

# Physics 2135 Exam 1

September 22, 2015

**Exam Total**

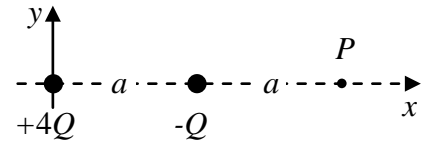
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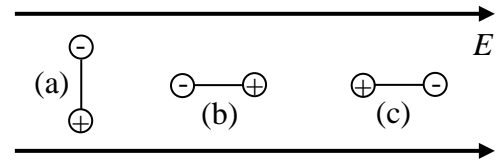
Five multiple choice questions, 8 points each. Choose the **best** or **most nearly correct** answer.

\_\_\_\_\_ 1. Positive charge  $+4Q$  is located at  $(x,y)=(0,0)$  and negative charge  $-Q$  is located at  $(x,y)=(a,0)$ . Which of the statements about the electric potential  $V_P$  and electric field  $\vec{E}_P$  at the point  $P(x,y)=(2a,0)$  is true? (Assume  $V=0$  at infinity.)



- [A]  $V_P > 0$  and  $\vec{E}_P$  points  $\rightarrow$       [B]  $V_P < 0$  and  $\vec{E}_P$  points  $\leftarrow$   
 [C]  $V_P = 0$  and  $\vec{E}_P$  is zero      [D]  $V_P > 0$  and  $\vec{E}_P$  is zero

\_\_\_\_\_ 2. The figure to the right shows three possible orientations of an electric dipole in a uniform electric field. For which orientation is the dipole electric potential energy minimum?

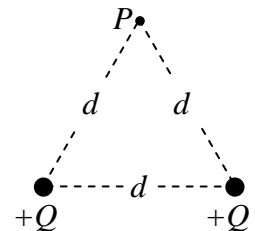


- [A] orientation (a)  
 [B] orientation (b)  
 [C] orientation (c)

\_\_\_\_\_ 3. When a positive charge  $+Q$  is placed inside a Gaussian surface, the electric flux through the surface is  $\Phi_0$ . If a second identical positive charge  $+Q$  is then placed just outside the Gaussian surface, the electric flux through the surface is

- [A]  $\Phi_0$       [B]  $\Phi_0/2$   
 [C]  $2\Phi_0$       [D] 0.

\_\_\_\_\_ 4. Identical positive point charges  $+Q$  are placed at two of the vertices of an equilateral triangle, as shown. Point  $P$  is at the third vertex. What charge must be placed at point  $P$  so that the electric potential energy of the system consisting of all three charges is zero?

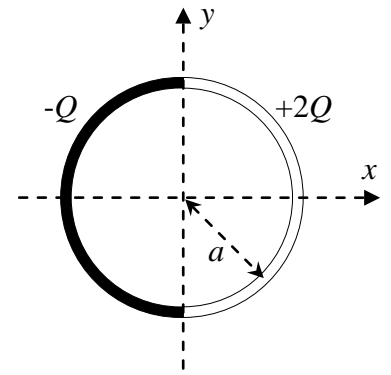


- [A]  $-2Q$       [B]  $-4Q$   
 [C]  $-Q/2$       [D]  $-Q$

\_\_\_\_\_ 5. What did Dr. Pringle say when the neutron asked for a peanut butter sandwich?

- [A] I'm positive we're out of bread today.  
 [B] For you, there is no charge.  
 [C] Are you sure you won't have a negative reaction to the peanuts?

6. (40 points total) A thin insulating ring of radius  $a$  lies flat in the  $xy$ -plane with its center at the origin of the coordinate system. The right half of the ring carries a positive charge  $+2Q$  uniformly distributed over its length while the left half carries a negative charge  $-Q$  uniformly distributed over its length.



(a) (5 points) Find the linear charge densities  $\lambda_{\text{left}}$  and  $\lambda_{\text{right}}$  of the left and right semicircles, respectively.

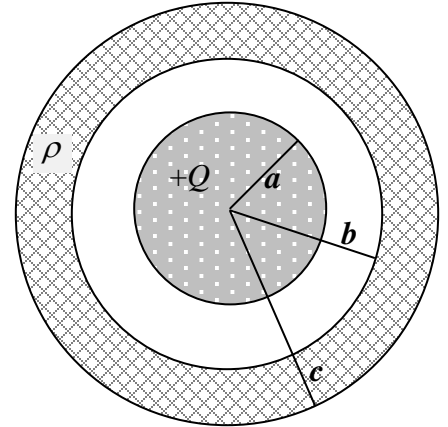
(b) (25 points) Find the magnitude and direction of the electric field at the origin of the coordinate system (use symmetry arguments when appropriate).

(c) (10 points) A small ball of mass  $m$  and negative charge  $-q$  is placed at the center of the ring and released from rest. Find magnitude and direction of its initial acceleration (gravity can be neglected).

7. (40 points total) A solid conducting sphere of radius  $a$  carries a net charge of  $+Q$ . The sphere is surrounded by a concentric insulating spherical shell of inner radius  $b$  and outer radius  $c$  which carries a uniform positive charge density  $\rho$ .

(a) (10 points) What is the **magnitude** of the electric field for  $r < a$ ?

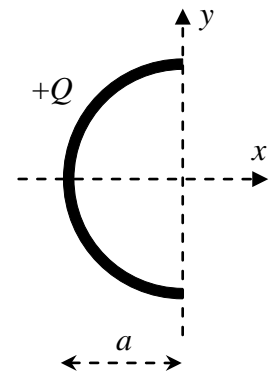
(b) (10 points) In the diagram to the right, draw a Gaussian surface that you could use to find the electric field for  $a < r < b$ . For a point of your choice on that surface, show the directions of the  $\vec{E}$  and  $d\vec{A}$  vectors.



(c) (10 points) Use Gauss's law to find the **magnitude** of the electric field for  $a < r < b$ .

(b) (10 points) Use Gauss's law to find the **magnitude** of the electric field for  $b < r < c$ .

8. (40 points total) A thin, uniformly charged insulating rod is bent into a semicircle with radius  $a$  and placed as shown, with its center of curvature at the origin. The total charge on the rod is  $+Q$ .



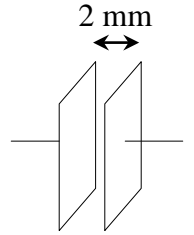
(a) (15 points) **Derive** an expression for the electrical potential  $V$  at the origin. You may assume that the electrical potential is zero at a point infinitely far away.

(b) (15 points) A positive charge  $+q$  with mass  $m$  is placed at the origin and released from rest. Calculate the work done by the electric field in moving the particle from the origin to infinity along the positive  $x$  axis.

(c) (10 points) Calculate the maximum speed of the particle after it is released from rest. Express your answer in terms of system parameters.

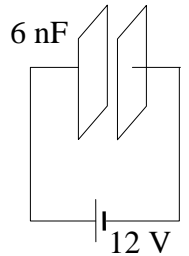
9. (40 points total) (All solutions MUST start with OSE's.)

(a) (10 points) A parallel-plate capacitor consists of two conducting plates of width 2 m and length 3 m. The separation between the two plates is 2 mm. What is the capacitance of the capacitor?



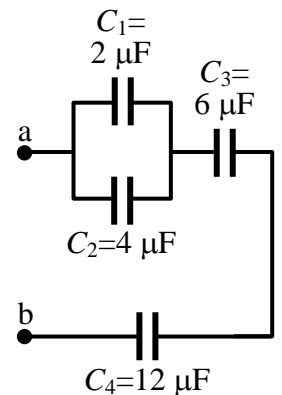
(b) (10 points) A 12 V battery is connected to a parallel-plate capacitor with capacitance of 6 nF.

(i) Calculate the charge stored in the capacitor.



(ii) The battery is then disconnected from the capacitor. What is the charge stored in the capacitor if the separation between the two plates is doubled?

(c) (10 points) Calculate the equivalent capacitance between a and b for the capacitor circuit shown.  $C_1 = 2 \mu\text{F}$ ,  $C_2 = 4 \mu\text{F}$ ,  $C_3 = 6 \mu\text{F}$ , and  $C_4 = 12 \mu\text{F}$ .



(d) (10 points) A battery supplying a potential difference of 15 V is connected across a and b in the capacitor circuit in part (c). Determine the charge stored in  $C_1$ .