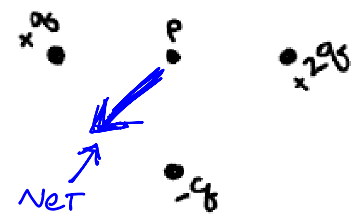
Final Exam (May 10, 2006)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work. Partial credit will be given.

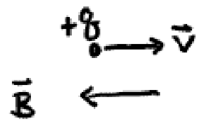
<u>Problem 1 (10 pts total, 2 points/part, no partial credit on each part, no justification needed)</u>

(a)



Please indicate the direction of the net electric field at point P. If there is no field write "No Net field".

(b)

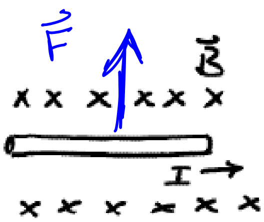


Please indicate the direction of the net force on charge q moving with velocity $\vec{v}$ in a uniform $\vec{B}$ field w/ $\vec{v}$ and $\vec{B}$ oriented as shown. If no force, write "No net force."

$F = q\vec{v}\times\vec{B} = 0$

No Net Force

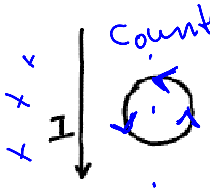
(c)



Please indicate the direction of the net force on the wire carrying current I in the direction shown. $\vec{B}$ is uniform and into the paper. If no force, write "No net force."

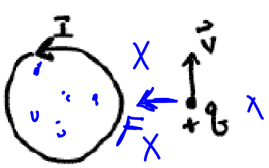
(d)

Counter clockwise



Indicate the direction of the induced current in the loop assuming I is decreasing with time. If no induced current, write "No current".

(e)



Indicate the direction of the force on the charge shown assuming I is constant. The loop and the velocity vector of +q are both in the plane of the paper. If no force, write "No net force."

Problem 2 (6 pts, show your work)

How much energy is released in the fusion reaction below?

$^2_1H + ^3_1H \rightarrow ^4_2He + n$

$$M_{^2_1H} + M_{^3_1H} = M_{^4_2He} + M_n + E$$

$$1875.328 + 2808.239 = 3726.818 + 939.565 + E$$

$$E = 17.184 \text{ MeV}$$

In what form(s) might this energy appear when the reaction happens?

The energy is released in the form of photons and in the kinetic energy of the ^4_2He and n.

Potentially useful information:
atomic mass of ^2_1H in MeV/c2 is 1875.328
atomic mass of ^3_1H in MeV/c2 is 2808.239
atomic mass of ^4_2He in MeV/c2 is 3726.818
mass of proton in MeV/c2 is 937.873
mass of neutron in MeV/c2 is 939.565
mass of electron in MeV/c2 is 0.511

1)	/10
2)	/6
3)	/6
4)	/7
5)	/6
6)	/7
7)	/5
8)	/6
9)	/8
10)	/9
11)	/9
12)	/8
13)	/10
14)	/3
tot	/100

Problem 3 (6 pts, show your work)

While in Europe, where the household voltage is 240 V, you buy a light bulb rated at 60 Watts. When you return home to America, where the household voltage is 120 V, if you use this light bulb, how will the brightness of this light bulb compare to the standard American 60 W light bulb? (Assume the resistance of the European bulb does not change depending on the applied voltage.)

Brightness $\propto$ power

$$\text{Power} = VI = I^2R = \frac{V^2}{R}$$

Find relevant resistance

$$P_{Europe} = \frac{V^2_{Europe}}{R}$$

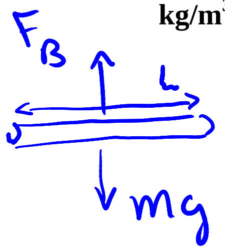
$$R = \frac{240^2}{60}$$

$$P_{America} = \frac{120^2}{R} = \frac{120^2(60)}{240^2}$$

$$P_{America} = \frac{60}{4} = 15 \text{ watts}$$

Problem 4 (7 pts, show your work)

A straight 2.0-mm-diameter copper wire floats horizontally in the air because of the force of the Earth's magnetic field B, with is horizontal, perpendicular to the wire, and of magnitude $5.0\text{x}10^{-5}$ T. What current does the wire carry? (The density of copper is 9000 kg/m^3.)



$F_B = ILB$ Floats when $\Sigma F_y = 0 = ILB - mg$

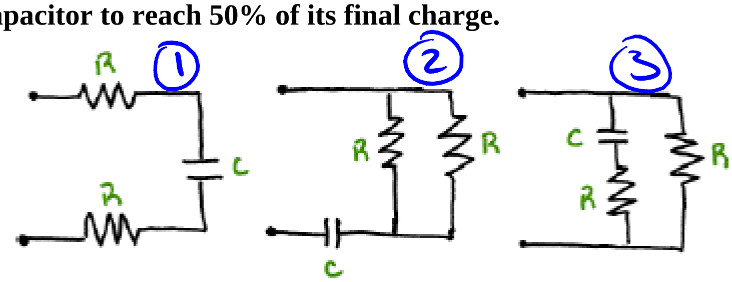
$F_{grav} = mg$ $ILB = mg$

$ILB = \underbrace{L \rho_{cu} A}_{\text{volume wire}} g$ $A = \pi (.001)^2$ radius in m

$I = \frac{\rho A g}{B} = \frac{(9000)\pi(.001)^2 \, 9.8}{5\times10^{-5}} = 5500$ Amperes

Problem 5 (6 pts, show your work)

After graduation, you take a job at Ed's Transmorgorizer Emporium. Ed comes in one day asking for help in the design of a circuit for a new and improved model of transmorgorizer. Ed shows you three circuits containing two resistors and one capacitor. They are each connected in turn across the same battery via a switch. The resistors are all identical and the capacitors are all identical. Rank the circuits in terms of the time required for the capacitor to reach 50% of its final charge.



Time required to charge capacitor goes as $R_{eff} C \equiv \tau$

$\tau_2 < \tau_3 < \tau_1$

R_{eff} is effective resistance

in 1 $R_{eff} = 2R$

in 2 $1/R_{eff} = \frac{2}{R} \rightarrow R_{eff} = R/2$

in 3 only one resistor relevant for charging capacitor $R_{eff} = R$

Problem 6 (6 pts, show all work)

What is the ionization energy of the metastable state of Li++ that has the electron with a quantum number of n=2?

$$E_{\substack{n=2 \\ Li^{++}}} = -\frac{Z^2}{n^2}|E_1| = -\frac{9}{4}(13.6)\,eV = -30.6\,eV$$

$Li \rightarrow Z=3$

Problem 7 (6 pts, show all work)

A hydrogen atom is known to have ℓ=3. What are the possible values of n, m_l and m_s for this atom?

$\ell = 3$

$\therefore\ n > 3$

$m_\ell = -2, -1, 0, +1, +2$

$m_s = \pm 1/2$

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Problem 8 (6 pts, show all work)

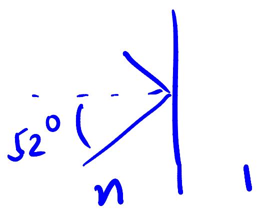
A ray of light travels at an angle of 52 degrees with respect to the normal of an air-liquid interface. The light is totally reflected at the interface. The liquid has index of refraction n, which is greater than 1.

a) **Given this information, is the light traveling in liquid or air just before it strikes the interface? Justify your answer.**

Total reflection implies light travels from high n (liquid) to low n (air). light traveling in liquid

b) **Given the information in this problem, what do you know about the index of refraction of the liquid? That is to say, mathematically constrain the value of n as much as possible.**

$n \sin\theta_c = 1$



$\theta_c \le 52$

$\sin^{-1}\frac{1}{n} \le 52$

$\frac{1}{n} \le \sin 52$

$$\boxed{n \ge \frac{1}{\sin 52} = 1.27}$$

Problem 9 (8 pts, show all work)

Two thin lenses of focal length f_1 and f_2, respectively, are aligned along the same axis and placed very close together. (Here "close together" means you can treat the two lenses as being at the same point. This is not a bad approximation if the focal lengths are long.) Determine the correct expression for the focal length, f, of the lens combination. You must justify your answer with an argument or mathematical proof to get credit.

A) $f = f_1 + f_2$
B) $f = f_1 - f_2$
C) $f = 1/f_1 + 1/f_2$
D) $f = 1/f_1 - 1/f_2$
E) $1/f = 1/f_1 + 1/f_2$
F) $1/f = 1/f_1 - 1/f_2$

image of 1st lens acts as object for second lens

let initial object be O away from 1st lens

$$\frac{1}{O} + \frac{1}{i} = \frac{1}{f}$$

$$\frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{O_1}$$

for 2nd lens this is object but is to right

so

$$\frac{1}{i_2} + \frac{1}{O_2} = \frac{1}{f_2}$$

$$\frac{1}{i_2} - \frac{1}{i_1} = \frac{1}{f_2}$$

$$\frac{1}{i_2} - \frac{1}{f_1} + \frac{1}{O_1} = \frac{1}{f_2}$$

This is thin lens eqn for combination

$$\frac{1}{i_2} + \frac{1}{O_1} = \frac{1}{f_1} + \frac{1}{f_2}$$

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Problem 10 (9 pts, show all work)

$^{87}_{37}Rb$ decays to the ground state of $^{87}_{38}Sr$ with a half-life of 4.7x10^{10} years. This is an important decay for the science of geochronology, i.e., the dating of rocks, meteorites, fossils, etc. $^{86}_{38}Sr$ is an isotope of Sr that does not have a radiogenic origin, i.e., the amount this isotope is constant with time. That means $^{86}_{38}Sr$ does not decay radioactively and it is not a product of radioactive decay. Consequently $^{86}_{38}Sr$ is used as a reference for the amount of $^{87}_{37}Rb$ and $^{87}_{38}Sr$ in a sample being dated.

a) **What kind of radiation is ~~emitted~~ by $^{87}_{37}Rb$ when it decays? Justify your answer.**

NOT discussed in class
Do NOT TAKE off pts if Missing

$$^{87}_{37}Rb \rightarrow {}^{87}_{38}Sr + e^- + \bar{\nu}_e$$

Z changes, Mass does NOT, change in Z means emitted particle is negative

b) **Professor Julie Tutankhamen, geologist extraordinaire, needs to know the date of origin of a rock in order to further her studies of historical tectonic plate movements. In her rock, the present day $^{87}_{38}Sr/^{86}_{38}Sr$ ratio is 2.5. From other sources of evidence, she knows the original $^{87}_{38}Sr/^{86}_{38}Sr$ ratio was 0.7. Consider the $^{87}_{37}Rb/^{86}_{38}Sr$ to be a constant of 50 as a function of time (this is approximately true when the ratio is large). Please calculate the age of Professor Tut's rock.**

$$^{87}_{38}Sr\Big|_t = {}^{87}_{38}Sr\Big|_0 + (\text{TOTAl amt of Rb That decays})$$

↳ Rb start − Rb remaining

$Rb(1-e^{-\lambda t})$

÷ thru by $^{86}_{38}Sr$

$$\left(\frac{^{87}_{38}Sr}{^{86}_{38}Sr}\right)_t = \left(\frac{^{87}_{38}Sr}{^{86}_{38}Sr}\right)_0 + \frac{^{87}_{37}Rb}{^{86}_{38}Sr}\left(1-e^{-\lambda t}\right)$$

2.5 0.7 50

$t_{1/2} = \frac{.693}{\lambda}$

$\lambda = 1.5\times10^{-11}\ \text{yr}^{-1}$

solve for t

$t = 2.4$ billion yrs

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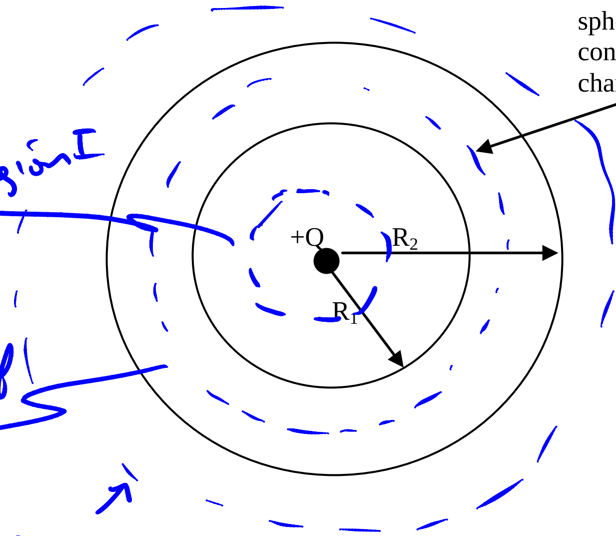
Problem 11 (9 pts, show all work)

A charge +Q is surrounded symmetrically by a non-conducting spherical shell with inner radius R1 and outer radius R2. A charge of -2Q is spread uniformly throughout the shell (between R1 and R2). Determine the electric field in all space.

This non-conducting spherical shell volume contains a uniform charge of -2Q



This is a spherical gauss' law problem.

Gaussian surf for region I

Gaussian surf for region II

gaussian surf. for region III

Region I $r < R_1$

$$\oint E \cdot dA = \frac{Q_{encl}}{\epsilon_0}$$

$$E 4\pi r^2 = \frac{Q}{\epsilon_0}$$

$$|E| = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$$

Direction radially outward

Region II

$$|E| 4\pi r^2 = \frac{\rho}{\epsilon_0}\left[\tfrac{4}{3}\pi r^3 - \tfrac{4}{3}\pi R_1^3\right] + \frac{Q}{\epsilon_0}$$

$$\rho = \frac{-2Q}{\frac{4}{3}\pi R_2^3 - \frac{4}{3}\pi R_1^3} = \frac{-2Q}{\frac{4}{3}\pi\left[R_2^3 - R_1^3\right]}$$

so

$$|E| = \frac{Q}{4\pi\epsilon_0}\left\{1 - \frac{2(r^3 - R_1^3)}{(R_2^3 - R_1^3)}\right\}$$

directed radially
when +, directed outward
when −, directed inward

Region III

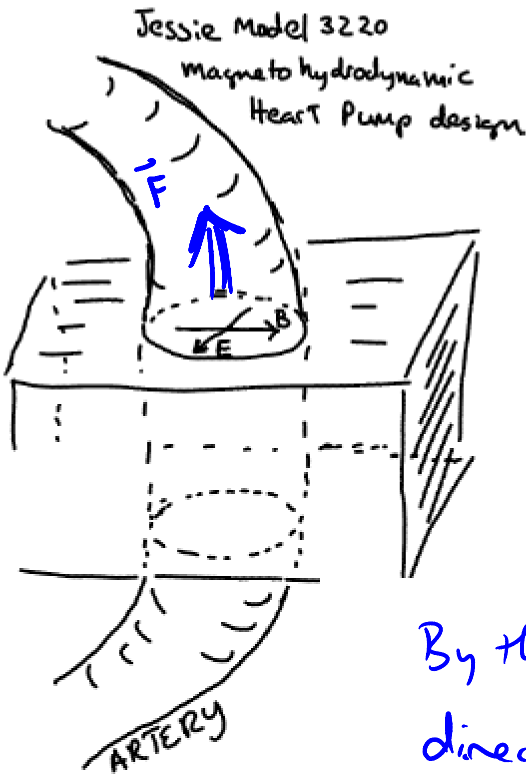
$$\oint E \cdot dA = \frac{Q_{enc}}{\epsilon_0} \Rightarrow |E| = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$$

directed inward

$$|E| 4\pi r^2 = \frac{-Q}{\epsilon_0}$$

Problem 12 (8 pts, show all work)

Fast forward a few years … With the help of a shady physics professor, you land a job with Jessie's Artificial Heart and Piercing Studio in Beverly Hills. It's where all the stars go to get artificial hearts and/or belly button studs. The problem with the business is that the mechanical motion in the artificial heart pumps frequently damage blood cells, causing them to form small clots which threaten to kill your clients. Anyway, your boss, Angina Jones, walks in and tosses a sketch on your desk and says, "One of my industrial spies just acquired this drawing from our main competitor. For your first assignment I want you to analyze this sketch and tell me how this works as a heart pump." Below, provide (in a brief and coherent discussion) your answer to your boss. Use concepts we have covered in this class and feel free to use equations or sketches as needed. *Hint: recall that blood contains electrolytes.*



Blood contains charged particles (electrolytes)

E accelerates these charged particles $\vec{F} = q\vec{E}$

Once the charges start moving along $\vec{E}$, there is a force on the currents due to $\vec{B}$ according to $\vec{F} = q\vec{v} \times \vec{B}$.

By the RHR, this force is in the direction shown.

The moving ions will drag the fluid along creating a pump that has no mechanical motion that might cause damage to blood cells.

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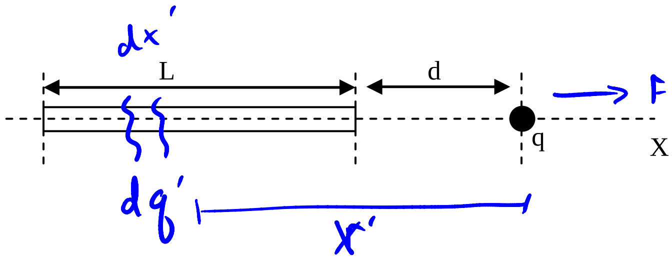
Problem 13 (10 pts, show all work)

A thin, non-conducting rod of length L carries a total charge positive Q distributed uniformly along it's length. Determine the electrostatic force of this rod of charge on a positive charge q located a distance d from one end of the rod along the central axis of the rod as shown in the sketch.



$\lambda = Q/L$

$\vec{F} = q\vec{E}$

$$dF = \frac{k\, q\, dq'}{x'^2}$$

$$\int x^{-2}dx = \frac{1}{x}$$

$$dF = \frac{k\, q\, \lambda\, dx'}{x'^2}$$

$$F = \int_{L+d}^{d} \frac{kq\lambda}{x'^2}\, dx = kq\frac{Q}{L}\int_{L+d}^{d}\frac{dx}{x^2}$$

$$= kq\frac{Q}{L}\,\frac{1}{x}\Bigg|_{L+d}^{d}$$

$$F = kq\frac{Q}{L}\left(\frac{1}{d} - \frac{1}{L+d}\right)$$

$$= kq\frac{Q}{L}\,\frac{L}{d(L+d)}$$

direction to right

$$F = \frac{kqQ}{d(L+d)}$$

full credit if Answered

Problem 14 (3 pts, I'm serious, wait until you are done with other parts of the exam)

To earn these 3 points you must read the section below and answer appropriately and honestly. Thank you for your help.

First, write your name neatly at the top of this page.

At the start of the semester, did you tell me that you did NOT want to participate in the computer visualization study? (*Note, if you chose to participate but were not selected to look at the visualizations, you should answer "no" to this.)* Yes ____ No _____

If you answered "yes", you are done with this question. Make sure you have completed your exam to the extent you can and hand it in.

If you answered "no" please proceed.

On a scale of 1 to 5, please rank the components of this course in terms of helpfulness in your learning. The scale you should use is as follows: 1=not helpful at all, 2=sometimes helpful, 3=helpful, 4=very helpful, 5=essential. Consider each component individually. You can have multiple components with the same rank. The word "learning" is meant to have a rather broad meaning here. Think of it in terms of preparation for exams as well as knowledge or skills you think will be useful to you in later years.

__ Textbook
__ Lecture
__ Workgroup
__ Problem sets
__ Computer visualizations
__ Project
__ TA office hours
__ Laboratories
__ Pre-exam question and answer sessions
__ Office hours with professor
__ PRS exercises in class

Were you selected to look at the computer visualizations? (If you received emails from me during the term supplying you links to the visualizations, you were selected. If not, you were not selected.) ___ yes ___ no

If you answered "no", you are done with this question. Make sure you have completed your exam to the extent you can and hand it in.

If you answered "yes", please proceed to the next page.

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Please write your name neatly at the top of this page.

You agreed to participate in the computer visualization study and were in the group selected to view the visualizations.

Estimate how many visualizations you looked at during the term. ***(Please be honest. There is no penalty for having not viewed the visualizations. This just helps me understand the degree of participation and calibrates other answers.)*** **________**

On a scale of 1 to 5, please rank the different assignments in terms of helpfulness in your learning. The scale you should use is as follows: 0=I did not view this applet, 1=not helpful at all, 2=a little helpful, 3=helpful, 4=very helpful, 5=essential. The word "learning" is meant to have a rather broad meaning here. Think of it in terms of preparation for exams as well as knowledge or skills you think will be useful to you in later years.

Professor Manly has screenshots of the different applets available for you to inspect up at the front of the room in order to refresh your memory.

____ Coulomb (force on test charge from up to 4 colored particles on a grid)
____ Electric fields (E fields surrounding up to 4 colored particles on a grid)
____ Electric flux (flux lines thru surface)
____ Magnetic fields (charged particle gun)
____ Magnetostatics (magnetic fields from currents on a grid)
____ Magnetic induction (wire loop moving in and out of B field)
____ Electromagnetic waves (oscillating E and B field vectors for traveling wave)
____ Polarization (oscillating E vectors from two orthogonal solutions in traveling wave)
____ Snell (ray of light hitting interface between two materials)
____ interference (two slit and single slit intensity patterns on screen)

Do you recall any of the applets as being particularly helpful in helping you visualize and learn a topic? If so, which ones:

Please feel free to provide any comment/input you wish concerning the computer visualization exercises.

Whew! Welcome to the end of your introductory physics sequence! I hope you will find some of what you have learned useful through the years. I have enjoyed your class.

As for grades: Because my TA's have exams through this week, I do not expect to have the exam grades in hand until the end of the weekend or Monday. I will post all the grades on WebCT once I have processed them and submitted them to the registrar. At that point, I will send you a long email about how to inspect the information that went into your grade calculation and what to do it you see an error or have a question.

Have a wonderful summer! Good luck moving out into the real world if you are graduating! -- SLM