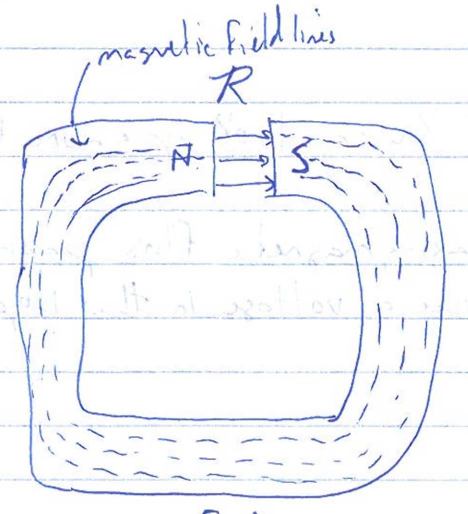
Alternating Current

Correction (kinda) from last lecture:



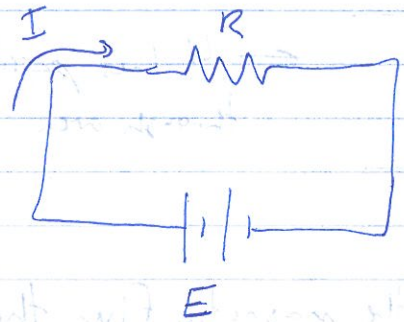
Φ ⇒ magnetic flux SI unit Weber

$\mathcal{F}$ ⇒ mmf magnetomotive force (SI unit Ampere)
↳ used to be ampere-turn

$\mathcal{R}$ ⇒ reluctance

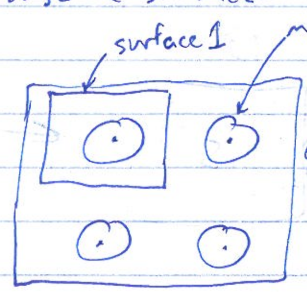
mmf ⇒ mag

$\mathcal{F} = \Phi \mathcal{R}$



$E = IR$

Φ ⇒ magnetic flux is the component of a magnetic field through a surface.



larger area means greater magnetic flux as there are more magnetic field lines passing through it.

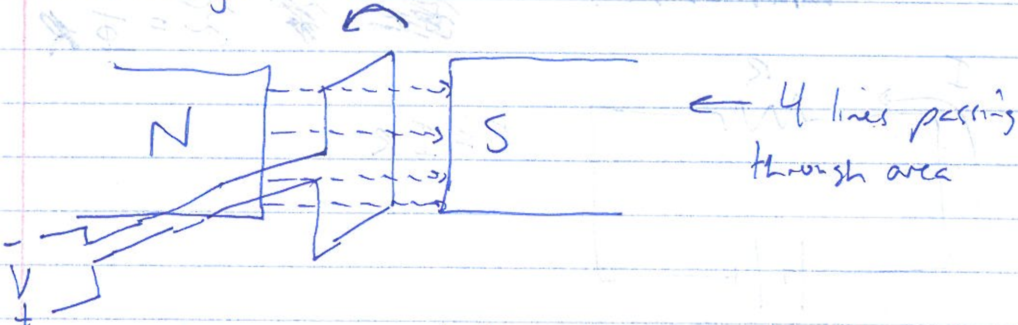
Why is this important?

It helps us understand how we generate alternating current.

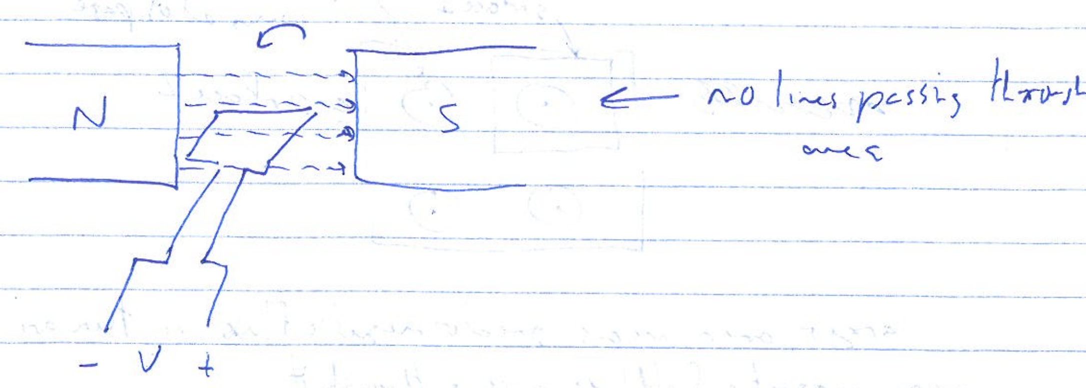
Faraday's Law: * You can look up a more formal definition *

For us: A changing magnetic flux passing through a conductive loop induces a voltage in that loop. (circuit)

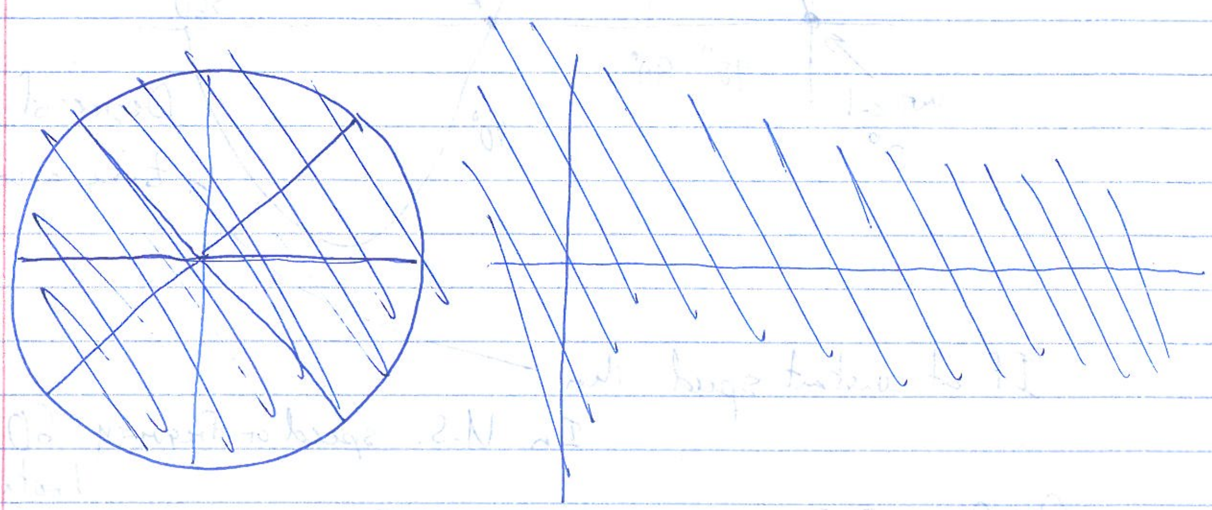
Drawing:



As loop rotates, the magnetic flux through it changes because the surface of the loop rotates so that the number of magnetic field lines through the loop changes.

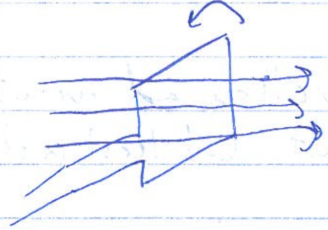


IF this loop is turned at a constant rotational speed then the induced voltage will have a sinusoidal shape

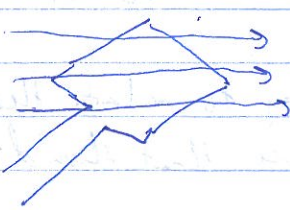


Induced voltage is proportional to change in magnetic flux.

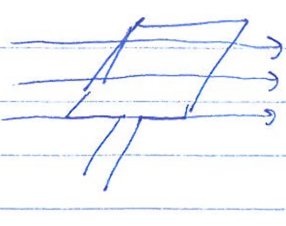
so



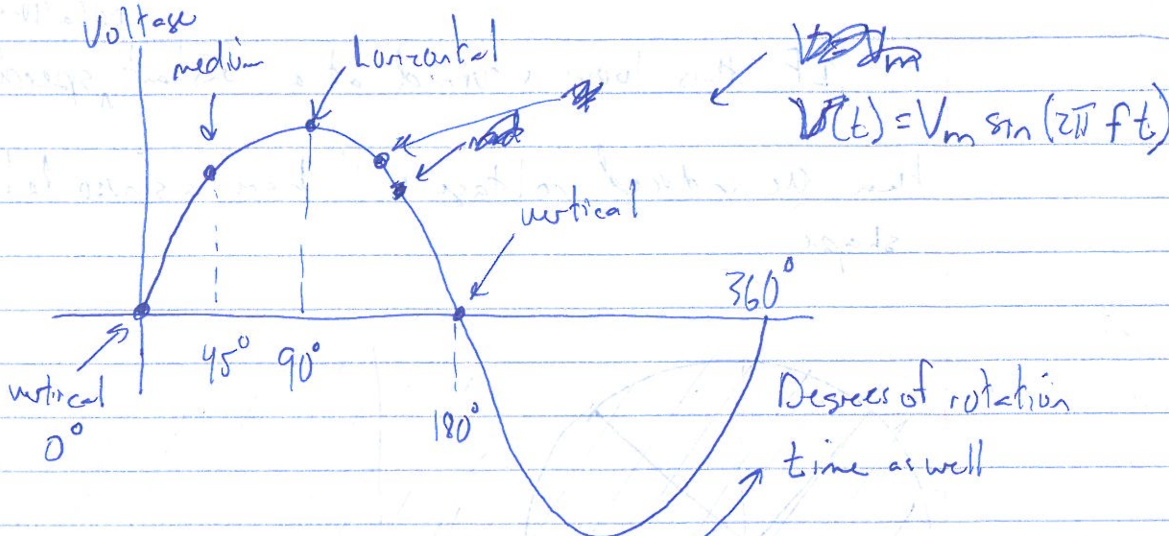
← At this point change in magnetic flux is small so small voltage



← $\Delta \Phi$ medium so medium voltage



$\Delta \Phi$ is largest so large voltage



IF at constant speed then

In U.S. speed or frequency 60 Hz
1 rotation/second

~~Vector Diagrams~~ In much of Europe → 50 Hz.

~~Instantaneous voltages and~~

Root-Mean squared or Effective ~~current~~ and voltage values

- When using DC → ~~xxxx~~ voltage and current values constant (at least in steady-state)

- When using AC → voltage and current values constantly changing
  - ~~*~~ We need a way to relate these two.
- * Can't use average value because that should be 0 V or A.

↓

RMS gives an effective value for alternating current and that will produce the same heating effect as a specific value of a steady DC-current.

i.e. 1A ac produces same heating rate of a resistor as 1A dc.

- That is multiply the ~~maximum~~ ~~voltage or~~ current ~~amp~~ by $\frac{1}{\sqrt{2}}$ or 0.707 ~~$V_{ac} = 0.707 V_m$~~ ~~$V_{rms} =$~~

- ~~Same for ac voltage~~

So if current is given by $i(t) = I_m \sin(2\pi f t)$

then $I_{ac} = 0.707 I_m$
I_{RMS} =

Same with voltage: $v(t) = V_m \sin(2\pi f t)$

$V_{ac} = 0.707 V_m$
V_{RMS} =

BTW definition of RMS ⇒
For periodic function

$$V_{RMS} = \frac{1}{T} \int_0^T v(t)^2 \, dt$$

↑ period $\frac{1}{f}$

So when we say 120V we mean $V_{RMS} = 120V$

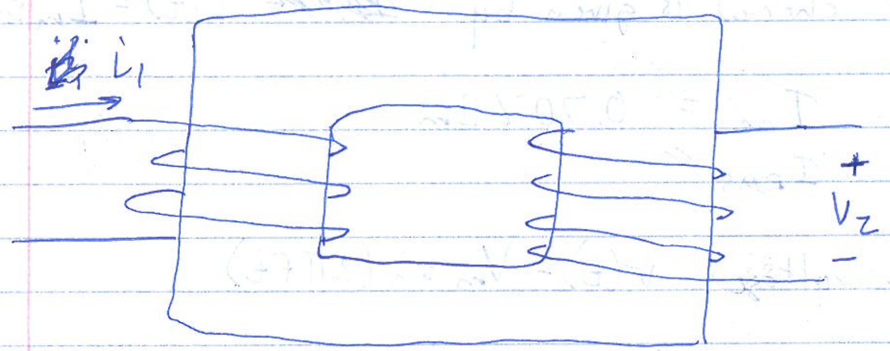
Actual magnitude is ~170V.

More on Electromagnetic Induction

→ Process by which a voltage is produced across a conductor or coil as result of changing magnetic field.

~~[illegible]~~

- Causes mutual inductance → How transformers work



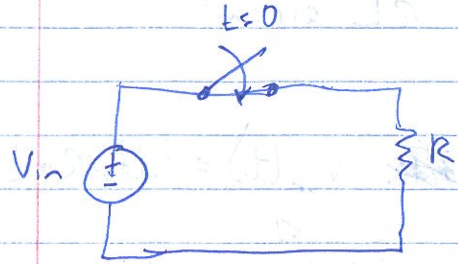
i_1 induces V_2

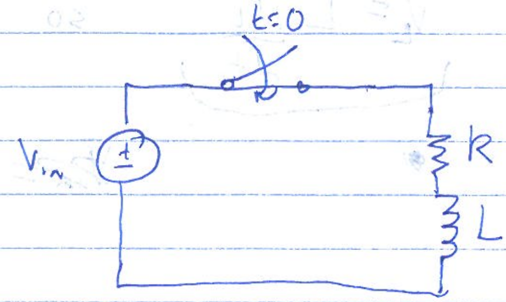
Also causes self-inductance. → ~~[illegible]~~

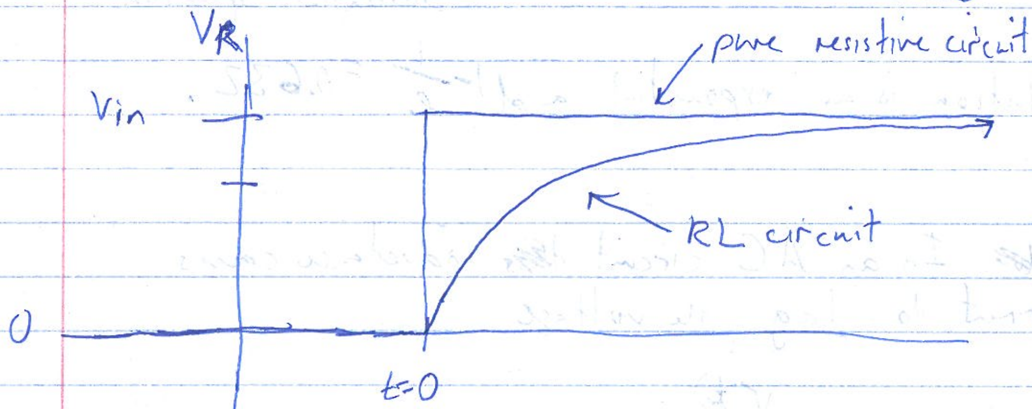
→ A change in current in a circuit causes a change in the magnetic field. This causes an induced voltage in the circuit opposed to the applied voltage.

→ Tends to retard changes in circuit current.

In DC circuits, this causes slow response to step changes in ~~current~~ applied voltage.







~~Time constant~~ ~~Inductor~~ Inductance unit (H) Henrys

time constant ⇒ measure of ~~how quickly~~ time it takes for current to reach it's maximum value

BUT: it's an exponential relationship so current NEVER ~~actually~~ truly reaches steady-state value.

$$\tau = \frac{R}{L}$$ units of seconds

⇒ time it takes for current to reach 63.2% of maximum

Why 63.2%? ~~Exponential relationship~~

Voltage/current relationship of inductor:

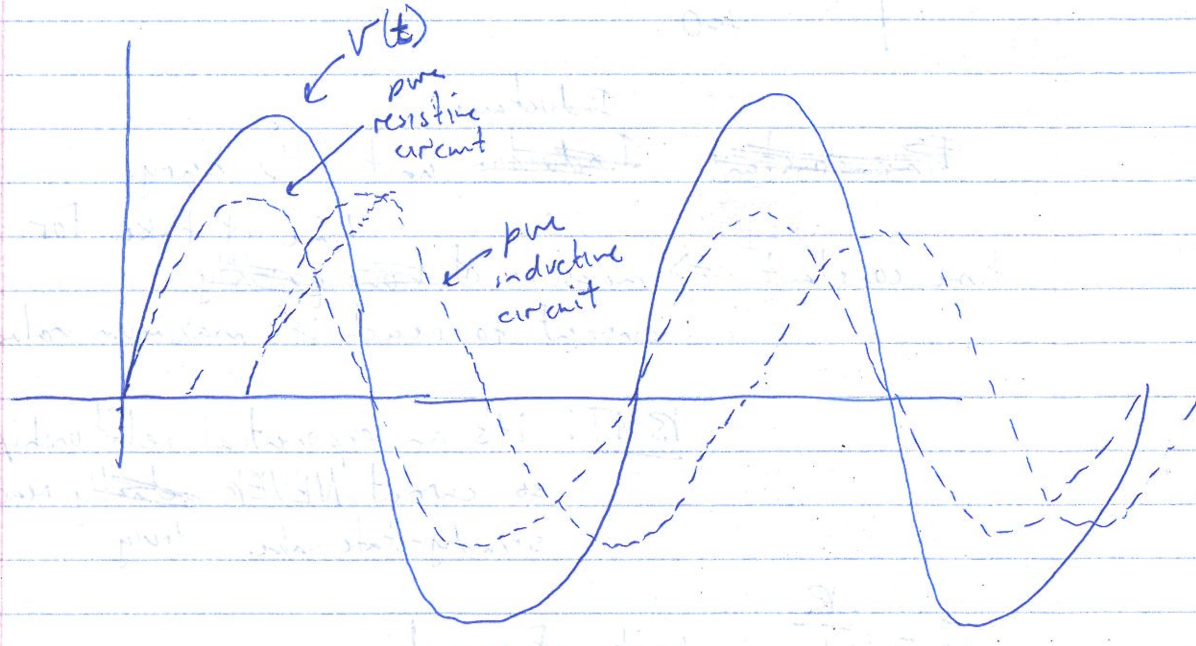
$$V_L = L\frac{di}{dt}$$ so in RL circuit

$$v_{in}(t) = i(t)R + L\frac{di}{dt}$$

↑ differential equation

solution is an exponential and $1-\frac{1}{e} = 0.632$.

In an AC circuit inductance causes current to lag the voltage



Inductive Reactance → opposition to flow of alternating current.

→ same unit of measurement as resistance
↳ but doesn't add simply.
→ Frequency dependant

$$X_L = 2\pi F L$$

~~For power system in US 60Hz~~

Total impedance of RL circuit.

usually expressed as:

$$Z = R + jX_L$$

↳ imaginary symbol don't use i because that's current.

For now know that $|Z| = \sqrt{R^2 + X_L^2}$

magnitude ↗

We are ignoring phase term for now. just know it lags

For AC circuits, Z replaces R in Ohm's Law:

$$V = I Z.$$