

**Problems:**

$$\underline{31.29}, \underline{31.7}, 31.21, 31.59, 31.30, 31.35, 31.61, 31.64 \tag{1}$$

Underlines are to be handed in. Do as many as you can.

**Magnetic Flux**

- Magnetic Flux

$$\Phi_B = \mathbf{B} \cdot \mathbf{A} = BA \cos(\theta) \tag{2}$$

In general  $\phi_B$  is an integral  $\int \mathbf{B} \cdot d\mathbf{A}$ .

- Gauss Law for magnetism

$$\oint \mathbf{B} \cdot d\mathbf{A} = 0 \tag{3}$$

In words the total magnetic flux through a closed surface is zero.

**Faradays Law - Overview**

- Changing magnetic flux produces electric fields / voltage  $\mathcal{E}$
- These electric fields sets up induced currents
  - The currents in the magnetic field experiences forces which try to stop the change in magnetic flux.
  - The induced currents produce magnetic fields which try to stop the change in magnetic flux.

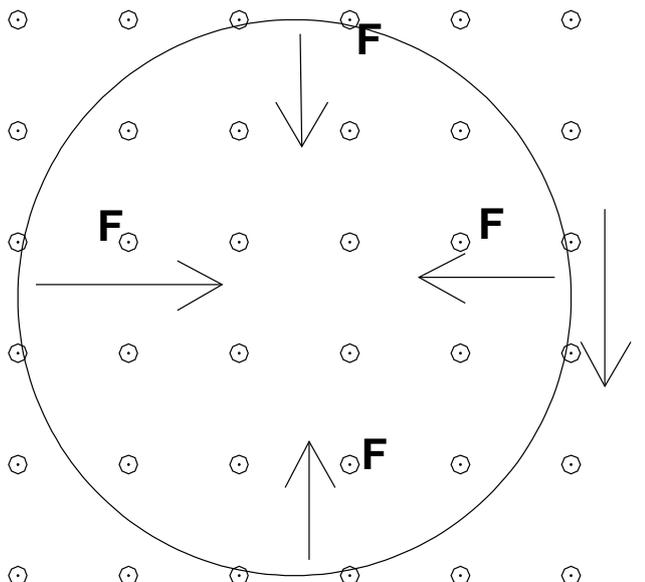
**Faraday's Law**

- Faradays law reads

$$\mathcal{E} = -N \frac{d\Phi_B}{dt} = -N \frac{d(BA \cos(\theta))}{dt} \tag{4}$$

where  $\mathcal{E}$  is the emf/voltage around the loop and N is the number of turns.

- To understand this equation look at the loop below with the magnetic field pointing out of the page and getting stronger.



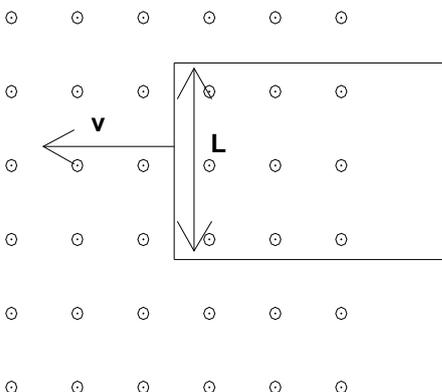
- Lets agree to choose the normal to the loop in the general direction of the magnetic field. (This is a choice – with this choice the magnetic flux is positive making life easier.) Then point your right hand thumb in the direction normal — out of the page in the example given.
- Calculate the change in magnetic flux. If the magnetic flux is increasing, flip the direction of your thumb. This is the meaning of the minus sign in Eq. (4). If the magnetic flux is decreasing ( $d\Phi_B/dt < 0$ ) leave your thumb in the same direction (since  $-d\Phi_B/dt > 0$ ) . In this case the magnetic field is getting stronger and therefore we reverse our thumb into the page.
  - \* Your fingers then curl in the direction of the resulting electric field. In the example given our fingers are curling clockwise.
  - \* Lenz's Law: The current always flows so that the magnetic field which the current produces (the induced field) opposes the change in flux. In this case the current produces a flux of magnetic field which points into the center of ring. This tends to counter-act the increasing magnetic field which increases the flux coming out of the ring.

**Calculating  $\frac{d\Phi_B}{dt}$  for a moving object or rotating**

- Suppose that I have a rectangular loop with side of length  $L$  entering a uniform magnetic field  $B$  with speed  $v$ . Then (with the conventions given above) the the magnetic flux is increasing. You shold be able to show that

$$\frac{d\Phi_B}{dt} = +BLv \tag{5}$$

Hint the area is  $A = Lx$  and  $dA/dt = L dx/dt$



- If a rectangular coil of wire is rotated at a constant rate in a (i.e.  $\theta = \omega t$ ) in a uniform field. The change in flux is

$$-\frac{d\Phi_B}{dt} = BA\omega \sin(\omega t) \tag{6}$$

see Fig. 31.22 in book.