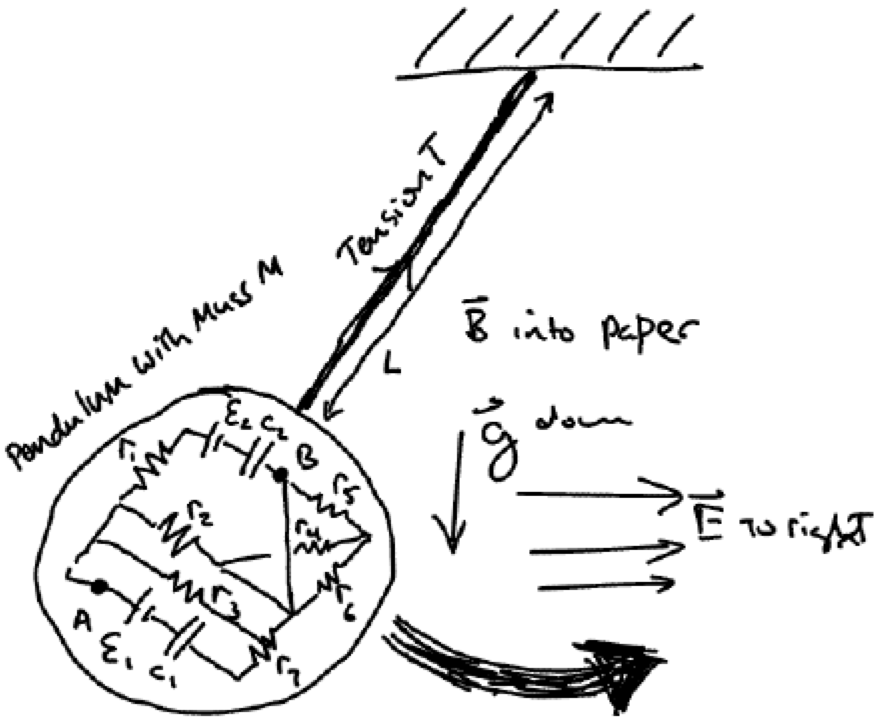
P114 University of Rochester NAME Soln Key - SlM
S. Manly Spring 2006

Exam 2 (March 28, 2006)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show your work. Partial credit will be given.

Problem 0 (0 pts):

Even I couldn't do this to you. Now, after the shock of seeing the drawing below, you ought to be ready to face anything. Move on to problem 1 and good luck!



Problem 1 (10 pts, must give brief justification):

Two parallel wires carry current in the same direction. Wire 1 carries a current I_1. Wire 2 carries a current $I_2=2I_1$. What is the relationship of the magnitudes of the forces on the two wires?

Sufficient

a) $F_1=F_2$ — By Newton's 3rd Law (action - reaction)

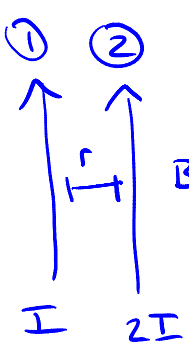
b) $F_1=2F_2$

c) $2F_1=F_2$

d) $F_1=4F_2$

e) $4F_1=F_2$

Could also prove using Ampere, RHR and $F = i\vec{L}\times\vec{B}$



B_1 at 2

$B\,2\pi r = \mu_0 I$

$B_1 = \dfrac{\mu_0 I}{2\pi r}$

$\dfrac{F_2}{L} = (2I)\dfrac{\mu_0 I}{2\pi r}$

B_2 at 1

$B\,2\pi r = \mu_0 2I$

$B = \dfrac{\mu_0 2I}{2\pi r}$

$\dfrac{F_1}{L} = I\,\dfrac{\mu_0 2I}{2\pi r}$

Force per unit length is the Same

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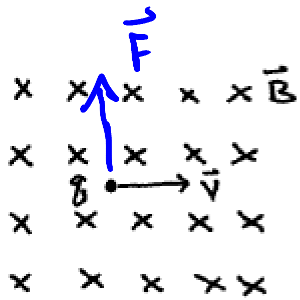
Problem 2 (20 pts, no justification necessary):

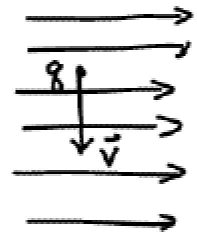
Please indicate on each sketch the direction of the force on the positively charged particle moving with velocity v. All vectors shown are in the plane of the paper except for the B field in part (a), where B is into the paper. There is no need for justification for this problem.

$\vec{F} = q\,\vec{v} \times \vec{B}$

(a)



(b)



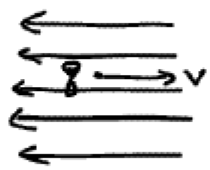
$\vec{F}$ out of Paper

B

(c)

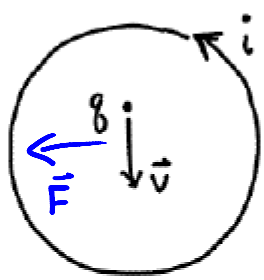
F into Paper

(d)



F = 0

(e)

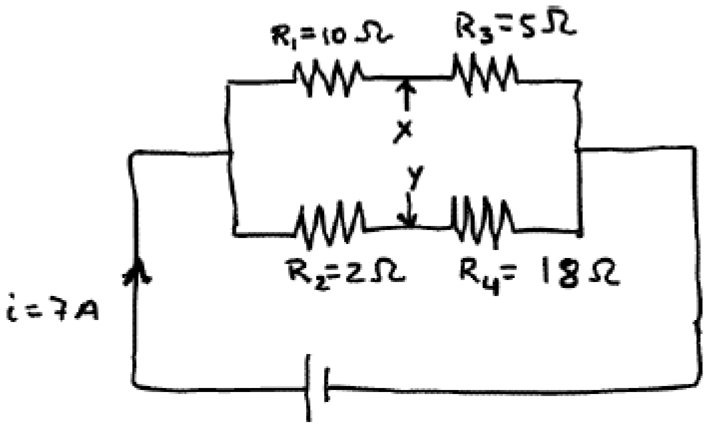


q is inside current loop with i in direction shown. Both motion of q and current loop are in plane of paper.

$\vec{B}$ is out so $\vec{F}$ is to left

Problem 3 (~~15~~ 20 pts, show all work):

(a) Determine the potential difference between points X and Y in the circuit below.



EMF not given. Must determine it using $V = i R_{eq}$

$R_{Top} = R_1 + R_3 = 15\,\Omega$

$R_{BoTT} = R_2 + R_4 = 20\,\Omega$

$\frac{1}{R_{eq}} = \frac{1}{R_{TOP}} + \frac{1}{R_{BoTT}}$

$R_{eq} = 8.6\,\Omega$

V across Req

$V = i R_{eq} = (7)(8.6)$

$V = 60.2\ V$

$V = i_{Top} R_{Top} \Rightarrow 60.2 = i_{Top}(15)$

$i_{Top} = 4\ A$

$V = i_{boTT} R_{BoTT} \Rightarrow 60.2 = i_{boTT}(20)$

$i_{boTT} = 3 A$

$V_X = 60.2 - i_{Top} R_1 = 60.2 - (4)(10) = 20.2$

$V_y = 60.2 - i_{boTT} R_2 = 60.2 - (3)(2) = 54.2$

$|V_{xy}| = 34.2\,V$

(b) Which point, X or Y, is at the higher potential? If you think both points are at the same potential, state that along with your reasoning.

V_y is at higher potential — see Above

$i_{boTT} R_2$ potential drop is less that $i_{top} R_1$ potential drop

Problem 4 (~~13~~ 15 pts, give brief justification):

Two identical capacitors, A and B, are connected in parallel across the same battery. If mica (K=5.4) is inserted in B,

a) both capacitors will retain the same charge.
b) B will have the larger charge.
c) A will have the larger charge.
d) The potential difference across B will increase.
e) The potential difference across A will increase.

V unchanged

$Q = CV$

C increases

$C = KC_0$

$\therefore Q_B$ increases

After the insertion of the mica, how will the energy stored in the two capacitors compared to the energy stored in the system before the mica was inserted? Explain your answer.

in each capacitor $U = \frac{1}{2}CV^2$

V is unchanged

TOTAL C is increased

because C_B is increased

$\therefore$ More energy is stored.

Problem 5 (~~13~~ 15 pts, show all work):

A heart pacemaker fires 72 times a minute. The timing is determined by an RC circuit. 0.25 nF **The pacemaker fires every time that a capacitor is charged to 0.632 of its full voltage (or charge). What is the value of the resistance in the circuit? (Note that 1/e is equal to 0.368.)**

$Q = C\mathcal{E}(1 - e^{-t/RC})$ charging eqn for RC circuit

capacitor charged to .632 of full value at

$t = RC$

$t = \frac{1}{72} 60\,s = .83\,s$

$.83 = (.25 \times 10^{-9}\,F)\,R$

$R = 3.3 \times 10^{9}\,\Omega$

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Problem ~~7~~ 6 (~~16~~ 20 pts, show all work):

A wire lies parallel to a conducting pipe of radius R and thickness ¼ R. The wire lies at a distance of 3R from the center of the pipe. The wire and pipe are configured perpendicular to the paper, as shown below in a sketch. The pipe carries a uniform current of magnitude I directed into the paper. The current is in the region shown. That is to say, the interior of the pipe (r<3/4/R) is empty and carries no current.

(a) Determine the magnitude and direction of current in the wire which will cause the magnetic field at point P to be zero.

B due to wire:

$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$

$B\, 2\pi r = \mu_0 I_{wire}$

$|B_P| = \dfrac{\mu_0 I_{wire}}{2\pi R}$

B due to Pipe:

$B\, 2\pi r = \mu_0 I$

$|B_P| = \dfrac{\mu_0 I}{2\pi (2R)}$

, B at pt P

for B = 0 at pt P

B_{wire} and B_{pipe} are equal in magnitude and opposite in direction.

$\dfrac{\mu_0 I_{wire}}{2\pi R} = \dfrac{\mu_0 I}{2\pi\, 2R}$

$\boxed{I_{wire} = I/2}$ current into paper

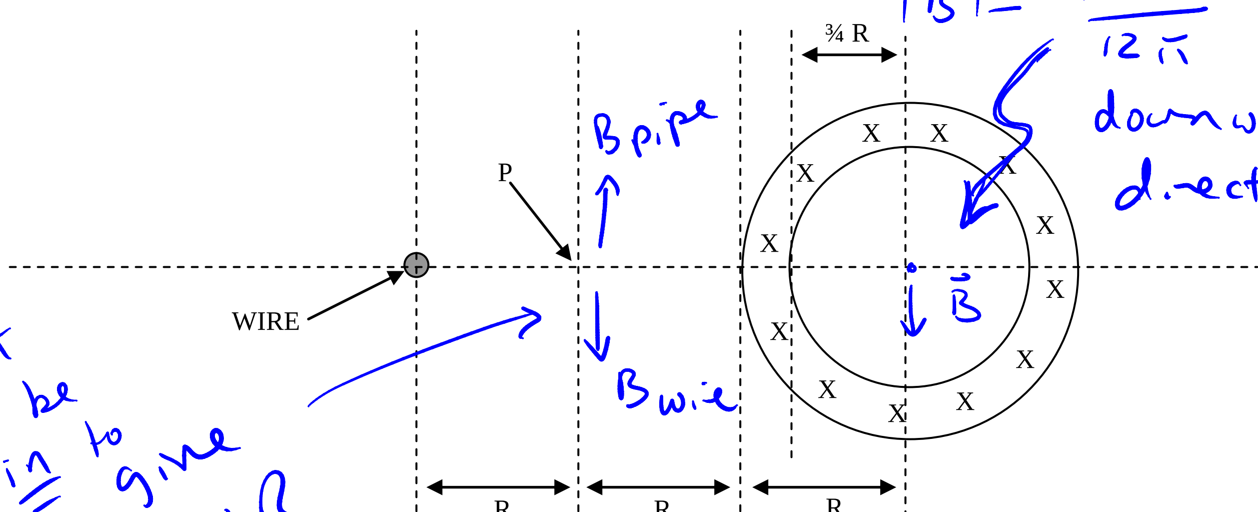
(b) Given your answer to part (a), what is the magnitude and direction of the magnetic field at the center of the current-carrying pipe?

At center of Pipe, $B_{pipe} = 0$ by Ampere's law

$\vec{B}_{center} = \vec{B}_{pipe} + \vec{B}_{wire}$ $\quad |\vec{B}_{wire}| = \dfrac{\mu_0}{2\pi(3R)}\, I/2$

$|\vec{B}| = \dfrac{\mu_0 I}{12\pi}$

downward direction



current must be in to give B_{wire} by RHR