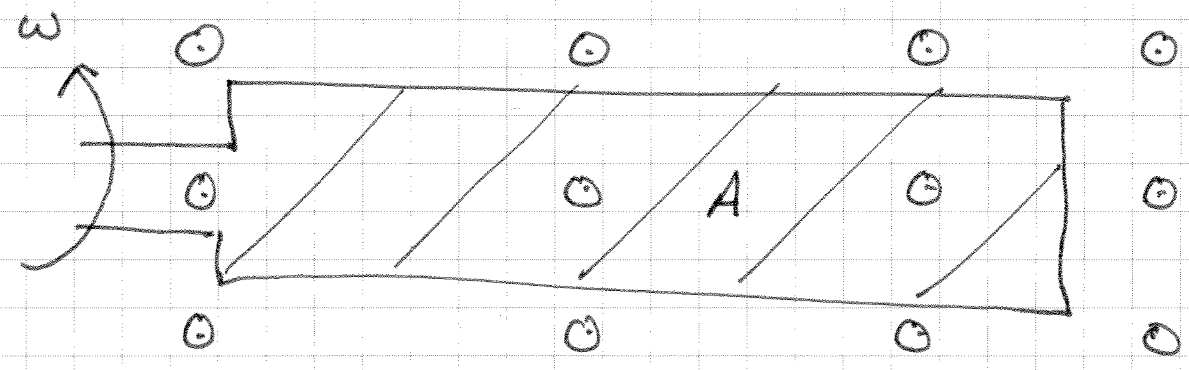
Electromotive Force III

Generators – Convert mechanical energy into electrical energy.



$$\Phi_m = N \vec{B} \cdot \hat{n} A$$

$$= NBA \cos \theta(t)$$

<u>Period</u> (T) - Time for one rotation

Frequency (f) - Rotations per second

$$f = \frac{1}{T}$$

$\Rightarrow$ Unit Hertz $1 Hz = 1 s^{-1}$

Angular Frequency (ω) - $\omega = 2\pi f$

If ω constant, $\theta(t) = \theta_0 + \omega t$

θ_0 = Angle between normal and field at $t = 0$.

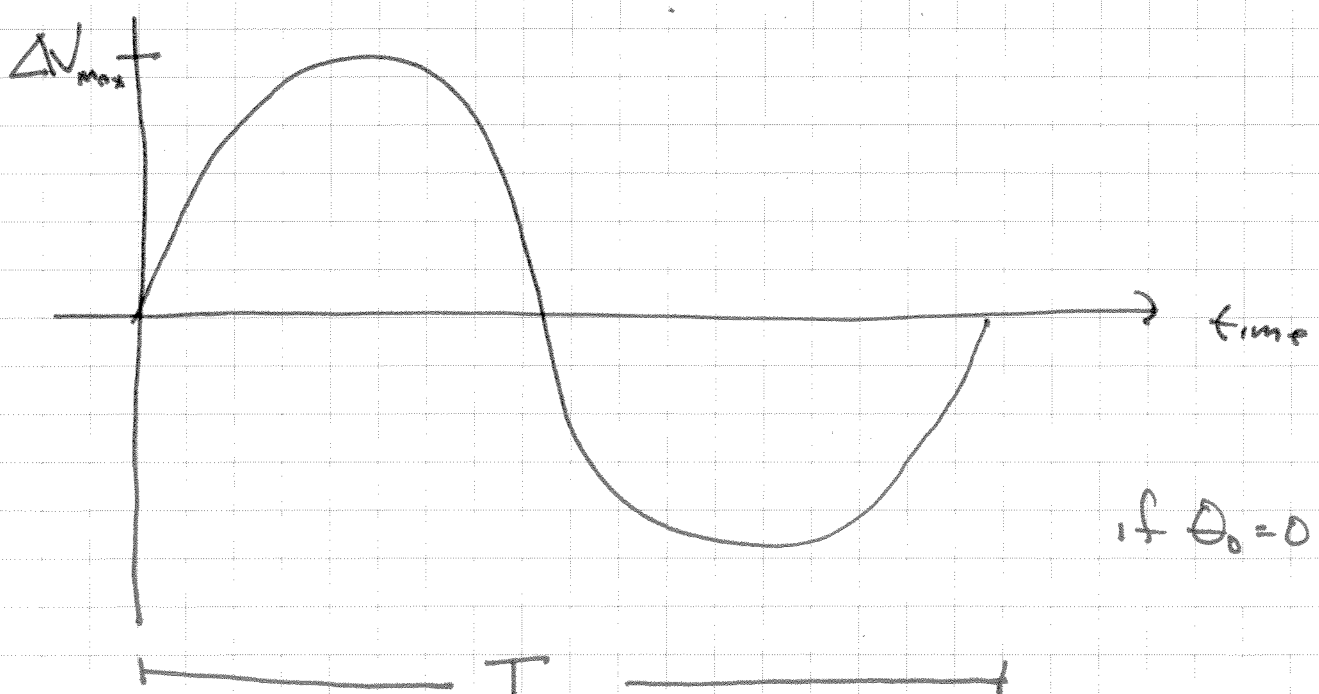
$$\Phi_m = NBA\cos(\theta_0 + \omega t)$$

Flux Rule

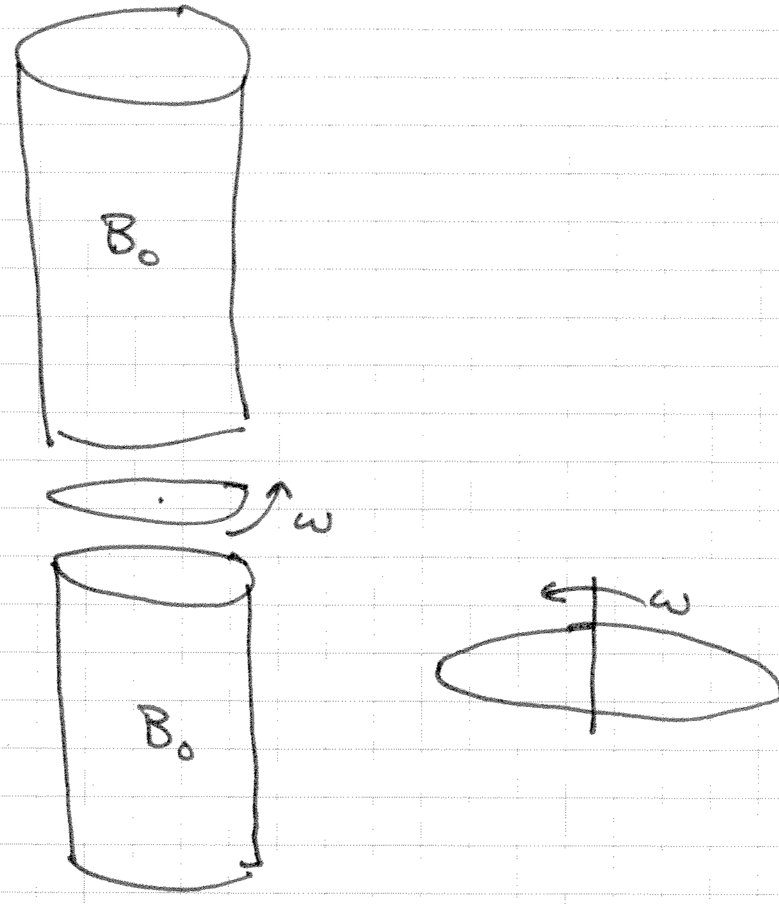
$$emf = -\frac{d\Phi_m}{dt} = NBA\omega \sin(\theta_0 + \omega t)$$

$$= \Delta V_{max} \sin(\theta_0 + \omega t)$$

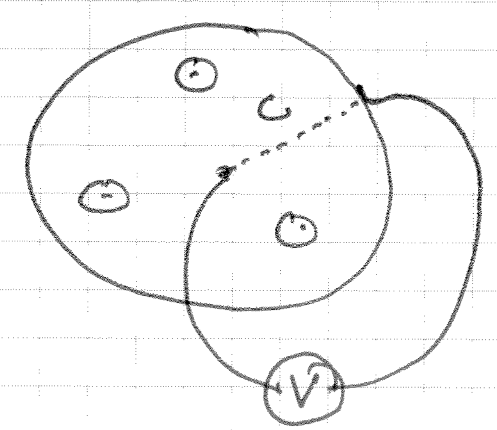
$$\Rightarrow \Delta V_{max} = NBA\omega$$



Faraday's Dynamo – Disk spinning in magnetic field.



Top View of Disk



Radius R

Using Motional Emf along dashed line

$$\text{emf} = \int_c (\vec{v} \times \vec{B}) \cdot d\vec{l} \qquad d\vec{l} = ds\,\hat{s}$$

$$\vec{v} = \omega s\,\hat{\phi} \qquad \vec{B} = B_0\,\hat{z}$$

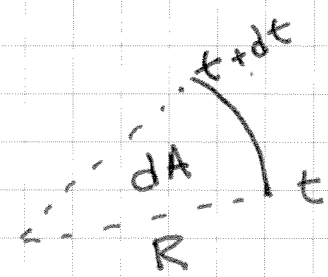
$$\vec{v} \times \vec{B} = \omega s B_0\,\hat{\phi} \times \hat{z} = \omega s B_0\,\hat{s}$$

$$\text{emf} = \int_c (\vec{v} \times \vec{B}) \cdot d\vec{l} = \omega B_0 \int_0^R s\,ds$$

$$= \frac{\omega B_0 R^2}{2}$$

Check with flux rule

In time dt, the curve C moving now with the disk describes a wedge



The area of the wedge is

$$dA = \left(\frac{1}{2} R\right)\left(R\,d\phi\right)$$

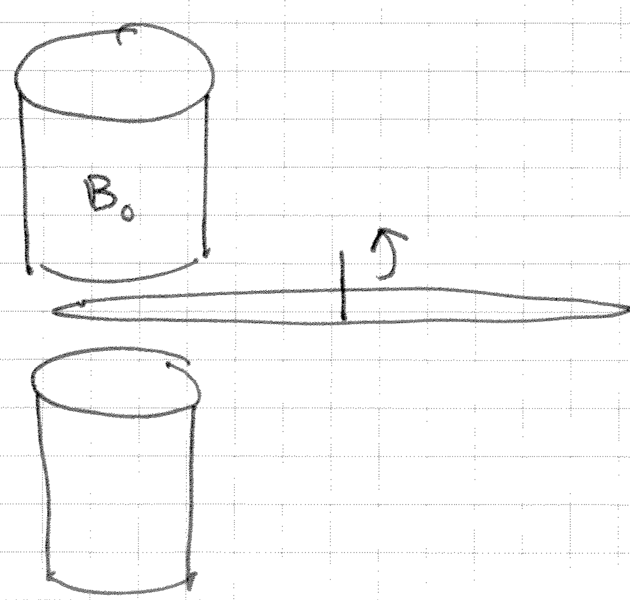
$$d\Phi_m = B_0\,dA = \frac{1}{2} B_0 R^2\,d\phi$$

$$|emf| = \left| -\frac{d\Phi_m}{dt} \right| = B_0 \frac{dA}{dt}$$

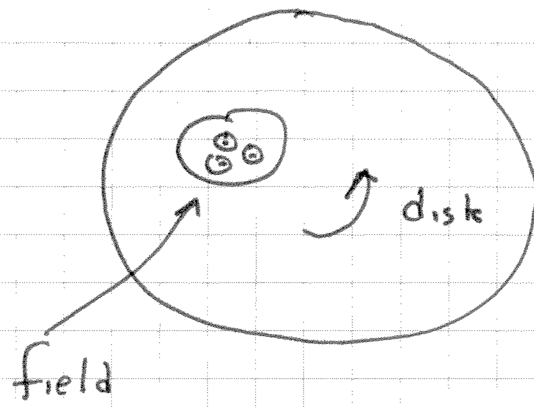
$$= \frac{1}{2} B_0 R^2 \frac{d\phi}{dt} = \frac{1}{2} B_0 R^2 \omega$$

If no load is connected to the dynamo, a region of positive charge will accumulate on the outer edge in a short time producing an electric force that balances the magnetic force. The disk will turn without additional input of energy.

Now move the disk off center



Top View



Now the flux through a portion of the conductor is constantly changing; the changing flux induces a current, eddy currants. These currents cause Joule heating. The energy lost to heat slows the disk $\Longrightarrow$ magnetic braking.