May 12, 2004   Physics 202

FINAL EXAM

Print your name and section <u>clearly</u> on all <u>nine</u> pages. (If you do not know your section number, write your TA's name.) Show all work in the space immediately below each problem. **Your final answer must be placed in the box provided**. Problems will be graded on reasoning and intermediate steps as well as on the final answer. Be sure to include units wherever necessary, and the direction of vectors. **Each problem is worth 25 points**. In doing the problems, try to be neat. Check your answers to see that they have the correct dimensions (units) and are the right order of magnitudes. You are allowed one 8.5" x 11" sheet and no other references. The exam lasts exactly two hours.

(Do not write below)

SCORE:

Problem 1: _____

Problem 2: _____

Problem 3: _____

Problem 4: _____

Problem 5: _____

Problem 6: _____

Problem 7: _____

Problem 8: _____

TOTAL: _____

Possibly useful information:

$\varepsilon_0 = 8.85 \times 10^{-12} \ C^2 N^{-1} m^{-2}$
$k = 8.99 \times 10^9 \ N \ m^{-2} C^{-2}$
$e = 1.602 \times 10^{-19} \ C$
$m_e = 9.11 \times 10^{-31} \ kg$
$1 \ eV = 1.602 \times 10^{-19} \ J$
$\mu_0 = 4\pi \times 10^{-7} \ NA^{-2}$
$1 \ T = 1 \ NA^{-1}m^{-1} = 10^4 \ G$
$c = 2.998 \times 10^8 \ m \ s^{-1}$

PROBLEM 1

A glass (n=1.50) thin lens has a flat back surface and its front surface is convex, with a radius of curvature of 10.0 cm.

a What is the focal length of the lens? *(5 pts.)*

b. An object is put 50.0 cm in front of the lens. How far is the image in **front** or in **back** *(circle one)* of the lens? *(5 pts.)*

c. What is the magnification of the object in part b)? Is the image **inverted** or **erect** *(circle one)*? Is the image **real** or **virtual** *(circle one)*? *(5 pts.)*

d. An object is put 15 cm in front of the lens. How far is the image in **front** or in **back** *(circle one)* of the lens? *(5 pts.)*

e. What is the magnification of the object in part d)? Is the image **inverted** or **erect** *(circle one)*? Is the image **real** or **virtual** *(circle one)*? *(5 pts.)*

PROBLEM 2

A slit 0.200 mm wide is illuminated by parallel rays of coherent light that has a wavelength of 500.0 nm. The diffraction pattern is observed on a screen that is 4.00 m from the slit. The intensity at the central maximum ($\theta = 0°$) is 5.00×10^{-6} W/m^2

a. What is the distance on the screen between the center of the central maximum to the first minimum?*(9 pts)*

b. What is the total phase difference from the center of the central maximum to a point on the screen midway between the center of the central maximum and the first minimum? *(8 pts)*

c. What is the intensity at the point on the screen midway between the center of the central maximum and the first minimum?*(8 pts)*

PROBLEM 3

A parallel plate capacitor is made from metal foil strips each 3.0 m long by 4.0 cm wide, separated by a polyethylene (dielectric constant = 2.3, dielectric strength = 7.5×10^8 V/m) sheet 2.0×10^{-5} m thick. We store 0.5 J of energy on the capacitor. ($\varepsilon_0 = 8.854 \times 10^{-12}$ F/m)

a What is the capacitance? *(5 pts.)*

b. What is the potential difference between the plates? *(5 pts.)*

c. What is the stored charge? *(5 pts.)*

d. What is the electric field strength? *(5 pts.)*

e. If a safe capacitor can hold up to 10% of its breakdown voltage, is this capacitor safe when storing 0.5 J? *(5 pts.)*

PROBLEM 4

A battery having an open circuit voltage of 12.0 V and an internal resistance of 0.40 Ω is connected (positive to positive) to a battery having an open circuit voltage of 6.0 V and an internal resistance of 0.2 . The connecting leads contain a 2.0 Ω resistor.
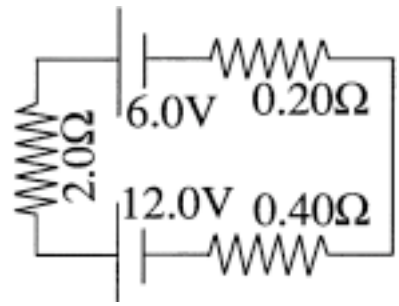
a. What is the current in the circuit? *(5 pts.)*

b. What is the power produced by the 12.0 V battery? *(5 pts.)*

c. What is the power dissipated in the 2.0 Ω resistor? *(5 pts.)*

d. What is the total power lost in the internal resistance of the two batteries?*(5 pts.)*

e. What is the charging power input to the 6.0 V battery? *(5 pts.)*

PROBLEM 5

A solenoid is made of two coils wound on a 0.50 m long cardboard tube with cross sectional area 6.0×10^{-4} m^2. The primary coil has exactly 200 turns and a resistance of 3.0 Ω. The secondary coil of exactly 1000 turns is wound closely on the first in the same direction, but is electrically insulated from it. A 12.0 V battery and a switch are connected to the first coil and there is a steady current after the switch is closed.

a. What is the magnetic flux in the solenoid when the steady current is established? *(6 pts.)*

b. What is the magnitude of the average induced EMF in the second coil if the current in the primary coil falls to zero in 0.80×10^{-3} sec when the switch is opened? Is the direction of the EMF the **same** or **opposite** to that in the first coil (*circle one*)? *(7 pts.)*

c. What is the mutual inductance of the two coils? *(5 pts.)*

d. What is the mutual inductance if the tube is filled with iron of permeability 1500 times that of air? *(6 pts.)*

PROBLEM 6

A light beam of wavelength 550.0 nm traveling in air enters a solid prism at surface 1 and strikes surface 2 of the prism at an angle of 42.0° with respect to the perpendicular to the surface as shown. The light beam is totally internally reflected parallel to surface 2.
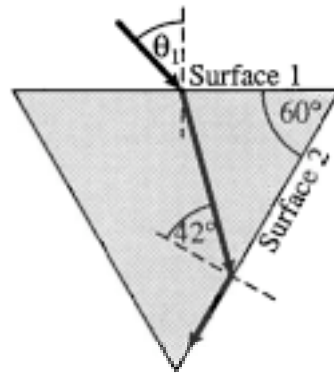
a. What is the index of refraction of the prism? *(5 pts.)*

b. What is the speed of light in the prism? *(5 pts.)*

c. What is the wavelength of the light in the prism? *(5 pts.)*

d. What is the frequency of the light in the prism?*(5 pts.)*

e. What is the angle of incidence, θ_1 *in degrees*, of the light beam at surface 1 with respect to a line perpendicular to that surface? *(5 pts.)*

PROBLEM 7

A water drop (n=1.33) lies on a horizontal glass plate (n=1.52). The drop is thicker near its center than near the edge. At a horizontal distance 0.60 mm from the edge the drop is 0.673 µm thick.

a. At what wavelength between 400.0 nm and 700.0 nm does this part of the drop appear completely dark in reflected light? *(5 pts.)*

b. At a horizontal distance 0.500 mm from the edge of the drop, because of constructive interference, the layer looks brightest when illuminated by $\lambda = 432$ nm light and also when illuminated by $\lambda = 648$ nm light. The thickness of the water layer at this point is the minimum thickness that satisfies these conditions. Find the thickness of the water layer at this position. *(10 pts.)*

c. If instead of glass the drop were on plastic with index of refraction n=1.22, at what wavelengths between 400.0 nm and 700.0 nm would the part of the drop with thickness 0.565 µm appear completely dark in reflected light? *(5 pts.)*

d. For the water drop on plastic, what is the wavelength *in the plastic* of the visible light (wavelength in air between 400 and 700 nm) that has the most transmission into the plastic? *(5 pts.)*

PROBLEM 8

The magnetic field of the Earth at a certain location is directed vertically downward (into the page as shown) and has a magnitude of 50.4 µT. A proton with mass $m_p=1.673 \times 10^{-27}$ kg initially moving horizontally to the east at 1.23×10^6 m/s is accelerated across a voltage V_0 until it is moving horizontally toward the east as shown in this field with speed 7.15×10^6 ms^{-1}.
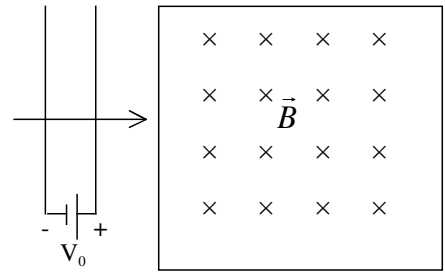
a. What is the magnitude of the voltage V_0? *(5 pts.)*

b. What is the direction of the magnetic force that the field exerts on this charge (north, south, east, or west)? *(5 pts.)*

c. What is the magnitude of the magnetic force the field exerts on this charge when it is moving at 7.15×10^6 m/s? *(5 pts.)*

d. What is the radius of curvature of the trajectory followed by this proton? *(5 pts.)*

e. The proton collides elastically with a second proton that is initially at rest. After the collision the trajectories of the two particles remain horizontal, and the radius of curvature of the first proton's trajectory has decreased by a factor of two compared to the value in part d. What is the kinetic energy in Joules of the second proton after the collision? *(5 pts.)*