$\bar{x} = 85$
$s = 11$

NAME KEY

PHYSICS 203 **EXAM #2**
19 November 2013

General Instructions: For each problem your solution must be readable and your logic followable. Put a box around any numerical answers.

Constants: $\mu_0 = 1.26 \times 10^{-6}$ H/m $e = 1.60 \times 10^{-19}$ C $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m
$c = 3.00 \times 10^8$ m/s $n_{water} = 1.33$ $n_{air} = 1.00$ $n_{diamond} = 2.42$
Prefixes: $c = 10^{-2}$ $m = 10^{-3}$ $\mu = 10^{-6}$ $n = 10^{-9}$

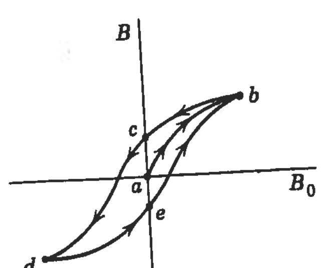
PART I - SHORT ANSWER QUESTIONS.
Do the 5 short questions/problems. Worth 8 points each.

1. A slab of diamond in placed in water. If a light ray reaches the interface at the critical angle for total internal reflection:
   2pts a) Does the ray reach the interface from the water side or from the diamond side?
   6pts b) What is the critical angle?

a) If $\theta_{incident} = \theta_{critical}$, the refracted ray is at 90°. Snells law becomes $n_1 \sin\theta_c = n_2 \sin 90°$ or $\sin\theta_c = \frac{n_2}{n_1}$. Since $\sin\theta_c \le 1$, $n_2 \le n_1$ & so ray starts from the diamond side

b) $\theta_c = \sin^{-1}\frac{n_{wat}}{n_{dia}} = \sin^{-1}\frac{1.33}{2.42} = \boxed{33.3°}$

2. The magnetization curve for a ferromagnetic material is shown below.
   a) If the sample is in the state indicated by point 'a' and an external field brings it to 'b', why doesn't the sample return to 'a' when the external field is reduced to zero?
   b) What is the significance of the point labeled 'c'?



a) When an external field (B_0) is applied to a ferromagnet domains with magnetization parallel to it tend to grow. When B_0 is reduced to zero, not all of the domains/dipoles randomized, leaving the sample with a net magnetic moment.

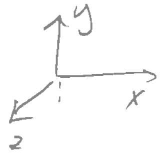
b) Point c indicates the remaining field due to domain alignment after the process described in part a).

3. The magnetic field portion of an electromagnetic wave is given by:

$B_y = (8.5\ \text{nT}) \cos[\pi(10^{15})(t - x/c)]$ with t in seconds and x in meters.

3 pts a) If this wave travels in the +x direction, what direction does the electric field point at a time when the magnetic field points in the –y direction?

5 pts b) If the electromagnetic wave hits a polarizer which has its polarization axis oriented at 30^0 from the y axis, what fraction of the incident wave's intensity makes it through?



a) If $\vec{B}$ points in the –y dir, $\vec{E}$ points in the +z direction since $\vec{E} \times \vec{B}$ points in the wave travel direction.

b) If 30° from the y-axis, polarizer is oriented at 60° from $\vec{E}$'s direction. $I = I_0 \cos^2 60° = \frac{1}{4} I_0$

$\frac{I}{I_0} = \frac{1}{4}$

4. What is scientism?

It is the philosophical point of view that truth can only be obtained by scientific methods.

5. A circuit includes a parallel plate capacitor with circular plates of radius R = 3.50 cm and plate separation of 0.22 cm. A time dependent potential given by: $V = (100\ \text{V}) \sin[(120\pi\ \text{s}^{-1})t]$ appears across the plates. What is the maximum value of $\oint \boldsymbol{B} \cdot \boldsymbol{ds}$ for a circular loop of radius R centered between the plates and parallel to them?

$\oint \vec{B} \cdot d\vec{s} = \mu_0 i + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$ $i = 0$ between the plates so

$\oint \vec{B} \cdot d\vec{s} = \mu_0 \varepsilon_0 \frac{d\,EA}{dt} = \mu_0 \varepsilon_0 \pi R^2 \frac{d}{dt} V/d = \frac{\mu_0 \varepsilon_0 \pi R^2}{d} \frac{dV}{dt}$

$= \frac{\mu_0 \varepsilon_0 \pi R^2}{d} (100\text{V})(120\pi\ \text{s}^{-1}) \cos(120\pi t)$ $\mu_0 \varepsilon_0 = \frac{1}{c^2}$

max is when $\cos(120\pi t) = 1$ so

$\oint \vec{B} \cdot d\vec{s}_{max} = \frac{\mu_0 \varepsilon_0 \pi R^2}{d} (100\text{V})(120\pi\ \text{s}^{-1}) = \frac{\pi(.035\text{m})^2(100\text{V})(120\pi\ \text{s}^{-1})}{(3.0 \times 10^8 \frac{\text{m}}{\text{s}})^2 (0.0022\text{m})}$

$= 7.33 \times 10^{-13}\ \text{Tm}$

Part III - Problems.

Do all three. Worth 20 points each. Show and explain your work.

1) An RLC series circuit has a 225 Ω resistor, a 14.0 μF capacitor, and an unknown inductance. The supply provides an emf of $\varepsilon = (20.0\text{ V}) \sin[(400\text{ s}^{-1})t]$ which causes a current to flow of $i = (0.0200\text{ A}) \sin[(400\text{ s}^{-1})t - \varphi]$.

5 a) What is the value of the inductance L?
3 b) What is the phase angle φ?
3 c) What is the maximum energy stored in the inductor?
3 d) What is the average power provided by the supply?
3 e) If the frequency were changed (and everything else stayed the same), what frequency, f, would lead to the greatest current amplitude?
3 f) At the frequency found in e), what is the current amplitude?

a) $\mathcal{E}_m = i_m Z$ so $\frac{\mathcal{E}_m}{i_m} = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} \Rightarrow \left(\frac{\mathcal{E}_m}{i_m}\right)^2 - R^2 = (\omega L - \frac{1}{\omega C})^2$

$\omega L = \frac{1}{\omega C} + \sqrt{\left(\frac{\mathcal{E}_m}{i_m}\right)^2 - R^2} \Rightarrow L = \frac{1}{\omega^2 C} + \frac{1}{\omega}\sqrt{\frac{(\mathcal{E}_m)^2}{(i_m)^2} - R^2}$

$L = \left(\frac{1}{(400)^2(14\times10^{-6})} + \frac{1}{400}\sqrt{\left(\frac{20}{.02}\right)^2 - (225)^2}\right) H = \boxed{2.88\,H}$

b) $\phi = \tan^{-1}\frac{\omega L - \frac{1}{\omega C}}{R} = \tan^{-1}\left(\frac{400(2.88) - \frac{1}{400(14\times10^{-6})}}{225}\right) = \boxed{77.0^\circ}$

c) $U_{max} = \frac{1}{2}L i_m^2 = \frac{1}{2}(2.88H)(0.0200A)^2 = \boxed{0.576\,mJ}$

d) $P_{av} = \mathcal{E}_{rms}\, i_{rms} \cos\phi = \frac{20.0V}{\sqrt{2}} \cdot \frac{0.0200A}{\sqrt{2}} \cos 77.0^\circ = \boxed{45.0\,mW}$

e) at resonance, i_m is largest. $\omega_{res} = \frac{1}{\sqrt{LC}} = 2\pi f$

$f = \frac{1}{2\pi}\frac{1}{\sqrt{LC}} = \frac{1}{2\pi}\frac{1}{\sqrt{2.88H \cdot 14\times10^{-6}F}} = \boxed{25.1\,Hz}$

f) $i_m = \frac{\mathcal{E}_m}{R} = \frac{20.0V}{225\Omega} = \boxed{0.0889A}$

2) A spherical mirror is placed +60.0 cm from an object. The image produced by the mirror has a magnification of +2.00.

4 a) How far from the mirror is the image located?
4 b) What is the focal length of the mirror?
3 c) Is the mirror concave or convex? How do you know?
3 d) What is the radius of curvature of the mirror?
3 e) Is the image real or virtual? How do you know?
3 f) Is the image upright or inverted? How do you know?

a) $m = \frac{-i}{p}$ so $i = -mp = -2.0(60.0\text{cm}) = \boxed{-120\text{cm}}$

(120 cm from mirror)

b) $f \Rightarrow \frac{1}{f} = \frac{1}{p} + \frac{1}{i} = \frac{1}{60.0\text{cm}} + \frac{1}{-120\text{cm}} = \frac{1}{120\text{cm}}$

$f = 120\text{cm}$

c) $\boxed{\text{Concave}}$ since $f > 0$

d) $r = 2f = \boxed{240\text{cm}}$

e) $\boxed{\text{virtual}}$ since $i < 0$

f) $\boxed{\text{upright}}$ since $m > 0$

3) A 5.00 mW helium-neon laser beam has a circular cross section with a diameter of 1.20 μm. It shines on a perfectly absorbing material.

5 a) What is the intensity of the beam?
10 b) What are the amplitudes of the electric and magnetic fields in this beam?
5 c) What radiation pressure does it exert on the absorbing material?

a) $I = \frac{\text{Power}}{\text{Area}} = \frac{5.00 \times 10^{-3} W}{\pi \left(\frac{1.2 \times 10^{-6} m}{2}\right)^2} = \boxed{4.42 \times 10^9 \, W/m^2}$

b) $I = \frac{1}{c\mu_0} E_{RMS}^2 = \frac{E_m^2}{2c\mu_0}$

$E_m = \sqrt{2c\mu_0 I} = \sqrt{2(3.0 \times 10^8 \frac{m}{s})(1.26 \times 10^{-6} \frac{H}{m})(4.42 \times 10^9 W/m^2)}$

$\boxed{E_m = 1.83 \times 10^6 \, V/m}$

$B_m = \frac{E_m}{c} = \boxed{6.09 \, mT = B_m}$

c) $P_r = \frac{I}{c} = \frac{4.42 \times 10^9 \, W/m^2}{3.00 \times 10^8 \, m/s} = \boxed{14.7 \, N/m^2}$