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PH 102 / LeClair Summer II 2010

Quiz 6: Solution

1. A technician wearing a conducting bracelet enclosing an area $0.005\,\mathrm{m}^2$ places her hand in a solenoid whose magnetic field is $5.0\,\mathrm{T}$ directed perpendicular to the plane of the bracelet. The resistance around the circumference of the bracelet is $0.02\,\Omega$. A power failure causes the field to drop to $1.50\,\mathrm{T}$ in a time of $0.02\,\mathrm{s}$. Find the current in the bracelet.

Solution: Once the power goes out, the magnetic field drops by an amount $\Delta B = 5 - 1.5 = 3.5\,\mathrm{T}$ in a time $\Delta t - 0.020\,\mathrm{s}$. This means, given the fixed area of the bracelet, that the magnetic flux is changing through the bracelet:

$$\frac{\Delta\Phi_B}{\Delta t} = A\frac{\Delta B}{\Delta t} = \left(0.005\,\mathrm{m}^2\right)\left(\frac{3.5\,\mathrm{T}}{0.020\,\mathrm{s}}\right) \approx 0.875\,\mathrm{Tm}^2/\mathrm{s} = 0.875\,\mathrm{V}$$

The change in flux leads to an induced voltage across the bracelet. Since the bracelet has a single loop of wire, the induced voltage is just

$$\Delta V = -\frac{\Delta\Phi_B}{\Delta t} = -0.875\,\mathrm{V}$$

The minus sign here is not important, since the ultimate direction of current flow is not important. Given the bracelet's resistance, we can find the induced current:

$$I = \frac{\Delta V}{R} \approx 43.75\,\mathrm{A}$$

Finally, we can find the power from the current and voltage, or either one and the resistance:

$$\mathscr{P} = I^2 R = I\Delta V = \frac{\Delta V^2}{R} \approx 38.28\,\mathrm{W}$$

This is an unreasonably large amount of power to be dumped into a bracelet on one's wrist, leading to an unreasonable generation of heat ... for this reason, you will not see personnel working regularly with MRI machines wearing much jewelry. At least, they shouldn't be.

2. During an in-class demonstration, we dropped a magnet and a non-magnet of equal weight and size through a conducting aluminum tube. The non-magnet fell through the tube at the expected rate, but the magnet took many times longer to fall out, due to eddy current braking. Is it possible to have a magnet strong enough (or a tube conductive enough, etc) that it would actually stop inside the tube? Explain.

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Solution: No. The eddy current braking comes from induced currents in the copper tube due to the falling magnet. The falling magnet represents a time-varying B field, which creates a time-varying flux through the copper tube. If the magnet actually stopped, there would be no eddy currents at all, and nothing to hold the magnet against gravity.

Once the magnet stops, the very force slowing it down ceases to exist. The flux in the tube is changing only because the magnet has some non-zero velocity. No emf, and therefore no eddy currents result from a stationary magnet giving a constant flux through the tube.

Putting it another way: the force is due to the relative velocity of the magnet and the charges in the copper. The magnetic force is $F = qvB$, where v is the *relative* velocity o f the tube and magnet. If $v = 0$, there is no force - so if the magnet could actually be stopped, the force holding it up would go to zero, and it would fall again! Clearly, the answer is no.