

171.106: Electromagnetic Theory I
Midterm Exam 3/11/10 1:30-2:30

A letter sized paper with formulae on both sides is permitted. Start each problem on a fresh page and please give detailed reasoning. If in a later question you need a result from a question that you cannot solve then write formulae with the unknown as a symbol and you will get due credit. Ask your proctor for clarification if the text is unclear.

Problem 1 (20 points)

Three particles with charge Q are located at the vertices of square with side-length d as shown in Fig. 1.

- (a) Find the direction and magnitude of the electric field on the vacant point of the square. (10 points)
- (b) Determine the work required to place the charged particles in this configuration starting from infinite separation. (10 points)

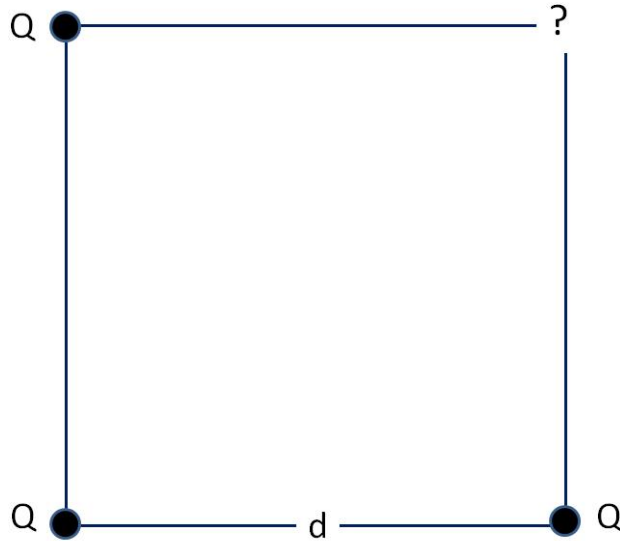


Figure 1

Problem 2 (20 points)

Consider a thin insulating ring with radius, a , onto which carries a line charge density given by $\lambda(\phi) = \frac{Q}{2\pi a} \cos \phi$. Here ϕ is the angle from the x -axis as indicated in Fig. 2 and Q has dimension of charge.

- Determine the total charge on the ring (5 points)
- Sketch the electric field lines (5 points)
- Determine magnitude and direction of the electric field at the origin (10 points)

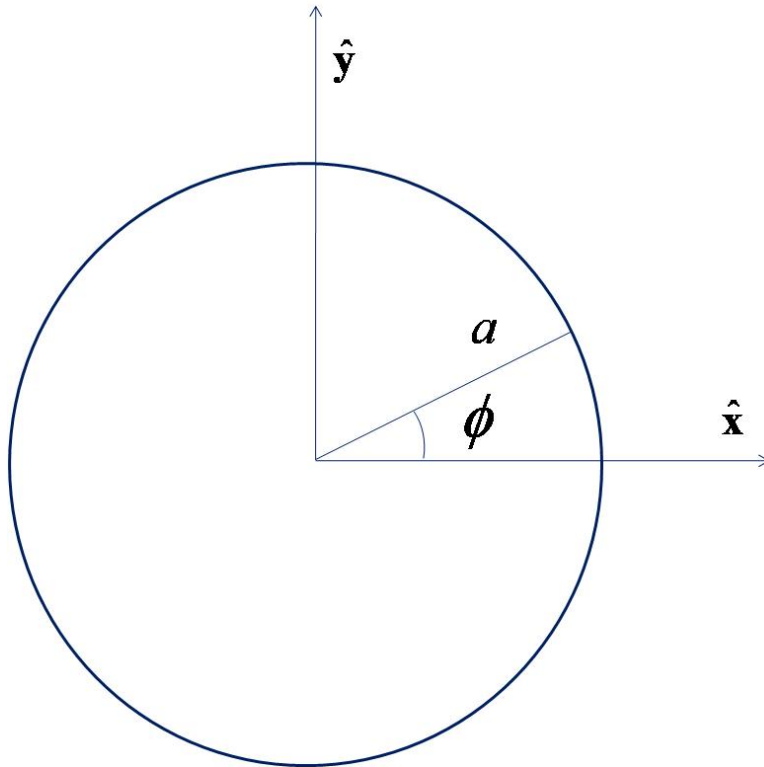


Figure 2

Problem 3 (30 points)

A thin insulating spherical shell of radius, a , carries a total charge, Q , which is uniformly distributed.

- (a) Determine the electric field throughout space. (5 points)
- (b) Determine the electric potential throughout space. (5 points)

A matching pair of hemispherical conducting shells have an inner radius $b_i > a$ and an outer radius $b_o > b_i$. The hemispherical shells are placed concentrically around the charged shell and joined to form a surrounding conducting shell as shown in Fig. 3.

- (c) Determine the resulting modifications to the electric field. (5 points)
- (d) Is the work, W , required to move the spheres from infinity to the concentric position positive or negative, and why? (5 points)
- (e) Determine W . (10 points)

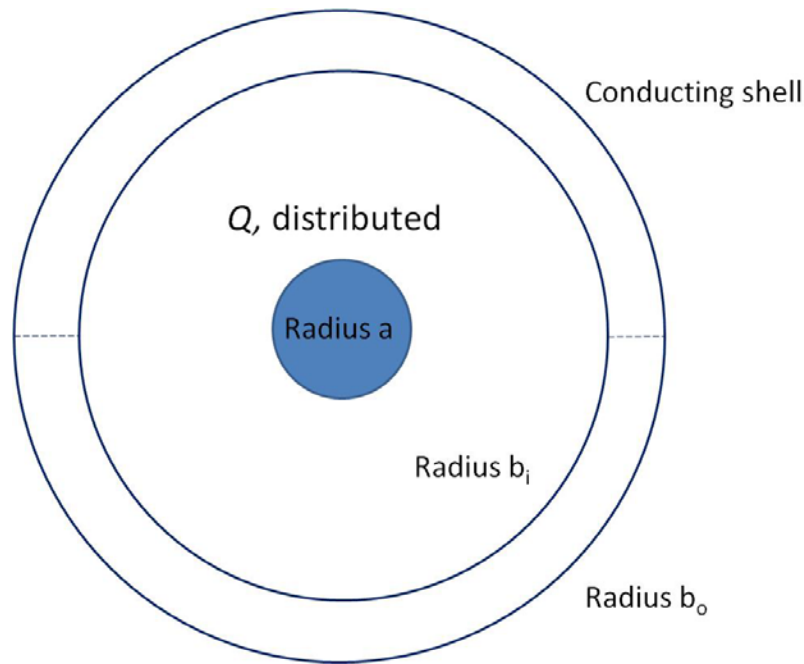


Figure 3

Problem 4 (30 points)

Consider two conducting spheres with radius a and b . The distance between the spheres is sufficiently large that you can consider the charge distribution on each sphere to be approximately spherical.

- (a) Determine the electrical capacity of each isolated sphere. (10 points)

The spheres are now connected by a conducting wire and a total amount of charge Q is placed on the resulting conducting system.

- (b) Determine the amount of charge on each sphere. (10 points)
- (c) Determine the electrical capacity of the connected spheres. (10 points)

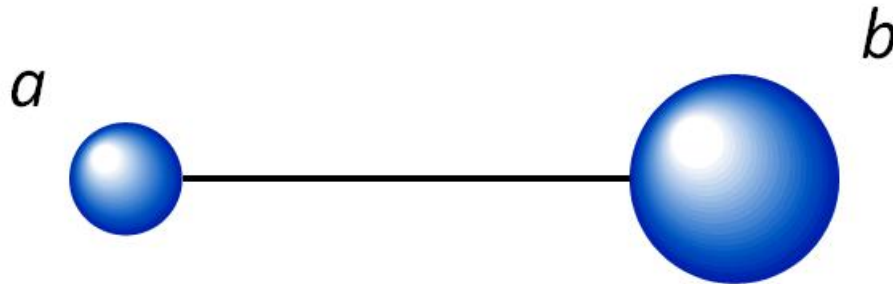


Figure 4