AP Physics C: Electricity & Magnetism
1999 Free-Response Questions

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1999

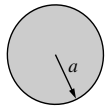
PHYSICS C

SECTION II, ELECTRICITY AND MAGNETISM

Time—45 minutes

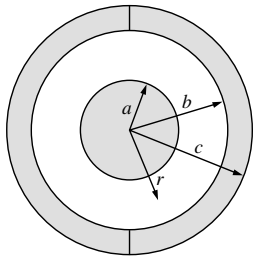
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.



E&M 1. An isolated conducting sphere of radius $a = 0.20\ \text{m}$ is at a potential of $-2{,}000\ \text{V}$.

(a) Determine the charge Q_0 on the sphere.



The charged sphere is then concentrically surrounded by two uncharged conducting hemispheres of inner radius $b = 0.40\ \text{m}$ and outer radius $c = 0.50\ \text{m}$, which are joined together as shown above, forming a spherical capacitor. A wire is connected from the outer sphere to ground, and then removed.

(b) Determine the magnitude of the electric field in the following regions as a function of the distance r from the center of the inner sphere.

i. $r < a$
ii. $a < r < b$
iii. $b < r < c$
iv. $r > c$

(c) Determine the magnitude of the potential difference between the sphere and the conducting shell.

(d) Determine the capacitance of the spherical capacitor.

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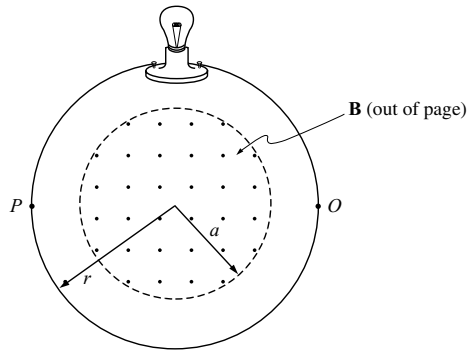
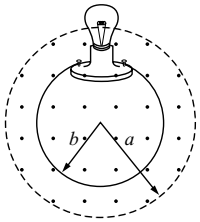


E&M 2. A uniform magnetic field $\mathbf{B}$ exists in a region of space defined by a circle of radius $a = 0.60$ m as shown above. The magnetic field is perpendicular to the page and increases out of the page at a constant rate of 0.40 T/s. A single circular loop of wire of negligible resistance and radius $r = 0.90$ m is connected to a lightbulb with a resistance $R = 5.0\ \Omega$, and the assembly is placed concentrically around the region of magnetic field.

(a) Determine the emf induced in the loop.

(b) Determine the magnitude of the current in the circuit. On the figure above, indicate the direction of the current in the loop at point O.

(c) Determine the total energy dissipated in the lightbulb during a 15 s interval.

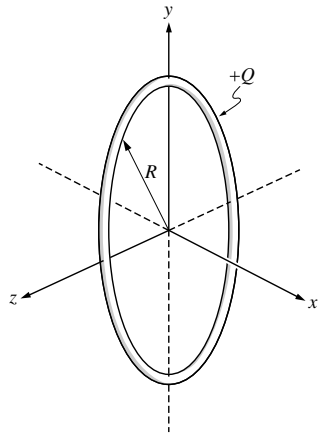


The experiment is repeated with a loop of radius $b = 0.40$ m placed concentrically in the same magnetic field as before. The same lightbulb is connected to the loop, and the magnetic field again increases out of the page at a rate of 0.40 T/s. Neglect any direct effects of the field on the lightbulb itself.

(d) State whether the brightness of the bulb will be greater than, less than, or equal to the brightness of the bulb in part (a). Justify your answer.

GO ON TO THE NEXT PAGE

1999 PHYSICS C—E & M



E&M 3. The nonconducting ring of radius R shown above lies in the yz-plane and carries a uniformly distributed positive charge Q.

(a) Determine the electric potential at points along the x-axis as a function of x.

(b) i. Show that the x-component of the electric field along the x-axis is given by

$$E_x = \frac{Qx}{4\pi\epsilon_0 (R^2 + x^2)^{\frac{3}{2}}}.$$

ii. What are the y- and z- components of the electric field along the x-axis?

(c) Determine the following.

i. The value of x for which E_x is a maximum

ii. The maximum electric field $E_{x\,\max}$

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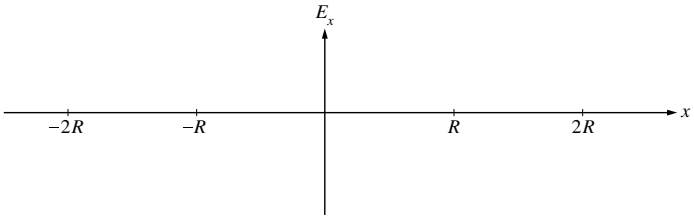
(d) On the axes below, sketch E_x *versus* x for points on the x-axis from $x = -2R$ to $x = +2R$.



(e) An electron is placed at $x = R/2$ and released from rest. Qualitatively describe its subsequent motion.

S T O P

END OF SECTION II, ELECTRICITY AND MAGNETISM