P114
S. Manly

NAME Soln key Sly

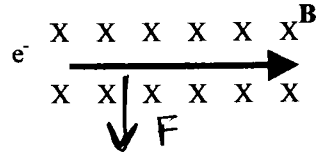
University of Rochester
Spring 2000

Exam 3 (March 30, 2000)

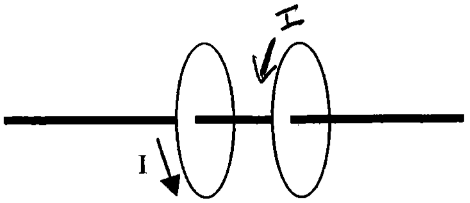
Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show all your work. Partial credit will be given unless noted otherwise. Try to be neat. TA's are known to be less generous with partial credit if they have to work hard to decipher the paper!

Problem 1 (25 pts, 5 pts per part) :

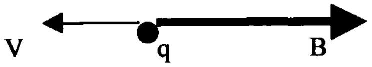
(a) An electron moves in the direction shown into a uniform magnetic field. Clearly indicate on the sketch the direction of the force (if any) on the electron. Write "zero" if there is no force.



(b) Consider the two coaxial circular conducting loops shown below. There is a current in the left loop that is decreasing in magnitude with time. Indicate the direction (if any) of the current in right loop. Write "zero" if there is no current in the second loop.



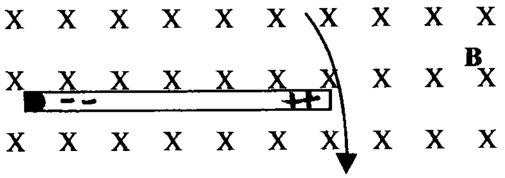
(c) A positive charge moves as shown in a uniform magnetic field. Clearly indicate on the sketch the direction of the force (if any) on the ~~electron~~ charge. Write "zero" if there is no force.



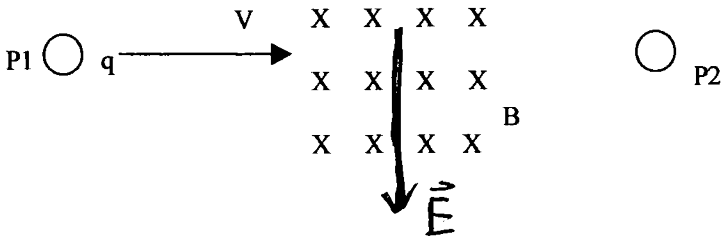
Zero

$\vec{v} \times \vec{B} = 0$

(d) A conducting rod with no net charge is spinning in a uniform magnetic field around an axis through one end as shown below. Indicate roughly on the drawing how the charge inside the conducting rod is distributed.



(e) A positive charge is moving initially with a velocity V directly from point P1 to point P2. It enters a region with a uniform magnetic field B and a uniform electric field E. The direction of the magnetic field is shown. Indicate clearly what the direction of the electric field must be in order for the charged particle to reach point P2.

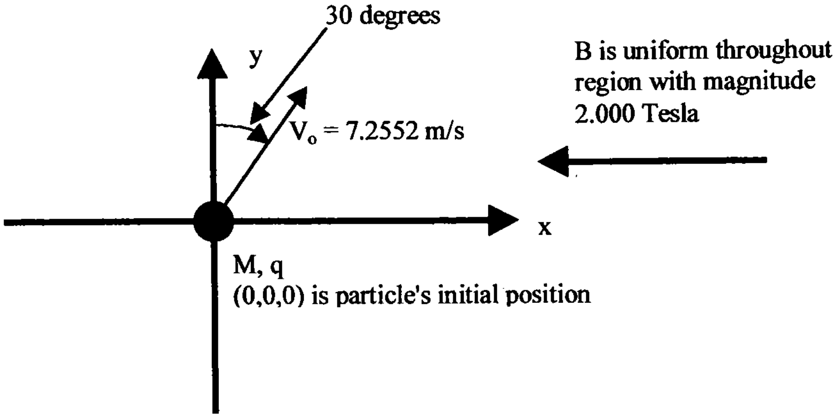


Problem 2 (20 pts) :

A positively charged particle moves in a uniform magnetic field. The initial condition is shown in the figure below. The magnetic field is in the negative x direction. The particle is initially at the origin with a velocity of 7.2552 m/s. The initial velocity is in the xy plane and makes an angle of 30 degrees with the positive y axis in the direction of the positive x axis. The magnetic field strength is 2.000 Tesla. The particle has a charge of 1.000 Coulomb and a mass of 0.3184 kg.

Scores	
1.	___/25
2.	___/20
3.	___/20
4.	___/20
5.	___/15
6.	___/20
EC	___/3
Total	___/113

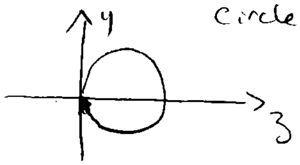
(a) What is the location of the particle at t=4.000 seconds?
(b) What is the velocity of the particle (magnitude and direction) at t=4.000 seconds?



Particle's motion is a circle in the y-z plane superimposed with constant velocity motion in the x direction → helix.

$V_{ox} = (7.2552)\sin 30 = 3.6276$ m/s

$V_{oy} = 7.2552 \cos 30 = 6.2832$ m/s



circle in y-z plane

what is period of circular motion in y-z plane?

$$qV_{oy}B = m\frac{V_{oy}^2}{R} \qquad \frac{mV_{oy}}{qB} = R = \frac{(.3184)(6.2832)}{(1.000)(2.000} = 1.000 \text{ m}$$

$$\frac{2\pi R}{V_{oy}} = T = \frac{2\pi(1)}{6.2832} = 1 \text{ second}$$

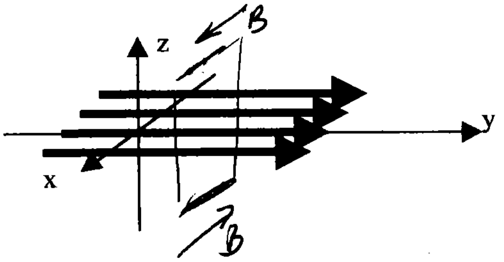
→ at T=4s the particle will be back at the x axis in the circular motion

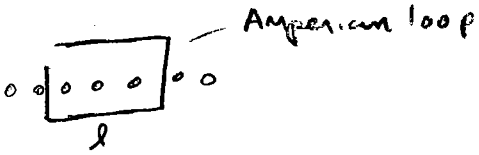
at T=4s the particle will be at $x = (4s)(3.6276) = 14.51$ m

T=4s particle at (14.51 m, 0, 0) with $\vec{V} = 7.2552$ m/s in same direction as at start of problem

Problem 3 (20 pts) :

An infinite number of long straight current-carrying wires are placed side-by-side in the x-y plane. All the wires are parallel to the y-axis and carry a current I in the positive y direction. There are n wires per meter as measured along the x-axis. You can assume the spacing between the wires is quite small, such that the current genuinely looks like a "plane of current". Find the magnetic field in the two regions of space z>0 and z<0.





from symmetry

$B(z>0)$ is in $+\hat{x}$

$B(z<0)$ is in $-\hat{x}$

$$\int B \cdot dl = \mu_0 I_{encl}$$

$$2Bl = \mu_0 n I l$$

$$\boxed{\vec{B} = \frac{\mu_0 n I}{2} \quad \begin{matrix} +\hat{x} & (z>0) \\ -\hat{x} & (z<0) \end{matrix}}$$

NAME Soln key Slm

Problem 4 (20 pts) :

Consider two concentric solenoids, one with radius r_1 and n_1 turns per unit length and one with radius r_2 and n_2 turns per unit length, where $r_1 < r_2$. Select the correct expression for the mutual inductance of the two solenoids. You must show your work and, to get full credit, it must be sufficient to convince the grader that you have derived the expression. (hint: The magnitude of the B field inside a solenoid = $\mu_o nI$)

(a) $M_{12} = n_1 n_2 \pi r_1^2 \pi r_2^2 \mu_o$

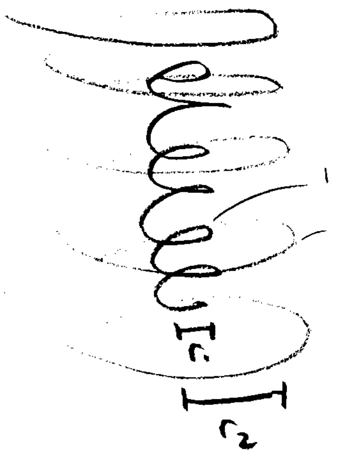
(b) $M_{12} = n_1 n_2 \pi r_2^2 \mu_o$

(c) $M_{12} = n_1 n_2 2\pi r_1 \mu_o$

(d) $M_{12} = n_1 n_2 I_1 I_2 \mu_o^2$

(e) $\boxed{M_{12} = n_1 n_2 \pi r_1^2 \mu_o}$

$$B_{solenoid} = \mu_o n I$$



$$\Phi_2 = M_{12} I_1$$

$$\Phi_2 = (\pi r_1^2)(\mu_o n_1 I_1) n_2$$

$$\frac{\Phi_2}{I_1} = M_{12} = \frac{n_2 (\pi r_1^2) \mu_o n_1 I_1}{I_1}$$

$$M_{12} = n_1 n_2 \pi r_1^2 \mu_o$$

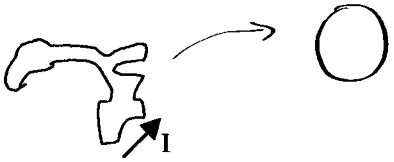
$$\Phi_1 = M_{21} I_2$$

$$M_{21} = \frac{\Phi_1}{I_2} = \frac{\mu_o n_2 I_2 (\pi r_1^2) n_1}{I_2} = n_1 n_2 \mu_o \pi r_1^2$$

can evaluate from either point of view

Problem 5 (15 pts, 5 pts per part) :

(a) A loose, squiggly loop of conducting wire lies on a flat, frictionless surface. A constant current passes through the wire in the direction shown. Does the wire bunch up or stretch out in a circle once the current begins to flow? Why?



Tight Circle

B caused by I on one side will cause outward force on wire carrying I on opposite side

(b) Chaz takes you on a tour of the National Magnet Laboratory, where he conducts occasional experiments on such important matters as the effect of high magnetic fields on the taste of canned beer. Before admitting you into the laboratory, Chaz asks that your leave wallet and all credit cards in the car. No … this is not a way of supplementing his income. Chaz says this is standard procedure. Why is this a good idea? What might happen to the credit cards? Explain this in terms of what we have discussed recently in this course.

Magnetic fields can change the orientation of magnetic domains on the magnetic strips on the credit cards - rendering the magnetic strips useless

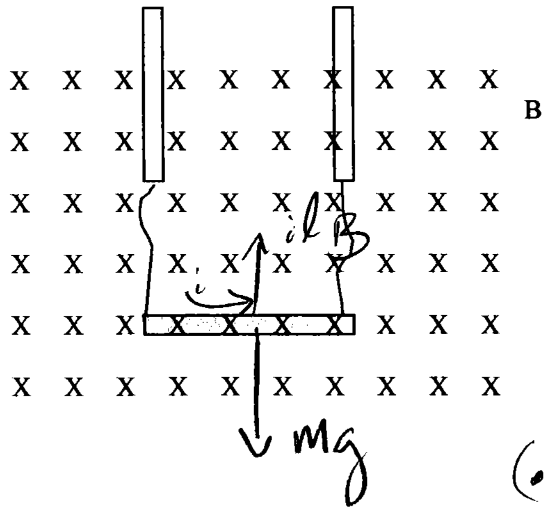
(c) Before agreeing to take you to the magnet laboratory, Chaz requested to know if you wear a pacemaker for your heart. He said people wearing pacemakers are not allowed in the laboratory. Why is this an important rule? What could happen to a person with a pacemaker in an area with high magnetic fields? (hint: Chaz was not worried that the excitement might be too much for your weak heart!)

The pacemaker controls the timing of the electric pulse that triggers heart muscle contraction. Changing magnetic fields around this device can induce an EMF in this device that may upset the regular pattern of EMF variation the pacemaker must maintain. This may upset the heart muscle contraction timing.

NAME Soln key - SM

Problem 6 (20 pts) :

A conducting bar of length 0.8 m and mass 30 g is suspended by a pair of flexible leads (that can provide a current) in a uniform 0.9 T magnetic field as shown below. What is the current (magnitude and direction) required to remove the tension in the supporting leads?



direction → to right in bar

$\sum F_y = 0$

$mg = i\ell B$

$(\underset{kg}{.030})(\underset{m/s^2}{9.8}) = (0.8)\, i\, (0.9)$

$\boxed{i = 0.41 \text{ Amps}}$