FREQUENTLY ASKED QUESTIONS

April 8, 2003

Administrative Questions

Why am I not getting psets back?

I am not sure. There seem to be a lot of missing psets this semester. I will try to track it down.

Content Questions

Why do charges move in circles in magnetic fields?

The $\vec{B}$ field produces a force on a moving charge according to $q\vec{v} \times \vec{B}$: this force is perpendicular to the velocity $\vec{v}$ at all times, so what it does is to change the *direction* of $\vec{v}$ and not its magnitude. A force that does this is a centripetal force, and causes motion in a circle (think of a ball on a string: the force is always perpendicular to the velocity).

If electric and magnetic fields are in the same direction, will the charged particle move in that direction?

No (but it may have a component in that direction). The force due to $\vec{B}$ is $\perp$ to $\vec{B}$, so the magnetic field causes motion in the plane perpendicular to $\vec{B}$, not in the direction of $\vec{B}$. On the other hand, the electric force on the charge is parallel to $\vec{E}$, so it will cause acceleration in the direction of $\vec{E}$.

In our textbook, there are a lot of specific examples of things related to magnetism (like mass spectrometers and motors)? Are we responsible for these? If so, can you clarify them?

Yes, you should understand some of these concepts (Prof. Roland's notes are probably a good guide). The mass spectrometer (section 27-9) is an important concept (and one of great practical use). The idea is that the radius of curvature of an ion in a magnetic field is proportional to its mass. Therefore, you can *measure* masses of ions by measuring the radii of the paths they traverse in a magnetic field! Motors we will see more about later when we talk about induction.

How do you do an integral with $d\vec{l} \times \hat{r}$ in it? What does it mean to have an integral of a cross-product? How do you choose $d\vec{l}$? Will we have to calculate these integrals? When do you integrate over angles? How do you apply Biot-Savart Law to non-straight lines of charge?

I think $d\vec{l} \times \hat{r}$ is not really as scary as it looks. It's just like any other vector cross-product, except that one of the vectors in it is an infinitesimal length element. This $d\vec{l}$ is just a little length vector along the wire pointing in the direction of the current. $\hat{r}$ is just the unit vector pointing from where $d\vec{l}$ is to the point where you're evaluating the magnetic field. The resulting contribution to the integral is then a vector, and the sum you do when you integrate is a vector sum. This vector sum sounds complicated, but in many practical cases, it's not so bad: often, each little vector piece in the integral $d\vec{l} \times \hat{r}$ has the *same* direction, and in this case the sum is just the sum of the magnitudes $|d\vec{l} \times \hat{r}|$, in the direction of any one of them (for examples, see today's handouts.)

The integrals you often get when applying the Biot-Savart formula over a finite length, however, sometimes *are* scary (or at least ugly). Often you have to change variables to be integrating over an angle, or something like that. See the handouts from today for examples. I think it's unlikely you will be asked to do such an integral on a test, but you should follow these examples and understand the ideas.

If the line is not straight, it's really the same idea. Sometimes simple circular paths can make the integral relatively easy, but funny wiggly paths are hard and may need to be done numerically.

How do you choose an Ampèrian loop? How many different shapes can you choose?

Just as Gauss' Law is true for any surface, Ampère's Law is true for any loop. But some loops will give you an easier time than others. As for Gauss' Law, typically you choose loops with the same symmetry as the current distribution. For instance, for a cylindrical wire, choose a concentric circular loop.

Is there a more formal way to evaluate the cross-product, such as with a determinant?

Yes, you can use the determinant method. This should work, but often it's not particularly convenient.

In the last Biot-Savart problem on CyberTutor, where does the $d\vec{l}$ go? What happens to it in the final answer?

I think $d\vec{l}$ should be in the final answer. In fact, units aren't even correct in the given answer. The formula given for $\vec{B}$ is in terms of an infinitesimal length $d\vec{l}$, so the LHS should be an infinitesimal contribution $d\vec{B}$. Please make comments to the CyberTutor people so they can fix this.

In the hexagon practice problem, how did you go from $B = \frac{\mu_0 I}{2\pi s\sqrt{3}/2}\left(\frac{s}{(s^2+4s^2 3/4)^{1/2}}\right)$ to $B = \frac{\mu_0 I}{2\pi\sqrt{3}s}$?

I just waved the Magic Algebra Wand. See the posted handout for a few more steps written out.

In the Ampère example in class, how come $|\vec{B}|$ is constant over the loop?

It's constant by symmetry. The $\vec{B}$ field's magnitude is the same everywhere a constant distance from the wire, so it's constant on a circle. By the RHR, the direction of the magnetic field generated by the wire is in a circle around the wire (thumb in direction of current, magnetic field curls around with fingers). So at any point on this circular loop, $\vec{B}$ and $d\vec{l}$ are tangent to the circle, and so parallel to each other. So $\oint \vec{B}\cdot d\vec{l} = \oint B dl = B\oint dl$.

Should you always relate current to current density when doing Ampère's Law problems, like the example in class today?

No, you don't always have to. Sometimes you already know the total current flowing through the loop.

What was that graph you drew for the Ampère's Law problem at the end of class?

That was a plot of B vs r. For $r < R$, the magnetic field grows linearly with r. For $r > R$, it falls off as $1/r$. See Figure 28-9 in your text.

Can you give an example of an Ampèrian loop where $\vec{B} \perp d\vec{l}$, or $\vec{B} = 0$?

An example would be the solenoid. Here the Ampèrian loop chosen is a rectangle with one side inside the solenoid and one side at infinity. $\vec{B} = 0$ along the side at infinity (so that part disappears from the integral.) On the sides of the loop that are perpendicular to the solenoid's length, and inside the solenoid, the $\vec{B}$ field is $\perp$ to the $d\vec{l}$ of the loop, so $\vec{B} \perp d\vec{l} = 0$. So the only part that counts is the part of the loop parallel to the solenoid. See text section 28-5.

Can you give an example where $I_{\text{encl}} = 0$?

Your pset 7, problem 5. Remember that currents in opposite directions have opposite signs.

Why is $\vec{B}$ not zero inside a solenoid, since you can draw an Ampèrian loop inside with no enclosed current?

The integral $\oint \vec{B} \cdot d\vec{l}$ is zero over a concentric loop inside the solenoid, no matter what $\vec{B}$ is. In fact each element $\vec{B} \cdot d\vec{l}$ in the integral is zero because $\vec{B} \perp d\vec{l}$ ($\vec{B}$ is along the axis of the solenoid).

Can you explain solenoids?

These are multiple loops of current; you can find the field from Ampère's Law (see above, also section 28-5 in text). The field inside is parallel to the axis of the solenoid, and constant everywhere in the solenoid and goes to zero outside (in the approximation of an infinite solenoid. In real life this approximation tends to be quite good, except near the ends of the solenoid).

Can you give us some hints for the pset?

- Problem 1: Think vectorially for this one. Remember that it's the component of the velocity perpendicular to $\vec{B}$ that matters for motion due to $\vec{B}$. On the other hand, the charge wants to accelerate *parallel* to the electric field.

- Problem 2: What is the magnitude of magnetic force if the particle has zero velocity?

- Problem 3: Remember that the particle will accelerate uniformly in an electric field (use 1-D acceleration formulae from 8.01x), and will execute circular motion (with known radius) in a magnetic field. Also remember that a constant magnetic field does not change magnitude of velocity.

- Problem 4: Biot-Savart Law howto should help. Note that you can skip step 2 and just use results from problems 36 and 37.

- Problem 5: Ampère's Law howto should help. Remember currents traveling in opposite directions have opposite signs. Note that the outer current is in a *shell*, and there's no current in between the inner and outer conductors.

Tidbits

Although electric charges exist, as far as we know, exactly analogous magnetic charges (magnetic monopoles) do not. However there's no known reason why they *should not* exist, and in fact, some Grand Unified Theories of particle physics predict that they should exist! They might actually exist, but just be very rare.

Just for your interest, here's some information about the search for magnetic monopoles: `http://hep.bu.edu/~macro/about.html`

Monopoles have inspired such musical/literary efforts as:

`http://www.haverford.edu/physics-astro/songs/monopoles.htm`

(To the tune of "Rock of Ages")
As the day requires the night,
As the left requires the right,

So are north and south entwined.
Then be sure to bear in mind–
As you strive for physics goals–
No magnetic monopoles!
– Marian McKenzie

`http://www.cithep.caltech.edu/macro/songs/glashow.html`

We must pity the student in his deep dark hole
Whose thesis depends on that one monopole
– Sheldon Glashow