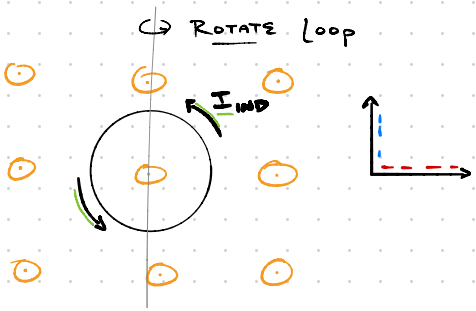
Lecture 21

Notes

— Generators & Transformers

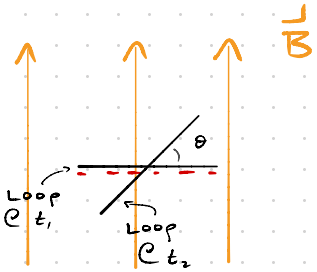
- In question 2d) of the lecture 20 questions we see the beginnings of a "generator":

Top View:



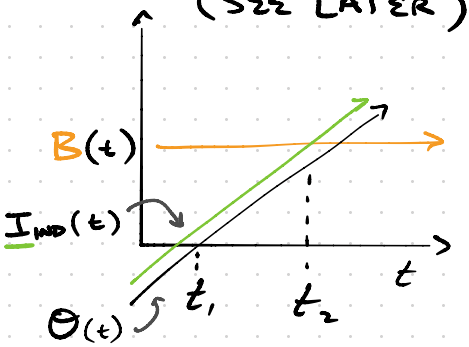
$\vec{B}$ constant in Time

Profile View:



$I_{IND}(t) \propto \theta(t)$

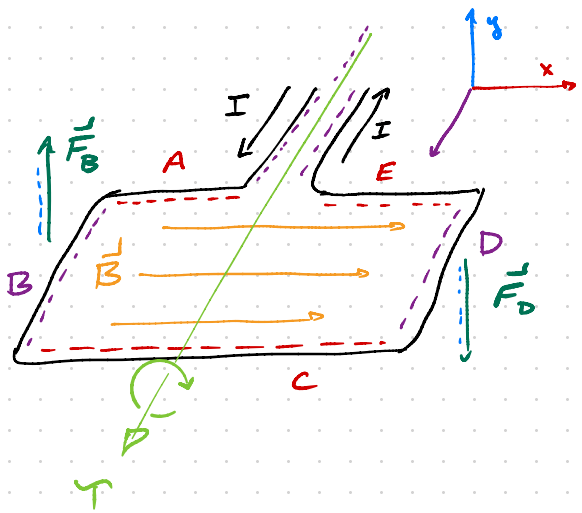
when $\theta \simeq 0°, 180°$ (see later)



Generator:

- (Rotational) Motion $\xrightarrow{\vec{B}}$ Electricity (i.e. current)

- Note the similarity with question 3a) from lecture 18 questions:



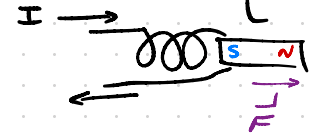
MOTOR:

ELECTRICITY (I.E. CURRENT) $\xrightarrow{\vec{B}}$ (ROTATIONAL) MOTION

OTHER "MOTORS":

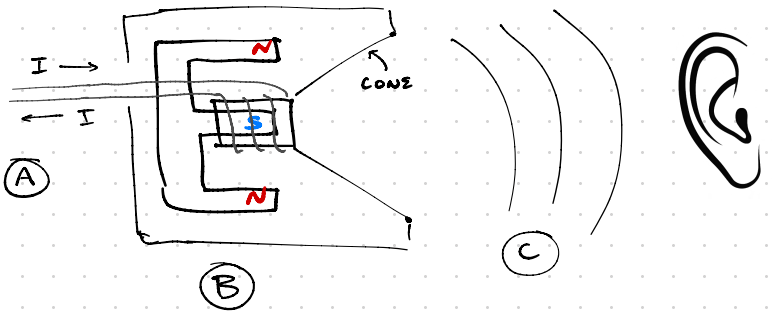
- AUDIO SPEAKER (LEC. 18 Y.T. VIDEO)

- RELAY [LEC. 19 NOTES]



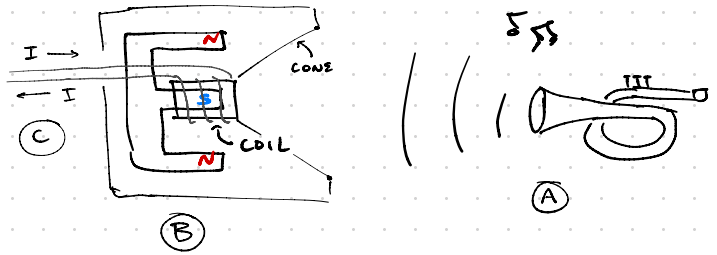
- GENERATOR: MOTOR THAT IS OPERATED "IN REVERSE"!
- E.G. "AN AUDIO SPEAKER IS THE SAME THING AS A MICROPHONE.":

LOUD SPEAKER ("FORWARDS")



SEND IN CURRENT → SPEAKER CONE MOVES → SOUND COMES OUT
A B C

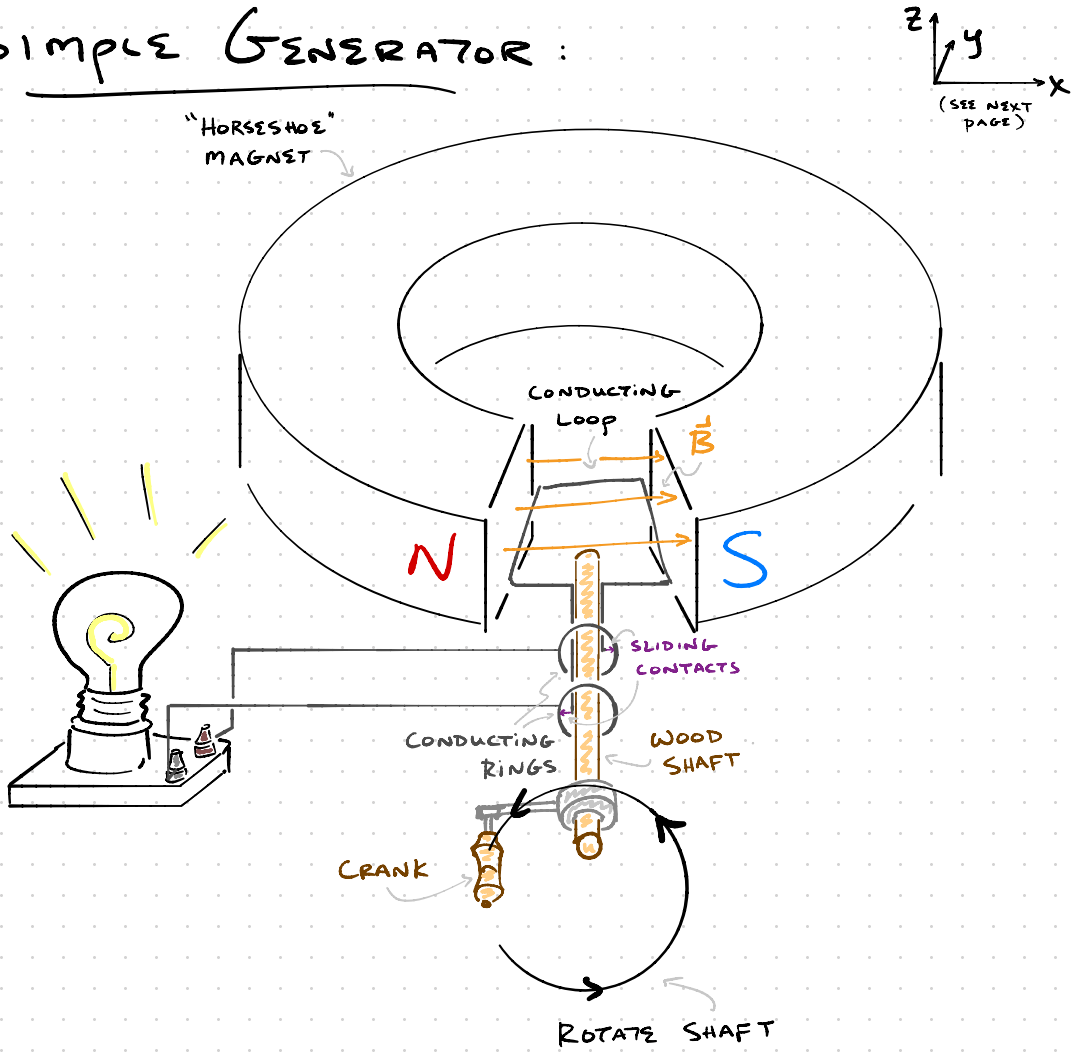
MICROPHONE ("BACKWARDS")



- SOUND COMES IN → SPEAKER CONE MOVES → CURRENT COMES OUT
  (CHANGING FLUX THRU COIL)

A B C

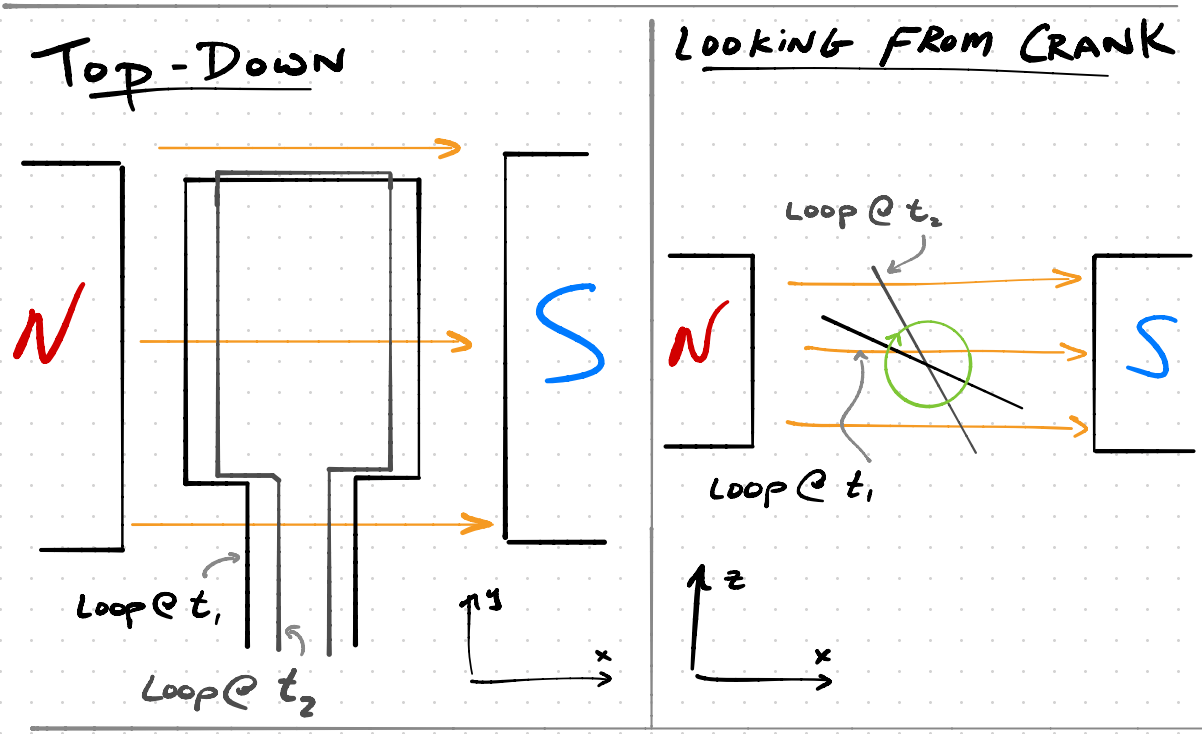
Simple Generator:



Turning crank rotates wire loop between magnet poles, inducing an emf which is used to power a light bulb.

Sliding contacts allow for continuous rotation without twisting.

- Zoomed-in view of previous diagram:

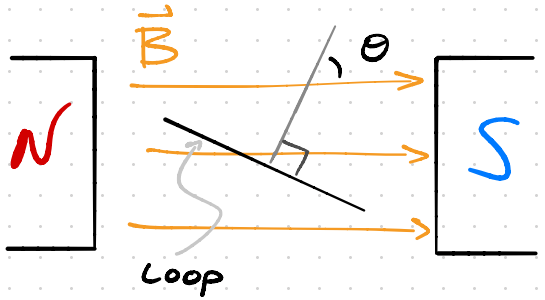


- What is the emf generated in loop as it rotates at a constant rate?

- CONSTANT ROTATION:

→ $\theta(t) = 2\pi f t$*

f: FREQUENCY OF ROTATION



- FOR UNIFORM $\vec{B}$ FIELD:

$$\Phi = BA\cos\theta$$

(A: LOOP AREA)

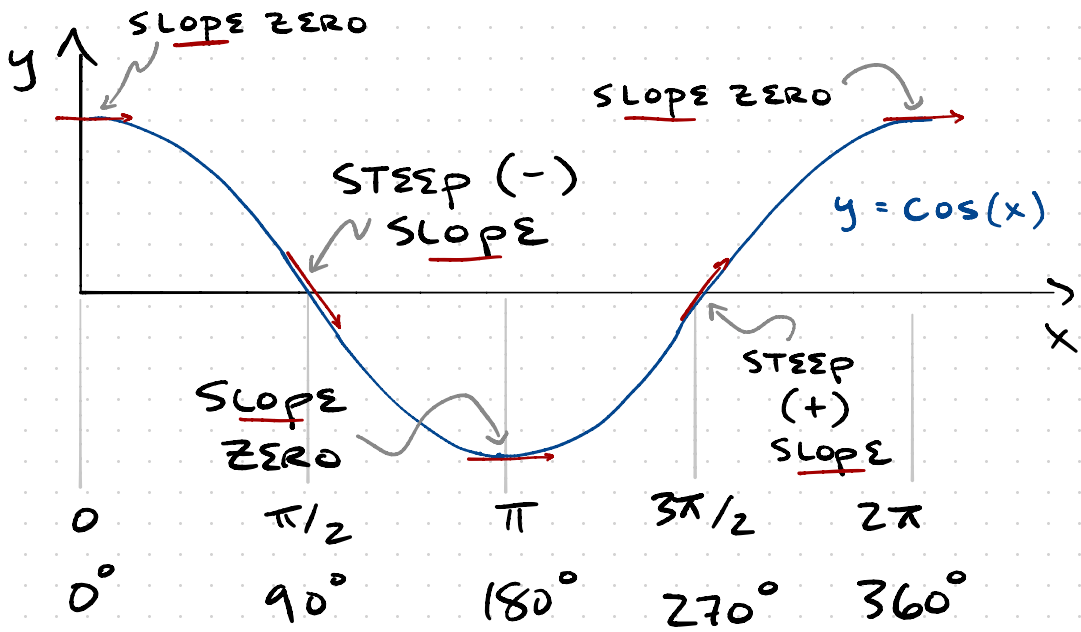
→ $\Phi(t) \propto \cos\theta(t)$ (1 LOOP)

- BUT $EMF = N\frac{\Delta\Phi}{\Delta t}$ [IN OUR CASE $N=1$]

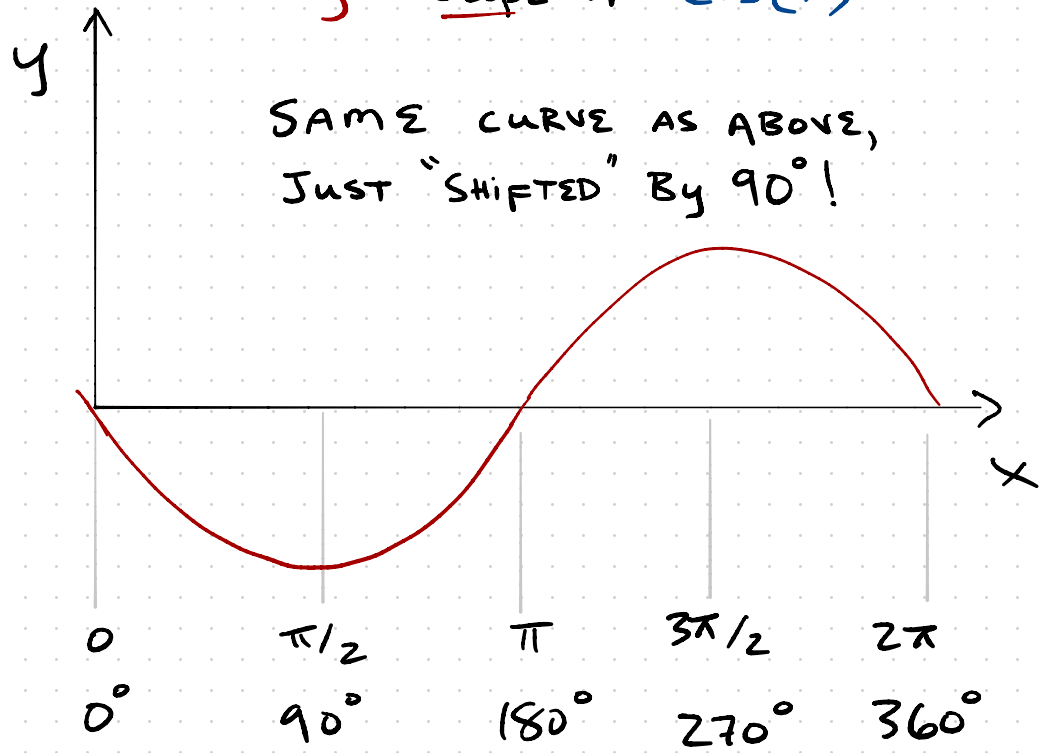
- SO IF $\Phi(t) \propto \cos(2\pi f t)$,

THEN HOW DOES $\frac{\Delta\Phi}{\Delta t}$ VARY W/ TIME?

* IN RADIANS

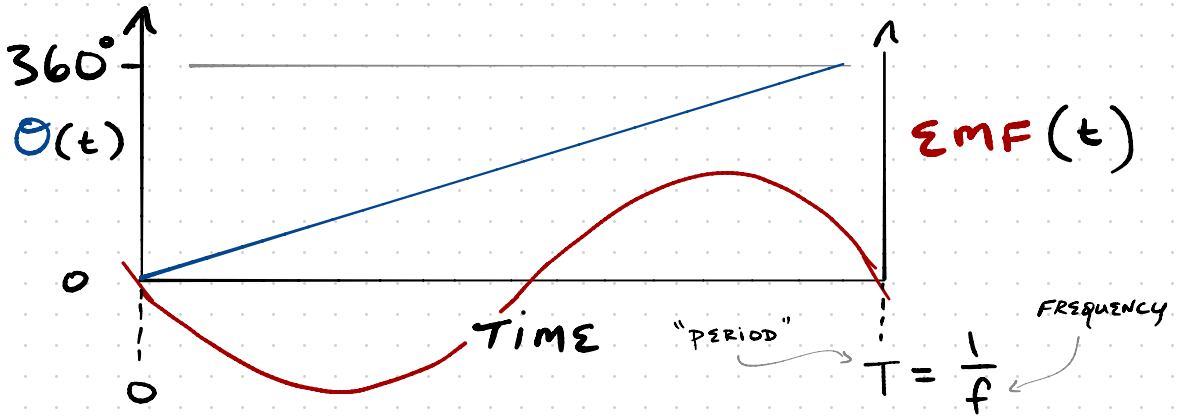


y = SLOPE OF cos(x)



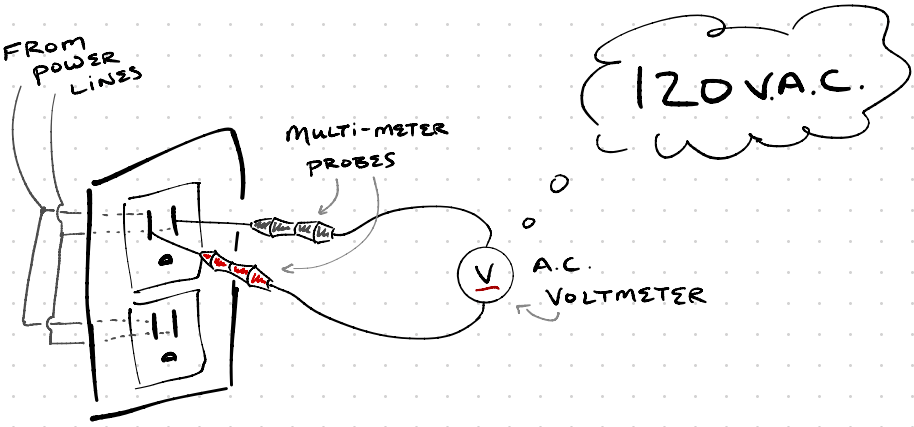
ALTERNATING CURRENT

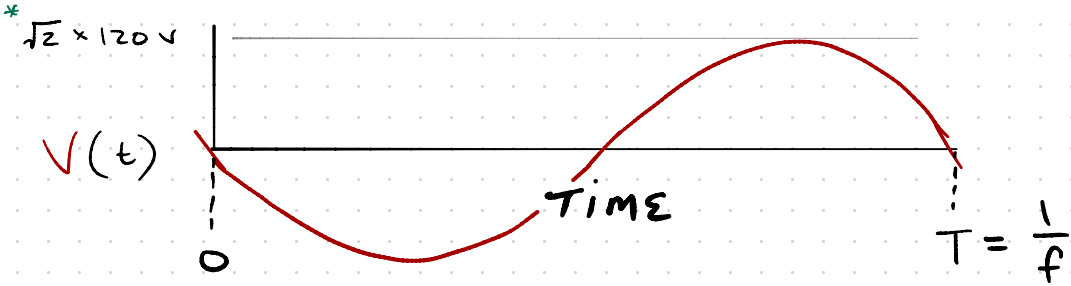
- So a loop rotating @ a constant rate in a uniform magnetic field generates a sinusoidally varying EMF across the loop!



- Circuits that use/generate ~ $\sin(2\pi f t)$ voltages / currents are called "A.C. circuits". [A.C. = "ALTERNATING CURRENT"]

• AN A.C. VOLTAGE IS WHAT COMES OUT OF YOUR WALL SOCKET:





$f = 60\ Hz$

$= 60\ \frac{cycles}{second}$

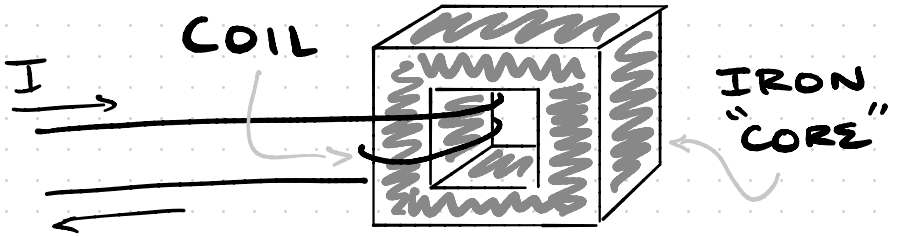
VARIES BY COUNTRY:

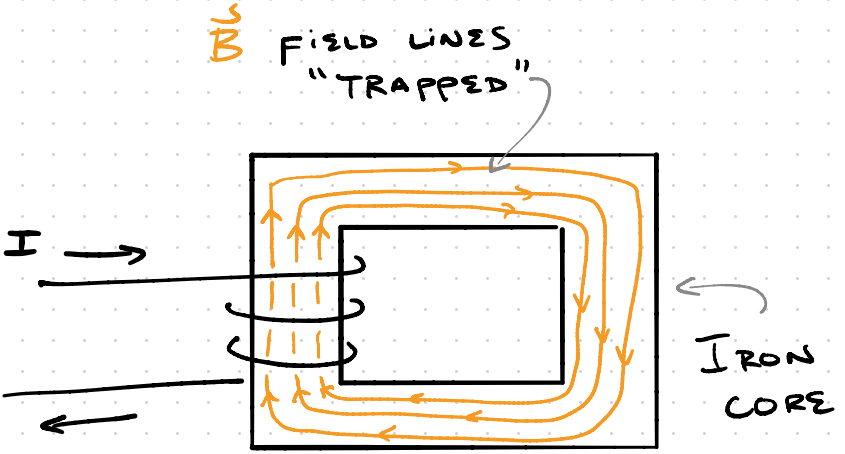
- U.S.A. : 120 VAC @ 60 Hz
- CHINA : 220 VAC @ 50 Hz
- SUDAN: 230 VAC @ 50 Hz

* BY CONVENTION, A.C. VOLTAGES ARE QUOTED BY THEIR "R.M.S." VALUE, WHICH IS $\sqrt{2}$ × SMALLER THAN THE AMPLITUDE.

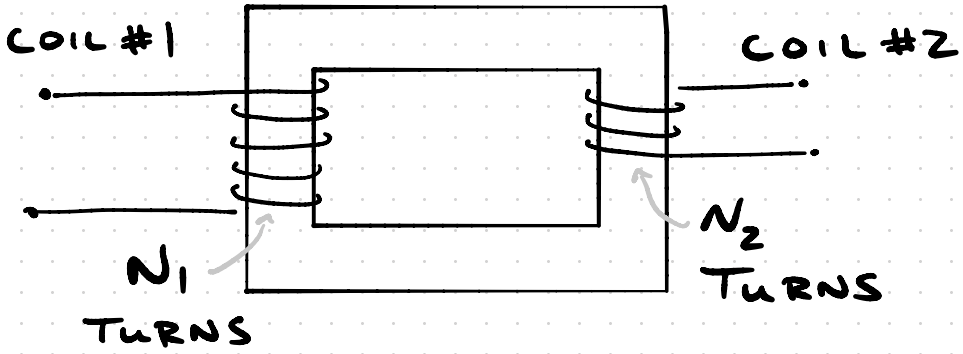
TRANSFORMER

- A IRON RING (OR "CORE") HAS THE PROPERTY OF "TRAPPING" ALL THE $\vec{B}$ FIELD LINES THAT ARE INSIDE:





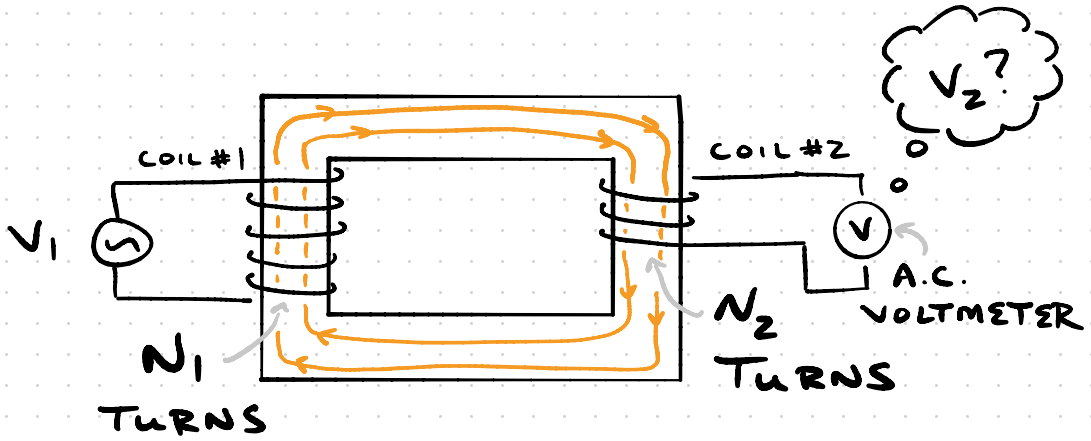
- A TRANSFORMER IS CONSTRUCTED BY WRAPPING TWO COILS AROUND AN IRON CORE:



- @ ANY TIME, THE FLUX Φ_1 THRU COIL #1 IS EQUAL TO THE FLUX Φ_2 THRU COIL #2 [SAME # $\vec{B}$ FIELD LINES]

$$\frac{\Delta \Phi_1}{\Delta t} = \frac{\Delta \Phi_2}{\Delta t}$$

- IF WE APPLY AN A.C. VOLTAGE TO COIL #1 & MEASURE THE RESULTING VOLTAGE INDUCED IN COIL #2:



FARADAY'S LAW:

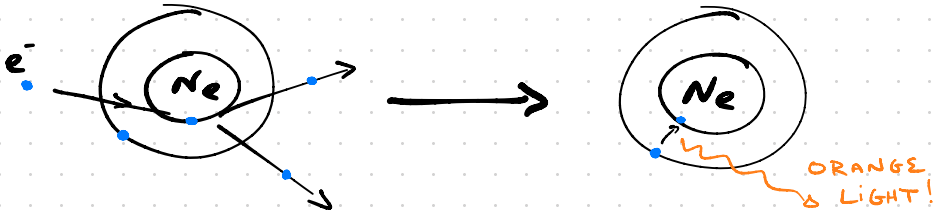
$$V = N \frac{\Delta \Phi}{\Delta t}$$

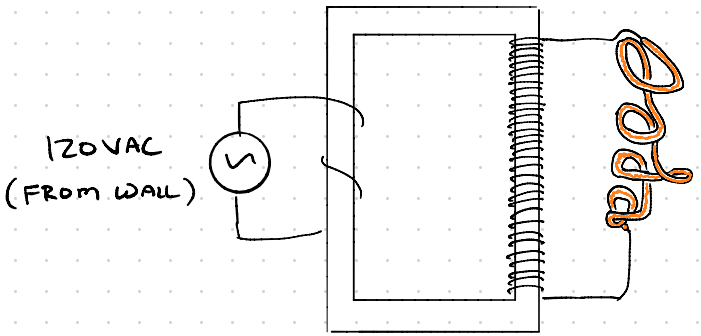
$$\longrightarrow V_2 = N_2 \frac{\Delta \Phi_2}{\Delta t} = N_2 \frac{\Delta \Phi_1}{\Delta t} = \boxed{\frac{N_2}{N_1} V_1}$$

- TRANSFORMERS *Multiply* A.C. VOLTAGES BY THE RATIO $\frac{N_2}{N_1}$!

EXAMPLE: NEON SIGN TRANSFORMER

- A NEON SIGN GLOWS BY CREATING A HIGH VOLTAGE (15 kV!) DISCHARGE IN NEON-FILLED TUBE:





$$\frac{V_2}{V_1} \approx \frac{15\,kV}{120\,V} \rightarrow \frac{N_2}{N_1} > 100!$$