Test 3 Solutions (Test sheet below.)

①

$$\frac{V^2}{R}\cdot t = \text{Energy}$$

$V = 10.000\,(V)$

$t = 600\,(s)$ (EXACT)

$$R = \frac{\rho L}{A} = \frac{\rho L}{\pi a^2 - a^2}$$

$$= \frac{(10^{-7})(0.05)}{(0.01)^2[\pi - 1]} = \frac{5\times10^{-9}}{(2.14)\,10^{-4}}$$

$$= \frac{5\times10^{-5}}{2.14} = 2.3\times10^{-5}\,\Omega$$

$\Rightarrow$ energy =

$$= \frac{10^2}{2.336\times10^{-5}}\cdot 600$$

$= 42.8\times10^{5}\cdot 600$

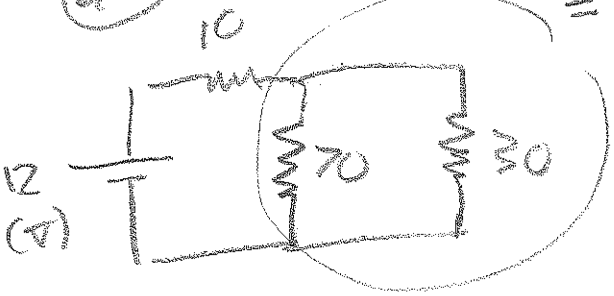
$= 256.8\times10^{7}$

$= 2.6\times10^{9}$ J

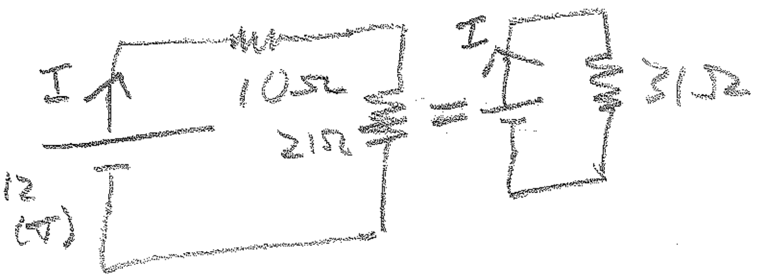
= ENERGY

②

(a)



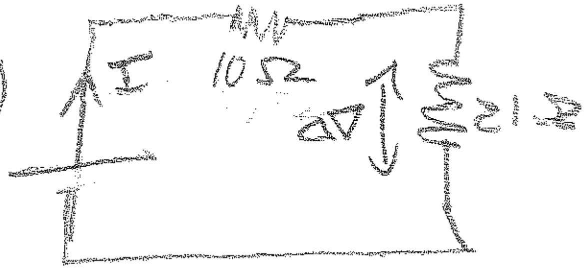
$$\frac{(70)(30)}{100} = \frac{2100}{100} = 21\,\Omega$$



(b)

$$I = \frac{12\,(V)}{31\,\Omega} = 0.387\,(A)$$

(c)



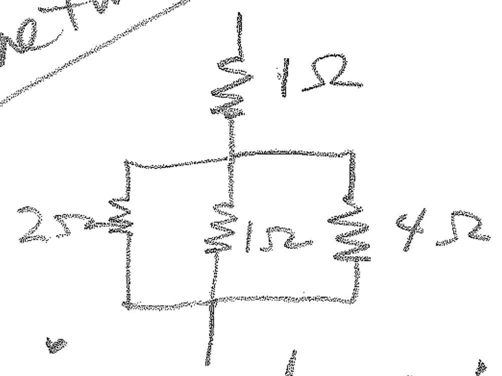
$\Delta V = I\cdot 21\,\Omega =$

$= 8.13\,(V)$

$$I_1 = \frac{8.13(V)}{R_1} = \frac{8.13}{70} = 0.116(A)$$

$$I_2 = \frac{8.13(V)}{30\,\Omega} = 0.271\,(A)$$

③. R-network:

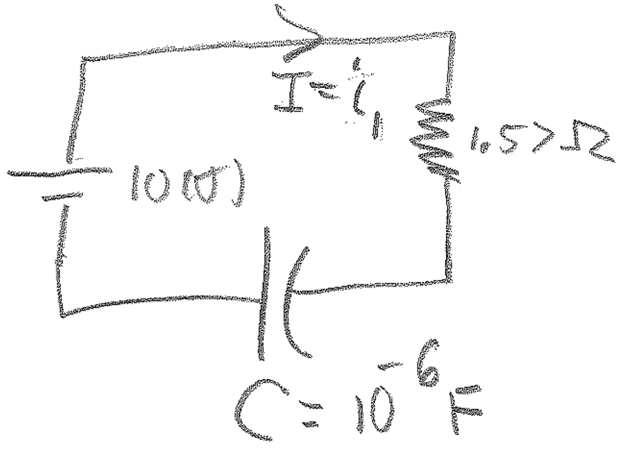


combine R-network:

$$\frac{1}{R_p} = \frac{1}{2} + \frac{1}{1} + \frac{1}{4}$$

$$\frac{1}{R_p} = \frac{2}{4} + \frac{4}{4} + \frac{1}{4} = \frac{7}{4} \rightarrow \boxed{R_p = \frac{4}{7} = 0.571\ \Omega}$$

$$\Rightarrow R_{eq} = 1 + \frac{4}{7} = 1\frac{4}{7} = 1.571\ \Omega$$



③. $$Q = C\cdot\mathcal{E}\cdot\left(1 - e^{-t/R_{eq}C}\right)^{C}$$

$$= (10^{-6})(10)\left(1 - e^{-\frac{10^6\cdot t}{1.57}}\right)$$

$$= 10^{-5}\cdot\left(1 - e^{-0.637\times10^{6}\cdot t}\right)$$

ⓐ at $t = 10^{-6}$:

$$Q = 10^{-5}\left(1 - e^{-0.637}\right)$$

$$= 10^{-5}(1 - 0.529)$$

$$= 0.471\times10^{-5} = 4.71\times10^{-6}\ (C)$$

$$= 4.71\ \mu C$$

ⓑ $$i_1 = \frac{dQ}{dt} = \frac{10(V)}{1.57\Omega}e^{-0.637\times10^{6}t}$$

$$i_1 = 6.36\cdot(0.529)$$

$$= 3.36\ (A)$$

Note: $I = i_1 = \frac{dQ}{dt}$, where $Q = 10^{-5}\cdot(1 - e^{-0.637t})$.

(c)

$$\Delta V_4 = I \cdot R_p$$

$$\Delta V_4 = (3.36)(0.571)$$

$$= 1.918\ (V)$$

$$i_4 = \frac{1.918}{4} = 0.480\ (A)$$

(d.)

$$\Rightarrow \Delta V = \frac{Q}{C}$$

$$E \cdot d = \frac{Q}{C}$$

$$E = \frac{Q}{C \cdot d}$$

Q at $t = 10^{-6}$ (s).

see formula part (a.)

$$E = \frac{4.71\times 10^{-6}}{(10^{-6})(2\times 10^{-2})}$$

$$= 2.355\times 10^{2} \left(\frac{V}{m}\right)$$

$$\cong 236 \left(\frac{V}{m}\right)$$

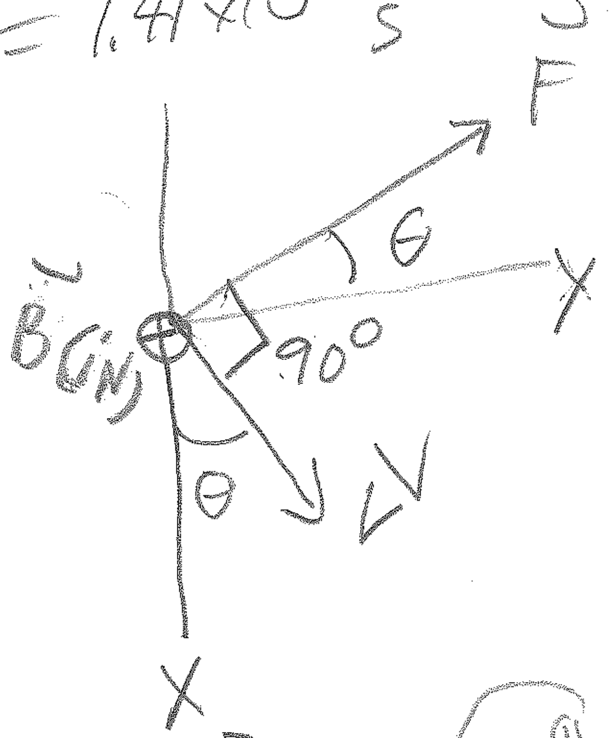
(4.)

$$|q|vB = \sqrt{(3)^2+(9)^2}\ 10^{-7}$$

$$v = \frac{9.48\times 10^{-7}}{(1.20)(5.6\times 10^{-9})}$$

$$= 1.41\times 10^{2}\ \frac{m}{s}$$

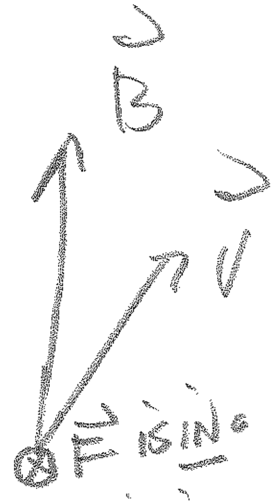
(b.)



$$\tan\theta = \frac{3}{9} \Rightarrow \theta = \boxed{18.4^{\circ}}$$

⑤

(a.)



$\vec{V}\times\vec{B}$ is OUT $\odot$

$-q\vec{V}\times\vec{B}$ is IN $\otimes$ (a.)

$$|\vec{F}| = |q| VB\sin 30$$

$$= (3.2\times10^{-19})(3\times10^{4})(1)\cdot\frac{1}{2}$$

$$= 4.8\times10^{-15}\ (N)$$ ⓑ

ⓒ

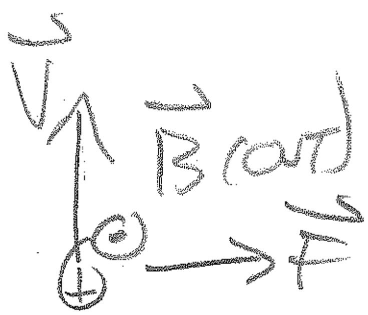
$$a = \frac{F}{m}$$

$$= \frac{4.8\times10^{-15}}{4.8\times10^{-27}}$$

$$= 10^{+12}\ \frac{m}{s^2}$$

($\vec{a}$ is IN) $\otimes$

⑥



(a.)

$$\frac{mv^2}{r} = qVB$$

$$B = \frac{mv}{qr}$$

$$= \frac{(8\times10^{-27})(1.41\times10^{6})}{(3.2\times10^{-19})\left(\frac{0.10}{2}\right)}$$

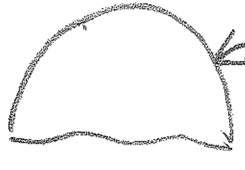
$$= 2\cdot\frac{8\cdot(1.41)}{0.32}\cdot10^{-8}\times10^{6} = 7.1\times10^{-1}$$

$$= 0.71\ (T)$$

(b.)

$$t = \cancel{\frac{\frac{2\pi R}{4}}{V}}$$

$$\boxed{t = \frac{\pi R}{2V}} = \frac{(3.14)(0.05)}{(2)(1.41\times10^{6})}$$

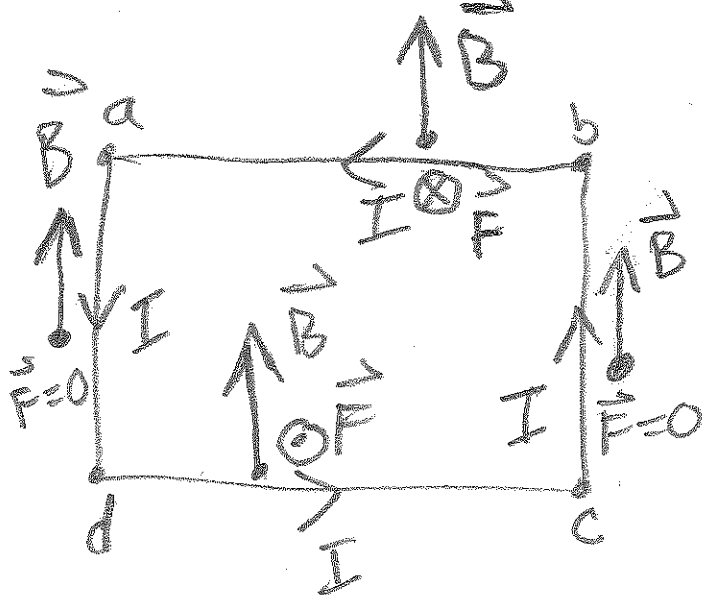


$R\cdot\frac{\pi}{2}$ = arc length.

$$t = 5.6\times10^{-8}\ (s)$$

SHORT time due TO LARge speed OVER moderate distance.

7.



ab: ⊗ $\vec{F}$ (IN)

$|\vec{F}_{ab}| = (10)(0.2)(1)\sin 90$

$= 2.00 (N)$.

bc: $\vec{F} = 0$ since $I\vec{L}\times\vec{B} = 0$ when $\vec{L}$ and $\vec{B}$ are in same direction.

$|I\vec{L}\times\vec{B}| = ILB\sin 0 = 0$.

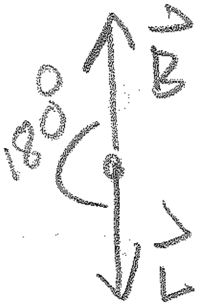
7.

cd: ⊙ $\vec{F}$ (OUT)

$|\vec{F}_{cd}| = (10)(0.2)(1)\sin 90$

$= 2.00 (N)$.

da: $\vec{F} = 0$ since $I\vec{L}\times\vec{B}$ when $\vec{L}$ and $\vec{B}$ are in opposite directions



$|I\vec{L}\times\vec{B}| = ILB\sin 180$

$= 0$.

(e) $\vec{\tau} = \vec{\mu}\times\vec{B}$; $\vec{\mu}$ is OUT of the page using R.H.R.:

$|\vec{\tau}| = \mu B \sin 90$

$= \mu B = I \cdot \text{area} \cdot B$

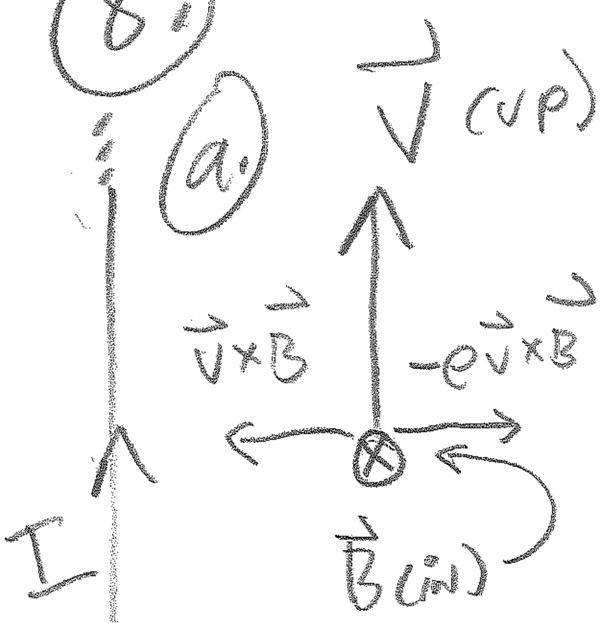
$= (10)(0.1)(0.2)\cdot(1) = \boxed{0.200\ N\cdot m}$

(6

NOTE: $q = -e < 0$

(8.)

(a.)



$\vec{F} = -e\vec{v}\times\vec{B}$

points

Right.

(b.)

$$|\vec{F}| = |q||\vec{v}|B\sin 90$$

$$= |q| \cdot v \cdot B$$

$$= (1.6\times10^{-19})(10^{7}) \cdot \frac{\mu_0 I}{2\pi r}$$

$$= (1.6\times10^{-19})(10^{7}) \cdot \frac{4\pi\times10^{-7}(50)}{2\pi r}$$

$$= \frac{3.2\times10^{-19} \cdot (50)}{(0.05)}$$

$$= 3.2\times10^{-16} \text{ (N)}$$

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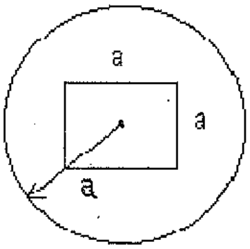
1. (40 POINTS) An experimental resistive wire is constructed by shaping a material of resistivity ρ into a hollow cylinder of length *L*. The hollow part is in the shape of a square of side *a* . The outer radius of the cylinder is *a.* See the figure below of front view of resistor.



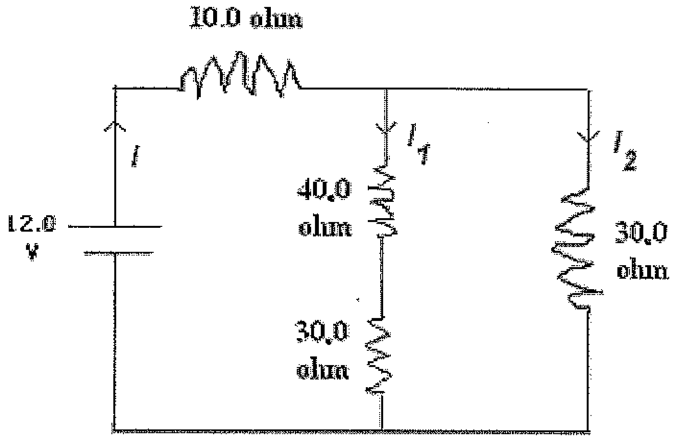
Suppose the resistor length was L = 5.00 cm in a special engineering trial run of this new product. How much heat energy (in Joules) would be generated in the resistor during a time period $\Delta t = 10$ minutes (exactly) while operating at voltage V=10.000 Volts applied between the ends of the resistor? Assume $a = 1.0$ cm and the resistivity $\rho = 1.0\text{x}10^{-7}$ ohm-m. FOR BEST RESULTS, use symbols and plug in values at last step to get final numerical answer. Thank you.

2. (40 points) A 12.0 (V) battery is connected to a resistor network as shown below in fig (*i*) for an automobile alarm circuit.

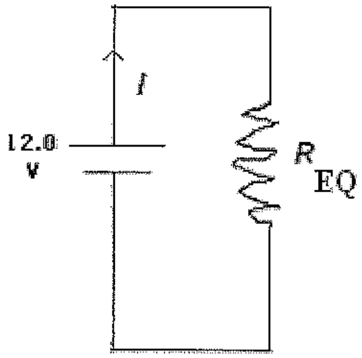
(a) (16 points) What's the *equivalent* resistance R_{EQ} of the circuit in fig (*ii*)?

(b) (14 points) What's the current I in fig (*ii*)?

(c) (10 points) What are the values of currents I_1 and I_2 shown in figure (i)?



(*i*)



(*ii*)

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3. (40 points)

The switch is closed at t = 0 in the *RC* network below used in a camera's light detector unit. The symbol C represents a parallel plate capacitor with distance between the plates d = 2.0 cm, a parameter used in the extra credit part (d.) below. The battery voltage is ε = 10.0 Volts. Also:

$C = 1,0\,\mu F$

$R1 = 1.0\,\Omega$

$R2 = 2,0\,\Omega$

$R3 = 1,0\,\Omega$

$R4 = 4,0\,\Omega$

Note:

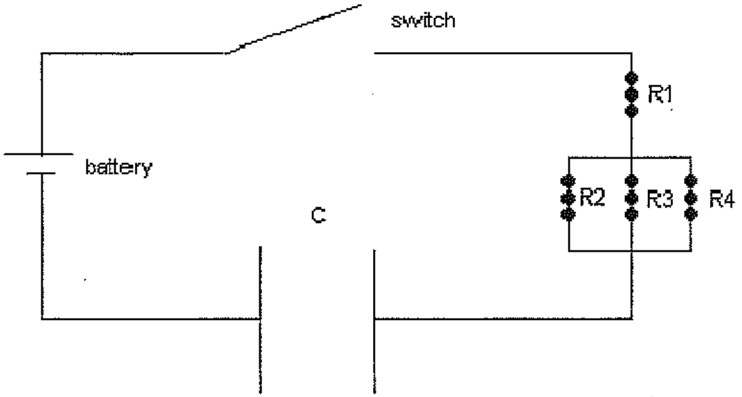
$1\mu F = 1x10^{-6}\,F$

a. **(30 points) Find the <u>charge</u> *q* on the capacitor after a time period of 1.0x10^{-6} seconds.**

b. **(5 points) What is the <u>current</u> *i* in *R1* at *t* = 1.0x10^{-6} seconds?**

c. **(5 points) What is the <u>current</u> i_4 in *R4* at *t* = 1.0x10^{-6} seconds?**

d. **(10 points) EXTRA CREDIT . What is the magnitude *E* of the electric field in the region between the parallel plates at *t* = 1.0x10^{-6} seconds?**



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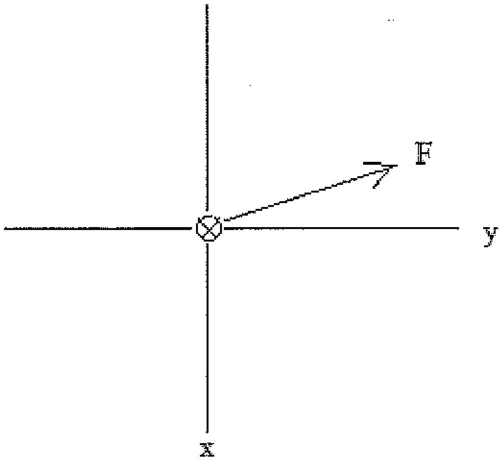
4. (30 POINTS) A huge cosmic particle with positive charge Q = + 5.60 nC is at the origin and is *moving in the x-y plane* parallel to this page. A uniform celestial magnetic field of magnitude B points into (IN, shown by symbol ⊗) the page in the negative z-direction. Note: B = 1.20 T. The magnetic force on the particle is measured to be $\vec{F}$ = -3.00x10 $^{-7}$ N $\hat{i}$ + 9.00 x10 $^{-7}$ N $\hat{j}$ using unit vector notation for x and y components projected on axes below.



(a) (15 points) What is the magnitude *v* of the cosmic particle's velocity?

(b) (15 points) What is the direction of the particle's velocity? To answer this question you must draw an arrow on the above x-y coordinate system representing the velocity. Calculate and *show* the angle it makes with the x-axis above.

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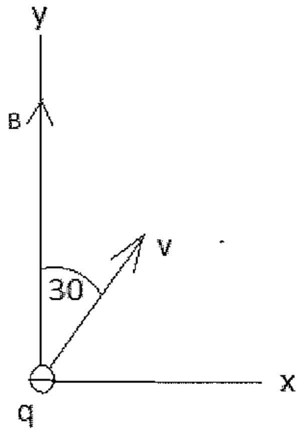
5. (14 POINTS) In a bold, new bio-chemistry *simulation*, an ionic particle is modeled with *negative* charge q = - 3.20x10 $^{-19}$ C and, at a given instant, speed v = 3.00x 10 ^{4} m/s in the x-y plane directed 30 degrees clockwise from the y axis shown. One of the magnetic fields used in rapidly repeated simulated measurements has magnitude B = 1.00 T and is directed along the positive y axis upward on the page. The x-y axes lie in the plane of the page. The z-axis is perpendicular to the page and the positive z- direction is *out* ⊙ of page's plane.

(a) (6 points) What is the direction of the magnetic force on the test particle at this instant, IN ⊗ or OUT ⊙? Explain *carefully* using the right hand rule with any extra diagrams you may choose to draw.

(b) (4 points) What is the magnitude of the magnetic force on the particle?

(c) (4 points) If the particle has mass m = 4.80x10 $^{-27}$ kg, what is the magnitude of the particle's *acceleration* at this instant? What is the direction of the particle's *acceleration*?



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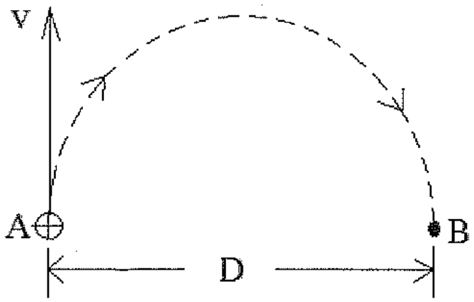
6. (20 points) In a heavy ion mass spectrometer, a positive particle at point A below has speed v of 1.41x10 ^{6} m/s and moves along a half circle parallel to the plane of the page. The ion has charge 3.2x10^{-19} (C) and mass 8.0x10 $^{-27}$ kg. Below, assume diameter D = 10 cm. Remember to convert to m.

Find:

- **(a) (14 points) the magnitude B and direction (IN or OUT of the page) of the magnetic field that will cause the ion to follow the semicircular (i.e., *half*-circular) path from A to B .**
- **(b) (6 points) and the *time* (in seconds) required for the ion to move from A to B.**



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7. (20 points) A rectangular 0.100 m by 0.200 m circuit carrying a 10.00 (A) *counter-clockwise* current I is momentarily oriented with its plane *parallel* to the page and *parallel* to a uniform 1.000 T magnetic field upward along the page. See figure below. EXPLAIN ALL WORK CLEARLY.

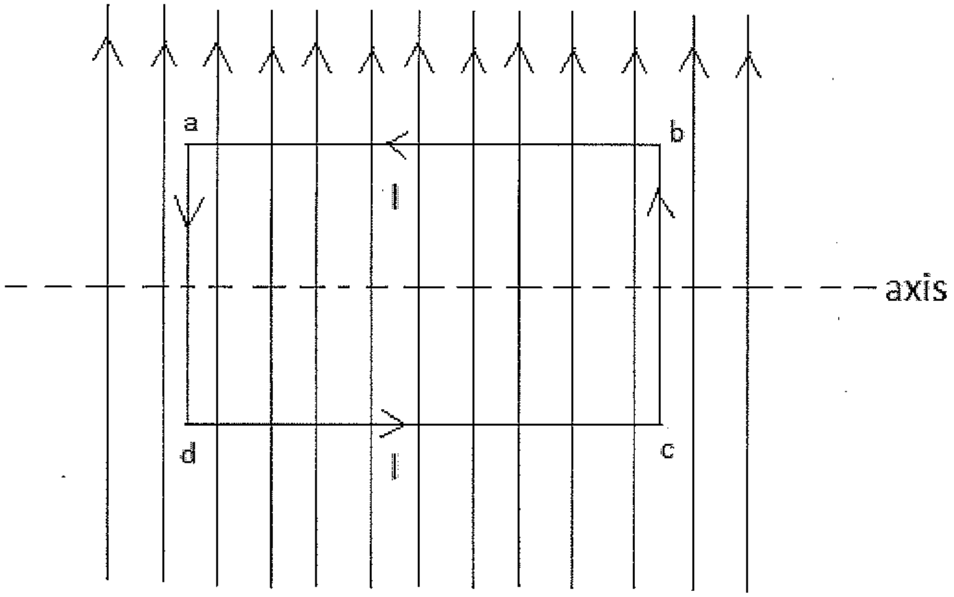
(a) (5 points) Find the magnitude and direction of the magnetic force on segment ab.

(b) (5 points) Find the magnitude and direction of the magnetic force on segment bc.

(c) (5 points) Find the magnitude and direction of the magnetic force on segment cd.

(d) (5 points) Find the magnitude and direction of the magnetic force on segment da.

(e) (5 points) Assume the rectangular wire loop below rotates as an electric motor would about a fixed axis lying along the page and through the center shown by the dotted line parallel to the long sides. Find the magnitude of the *torque* on this motor about that axis at this instant of time.



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8. EXTRA CREDIT: GIEGER COUNTER MODEL REVISITED: A young applied scientist, fresh out of engineering school, first day on the job, is asked to investigate the role of magnetic forces in Geiger counter technology. She proposes setting up a long wire with current 50.0 A upward in the plane of page as shown below. At a distance of r = 5.0 cm from the wire, a particle of NEGATIVE charge (i.e., an electron) with $q = -1.60 \times 10^{-19}$ C could move parallel to the wire and in the SAME direction as the current. The upward directed speed of the particle is v = 1.0x10^{7} m/s.

a. **(5 points) What is the <u>direction</u> of the force on the particle due to the magnetic field of the wire? To get partial credit, you must <u>show all work.</u> <u>Show the direction of the force with an arrow.</u> Show how you got the arrow representing the force.**

b. **(5 points) What is the <u>magnitude</u> of the force on the particle due to the magnetic field of the wire? To get partial credit, you must <u>show all work</u>.**