Name______________________________

Apr. 4, 2002

10 am   11 am

Phys 2020 — Spring 2002
Exam #2

1.	________________	(8)
2.	________________	(9)
3.	________________	(13)
4.	________________	(10)
5.	________________	(9)
6.	________________	(8)
7.	________________	(13)
8.	________________	(10)
MC	________________	(20)
Total	________________	(100)

$$c = 2.998 \times 10^8\ \tfrac{\text{m}}{\text{s}} \qquad 1\ \text{nm} = 10^{-9}\ \text{m} \qquad \epsilon_0 = 8.854 \times 10^{-12}\ \tfrac{\text{C}^2}{\text{N}\cdot\text{m}^2} \qquad \mu_0 = 4\pi \times 10^{-7}\ \tfrac{\text{T}\cdot\text{m}}{\text{A}}$$

$$W = Pt \qquad R = \rho\frac{L}{A} \qquad V = IR \qquad P = VI = I^2R$$

$$F = qvB\sin\theta \qquad F = ILB\sin\theta \qquad B = \frac{\mu_0 I}{2\pi r} \qquad \frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r}$$

$$\Phi = BA\cos\phi \qquad \mathcal{E} = -N\frac{\Delta\Phi}{\Delta t} \qquad \mathcal{E} = -L\frac{\Delta I}{\Delta t} \qquad \mathcal{E}_{\text{max}} = NAB\omega$$

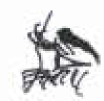
$$\lambda f = c \qquad \overline{S} = \tfrac{1}{2}c\epsilon_0 E_0^2 = \frac{c}{2\mu_0}B_0^2 \qquad \overline{S}_{\text{pol}} = \tfrac{1}{2}\overline{S}_{\text{unpol}} \qquad \overline{S} = \overline{S}_0\cos^2\theta$$

$$|f| = \frac{R}{2} \qquad \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \qquad n = \frac{c}{v}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2 \qquad \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

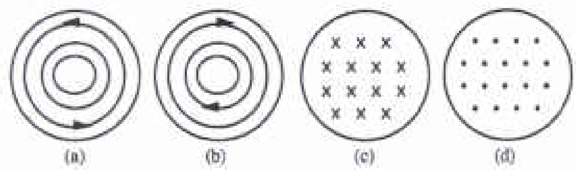
Multiple Choice

Pick the best answer from among the four.



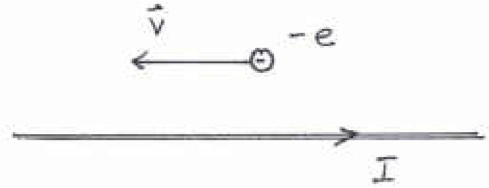
1. A long wire carries that a current I is bent into five concentric loops as shown here. If Jan could "see" the magnetic field inside this arrangement of loops, how would it appear?

a)
b)
c)
d)



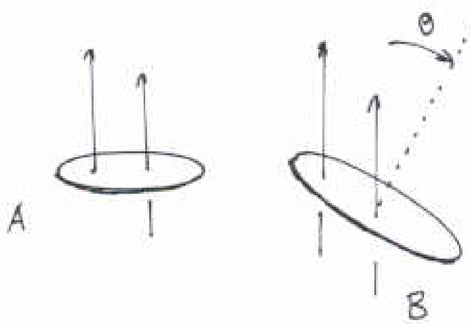
2. A long straight current–carrying wire is in the plane of the page, with the direction of the current as shown; a particle with charge $-e$ has a velocity in the plane of the page, as shown. The direction of the force on the particle is

a) Up.
b) Down.
c) Into the page.
d) Out of the page.



3. Two conducting loops (single-turn, planar) are in a uniform magnetic field whose direction is perpendicular to the plane of loop A. Loop B has twice the area of A. The flux through both loops is the same. The angle that the field makes with the normal to loop B is

a) 15°
b) 30°
c) 45°
d) 60°



4. The units for the intensity S of an electromagnetic wave is (are):

a) $\frac{\mathrm{J}}{\mathrm{s}}$
b) $\frac{\mathrm{J}}{\mathrm{m}^2}$
c) $\frac{\mathrm{W}}{\mathrm{s}}$
d) $\frac{\mathrm{W}}{\mathrm{m}^2}$

5. Which one of the following is a possible wavelength for visible light?

a) 0.490 mm
b) 490 nm
c) 0.490 nm
d) 4.90×10^{-12} m

6. When doing ray tracing for spherical mirrors, the ray which goes along a line which connects to the center of curvature

a) Goes back along the same line.

b) Goes back out along a line parallel to the principal axis.

c) Goes back out along the principal axis itself.

d) Goes back out along a line which connects to the focal point.

7. The SI ("physics") unit of (self-) inductance is the

a) Debye

b) Weber

c) Henry

d) Oersted

8. When a convex mirror forms an image from an object, the image is:

a) Always Virtual and Upright

b) Always Real and Upright.

c) Possibly Virtual or Real, and Upright.

d) Possibly Virtual or Real and Inverted.

9. For a beam of light passing from air ($n = 1.000$) to water ($n = 1.333$) the critical angle is

a) $24.3°$.

b) $45.0°$.

c) $48.6°$.

d) None of these.

10. If, for rays passing from plastic to air, the critical angle is $45°$, the index of refraction of the plastic is:

a) 1.250

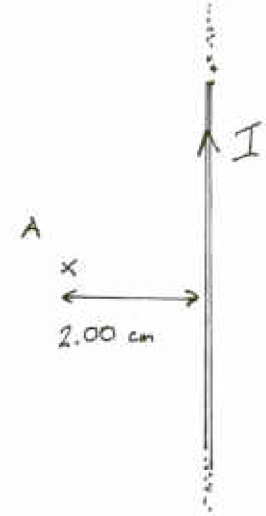
b) 1.414

c) 1.333

d) 2.000

Problems

1. A long straight wire lies in the plane of the page with a current flowing in the direction shown.



a) What is the direction of the magnetic field at point A? (2)

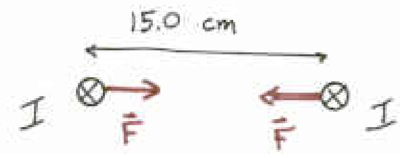
Out of the page (by RHR-2).

b) If the magnitude of the magnetic field at A is 0.010 T and A is 2.00 cm from the wire, what is the current in the wire? (6)

From $B = \frac{\mu_0 I}{2\pi r}$, solve for I:

$$I = \frac{2\pi r B}{\mu_0} = \frac{2\cancel{\pi}(2.00\times10^{-2}\,m)(0.010\,T)}{{}_2\cancel{4}\cancel{\pi}\times10^{-7}\,T.m/A} = 1.0\times10^{3}\,A \quad (!)$$

2. Two infinite straight parallel wires each carry a current directed into the paper. The wires are separated by a distance of 15.0 cm and each carries a current of 4.00 A.



a) On the figure, draw the direction of the force on each wire. (3)

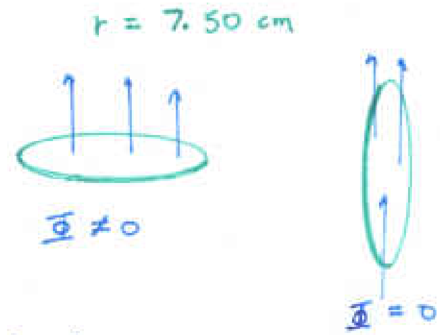
Parallel currents attract!

b) Find the magnitude of the force per unit length between the two wires. (6)

(Use formula for F/L for the parallel currents on 1st page:)

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi\, r} = \frac{(\overset{2}{\cancel{4}}\pi\times10^{-7}\,\frac{T.m}{A})(4.00\,A)^2}{\cancel{2}\pi\,(0.150\,m)} = 2.13\times10^{-5}\,\frac{N}{m}$$

3. A circular–loop coil with 100 turns and a diameter of 15.0 cm is initially aligned to that its axis is parallel to a uniform magnetic field of magnitude 0.200 T. In 2.0 ms the coil is flipped to that its axis is perpendicular to the magnetic field.



a) What is the average induced emf during the time that the coil is being flipped? (6)

Final flux is zero, so change in flux has magnitude

$$|\Delta \Phi| = B \cdot A \cdot 1 = (0.200\,T)\,\pi\,(7.50 \times 10^{-2}\,m)^2 = 3.53 \times 10^{-3}\,T \cdot m^2$$

Avg induced emf has magnitude:

$$\mathcal{E}_{avg} = N \frac{\Delta \Phi}{\Delta t} = (100)\frac{(3.53 \times 10^{-3}\,T \cdot m^2)}{(2.0 \times 10^{-3}\,s)} = 178\,V$$

b) What is the (average) induced current in the coil? (3) Use $R_{coil} = 10\,\Omega$!

$$I_{avg} = \frac{\mathcal{E}_{avg}}{R} = \frac{178\,V}{10\,\Omega} = 17.8\,A$$

c) How much electric energy is lost in the process? (4)

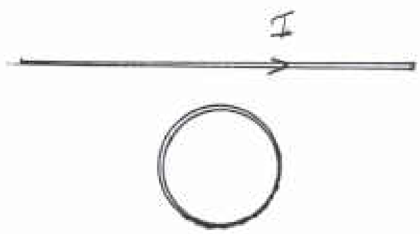
Avg power dissipated is

$$\overline{P} = I^2 R = (17.8\,A)^2 (10\,\Omega) = 3.12 \times 10^3\,W$$

Energy lost is

$$= \overline{P} t = (3.12 \times 10^3\,W)(2.0 \times 10^{-3}\,s) = 6.25\,J$$

4. Shown here are a long straight wire carrying a constant current in the direction shown, and a conducting loop, both in the plane of the page.

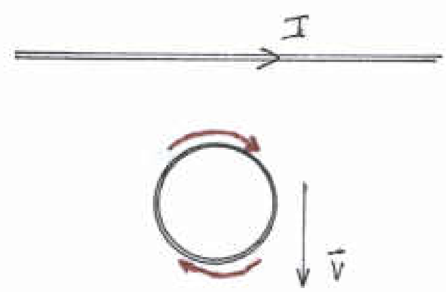


a) What is the direction of the magnetic field (due to the wire) for points inside the loop?(2)

Into the page !

b) Now suppose the loop is moving away from the wire. Give the sense (direction) of the flux through the loop and how it is changing. (4)

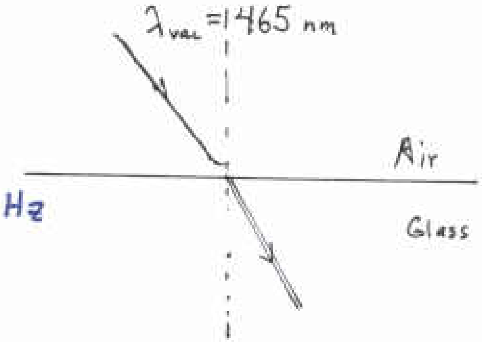
Since magnetic field decreases in strength as we move away from the wire, the magnetic flux (as taken in the dir. into the page) is decreasing.



c) Indicate the direction of the current induced in the loop while it is being moved. Be sure to include the *reason* for your choice. (5)

From 'Lenz's Law' and part (b) the induced current must produce a flux into the page (to oppose the change given in (b). By RHR-2, the current indicated (clockwise) gives such a flux.

5. A beam of monochromatic light of (vacuum) wavelength 465 nm enters a block of glass with index of refraction 1.55



a) What is the frequency of the light? (3)

$$f = \frac{c}{\lambda_{vac}} = \frac{(2.998 \times 10^8 \, \text{m/s})}{(465 \times 10^{-9} \, \text{m})} = 6.45 \times 10^{14} \, \text{Hz}$$

b) What is the speed of light inside the glass? (3)

From $n = c/v$,

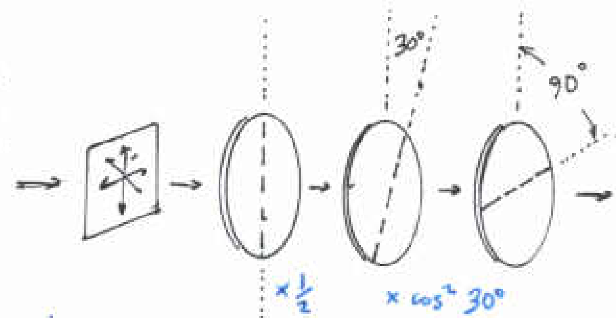
$$v = c/n = \frac{2.998 \times 10^8 \, \text{m/s}}{1.55} = 1.93 \times 10^8 \, \text{m/s}$$

c) What is the wavelength of the light inside the glass? (3)

Frequency is the same as given in (a), so

$$\lambda_{glass} = \frac{v}{f} = \frac{1.93 \times 10^8 \, \text{m/s}}{6.45 \times 10^{14} \, 1/\text{s}} = 3.00 \times 10^{-7} \, \text{m} = 300 \, \text{nm}$$

6. Unpolarized light is incident on a polarizer. The beam then passes through an analyzer whose axis is rotated 30° from that of the polarizer and then through another analyzer whose axis is rotated 90° from the direction of the (first) polarizer.



a) What fraction of the original light intensity gets through the first ~~polarizer~~ analyzer! (tilted at 30°)? (4)

Polarizer (first polaroid) transmits $\frac{1}{2}$ the intensity and polarizes the light vertically. First analyzer transmits $\times \cos^2 30°$ and polarizes the light along axis at 30°.

A this point the initial intensity has been reduced by a factor of

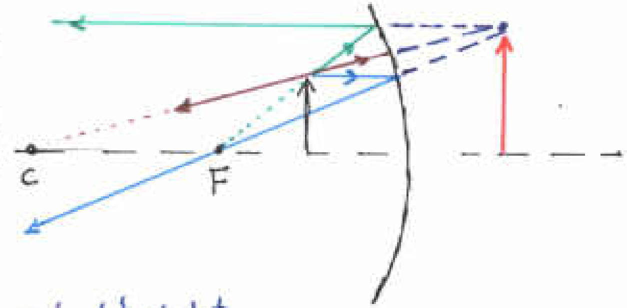
$$\times \frac{1}{2} \times \cos^2 30° = 0.375 = 37.5\,\%$$

b) What fraction of the original light intensity gets through the second polarizer (tilted at 90°)? (4)

The next analyzer is tilted at $90° - 30° = 60°$ from the previous one. So the intensity is further reduced by a factor of $\cos^2 60° = 0.250$ (and the light is polarized along axis at 90°). Fraction of original intensity is now

$$\frac{1}{2} \times \cos^2 30° \times \cos^2 60° = (0.375)(0.250) = 0.094$$
$$= 9.4\,\%$$

7. Shown here is a concave mirror with its center of curvature and focal point and an object (the arrow).



Find out the location, size and orientation of the image by tracing rays on this figure. You need only include enough rays to answer the question). (6)

b) Is the image real or virtual? Upright or Inverted? (3)

As seen from the ray diagram, image is Virtual and Upright.

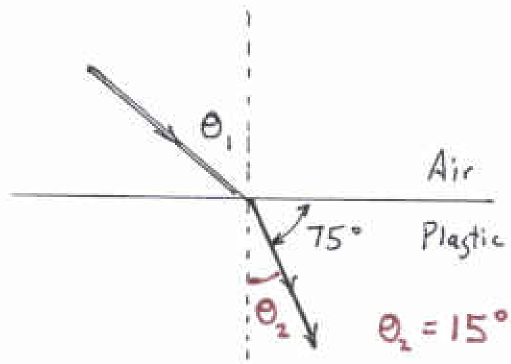
c) Suppose the focal length of the mirror is 20.0 cm and the object is 10.0 cm in front of the mirror. What is the location of the image? (4)

With $f = 20.0\text{ cm}$ and $d_o = 10.0\text{ cm}$ then from $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$,

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{(20.0\text{ cm})} - \frac{1}{(10.0\text{ cm})} = -5.0\times10^{-2}\text{ cm}^{-1}$$

$d_i = -20.0\text{ cm}$ i.e. 20 cm behind mirror

8. A beam of laser light enters a block of plastic with $n = 1.52$ (from air) such that *the angle shown* is 75°.



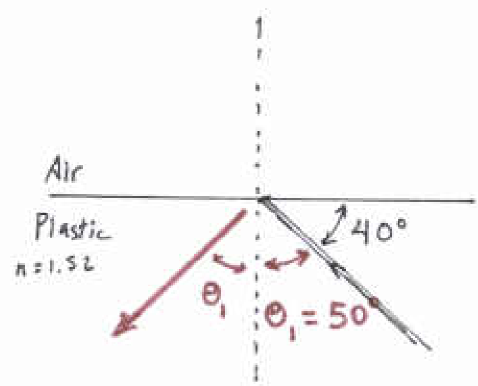
a) What was the angle of incidence, θ_1? (5)

The refraction angle in the plastic is $\theta_2 = 15°$.
Then from $n_1 \sin\theta_1 = n_2 \sin\theta_2$, get:

$$\sin\theta_1 = \frac{n_2}{n_1}\sin\theta_2 = \frac{1.52}{1.00}\sin 15° = 0.393$$

$$\longrightarrow \theta_1 = 23.2°$$

b) Tell what happens to a beam which originates in the plastic such that the angle shown is 40.0°. Be sure to include your reasoning! (5)



The angle of incidence is $\theta_1 = 50°$.
The critical angle for the plastic (in air) is

$$\theta_c = \sin^{-1}\left(\frac{1.00}{1.52}\right) = 41.1°$$

Our angle of incidence is larger than this, so all of the light is ("internally") reflected back into the plastic (at an angle $\theta_1 = 50°$) with none transmitted to the air.