Lenz's Law & Inductance

Lecture 21

Physics 100
General Physics I

Monday, March 23rd, 2009

pp. 760–764 (4th ed.), pp. 736–739 (3rd ed.)

From Faraday's law of induction, we can predict the EMF and hence the current that flows in a circuit, associated with *any* agent of changing magnetic flux. For a moving circuit, we know that it is the magnetic force that causes charge to start moving, but for a stationary circuit with a moving magnetic field, we don't yet know the cause of the current flow. Faraday's law still applies, and in this case, we can get the direction of current flow from Lenz's law: "current will flow in a direction that sets up a magnetic field to oppose the change in flux".

pp. 788–794 (4th ed.), pp. 758–765 (3rd ed.)

For a solenoid, we can imagine sending a time-varying current through the wire wrapping the cylinder, $I(t)$. The magnetic field inside the solenoid will acquire some time dependence, and then there will be a change in magnetic flux through the wire loops of the solenoid. That time dependence will generate an EMF, and a current will flow in the wires due to this EMF, $I_E(t)$. The current will flow in a direction given by Lenz's law – if, for example, we start with no current in the wire, and then turn on I, then the induced current, $I_E(t)$ will flow in a direction to restore the zero magnetic flux we had before we turned on I, i.e. *opposite* I. If current I was flowing, and we suddenly turn off the power, then the induced current I_E will attempt to keep the magnetic flux as it was before we turned off I, so that I_E will flow in the direction I was flowing.

In the case of a solenoid, we can directly calculate the response to varying $I(t)$. In general, a change in $I(t)$ causes an EMF given by:

$$\mathcal{E} = -L\,\frac{dI(t)}{dt} \tag{21.1}$$

where L is called the "self-inductance", and has units of henries. We can use inductors in circuits.

Homework Due Wednesday, March 25th

Reading: Giancoli, pp. 760–764, 788–794 (4th ed.), pp. 736–739, 758–765 (3rd ed.).

Problems in brackets refer to the 3rd edition numbering.

Problem 21.1

Giancoli 29.12 [29.14]. Force and constant velocity motion for a circuit loop. For third edition, use $B = .650$ T, effective resistance $R = .280\,\Omega$, $v = 3.40$ m/s, and a loop height of $.350$ m.

Problem 21.2

Giancoli 29.9 [29.9]. Practice with Lenz's Law.

Problem 21.3

Giancoli 29.78. Finding the magnetic flux driving an RC circuit. A circular-shaped circuit of radius r containing a resistance R and capacitance C, is situated with its plane perpendicular to a spatially uniform magnetic field $\mathbf{B}$ directed into the page (see Figure 21.1). Starting at time $t = 0$, the voltage difference $V_{\mathsf{ba}} \equiv V_{\mathsf{b}} - V_{\mathsf{a}}$ across the capacitor plates is observed to increase with time t according to

$$V_{\mathsf{ba}} = V_0 \left(1 - e^{-t/\tau}\right), \tag{21.2}$$

where V_0 and τ are positive constants. Determine $\frac{dB}{dt}$, the rate at which the magnetic field magnitude changes with time. Is B becoming larger or smaller as time increases?

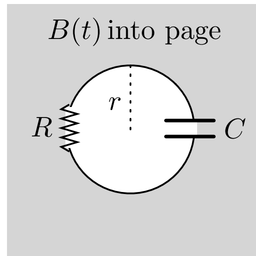

Figure 21.1: An RC circuit in a magnetic field.

Note: This problem is analogous to finding $\mathcal{E}$ (the EMF) in the following circuit:

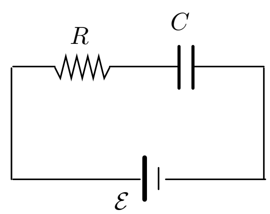

Figure 21.2: Finding $\mathcal{E}$ given R, C, with time-constant $\tau \equiv RC$.

and relating that to a flux change driven by a changing magnetic field magnitude.

***Problem 21.4**

Giancoli 29.73. A disguised "circuit".