I have an electric field of $10\, V/m$ pointing down and to the left, an angle of 225 degrees from the positive x axis. A charge $q$ is moving through it and a magnetic field of 2T. The magnetic field is pointing into the page. What is the velocity vector?

I start with the definition of forces from an electric field and a magnetic field.

\[ F_E = qE \]
\[ F_B = qvB \]
\[ qE = qvB \]
\[ v = \frac{E}{B} = \frac{10\, V}{2T} = 5\, m/s \]

If it is a proton, the electric field will push it in the direction of 225 degrees. To counter it, the magnetic field must produce a force at 45 degrees. Using the right-hand rule, we find that the velocity must be at 315 degrees. It doesn’t matter what the particle is, it must have a velocity of $5\, m/s$ at 315 degrees. It can have any other velocity into or out of the page in addition to the one defined in the x and y directions.

He then asked what we could do to point the velocity in the opposite direction. We can invert either the electric field or the magnetic field. Pointing the velocity in the opposite direction will invert the magnetic force. We need to invert magnetic field to put the force back or invert the electric field to cancel the new magnetic force.

We now have a particle of mass $m = 4 \times 10^{-12} kg$ and charge $q = -8 \times 10^{-6} C$ circulating in a magnetic field with a velocity of $v = 5 \times 10^4 m/s$ counter-clockwise. The radius of the motion is .4m. What is the magnitude and direction of the magnetic field? What is the frequency of circulation?

I start with the definition of the magnetic force and the centripetal force. \[ F = m\frac{v^2}{r} \]
\[ qvB = m\frac{v^2}{r} \]
\[ B = \frac{mv}{qr} = \frac{4 \times 10^{-12} kg \times 5 \times 10^4 m}{8 \times 10^{-6} C \times .4 m} \]
\[ B = .0625 T \]

Velocity cross magnetic field needs to point out of the circle. The negative of the charge will make that force point into the circle. To get that to happen with the right-hand rule, we need to get the magnetic field pointing out of the paper.

I can show that the frequency in radians per second is velocity over radius and frequency in cycles per second is velocity over circumference.

\[ f = \frac{v}{2\pi r} = \frac{5 \times 10^4 m}{2\pi \times .4 m} = 19894 Hz \]
\[ \omega = \frac{v}{r} = \frac{5 \times 10^4 m}{.4 m} = 125000 \frac{rad}{s} \]

I did talk about how we ended up with AC in our power lines. It comes down to distribution. To distribute electricity efficiently, you need high potentials. To get AC to high potentials and back down again is easy to do with transformers. Transformers reject DC current. We can do that now with solid state electronics, but not when the electrical grid was first made. So we used AC current. But the problem here with constantly changing magnetic fields, we leak energy off our power lines and into the earth making AC less efficient that DC to distribute with current technology. Also all electronic devices require DC inside them.
meaning we are losing more energy to the transformers at every point we do this. Meaning things would be more efficient if everything switched to DC today.