Name_____ **Section**_____

University of Maryland

Department of Physics

Physics 122 Dr. David Noyes: Exam 2

Instructions: Do not open this examination until the proctor tells you to begin. Read these instructions while waiting.

1. When the proctor tells you to begin, **write your name and section number at the top of every page.**

2. Do your work for each problem on the page for that problem. I will pass around paper so you can do your scratch work on it before starting to write out your answer on the exam. **If part of your answer is on the back, be sure to check the box on the bottom of the page so the grader knows to look on the back!**

3. Partial credit will be granted for correct steps shown, even if the final answer is wrong. So be sure to show your work.

4. Write clearly and logically so I can understand what you are doing and can give you as much partial credit as you deserve. I cannot give credit for what you are thinking — only for what you show on your paper.

5. If on a multi-step problem you can't do a particular part, don't give up. Go on to the next part anyway. If necessary, define a name for the quantity you couldn't find and express your answer in terms of it.

6. You are not permitted to have any outside information during this exam. This includes any written information and any relevant information programmed into a calculator. If you are caught using such information, you will be prosecuted and may receive a grade of XF for this course.

7. If there is a formula or constant that is not given, but you think is needed, ask me and if reasonable, I will put it on the board. However I will not tell you which equation is needed for a given problem. Also note that some of the formulas that are given only apply in certain situations, so be sure to take that into account.

8. Take a deep breath, relax, and good luck!

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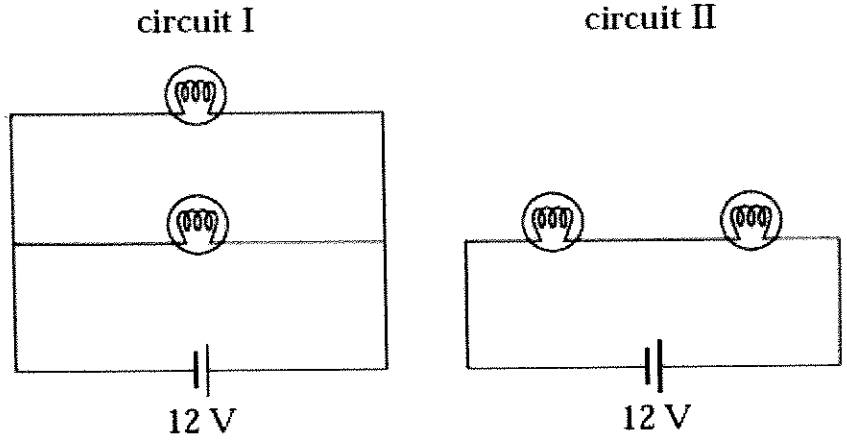
DC Circuits (25 points) **/5 + /20 = /25**

1) **(5 points)** If the bulbs in the circuits below are all identical, which circuit puts out more light?



(a) Circuit I
(b) Circuit II
c. The two circuits put out the same amount of light.

Sorry!

2) **(20 points)** For the circuit shown below(show work on back of this page, put final answer below):

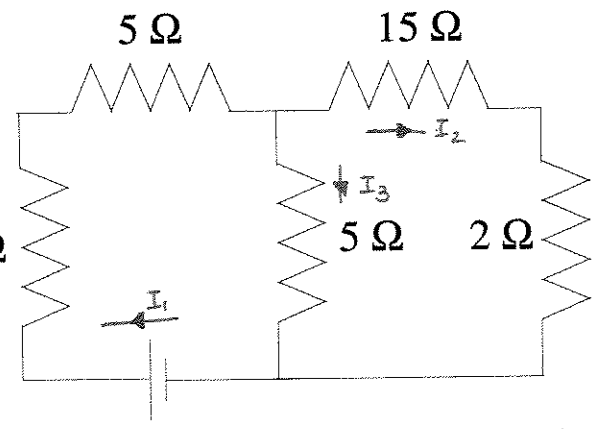
a. **(10 points)** Use Kirchhoff's rules to find the current through through each resistor.

$I_1 = \frac{44}{83}$ A , $I_2 = \frac{10}{83}$ A , $I_3 = \frac{34}{83}$ A .

b. **(4 points)** Calculate the power dissipated by the 2Ω resistor.

$P = IV = I^2R = \left(\frac{10}{83}\text{A}\right)^2(2\Omega) = \frac{200}{6889}$ Watt

c. **(6 points)** Find the equivalent resistance of the circuit.



$R_{eq} = \frac{10V}{I_1}$

$= \frac{10\text{ V}}{\left(\frac{44}{83}\right)\text{Amp}}$

$= \frac{83}{44}\ \Omega$

$= \frac{415}{22}\ \Omega$

$I_1 = I_2 + I_3$

$10 - 10I_1 - 5I_1 - 5I_3 = 0$

$-15I_2 - 2I_2 + 5I_3 = 0$

$I_1 = I_2 + I_3$

$10 - 15I_1 - 5I_3 = 0$

$-17I_2 + 5I_3 = 0$

$I_1 = I_2 + I_3$

$2 - 3I_1 - I_3 = 0$

$-17(I_1 - I_3) + 5I_3 = 0$

$2 - 3I_1 - I_3 = 0$

$-17I_1 + 22I_3 = 0$

$2 - 3I_1 - I_3 = 0$

$I_3 = \frac{17}{22}I_1$

$2 - 3I_1 - \frac{17}{22}I_1 = 0$

$2 - \frac{66+17}{22}I_1 = 0$

$I_1 = \frac{44}{83}$ amp

$I_2 = \frac{10}{83}$ amp

$I_3 = \frac{17}{22}\frac{44}{83}$ amp

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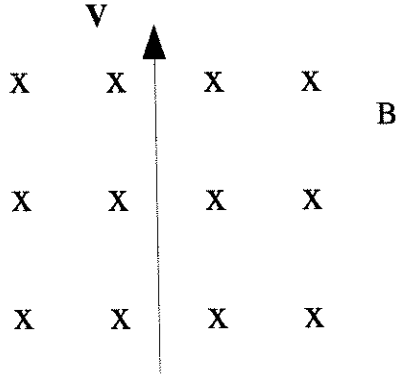
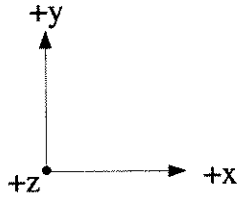
Magnetism (25 points) **/10 + /15 = /25**

3) **(10 points)**

a.) **(5 points)** A particle with charge q = 10 μC moves and with velocity v = 1000 m/s in the +y direction in the presence of a magnetic field B = 10 T which is in the -z direction. Find the magnitude and direction of the magnetic force on the particle.

Note: directions refer to the coordinate system at the right.





$\vec{F}_B = q\,\vec{v} \times \vec{B}$

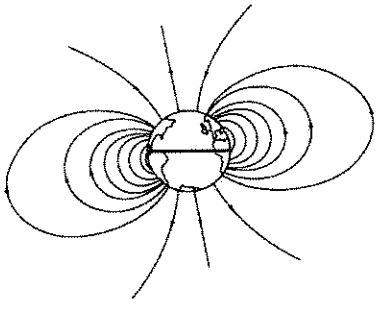
$= (10\,\mu C)\left(1000\,\frac{m}{s}\right)(10\,T)\left(\hat{y} \times (-\hat{z})\right)$

$= 10^{-2}\,N\ (-\hat{x})$

The force points to the left.

b.) **(5 points)** Cosmic rays (atomic nuclei stripped bare of their electrons) would continuously bombard Earth's surface if most of them were not deflected by Earth's magnetic field. Given that Earth's magnetic field is similar to that of a bar magnet as shown below, the intensity of cosmic rays bombarding its surface is greatest at the

(a.) poles.
b.) mid-latitudes.
c.) equator.



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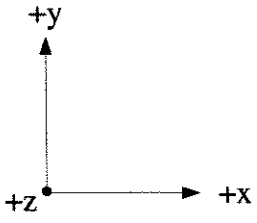
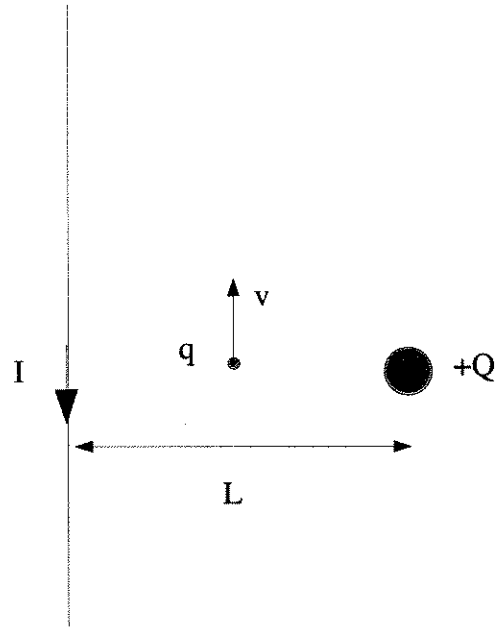
4.) **(15 points)** A charged sphere with net charge Q is fixed in place a distance L from a long wire carrying a current I as shown below. At the instant shown, a charge q is at the midpoint between the wire and the fixed charge.

The magnitude of the magnetic field from a long wire is $B = \mu_0 I/2\pi r$, and the magnitude of the electric field due to a point charge Q is $E = kQ/r^2$. Where $k = 9\text{x}10^9$ N m^2/C^2, and $\mu_0 = 4\pi$ x 10^{-7} T m/A. Use the coordinate system below to answer the following questions.





a.) **(3 points)** Give the magnitude and direction of the magnetic and electric **fields** at the location of the charge q.

$\vec{B}$ points in the $+\hat{z}$ direction: $|\vec{B}| = \frac{\mu_0 I}{2\pi r}$ #

$\vec{E}$ points in the $-\hat{x}$ direction:

$|\vec{E}| = \frac{kQ}{r}$

b.) **(6 points)** Give the direction and magnitude of the magnetic and electric **forces** on the particle at the instant shown.

$\vec{F}_B$ points in the $(\hat{y} \times +\hat{z}) = \hat{x}$ direction

$\vec{F}_E$ points in the $-\hat{x}$ direction.

$|\vec{F}_B| = \frac{\mu_0 I}{2\pi r} q v$, $|\vec{F}_E| = \frac{kQq}{r}$

c.) **(6 points)** If Q = 10 μC, q = 10nC, v = 10 m/s, I = 1A, and L = 1 mm, give the magnitude and direction of the net force on the particle, and sketch the initial trajectory of the particle.

$$\vec{F}_{net} = \left(\frac{\mu_0 I}{2\pi r} v - \frac{kQ}{r}\right) q \ (\hat{x})$$

$$= \frac{q}{r}\left(\frac{\mu_0 v}{2\pi} - kQ\right) (\hat{x})$$

$$= \frac{q}{(L/2)}\left(\frac{\mu_0 v}{2\pi} - kQ\right) (\hat{x})$$

F_{net} is in $-x$ direction.

so: ↖ q is initial trajectory.

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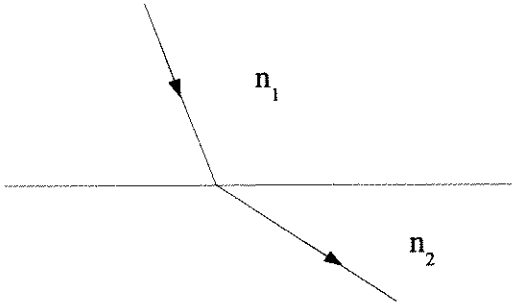
Reflection and Refraction + Mirrors and Lenses (50 points)

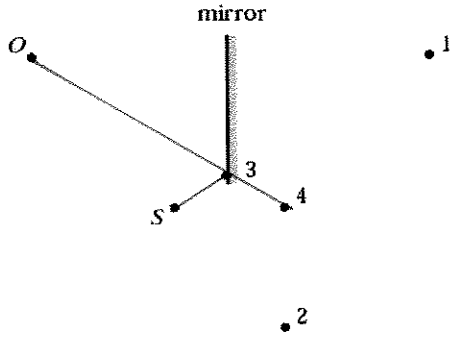
/5 + /5 + /23 + /17 = /50

5.) **(5 points)** A light ray travels from medium one (with index of refraction n_1) to medium 2 (with index of refraction n_2) as indicated below. Which of the following is true

(a.) $n_1 > n_2$
b. $n_1 < n_2$
c. n_1 and n_2 are the same
d. we need more information to tell.



6.) **(5 points)**An observer O, facing a mirror, observes a light source S. Where does O perceive the mirror image of S to be located?



a. 1
b. 2
c. 3
(d.) 4
e. Some other location.
f. The image of S cannot be seen by O when O and S are located as shown.

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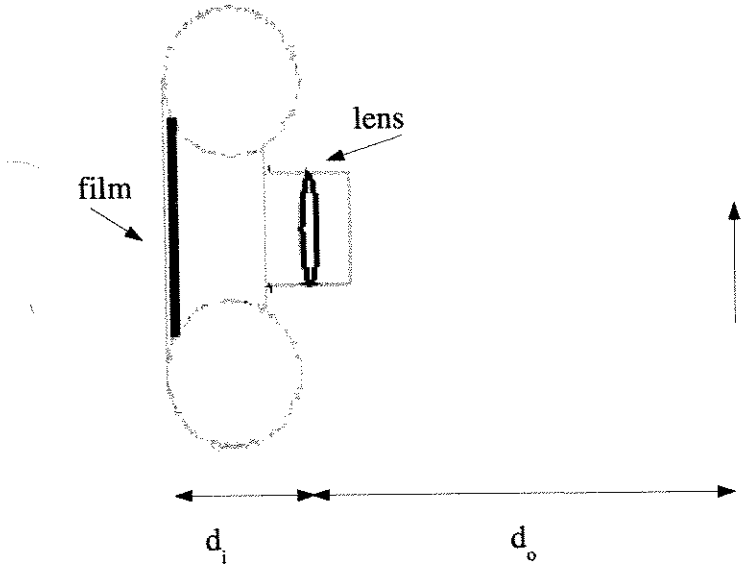
7.) **(23 points)** A simple, old-fashioned film camera is shown in the picture below. It has only a single lens (fancy cameras have multiple lenses) and it can only move back and forth a limited distance. The closest it can get to the film is 20 mm and the farthest it can get from the film is 40 mm. The camera is focused on an object when the image of the object produced by the lens falls on the film. The focal length of the lens is 20 mm.



a.) **(5 points)** I want to focus on a distant landscape. Should I set the distance of the lens from the film close to 20 mm or close to 40 mm? Explain your reasoning.

20 mm ; $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$, and since d_o is large , $\frac{1}{d_o} \sim 0$, so the image distance will be focal length , and image is focused on the film

b.) **(5 points)** I want to get as close to a butterfly as possible to take a picture. Should I set the distance of the lens from the film as 20 mm or 40 mm? Explain your reasoning.

40 mm ; Since d_o is small and f is fixed , d_i will be larger compared to the previous case.

c.) **(8 points)** How close can I get and still have my picture in focus?

The largest d_i can be is 40 mm , so we have

$\frac{1}{20mm} = \frac{1}{40mm} + \frac{1}{d_o} \Rightarrow d_o = 40mm$. (For any $d_o < 40$ mm , d_i will be greater than 40 mm , which will not be focused

d.) **(5 points)** If the butterfly is 15 mm across, will its image fit on my film (which is 35 mm across)? Explain your reasoning.

$M = -\frac{d_i}{d_o} = -1$, so the butterfly will fit on the film.

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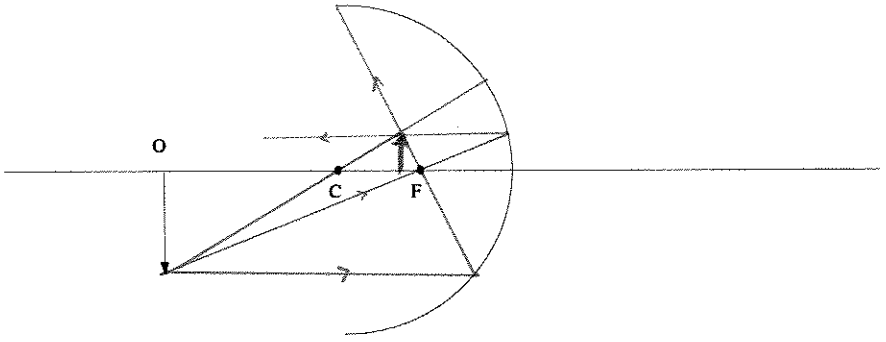
8.) **(17 points)** An object indicated by the arrow is in front of a concave spherical mirror with center and focal point indicated as shown below.



a.) **(5 points)** On the image draw three rays to locate the image.

b.) **(2 points)** Is the image real or virtual? Real.

c.) **(5 points)** If the object is at a distance of 30 cm, and the focal length of the mirror is 10 cm, what is the image distance?

$\frac{1}{30\,cm} = \frac{1}{30\,cm} + \frac{1}{d_i}$, $d_i = 15\,cm$.

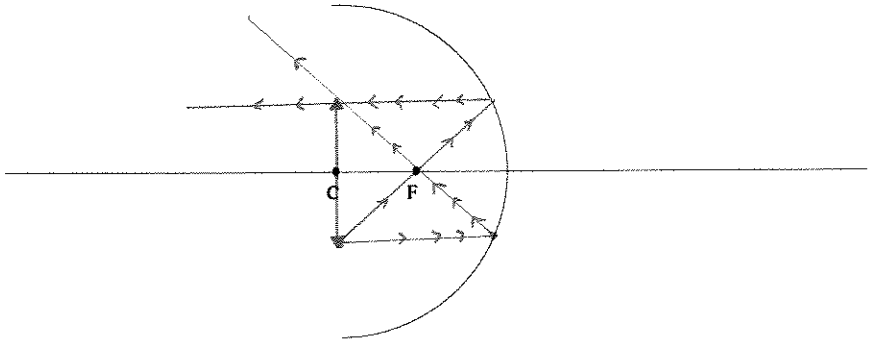
d.) **(5 points)** Recall the demo we did in class with the two light bulbs in front of a mirror. One was illuminated, upside down in a box (like the object in this problem). The image of the light bulb was at the same point, but was upright and was not illuminated. At what distance from the mirror did we have to place the light bulbs for this to occur? Use the mirror equation to determine this, and verify by drawing rays below:

We need $d_o = d_i$, so we have

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_o} = \frac{2}{d_o}$

$d_o = 2f = C$

So the object should be placed at the center.



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Extra Credit (5 points)

The amount of energy from the sun that reaches the ground is on the order of 1 kW/m^2. Use this information to estimate the area you would need to provide all the electricity in your house. You can ignore any inefficiencies involved in collecting this energy. Explain your assumptions and reasoning carefully.