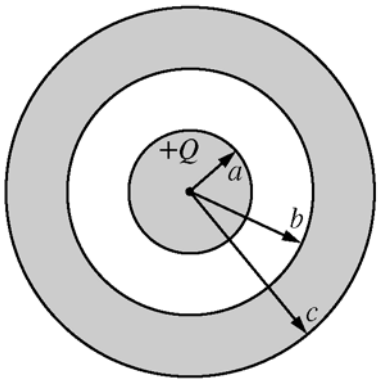
PHYSICS C: ELECTRICITY AND MAGNETISM
SECTION II
Time—45 minutes

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.

A metal sphere of radius a contains a charge $+Q$ and is surrounded by an uncharged, concentric, metallic shell of inner radius b and outer radius c, as shown above. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Determine the induced charge on each of the following and explain your reasoning in each case.

i. The inner surface of the metallic shell

ii. The outer surface of the metallic shell

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

i. $r < a$

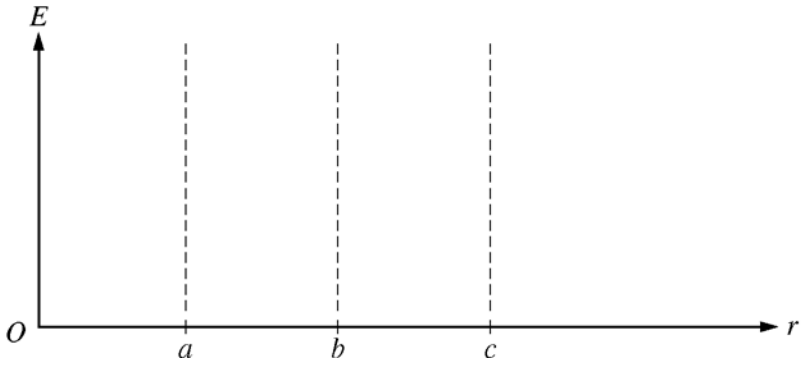
ii. $a < r < b$

iii. $b < r < c$

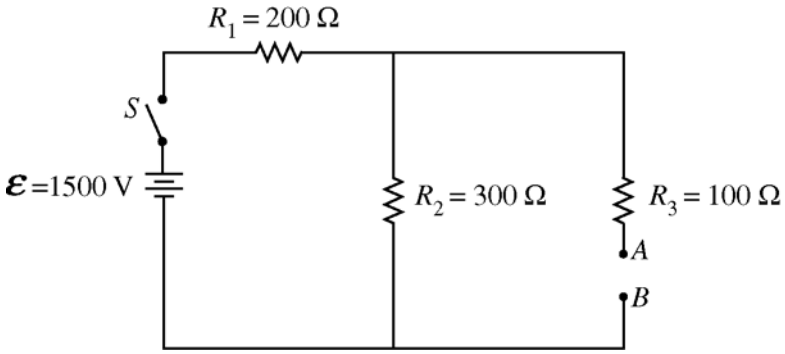
iv. $c < r$

GO ON TO THE NEXT PAGE.

(c) On the axes below, sketch a graph of E as a function of r.



(d) An electron of mass m_e carrying a charge $-e$ is released from rest at a very large distance from the spheres. Derive an expression for the speed of the particle at a distance $10r$ from the center of the spheres.



E&M. 2.

In the circuit shown above, A and B are terminals to which different circuit components can be connected.

(a) Calculate the potential difference across R_2 immediately after the switch S is closed in each of the following cases.

i. A 50 Ω resistor connects A and B.

ii. A 40 mH inductor connects A and B.

iii. An initially uncharged 0.80 μF capacitor connects A and B.

(b) The switch gets closed at time $t = 0$. On the axes below, sketch the graphs of the current in the 100 Ω resistor R_3 versus time t for the three cases. Label the graphs R for the resistor, L for the inductor, and C for the capacitor.

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Question 1

15 points total **Distribution of points**

(a)

(i) 2 points

For indicating that the charge on the inner surface of the shell is $-Q$ 1 point

For a correct explanation with no incorrect statements 1 point

Examples:

- Applying Gauss's law to a Gaussian surface within the shell gives $Q_{\text{enclosed}} = 0$, since the field within a conductor is zero. Therefore the charge on the inner surface of the shell is $-Q$.
- The $+Q$ on the sphere attracts an equal and opposite charge onto the inner surface of the shell. (Equal magnitude could be implied by a statement that earned the first point.)

(ii) 2 points

For indicating that the charge on the outer surface of the shell is $+Q$ 1 point

For a correct explanation with no incorrect statements 1 point

Examples:

- Applying Gauss's law to a Gaussian surface outside the shell gives $Q_{\text{enclosed}} = +Q$, therefore the sum of the charges on the inner and outer surfaces of the shell must be 0.
- The net charge on the shell is zero. Therefore the charge on the outer surface must be the opposite of the charge on the inner surface because of conservation of charge.

Note: If the correct sign of the charge is given in part i or ii without the magnitude (Q), a correct explanation could receive 1 point.

(b)

(i) 1 point

Since the sphere is a conductor all the charge lies on the outside surface. Applying Gauss's law to any Gaussian surface inside the sphere gives $Q_{\text{enclosed}} = 0$.

For a correct answer 1 point

$E = 0$

(ii) 1 point

For any surface between the sphere and the shell the net enclosed charge is $+Q$.

Applying Gauss's law

$E4\pi r^2 = Q/\epsilon_0$

For a correct answer 1 point

$E = Q/4\pi\epsilon_0 r^2$ or $E = kQ/r^2$