Magnetism

1. A -6.5 mC charged particle of mass 58 grams is shot into a uniform magnetic field given by $\boldsymbol{B} = \langle 6.2, 1.8, -5.9 \rangle$ mT. Its initial velocity is given by $\boldsymbol{v}_0 = \langle 3.2, -4.5, 7.2 \rangle$ m/s.
   a. How fast is the particle traveling at time zero?
   b. How fast is it traveling after 6.3 s? *Hint: This is an easy question. Explain your answer FULLY* !
   c. How strong is the magnetic field?
   d. As best as you can, draw each vector on a set of coordinate axes (in 3-D). Place the tail of each vector at the origin. To give your picture some perspective, put an $\times$ in the *x-y* plane to mark the spot directly above or below the tip of each of vector. For each vector use a dotted line connect the tip of the vector to the $\times$.
   e. Find the magnetic force on the particle. Find its magnitude as well.
   f. Compute $\boldsymbol{F} \cdot \boldsymbol{v}_0$ and $\boldsymbol{F} \cdot \boldsymbol{B}$ (without messing with angles). This should serve as a check on your answer for $\boldsymbol{F}$. Explain why.
   g. Find the particle's radius of curvature.

2. Compare/contrast a generator and motor in terms of energy, torque, current, and magnetic field. Explain briefly IN YOUR OWN WORDS how each works.

3. Schmedrick's little brother Poindexter says to Schmed, "Hey big bro, do moving charges feel a magnetic force, or do they produce their own magnetic fields? If they do both, which way do they push themselves?" What should Schmed say to clear up his brother's confusion?

4. A uniform magnetic field of 0.13 T is pointing straight down. A circular wire loop of radius 89 cm and internal resistance of 0.25 Ω is placed in the field, making an angle of 10º with the horizontal.
   a. What is the magnetic flux through the loop?
   b. If the field strength is increased steadily to 0.45 T over a 3 s time interval, find the strength and direction of the induced current.

5. Every electron is like a magnet for two reasons.
   a. Using the analogy as discussed in class, what are these reasons?
   b. Explain why most atoms are barely magnetic at all, despite the fact that the electrons that comprise them have magnetic properties.
   c. Explain why the magnetic field around most materials is about zero, even materials that are comprised of "atomic magnetic."

Solution steps/hints:
1. a. Speed is simply the magnitude of velocity; use the 3D version of the distance formula (sort of an extension of the Pythag. theorem).
b. No computation necessary! Keep in mind that the magnetic force on a moving, charged particle is always produces a certain type of force that begins with a C. Think about what effect this sort of force has on the magnitude and direction of a velocity vector.
c. See hint for part (a).
d. There are different ways to draw a 3D coordinate system. You might draw the corner of a room. It matters how you label your axes. In terms of unit vectors, $\boldsymbol{i} \times \boldsymbol{j} = \boldsymbol{k}$, in order to be a "right-hand system."
e. Use the determinant formula for cross products. When you do $q\boldsymbol{v} \times \boldsymbol{B}$, you can put the components of $q\boldsymbol{v}$ on the second line or, to make things simpler, do $q(\boldsymbol{v} \times \boldsymbol{B})$. That is, do the determinant to get $\boldsymbol{v} \times \boldsymbol{B}$, then distribute the

scalar q to the components of the cross product.
f. Use the definition of the dot product. For the explanation, here are two hints: recall an equation that relates the dot of two vectors and the angle between them; think about the right-hand rule for cross products and the direction that the cross product vector points compared to the original two.
g. There's a formula for this in the slides that you should be able to derive on a quiz. It comes about by equating centripetal force and magnetic force.

3. It might be helpful to think about Newton's laws here.

4. a. Use the definition of magnetic flux, keeping in mind the orientation of the loop matters. Remember, the angle in that formula is the angle between the magnetic field vector and the area vector. The area vector points perpendicular to the loop!
b. Use Faraday's law to find the induced emf. The change in flux is simply the area times the cosine times the change in field strength, since the area and angle are not changing. You can get the induced current with the induced emf (which is a voltage) and the internal resistance.