Physics 1C Spring 2018 First midterm

TOTAL POINTS

88 / 100

QUESTION 1

1 1.a **5 / 5**

✓ + **2 pts** Positive

✓ + **3 pts** explain why positive (RHR, v cross B......)

+ **0 pts** wrong

QUESTION 2

2 1.b **5 / 5**

✓ + **5 pts** correct

+ **2 pts** Partial points for knowing F=qvB

+ **2 pts** Partial points for knowing mv^2/R=F

+ **0 pts** wrong

QUESTION 3

3 1.c **5 / 5**

✓ + **5 pts** Correct

+ **4 pts** almost correct. Like knowing T=2Pi*m/qB, but forget that we only have a semi circle here.

+ **2 pts** partial points for knowing t=pi*R/v. (understand this is part of uniform circular motion)

+ **0 pts** wrong

QUESTION 4

4 1.d **15 / 15**

✓ + **5 pts** semi circle

✓ + **5 pts** CW

✓ + **5 pts** correct R

+ **0 pts** wrong

QUESTION 5

5 2 **30 / 35**

+ **35 pts** Correct

✓ + **30 pts** almost correct, but with some small errors.

+ **10 pts** Kind of understand the problem but don't know the correct expression for magnetic field.

+ **5 pts** nice try

+ **7 pts** partial point, get the B field of pipe correct. B=0 inside and B=u*I/2*pi*r outside

+ **7 pts** partial point, get the B field of wire correct. B=u*I/2*pi*r

+ **8 pts** partial point, get the B field at the center of pipe correct. Bc=u*I_wire/2*pi*3R

+ **8 pts** partial point, get the B field at point P correct. Bp=u*I_wire/2*pi*R - u*I_pipe/2*pi*2R

+ **5 pts** Partial point, get the ratio expression correct. Bp/Bc=-x.

+ **0 pts** no point

QUESTION 6

6 3.a **8 / 8**

✓ + **2 pts** Identification of magnetic flux as magnetic field times area

✓ + **2 pts** Correct (or almost correct) integration over non-constant magnetic field through the loop

✓ + **4 pts** Correct final expression for magnetic flux

+ **0 pts** No points

QUESTION 7

7 3.b **12 / 12**

✓ + **4 pts** Correct direction

✓ + **4 pts** Correct (or almost correct) application of Faraday's Law (in some form)

✓ + **4 pts** Correct expression for the current (up to a factor of +/-1)

+ **0 pts** No points

QUESTION 8

8 3.c **8 / 15**

✓ + **4 pts** Calculate (or at least begin to calculate...) dissipated Ohmic power (P = I*R^2)

✓ + **4 pts** Calculate external power (P = F*v) in full

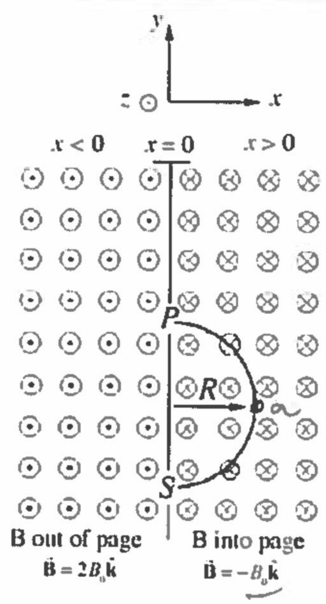
+ **7 pts** Correctly show that the two expressions are equal

+ **0 pts** No points

Physics 1C – Spring 2018: Midterm 1

This exam is closed book and closed notes. Electronics are not permitted, except for one calculator. Please show your full solution in the boxes provided (where the scanners can pick them up). Your solutions will be graded on correctness and coherence; results given with no details will receive zero credit. There is additional scratch paper attached so you can collect your thoughts first. Academic dishonesty is reported to the Office of the Dean of Students.

Problem 1. The x-y plane for $x < 0$ is filled with a uniform magnetic field pointing out of the page, $\mathbf{B} = 2B_0\hat{k}$ with $B_0 > 0$, as shown. The x-y plane for $x > 0$ is filled with a uniform magnetic field $\mathbf{B} = -B_0\hat{k}$, pointing into the page, as shown. A charged particle with mass m and charge q is initially at the point S at x=0, moving in the positive x- direction with speed v. It subsequently moves counterclockwise in a circle of radius R, returning to x = 0 at point P, a distance 2R from its initial position, as shown in the sketch.



a. Is the charge positive or negative? Briefly explain your reasoning.

positive, since force is inwards and magnetic field points down, velocity goes from bottom to top
(ie @ pt. a, F is in −x direction, B field is in −z direction, velocity is in +y direction (RHR)

b. Find an expression for the radius R of the trajectory shown, in terms of v, m, q and B_0 as needed.

$$\frac{m v^{\cancel{2}}}{R} = q \cancel{v} B_0$$

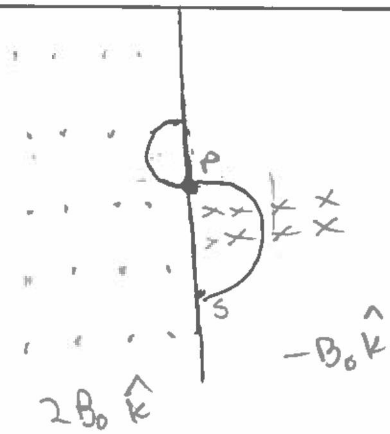
$$\boxed{R = \frac{mv}{qB_0}}$$

c. How long does the particle take to return to the plane x=0 at point P, in terms of v, m, q and B_0 as needed?

$$\omega = \frac{qB}{m}, \quad f = \frac{qB}{2\pi m}, \quad T = \frac{2\pi m}{qB}$$

To get to P (half of period), it takes $\boxed{\frac{\pi m}{qB_0}}$

d. Describe and sketch the entire subsequent trajectory of the particle after it passes point P. Define any relevant distances in terms of v, m, q and B_0.



after point P

F still points towards $x=0$, but B is directed up.

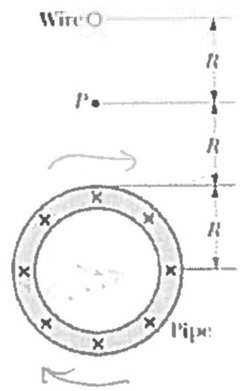
There velocity will be curving the other way, making the particle still move upwards (RHR)

The magnitude of the B field is twice as much as the B field for $x>0$ so R will be half as big.

The new radius will be.

$$R = \frac{mv}{2qB_0}$$

Problem 2. In the figure below a long circular pipe with outside radius R carries a (uniformly distributed) current I into the page. A long wire runs parallel to the pipe at a distance of 3.00R from center to center. Find the current in the wire such that the ratio of the magnitude of the net magnetic field at point P to the magnitude of the net magnetic field at the center of the pipe is x, but it has the opposite direction.



Let I_0 = current in the wire

B field of wire @ P

$B \cdot 2\pi R = \mu_0 I_0$

$B = \dfrac{\mu_0 I_0}{2\pi R}$

B field at center of pipe

due to the wire

$B \cdot 2\pi(3R) = \mu_0 I$

$B = \dfrac{\mu_0 I_0}{6\pi R}$

$3 - \dfrac{3\mu_0 I}{2\mu_0 I_0} = x$

$3 - x = \dfrac{3I}{2I_0}$

$\boxed{I_0 = \dfrac{3I}{(3-x)2}}$

B field of pipe @ P

$B \cdot 2\pi(2R) = \mu_0 I$

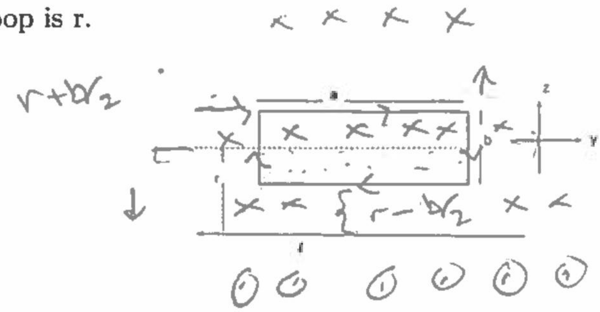
$B = \dfrac{\mu_0 I}{4\pi R}$

$$\frac{\dfrac{\mu_0 I_0}{2\pi R} - \dfrac{\mu_0 I}{4\pi R}}{\dfrac{\mu_0 I_0}{6\pi R}} = x$$

$$\frac{6\mu_0 I_0 - 3\mu_0 I}{2\mu_0 I_0} = x$$

$$\frac{6\mu_0 I_0}{2\mu_0 I_0} - \frac{3\mu_0 I}{2\mu_0 I_0} = x$$

Problem 3. A rectangular loop of wire with length a, width b, and resistance R is placed near an infinitely long wire carrying current i, as shown in the figure . The distance from the long wire to the center of the loop is r.



$dA = a \cdot dr'$

a. Find an expression for the total flux through the loop.

$$B = \frac{\mu_0 i}{2\pi r}$$

$$\Phi = \int B \cdot dA = \frac{\mu_0 i}{2\pi} \int \frac{1}{r'} a \cdot dr' = \frac{\mu_0 i a}{2\pi} \int_{r-b/2}^{r+b/2} \frac{dr'}{r'}$$

$$\boxed{\Phi = \frac{\mu_0 i a}{2\pi} \left[\ln(r + b/2) - \ln(r - b/2) \right]}$$

b. What is the magnitude and direction of the current flowing in the circuit as it is pulled away from the wire with velocity $\mathbf{v} = v_0 \hat{k}$.

$$\mathcal{E} = -\frac{d\Phi}{dt} = -\frac{d\Phi}{dr} \cdot \frac{dr}{dt} \qquad v = \frac{dr}{dt} \qquad I = \frac{\mathcal{E}}{R}$$

$$\mathcal{E} = -\frac{\mu_0 i a}{2\pi} \left[\frac{1}{r+b/2} - \frac{1}{r-b/2} \right] \cdot v_0 \hat{k}$$

as the loop is pulled away, the flux will decrease. An induced B field will be generated into the page by Lenz's law, will induce a current $\boxed{\text{clockwise}}$ with magnitude

$$\boxed{\frac{-\frac{\mu_0 i a}{2\pi} \left[\frac{1}{r+b/2} - \frac{1}{r-b/2} \right] \cdot v_0}{R}}$$

c. Show that to maintain this motion, the rate at which the external force is doing work on the loop is equal to the rate at which energy is being dissipated in the loop.

Energy dissipated = power

$P = I^2 R =$

$$\left(\frac{-\frac{\mu_0 i a}{2\pi}\left[\frac{1}{(r+b/2)} - \frac{1}{(r-b/2)}\right] \cdot v_0}{R} \right)^2 \cdot R =$$

$$\left[\frac{-\frac{\mu_0 i a}{2\pi}\left(\frac{1}{r+b/2} - \frac{1}{r-b/2}\right) \cdot v_0}{R} \right]^2$$

External power

$P = F \cdot v$ since velocity is constant,

$F_{ex} = F_B$

F_B on the sides w/ length b cancel, $F_{Bnet} =$

$$\frac{I a \mu_0 i}{2\pi(r-\frac{b}{2})} - \frac{I a \mu_0 i}{2\pi(r+b/2)} = \frac{I a \mu_0 i}{2\pi}\left(\frac{1}{r-\frac{b}{2}} - \frac{1}{r+b/2}\right) \cdot$$

Since $P_{dis} = P_{Ex}$, the work done is the same as the energy dissipated

Scratch paper