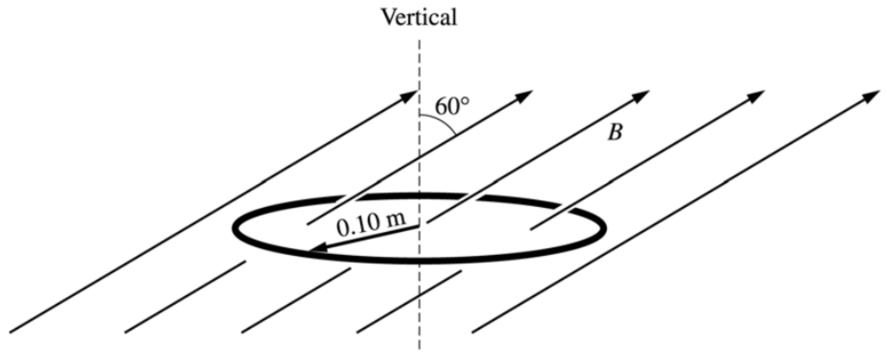
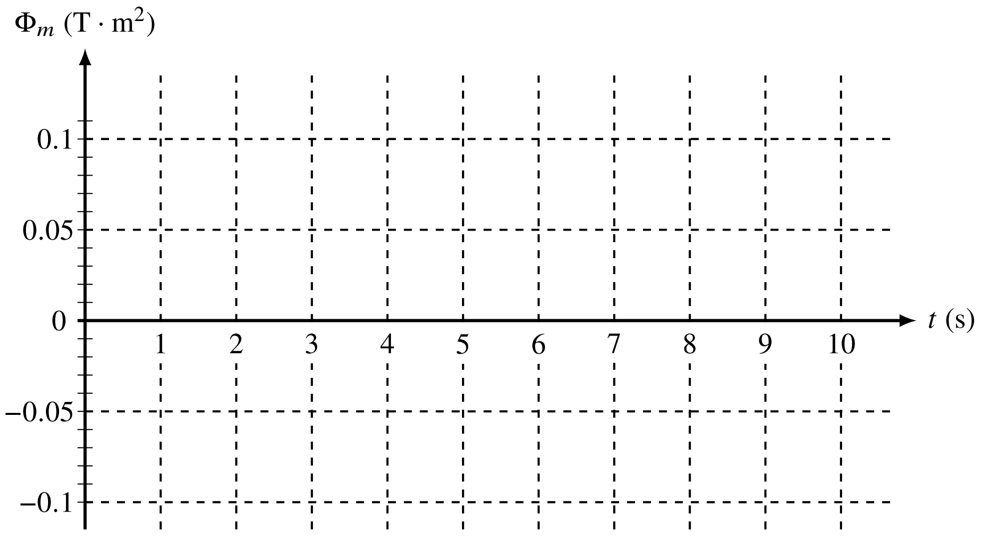
Student #: ____________________________ Student Name: ____________________________

AP PHYSICS C: MAGNETISM
SECTION II
5 Questions

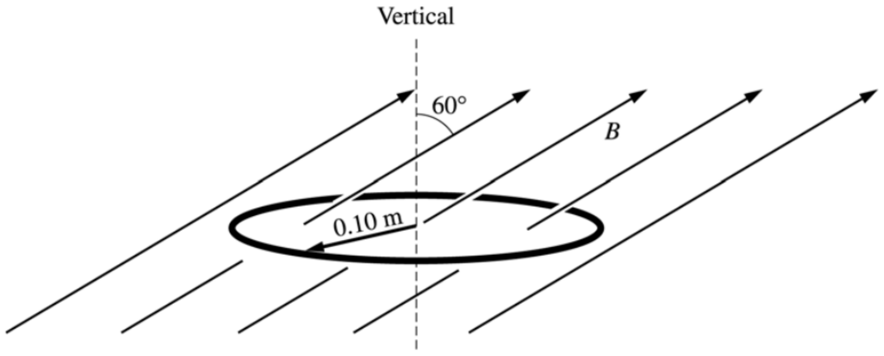
Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.

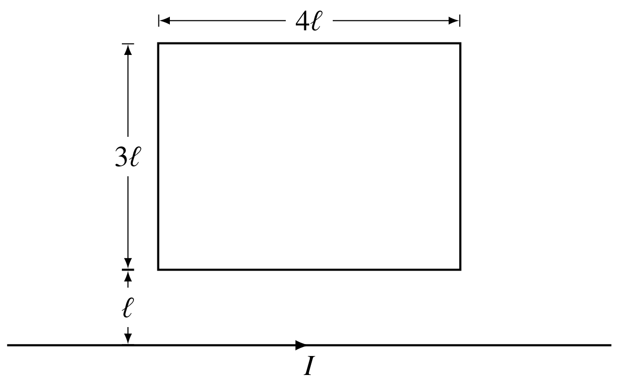


1. A circular wire loop with radius 0.10 m and resistance 50 Ω is suspended horizontally in a magnetic field of magnitude B directed upward at an angle of 60° with the vertical, as shown above. The magnitude of the field in teslas is given as a function of time t in seconds by the equation $B = 4(1 - 0.2t)$.
   (a) Determine the magnetic flux Φ_m through the loop as a function of time.
   (b) Graph the magnetic flux Φ_m as a function of time on the axes below.



   (c) Determine the magnitude of the induced emf in the loop.
   (d) i. Determine the magnitude of the induced current in the loop.
   ii. Show the direction of the induced current on the following diagram.





2. A rectangular loop of dimensions 3ℓ and 4ℓ lies in the plane of the page as shown above. A long straight wire also in the plane of the page carries a current I.

   (a) Calculate the magnetic flux through the rectangular loop in terms of I, ℓ, and fundamental constants.

   Starting at time $t = 0$, the current in the long straight wire is given as a function of time t by $I(t) = I_0 e^{-kt}$, where I_0 and k are constants.

   (b) The current induced in the loop is in which direction? Justify your answer.

   _______ Clockwise _______ Counterclockwise

   The loop has a resistance R. Calculate each of the following in terms of R, I_0, k, ℓ, and fundamental constants.

   (c) The current in the loop as a function of time t

   (d) The total energy dissipated in the loop from $t = 0$ to $t = \infty$

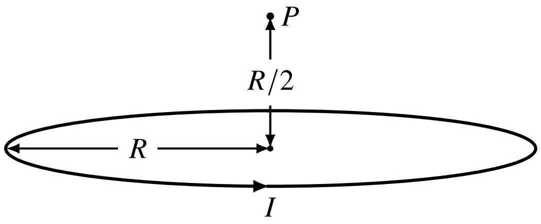


Figure 1

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.

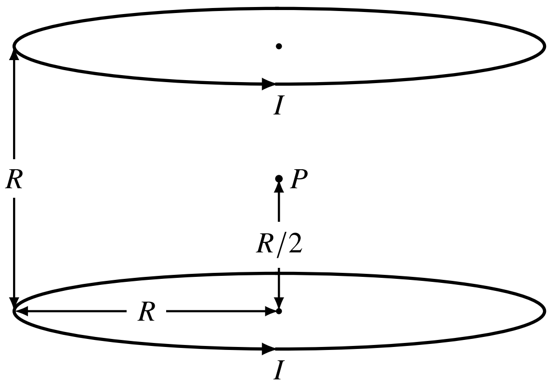


Figure 2

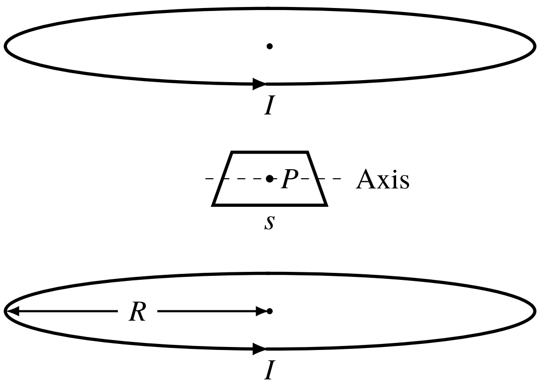


Figure 3

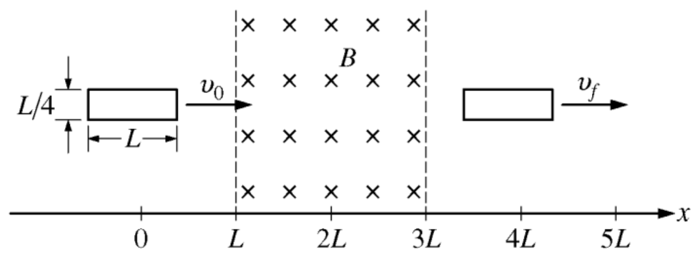
A second identical loop also carrying a current I is added at a distance of R above the first loop, as shown in Figure 2 above.

(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 $t = 0$.



4. The rectangular loop of wire shown on the left in the figure above has mass M, length L, width $L/4$, and resistance R. It is initially moving to the right at constant speed v_0 , with no net force acting on it. At time $t = 0$ the loop enters a region of length $2L$ that contains a uniform magnetic field of magnitude B directed into the page. The loop emerges from the field at time t_f with final speed v_f . Express all algebraic answers to the following in terms of M, L, R, B, v_0, and fundamental constants, as appropriate.

   (a) Let x represent the position of the right end of the loop. Place a check mark in the appropriate box in each column in the table below to indicate whether the speed of the loop increases, decreases, or stays the same as the loop moves to the right.

   (b) Derive an expression for the magnitude of the current induced in the loop as its right edge enters the field.

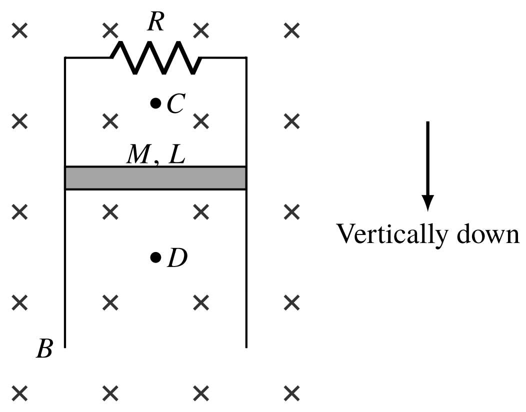
   (c) What is the direction of the induced current determined in part (b) ? Justify your answer.

   _______ Clockwise _______ Counterclockwise

   (d) Write, but do not solve, a differential equation for the speed v as a function of time as the loop enters the field.

   (e) What is the direction of the acceleration of the loop just before its left edge leaves the field? Justify your answer.

   _______ Left _______ Right _______ Up _______ Down



5. A conducting bar of mass M, length L, and negligible resistance is connected to two long vertical conducting rails of negligible resistance. The two rails are connected by a resistor of resistance R at the top. The entire apparatus is located in a magnetic field of magnitude B directed into the page, as shown in the figure above. The bar is released from rest and slides without friction down the rails.

   (a) What is the direction of the current in the resistor?

   _______ Left   _______ Right

   (b) i. Is the magnitude of the net magnetic field above the bar at point C greater than, less than, or equal to the magnitude of the net magnetic field before the bar is released? Justify your answer.

   _______Greater than   _______Less than   _______Equal to

   ii. While the bar is above point D, is the magnitude of the net magnetic field at point D greater than, less than, or equal to the magnitude of the net magnetic field before the bar is released? Justify your answer.

   _______Greater than   _______Less than   _______Equal to

   Express your answers to parts (c) and (d) in terms of M, L, R, B, and physical constants, as appropriate.

   (c) Write, but do NOT solve, a differential equation that could be used to determine the velocity of the falling bar as a function of time t.

   (d) Determine an expression for the terminal velocity v_T of the bar.

   Express your answers to parts (e) and (f) in terms of v_T, M, L, R, B, and physical constants, as appropriate.

   (e) Derive an expression for the power dissipated in the resistor when the bar is falling at terminal velocity.

   (f) Using your differential equation from part (c), derive an expression for the speed of the falling bar v_t as a function of time t.