February 20, 2005

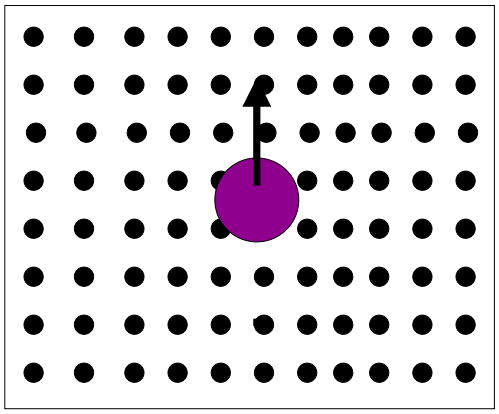
PHY 114 – Second Hour Test

Note: This exam has 4 problems each worth 25 points. For some problems, you may wish to draw on this exam paper, but most of your work – algebraic setup, mathematical manipulations, and your answers – should be recorded in the blue book. Please show your intermediate steps so that partial credit can be awarded if appropriate. When your work is completed, please turn in: (1) the exam booklet, (2) your equation sheet, and (3) this exam paper. It is assumed that all work will be done under the guidelines of the honor code.

Useful constants

Coulomb Constant: $k_e \equiv \frac{1}{4\pi\epsilon_0}$: 8.98755×10^9 N $\cdot$ m^2/C^2
Permittivity constant: ϵ_0: 8.854×10^{-12} C^2/N $\cdot$ m^2
Permeability constant: μ_0: $4\ \pi \times 10^{-7}$ T $\cdot$ m/A
Elementary charge e: 1.602177×10^{-19} C
Mass of electron m_e: 9.10939×10^{-31} kg
Mass of proton m_p: 1.6726×10^{-27} kg
Area of a circle of radius r: πr^2
Circumference of a circle of radius r : $2\pi r$
Area of a sphere of radius r: $4\pi r^2$
Gravitational acceleration near Earth's surface g: 9.8 m/s^2

1.

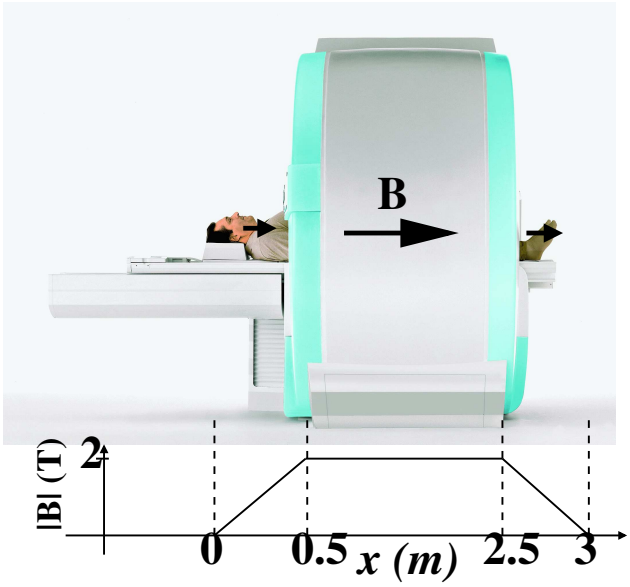


The figure on the left shows a proton with charge $q = 1.6 \times 10^{-19}$ C and mass $m = 1.67 \times 10^{-27}$ kg which is moving vertically in the plane of the page at a velocity of $v = 1 \times 10^6$ m/s in a magnetic field pointing *out of the page* with a magnitude of $\mathbf{B} = 0.5$ T.

(a) What is the direction and magnitude of the magnetic force on the proton?

(b) How will the proton move in response to this force? Sketch the trajectory of the proton, giving a numerical value of at least one appropriate distance which characterizes the trajectory.

2.



The figure above shows a man in an MRI solenoid (taken from the website www.siemens.com). For the purposes of this question, we will neglect the time-dependent magnetic fields which are used for producing the imaging signal and simplify the fringing fields from the solenoid. Inside the cylindrical cavity of the solenoid the magnetic field is uniform and constant ($\mathbf{B} = 2$ T) and in the horizontal direction as shown. Outside the solenoid, we approximate the horizontal component of of the magnetic field to decrease linearly with distance as indicated in the graph of field $\mathbf{B}$ versus distance (and neglect any other components). We approximate $dB/dx = 4$ T/m for $0 \leq x \leq 0.5$ m and $dB/dx = -4$ T/m for $2.5 \leq x \leq 3$ m.

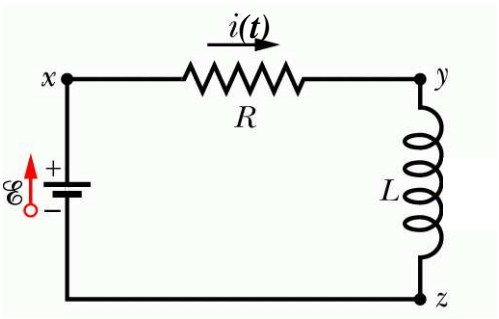
The man is wearing a gold ring on his hand which is by his side so that the plane of the ring is perpendicular to the field direction. Assume that he does not move his hand. The ring has a radius of $r = 0.01m$ and a resistance of $R = 5 \times 10^{-3}\Omega$.

(a) Calculate the magnetic flux through the ring when it is in the solenoid.

(b) Now consider what happens when the man is pulled out of the solenoid at a constant velocity $\mathbf{v} = -0.1\hat{\mathbf{x}}$ m/s.

i. Determine the induced emf $\mathcal{E}$ and current i through the ring while it is in the solenoid (in the range $0.5 \leq x \leq 2.5$).

ii. Determine the induced emf $\mathcal{E}$ and current i in the ring while it is in the fringing field of the solenoid (range $0 \leq x \leq 0.5$).

3. 

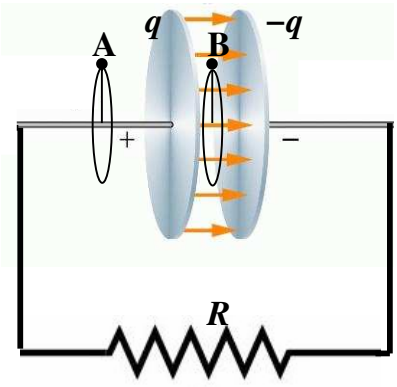
The figure on the left shows a circuit containing a constant emf source $\mathcal{E} = 5$ V, a resistance of $R = 5\Omega$, and an inductor of $L = 2$ H.

(a) What is the time constant for this circuit?

(b) Assume that at $t = 0$, there is a current of $i_0 = 0.2$ A in the circuit.

i. Write a general expression for the current in this circuit at times $t > 0$.

ii. What is the current in the circuit at $t = 0.2$ s?

4. 

The figure on the left shows a circuit containing a capacitor with $C = 3 \times 10^{-8}$ F and a resistance of $R = 2\Omega$. At time $t = 0$ s, the capacitor is fully charged with $q(0) = q_0 = 1 \times 10^{-6}$ C. (The capacitor consists of two parallel plates of area $A = 0.33898$ m^2 separated by a distance $d = 0.0001$ m.)

(a) What is the time constant for this circuit?

(b) What is the initial current $i(t = 0)$ in the circuit?

(c) At time $t = 0$, what is the magnetic field at the point **A** which is near to the wire at a distance $a = 0.001$ m?

(d) At time $t = 0$, what is the magnetic field at the point **B** which is in the middle of the capacitor at a distance $a = 0.001$ m from the center of the capacitor?

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