

# Formula Sheet – Phys 222– Fall 2010

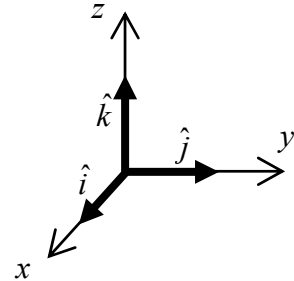
## Vectors and math

$$|\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2} \quad \vec{A} \cdot \vec{B} = AB \cos \theta = A_x B_x + A_y B_y + A_z B_z$$

$$|\vec{A} \times \vec{B}| = AB \sin \theta \quad \vec{A} \times \vec{B} = (A_y B_z - A_z B_y) \hat{i} + (A_z B_x - A_x B_z) \hat{j} + (A_x B_y - A_y B_x) \hat{k}$$

$$ax^2 + bx + c = 0 \quad \Rightarrow \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\frac{d}{dx} x^n = nx^{n-1} \quad \frac{d}{dx} \sin x = \cos x \quad \frac{d}{dx} \cos x = -\sin x$$



## Geometry

perimeter circle:  $2\pi R$

area sphere:  $4\pi R^2$

area circle:  $\pi R^2$

volume sphere:  $\frac{4}{3}\pi R^3$

1 revolution =  $2\pi$  radians =  $360^\circ$

$10^{-15}$	femto- (f)
$10^{-12}$	pico- (p)
$10^{-9}$	nano- (n)
$10^{-6}$	micro- ( $\mu$ )
$10^{-3}$	milli- (m)
$10^{-2}$	centi- (c)
$10^3$	kilo- (k)
$10^6$	mega- (M)
$10^9$	giga- (G)
$10^{12}$	tera- (T)

## Conversion factors

$1 \text{ m}^3 = 1000 \text{ liters}$

$1 \text{ atm} = 1.01 \times 10^5 \text{ Pa} = 760 \text{ mm Hg}$

## Physical constants

$g = 9.81 \text{ m/s}^2 \quad |e| = 1.6 \times 10^{-19} \text{ C}$

$\mu_0 = 4\pi \times 10^{-7} \frac{\text{Wb}}{\text{A} \cdot \text{m}} \quad \epsilon_0 = 8.85 \times 10^{-12} \frac{\text{C}^2}{\text{N} \cdot \text{m}^2} \quad c = 3.00 \times 10^8 \text{ m/s}$

## Fluids

$P = \frac{F}{A}$

$P = P_0 - \rho gy$

$\frac{dV}{dt} = Av = \text{constant}$

$P + \rho gy + \frac{1}{2} \rho v^2 = \text{constant}$

## Electrostatics

$$\vec{F}_{\text{Coulomb}} = k_e \frac{q_1 q_2}{r^2} \hat{r} \quad \vec{E} = \frac{\vec{F}}{q_0} \quad \vec{p} = |Q| \vec{d} \quad \vec{\tau} = \vec{p} \times \vec{E} \quad U = -\vec{p} \cdot \vec{E}$$

$$\Phi_E = \int_{\text{surface}} \vec{E} \cdot d\vec{a} \quad \int_{\text{closed surface}} \vec{E} \cdot d\vec{a} = \frac{q_{\text{enclosed}}}{\epsilon_0} \quad \vec{E} = k_e \frac{q}{r^2} \hat{r} \quad \vec{E} = k_e \frac{2\lambda}{r} \hat{r} \quad \vec{E} = \pm \frac{\sigma}{2\epsilon_0} \hat{x}$$

$$\rho = \frac{dQ}{dV} \quad (V \equiv \text{volume}) \quad \sigma = \frac{dQ}{dA} \quad (A \equiv \text{area}) \quad \lambda = \frac{dQ}{dl} \quad (l \equiv \text{length})$$

$$V_A - V_B = -\int_B^A \vec{E} \cdot d\vec{l} \quad \vec{E} = -\vec{\nabla}V \quad W = -\Delta U = -q_0 \Delta V \quad U = q_0 V$$

$$V = k_e \frac{q}{r} \quad \Delta V = \pm Ed$$

$$k_e = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \frac{\text{N m}^2}{\text{C}^2} \quad \epsilon_0 = 8.85 \times 10^{-12} \frac{\text{C}^2}{\text{N m}^2} \quad e = 1.60 \times 10^{-19} \text{ C}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg} \quad m_p = 1.67 \times 10^{-27} \text{ kg}$$

## Capacitors

$$C = \frac{Q}{V} \quad C_{\text{eq}} = C_1 + C_2 + C_3 + \dots \quad \frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

$$C = \epsilon_0 \frac{A}{d} \quad C = \frac{2\pi\epsilon_0 L}{\ln(a/b)} \quad C = 4\pi\epsilon_0 \frac{ab}{b-a} \quad C = 4\pi\epsilon_0 R$$

$$U = \frac{1}{2} CV^2 = \frac{Q^2}{2C} = \frac{1}{2} QV \quad u = \frac{1}{2} \epsilon E^2 \quad \epsilon = \kappa \epsilon_0 \quad C = \kappa C_0$$

## Electric current and resistor circuits

$$I = \frac{dQ}{dt} \quad V = IR \quad J = \frac{I}{A} = qn v_d \quad E = J\rho \quad R = \rho \frac{L}{A}$$

$$\rho = \rho_0 (1 + \alpha(T - T_0)) \quad R = R_0 (1 + \alpha(T - T_0))$$

$$R_{\text{eq}} = R_1 + R_2 + R_3 + \dots \quad \frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \quad P = IV = I^2 R = \frac{V^2}{R}$$

## RC circuits

$$Q(t) = Q(\infty) \left(1 - e^{-t/\tau}\right) \quad Q(t) = Q(0) e^{-t/\tau} \quad \tau = RC \quad I(t) = I(0) e^{-t/\tau}$$

## Magnetic field

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) \quad d\vec{F} = Id\vec{l} \times \vec{B} \quad \Phi_B = \int \vec{B} \cdot d\vec{A} \quad R = \frac{mv}{|q|B}$$

$$\mu = IA \quad \vec{\tau} = \vec{\mu} \times \vec{B} \quad U = -\vec{\mu} \cdot \vec{B}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2} \quad d\vec{B} = \frac{\mu_0}{4\pi} \frac{Id\vec{l} \times \hat{r}}{r^2} \quad B = \frac{\mu_0 I}{2\pi x} \quad \frac{F}{L} = \frac{\mu_0 I I'}{2\pi r} \quad c^2 = \frac{1}{\mu_0 \epsilon_0}$$

$$B_x = \frac{\mu_0 I a^2}{2(x^2 + a^2)^{3/2}} \quad B_x = \frac{\mu_0 N I}{2a} \quad B = \mu_0 n I \quad \oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enclosed}}$$

## Induction

$$\epsilon = -N \frac{d\Phi_B}{dt} \quad \epsilon = \oint (\vec{v} \times \vec{B}) \cdot d\vec{l} \quad \oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 (i_C + i_D)_{\text{enclosed}} \quad i_D = \epsilon \frac{d\Phi_E}{dt}$$

## Maxwell's equations

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\epsilon_0}$$

$$\oint \vec{B} \cdot d\vec{A} = 0$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \left( i_C + \epsilon_0 \frac{d\Phi_E}{dt} \right)_{\text{enclosed}}$$

## Inductance

$$\epsilon_1 = -M \frac{di_2}{dt} \quad \epsilon_2 = -M \frac{di_1}{dt} \quad M = \frac{N_1 \Phi_{B1}}{i_2} = \frac{N_2 \Phi_{B2}}{i_1} \quad \epsilon = -L \frac{di}{dt} \quad L = \frac{N \Phi_B}{i}$$

$$i = I_\infty \left( 1 - e^{-\frac{t}{\tau}} \right) \quad i = I_0 e^{-\frac{t}{\tau}} \quad \tau = \frac{L}{R} \quad L = \mu_0 n^2 l A \quad U = \frac{1}{2} L I^2 \quad u = \frac{B^2}{2\mu_0}$$

$$q = Q_0 \cos(\omega t + \phi) \quad \omega = \sqrt{\frac{1}{LC}}$$

$$q = Q_0 e^{-\frac{R}{2L}t} \cos(\omega' t + \phi) \quad \omega' = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

## AC current

$$i = I \cos \omega t \quad I_{\text{rav}} = \frac{2}{\pi} I \quad I_{\text{rms}} = \frac{I}{\sqrt{2}} \quad V_{\text{rms}} = \frac{V}{\sqrt{2}} \quad V_{\text{rms}} = I_{\text{rms}} Z$$

$$V_R = IR \quad V_L = IX_L \quad X_L = L\omega \quad V_C = IX_C \quad X_C = \frac{1}{C\omega}$$

$$V = IZ \quad Z = \sqrt{R^2 + (X_L - X_C)^2} \quad \tan \phi = \frac{X_L - X_C}{R} \quad v = V \cos(\omega t + \phi)$$

$$p = iv \quad P_{\text{average}} = \frac{1}{2} IV \cos \phi = I_{\text{rms}} V_{\text{rms}} \cos \phi = I_{\text{rms}}^2 R \quad \frac{V_2}{V_1} = \frac{N_2}{N_1} \quad V_1 I_1 = V_2 I_2$$

## EM waves

$$\vec{E}(x, t) = E_{\text{max}} \cos(kx - \omega t) \hat{j} \quad \vec{B}(x, t) = B_{\text{max}} \cos(kx - \omega t) \hat{k} \quad E_{\text{max}} = cB_{\text{max}}$$

$$E = cB \quad c = \frac{1}{\sqrt{\epsilon_0 \mu_0}} \quad u = \frac{1}{2} \epsilon_0 E^2 + \frac{1}{2\mu_0} B^2 = \epsilon_0 E^2 = \frac{B^2}{\mu_0} \quad \frac{1}{A} \frac{dp}{dt} = \frac{S}{c} = \frac{EB}{\mu_0 c}$$

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B} \quad I = S_{\text{average}} = \frac{E_{\text{max}} B_{\text{max}}}{2\mu_0} = \frac{E_{\text{max}}^2}{2c\mu_0} = \frac{1}{2} \sqrt{\frac{\epsilon_0}{\mu_0}} E_{\text{max}}^2 = \frac{1}{2} \epsilon_0 c E_{\text{max}}^2$$

$$c = \lambda f = \frac{\omega}{k} \quad k = \frac{2\pi}{\lambda} \quad \omega = 2\pi f$$

## Geometric optics

$$n = \frac{c}{v} \quad \theta_i = \theta_r \quad n_1 \sin \theta_1 = n_2 \sin \theta_2 \quad \sin \theta_{\text{crit}} = \frac{n_2}{n_1} \quad I = I_{\text{max}} \cos^2 \phi \quad \tan \theta_p = \frac{n_2}{n_1}$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad m = \frac{y'}{y} = -\frac{s'}{s} \quad f_{\text{spherical mirror}} = \frac{R}{2} \quad \frac{1}{f} = (n-1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{n_a}{s} + \frac{n_b}{s'} = \frac{n_b - n_a}{R} \quad m = \frac{y'}{y} = -\frac{n_a s'}{n_b s} \quad M = \frac{\theta'}{\theta}$$

## Interference and diffraction

$$d \sin \theta = m\lambda \quad y = mR \frac{\lambda}{d} \quad I = I_{\text{max}} \cos^2 \left( \frac{\phi}{2} \right) \quad \phi = 2\pi \frac{r_2 - r_1}{\lambda} = 2\pi \frac{d \sin \theta}{\lambda}$$

$$d \sin \theta = \left( m + \frac{1}{2} \right) \lambda \quad 2t = m\lambda_n \quad 2t = \left( m + \frac{1}{2} \right) \lambda_n$$

$$a \sin \theta = m\lambda \quad \beta = 2\pi \frac{a \sin \theta}{\lambda} \quad I = I_{\text{max}} \frac{\sin^2 \left( \frac{\beta}{2} \right)}{\left( \frac{\beta}{2} \right)^2} \quad I = I_{\text{max}} \cos^2 \left( \frac{\phi}{2} \right) \frac{\sin^2 \left( \frac{\beta}{2} \right)}{\left( \frac{\beta}{2} \right)^2}$$

$$R = \frac{\lambda}{\Delta \lambda} = Nm \quad \sin \theta_1 = 1.22 \frac{\lambda}{D} \quad 2d \sin \theta = m\lambda$$