Physics 212E – Chowdary
Classical and Modern Physics
Spring 2005

E Problems for Unit I

E1: **Charged Balloon.** Charge up a balloon, and determine whether it has "T" charge or "B" charge. Describe your experiment. Next, discharge the balloon (or blow up another one); verify that this balloon is overall neutral. (How can you determine if the balloon is neutral?) See if you can charge up the balloon so that it has an opposite sign charge to your first case. Describe your attempts to charge the balloon with opposite sign. Feel free to discuss your attempts at the Discussion Board at the course web-site.

E2: **Visualizing Electric Fields.** The following web exercises will give you practice with the electric field from various configurations of charges (both field lines and field vectors). The first one is from Salt Lake Community College, and the second one from the Davidson College Physlets site.

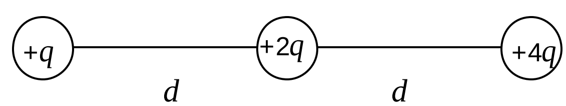
a) Go to **http://www.slcc.edu/schools/hum_sci/physics/tutor/2220/e_fields/java/**
and play around with different configurations of charges (points of a triangle, corners of a square, positive vs. negative, different magnitudes) and see the various kinds of electric field lines you can obtain. You may ignore "Draw an equipotential line" and "Auto draw electric potential lines".

b) Go to **http://www.eg.bucknell.edu/~phys211/physlets/sp2000/e_problem1.html**
Work through problems 1, 2, 3, and 4. This is different from the previous exercise in that you can see the magnitude and direction of the field vector at given points.

c) Go to **http://www.eg.bucknell.edu/~phys211/physlets/sp2000/e_problem4.html**
(This is just problem 4 from part b again.) Increase the separation distance between the poles of the dipole by about twice. Consider the line connecting the two charges. Move the red dot along that line, starting from left of the positive charge, to the middle of the charges, and ending to the right of the negative charge. What interesting things do you notice?

d) Continues from part c). Now, consider the perpendicular line that bisects the line segment connecting the poles of the dipole. Move the red dot from the center of the dipole out along that perpendicular bisector. What do you notice about the length of the arrow?

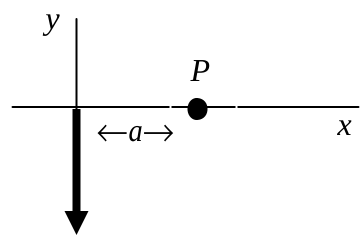
E3: **Charges on Strings.** Three (point like) charges: $+q$, $+2q$, and $+4q$ are connected by (massless, inextensible) strings as shown in the figure below, with separation distance d between nearest neigbors. Find the tension in each string.



E4: **Party Balloons.** Balloons on the walls at a party look festive. Balloons on the floor at a party get stomped. To prevent a balloon stomping, you charge up a balloon by rubbing it through your hair or on some clothes; the balloon will then stick to the wall. Explain using words and "cartoon" sketches why a charged balloon will stick to a wall, even though the wall likely does not have any net charge.

E5: **Electron Orbit.** A simple model of a hydrogen atom has the electron moving in a circular orbit about a stationary proton (protons are about 2000 times more massive than electrons). The centripetal force is provided by the electrostatic force of attraction between the proton and the electron. The electron has kinetic energy 2.18×10^{-18} J. (a) What is the speed of the electron? (b) What is the radius of the orbit of the electron? Note: later in the semester, we'll develop better models for atoms that utilize quantum mechanics.

E6: **Electric Fields through Integration – Semi-infinite rod I.** In the figure to the right, point P is located on the positive x-axis, a distance a from the origin. A semi-infinite rod with (uniform) linear charge density $\lambda > 0$ begins at the origin and extends along the negative y-axis, as shown.

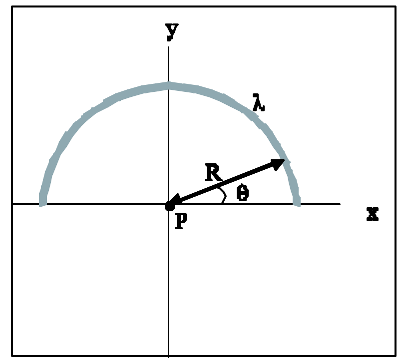


a) Set up and evaluate the integral that will allow you to calculate the x-component of the electric field at the point P.

b) Set up and evaluate the integral that will allow you to calculate the y-component of the electric field at the point P.

c) What interesting (and likely surprising) thing do you notice about the magnitudes of the x- and y- components of the electric field at this particular point P?

E7: **Electric Fields through Integration – Arcs.** The figure to the right shows an arc of radius R in the x-y plane running from $\theta = 0$ to $\theta = \pi$, which carries a linear charge density λ.

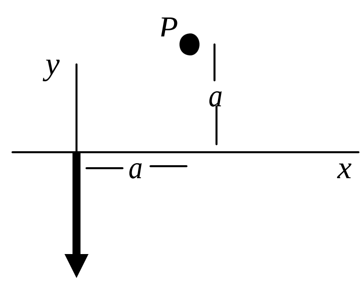


a) Assume that λ is positive and uniform. Set up and evaluate the integrals that will allow you to determine the x- and y- components of the electric field at the point P, which is at the origin. Though you may be able to use a symmetry argument for one of the components, please explicitly evaluate the integrals to verify your intuition.

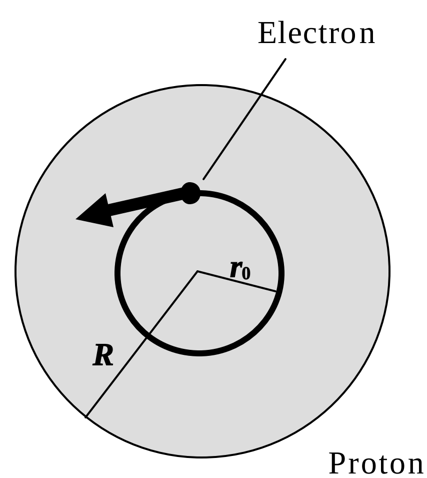
b) Now, assume that the charge density λ depends on the angle θ such that $\lambda = \lambda_0 \cos\theta$ (with λ_0 positive). Set up and evaluate the integrals that will allow you to determine the components of the electric field at the origin.

E8: **Flux through a Cube.** A positive point charge q is at the center of a cube of side length L. Determine the net outward flux of the electric field through the entire cubic surface, and determine the flux through just one face of the cube. Which of your answers would change if the charge weren't at the center of the cube?

E9: **Electric Fields through Integration – Semi-infinite rod II.** In the figure to the right, point P is located in the first quadrant, a distance a to the right of the origin, and a distance a above the origin. A semi-infinite rod with negative (uniform) linear charge density begins at the origin and extends along the negative y-axis, as shown. Set up and evaluate the integral to calculate the x-component of the electric field at the point P.



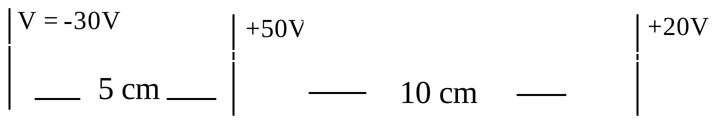
E10: **Electron Orbit, Revisited.** An early model of the hydrogen atom considered the atom to consist of a proton (treated as a uniformly charged sphere of radius R), with the electron (mass m) in an orbit of radius r_0 that was actually *inside* the proton, as shown in the figure.



a) Use Gauss's law to obtain the magnitude of E (the field due to the proton) at the position of the electron. Give your answer in terms of e (the charge on the proton), r_0 and R as well as any fundamental constants.

b) Obtain an expression for the frequency of revolution f in terms of any of the givens m, e, R, r_0 and any fundamental constants.

E11: **Constant Potential Parallel Plates.** The sketch shows three large parallel plate conductors held at the potentials shown.



a) Find the direction and magnitude of the uniform electric field in each of the two interior regions. How do you know the electric field is uniform?

b) An electron is released from rest exactly half way in between the + 50 V plate and the +20 V plate. Which plate does the electron head toward?

c) What speed does this electron have when it collides with the plate it is moving towards?

E12: **Let There Be Light (Bulbs).** In lab, for Experiment 13: Circuits, you played with some batteries, light bulbs, and wires. You have all those in your kits. Place the batteries in the battery holder and a bulb in the bulb holder.

a) Make a circuit with the one of the leads from the battery case connected in series to an alligator clip lead connected in series to a light bulb connected in series to the other lead from the battery case. Note the brightness. Now add a full length of one of your nichrome wires (bare silvery wire) to your circuit between the positive side of your batteries and the bulb. What happens to the brightness of the bulb? Explain briefly.

b) Repeat with the other equal piece of nichrome wire, using the same length you used in the previous part. Which wire has a larger resistance? A larger resistivity? Explain how you know. Examine the two wires carefully. Do you note any difference?

c) Now use just the higher resistance wire in the circuit. Carefully unclip the lead on the wire nearest the battery, and touch it onto the wire at various places. How is the bulb's brightness affected? This is basically how a dimmer switch works!

d) Now, make another circuit as in part a), but this time with two bulbs in series. Note the brightness.

e) Now replace one of the bulb holders in the circuit with the higher resistance nichrome wire, and slide the alligator lead from the batteries along the wire (reducing the length of the part of the wire in the circuit) until the remaining bulb is about as bright as before with the two bulbs. This means the resistance of that length of nichrome is the same as a bulb. Measure this length.

f) Since the wire is known to have a diameter of 0.25 mm, you can look up the resistivity of the wire in the text, and calculate the resistance of the wire, and therefore of the bulb.

g) From the battery voltage and the resistance of one bulb, determine the current through a normal flashlight bulb that uses two D-batteries (assume the batteries have the voltage they are labeled with).

E13: **Do the Twist.** Take your two (very strong!) cylindrical bar magnets from your toy kits.

a) Play with the magnets. If you don't think they are awesome, you must be dead inside. Write down some of the awesome things you did with these magnets. Don't write down if you did anything illegal or immoral. If you didn't find anything awesome to do with these magnets, write down why you are dead inside. Post your responses to the Discussion Board at the course web-site.

b) Take out the piece of string from your kit, and put the magnets together so that they squeeze the string in between them and are suspended from the string. Gently put one finger to the magnets so that they come to rest. When at rest, do the magnets have a preferred orientation? Check this by displacing them slightly from their equilibrium position or by slightly twisting the string. Why might these magnets have a preferred orientation?

c) We said that a magnetic moment in an external magnetic field would undergo a torque that tended to align the magnetic moment with the external field. Find someone else with a magnet, and test this out. Remember that the field lines from a bar magnet go out the North pole end and come in the South pole end.

E14: **Mapping Magnetic Field Lines.** Get your cylindrical bar magnet and place it, laying down (long axis horizontal), on a piece of paper. Use your compass to determine the "red" pole and the "white" pole of the bar magnet.

a) Now, leaving the bar magnet on the paper, trace out the magnet (it should look like a little rectangle) and indicate the "red" pole and the "white" pole on your drawing. Next, predict and sketch the magnetic field due to the bar magnet by drawing little **x**'s at various points on the paper and indicating the direction of the magnetic field using arrows.

b) Place your compass at the various **x**'s and draw a sketch of what you observe. Your sketch for the compass should have a little circle with an arrow carefully showing the direction the red part of the compass needle was pointing.

c) Your predicted arrows from part a) and the experimentally determined arrows from part b) shouldn't be perfectly aligned. How come? (Hint: consider what the purpose of a compass is, and how it accomplishes this.)

E15: **Repulsion Race.** Consider a proton and an alpha particle (which is a nucleus consisting of two protons and two neutrons) initially held 1 nm apart at rest.

a) The proton and alpha particle are released from rest and move away from each other. Assume the particles only interact with each other when released. When they are very far apart, the proton is moving 4 times as fast as the alpha particle. Explain, using a conservation law, why this must be the case.

b) Determine the final speed of the proton when it is very far away from the alpha particle.

E16: **Magnetic Home?** We've seen that currents are a source of magnetic fields by looking at the deflection of a compass needle due to current in a wire. Your dorm room, class rooms, and houses contain lots of wires carrying current through them. Do you need to be concerned about all the magnetic fields from power lines in your home?

a) The wire to a 100 Watt lamp carries about 1 amp of current to light the lamp. Calculate the magnetic field 5 mm from a wire carrying a steady current of 1 amp. Compare this to the Earth's field of approximately 0.7 G (= 7 x 10^{-5} T).

b) Put your compass near various wires in your room leading to electrical appliances and lights. Describe the compass deflections. Why don't you see much? (Hint: you've probably noticed that all plugs have at least two prongs; what do you think these two prongs are for?)

E17: **C'mon, Baby, Light My …. Light Bulb?** Let's see if we can use Faraday induction to light a light bulb, using a moving magnet.

a) Make a circuit consisting of a light bulb and one alligator lead. Hook both ends to the light bulb so that the wire makes a circle. Lay your circuit on the table and wave your magnet over it with the north pole pointing down. Be sure the magnet moves from directly over the circuit to at least a foot away from above the center of the circuit. Does the bulb light?

b) The magnetic field at the north pole of the magnet could be as strong as 0.1 T, but it is only this large over an area the size of the circular magnet end face. Estimate this area and the time it takes to move from flux to no flux, and thus estimate the induced emf. Use this to explain your answer to part a).

c) In lab, during Experiment 15: Motors and Generators, you were able to light up a special kind of light bulb (a Light Emitting Diode, or LED). Discuss at least two important things that were different between what you did in part a) and what you did in lab that resulted in getting the LED to light up.

E18: **Current Loop as Magnetic Dipole.** The claim was made in the book and during class discussion that the magnetic field from a loop of current is that of a magnetic dipole. Verify this claim using objects from your kit. Explain your idea, your method and your results.

E19: **Straight wire, Rectangular Loop.** Consider the long straight wire carrying current *I* from CH 28, #24 shown in Figure 28-45 of your textbook. The magnetic flux in the rectangular loop due to the *B*-field from the long straight wire was determined to be $\frac{\mu_0}{4\pi} 2Ib \ln\left|\frac{d+a}{d}\right|$.

a) The current in the long straight wire increases with time such that $I(t) = I_0 t^2 + c$, where I_0 and c are positive constants. Assume that the rectangular loop has resistance R, and that it is held fixed along with the long straight wire. Determine the magnitude of any current induced in the rectangular loop as a function of time and any provided or fundamental constants.

b) The rectangular loop is released from rest so that it is free to move. Determine the direction the of the net force (if any) acting on the loop after it is released. Explain your answer.

c) The rectangular loop is released from rest so that it is free to move. Determine the direction of the torque (if any) acting on the loop immediately after it is released; take the center of the loop as the reference point. Explain your answer.