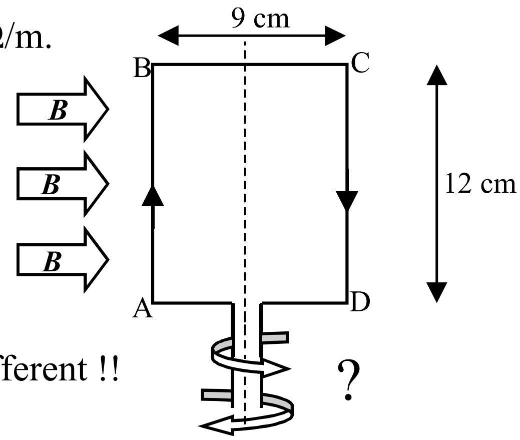
Week 6 Solutions

1. Turning the Loop, Generating the Current

a) This loop has 100 turns of wire with resistance 0.3 Ω/m. It is turned at a steady rate and dissipates energy with a peak power of 200 W. If the external magnetic field is constant at 0.02 T what is the frequency of revolution of the loop in cycles per second?



NOTE: Although the figure is the same as one from last week, the question being asked is completely different !!

$R_{\text{loop}} = 0.3\ \Omega/\text{m} \times 0.42\ \text{m/turn} \times 100\ \text{turns} = 12.6\ \Omega$

$P = I^2R = V^2/R$, so $\mathcal{E}_{\max} = \sqrt{P_{\max} R_{\text{loop}}} = 50.2\ \text{V}$

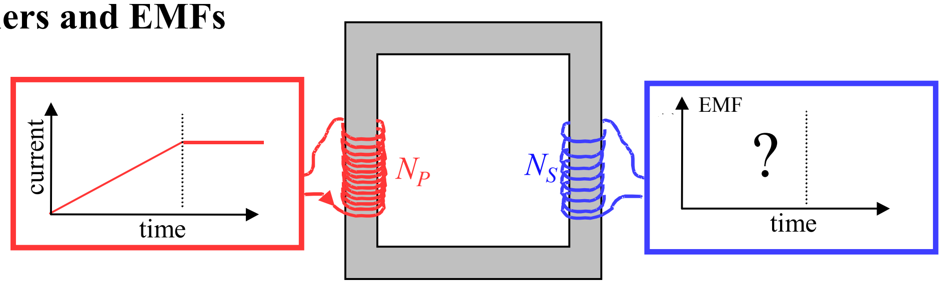
$\mathcal{E}_{\max} = NAB(2\pi f)$, so $f = \mathcal{E}_{\max} / (2\pi NAB) = 370/\text{sec}$

b) Does it matter which way the loop is turned? Discuss this with your partners. Which way should the loop turn in order for the current to flow in the direction shown at the time this image of the loop is taken? Express your answer by saying whether side AB should come out of the page or go into the page.

If the loop rotates the opposite direction, at any given moment the EMF has the opposite sign. At the instant shown, the induced flux points into the page, so the ***change*** of the external flux must point out. This means that the left side of the loop (AB) must be coming out of the page.

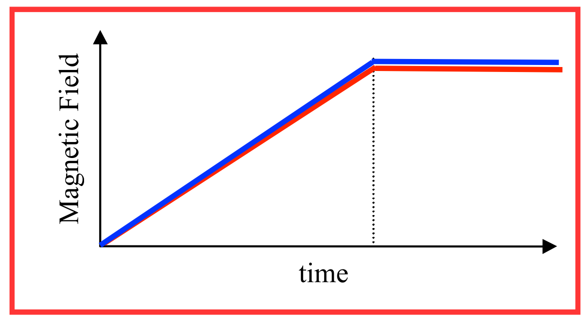
Week 6 Solutions

2: Transformers and EMFs



In the transformer above, the primary coils are connected to a box that produces a current following the red graph. Notice that as it turns on, the current increases at a constant rate until it reaches a fixed final value.

a) Let's look at this problem in stages. Draw a curve of the magnetic field inside the red (primary) coils versus time.



b) Now, on the same plot, draw the magnitude of the magnetic field through the blue (secondary) coils versus time. Use a different color pencil or pen and mark it. In what ways are they the same or different?

The magnetic field lines are trapped in the iron. Therefore, the magnetic field at the blue coil equals the field at the red coil. (The separation on the graph is solely for visibility.)

c) How would your curve look in part b) if the vertical axis were magnetic flux rather than magnetic field? Go ahead and draw this one too on the same plot. (Is it getting busy yet?)

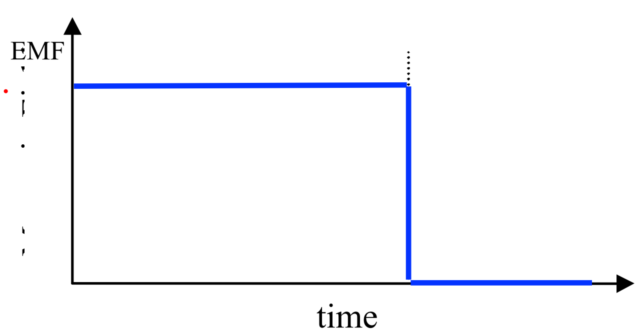
The blue magnetic flux curve looks the same as the magnetic field curve, except multiplied by $N_S A$. The red curve is multiplied by $N_P A$, so the ratio of the fluxes is N_S/N_P.

d) When the flux is constant through the secondary coils, what is the induced EMF in the coil?

If the flux isn't changing, there is no EMF.

e) Finally, make a plot of EMF in the secondary versus time.

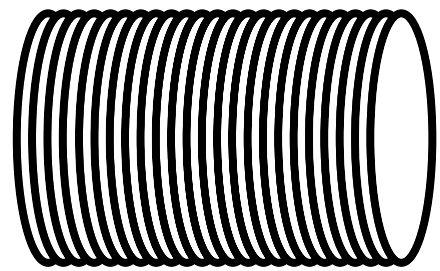
The EMF curve is proportional to the slope of the flux curve.



Week 6 Solutions

3. An Inductor

An inductor is made in the cylindrical shape shown. There are 1000 turns of wire. The radius of the coil is 1 cm, and its length is 10 cm.



a) What is the magnetic field strength inside the inductor if a current of 1 Amp is flowing? First, write a general equation, then calculate a value.

$B = \mu_0 (N/L) I = 0.0126$ T

b) What flux does the magnetic field from part a) generate through one turn of wire? Again, write a general equation, then calculate a value.

$\Phi = BA = B\pi r^2 = 3.96\times10^{-6}$ Wb

c) Look at the equation for self-inductance (page VI-2). What value of *L* does this inductor have?

$L = N\Phi/I = 3.96$ mH

d) If the current shown below (*i.e.*, it varies with time) flows through the inductor, sketch the EMF of the inductor on the plot on the right.