PH202-1G
Spring 2014

Worksheet February 19

Lenz's law

Describe Lenz's law qualitatively. What information can be get from it?

Lenz's law describes the polarity (direction) of an induced emf, which is related to the direction of the current. Formally, the induced emf produces an induced current in a direction such that the induced magnetic field opposes the change in magnetic flux.

Describe the three steps necessary to determine the polarity of an induced emf.

1) Determine whether the magnetic flux is increasing or decreasing

2) Determine the direction the induced magnetic field must point to oppose the change in magnetic flux.

3) Determine the direction the current must flow to induce the appropriate magnetic field.

Electric generator

Describe the process by which an electric generator produces a current.

A coil of wire is rotated in a uniform magnetic field. The changing magnetic flux as the coil rotates produces an induced emf which generates a current.

Give a mathematical expression for the emf induced in an electric generator as a function of the angle between the magnetic field and the normal to the area of the loop.

This is just Faraday's law: $\text{emf} = -N\frac{\Delta\Phi_B}{\Delta t} = -NBA\frac{\Delta\cos\phi}{\Delta t}$

Give a mathematical expression for the emf induced in an electrical generator as a function of the angular speed.

$\omega = \frac{\Delta\phi}{\Delta t} = 2\pi f$

$\frac{\Delta\cos\phi}{\Delta t} = -\omega\sin\phi \Rightarrow \text{emf} = NBA\omega\sin\omega t = NBA\cdot 2\pi f\sin(2\pi f t)$

What kind of current is produced by this method of generating electricity? Why?

Alternating current. The magnetic flux increases and decreases as the rotation of the coil goes through a full cycle.

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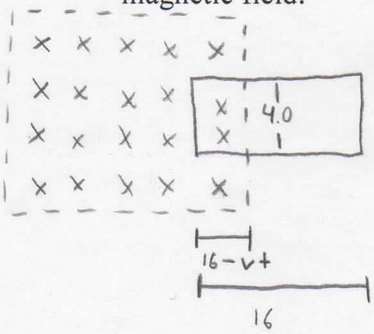
Problems

1. A rectangular loop of wire with a width of 4.0 cm and a length of 16 cm sits in a square region of uniform magnetic field. The magnetic field points into the page with a magnitude of 9 T. A force is applied to the shorter side of the wire such that it moves to the right with a constant speed of 0.73 m/s. Find the magnitude and direction of the induced emf when the loop a) is moving completely within the magnetic field and b) is moving out of the region containing the magnetic field.



a) While the loop is completely in the field, there is no change in flux and no induced emf

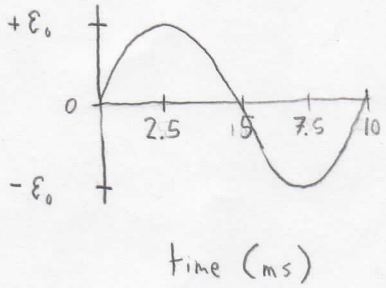
b) The area in the field at time t after the loop begins exiting the field is $4(16 - vt)$ (units of cm^2). The change in area is $\Delta A = [16 - vt_2 - (16 - vt_1)] \cdot 4$

$\Delta A = -4vt_2 + 4vt_1 = -4v\Delta t$

Since the area in the field is decreasing, the change in flux is out of the page. By Lenz's law, the induced emf must be clockwise to create a change in flux into the page to oppose the decrease in area.

Magnitude is $emf = -N\frac{\Delta \Phi_B}{\Delta t} = -NB\frac{\Delta A}{\Delta t} = -NB\frac{-4v\Delta t}{\Delta t} = 4NBv = 4\,cm\left(\frac{1\,m}{100\,cm}\right)(1)(9\,T)(0.73\,m \cdot s^{-1}) = 0.26\,V$

2. A circular loop of wire with a radius of 10 cm and an internal resistance of 0.030 Ω sits in a uniform magnetic field and is rotated by a mechanical force. At time t = 0, an ammeter attached to the loop of wire detects no current. The current increases to a maximum value of 21 A at 2.5 ms and then reaches zero again at 5.0 ms. What are the frequency and angular speed of the rotation and the magnitude of the uniform magnetic field?



Remember – one full cycle is zero, maximum, zero, minimum, zero.

One full cycle is 10 ms, so frequency is $f = \frac{1}{0.010\,s} = 100\,Hz$

Angular speed is $\omega = 2\pi f = 200\pi\ rad \cdot s^{-1}$

Magnitude of emf is $\mathcal{E}_0 = NBA\omega = NB\pi r^2\omega$ where $N = 1$ and $\mathcal{E}_0 = I_{max}R$

$$B = \frac{\mathcal{E}_0}{\pi r^2 \omega} = \frac{21\,A \cdot 0.030\,\Omega}{\pi(0.10\,m)^2(200\pi\,s^{-1})} = 0.032\,T$$