PHYS1120
Summer 2025

Equations

- $F_B = qvB\sin\theta$
- $\mathscr{E}_{\text{hall}} = lBv$
- $\tau = NIAB\sin\theta$
- $B = \frac{N\mu_0 I}{2R}$
- $F = \frac{\mu_0 I_1 I_2}{2\pi r}$
- $\mathscr{E}_{\text{ind}} = -N\frac{\Delta\Phi_B}{\Delta t}$
- $n = \frac{c}{v}$
- $n_1\sin\theta_1 = n_2\sin\theta_2$
- $P = \frac{1}{f}$
- $m = \frac{h_i}{h_o}$
- $f = \frac{R}{2}$
- $d\sin\theta = \left(m + \frac{1}{2}\right)\lambda$ (double slit, destructive)
- $D\sin\theta = m\lambda$ (single slit, destructive)
- $d\sin\theta = m\lambda$ (multiple slit, constructive)
- $\frac{1}{\lambda} = R\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$
- $E_n = -13.6\text{ eV}\frac{Z^2}{n^2}$
- $l = 0, 1, 2, ..., n-1$
- $m_s = \pm\frac{1}{2}$
- $R = \frac{mv}{qB}$
- $F_B = IlB\sin\theta$
- $B = \frac{\mu_0 I_{\text{enc}}}{2\pi r}$
- $B = \frac{N\mu_0 I}{L}$
- $\Phi_B = BA\cos\theta$
- $\mathscr{E}_{\text{motional}} = lBv$
- $\theta_i = \theta_r$
- $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$
- $\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f}$
- $m = -\frac{d_i}{d_o}$
- $c = \lambda f$
- $d\sin\theta = m\lambda$ (double slit, constructive)
- $m = -2, -1, 1, 2, ...$ (single slit, destructive)
- $m = -2, -1, 0, 1, 2, ...$ (multiple slit, constructive)
- $E = hf$
- $n = 1, 2, 3, ...$
- $m_l = -l, -l+1, ..., -1, 0, 1, ..., l-1, l$
- $N = N_0 e^{-\lambda t}$

- $\lambda = \frac{\ln|2|}{t_{1/2}}$
- $K = \frac{1}{2}mv^2$
- $U = qV$
- $E_1 = E_2$

Constants

$e = 1.60 \times 10^{-19}$ C

$m_e = 9.11 \times 10^{-31}$ kg

$m_p = 1.67 \times 10^{-27}$ kg

$\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}

$c = 3 \times 10^{8}$ m s^{-1}

$h = 6.63 \times 10^{-34}$ J s

1 eV $= 1.60 \times 10^{-19}$ J

$\epsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}

SI prefixes

Name	Symbol	Base 10
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto	f	10^{-15}

Show all work and draw pictures for full credit!

1. (20 pts.) A beam of charged particles of charge $q = +3$ mC and mass 4 μg are accelerated from rest by passing through a potential difference of -80 V. The charges (moving to the right) then enter a region with uniform magnetic field directed out of the page and uniform electric field $|E| = 1800$ N C^{-1}.

(a) (5 pts.) Calculate the speed of the charged particles as they enter this region.

(b) (5 pts.) What direction must the electric field be oriented in to allow the charges to move through the region undeflected? Why?

(c) (5 pts.) What must the strength of the magnetic field be to allow the charges to move through the region undeflected?

(d) (5 pts.) After traveling a certain distance, the electric field quickly vanishes but the magnetic field remains the same. Describe, thoroughly, the charges' motion in this new region.

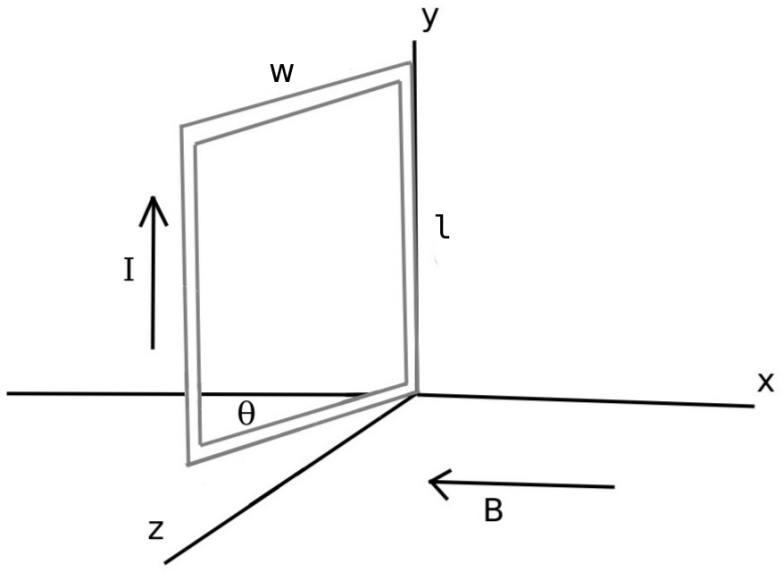
2. (20 pts.) A rigid rectangular loop with dimensions $w = 0.50$ m and $l = 0.40$ m carries a current of 10 A in a region with a uniform magnetic field $B = 0.05$ T in directions indicated in the figure below. At this instant, the bottom segment of the loop is 63 ° to the negative $x-$axis.

(a) **(6 pts.) Calculate the force (magnitude and direction) on each segment at this instant.**

(b) **(6 pts.) Calculate the net torque (magnitude and direction) acting on the loop at this instant.**

(c) **(4 pts.) Calculate the magnetic flux through the loop at this instant.**

(d) **(4 pts.) If the loop rotates such that its base and top segments are aligned with the magnetic field in 0.67 s, find the induced emf in the loop.**



3. (20 pts.) A beam of white light is directed into a prism (like the Pink Floyd album, Dark Side of The Moon). The beam is incident on the prism at an angle of $32\ ^\circ$ from the normal. The index of refraction in this prism is variable, with red light having $n_r = 1.512$, and blue light $n_b = 1.524$.

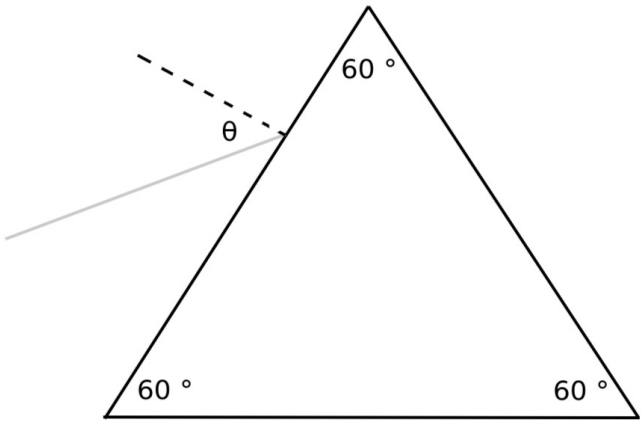
(a) (2 pts.) Calculate the critical angle for red light.

(b) (2 pts.) Calculate the critical angle for blue light.

(c) (6 pts.) Calculate the angle the red light exits the prism.

(d) (6 pts.) Calculate the angle the blue light exits the prism.

(e) (4 pts.) Using your work and answers from parts (c) and (d), sketch the paths taken by the red and blue light.



4. (20 pts.) A 5 mm tall object is placed 32 cm left from a converging lens, with focal length $f_1 = +24$ cm. 16 cm to the right of the converging lens, there's a $f_2 = -16$ cm diverging lens.

(a) (8 pts.) Calculate the final image distance, relative to the diverging lens.

(b) (4 pts.) Is the image upright or inverted?

(c) (4 pts.) Is the image real or virtual?

(d) (4 pts.) Find the height of the image.

5. (20 pts.) Neutral hydrogen is a hydrogen-like atom with 1 proton, and Rydberg constant $R = 1.097 \times 10^7$ m^{-1}.

(a) (6 pts.) Calculate the third and second energy levels, E_3 and E_2, in eV.

(b) (6 pts.) Calculate the wavelength of light emitted for the $n = 3 \to 2$ transition, in nm.

(c) (8 pts.) Now suppose this wavelength of light is passed through a double slit, with unknown distance between slits. You measure the third order bright fringe is at an angle of $\theta = 10.32\ ^\circ$ to the horizontal. What is the separation between the two slits?

Answer Key: (1a) 1.10×10^4 **m s^{-1}; (1b) upwards, F_B is downwards; (1c)** 0.164 **T; (1d) Cyclotron motion,** $R = 8.89$ **cm; (2a) Left:** 0.200 **N in +z, Top:** 0.223 **N in +y,** 0.200 **N in -z,** 0.223 **N in -y (explain directions using RHR); (2b)** 0.0891 **N · m CCW (explain directions using RHR); (2c)** 0.00454 **T m^2; (2d)** 6.78 **mV; (3a)** 41.40 °**; (3b)** 41.01 °**; (3c)** 74.03 °**; (3d)** 76.53 °**; (3e) ...; (4a)** 20 **cm left of diverging lens; (4b) upright; (4c) virtual; (4d)** 3.75 **mm; (5a)** $E_2 = -3.40$ **eV,** $E_3 = -1.51$ **eV; (5b)** 656.3 **nm; (5c)** 11.0 μ**m**