PHYS 1120 Discussion 6:
Capacitors, Lorentz force

Problems

As usual, there is no room on this sheet. Use scratch paper.

1. This question is a slightly modified version of problem 18.63 in your textbook.

   An electric eel (it's not really an eel, but it *is* electric) stuns its prey and defends itself from threats using electric shocks. It produces its shocks by specialized structures called *electrocytes*. A single electrocyte can maintain a voltage of 150 mV over a current of 1.0 A for a duration of 2.0 ms. It can produce 300 shocks in 1 second before it is depleted. An adult fish may contain 4000 electrocytes in its electric organ.

   A. What is the average power a single electrocyte produces in a single shock?

   B. How much energy does a single electrocyte produce in a single shock?

   C. If all electrocytes fire together in a shock, how much energy is released in that shock?

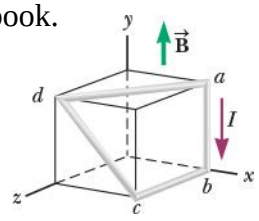
   D. If all the electrocytes are connected in parallel, what is the voltage and current in a single shock?

   E. If all the electrocytes are connected in series, what is the voltage and current in a single shock?

   F. Shocks from electric eels have been measured at up to 850 volts. Knowing this, are the electrocytes connected in series or in parallel?

   Yes, in case you were wondering, electrocytes act as capacitors.

2. This question is modified not at all from problem 19.33 in your textbook.

   In the Figure, the cube is 40.0 cm on each edge. Four straight segments of wire—*ab*, *bc*, *cd*, and *da*—form a closed loop that carries a current I = 5.00 A in the direction shown. A uniform magnetic field **B** of magnitude 0.020 T is in the positive *y*-direction (upward). Determine the magnitude and direction of the magnetic force on each segment.

3. Continuing my stealing problems from the book, here is problem 19.35, slightly modified.

   A current of 17.0 mA is maintained in a single circular loop with a circumference of 2.00 m. A magnetic field of 0.800 T is directed parallel to the plane of the loop.

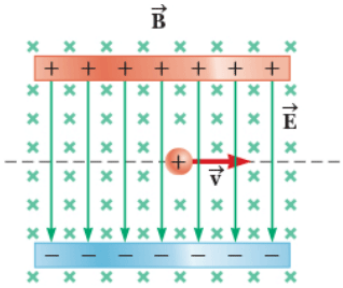
   A. What is the area of the loop?

   B. What is the magnitude of the magnetic moment of the loop?

   C. What is the angle between the magnetic moment of the loop and the magnetic field?

D. What is the magnitude of the torque the magnetic field applies to the loop?

4. Uniform magnetic and electric fields oriented perpendicular to each other create a *velocity selector*. Follow along to understand why it is given that name.



In the diagram to the right, a magnetic field $\vec{B}$ (represented by ×) is directed into the page, and an electric field $\vec{E}$ (arrows) is directed downward. Electric charges enter the device from the left, initially moving to the right.

A. What is the magnitude and direction of the electric force exerted on a charge q moving to the right at speed v in this device?

B. What is the magnitude and direction of the magnetic force exerted on a charge q moving to the right at speed v in this device?

C. What is the formula for the total force on the charge from both fields?

D. What is the condition for the net force on the charged particle to be zero?

E. What happens to a charged particle entering the device at a speed slower than v? At a speed faster than v?

5. The magnetic force on a charged particle is always perpendicular to its velocity, so if no other force acts on a charged particle, its path will be a circle or a helix. Let's look at the characteristics of this motion.

Suppose a charged particle with mass m and charge q travels at speed v perpendicular to a magnetic field with magnitude B.

A. What is the formula for the magnitude of the force exerted on the charge by the magnetic field?

B. The magnitude of the net force on a particle of mass m traveling at speed v in a circular path of radius r is mv^2/r. If this net force is the magnetic force on the particle, what is the radius of its path?

C. Consider how the radius of the path depends on the quantities m, q, v, and B. Verify that the units work, and that the dependencies make sense.

D. What is the period (time to complete one circuit) T of the path? Recall that $v = 2\pi r/T$.

E. Consider how the depends on the quantities m, q, v, and B. Verify that the units work, and that the dependencies make sense.

F. Suppose a charged particle circling in a magnetic field gradually slows down because of a drag force. How will the radius and period of its path change with time?