{\lambda}$$
$$\frac{\omega}{2\pi} = f = \frac{1}{T}$$
$$v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f$$
$$v = \sqrt{\frac{\tau}{\mu}}$$
$$y(x,t) = 2y_m \sin kx \cos \omega t$$
$$f = n\frac{v}{2L}$$

## Sound Waves

$$v = \sqrt{\frac{B}{\rho}}$$
$$I = \frac{P}{A}$$
$$I = \frac{P_S}{4\pi r^2}$$
$$\beta = (10\text{dB})\log\frac{I}{I_0}$$
$$f_{\text{beat}} = f_1 - f_2$$
$$f = f\,\frac{v \pm v_D}{v \pm v_S}$$

## Geo. Optics

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$
$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$
$$m = -\frac{i}{p}$$
$$|m| = \frac{h'}{h}$$
$$m_\theta = \frac{25\text{cm}}{f}$$

## Interference

$$\lambda_n = \frac{\lambda}{n}$$
$$d\sin\theta = m\lambda$$
$$d\sin\theta = \left(m + \frac{1}{2}\right)\lambda$$
$$2L = \left(m + \frac{1}{2}\right)\frac{\lambda}{n_2}$$
$$2L = m\frac{\lambda}{n_2}$$

## Diffraction

$$a\sin\theta = m\lambda$$
$$\sin\theta = 1.22\frac{\lambda}{d}$$
$$\theta_R = 1.22\frac{\lambda}{d}$$
$$d\sin\theta = m\lambda$$
$$\Delta\theta_{\text{hw}} = \frac{\lambda}{Nd\cos\theta}$$

## Electrostatics

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$
$$\mathbf{E} = \frac{\mathbf{F}}{q}$$
$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$
$$\boldsymbol{\tau} = \mathbf{p} \times \mathbf{E}$$
$$\mathbf{p} = qd$$

$$\Phi_E = \oint \mathbf{E}\cdot d\mathbf{A} = \frac{q_{\text{enc}}}{\varepsilon_0}$$
$$E = \frac{\sigma}{\varepsilon_0}$$
$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$
$$E_{\text{ins. }\infty\text{ plane}} = \frac{\sigma}{2\varepsilon_0}$$
$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

$$\Delta U = U_f - U_i = -W$$
$$\Delta V = V_f - V_i = -\frac{W}{q}$$
$$V = \frac{U}{q}$$
$$V_f - V_i = -\int_i^f \mathbf{E}\cdot d\mathbf{s}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$
$$V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$$
$$E = -\nabla V = -\frac{\partial V}{\partial s}$$

## Capacitance

$$Q = VC$$
$$C = \frac{\varepsilon_0 A}{d}$$
$$C_{\text{eq}} = \sum_n C_n$$
$$\frac{1}{C_{\text{eq}}} = \sum_n \frac{1}{C_n}$$
$$U = \frac{q^2}{2C} = \frac{1}{2}CV^2$$

## Current

$$I = \frac{dq}{dt}$$
$$I = \int \mathbf{J}\cdot d\mathbf{A}$$
$$\mathbf{J} = (ne)\mathbf{v}_d$$
$$V = IR$$
$$\rho = \frac{1}{\sigma} = \frac{E}{J}$$
$$R = \rho\frac{L}{A}$$
$$P = IV = I^2R = \frac{V^2}{R}$$

## Circuits

$$\mathscr{E} = \frac{dW}{dq}$$
$$R_{\text{eq}} = \sum_n R_n$$
$$\frac{1}{R_{\text{eq}}} = \sum_n \frac{1}{R_n}$$
$$Q = C\mathscr{E}\left(1 - e^{-t/RC}\right)$$
$$Q = Q_0 e^{-t/RC}$$

## Magnets

$$F = q(\mathbf{E} + \mathbf{v}\times\mathbf{B})$$
$$qvB = \frac{mv^2}{r}$$
$$F_B = I\mathbf{L}\times\mathbf{B}$$
$$\boldsymbol{\tau} = \boldsymbol{\mu}\times\mathbf{B}$$
$$\mu = NIA$$
$$d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{I\,d\mathbf{s}\times\hat{r}}{r^2}$$
$$B_{\text{wire}} = \frac{\mu_0 I}{2\pi R}$$

## Magnets

$$B_{\text{arc}} = \frac{\mu_0 I\phi}{4\pi R}$$
$$F = \frac{\mu_0 L I_a I_b}{2\pi d}$$
$$\oint \mathbf{B}\cdot d\mathbf{s} = \mu_0 I_{\text{enc}}$$
$$B_{\text{sol}} = \mu_0 I n$$
$$B_{\text{toroid}} = \frac{\mu_0 IN}{2\pi}\frac{1}{r}$$
$$\mathbf{B}(z) = \frac{\mu_0}{2\pi}\frac{\boldsymbol{\mu}}{z^3}$$

## Magnets

$$\Phi_B = \int \mathbf{B}\cdot d\mathbf{A}$$
$$\mathscr{E} = -\frac{d\Phi_B}{dt}$$
$$\mathscr{E} = -N\frac{d\Phi_B}{dt}$$
$$\oint \mathbf{E}\cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}$$
$$L = \frac{N\Phi_B}{I}$$

## Inductance

$$\frac{L}{l} = \mu_0 n^2 A$$
$$\mathscr{E}_L = -L\frac{dI}{dt}$$
$$I = \frac{\mathscr{E}}{R}\left(1 - e^{-tR/L}\right)$$
$$I = I_0 e^{-tR/L}$$
$$U_B = \frac{1}{2}LI^2$$

## LC(R) circuits

$$q = Q\cos(\omega t + \phi)$$
$$\omega = \frac{1}{\sqrt{LC}}$$
$$q_{\text{damped}} = Qe^{-Rt/2L}\cos\left(\omega' t + \phi\right)$$
$$\omega' = \sqrt{\omega^2 - (R/2L)^2}$$

## EM waves

$$\mathbf{S} = \frac{1}{\mu_0}\mathbf{E}\times\mathbf{B}$$
$$S = \frac{1}{c\mu_0}E^2$$
$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

## Mechanics

$$x(t) = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$
$$v(t) = v_{x0} + a_x t$$
$$v_x^2 - v_{x0}^2 = 2a_x(x - x_0)$$
$$\mathbf{F} = m\mathbf{a}$$
$$K.E. = \frac{1}{2}mv^2$$
$$a_c = \frac{v^2}{r}$$
$$F_G = G\frac{m_1 m_2}{r^2} = mg$$

## Constants

$$\varepsilon_0 = 8.85\times10^{-12}\ \text{F/m}$$
$$\mu_0 = 4\pi\times10^{-7}\ \text{V}\cdot\text{s/(A}\cdot\text{m)}$$
$$c = 3.00\times10^{8}\ \text{m/s}$$
$$I_0 = 1\times10^{-12}\ \text{W/m}^2$$

$$q_{\text{electron}} = -1.602\times10^{-19}\ \text{C}$$
$$m_{\text{electron}} = 9.11\times10^{-31}\ \text{kg}$$
$$q_{\text{proton}} = +1.602\times10^{-19}\ \text{C}$$
$$m_{\text{proton}} = 1.623\times10^{-27}\ \text{kg}$$