

# Physics 4C Formula List

Use this to do the homework.

A copy of this will be available on all exams.

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8 \frac{\text{m}}{\text{s}} ; \mu_0 = 4\pi \times 10^{-7} \frac{\text{Tm}}{\text{A}} ; h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$$

$$k_e = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} ; \epsilon_0 = 8.854 \times 10^{-12} \frac{\text{C}^2}{\text{Nm}^2} ; \hbar = \frac{h}{2\pi}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg} = 511 \text{ keV}/c^2 = 0.511 \text{ MeV}/c^2$$

$$m_p = 1.6726 \times 10^{-27} \text{ kg} = 938.272 \text{ MeV}/c^2 = 1836 m_e = 1.00728 \text{ u}$$

$$m_n = 1.6749 \times 10^{-27} \text{ kg} = 939.566 \text{ MeV}/c^2 = 1.00867 \text{ u}$$

$$e = 1.602 \times 10^{-19} \text{ C} ; \text{ Bohr radius} = a_0 = 5.29 \times 10^{-11} \text{ m}$$

$$1 \text{ electron-volt} = 1 \text{ eV} = 1.602 \times 10^{-19} \text{ J} ; hc = 1240 \text{ eV} \cdot \text{nm}$$

$$1 \text{ atomic mass unit} = \text{u} = 1.66054 \times 10^{-27} \text{ kg} ; 360^\circ = 2\pi \text{ radians}$$

$$k_B = 1.381 \times 10^{-23} \text{ J/K} ; \sigma = 5.6705 \times 10^{-8} \text{ W}/(\text{m}^2 \text{ K}^4)$$

$$1 \frac{\text{Tm}}{\text{s}} = 1 \frac{\text{N}}{\text{C}} = 1 \frac{\text{V}}{\text{m}} ; 1 \text{ A} = 1 \frac{\text{C}}{\text{s}} ; 1 \text{ V} = 1 \frac{\text{J}}{\text{C}} ; 1 \text{ T} = 1 \frac{\text{N}}{\text{C}(\frac{\text{m}}{\text{s}})}$$

$$\omega/k = \lambda f = c ; k = 2\pi/\lambda ; \omega = 2\pi f ; E/B = c$$

$$S = \frac{1}{\mu_0} E \times B ; I = \frac{\text{Power}}{\text{Area}} = S_{av} = cu_{av} = \frac{E_{max} B_{max}}{2\mu_0}$$

$$P = \frac{I}{c} \text{ (absorption)} ; P = \frac{2I}{c} \text{ (reflection)} ; \text{ Pressure} = \text{Force}/\text{Area}$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 ; \sin \theta_c = \frac{n_2}{n_1} ; n = \frac{\lambda_0}{\lambda_n}$$

$$n = \frac{c}{v} ; M = \frac{h'}{h} = -\frac{q}{p} ; \frac{1}{p} + \frac{1}{q} = \frac{1}{f} ; f = R/2$$

$$\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R} ; \frac{1}{f} = (n - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} \right] ; \sin \theta \approx y/L$$

## Sign Conventions for Mirrors

$p > 0$  if the object is in **front** of the mirror (a real object).

$p < 0$  if the object is in **back** of the mirror (a virtual object).

(For objects this happens only in multiple mirror systems.)

$q > 0$  if the image is in **front** of the mirror (a real image).

$q < 0$  if the image is in **back** of the mirror (a virtual image).

Both  $f > 0$  and  $R > 0$  for a **concave** mirror,

which has its center of curvature in **front** of the mirror.

Both  $f < 0$  and  $R < 0$  for a **convex** mirror,

which has its center of curvature in **back** of the mirror.

$M > 0$  if the image is **upright**.

$M < 0$  if the image is **inverted**.

$|M| > 1$  if the image is **magnified**/larger.

$|M| < 1$  if the image is **diminished**/demagnified/minified/smaller.

## Sign Conventions for Lenses

The front of the lens is the side the light comes from, i.e., the object side.

$p > 0$  if the object is in **front** of the lens (a real object).

$p < 0$  if the object is in **back** of the lens (a virtual object).

$q > 0$  if the image is in **back** of the lens (a real image).

$q < 0$  if the image is in **front** of the lens (a virtual image).

$R_1 > 0$  if the front of the lens has a center of curvature in **back** of the lens.

$R_2 > 0$  if the back of the lens has a center of curvature in **back** of the lens.

$R_1 < 0$  if the front of the lens has a center of curvature in **front** of the lens.

$R_2 < 0$  if the back of the lens has a center of curvature in **front** of the lens.

$f > 0$  if the lens is **converging**.

$f < 0$  if the lens is **diverging**.

$M > 0$  if the image is **upright**.

$M < 0$  if the image is **inverted**.

$|M| > 1$  if the image is **magnified**/larger.

$|M| < 1$  if the image is **diminished**/demagnified/minified/smaller.

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

$$2nt = (m + \frac{1}{2})\lambda \quad ; \quad 2nt = m\lambda \quad (m = 0, 1, 2 \dots)$$

$$I_{av} = I_0 \cos^2 \left( \frac{\pi d \sin \theta}{\lambda} \right) \quad ; \quad \phi = \frac{2\pi d \sin \theta}{\lambda}$$

$$I = I_0 \left[ \frac{\sin(\beta/2)}{\beta/2} \right]^2 \quad ; \quad \beta = \frac{2a\pi \sin \theta}{\lambda}$$

$$a \sin \theta = m\lambda \quad (m = \pm 1, \pm 2, \pm 3 \dots) \quad \sin \theta \approx \frac{y}{L}$$

$$\theta_{\min} = 1.22\lambda/D \quad ; \quad R = Nm \quad ; \quad I = I_{\max} \cos^2 \theta$$

$\tan \theta_p = n_2/n_1$  where  $n_2$  is the reflecting medium.

$$\gamma = \frac{1}{\sqrt{1-(\frac{v}{c})^2}} \quad ; \quad \Delta t = \gamma(\Delta t_p) \quad ; \quad L = \frac{L_p}{\gamma}$$

$$x' = \gamma(x - vt) \quad ; \quad y' = y \quad ; \quad z' = z \quad ; \quad t' = \gamma \left( t - \frac{v}{c^2}x \right)$$

$$u_x = \frac{u'_x + v}{1 + \frac{u'_x v}{c^2}} \quad ; \quad u'_x = \frac{u_x - v}{1 - \frac{u_x v}{c^2}} \quad ; \quad u'_y = \frac{u_y}{\gamma \left( 1 - \frac{u_x v}{c^2} \right)} \quad ; \quad u'_z = \frac{u_z}{\gamma \left( 1 - \frac{u_x v}{c^2} \right)}$$

For relativistic motion (where  $v$  approaches  $c$ ):

$$p = \gamma m v \quad ; \quad E = \gamma m c^2 \quad ; \quad E^2 = p^2 c^2 + m^2 c^4 \quad ; \quad KE = E - m c^2 = (\gamma - 1) m c^2$$

$$\lambda_{\max} T = 2.898 \times 10^{-3} \text{ m} \cdot \text{K} \quad ; \quad E_n = n h f \quad ; \quad E_{\text{photon}} = h f$$

$$K_{\max} = h f - \phi \quad ; \quad \lambda' - \lambda_0 = \frac{h}{m c} (1 - \cos \theta) \quad ; \quad \lambda = \frac{h}{p}$$

$$\Delta x \Delta p_x \geq \hbar/2 \quad ; \quad \Delta E \Delta t \geq \hbar/2$$

For non-relativistic motion (where  $v \ll c$ ), such as electrons in atoms,

$$p = m v \quad ; \quad KE = \frac{1}{2} m v^2 = \frac{p^2}{2m}$$

$$\frac{d^2\psi}{dx^2} = \frac{-2m}{\hbar^2}(E - U)\psi(x) \quad ; \quad P_{ab} = \int_a^b |\psi(x)|^2 dx \quad ; \quad 1 = \int_{-\infty}^{\infty} |\psi(x)|^2 dx$$

$$\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi x}{L}\right) \quad ; \quad E_n = \left(\frac{\hbar^2}{8mL^2}\right) n^2, \quad n = 1, 2, 3, \dots$$

$$mvr = n\hbar \quad ; \quad r_n = a_0 n^2 \quad ; \quad \Delta E = E_i - E_f = hf$$

$$E_n = -\frac{k_e e^2}{2a_0} \left(\frac{1}{n^2}\right) = -\left(\frac{13.6}{n^2}\right) \text{ eV}, \quad n = 1, 2, 3, \dots$$

$$\left(\frac{1}{\lambda}\right) = \left(\frac{1}{91.2 \text{ nm}}\right) \left[\left(\frac{1}{n_f^2}\right) - \left(\frac{1}{n_i^2}\right)\right]$$

$$E_n = -\frac{k_e e^2}{2a_0} \left(\frac{Z_{eff}^2}{n^2}\right) = -Z_{eff}^2 \left(\frac{13.6}{n^2}\right) \text{ eV} \quad n = 1, 2, 3, \dots$$

$$E_L \approx -\frac{(Z-1)^2}{4} (13.6 \text{ eV}) \quad ; \quad E_K \approx -(Z-1)^2 (13.6 \text{ eV})$$

$$l = 0, 1, 2, \dots, n-l \quad ; \quad m_l = 0, \pm 1, \pm 2, \dots, \pm l \quad ; \quad m_s = \pm 1/2$$

$$\Delta l = \pm 1 \quad ; \quad \Delta m_l = 0, \pm 1$$

$$L = \sqrt{l(l+1)} \hbar \quad ; \quad L_z = m_l \hbar \quad ; \quad L_z = L \cos \theta$$

$$S = \sqrt{s(s+1)} \hbar \quad ; \quad s = 1/2 \quad ; \quad S_z = m_s \hbar$$

$$spdf \quad ; \quad 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 \dots$$

$$E_{rot} = \frac{\hbar^2}{2I} J(J+1), \quad J = 0, 1, 2, 3, \dots \quad ; \quad \Delta J = \pm 1 \quad ; \quad I = \mu r^2$$

$$E_{vib} = \left(\nu + \frac{1}{2}\right) \hbar \sqrt{\frac{k}{\mu}}, \quad \nu = 0, 1, 2, 3, \dots \quad ; \quad \Delta \nu = \pm 1 \quad ; \quad \mu = \frac{m_1 m_2}{m_1 + m_2}$$

$$E_F(T = 0 \text{ K}) = \frac{\hbar^2}{2m_e} \left(\frac{3n_e}{8\pi}\right)^{2/3} \quad ; \quad E_{av} = \frac{3}{5} E_F$$

$$E_b = (Zm_p + Nm_n - M_A)(931.494 \text{ MeV/u})$$

$$E_b = C_1 A - C_2 A^{2/3} - C_3 \frac{Z(Z-1)}{A^{1/3}} - C_4 \frac{(N-Z)^2}{A}$$

$$N = N_0 e^{-\lambda t} \quad ; \quad R = \left|\frac{dN}{dt}\right| = \lambda N_0 e^{-\lambda t} = R_0 e^{-\lambda t} \quad ; \quad T_{1/2} = \frac{\ln 2}{\lambda}$$

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ decays/sec} \quad ; \quad 1 \text{ Bq} = 1 \text{ decay/sec}$$