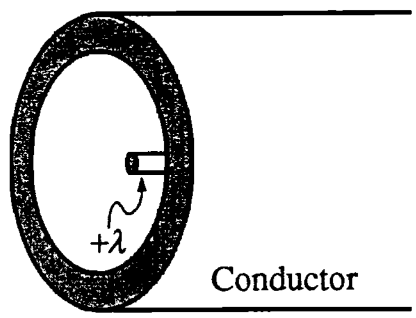
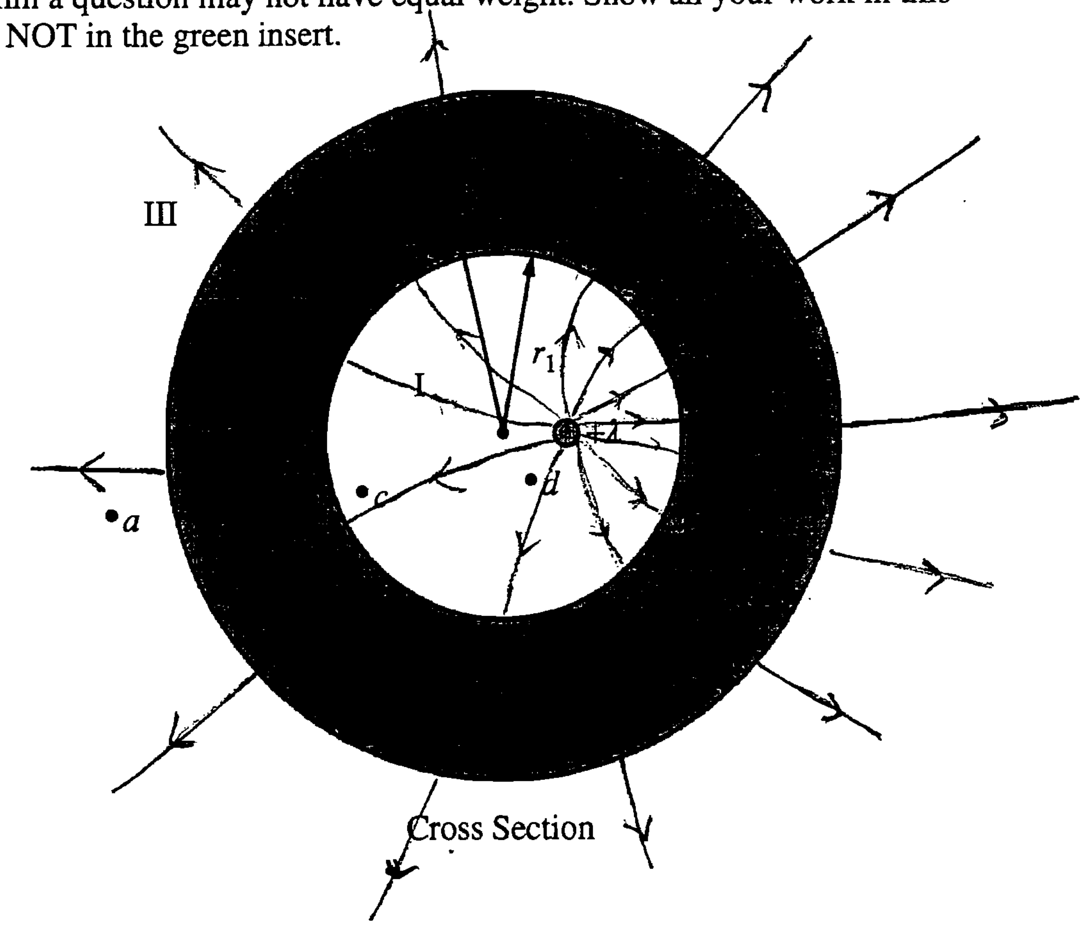
AP® Physics C: Electricity and Magnetism
2004 Sample Student Responses

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





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

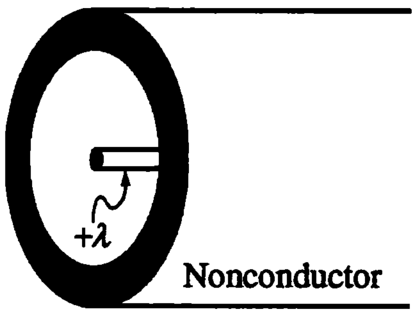
ii. use + and – signs to indicate any charge induced on the conductor.

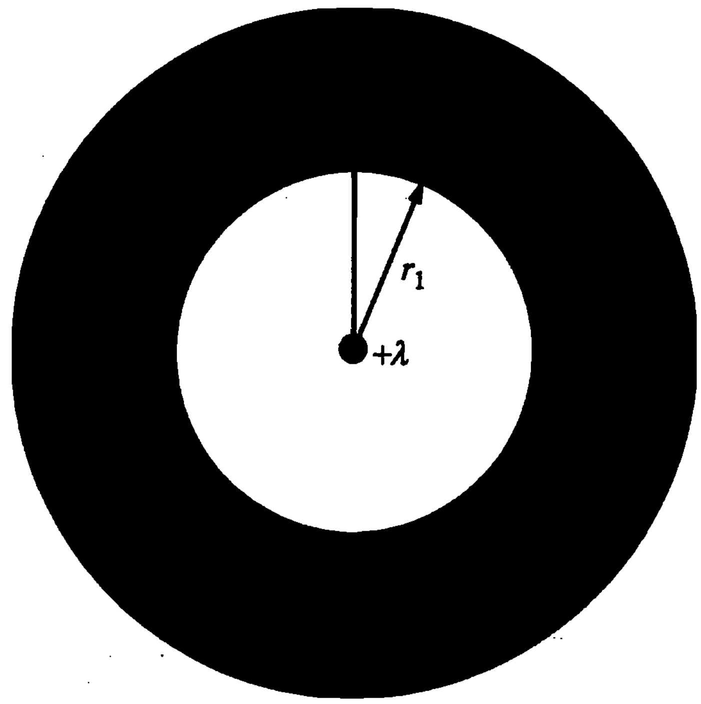
(b) In the spaces below, rank the electric potentials at points a, b, c, d, and e from highest to lowest (1 = highest potential). If two points are at the same potential, give them the same number.

4 V_a 3 V_b 2 V_c 1 V_d 3 V_e

GO ON TO THE NEXT PAGE.

A2





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. $r < r_1$

$$\lambda = \frac{dq}{d\ell}$$

$$\frac{\lambda}{\epsilon_0} = \frac{d\Phi}{d\ell} = E \cdot 2\pi r \qquad \frac{\lambda}{\epsilon_0} = E \cdot 2\pi r \qquad E = \frac{\lambda}{2\pi r \epsilon_0}$$

ii. $r_1 \leq r \leq r_2$

$$\rho \cdot \pi (r^2 - r_1^2) + \lambda = \frac{dq}{d\ell}$$

$$\frac{\rho \cdot \pi (r^2 - r_1^2) + \lambda}{2\pi r \epsilon_0} = E$$

iii. $r > r_2$

$$\rho \cdot \pi (r_2^2 - r_1^2) + \lambda = \frac{dq}{d\ell}$$

$$\frac{\rho \pi (r_2^2 - r_1^2) + \lambda}{2\pi r \epsilon_0} = E$$

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B1

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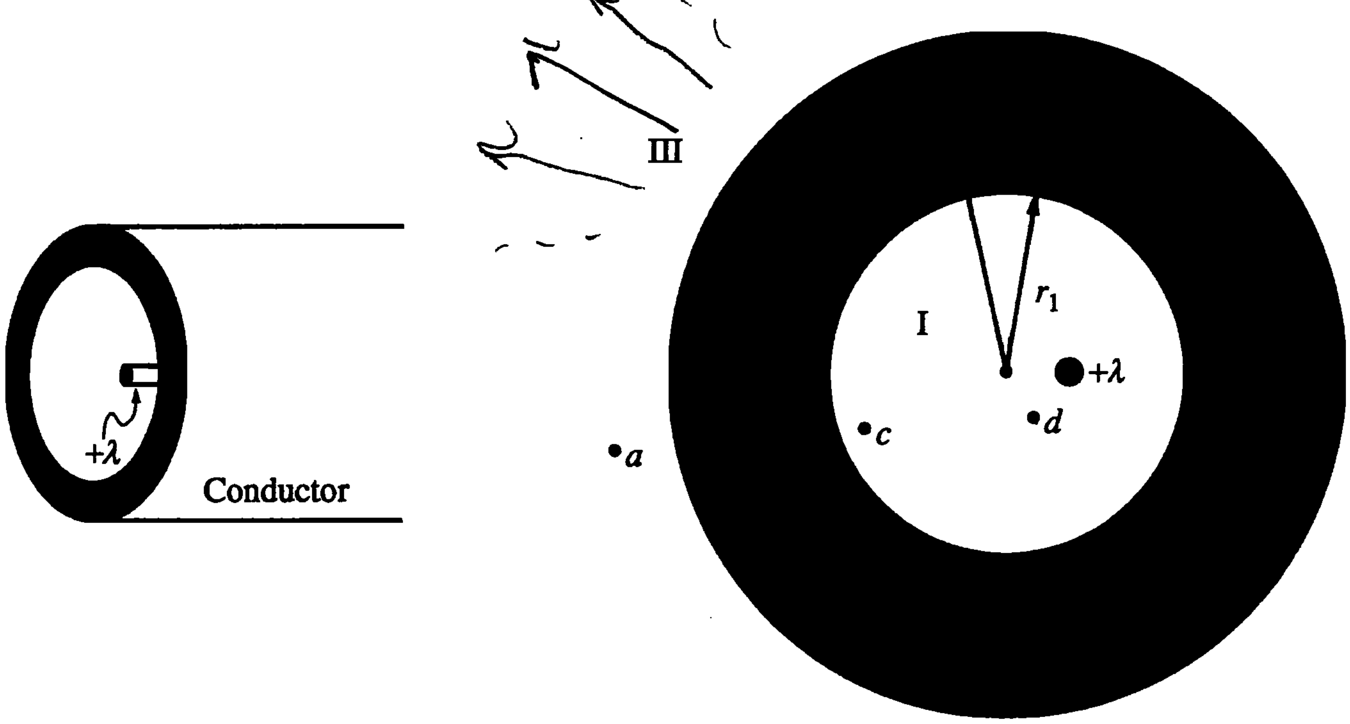

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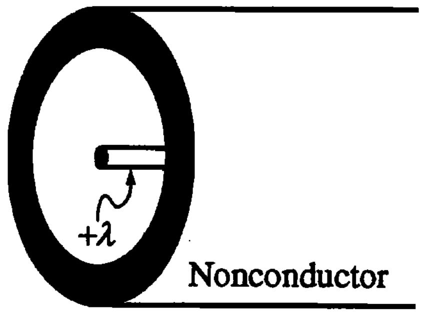
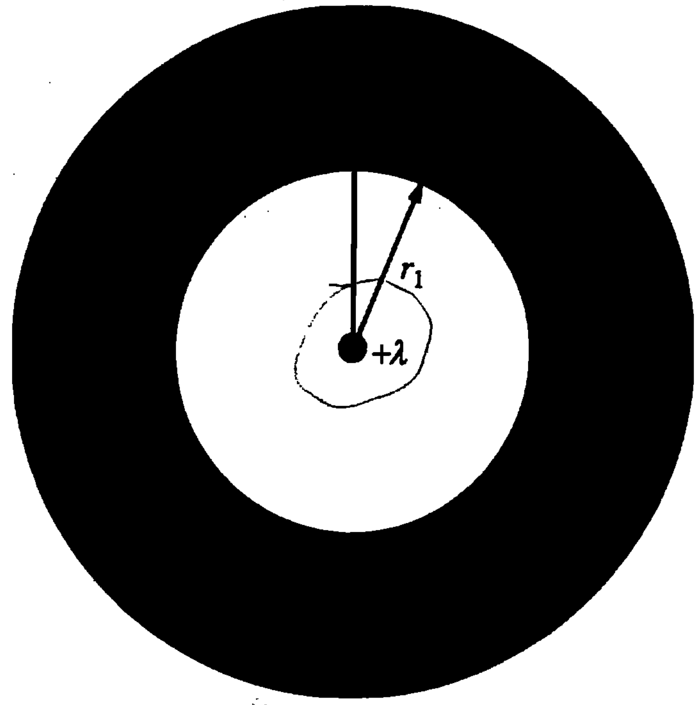
1 V_a 3 V_b 2 V_c 1 V_d 3 V_e

GO ON TO THE NEXT PAGE.

B2





Cross Section

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i. $r < r_1$

$2\pi r l$ cylinder with end's flux=0

$$\oint E \cdot dA \quad E(2\pi r l) = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi r \varepsilon_0}$$

ii. $r_1 \leq r \leq r_2$

$$E(2\pi r l) = \frac{\lambda l + \rho l \pi r^2 - \rho l \pi r_1^2}{\varepsilon_0}$$

$$E = \frac{\lambda + \rho \pi (r^2 - r_1)}{2\pi r \varepsilon_0}$$

iii. $r > r_2$

$$E(2\pi r l) = \frac{\lambda l + \rho l \pi r_2 - \rho l \pi r_1}{\varepsilon_0}$$

$$E = \frac{\lambda + \rho\pi(r_2 - r_1)}{2\pi r \varepsilon_0}$$

GO ON TO THE NEXT PAGE.