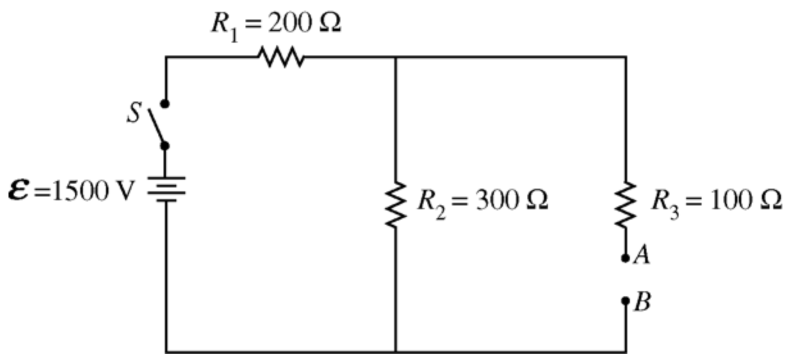

E&M. 2.

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.

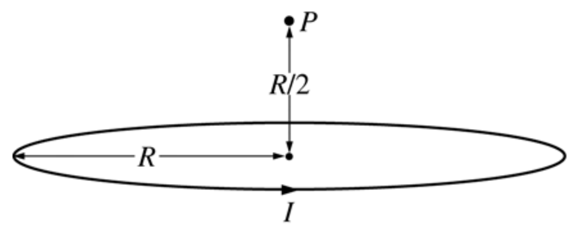

Figure 1

E&M. 3.

The circular loop of wire in Figure 1 above has a radius of R and carries a current I. Point P is a distance of $R/2$ above the center of the loop. Express algebraic answers to parts (a) and (b) in terms of R, I, and fundamental constants.

(a)

i. State the direction of the magnetic field B_1 at point P due to the current in the loop.

ii. Calculate the magnitude of the magnetic field B_1 at point P.

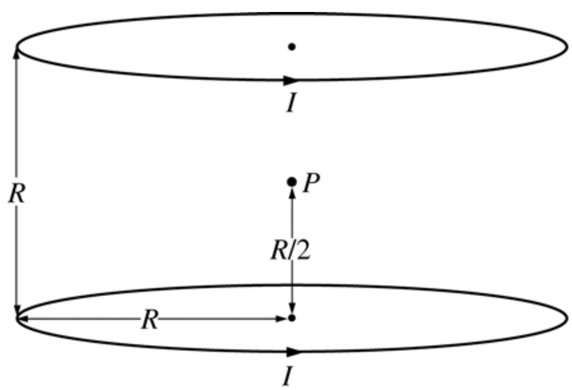

Figure 2

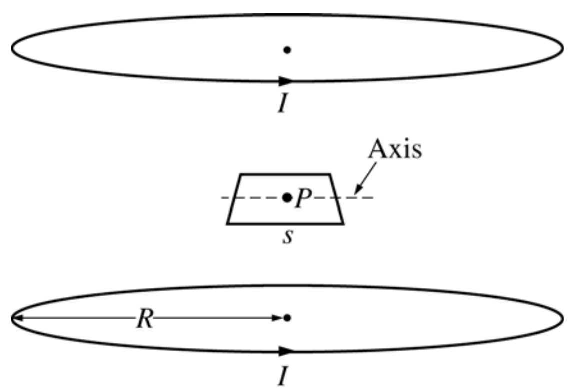

Figure 3

A second identical loop also carrying a current I is added at a distance of R above the first loop, as shown in Figure 2 above.

(b) Determine the magnitude of the net magnetic field B_{net} at point P.

A small square loop of wire in which each side has a length s is now placed at point P with its plane parallel to the plane of each loop, as shown in Figure 3 above. For parts (c) and (d), assume that the magnetic field between the two circular loops is uniform in the region of the square loop and has magnitude B_{net}.

(c) In terms of B_{net} and s, determine the magnetic flux through the square loop.

(d) The square loop is now rotated about an axis in its plane at an angular speed ω. In terms of B_{net}, s, and ω, calculate the induced emf in the loop as a function of time t, assuming that the loop is horizontal at $t = 0$.

END OF EXAM

Question 2 (continued)

Distribution of points

(a) (continued)

(ii) 2 points

For indicating that the current in branch 3 is zero immediately after the switch is closed, either explicitly or by correctly calculating the total resistance at this instant — 1 point

$R_{indT} = R_1 + R_2 = 200\ \Omega + 300\ \Omega = 500\ \Omega$

For correctly using the total resistance to calculate the voltage across resistor R_2 — 1 point

$I_{indT} = \mathcal{E}/R_{indT} = 1500\ \text{V}/500\ \Omega = 3\ \text{A}$

$V_{2ind} = (3\ \text{A})(300\ \Omega) = 900\ \text{V}$

Alternate solution — *Alternate points*

For one correct Kirchhoff equation indicating knowledge that there is no current through resistor R_3 — *1 point*

$1500\ \text{V} - (200\ \Omega)I_{indT} - (300\ \Omega)I_{indT} = 0$

$I_{indT} = 3\ \text{A}$

For correctly using the current to calculate the voltage across resistor R_2 — *1 point*

$V_{2ind} = (3\ \text{A})(300\ \Omega)$

$V_{2ind} = 900\ \text{V}$

(iii) 3 points

For indicating that the voltage across the capacitor is zero immediately after the switch is closed, either explicitly or by correctly calculating the total resistance — 1 point

$$\frac{1}{R_{capP}} = \frac{1}{100\ \Omega} + \frac{1}{300\ \Omega} = \frac{4}{300\ \Omega}$$

$R_{capP} = 75\ \Omega$

$R_{capT} = R_1 + R_{capP} = 200\ \Omega + 75\ \Omega = 275\ \Omega$

For correctly using the total resistance to compute the current through the battery — 1 point

$I_{capT} = \mathcal{E}/R_{capT} = 1500\ \text{V}/275\ \Omega = 5.45\ \text{A}$

For correctly using the total current to compute the voltage across R_2 — 1 point

$V_{2cap} = I_{capT}R_{capP} = (5.45\ \text{A})(75\ \Omega)$

$V_{2cap} = 410\ \text{V}$ (rounded to two significant digits)