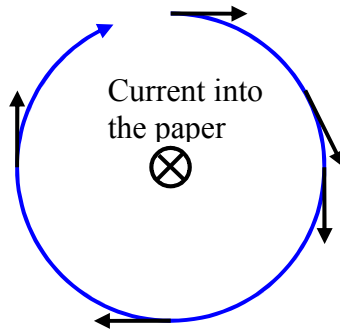
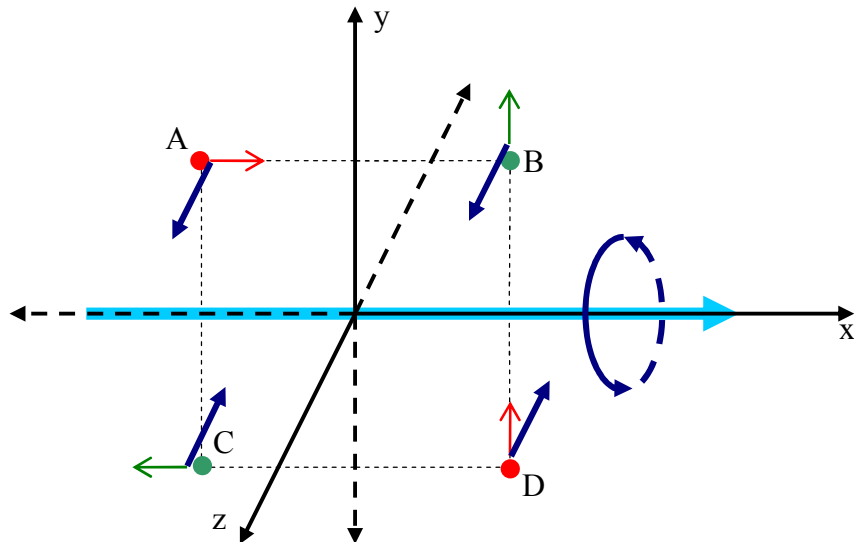


Physics 122  
Chapter 20  
Problem Solutions

- Q3 Use right hand rule number 1. Point the thumb of your right hand away from you (in the direction of the current) and curl the fingers. Above the current the field is left to right. To the right of the current the field is top to bottom. If you are looking at it from your perspective the picture looks like this.



- Q8 The force is given by the Lorentz force law;  $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$ . With the electric field taken to be zero, the force is entirely the result of the cross product which is perpendicular to the plane formed by the vectors  $\vec{v}$  and  $\vec{E}$ . Since it is perpendicular to the velocity, then the work done by this force must be zero. If the work is zero and there are no potential energy changes to consider then the kinetic energy must remain unchanged.
- Q9 I will redraw the picture with a coordinate system so that the directions are easier to discuss.



The red particles ( A & D ) are positively charged and the green particles ( B & C ) are negative. The particles themselves are all, at this moment, in the x-y plane.

- $\vec{v}_A$  is in the x direction.
- $\vec{v}_B$  and  $\vec{v}_D$  are in the y direction.
- $\vec{v}_C$  is in the -x direction.

The magnetic field ( dark blue ) generated by the current in the wire is in the z direction directly above the wire ( particles A and B ) and in the -z direction directly below the wire ( particles C and D ). If I call the size of the velocity v, the magnitude of the charges Q, and the size of the magnetic field B, then the Lorentz force law is easily used in each case.

Each force will have a magnitude of QvB. The issue is the direction.

- Use the right hand rule number 2 with the first vector being the velocity.
- Remember to turn the direction around if the charge is negative.
  - For particle A the direction of the force is the -y direction.
  - For particle B the direction of the force is -x direction.
  - For particle C the direction of the force is +y direction.
  - For particle D the direction of the force is -x direction.

Q23 It seems to me that there are two possible ways to think of this question. One requires us to simply look at the results of a single experiment and then decide what magnetic field and electric field might be present. The second way of thinking of it allows us to change the velocity of the particles. Because the question specifies electrons I take it that the mass and charge are fixed.

First, let us suppose that nothing is under our control. A magnetic field produces an acceleration that is always perpendicular to the velocity regardless of the velocity. An electric field simply pushes in the direction of the field. However, it is possible to arrange a setting where the two cannot be distinguished. Consider a charge q moving at speed v at right angles to a uniform magnetic field B. It will

feel a force qvB in size and move in a circle of radius  $\frac{mv}{qB}$ . Suppose that I now remove the magnetic field a place a charge Q at the center of the circle where

$Q = \frac{m^2 v^3}{kq^2 B}$  and is opposite in sign from q. Then the Coulomb force will be

identical in size to the former magnetic force and it will also be toward the center of the circle. **You should be able to show that this statement is correct.** I will then be unable to tell which type of field is present.

If we are allowed to change the velocity of the moving charges then the difference between magnetic field and electric field will be easy to see. By reversing the velocity we will reverse the direction of the magnetic force but we will not change

the electric force at all. In that case you could measure the acceleration for the particle as it moves in each direction and multiply half the difference by the mass. This would be the magnetic force ( why\*? ). The electric force would be half the sum of the two accelerations times the mass ( why? ).

Q29 The position on the film as measured from the entrance slit is twice the cyclotron radius for the particle. Since both will have passed through the velocity selector we may take it that they have the identical velocities as well as identical masses. The magnetic field is, of course, the same for each. Look up the cyclotron radius on page 561 and you will see that the doubly ionized particle will arrive at one half the position of the singly ionized particle.

P8 For the wire to float the force per unit length must be zero. The magnetic force will be upward and the weight will be downward.

$$|\vec{F}_M / L| = |m\vec{g} / L| \quad (\text{P8-1})$$

The weight per unit length is the mass per unit length multiplied by g. For a length L of wire with cross sectional area A the volume is A·L. The mass per unit length is

$$\frac{m}{L} = \rho \cdot A \quad (\text{P8-2})$$

The magnitude of the magnetic force per unit length is I·B since the angle between them is 90°. Combine this with (P8-1) and (P8-2).

$$\begin{aligned} I \cdot B &= \rho \cdot A \cdot g \\ I &= \frac{(8.9 \cdot 10^3 \text{ kg} / \text{m}^3) (\pi \cdot (5 \cdot 10^{-4} \text{ m})^2) (9.8 \text{ m} / \text{s}^2)}{5 \cdot 10^{-5} \text{ T}} \\ I &= 1370 A \end{aligned} \quad (\text{P8-3})$$

This does seem rather a lot of current. Let's find out how much heat 1m of the wire would have to dissipate. Resistance is<sup>†</sup>  $R = \frac{(\text{resistivity})(\text{length})}{(\text{area})}$ . Combine this with Joule's law and (P8-3) to find the power dissipated.

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\*  $\vec{F}_1 = \vec{F}_E + \vec{F}_B$ . After reversing the velocity the total force simply has the direction of the magnetic part reversed as well,  $\vec{F}_2 = \vec{F}_E - \vec{F}_B$ . Now find half the difference and you have  $\vec{F}_B$ ; half the sum is  $\vec{F}_E$ .

† See section 18-4 pp. 500

$$P = (1370 \text{ A})^2 \left[ \frac{(1.68 \cdot 10^{-8} \Omega m)(1 m)}{(\pi \cdot (5 \cdot 10^{-4} m)^2)} \right]$$

$$= 40,150 W$$

We did not study this last semester<sup>‡</sup> but one can get a lowest temperature for the wire to radiate heat at this rate. It turns out to be about 3875°K. Copper melts at about 1350°K so we will have a hard time levitating the wire.

Is there some copper wire that could be levitated? The required current is proportional to the radius of the wire squared<sup>§</sup>. The resistance is inversely proportional to the radius squared. The power is equal to current squared multiplied by resistance so it goes as radius squared. Smaller wires will then radiate less power. But the temperature depends upon the surface area of the wire as well as the power and so it turns out that the temperature is proportional to the radius to the 0.25 power. Suppose that I want my wire to get no warmer than about 500°K. Then I want to reduce the temperature by something like a factor of 8. The radius must then be reduced by  $8^4 = 4096$ . The wire needs to be something like 0.25 microns in diameter or smaller<sup>\*\*</sup>.

- P9 We simply need the expression for the cyclotron radius that was derived in lecture ( and may also be found in your textbook ).

$$r = \frac{mv}{qB} \tag{P9-1}$$

All of the requisite quantities have been supplied in the problem statement. So we need only solve (P9-1) for B.

$$B = \frac{(6.6 \cdot 10^{-27} \text{ kg})(1.6 \cdot 10^7 \text{ m/s})}{(2 \cdot 1.6 \cdot 10^{-19} \text{ C})(0.25 \text{ m})}$$

$$= 1.32 T$$

- P11 Let's let to the right be the x direction, to the top of the page be the y direction, and then out of the page toward you will have to be the z direction. For each of these cross product will give the negative of the force direction because the charge is negative.

A) v is in the z direction and B is in the negative y direction.

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<sup>‡</sup> See section 14-8

<sup>§</sup> See (P8-3)

<sup>\*\*</sup> This is smaller than the wavelength of visible light. You could not see this wire.

The force is in the negative x direction – that is, to the left.

B) v is in the negative y direction and B is in the negative z direction.

The force is in the negative x direction – that is, to the left.

C) v is in the negative z direction and B is in the x direction.

The force is in the y direction – that is, to the top of the page.

D) v is in the x direction and B is in the y direction.

The force is in the negative z direction – that is, into the page.

E) v is in the negative x direction and B is in the x direction.

The force is in no particular direction as it is zero in magnitude.

F) v is in the negative x direction and B is in the z direction.

The force is in the negative y direction – that is, to the bottom of the page.

P12 In P11 we could simply follow a procedure for evaluating vector products to arrive at an answer to the question. This is a bit harder. Keep in mind that the magnetic field you are looking for will be perpendicular to the force.

I think the easiest way forward is to use right hand rule #1 and ask “If the velocity is this way ( point fingers ) and the force is that way ( extend thumb ) then what must be the direction of the magnetic field ( bend fingers to make right angle with palm )?” We will assume that the magnetic field is perpendicular to the velocity.

For question a) the fingers point to the left, the thumb points out of the paper, and then when the fingers are bent  $90^\circ$  they point toward the bottom of the page.

For question b) the fingers point to the right, the thumb points to the top of the paper, and then when the fingers are bent  $90^\circ$  they point into the page.

For question c) the fingers point into the paper, the thumb points to the bottom of the paper, and then when the fingers are bent  $90^\circ$  they point to the right.

- P16 This problem requires that a beam of electrons be undeflected as they move through a region of space that contains electric and magnetic fields. Undeflected really means that there is no acceleration perpendicular to the velocity. However, I will take what I think is the author's meaning and say that there should be no acceleration at all.

The magnetic force will be perpendicular to the velocity due to its nature ( $q\vec{v} \times \vec{B}$ ). The only thing that can offset this force is the electric force and so it must be perpendicular to the velocity as well. There are no other choices for the relative directions of the velocity and the two fields if the net force is to be zero. Now we need only apply the Lorentz force law and ask that the total force be zero.

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B}) \quad (\text{P16-1})$$

As the charge on an electron is not zero, the only way we can have the right hand side of this expression be zero is if the quantity in parentheses is zero. Recalling that the three vectors are mutually perpendicular we can write

$$0 = E + vB \quad (\text{P16-2})$$

or

$$|v| = \left| \frac{-E}{B} \right| \quad (\text{P16-3})$$

Putting the supplied values for the field strengths into (P16-3) we find the speed of the electrons is  $2.51 \cdot 10^6$  m/s.

We can find the cyclotron radius for these electrons by looking up the mass of the electron.

$$r = \frac{mv}{qB}$$

$$r = \frac{(9.11 \cdot 10^{-31} \text{ kg})(2.51 \cdot 10^6 \text{ m/s})}{(1.6 \cdot 10^{-19} \text{ C})(3.5 \cdot 10^{-3} \text{ T})} \quad (\text{P16-4})$$

$$r = 4.1 \text{ mm}$$

- P18 The place that you might begin in thinking about this problem is the expression for the radius of the cyclotron orbit. A particle of mass  $m$  and charge  $q$  moving in a direction perpendicular to a uniform magnetic field of strength  $B$  will trace out a circle of radius  $r$  such that

$$r = \frac{mv}{qB} \quad (\text{P18-1})$$

We are asked for the ratios of the deuteron or alpha radii to the proton radius.  
Let's just use (P18-1) to write those down.

for the deuteron  $r_d = \frac{m_d v_d}{q_d B} \quad (\text{P18-2})$

for the alpha particle  $r_a = \frac{m_a v_a}{q_a B} \quad (\text{P18-3})$

for the proton  $r_p = \frac{m_p v_p}{q_p B} \quad (\text{P18-4})$

The ratios are created by dividing (P18-2) or (P18-3) by (P18-4).

alpha to proton  $\frac{r_a}{r_p} = \left(\frac{m_a}{m_p}\right)\left(\frac{v_a}{v_p}\right)\left(\frac{q_p}{q_a}\right) \quad (\text{P18-5})$

deuteron to proton  $\frac{r_d}{r_p} = \left(\frac{m_d}{m_p}\right)\left(\frac{v_d}{v_p}\right)\left(\frac{q_p}{q_d}\right) \quad (\text{P18-6})$

The mass ratios and the charge ratios are easily written down from the given information. What about the velocity ratios? The statement says that the particles were accelerated through the same potential V.

How do you turn electric potential difference, charge, and mass into a speed?  
Think about this before you move on – it is a standard idea we use all the time.

Try the work-energy theorem.

$$W = \Delta PE + \Delta KE \quad (\text{P18-7})$$

- $W = 0$
- $\Delta PE = q(V_f - V_i)$ 
  - $V_f - V_i = -V$  This is a negative quantity because when it is said, “The particle was accelerated through a potential of 38,000V,” what is meant is that the initial potential was 38,000V higher than the final potential.
- $\Delta KE = \frac{mv_f^2}{2} - \frac{mv_i^2}{2}$

○  $v_i = 0$

Solve (P18-7) for the velocity of each particle as it enters the magnetic field in terms of mass, charge, and the accelerating potential  $V$ .

$$v_p = \sqrt{\frac{2 \cdot e \cdot V}{m_p}} \quad (\text{P18-8})$$

$$\begin{aligned} v_d &= \sqrt{\frac{2 \cdot e \cdot V}{2m_p}} \\ &= \frac{v_p}{\sqrt{2}} \end{aligned} \quad (\text{P18-9})$$

$$\begin{aligned} v_a &= \sqrt{\frac{2 \cdot 2e \cdot V}{4m_p}} \\ &= \frac{v_p}{\sqrt{2}} \end{aligned} \quad (\text{P18-10})$$

We can now fill in all of the ratios in (P18-5) and (P18-6)

$$\begin{aligned} \frac{r_a}{r_p} &= \left( \frac{4m_p}{m_p} \right) \left( \frac{1}{\sqrt{2}} \right) \left( \frac{e}{2e} \right) \\ &= \sqrt{2} \end{aligned}$$

$$\begin{aligned} \frac{r_d}{r_p} &= \left( \frac{2m_p}{m_p} \right) \left( \frac{1}{\sqrt{2}} \right) \left( \frac{e}{e} \right) \\ &= \sqrt{2} \end{aligned}$$

P19 Let's begin this problem with things that we should be carrying around with us:

- The definition of average speed
- Newton's 2<sup>nd</sup> law
- The expression for centripetal acceleration.
- The Lorentz force law

The time for one orbit of the particle is the distance around the circle divided by the speed at which it is moving.

$$T = \frac{2\pi r}{v} \quad (\text{P19-1})$$

Apparently I would like to find the ratio between the radius of the orbit and the speed of the particle.

The particle is moving in a circle because there is a force that pulls it toward the center of the circle with a force of constant size.  $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$  The electric field is zero and we have been told that the magnetic field is perpendicular to the velocity. The magnitude of the Lorentz force is then

$$F = qvB \quad (\text{P19-2})$$

Newton says that this force causes the centripetal acceleration,  $a = \frac{v^2}{r}$ .

Combine this with (P19-2) in Newton's 2<sup>nd</sup> law and solve for the radius to speed ratio that I need in (P19-1).

$$\begin{aligned} qvB &= m \frac{v^2}{r} \\ \frac{qB}{m} &= \frac{v}{r} \\ \frac{r}{v} &= \frac{m}{qB} \end{aligned}$$

Now we readily write down our result.  $T = (2\pi) \left( \frac{m}{qB} \right)$

- P32 We can simply apply our result from Ampere's law for the strength of a magnetic field due to a long straight current.

$$\begin{aligned} B &= \frac{\mu_0 I}{2\pi r} \\ &= \frac{(4\pi \cdot 10^{-7} \text{ Tm/A})(95 \text{ A})}{2\pi \cdot 8.5 \text{ m}} \\ &= 2.2 \cdot 10^{-6} \text{ T} \end{aligned}$$

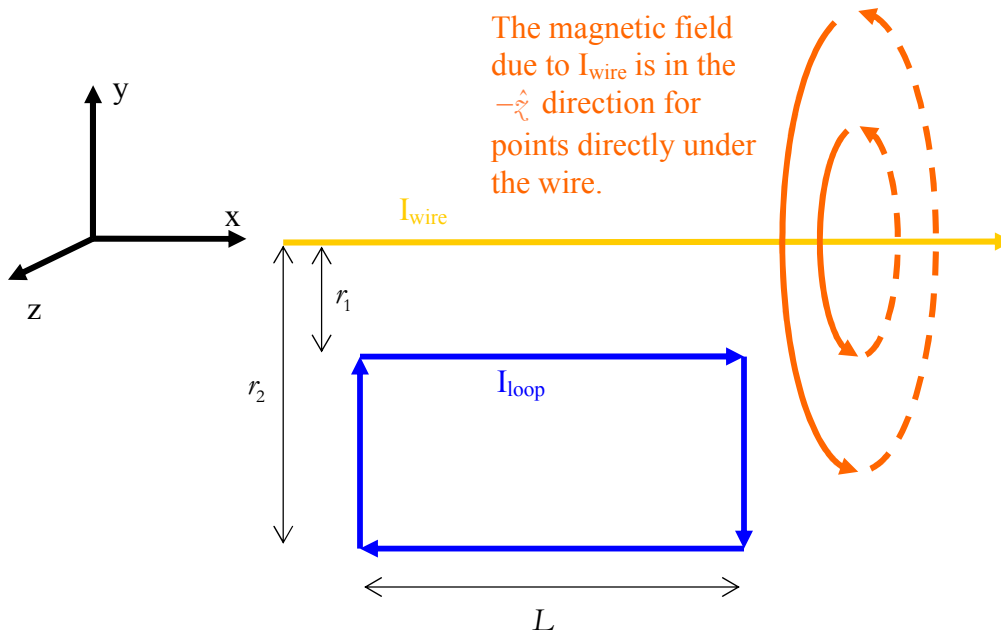
The conversion from Gauss to Tesla is found on page 559.  $10^4 \text{ G} = 1 \text{ T}$  This field strength is 0.022G or 1/25 of the size of the Earth's magnetic field.

- P41 This is a particular case of a problem we worked in lecture. The loop carries a current that interacts with the magnetic field produced by the current in the long

straight wire. The sum of the interactions for the four sides of the loop gives the net force on the loop.

The starting point for this problem is the expression we derived from the Lorentz force law for the force per unit length on a current.

$$\frac{\vec{F}}{L} = \vec{I} \times \vec{B} \quad (\text{P41-1})$$



Along the top of the loop the size of the magnetic force is

$$|\vec{F}_{\text{top}}| = (I_{\text{loop}})(B_{\text{wire}})(L) \quad (\text{P41-2})$$

We will need to find the size of the magnetic field. The direction of the force will be up; parallel currents attract. To find the size of the magnetic field at a distance  $r_1$  from the wire use our result from Ampere's law;  $B_{\text{wire}}(r) = \frac{\mu_0 I_{\text{wire}}}{2\pi r}$ . This makes

(P41-2) become

$$|\vec{F}_{\text{top}}| = \frac{\mu_0 I_{\text{wire}} I_{\text{loop}} L}{2\pi \cdot r_1} \quad (\text{P41-3})$$

The force on the bottom wire will differ from this in that its direction will be opposite since the current along the bottom of the loop moves in the negative x direction ( anti-parallel and so the currents repel ) rather than in the positive x direction and that the distance from the wire is  $r_2$  instead of  $r_1$ .

$$|\vec{F}_{bottom}| = \frac{\mu_0 I_{wire} I_{loop} L}{2\pi \cdot r_2} \quad (\text{P41-4})$$

The forces on the sides are not so easy to calculate since the strength of the magnetic field is changing along the length of the side. However, for each tiny bit of the right side that feels some force to the right ( **How do I know the direction? Make yourself come up with the answer.** ) there is an identical piece of wire on the left side carrying the same size current in the opposite direction that is in a magnetic field of exactly the same size and so feels that force to the left. The result is complete cancellation of the forces on the right and left sides.

The total force is, then, the sum of the top and bottom forces. Take the upward direction to be positive.

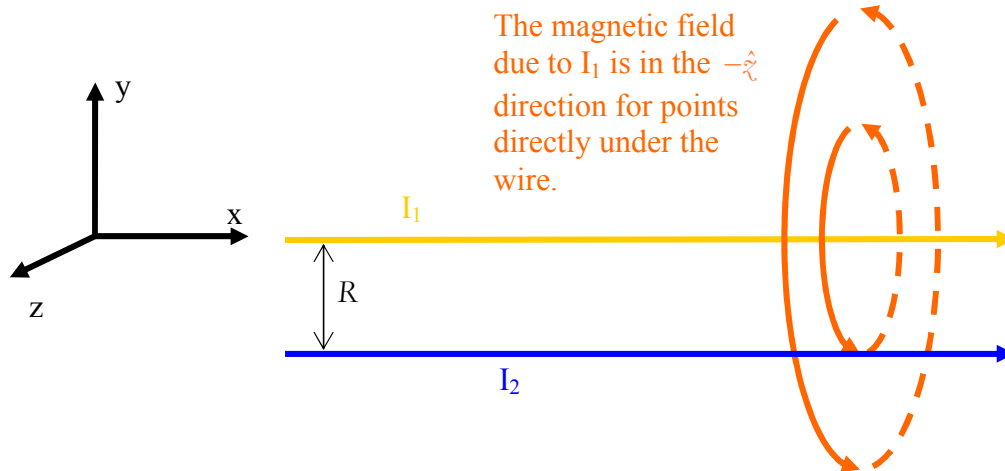
$$\begin{aligned} \vec{F}_{total} &= \frac{\mu_0 I_{wire} I_{loop} L}{2\pi \cdot r_1} - \frac{\mu_0 I_{wire} I_{loop} L}{2\pi \cdot r_2} \\ &= \left( \frac{\mu_0 I_{wire} I_{loop} L}{2\pi} \right) \left( \frac{1}{r_1} - \frac{1}{r_2} \right) \\ &= \left( \frac{(4\pi \cdot 10^{-7} \text{ Tm} / \text{A})(2.5 \text{ A})(2.5 \text{ A})(0.1 \text{ m})}{2\pi} \right) \left( \frac{1}{0.03 \text{ m}} - \frac{1}{0.08 \text{ m}} \right) \\ &= (2.6 \cdot 10^{-6} \text{ N}) \end{aligned}$$

P45 We looked at something much like this in lecture. We need the force per unit length result that we found using the Lorentz force law and then we need the strength of the magnetic field from a long straight current that we produced with the help of Ampere's law.

$$\frac{\vec{F}}{L} = \vec{I} \times \vec{B} \quad (\text{P45-1})$$

$$B = \frac{\mu_0 I}{2\pi r} \quad (\text{P45-2})$$

Consider two parallel wires carrying currents  $I_1$  and  $I_2$  in the same direction. If they are separated by a distance  $R$ , what is the force per unit length felt by wire 2 due to the presence of wire 1? This can be found by combining (P45-1) and (P45-2) where the direction of the magnetic field is found using the right hand rule #1.



The strength of the magnetic field at the location of current 2 due to current 1 is

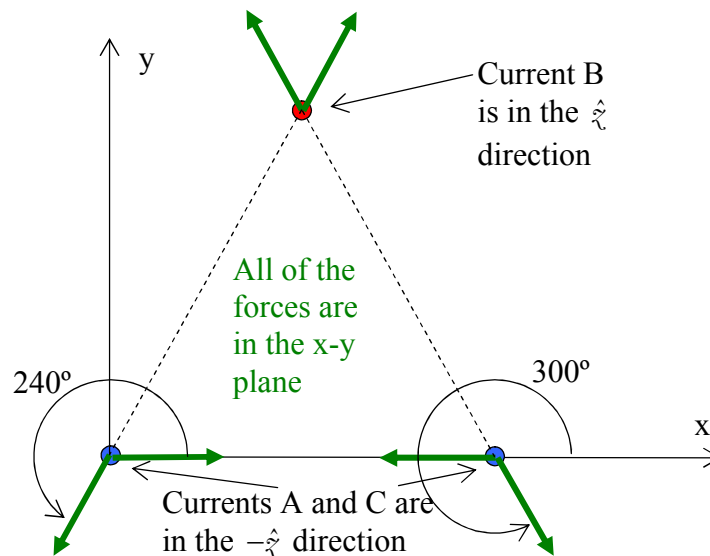
$$|\vec{B}_1| = \frac{\mu_0 I_1}{2\pi R}$$

and so

$$\begin{aligned} \left| \frac{\vec{F}_{on2}}{L} \right| &= (I_2) \left( -\frac{\mu_0 I_1}{2\pi R} \right) \\ &= \frac{\mu_0 I_1 \cdot I_2}{2\pi R} \end{aligned}$$

(P45-3)

The force pulls the wires together. If current 2 had been in the  $-\hat{x}$  direction then the force would have pushed the wires apart. Now draw an end view of the three currents.



All three currents are the same size ( 8A ) and the distance between each pair of wires in the same ( 3.8cm ) so that the magnitude of the force per unit length, (P45-3), is the same in each case. The only issue is the direction; it is attractive for currents A and C and repulsive for currents A and B or C and B.

The magnitude of any of the green force vectors in the drawing is

$$\begin{aligned}\frac{F}{L} &= \frac{(4\pi \cdot 10^{-7} Tm / A)(8A)^2}{2\pi \cdot 0.038m} \\ &= 3.37 \cdot 10^{-4} N / m\end{aligned}$$

The x components of the forces on current B cancel and the y components add. The total force on B is in the + y direction.

$$\begin{aligned}\left| \frac{\vec{F}_B}{L} \right| &= 2 \cdot \left[ (3.37 \cdot 10^{-4} M / m) (\sin(60^\circ)) \right] \\ &= (5.83 \cdot 10^{-4} M / m)\end{aligned}$$

The forces on current A derive from the other two currents. First, there is a horizontal piece due to C. It is in the x direction. Second, there is a force due to B that is down and to the left. We need to break it into components. Remember that  $\hat{x}$  and  $\hat{y}$  just mean in the x direction or in the y direction. I put in angles that go back to the positive x-axis just so that you can see that this will work. You can just use a  $60^\circ$  angle up to the negative x-axis if you wish. If you do this you have to supply the negative signs yourself.

$$\begin{aligned}\frac{\vec{F}_A}{L} &= (3.37 \cdot 10^{-4} M / m) \hat{x} + (3.37 \cdot 10^{-4} M / m) (\cos(240^\circ) \hat{x} + \sin(240^\circ) \hat{y}) \\ &= (1.69 \cdot 10^{-4} M / m) \hat{x} - (2.92 \cdot 10^{-4} M / m) \hat{y}\end{aligned}$$

The forces on current C work out in the same way.

$$\begin{aligned}\frac{\vec{F}_C}{L} &= (-3.37 \cdot 10^{-4} M / m) \hat{x} + (3.37 \cdot 10^{-4} M / m) (\cos(300^\circ) \hat{x} + \sin(300^\circ) \hat{y}) \\ &= (-1.69 \cdot 10^{-4} M / m) \hat{x} - (2.92 \cdot 10^{-4} M / m) \hat{y}\end{aligned}$$

- P54 When the problem statement says that the face of the loop is parallel to the magnetic field they mean that the area vector is perpendicular to the field. The torque is then

$$\vec{\tau} = \vec{M} \times \vec{B} \quad (\text{P54-1})$$

We do not care about the direction of the torque. We are only given its magnitude. So (P54-1) becomes  $\tau = MB \sin(90^\circ)$ . For a single loop, the magnetic moment is the area multiplied by the current so we should be able to solve this for the magnetic field.

$$\begin{aligned} \tau &= IAB \\ B &= \frac{0.325 \text{ N} \cdot \text{m}}{(0.22 \text{ m})^2 (6.3 \text{ A})} \\ B &= 1.07 \text{ T} \end{aligned}$$

- P75 To find the velocity as a function of time you need the acceleration. This is a Newton's 2<sup>nd</sup> law problem. The only force in the horizontal direction for part a) is the magnetic force.

$$\frac{\vec{F}}{L} = \vec{I} \times \vec{B} \quad (\text{P75-1})$$

With the current moving toward the top of the page and the magnetic field coming out of the page, the cross product in (P75-1) gives a direction toward the right; the problem labels this as East. The magnitude of the force is then  $ILB$  and the acceleration is  $ILB/m$ . The velocity as a function of time is

$$v(t) = \frac{ILB}{m} t$$

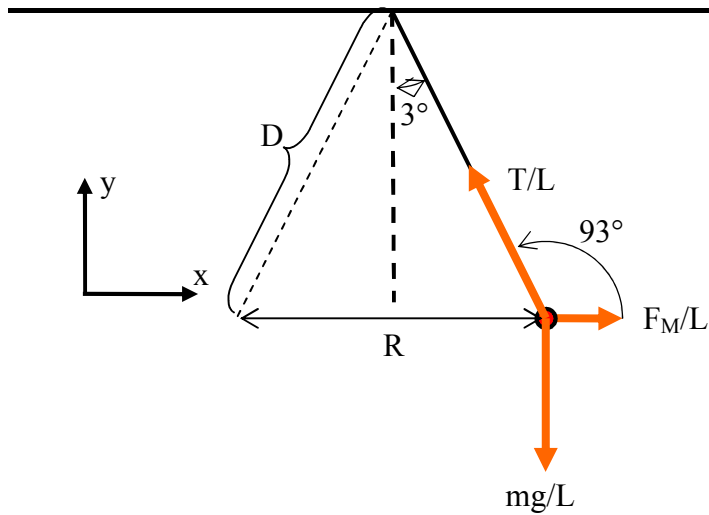
Notice that the problem specifies a constant current source. As the rod moves to the right there will be a potential difference that develops between the ends of the rod due to the Lorentz force on the charges in the rod. The size of this potential difference will be  $LBv(t)$  and it would tend to drive a current in the opposite direction ( toward the bottom of the page ). Thus if the rails were hooked to a voltage source the current would diminish and at some terminal velocity go to zero. BUT NOT IN THIS PROBLEM because the current is held constant regardless of this new potential.

In part b) there is simply a second constant force that acts in the opposite direction. The size of the frictional force is  $\mu_k mg$ . The total force then becomes  $ILB - \mu_k mg$  and the new acceleration is  $ILB/m - \mu_k g$ . Multiply by time and you are done.

- P86 Compare this problem to P45. The two wires will repel and the force per unit length will be given by (P45-3) except that this force will be horizontal as the two wires are side by side. At this point we have a statics problem from last semester. The procedure is to

1. Draw a free body diagram of one of the wires.
2. Supply a coordinate system.
3. Sum the forces in each coordinate direction and set the sum to zero.
4. Solve the system of equations for whatever you don't know.

The one difference for this problem is that we will find the forces for a unit length of wire. It may help to think of this as exactly 1m although any length will do.



Sum the forces in the x direction.

$$\frac{F_M}{L} + \frac{T}{L} \cos(93^\circ) = 0 \quad (\text{P86-1})$$

Sum the forces in the y direction

$$\frac{T}{L} \sin(93^\circ) - \frac{mg}{L} = 0 \quad (\text{P86-2})$$

Copy a version of (P45-3).

$$\frac{F_M}{L} = \frac{\mu_0 \cdot I \cdot I}{2\pi R} \quad (\text{P86-3})$$

I am looking for the current so I will start by eliminating T/L. Combine (P86-1) with (P86-2) to do this.

$$\frac{F_M}{L} + \left[ \frac{mg}{L \sin(93^\circ)} \right] \cos(93^\circ) = 0 \quad (\text{P86-4})$$

I could substitute in for  $F_M/L$  from (P86-3) if I knew what to put in for R. Looking at the diagram I can see that

$$\frac{R}{2} = D \sin(3^\circ)$$

$$\frac{\mu_0 I^2}{4\pi D \sin(3^\circ)} + \frac{mg \cos(93^\circ)}{L \sin(93^\circ)} = 0 \quad (\text{P86-5})$$

Let's check what is known.

- $\mu_0 = 4\pi \cdot 10^{-7} \text{Tm/A}$
- $D = 0.5\text{m}$
- $g = 9.8\text{m/s}^2$
- What about  $m/L$  ?

I know that this is aluminum wire of radius  $r = 0.25\text{mm}$ . If A is the cross sectional area,  $\pi r^2$ , and L is the length then  $L \cdot \pi r^2$  is the volume and this multiplied by the density  $\rho$  gives the mass.  $m = \pi r^2 L \rho$  This can be divided by the length to give me what I need.

$$\frac{m}{L} = \pi r^2 \rho$$

Solve for the current.

$$\frac{\mu_0 I^2}{4\pi D \sin(3^\circ)} + (\pi r^2 \rho) \frac{g \cos(93^\circ)}{\sin(93^\circ)} = 0$$

$$I = \sqrt{-\left(\pi r^2 \rho\right) \frac{g \cos(93^\circ)}{\sin(93^\circ)} \left(\frac{4\pi D \sin(3^\circ)}{\mu_0}\right)}$$

$$I = \sqrt{-\left(\pi (2.5 \cdot 10^{-4} \text{ m})^2 (2.7 \cdot 10^3 \text{ kg/m}^3)\right) \frac{(9.8 \text{ m/s}^2)(-0.0523)}{(0.9986)} \left(\frac{4\pi (0.5 \text{ m})(0.0523)}{4\pi \cdot 10^{-7} \text{ Tm/A}}\right)}$$

$$I = 8.44 \text{ A}$$