Answer on Question 66512, Physics, Electromagnetism

Question:

You had so much fun making a capacitor that you decide to make an electric motor. You have copper wire (resistivity, $\rho = 1.70 \cdot 10^{-8}\ \Omega \cdot m$) with a cross-sectional area of $2.00 \cdot 10^{-7}\ m^2$, and using $1.00\ m$ of this wire you make a rectangular coil with sides having lengths of $1.50\ cm$ and $1.00\ cm$. Your ceramic magnet has a magnetic field of $0.30\ T$ in which you will immerse this coil. You will power it with a standard D-cell battery, so the potential difference is $1.50\ V$. Determine the maximum torque on your electric motor. (There are a lot of little steps in this problem, including geometry and equations from prior chapters.)

Solution:

Let's first find the resistance of the wire:

$$R = \rho \frac{l}{A},$$

here, R is the resistance of the wire, ρ is the resistivity of the wire, l is the length of the wire and A is the cross-sectional area of the wire.

Then, we can calculate the resistance of the wire:

$$R = \rho \frac{l}{A} = 1.70 \cdot 10^{-8}\ \Omega \cdot m \cdot \frac{1.00\ m}{2.00 \cdot 10^{-7}\ m^2} = 0.085\ \Omega.$$

We can find the current through the wire from the Ohm's law:

$$I = \frac{V}{R},$$

here, I is the current through the wire, V is the potential difference across the wire and R is the resistance of the wire.

So, we get:

$$I = \frac{V}{R} = \frac{1.50\ V}{0.085\ \Omega} = 17.65\ A.$$

We can find the torque on the rectangular coil from the formula:

$$\tau = NIabBsin\theta,$$

here, N is the number of the loops of the wire (using $1.00\ m$ of the copper wire we can make the rectangular coil of 20 loops; each loop has the sides length of $1.50\ cm$ and $1.00\ cm$, respectively), I is the current through the wire, a, b is the sides of the rectangular coil, B is the magnetic field, θ is the angle between the magnetic field and the normal to the plane of the coil.

The maximum torque on the rectangular coil when $\theta = 90^{\circ}$, so that the coil is in the plane of the magnetic field:

$$\tau_{max} = NIabBsin90^{\circ} = NIabB = 20 \cdot 17.65\ A \cdot 0.015\ m \cdot 0.01\ m \cdot 0.3\ T = \\ = 0.016\ N \cdot m.$$

Answer:

$\tau_{max} = 0.016\ N \cdot m.$