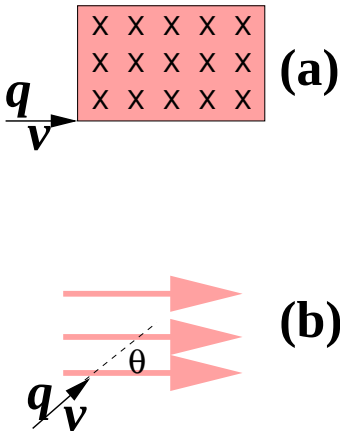
February 25, 2003

PHY 114 – Second exam

Note: This is a take-home exam which must be turned in to the physics office (Olin 100) within 24 hours of when you received the exam. You may consult your text, your lecture notes, and your homework assignments, but *no other resources are allowed*. Please record all of your work (diagrams, mathematical manipulations, and numerical work) in the exam booklet. Please show your intermediate steps so that partial credit can be awarded if appropriate. When your work is completed, please place your work including (1) the exam booklet, (2) this exam, and (3) any scratch work, in the original envelope and return it to the physics office. It is assumed that all work will be done under the guidelines of the honor code. The exam is available starting at 9 AM Monday, March 3, 2003. All exams must be received by the Physics Office before 5 PM Friday, March 7, 2003. There are 6 problems of equal weight.

1.

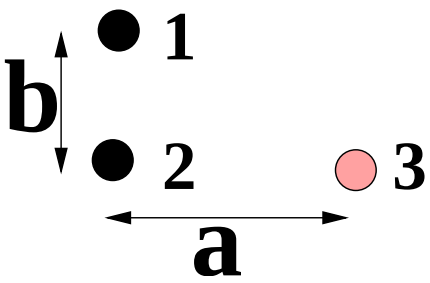


The diagram on the left shows two different configurations in which a particle of mass $m = 1.7 \times 10^{-27}$ kg, charge $q = 1.6 \times 10^{-19}$ C, and speed $v = 1 \times 10^{6}$ m/s, is about to enter a magnetic field of strength $\mathbf{B} = 2$ T. For case (a), the magnetic field is pointing into the page and the particle velocity is pointing horizontally in the plane of the page, while in case (b), the magnetic field is pointing horizontially in the plane of the page and the particle velocity is pointing at an angle $\theta = 20^{o}$ in the plane of the page. For each case find:

(i) The magnitude and direction of the force exerted on the particle by the magnetic field just as it enters the region of the field.

(ii) The form of the trajectory of the particle in each case. Be as quantitative as possible – if there is circular or helical motion, determine the radius of the circle or projected circle.

2.

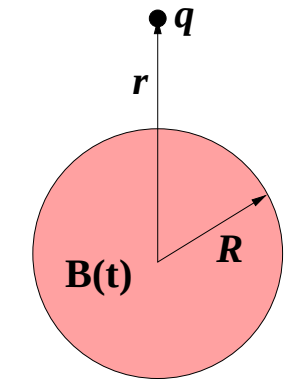


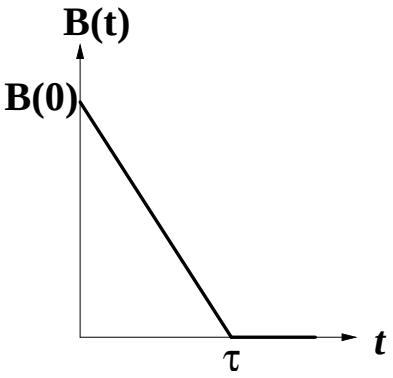
The diagram on the left represents 3 wires, each of length l=0.5 m and oriented perpendicular to the plane of the paper. For wires #1 and #2, the current $I_1 = I_2 = 2$ A is flowing out of the page and for wire #3, the current $I_3 = 3$ A is flowing into the page. The distance values are $a = 0.4$ m and $b = 0.2$ m.

(a) What is the magnitude and direction of the magnetic field produced by wires #2 and #3 at the location of wire #1?

(b) What is the magnitude and direction of the force on wire #1 due to wires #2 and #3?

3.





The diagram on the left shows a point charge with $q = 2 \times 10^{-3}$ C positioned above a solenoid with $r = 0.7$ m. Inside the solenoid (radius $R = 0.3$m) the magnetic field is uniform and pointing out of the page. Initially the field strength is $\mathbf{B}(0) = 1.3$ T. For the purposes of this problem, neglect the effects of gravity.

(a) What is the initial magnitude and direction of the force on the charge q, when the field strength is still $\mathbf{B}(0) = 1.3$ T?

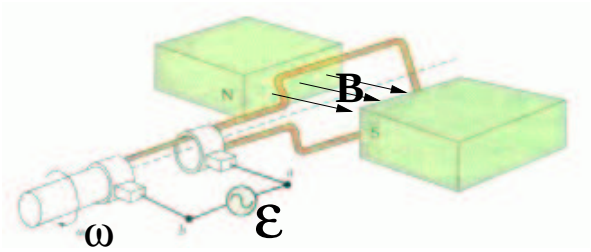
(b) Starting at $t = 0$ s, the magnetic field in the solenoid is decreased at a constant rate until it reaches 0 field at time $t = \tau = 0.02$ s, as shown in the plot. The following questions pertain to the time interval $0 \leq t \leq \tau$.

i. What is the magnitude and direction of the electric field produced at the position of the point charge q?

ii. What is the magnitude and direction of the force on the point charge q?

(c) What is the magnitude and direction of the force on the point charge q for $t > \tau$?

4.



The figure on the left shows a schematic diagram of an alternating current generator in which a coil having a cross sectional area of $A = 0.02$ m^2 and $N = 300$ turns is rotated at a angular frequency of $\omega = 380$ rad/s in a uniform magnetic field $B = 1.3$ T.

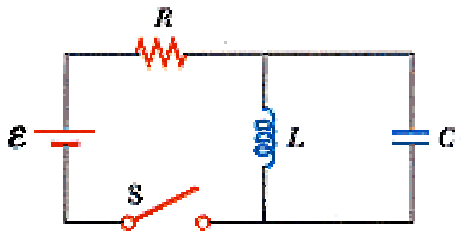
(a) Write an expression for the emf $\mathcal{E}(t)$ as a function of time, evaluating the all of the parameters other than t.

(b) If the total resistance in the coil and contacts is $R = 0.7\ \Omega$, what is the current that flows through the coil?

(c) Noting that a magnetic field produces a torque on current loop, write an expression for the torque on the generator coil in terms of the current and other relevant parameters. Evaluate the expression as a function of time.

(d) Evaluate the direction of the torque on the coil. Does the torque act to enhance or oppose the generator angular frequency ω?

5.



In the circuit diagram shown on the left, the DC emf has the value $\mathcal{E} = 300$ V and the circuit elements have the values $R = 10\Omega$, $L = 6.25$ H, and $C = 1 \times 10^{-4}$ F. The switch is initially closed for long enough so that the current has reached its steady state value and there is no charge on the capacitor.

(a) What is the steady state current through the inductor (when the switch has been closed for a long time)?

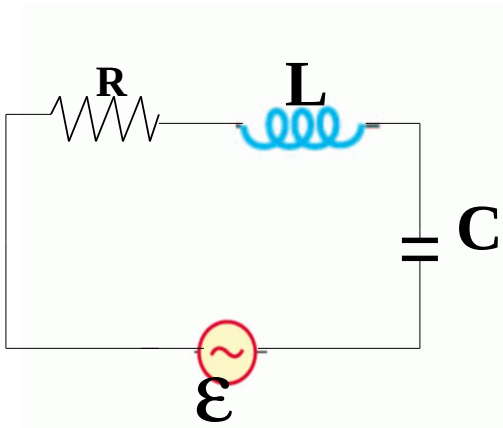
(b) When the switch is opened, the current oscillates between the inductor and the capacitor.

i. What is the frequency of the oscillation of the current?

ii. How much energy is stored in this LC circuit?

iii. What is the maximum voltage across the capacitor?

6.



In the circuit diagram shown on the left, the AC emf takes the form $\mathcal{E}(t) = \mathcal{E}_{\max} \cos(\omega t)$, with $\mathcal{E}_{\max} = 300$ V and $\omega = 700$ rad/s. The circuit elements have the values: $R = 100\Omega$, $L = 0.006$ H, and $C = 1 \times 10^{-5}$ F.

(a) Write down Kirchhoff's equation(s) for this circuit.

(b) Find an expression for the current $I(t)$ as a function of time, evaluating all of the terms except for the time.

(c) Find an expression for the charge $q(t)$ as a function of time, evaluating all of the terms except for the time.

**********Extra credit**********

For the circuit in problem 4 with the switch closed, write down Kirchhoff's equations and solve them as a function of time for the current through the resistor, inductor, and capacitor.

**********End of Exam**********