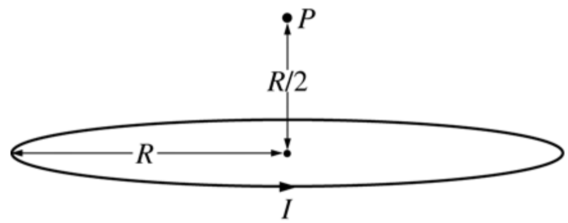

Figure 1

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.

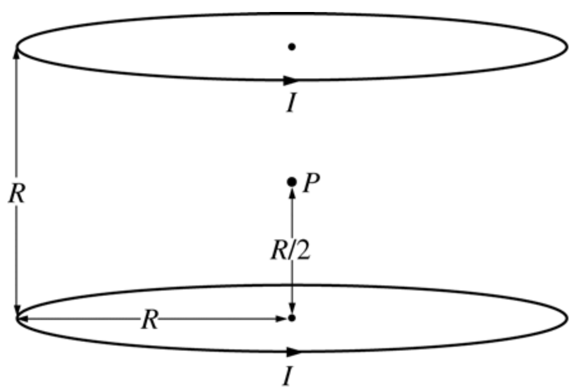

Figure 2

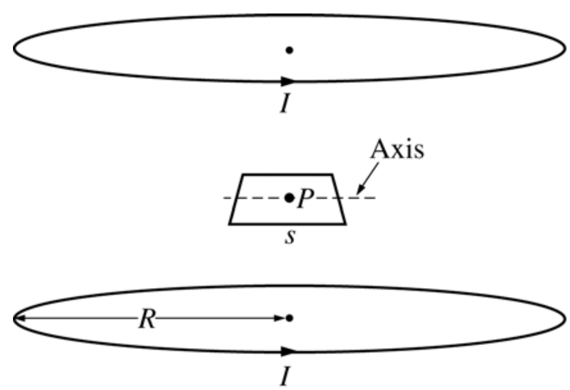

Figure 3

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 3 (continued)

	Distribution of points
(b) 2 points	
For recognizing that B_{net} is the vector sum of the field generated by the first loop and the field generated by the second loop	1 point
For recognizing that the B field from top loop is in the same direction and has the same magnitude as that from the bottom loop	1 point
$B_{net} = 2B_1 = \frac{8}{5\sqrt{5}}\frac{\mu_0 I}{R}$	
(c) 2 points	
For identifying B as B_{net} in a correct expression for magnetic flux	1 point
$\phi = \int \mathbf{B}\bullet d\mathbf{A} = \int B_{net} dA = B_{net} A$	
For correctly substituting the area as s^2	1 point
$\phi = B_{net} s^2$	
(d) 4 points	
For using Faraday's law with ϕ identified as magnetic flux	1 point
$\mathcal{E} = -\frac{d\phi}{dt}$ with some work showing understanding of ϕ	
For recognizing that there is an angular dependence	1 point
$\phi = B_{net} s^2 \cos\theta$	
For correctly relating the angle to the angular velocity	1 point
$\phi = B_{net} s^2 \cos\omega t$	
For the correct final expression	1 point
$\mathcal{E} = -B_{net}\frac{d}{dt}\left(s^2\cos\omega t\right) = B_{net} s^2 \omega \sin\omega t$	