短答问题
(5 分每题)

1. 一块平行侧的冰层浮在水面上。如果光线以 20.0° 的入射角照射上表面，那么在水中的折射角是多少？注意 n_{ice} = 1.30 和 n_{water} = 1.33。

\[ \frac{n_{air}}{\sin(\theta_i)} = \frac{n_{water}}{\sin(\theta_r)} \quad n_{air} \approx 1 \]

\[ \Rightarrow \quad \sin(\theta_r) = \frac{\sin(20.0^\circ)}{1.33} \]

\[ \Rightarrow \quad \theta_r = 14.0^\circ \]

2. 一个固体立方体的边长为 8.00 cm，当测量时它静止。当观测者以 90.0% 的光速看到立方体在移动时，其体积是多少？

\[ V_0 = L_0^3 \quad \text{ONE SIDE IS LENGTH CONTRACTED} \]

\[ \Rightarrow \quad V = L_0^2 L = L_0^3 \sqrt{1 - \frac{v^2}{c^2}} = (8.00 \text{ cm})^3 \sqrt{1 - (0.900)^2} \]

\[ \Rightarrow \quad V = 223 \text{ cm}^3 \]

3. 一束光从空气射入琥珀，入射角为 23.0°，折射角为 14.6°。什么是琥珀的折射率？

\[ \frac{n_{air}}{\sin(\theta_i)} = \frac{n_{amber}}{\sin(\theta_r)} \quad n_{air} \approx 1 \]

\[ \Rightarrow \quad n_{amber} = \frac{\sin(23.0^\circ)}{\sin(14.6^\circ)} \]

\[ \Rightarrow \quad n_{amber} = 1.55 \]
4. An object is placed 7.50 cm in front of a converging lens. What must the lens' focal length be in order for the image to be upright and 50.0% larger than the actual object?

\[ M = +1.50 \quad P = 7.50\, \text{cm} \quad M = \frac{-q}{p} \quad \Rightarrow \quad 1.50 = \frac{-q}{7.50\, \text{cm}} \]

\[ \Rightarrow \quad q = -11.25\, \text{cm} \quad \text{Plug this into:} \quad \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \]

\[ \Rightarrow \quad \frac{1}{7.50\, \text{cm}} + \frac{1}{-11.25\, \text{cm}} = \frac{1}{f} \quad \Rightarrow \quad f = 22.5\, \text{cm} \]

5. How fast must a spacecraft move relative to Earth in order for six months to pass on Earth while its passengers only age six weeks?

\[ \Delta t = \frac{\Delta t'}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \Delta t = 6.00\, \text{months} = 26.07\, \text{weeks} \]

\[ \Delta t' = 6.00\, \text{weeks} \]

Solve for \( v \)...

\[ v = c \sqrt{1 - \left(\frac{\Delta t'}{\Delta t}\right)^2} \]

**Hence**

\[ v = (0.973) \, c \]

6. A particle with charge \( q = 2.60 \times 10^{-9} \, \text{C} \) moves with a velocity \( \vec{v} = 4.50\, \text{m/s} \hat{i} - 8.20\, \text{m/s} \hat{k} \) in a magnetic field \( \vec{B} = 2.00\, \text{T} \hat{j} + 7.00\, \text{T} \hat{j} \). There is also an electric field given by \( \vec{E} = 8.00\, \text{N/C} \hat{i} \) present. If this takes place in a vacuum, and there is no gravity, what is the net force on the particle?

\[ \vec{F} = q (\vec{E} + \vec{v} \times \vec{B}) \]

\[ \vec{v} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 4.50\, \text{m/s} & -8.20\, \text{m/s} & 0 \\ 2.00\, \text{T} & 7.00\, \text{T} & 0 \end{vmatrix} = 57.4\, \text{m/s} \hat{\imath} - 16.4\, \text{m/s} \hat{j} + 31.5\, \hat{k} \]

\[ \Rightarrow \quad \vec{F} = (1.70 \times 10^7) \hat{\imath} - (4.26 \times 10^8) \hat{j} + (8.19 \times 10^8) \hat{k} \]
4. Two long, vertical wires run parallel to one another and are separated by a distance of 12.5 cm. The current in the left wire is 6.20 A and flows upwards. The current in the right wire is 8.40 A and flows downwards. What is the magnitude and direction of the magnetic field at a point located 3.50 cm to the left of the right wire?

\[
\begin{align*}
B_L &= \frac{\mu_0 I_L}{2\pi r_L} = \frac{(4\pi \times 10^{-7}) (6.20)}{2\pi (0.09)} T = 1.38 \times 10^{-5} T \text{ IN} \\
B_R &= \frac{\mu_0 I_R}{2\pi r_R} = \frac{(4\pi \times 10^{-7}) (8.40)}{2\pi (0.035)} T = 4.80 \times 10^{-5} T \text{ IN} \\
\Rightarrow \quad \vec{B} &= B_L + B_R = 6.18 \times 10^{-5} T \text{ IN}
\end{align*}
\]

5. An electron (charge is \( q = -1.60 \times 10^{-19} \) C) moves directly down the negative x-axis (towards the left side of this page) with a speed of 10.0 m/s. Imagine that it does so in a uniform magnetic field pointing straight out of this page towards you. The strength of the magnetic field is \( B = 3.50 \) T. What are the magnitude and direction of the magnetic force on the electron?

\[
F = qvB \sin(\theta)
\]

\[
= (1.6 \times 10^{-19} \text{ C}) (10.0 \text{ m/s}) (3.50 \text{ T}) \sin(\pi/2)
\]

\[
= 5.60 \times 10^{-18} \text{ N}
\]

**Downwards!**

**Use the right hand rule!** OR...

\[
\vec{F} = q \vec{v} \times \vec{B} = (-1.6 \times 10^{-19} \text{ C}) \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ 0 & -10.0 \text{ m/s} & 0 \\ 3.50 \times 10^{-18} \text{ T} & 0 & 0 \end{vmatrix} = -5.60 \times 10^{-18} \text{ N} \hat{z}
\]

**Same answer!**
Problems
(20 Points Each)

1. A circular coil of wire with $N$ loops and a radius $r$ lies flat in the xy-plane with its center at the origin. The wire has an electrical resistance of $R$. A magnetic field pointing along the $z$-axis is present and varies with time according to the formula $B(t) = B_0 \cos(\omega t)$. At $t = 0$ the coiled loops of wire begin to be rotated about the $x$-axis by a crank so that the angle through which the loops have rotated is given by $\theta(t) = \omega t$.

(a) Determine the current induced in the wire as a function of time.

(b) Evaluate the formula you obtained in part (A) for $N = 100$, $r = 7.0$ cm, $R = 0.80$ $\Omega$, $B_0 = 1.8$ T, $\omega = 15$ Rad/s, and $t = 1.5$ s.

(c) Is this DC current or AC current? Explain.

$$
\mathcal{E} = -N \frac{d\Phi_B}{dt} \quad \Phi_B = BA \cos(\theta) \quad I = \frac{V}{R}
$$

\begin{align*}
\text{a)} \quad I &= \frac{-N}{R} \frac{d}{dt} \left[ B_0 \pi r^2 \cos^2(\omega t) \right] = \frac{N \pi B_0 \omega r^2}{R} \left[ \frac{2 \sin(\omega t) \cos(\omega t)}{\sin(2\omega t)} \right] \\
&\Rightarrow I(t) = \frac{N \pi B_0 \omega r^2}{R} \sin(2\omega t)
\end{align*}

\begin{align*}
\text{b)} \quad I(t = 1.5_s) &= \frac{100 \pi (1.8T)(15 m^2)(0.07 m)^2}{(0.80 m)} \sin \left( 30 \text{ rad/s} \cdot 1.5_s \right) \\
&= 44.2 A
\end{align*}

\begin{align*}
\text{c)} \quad \text{AC current!}
\end{align*}
2. A diverging lens of focal length 7.50 cm forms an image of an angry hornet. Determine the image’s location, orientation, and magnification for the following scenarios:

(a) When the hornet is located 27.0 cm in front of the lens.

(b) When the hornet is located 4.50 cm in front of the lens.

(c) When the hornet is really, really far away from the lens.

(d) Repeat part (a) but for a converging lens instead of a diverging lens.

General Formula: \( \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow q = \frac{pf}{p-f} \)

\( a) \quad p = 27.0 \text{ cm}, \quad f = -7.50 \text{ cm} \Rightarrow \quad q = -5.87 \text{ cm}, \quad M = 0.217 \)

\( b) \quad p = 4.50 \text{ cm}, \quad f = -7.50 \text{ cm} \Rightarrow \quad q = -2.81 \text{ cm}, \quad M = 0.625 \)

\( c) \quad p \to \infty \Rightarrow \quad \frac{1}{p} \to 0 \quad \text{so...} \quad \frac{1}{q} = \frac{1}{f} \Rightarrow \quad q = f \)

Hence, \( q = -7.5 \text{ cm} \) and \( M = \frac{-q}{p} \to 0 \) \text{ Image / No Zero Size} \)

\( d) \quad \text{Now} \quad f = +7.50 \text{ cm} \Rightarrow \quad q = 10.4 \text{ cm}, \quad M = -0.385 \)
3. Space Station Zig and space station Zubarg are approximately at rest with respect to one another and are separated by a distance of $7.8 \times 10^{10}$ km (in their frame). A transport ship leaves Zig and travels at 98% the speed of light towards Zubarg.

(a) How long does it take the ship to get to Zubarg from the perspective of the people living on Zubarg?

(b) How long does it take the ship to get to Zubarg from the perspective of the people on the transport ship?

\[ \Delta t = \Delta t' \]

\[ (0.98)(3.00 \times 10^8) \Delta t = (7.8 \times 10^8) \]

\[ \Rightarrow \Delta t = 2.6 \times 10^5 \text{ s} \approx 3 \text{ years} \]

\[ \Delta t = \frac{\Delta t'}{\sqrt{1 - \frac{v^2}{c^2}}} \]

\[ \Rightarrow \Delta t' = \Delta t \sqrt{1 - \frac{v^2}{c^2}} \]

\[ \text{Hence: } \Delta t' = (2.6 \times 10^5) \sqrt{1 - (0.98)^2} \]

\[ \Rightarrow \Delta t' = 5.3 \times 10^4 \text{ s} \approx 15 \text{ hours} \]