Physics 4C Formula List

Use this to do the homework.
A copy of this will be available on all exams.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$\theta_{\text{min}} = 1.22\lambda/D \;\; ; \;\; R = Nm \;\; ; \;\; I/I_{\text{max}} = I_2/I_1 = \cos^2(\theta_2 - \theta_1)$

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

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

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

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

For relativistic motion (where v approaches c):
$p = \gamma mv \;\; ; \;\; E = \gamma mc^2 \;\; ; \;\; E^2 = p^2c^2 + m^2c^4 \;\; ; \;\; KE = E - mc^2 = (\gamma - 1)mc^2$

$\lambda_{\text{max}}T = 2.898 \times 10^{-3}\ \text{m}\cdot\text{K} \;\; ; \;\; I = \sigma T^4 \;\; ; \;\; E_{\text{n}} = nhf \;\; ; \;\; E_{\text{photon}} = hf$

$K_{\text{max}} = hf - \Phi \quad ; \quad \lambda' - \lambda_0 = \frac{h}{mc}(1 - \cos\theta\ ) \quad ; \quad \lambda = \frac{h}{p}$

$\Delta x\ \Delta p_x \geq \hbar/2 \quad ; \quad \Delta E\ \Delta t \geq \hbar/2 \quad ; \quad I(\lambda, T) = \frac{2\pi hc^2}{\lambda^5[\exp(\frac{hc}{\lambda k_B T}) - 1]}$

For non-relativistic motion (where $v << c$), such as electrons in atoms,
$p = mv \quad ; \quad KE = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

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

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

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

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

$$\left(\frac{1}{\lambda}\right) = \left(\frac{1}{91.2\ \text{nm}}\right)\left[\left(\frac{1}{n_i{}^2}\right) - \left(\frac{1}{n_f{}^2}\right)\right] = \left(\frac{13.6\ \text{eV}}{hc}\right)\left[\left(\frac{1}{n_i{}^2}\right) - \left(\frac{1}{n_f{}^2}\right)\right]$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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