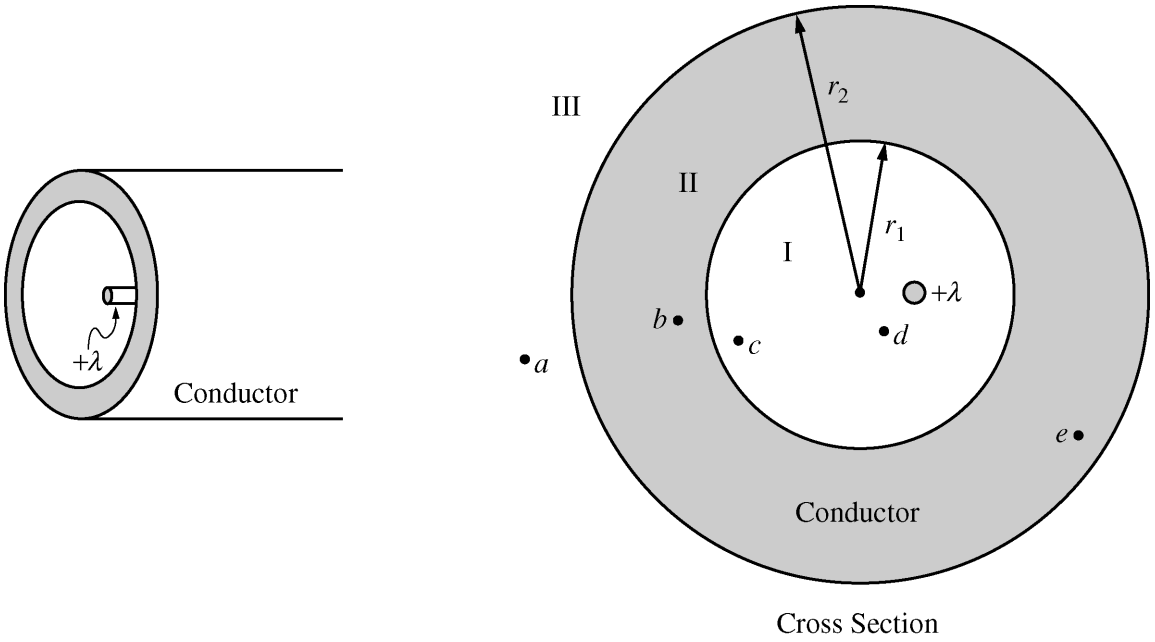
PHYSICS C

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 booklet in the spaces provided after each part, NOT in this green insert.



Cross Section

E&M. 1.

The figure above left shows a hollow, infinite, cylindrical, uncharged conducting shell of inner radius r_1 and outer radius r_2. An infinite line charge of linear charge density $+\lambda$ is parallel to its axis but off center. An enlarged cross section of the cylindrical shell is shown above right.

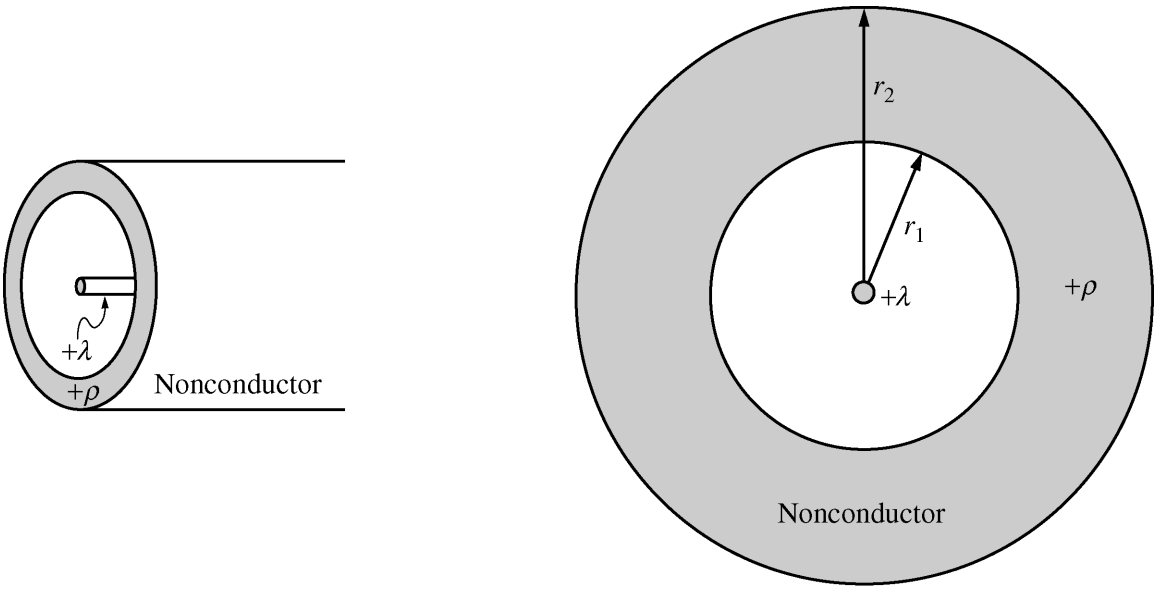
(a) On the cross section above right,

i. sketch the electric field lines, if any, in each of regions I, II, and III and

ii. use + and − signs to indicate any charge induced on the conductor.

(b) In the spaces below, rank the electric potentials at points a, b, c, d, and e from highest to lowest (1 = highest potential). If two points are at the same potential, give them the same number.

____ V_a ____ V_b ____ V_c ____ V_d ____ V_e



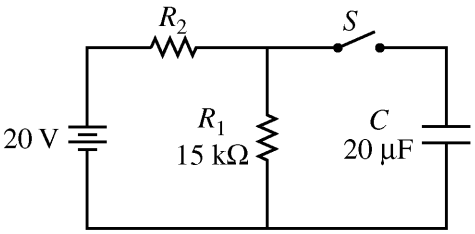
Cross Section

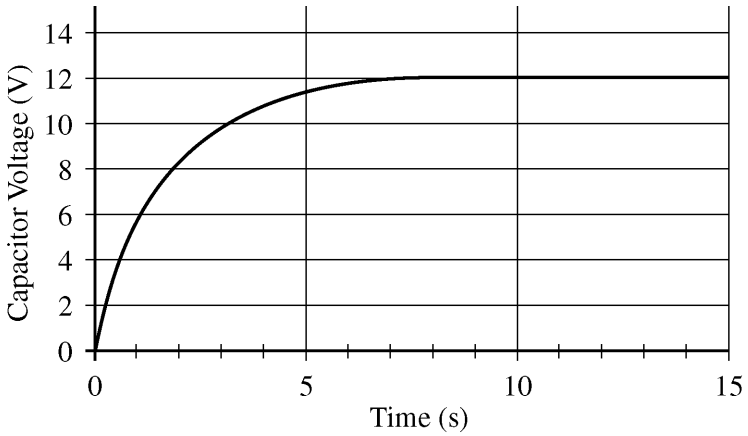
(c) The shell is replaced by another cylindrical shell that has the same dimensions but is nonconducting and carries a uniform volume charge density $+\rho$. The infinite line charge, still of charge density $+\lambda$, is located at the center of the shell as shown above. Using Gauss's law, calculate the magnitude of the electric field as a function of the distance r from the center of the shell for each of the following regions. Express your answers in terms of the given quantities and fundamental constants.

i. $r < r_1$

ii. $r_1 \leq r \leq r_2$

iii. $r > r_2$





E&M. 2.

In the circuit shown above left, the switch S is initially in the open position and the capacitor C is initially uncharged. A voltage probe and a computer (not shown) are used to measure the potential difference across the capacitor as a function of time after the switch is closed. The graph produced by the computer is shown above right. The battery has an emf of 20 V and negligible internal resistance. Resistor R_1 has a resistance of 15 kΩ and the capacitor C has a capacitance of 20 μF.

(a) Determine the voltage across resistor R_2 immediately after the switch is closed.

(b) Determine the voltage across resistor R_2 a long time after the switch is closed.

(c) Calculate the value of the resistor R_2.

(d) Calculate the energy stored in the capacitor a long time after the switch is closed.

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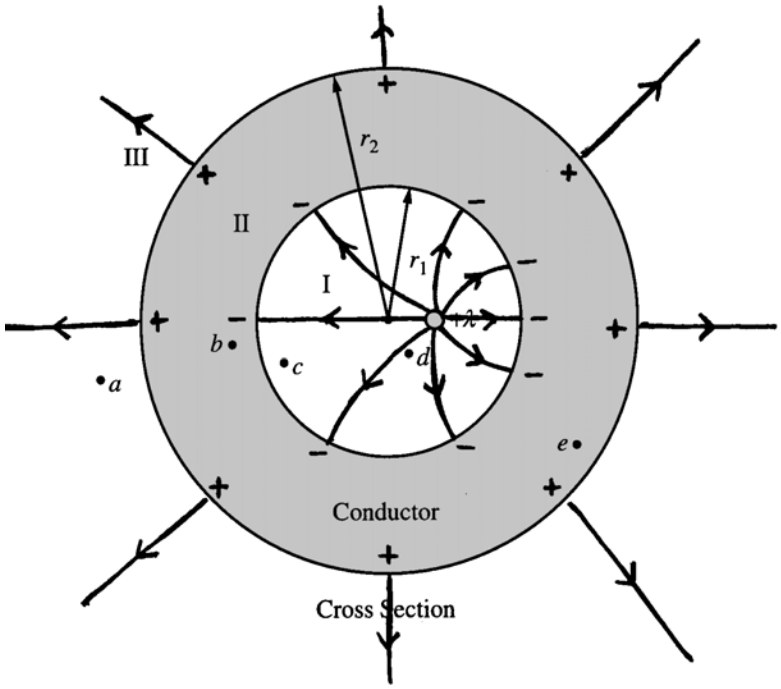
2004 SCORING GUIDELINES

Question 1

15 points total **Distribution of points**

(a)



i. 3 points

For field lines inside the shell that point outward and are reasonably close to being 90° to both the line charge and the shell surface, with obviously more lines on the right side than the left — 1 point

For field lines outside the shell that are radial and noncontinuous with those inside the shell, reasonably close to 90° to the shell surface, and approximately evenly spaced — 1 point

For no field lines inside the shell, given that there are field lines drawn elsewhere — 1 point

ii. 2 points

For only negative charges on the inside surface of the shell, with obviously more charges on the right side — 1 point

For only positive charges on the outside of the shell, approximately evenly spaced — 1 point