

PHYS 2415 Formula Sheet

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Electricity

$$E = \frac{1}{4\pi\epsilon} \frac{Q}{r^2}$$

$$\Delta V = V_B - V_A = \frac{\Delta U}{q} = - \int_A^B \vec{E} \cdot d\vec{l}$$

$$\Delta U = U_b - U_a = q(V_b - V_a)$$

$$V = k \frac{Q}{r} = k \int \frac{dq}{r}$$

$$\vec{E} = -\vec{\nabla} V$$

$$\vec{F} = q\vec{E}$$

$$U_{\text{system}} = k \sum_{\text{pairs } i, j} \frac{q_i q_j}{r_{ij}}$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0} = \frac{1}{\epsilon_0} \iiint \rho dV$$

$$E_{\text{rod}} = k \frac{\lambda L}{x \sqrt{x^2 + L^2/4}} \approx \frac{\lambda}{2\pi\epsilon_0 x}$$

$$E_{\text{ring}} = k \frac{Qx}{(x^2 + R^2)^{3/2}}$$

$$E_{\text{disk}} = \frac{\sigma}{2\epsilon_0} \left[1 - \frac{z}{\sqrt{z^2 + R^2}} \right] \approx \frac{\sigma}{2\epsilon_0}$$

$$E_{\text{conducting plane}} = \frac{\sigma}{\epsilon_0}$$

$$\text{dipole moment } p = Ql$$

$$\tau = \vec{p} \times \vec{E} = pE \sin \theta$$

$$W = \int_{\theta_1}^{\theta_2} \tau d\theta = -pE \int_{\theta_1}^{\theta_2} \sin \theta d\theta \\ = pE(\cos \theta_2 - \cos \theta_1) = -\vec{p} \cdot \vec{E}$$

$$C_{\text{plate}} = K\epsilon_0 \frac{A}{d}$$

$$U = \frac{1}{C} \int_0^Q q dq = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2 = \frac{1}{2} QV$$

$$u = \frac{1}{2} \epsilon_0 \vec{E}^2 (J/m^3)$$

$$R = \rho \frac{l}{A}$$

$$\rho = \rho_0 [1 + \alpha(T - T_0)]$$

$$V = V_0 \sin 2\pi ft = V_0 \sin \omega t$$

$$I = I_0 \sin \omega t$$

$$\bar{P} = \frac{1}{2} I_0^2 R = \frac{1}{2} \frac{V_0^2}{R} = I_{\text{rms}} V_{\text{rms}}$$

$$I_{\text{rms}} = \sqrt{I^2} = \frac{I_0}{\sqrt{2}}$$

$$V_{\text{rms}} = \sqrt{V^2} = \frac{V_0}{\sqrt{2}}$$

$$\text{Current density } j$$

$$j = \frac{I}{A} = -ne\vec{v}_d$$

$$\text{Number of electrons over volume}$$

$$n = \frac{N}{V}$$

$$\varepsilon = IR + \frac{Q}{C}$$

$$Q = C\varepsilon \left(1 - e^{-\frac{t}{RC}} \right)$$

$$Q = Q_0 e^{-\frac{t}{RC}}$$

Magnetism

$$\vec{F} = q\vec{v} \times \vec{B} \quad \vec{F} = I\vec{l} \times \vec{B}$$

$$qvB = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{qB}$$

$$\vec{\tau} = NI\vec{A} \times \vec{B} = \vec{\mu} \times \vec{B}$$

$$U = \int \tau d\theta = -\mu B \cos \theta = -\vec{\mu} \cdot \vec{B}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{Id\vec{l} \times \hat{r}}{r^2} = \frac{\mu_0 N I R^2}{2(R^2 + x^2)^{3/2}} \text{ Coil}$$

$$B_{\text{Solenoid}} = \frac{1}{2} \frac{\mu_0 N I}{l}$$

$$B_{\text{long wire}} = \frac{\mu_0 I}{2\pi r} \text{ (from Ampere's law)}$$

$$\chi_\mu = \frac{\mu - \mu_0}{\mu_0} \text{ magnetic susceptibility}$$

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$\varepsilon = \oint \vec{E} \cdot d\vec{l} = -\frac{\partial}{\partial t} \oint \vec{B} \cdot d\vec{A}$$

$$\varepsilon_1 = -M \frac{dI_2}{dt}, \quad \varepsilon_2 = -M \frac{dI_1}{dt}$$

$$L = \frac{N\Phi_B}{I}, \quad \varepsilon = -N \frac{d\Phi_B}{dt} = -L \frac{dI}{dt}$$

$$U = \frac{1}{2} L I^2 = \frac{1}{2} \frac{B^2}{\mu_0} A l, \quad \mu = \frac{1}{2} \frac{B^2}{\mu_0}$$

$$I = I_0 e^{-\frac{t}{\tau}}, \quad \tau = \frac{L}{R}$$

$$Z_{RLC} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C} \right)^2}$$

$$\cos \phi = \frac{V_{R0}}{V_0} = \frac{R}{Z}$$

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{encl}} + \mu_0 \epsilon_0 \frac{\partial}{\partial t} \oint \vec{E} \cdot d\vec{A}$$

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

Waves

$$v = \sqrt{\frac{F_T}{\mu}} = \sqrt{\frac{E}{\rho}}, \mu = \frac{m}{l}$$

$$E = 2\pi^2 m f^2 A^2 = 2\pi^2 \rho S v t f^2 A^2$$

$$E = 2\pi^2 \mu v t f^2 A^2$$

$$S: \text{cross section area. } \mu: \text{linear density}$$

$$\text{Intensity } I = \frac{\bar{P}}{S}$$

$$\frac{\partial^2 D}{\partial x^2} = \frac{\mu}{F_T} \frac{\partial^2 D}{\partial t^2}$$

$$E = E_0 \sin(kx - \omega t)$$

$$\text{Standing wave and } n^{\text{th}} \text{ harmonics}$$

$$\lambda_n = \frac{2l}{n}, n = 1, 2, 3, \dots$$

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

$$E_0 = cB_0$$

$$\mu = \frac{1}{2} \epsilon_0 E^2 + \frac{1}{2} \frac{B^2}{\mu_0} = \epsilon_0 E^2 = \frac{B^2}{\mu_0}$$

$$\vec{S} = \frac{1}{\mu_0} (\vec{E} \times \vec{B}) = \frac{1}{2} \epsilon_0 c E_0^2 = \frac{1}{2} \frac{c}{\mu_0} B_0^2$$

$$\bar{S} = \frac{E_{\text{rms}} B_{\text{rms}}}{\mu_0} = \frac{E_0 B_0}{2\mu_0}$$

$$P_{\text{refl}} = \frac{2}{Ac} \frac{dU}{dt} = \frac{2\bar{S}}{c}$$

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

Geometric Optics

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$f = \frac{R}{2}$$

$$m = -\frac{d_i}{d_o}$$

Sign convention

1. d_o positive if object at side where the light comes from, negative otherwise
2. d_i positive if image at the opposite side where the light comes from, negative otherwise.
3. f positive for converging lens and concave mirror, negative for diverging lens and convex mirror.

Lensmaker's equation. Note: if concave, R is negative.

$$\frac{1}{f} = (n - 1) \left(\frac{1}{R_1} + \frac{1}{R_2} \right)$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$n = \frac{c}{\sqrt{\mu\epsilon}}$$

$$\lambda_n = \frac{v}{f} = \frac{c}{nf} = \frac{\lambda}{n}$$

where λ_n is the wavelength in the material with index of refraction n .

$$P = \frac{1}{f} \text{ Units: dipoter. } 1D = 1m^{-1}$$

Diffraction and Interference

Single-slit

Position of **minima**. Note that D is the width of the slit and $m = 0$ corresponds to the central maximum.

$$D \sin \theta = m\lambda, \quad m = \pm 1, \pm 2$$

$$I_\theta = I_0 \left[\frac{\sin \left(\frac{\pi D \sin \theta}{\lambda} \right)}{\left(\frac{\pi D \sin \theta}{\lambda} \right)} \right]^2$$

Double-slit

Constructive interference (bright)

$$d \sin \theta = m\lambda, \quad m = 0, \pm 1, \pm 2 \dots$$

Destructive interference (dark)

$$d \sin \theta = \left(m + \frac{1}{2} \right) \lambda, \quad m = 0, \pm 1, \pm 2 \dots$$

$$I_\theta = I_0 \cos^2 \left(\frac{\delta}{2} \right)$$

$$\delta = \frac{2\pi}{\lambda} d \sin \theta$$

Thin-film

If light reflects from the surface where $n_1 < n_2$, there will be 180° phase shift ($\frac{1}{2}\lambda$ wavelength).

Constructive interference

$$\frac{2tn}{\lambda_{\text{vacuum}}} = m + \frac{1}{2}$$

Destructive interference

$$\frac{2tn}{\lambda_{\text{vacuum}}} = m$$

where t is the thickness and n is the index of refraction of the material

Diffraction grating

Positions of principle **maxima**. d is the width between slits.

$$d \sin \theta = m\lambda$$

Other

Angular resolution (Rayleigh criterion).

D : diameter.

$$\theta = \frac{1.22D}{\lambda}$$
