HW #7 Solutions

Ch. 20

Q8) The kinetic energy will stay the same. The force on the charged particle due to the magnetic field is perpendicular to the direction the particle is traveling and therefore no work is done ($W = Fd\cos\theta$; $\theta = 90^\circ$). Since no work is done the kinetic energy remains constant.

Q15) You cannot set a resting electron into motion with a magnetic field. The force on a charged particle due to a magnetic field is $F = qvB\sin\theta$. Since $v = 0$, $F_{mag} = 0$, and so accel = 0. Thus the velocity will remain at 0.

You can set a resting electron into motion with an electric field (of course!).

P5) $F = IlB$; 1.28 N = (8.75 A) × (0.555 m) × B. Therefore B = 0.264 N/A·m = 0.264 T. Why does it say the force is a maximum of 1.28 N? Because the force depends on the angle between the magnetic field and the current. The force will be a maximum when the angle is 90°.

P16) If the electrons are undeflected, then the magnetic force must equal the electric force:

$$qvB = qE.$$

Thus v = E/B = (8800 V/m)/(0.0035 T) = 2,500,000 m/s.

If the electric field is turned off, and the electrons still have the same speed, they will bend into a circular orbit with $qvB = mv^2/R$. Solving gives R = 0.0041 m = 4.1 mm.

P29) $F = (\mu_0 I_1 I_2 l)/(2\pi r)$ so $F/l = (\mu_0 I_1 I_2)/(2\pi r)$. F/l = 0.00088 N/m, r = 0.07 m, and I_1 = 24A, so I_2 = 12.8 A ≅ 13 A. To be attractive, the two currents must flow in the same direction, so the current direction is up.

P38) For this problem you have to realize that both currents produce a magnetic field at the point of interest. By the right hand rule, the field produced by the upward current in the right hand wire produces a magnetic field into the page at the point of interest. The field produced by the current in the left hand wire is out of the page at the point of interest. You might think that the two fields cancel completely, but the distances are slightly different so they don't exactly cancel. B due to the right hand wire is given by $B = \frac{\mu_0 I}{2\pi r} = \frac{(1.257\times10^{-6}\ \frac{T\cdot m}{A})\times(25A)}{2\pi(0.10-0.0014m)} = 0.0000507T$.

B due to the other wire is $B = \frac{\mu_0 I}{2\pi r} = \frac{(1.257\times10^{-6}\ \frac{T\cdot m}{A})\times(25A)}{2\pi(0.10+0.0014m)} = 0.0000493T$. The net magnetic field is 0.0000507-0.0000493 T = 0.0000014 T = 1.4×10^{-6} T. This is quite a bit weaker than the field due to the earth of 5×10^{-5} T. If you rounded to two sig figs when finding B, you would get that the field is 2.0×10^{-6} T. Quantitatively, the field due to the currents is only about 2.8% of the earth's field.

P41) The 4 segments of the loop feel different forces due to the field produced by the long straight wire. The left hand segment and the right hand segment will feel forces with the same magnitude, but opposite directions so they do not contribute to the net force. The top segment of the loop feels an attraction to the top wire and the bottom segment feels a repulsion. We use the standard force between two currents equation (see P29) to calculate these two forces. For the top segment, l = 0.1 m and r = 0.03 m. For the bottom segment, l = 0.1 m and r = 0.08 m. The forces are 0.00000417 N on the top wire and 0.00000156 N on the bottom wire. Since the force on the top wire is up and the force on the bottom wire is down, we subtract to get a net force of 0.0000026 N up.

Notice that we have ignored something in this problem. There is also a force on the top segment due to the current in the bottom segment. However, there is a force on the bottom segment due to the current in the top segment as well. By Newton's third law, or just from the math, these forces are equal and opposite and so do not result in any net force on the loop. So we didn't have to worry about these forces, but in physics worrying about the details is always a good idea, and in some cases is even instructive.

P43) By the right hand rule, the field due to the top wire points to the right at the point of interest. The field due to the bottom wire comes out of the page. These two fields must be added together as vectors. Since they are at right angles, one can use the Pythagorean theorem. We only care about the magnitude. Using the formula for the field due to a long straight wire we find that the field due to the top wire has a magnitude of 0.00004 T. The field due to the bottom wire has a magnitude of 0.00001 T since the current is only 5 A instead of 20 A. Squaring, adding, and taking the square root gives $B = 0.000041$ T. If you were asked for the direction you could use the tan to get an angle: $\tan\theta = 0.00001/0.00004 = 0.25$, so $\theta = 14^\circ$. Thus the direction is to the right, but 14° out of the page.

P49) $B = \mu_0 IN/l$. Thus $0.385\ \text{T} = (1.257 \times 10^{-6}\ \text{T}\cdot\text{m/A})\cdot I\cdot(975)/(0.3\ \text{m})$. Solving gives I = 94 A. Hmmmmm!. If there are 945 turns of the wire in a length of 30 cm, and the diameter of the coil is 1.25 cm, the wire must be pretty fine. I don't think you want to send 94 A through the wire for vary long, or you will melt the wire from the heat produced.

P50) First find the magnetic field using the equation used in P49, then find the force using $F = IlB$. The magnetic field is $(1.257 \times 10^{-6}\ \text{T}\cdot\text{m/A})\cdot 33\text{A}\cdot(550)/(0.15\ \text{m}) = 0.15$ T. The force is $(22\text{A}) \times (0.03\ \text{m}) \times (0.15\ \text{T}) = 0.10$ N.

AP1) a) The B field points from west to east. The positive particle is moving from south to north. The force must be perpendicular to the velocity and the field so it must be either up or down. Point fingers of right hand north (velocity) and curl fingers to the east. Your thumb points **Down**.

b) The B field points east and the velocity is down. Point fingers down (velocity) and curl to the east. Thumb points to the south. But wait, the particle is negative so the force is **North**.

c) The B field points east and the velocity is to the east. In this case $\theta = 0$, so $F=qvB\sin\theta = 0$. There is only a force if v has at least some component perpendicular to the magnetic field.

AP2) a) Conventional current is positive. It flows from higher potential to lower potential. The longer bar of the battery is the higher potential side, so conventional current leaves the longer bar and goes through the strip from **left to right** before arriving at the shorter bar of the battery.

b) The force is **up** by the right hand rule.

c) The positive charges would flow along the top part of the strip, making the bottom part of the strip negative. The top part of the strip would be at a higher potential because of the positive charges there. Since the right terminal of the voltmeter is connected to the top part of the strip the voltmeter will read positive.

d) Negative charges will flow from **right to left** in the strip.

e) The force is **up**.

f) The negative charges would flow along the top part of the strip, making the bottom part of the strip positive. Since the top part of the strip is at a lower potential, the voltmeter will read negative.

AP3) a) By conservation of energy, $q\Delta V = 1/2mv^2$. $\Delta V = 1200$ volts. Solving for v gives $v_{12} = 1.386 \times 10^5$ m/s, and $v_{14} = 1.281 \times 10^5$ m/s.

b) As they enter the magnetic field the ions are moving up and the force on them is to the right, so by the right hand rule B must be out of the page.

c) We know that for the circular path of the ions $qvB = mv^2/r$. Simplifying and applying this equation to both ions gives $qB = m_{12}v_{12}/r_{12}$ and $qB = m_{14}v_{14}/r_{14}$. If we set the right side of these two equations equal to each other and rearrange we get
$\frac{r_{14}}{r_{12}} = \frac{m_{14}v_{14}}{m_{12}v_{12}} = \frac{3.00 \times 10^{-21}}{2.77 \times 10^{-21}} = 1.08$. So we see that the heavier ion has the larger radius orbit.

We know that the two spots on the detector are separated by 1.5 mm. This means that $r_{14} = r_{12} + 0.00075$ m. Substituting into the previous equation gives $\frac{r_{12} + 0.00075}{r_{12}} = 1.08$. Solving for r_{12} gives $r_{12} = 0.0094$ m. Substituting this value into $qB = m_{12}v_{12}/r_{12}$ and solving for B gives B = 2.0 tesla.

d) We already know r_{12}. Adding 0.00075 m gives $r_{14} = 0.0102$ m.

I do not know much about the design of modern mass spectrometers, but the numbers for the radii seem unrealistic to me. I would have thought the radii were bigger by perhaps a factor of 10, and that is consistent with examples in the text book. It may be that the problem should have said that the ions are separated by 1.5 cm at the detector, not 1.5 mm. In that case the radii would have come out as 0.094 m and 0.102 m, or 9.4 cm and 10.2 cm, and the B field would have come out as 0.2 T. These numbers are more like what I would expect to encounter in a real mass spectrometer, but I do not know for sure that the numbers in the original problem were incorrect.