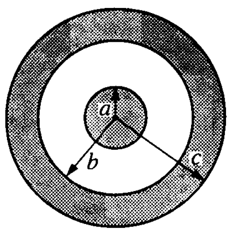
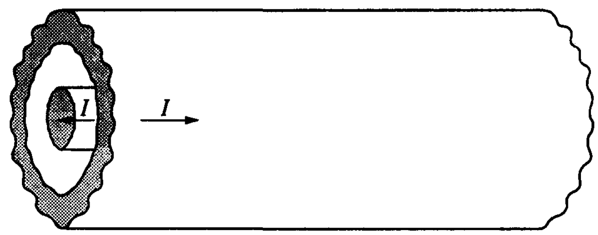
# Magnetic Field & Flux:
# Ampere's Law & Faraday's Law

**PHYSICS 204, YAVERBAUM**
**JOHN JAY COLLEGE OF CRIMINAL JUSTICE, THE CUNY**

**(THE FOLLOWING CONSISTS OF 4 PROBLEMS)**



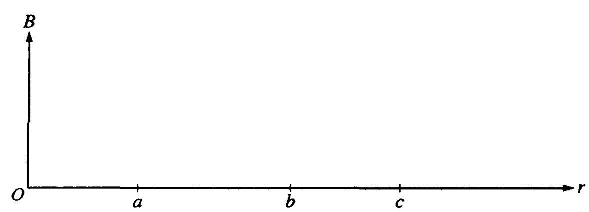

Cross Section

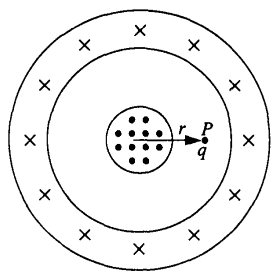



Coaxial Cable

I. A long coaxial cable, a section of which is shown above, consists of a solid cylindrical conductor of radius a, surrounded by a hollow coaxial conductor of inner radius *b* and outer radius c. The two conductors each carry a uniformly distributed current I, but in opposite directions. The current is to the right in the outer cylinder and to the left in the inner cylinder. Assume $\mu = \mu_0$ for all materials in this problem.

a. Use Ampere's law to determine the magnitude of the magnetic field at a distance r from the axis of the cable in each of the following cases.
   i. $0 < r < a$ ii. $a < r < b$
b. What is the magnitude of the magnetic field at a distance r = 2c from the axis of the cable?
c. On the axes below, sketch the graph of the magnitude of the magnetic field B as a function of r, for all values of r. You should estimate and draw a reasonable graph for the field between b and c rather than attempting to determine an exact expression for the field in this region.




Cross Section

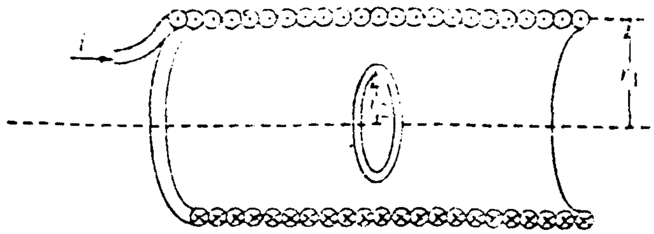
II. The coaxial cable continues to carry currents I as previously described. In the cross section above, current is directed out of the page toward the reader in the inner cylinder and into the page in the outer cylinder. Point P is located between the inner and outer cylinders, a distance r from the center. A small positive charge q is introduced into the space between the conductors so that when it is at point P its velocity v is directed out of the page, perpendicular to it, and parallel to the axis of the cable.

d. i. Determine the magnitude of the force on the charge q at point P in terms of the given quantities.
   ii. Draw an arrow on the diagram at P to indicate the direction of the force.

e. If the current in the outer cylinder were reversed so that it is directed out of the page, how would your answers to (d) change, if at all?

III. The long solenoid shown in the left-hand figure above has radius $r_1$ and n turns of wire per unit length, and it carries a current i. The magnetic field outside the solenoid is negligible.

a. Apply Ampere's law using the path abcda indicated in the cross section shown in the righthand figure above to derive an expression for the magnitude of the magnetic field B near the center of the solenoid: This path is A SQUARE HALF IN, HALF OUTSIDE OF THE SOLENOID. a, b, c and d are vertices of this square. The path walks around the vertices counter-clockwise.

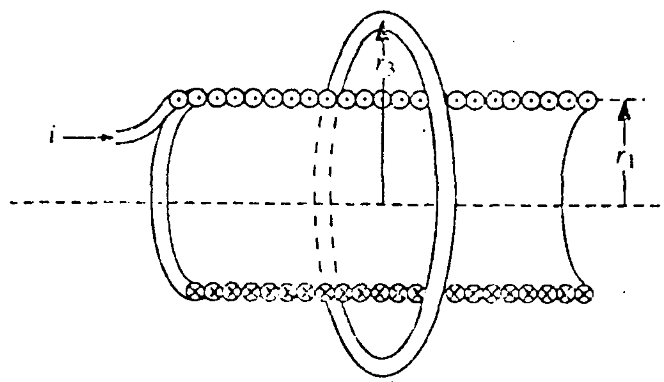



A loop of radius $r_2$ is then placed at the center of the solenoid, so that the plane of the loop is perpendicular to the axis of the solenoid, as shown above. The current in the solenoid is decreased at a steady rate from i to zero in time t. In terms of the given quantities and fundamental constants, determine:

b. The emf induced in the loop.

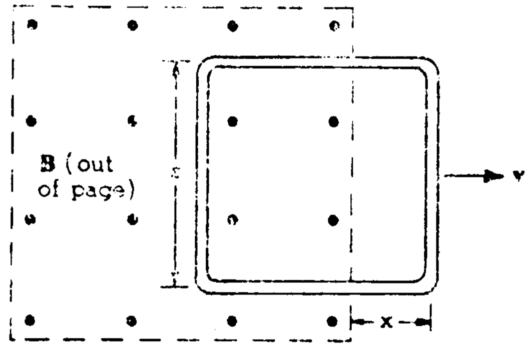
c. The magnitude of the induced electric field at a point in the loop.

The loop is now removed and another loop of radius $r_3$ is placed outside the solenoid, so that the plane of the loop is perpendicular to the axis of the solenoid, as shown above. The current in the solenoid is again decreased at a steady rate from i to zero in time t. In terms of the given quantities and fundamental constants, determine:




d. The emf induced in the loop.

e. The magnitude of the induced electric field at a point in the loop.




IV. A square loop of wire of side s and resistance R is pulled at constant velocity **v** out of a uniform magnetic field of intensity B. The plane of the loop is always perpendicular to the magnetic field. After the leading edge of the loop has passed the edge of the B field as shown in the figure above, there is an induced current in the loop.

a. On the figure above, indicate the direction of this induced current.

b. Using Faraday's law of induction, develop an expression for the induced emf $\varepsilon$ in the loop.

c. Determine the induced current I in the loop.

d. Determine the power required to keep the loop moving at constant velocity.