

# Solutions to Quiz 3, Physics 1b (Levine)

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## Answers

**Version A:** 1-b 2-d 3-b 4-b 5-d 6-c 7-a 8-a

**Version B:** 1-a 2-b 3-b 4-d 5-d 6-c 7-a 8-b

**Version C:** 1-c 2-a 3-b 4-b 5-d 6-d 7-b 8-a

## Having some difficulty with this class?

Don't forget - my office hours are Tuesday and Wednesday from 2–3 PM in the Physics Tutorial Center. If you can't make those times, I would be happy to meet with you by appointment!

## Problem A1/B2/C3

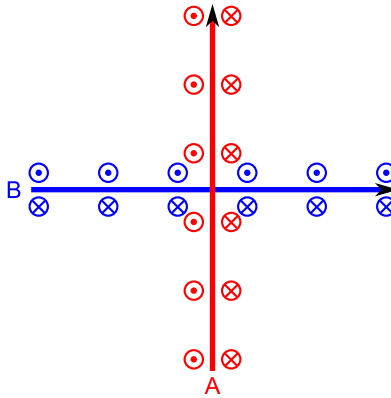
First let's list what we know about this setup: The two isotopes are both singly ionized, so they both have the same charge. We also know that the two isotopes have the same velocity, and travel in the same magnetic field. Now, let's use the equation for the motion of a charged particle in a magnetic field:

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

Since mass and radius are directly proportional, we can say that  $\frac{m_X}{m_Y} = \frac{r_X}{r_Y} = 0.96$  (*choice b*).

**Note:** you can also solve this problem using the equation for charge-to-mass ratio, from the section on mass spectrometers. It's the same equation as (1), just rearranged.

## Problem A2/B5/C6



Look at the diagram above. Each wire has a current flowing through it. This means that each wire will generate a magnetic field, and each wire will also be acted upon by the magnetic field of the other wire. We will use the equation for (magnetic) force on a current-carrying wire:

$$\vec{F} = I\vec{\ell} \times \vec{B} \quad (2)$$

Since current flows uniformly through our wires, the direction of the magnetic field is the main thing that determines the direction of the force acting on each wire. In the upper half of wire A, the magnetic field from wire B points out of the page ( $\odot$ ), so the force on that part will point to the right (East). On the bottom half of wire A, the magnetic field from wire B points into the page ( $\otimes$ ), so the force will be to the left (West). Thus, the net force on wire A due to the magnetic field of wire B is zero. The same argument applies to the force on wire B due to the magnetic field of wire A: the right side of wire B will experience a force pointing up (North), and the left half will experience a force pointing down (South). Thus, even though each wire does exert forces on the other, those forces balance out to zero (*choice d*).

## Problem A3/B3/C4

We know that the torque exerted on a current loop in a magnetic field is given by:

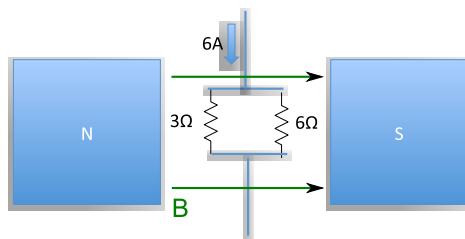
$$\tau = I\vec{A} \times \vec{B} \quad (3)$$

where  $\vec{A}$  is a vector corresponding to the area and direction of the current loop. The torque is a maximum when  $\vec{A}$  and  $\vec{B}$  are exactly perpendicular to each other:

$$\tau_{max} = IAB$$

Knowing  $\tau_{max}$ ,  $A$  and  $B$ , we can easily say  $I = 100$  A. But we must also remember that this coil of wire has 220 turns. That 100 A current represents the contributions of 220 loops of the wire. Thus, the current through only one turn of the wire is  $100 \text{ A} \div 220 = 0.45 \text{ A}$  (*choice b*).

### Problem A4/B8/C7



Like many problems in physics, this one has a longer way and a shorter way. I'll cover both. No matter which way we choose to do the problem, the place to begin is equation (2), which describes the magnetic force on a current-carrying wire.

The longer way is to find the force on each wire separately, and add them together to get the total force. Using what we know about resistors in parallel, you will find that  $I_{3\Omega} = 4$  A and  $I_{6\Omega} = 2$  A, so  $F_1 + F_2 = 1.2 \times 10^{-3}$  N. The direction (out of the page,  $\odot$ ) is found using the right hand rule.

The shorter way is to realize that even though the 6 A current splits between two resistors, there is still a current of 6 A flowing through a length of 2 cm, so no matter how you split it up, the sum of the forces on each wire is equal to  $(6 \text{ A}) \cdot (0.02 \text{ m}) \cdot (0.01 \text{ T}) = 1.2 \times 10^{-3}$  N, with the direction  $\odot$  again determined using the right hand rule (*choice b*).

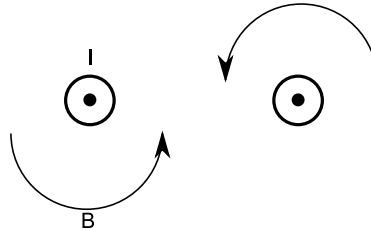
### Problem A5/B4/C5

This problem requires a simple application of the Lorentz Force Law. In its full form, this law says:

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B} \quad (4)$$

The Earth doesn't really have an electric field, so the first term is zero here. Next, we need to know which way the Earth's magnetic field points. Recall that the Earth's geographic "north pole" is a magnetic south pole, and vice versa. That means that on the Earth's surface, the magnetic field lines come out of Antarctica, and move North toward the arctic circle. We can now find the direction of the force on our electron. First off: down (velocity)  $\times$  North (B-field) = East. But don't forget that this particle is an electron, and  $q_e$  is negative, so the actual force vector points West (*choice d*).

## Problem A6/B6/C1



Let's begin with the equation for the magnitude of a magnetic field, at some distance  $r$  from an infinite wire. This result can be derived using either Ampère's Law or the Biot-Savart Law:

$$B = \frac{\mu_0 I}{2\pi r} \quad (5)$$

This equation tells us the magnitudes of the magnetic fields from each wire; now we need their directions. Using the right hand rule, we see that in between the two wires, the magnetic field from one wire points in the opposite direction of the magnetic field from the other wire, as shown above. If we subtract one magnitude from the other, we get a total magnitude of  $5 \times 10^{-6} \text{ T}$  (*choice c*).

## Problem A7/B1/C8

The magnitude of the magnetic field inside a solenoid is given by:

$$B = \mu_0 \frac{N}{\ell} I \quad (6)$$

Our solenoid is stretched from a length of 12 cm to 30 cm, that is to say  $\ell \rightarrow \frac{5}{2}\ell$ , so based on equation (6) we can expect  $B \rightarrow \frac{2}{5}B$ . That means that after stretching,  $B = 1.6 \text{ T}$  (*choice a*).

## Problem A8/B7/C2

This problem requires us to know something about magnetic field lines. Magnetic field lines never go out to infinity, the way electric field lines do. Rather, magnetic field lines always loop around to come back to where they started from (in this case, the current loop at the center of the sphere). That fact has important consequences for this problem. First, some magnetic field lines will be entirely contained within the metal sphere. They will loop around back to where they started without ever passing through the surface of the sphere. This means they do not contribute to the magnetic flux through the surface of the sphere. Second, any magnetic field line that is big enough to penetrate out of the sphere will have to come back into the sphere to close itself up into a loop.

If a field line goes out of the sphere and comes back in somewhere else, its net contribution to the flux is also zero. Therefore, the total magnetic flux through the sphere is zero (*choice a*).

(In my illustration below, the current loop is in magenta, the field lines are in green, and the sphere is in red).

