Electricty & Magnetism Core Proficiency Exam
January 2022
Problems provided by the Physics Faculty.
Exam assembled by the CPE Committee

Instructions

The exam consists of two longer questions and two shorter questions.
All four problems will be graded. You have two hours to work on the solutions.
You are allowed one textbook of your choice, one math reference, and a calculator
(no cell phone calculator allowed).

Write your personal identifier (e.g. name, number, etc.) on the cover sheet of this exam.

We will scan the exams to PDF, so please write only on one side of the page.
Sort your copy of the exam together with your scratch paper (exam on top) with the problems in numerical order. You may wish to number the pages so we can check the scanner did not miss a page.

Problem	Points	Score			Final Score
1	20				
2	20				
3	30				
4	30				
Total	100				

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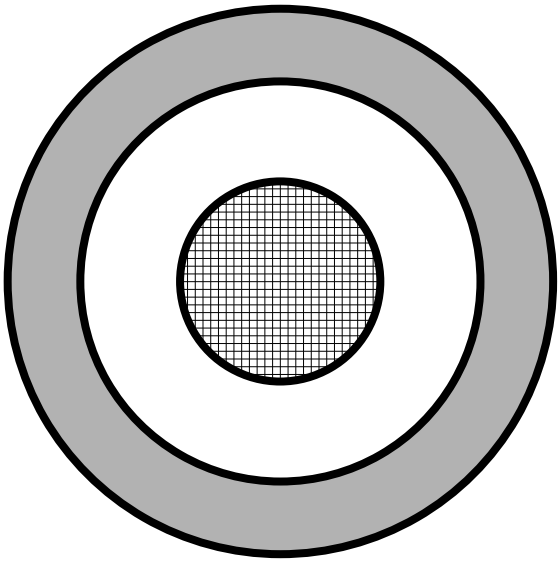
Problem #1 (20 points)



(20 points): There is an empty conducting shell with an inner radius of b=5.0 cm and an outer radius of c=7.0 cm, and it has an excess charge of 20 nC. At the center of that shell is a non-conducting sphere of radius a=3.0 cm with an excess charge of -75 nC uniformly distributed throughout the volume.

(5 points each) What is the magnitude of the electric field at a point

(a) 1.5 cm,
(b) 4.5 cm,
(c) 6.0 cm and
(d) 8.0 cm from the center of the shell?

Problem #2 (20 points)

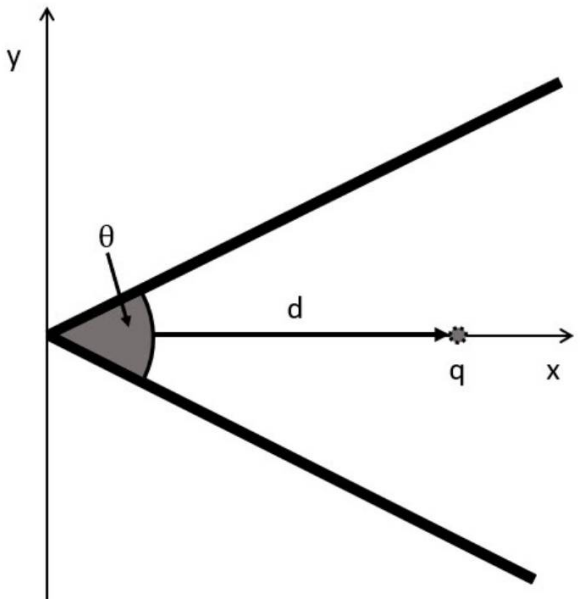
Question (20 points): Suppose you have two infinitely long current-carrying wires perpendicular to this page and 5cm apart as suggested by the figure. The left wire carries 1.3A of current out of the page. For this problem, you can restrict your analysis to the 1-dimensional line which intersects the wires (and is perpendicular to the wires).

a) (10 points) If we want the magnetic field to be zero at some point to the left of the left wire, what direction must the current in the second wire be pointing? What are the resulting directions of the magnetic fields due to each wire at that point?

b) (10 points) What is the expression of the current in terms of the distance, I(x), that would result in a zero magnetic field at some point ‘x’ to the left of the left current? What does this expression tell you in the limit that the point ‘x’ is at a distance <u>much larger than</u> the distance between the two wires ($x \rightarrow \infty$)?

Problem #3 (30 points)

Two perfectly conducting, infinite and grounded half-planes intersect at angle $\theta = \pi/3$ (see figure). A charge q is located half-way between the planes at distance d from the intersection.



(a) Find the potential V(x, y) for the region between the plates where the charge is located.

(b) Find the force, F, the conducting planes exert on the point charge.

(c) Calculate how much work is required to bring the charge q from infinity to its position shown in the figure.

Problem #4 (30 points)

(30 points) Current I(t) flows in an infintely long thin wire that lies along the z-axis.
For $t \leq 0$, the current is I_0; the current goes to zero linearly in time T and remains zero for $t \geq T$.
A square loop of wire with resistivity ρ, side length L, and circular cross section with diameter d lies in the xz-plane.
The vertices of the square are at points (a, 0, ±L/2), (a+L, 0, ±L/2).

(a) (6 points) At time t, where $0 < t < T$, what is the magnetic flux through the loop?

(b) (10 points) At time t, where $0 < t < T$, what is the current in the loop?

(c) (14 points) At time t, where $0 < t < T$, is there a force or a torque on the loop? If so, calculate the magnitude and direction from the given quantities.