Name______________________________

Dec. 11, 2002

Phys 2020 — Fall 2002
Exam #3

1.	________________	(13)
2.	________________	(17)
3.	________________	(11)
4.	________________	(9)
5.	________________	(5)
6.	________________	(6)
7.	________________	(6)
8.	________________	(6)
9.	________________	(7)
MC	________________	(20)
Total	________________	(100)

Multiple Choice Chose the best answer from the four.

1. An α particle (a $^4_2$He nucleus) is accelerated from rest through a potential difference of 1000 V. Its final kinetic energy is

a) 250 eV
b) 500 eV
c) 1000 eV
d) 2000 eV

2. A convex lens produces an image which is

a) Always real.

b) Always virtual.

c) Can be real or virtual, for *any* convex lens.

d) Answer depends on the focal length of the convex lens.

3. When a beam of monochromatic light passes from air into some transparent material with $n > 1$,

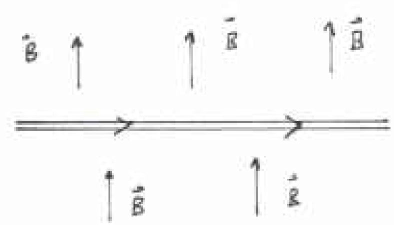
a) Only the frequency of the light is the same as it was in the air.

b) Only the wavelength of the light was the same as it was in the air.

c) Both the frequency and wavelength of the light are the same as they were in the air.

d) Neither the frequency nor the wavelength of the light are the same as they were in the air.

4. A long straight wire carries a current to the right, within a uniform magnetic field directed "up" (as shown). The force on the wire is directed



a) Out of the page.

b) Into the page.

c) To the left.

d) To the right.

5. A beam of light goes from air to glass at an angle of incidence of 50°. What happens to the beam?

a) It is all transmitted.

b) It is all reflected.

c) Some is transmitted and some is reflected.

d) We cannot say without knowing n for the glass.

6. Einstein's explanation of the photoelectric effect used the idea of

a) The wave nature of electrons.

b) The particle nature of light.

c) The quantization of electric current.

d) The quantization of orbital angular momentum.

7. X-rays are normally produced by

a) Transitions made by protons (within the nucleus).

b) Transitions made by neutrons (within the nucleus).

c) Transitions made by "inner–shell" electrons.

d) Transitions made by "outer–shell" electrons.

8. When the nucleus $^{241}_{95}\mathrm{Am}$ undergoes α decay, the daughter nucleus is

a) $^{241}_{96}\mathrm{Cm}$

b) $^{241}_{94}\mathrm{Pu}$

c) $^{237}_{93}\mathrm{Np}$

d) $^{245}_{97}\mathrm{Bk}$

9. When the nucleus $^{16}_{7}\mathrm{N}$ undergoes β^- decay, the daughter nucleus is

a) $^{16}_{8}\mathrm{O}$

b) $^{16}_{6}\mathrm{C}$

c) $^{18}_{8}\mathrm{O}$

d) $^{14}_{6}\mathrm{C}$

10. Carbon–14 dating is useful for artifacts with a maximum age of

a) 400 years.

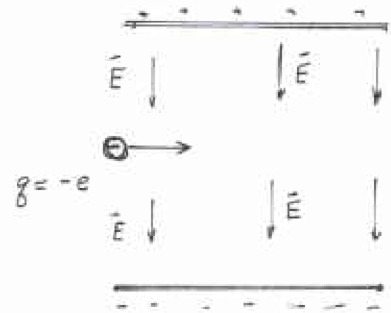
b) 40,000 years.

c) 4 million years.

d) 400 million years.

Problems

1. An ion with a single negative charge ($-e$) moves through a region where there are both electric and magnetic fields. As shown at the right, the ion moves to the right with speed v, and the electric field (which has magnitude 5.00×10^4 N/C) points "down".



(Also a magnetic field.)

a) What is the direction of the electric force on the ion? (2)

From $\vec{F} = q\vec{E}$, if q is negative, $\vec{F}$ points opposite to the $\vec{E}$ field:

Force on the ion is $\boxed{\text{upward}}$.

b) What is the magnitude of the electric force on the ion? (3)

$$|\vec{F}| = |q\vec{E}| = (1.602 \times 10^{-19}\,C)(5.00 \times 10^4\,N/C)$$

$$= \boxed{8.0 \times 10^{-15}\,N}$$

c) The magnetic field is perpendicular to the ion's velocity and is such that it cancels the electric force on the ion. What is the direction of the magnetic field? (3)

The magnetic force needs to go downward. From RHR-1 (remembering that this is a negative charge!) we see that if the $\vec{B}$ field points $\boxed{\text{into the page}}$ then the mag. force is downward.

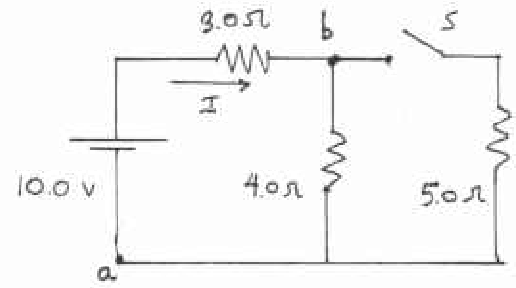
d) The magnitude of the magnetic force is the same as that of the electric force. If the magnetic field has magnitude 0.250 T, what is the speed of the ion? (5)

The magnitudes of the forces are equal, so

$eE = evB$; the charge e cancels! So:

$$v = \frac{E}{B} = \frac{(5.00 \times 10^4\,N/C)}{(0.250\,T)} = \boxed{2.0 \times 10^5\,m/s}$$

$\vec{v}$ is perp to $\vec{B}$ so $|\vec{F}_{mag}| = |qvB|$



2. In the circuit at the right the switch is initially open.

a) What is the (equivalent) resistance of the circuit? (3)

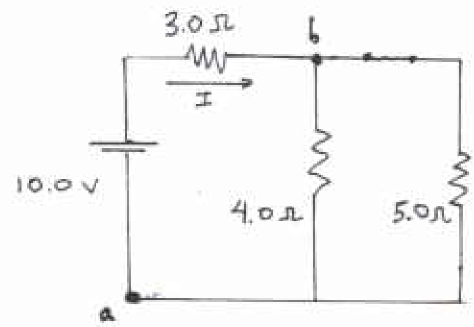
With S open the 5.0Ω resistor is not in the circuit, just the series comb. of 3.0Ω and 4.0Ω, so:

$$R_{eq} = 3.0\Omega + 4.0\Omega = \boxed{7.0\,\Omega}$$

b) What is the current through the 3.0 Ω resistor? (3)

Current in the 3.0Ω is the total current, so:

$$I = \frac{V}{R_{eq}} = \frac{10.0\text{ V}}{7.0\,\Omega} = \boxed{1.43\text{ A}}$$



c) Now the switch is closed. What is the equivalent resistance of the circuit now? (4)

Now 4.0Ω and 5.0Ω are in parallel with that comb. in series w/ 3.0Ω resistor. Thus:

$$R_{4,5} = \left(\frac{1}{4\Omega} + \frac{1}{5\Omega}\right)^{-1} = 2.22\,\Omega$$

$$R_{eq} = 3.0\Omega + 2.2\Omega = \boxed{5.2\,\Omega}$$

d) What is the (new) current through the 3.0 Ω resistor? (3)

Now the (total) current is:

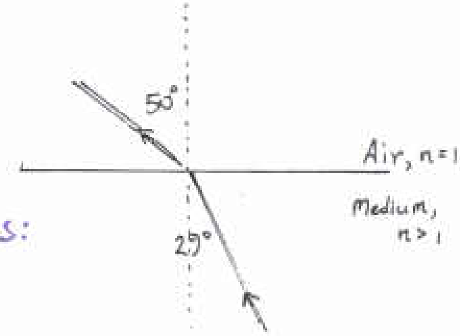
$$I = \frac{V}{R_{eq}} = \frac{10.0\text{ V}}{5.2\,\Omega} = \boxed{1.9\text{ A}}$$

e) What is the potential difference between points a and b? (4)

Going from a to b there is a +10.0V change across the battery and a $-IR = -(1.9\text{A})(3\Omega) = -5.7\text{ V}$ change across the 3.0Ω resistor. Total potential difference is

$$10.0\text{V} - 5.7\text{ V} = \boxed{+4.26\text{ V}}$$

3. A light ray passes from a transparent medium into air. The angles the ray makes with the surface are as shown.



a) What is the index of refraction of the medium? (4)

With 1 = medium & 2 = air, Snell's $n_1 \sin\theta_1 = n_2 \sin\theta_2$ gives:

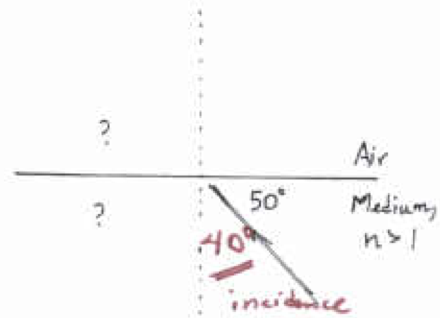
$$n \sin 25° = 1 \sin 50°$$

$$n = \frac{\sin 50°}{\sin 25°} = \boxed{1.58}$$

b) What is the speed of light in the medium? (3)

From $n = \frac{c}{v}$, $v = c/n$ so

$$v = \frac{3.00\times10^{8}\,\text{m/s}}{1.58} = \boxed{1.90\times10^{8}\,\text{m/s}}$$

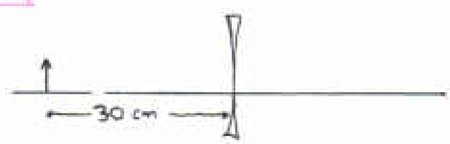


c) If the beam of light is incident at the angle shown at the right, tell what happens to the light ray and carefully explain *how you know this.* (4)

The critical angle for medium → air is

$\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1}{1.58}\right) = \boxed{39.2°}$. But here the incidence angle is $\boxed{40°}$, bigger! The ray is $\boxed{\text{totally reflected.}}$

4. An object sits in front of a *diverging* (concave) lens of focal length −20.0 cm. The distance from the object to the lens is 30.0 cm.



a) Find the the location of the image. State *explicitly* whether the image is on the left or the right side of the lens. (5)

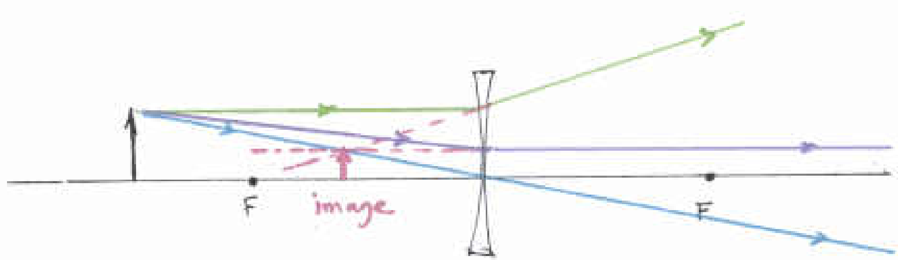
With $d_o = 30.0$ cm, $f = -20.0$ cm we find:

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{(-20.0\,\text{cm})} - \frac{1}{(30.0\,\text{cm})} = -8.3\times10^{-2}\,\text{cm}^{-1} \Rightarrow d_i = \boxed{-12.0\ \text{cm}}$$

The ⊖ tells us the image is on the $\boxed{\text{left}}$ side of the lens

b) The situation with lens and object given part (a) is shown here. Draw a ray diagram illustrating the location of the image. Do it clearly; if you did part (a) correctly, you know what the result should be! (4)

Tracing rays as is proper for a diverging lens, we find the location of the image:



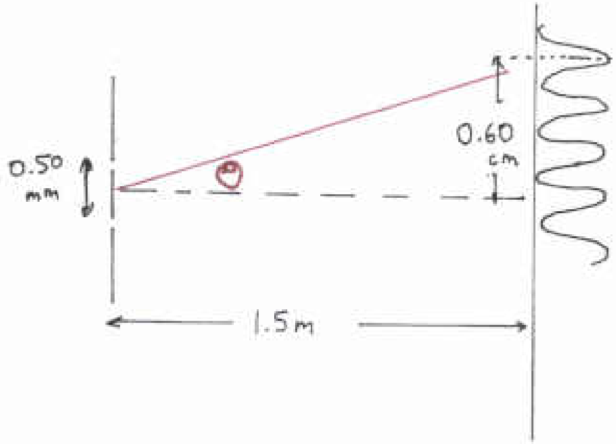
5. Explain how glasses help a nearsighted person (person who has trouble seeing things far away).

Your brief explanation should describe what the lens does and should contain the words "infinity" and "far point". (5)

The proper lens for a nearsighted person should take an object located at infinity and make an image at the person's far point [the max distance at which person can focus things]. With such a lens all distant objects can be seen properly.

6. In an (ideal) two–slit experiment, a screen with two slits separated by 0.50 mm is illuminated by monochromatic coherent light; a pattern of fringes appears on a wall 1.50 m away.

The central bright fringe and the third bright fringe are separated by 0.60 cm. What is the wavelength of the incident light? (6)

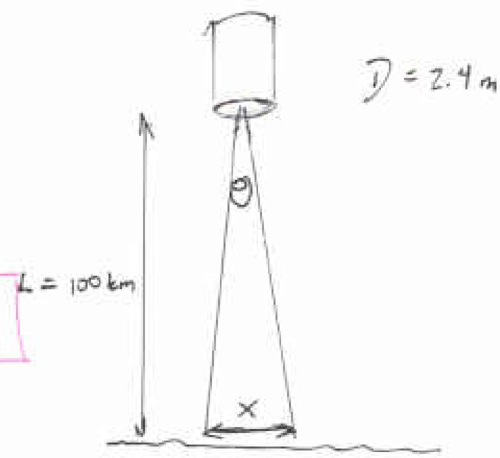


Angle θ is $\theta = \tan^{-1}\left(\frac{0.60\times10^{-2}}{1.5}\right) = 0.229°$

$\sin\theta = 4.00\times10^{-3} = m\lambda/d = 3\frac{\lambda}{(0.50\times10^{-3}m)}$

So: $\lambda = \frac{(0.50\times10^{-3}m)(4.00\times10^{-3})}{3} = 6.67\times10^{-7}m = \boxed{667\ nm}$

7. Suppose the Hubble telescope, 2.4 m in diameter and in orbit 100 km above the Earth's surface, is turned at the Earth, to observe light of wavelength 500 nm . (We ignore the effects of the atmosphere.)



a) What is the smallest angle of separation for two points of light which it can resolve? (3)

$\theta_{min} = \sin^{-1}\left[(1.22)\frac{(500\times10^{-9}m)}{(2.4\ m)}\right] = \boxed{1.5\times10^{-5}\ deg}$

b) What is smallest linear separation x for objects on the ground which the telescope can resolve? (3)

Hint: $\sin\theta \approx x/L$

$\sin\theta_{min} \approx \frac{x}{L} = \frac{x}{(100\times10^{3}m)}$

This gives:

$x = (100\times10^{3}m)\sin(1.5\times10^{-5}deg) = 2.54\times10^{-2}m = \boxed{2.54\ cm}$

$= \boxed{1\ inch}$!

8. Find the energy of the photon emitted when the electron in a hydrogen atom makes a transition from level 10 to level 5. (6)

$$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{10^2}\right) = (1.097\times 10^7\,m^{-1})\left(\frac{1}{25} - \frac{1}{100}\right) = 3.3\times 10^5\,m^{-1}$$

$$\lambda = 3.0\times 10^{-6}\,m$$

$$E = hf = h\frac{c}{\lambda} = (6.626\times 10^{-34}\,J\cdot s)\frac{(3.00\times 10^8\,m/s)}{(3.0\times 10^{-6}\,m)} = \boxed{6.5\times 10^{-20}\,J}$$

$$= \boxed{0.41\,eV}$$

9. The hydrogen isotope tritium (^3_1H) has one proton and two neutrons. It is not stable and decays with at half-life of 12.3 years.

a) Find the the decay constant for tritium. Hint: You don't need to work in seconds: You can express the answer in s^{-1} or $year^{-1}$.) (2)

From $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$, $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$, so:

$$\lambda = \frac{\ln 2}{(12.3\,yr)} = \boxed{5.6\times 10^{-2}\,yr^{-1}}$$

b) If we start with a sample of 1.0×10^{20} tritium nuclei, how many are left after 50.0 years? (5)

$$N = N_0 e^{-\lambda t}$$

$$= (1.0\times 10^{20})\exp\left(-(5.6\times 10^{-2}\,yr^{-1})(50.0\,yr)\right)$$

$$= \boxed{6.0\times 10^{18}}$$

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

$$e = 1.602 \times 10^{-19}\,\mathrm{C} \qquad 1\,\mathrm{eV} = 1.602 \times 10^{-19}\,\mathrm{J} \qquad m_e = 9.109 \times 10^{-31}\,\mathrm{kg}$$

$$1\,\mathrm{year} = 3.16 \times 10^7\,\mathrm{s} \qquad 1\,\mathrm{amu} = 1.661 \times 10^{-27}\,\mathrm{kg} \qquad h = 6.626 \times 10^{-34}\,\mathrm{J\cdot s}$$

$$\mathbf{F} = m\mathbf{a} \qquad g = 9.80\,\tfrac{\mathrm{m}}{\mathrm{s}^2} \qquad F_c = \frac{mv^2}{r} \qquad A = \pi r^2$$

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \,\tfrac{\mathrm{N\cdot m}^2}{\mathrm{C}^2} \qquad \epsilon_0 = 8.85 \times 10^{-12} \,\tfrac{\mathrm{C}^2}{\mathrm{N\cdot m}^2} \qquad F = k\frac{|q_1 q_2|}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{|q_1 q_2|}{r^2}$$

$$A_{\mathrm{circle}} = \pi r^2 \qquad \mathrm{Energy} = Pt \qquad |E_x| = \left|\frac{\Delta V}{\Delta x}\right| \qquad q = CV \qquad C = \frac{\epsilon_0 A}{d} \qquad \mathrm{Energy} = \tfrac{1}{2}CV^2$$

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

$$R_{\mathrm{ser}} = R_1 + R_2 + \ldots \qquad \frac{1}{R_{\mathrm{par}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

$$F = qvB\sin\theta \qquad F = ILB\sin\theta \qquad r = \frac{mv}{qB} \qquad m = \left(\frac{qr^2}{2V}\right)$$

$$B = \frac{\mu_0 I}{2\pi r} \qquad \frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r} \qquad B_{\mathrm{coil}} = \frac{N\mu_0 I}{2R} \qquad B_{\mathrm{sol}} = \mu_0 n I$$

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

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

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

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

$$\sin\theta_{\mathrm{br}} = m\frac{\lambda}{d} \qquad \sin\theta_{\mathrm{dark}} = \left(m + \tfrac{1}{2}\right)\frac{\lambda}{d} \qquad m = 0, 1, 2, 3, \ldots$$

$$\sin\theta_{\mathrm{dark}} = m\frac{\lambda}{w} \qquad m = 1, 2, 3, \ldots \qquad \sin\theta_{\mathrm{min}} = (1.22)\frac{\lambda}{D}$$

Small-angle approx: $\theta(\mathrm{rad}) \approx \sin\theta \approx \tan\theta$

$$\lambda f = c \qquad E_{\mathrm{phot}} = hf = \frac{hc}{\lambda} \qquad \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad R = 1.097 \times 10^7\,\mathrm{m}^{-1}$$

$$\mathrm{BE} = (\Delta m)c^2 \qquad \frac{\Delta N}{\Delta t} = -\lambda N \qquad N = N_0 e^{-\lambda t} \qquad T_{1/2} = \frac{\ln 2}{\lambda}$$

$$\alpha = {}^4_2\mathrm{He} \qquad \beta = \mathrm{electron} \qquad \gamma = \mathrm{photon} \qquad T_{1/2}({}^{14}_{6}\mathrm{C}) = 5730\,\mathrm{year}$$