21-2Q
One of the most important facts that you can remember for this question is that the magnetic force is always perpendicular to the field as well as the velocity.

a) What direction can we place the field such that it is perpendicular to both of the force vectors? The field must be along the x-axis, either in the positive or negative direction.

b) The velocity vectors must be perpendicular to the resulting force. For electron #1, this means that the velocity vector is in the x-y plane (since the force vector is in the x direction). Electron #2’s velocity vector must be in the x-z plane. (Note that these velocity vectors do not have to be perpendicular to the field, just the forces.)

21-2P
In this situation, we have the magnetic field pointing into the page and three particle are fired into the magnetic field from below. Particle #2 must be neutral as it doesn’t seem to feel any force- it’s path is unchanged. What are the signs on the other two particles? To answer this we’ll want to use the right hand rule that related the velocity vector, magnetic field, and charge to the force. For particle #1 we see that the force is to the left as it enters the region. The velocity vector is up, the field is into the page. If we say that the particle is positive, then the force is to the left, as we want. For particle #3, the field is into the page, the velocity vector is up (at the start of the path). If we try making it a positive charge, then the force would be to the left, which isn’t what’s going on. Since it curves to the right, we know the force is the other way, meaning it is a negatively charged particle. So, which has the greater charge magnitude? It must be #3, if both have the same mass, speed and magnetic field, it must be the difference in charge which causes the differences in the paths. Path #3 is much tighter (smaller radius), this means that this particle is experiencing a greater force, thus #3 has a greater charge magnitude.

21-12P
By “levitate”, we mean the net force is equal to zero. If this is the case, then the wire will not fall down, it will remain wherever we place it.

Here, the only forces acting on the wire are gravity and magnetic force.

\[ F_g = mg = (2 \times 10^{-3} \text{ kg}) (9.8 \text{ N/kg}) \]

The magnetic force is given by equation 21-5, with \( \theta = 90^\circ \). Why? We’re looking for the weakest field that we need to levitate the wire. If we place the field at some other angle with respect to the current, then we would need a larger field to do the same job. The most efficient configuration is to have the field and current perpendicular.
\[ F_B = I/B = 8A(0.05m)B \]

We can now set the two forces equal to each other, and solve for the magnetic field. We find that this field must be at least 0.05T. The direction depends on the direction of the wire. (The current must be moving horizontally though to produce an upward magnetic force.)

**21-17P**

The simplest way to approach this problem is to use the ideas and tools of a dipole moment. This way we can compute the torque without having to identify the forces on every portion of the loop. In a way dipole moment calculations are a bit of bookkeeping elegance, but they also let us treat the loop as a whole rather than a collection of parts.

The dipole moment (magnetic) is defined to have the following magnitude:

\[ m = IAN \]

I is the current in the loop, A is the loop’s area, N is the number of turns. Here the number is simply 1, there is only one wire. The area can be found from the given radius. To get the current we need to use Ohm’s Law:

\[ I = \frac{V}{R} \]

So, the complete expression for the dipole moment (in terms of known quantities) is:

\[ m = \frac{V}{R} r^2 \]

which equals 11.3 Am².

To find the torque we can use the relationship between torque, dipole moment, and field:

\[ \tau = mB \sin \theta \]

The angle is once again the angle between the two vectors. Here this will be 90° as the dipole moment either points in or out of the page. So, with the given field, we find that the torque will be 4.5 Nm.

**21-24P**

This system is essentially the mass spectrometer shown in example 7. Using a potential difference, we accelerate a charged particle and then send it in a magnetic field. When it is in this field, the particle experiences a force causing it’s path to bend in circular arc. The radius of this arc will be given by equation 21-10

\[ r = \frac{mv}{qB} \]
We know the mass, the charge and the applied field. The only obstacle in our way is the lithium’s speed. To get this we can use the idea of conservation of energy. The particle starts with zero kinetic energy, and all potential energy, then at the end this potential energy has been converted to kinetic.

\[ U_i + 0 = 0 + K_f \]

The potential energy can be related to the potential using the ideas of our last unit.

\[ U_i = qV_i \]

where \( V_i \) is the initial potential. (500V). The speed is therefore:

\[ v = \sqrt{\frac{2qV}{m}} \]

The lithium is therefore moving at 1.17 x 10\(^5\) m/s (remember, the ion is singly charged, so q= 1.6 x 10\(^{-19}\) C)

The radius of the path is then 2.1 cm.