PHYS 2250 Final Exam

Due: Friday, December 18, 2020 at 11:59 PM

Instructions: *You have until 11:59 PM on Friday to submit your exam. Please answer only one problem per page, and clearly label which problem you are working on. The exam must be submitted on Canvas as a single PDF via a scanner, or a smart-phone scanner app.* ***I reserve the right to deduct points if I can't read your work!*** *Partial credit may be awarded, so you are encouraged to clearly and legibly show your work for each problem. Email me if you have questions.*

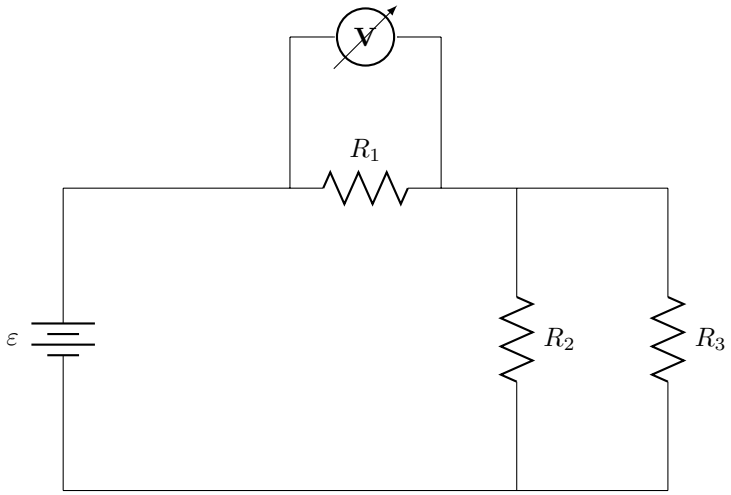
Academic Integrity: *The exam is open-book and open-note, but you are not allowed to discuss anything on the exam with your classmates (until after Friday night). Evidence of collaboration with classmates constitutes a violation of the University's academic honesty policy and may result in the complete forfeiture of your exam grade. This applies if you receive help from others or if you provide help to others*

1. You are given two electrons and two protons. What is one possible way to arrange the four charges such that the net electric field at the origin will be zero? (To specify your arrangement, give the x, y, and z coordinates of each charge, and sketch the arrangement.)

   *Note: there may be many possible answers, but you **may not** arrange all of the charges on the same axis!*

2. For this question, choose one of either (a) or (b) to solve. Clearly indicate which problem you are solving. If you solve both, you will not receive extra credit, but I will count the problem for which you received the most points.

   (a) In the circuit below: $\varepsilon = 9$ V, $R_1 = 120\ \Omega$, $R_2 = 100\ \Omega$, and $R_3 = 150\ \Omega$. A voltmeter is connected across R_1. If the resistor inside of the voltmeter has a resistance of of 1 kΩ, by what percentage is the voltmeter off from the "true" value (the voltage across the resistor when the voltmeter is not connected)?

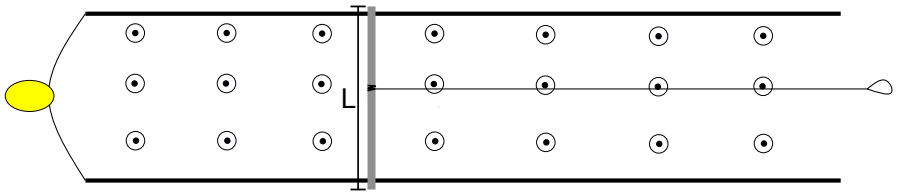


(b) You want to wire together a strand of Christmas lights. You have 5 bulbs, each with a resistance of 10 Ω. The power source for your circuit will be a standard 120 V wall outlet (you can treat this as a 120 V battery). Design a circuit which meets the following specifications:

- Your circuit must contain all 5 bulbs
- The power dissipated over each bulb is at least 0.5 W
- The current through each bulb may not exceed 3 A
- When one bulb burns out, the others stay lit

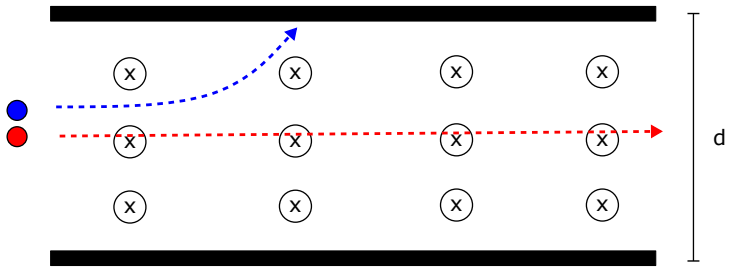
You also have at your disposal a variable resistor which can be set to any value between 10-500 Ω. Sketch your circuit and show that it meets the above specifications.

3. You are celebrating Christmas with your family when suddenly the power goes out and all of the Christmas lights go off. Not to fear, because you learned in your physics class how to generate power! Using an assembly of refrigerator magnets, you create a uniform magnetic field with a magnitude of 2 T. You then assemble a very long circuit with a movable bar of length $L = 10$ cm sliding along the frictionless circuit, like the one shown in the figure. The magnetic field is perpendicular to this circuit and points out of the page. Your plan is to tie a string to the bar and pull it to produce a current through a single Christmas tree bulb, which requires 0.5 W of power to illuminate and has a resistance of 10 Ω. How fast do you need to pull the bar in order to light the bulb?



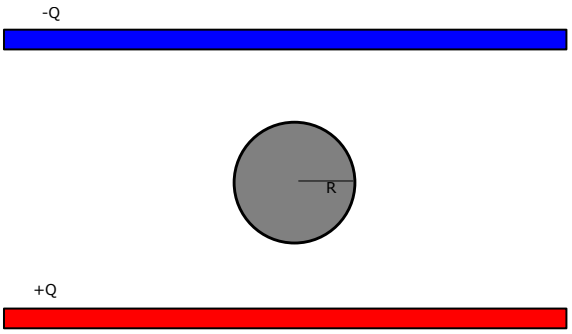
4. An experimental setup consists of two large plates holding equal and opposite charge, with a uniform magnetic field of magnitude 0.3 T in between them which points into the page(see the figure). The plates are a distance $d = 2$ cm apart.

   You fire a proton from the left with velocity $v = 700$ m/s and observe that the proton passes through the plates undeflected. Next, you fire an electron from the left with a velocity of $v = 650$ m/s, and observe that the electron drifts towards the top plate (as shown). What is the electric potential of the top plate relative to the bottom plate ($V_{top} - V_{bottom}$)?

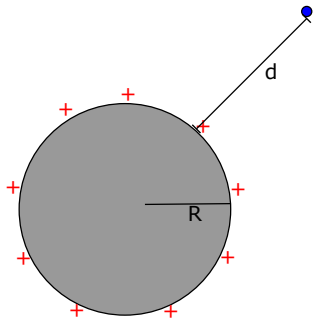


5. From the following: pick one to solve. If you solve more than one, you will receive credit for the problem with the highest score.

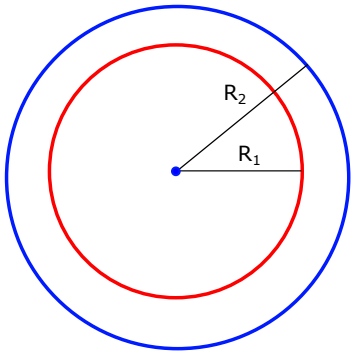
   (a) A charge-neutral sphere of radius $R = 0.05$ cm is situated in between the plates of a parallel plate capacitor with charge $Q = 9$ nC. The top plate carries the negative charge (see the figure). What is the total electric flux through the sphere?



(b) An electron (mass = 9.11×10^{-31} kg) is released from rest a distance $d = 12$ cm from the surface of a uniformly charged sphere with radius $R = 5$ cm and total charge $Q = 12$ nC. What is the velocity of the electron immediately before it collides with the surface of the sphere?



6. Two uniformly charged spherical shells are concentric with a point charge at the shared center (see figure). The point charge has a charge $Q_{pt} = -4\ \mu$C. The inner shell has a total charge $Q_{inner} = 2\ \mu$C, and radius $R_1 = 0.2$ m, and the outer shell has a total charge $Q_{outer} = -2\ \mu$C and a radius $R_2 = 0.3$ m. The shells are separated by vacuum (they are not in conductive contact).

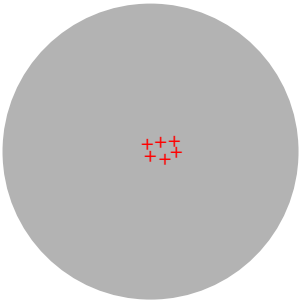


(a) What is the potential difference between the surfaces of the inner and outer shell?

(b) What is the magnitude of the net force experienced by a proton placed 0.5 m away from the center of the shells?

7. (a) You release a proton from rest in the presence of an unknown force field. Seconds later, you measure the velocity of the proton to be 450 m/s. Which force(s) may have contributed to this acceleration? (Circle all that apply, and justify your answer).
   1. Gravitational Field
   2. Magnetic Field
   3. Electric Field
   4. Hydrostatic Field

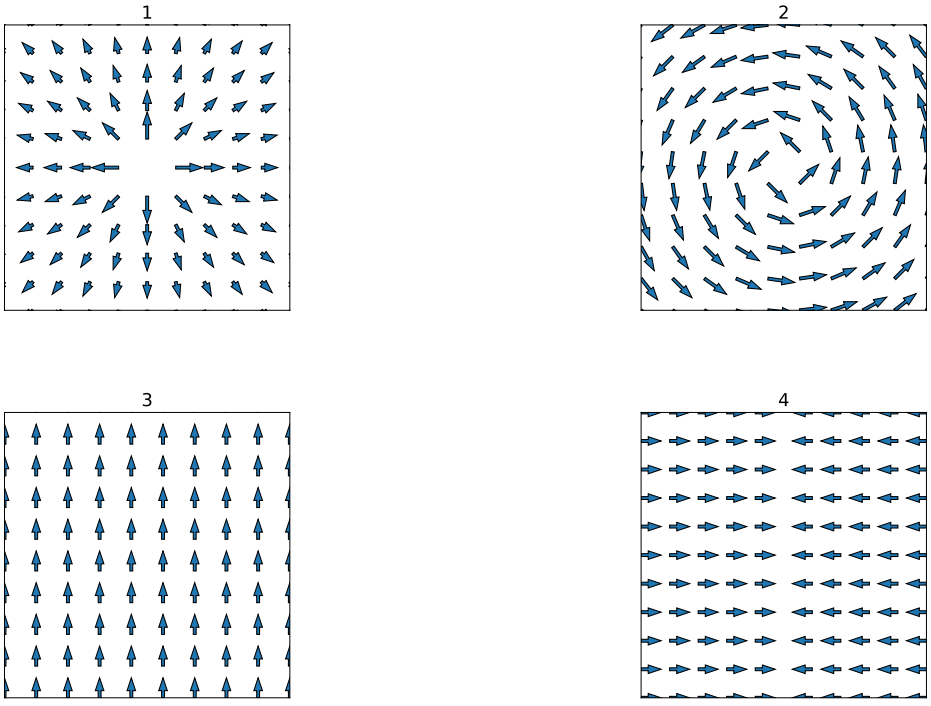
   (b) Several positive charges are placed at the center of a solid insulating sphere



   i. Sketch the approximate charge distribution a few seconds later (long after any equilibrium has been reached)

   ii. The exact process is repeated, this time for a solid conducting sphere. Once again, sketch the approximate charge distribution several seconds later.

   (c) For each of the four electric field patterns shown below, sketch a possible charge distribution responsible for creating that field. If the field is not possible, say so and explain why.



8. This problem is for extra credit and is worth 1/2 of a regular problem.

   A loop of wire with dimensions $h \times w$ rotates about its central axis with an angular frequency ω. The wire is in the presence of a uniform magnetic field which points in the upward direction at all times. If $w = 10$ cm, $h = 15$ cm, $|\vec{B}| = 0.2$ T, and $\omega = 400$ s^{-1}, what is the maximum emf generated around the loop?