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Chp 1-3

$Q = IC = 6.25 \times 10^{18} e^-$

$V = \frac{W}{Q}$ ← Joules. / $W = QV$ ← workdone ← Joule

$I = \frac{Q}{t}$ ← C, ← s

$R = \frac{\rho l}{A}$ ← length, A ← cross-sectional area / $\rho = \Omega m$ ← resistivity

5.6×10^{13}

$1 \leq a < 10$

0 - 10

scientific notation → ~~[illegible]~~ $\times 10^{4}$ ← any number

engineering notation → 0 - 1000 $\times 10^{3}$ ← multiple of 3

57.6×10^{21}

Charge (Q) → Columb (C)

$1C = 6.25 \times 10^{18} - e$

$Q = \frac{\text{no. electron}}{6.25 \times 10^{18}} C$

Chp 4

$P = \frac{W}{t}$ ← Joules, ← s

$Pt = W$

~~W = Wt~~

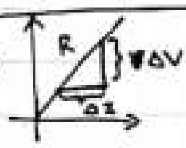
kWh

$P = IV$

$P = I^2 R$.

$R = \frac{V^2}{R}$

Ohm's Law →



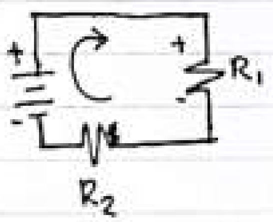
$V = IR$

$R = \frac{V}{I}$

$I = \frac{V}{R}$

Chp 5

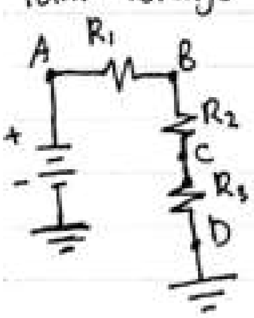
Series circuit

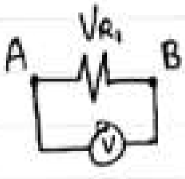


- same current through all the component
- convectional current flow
- volt at R_1 & R_2 ≠ V_{R_1} & V_{R_2}

$V_{R_1} = \left(\frac{R_1}{R_1 + R_2}\right) \times V_s$ / $V_{R_2} = \left(\frac{R_2}{R_1 + R_2}\right) \times V_s$

Point voltage





V_A | $V_{R_1} = V_s \left(\frac{R_1}{R_1 + R_2 + R_3}\right)$

V_B | $V_{R_1} = V_{AB} = V_A - V_B$

~~$V_{R_2} = V_{BC} = V_B - V_C$~~

$V_{R_2} = V_{BC} = V_B - V_C$

~~SQ~~ SRQ

1. $R = \frac{\rho l}{A} = \frac{5.6 \times 10^{-8} \times 5}{\pi \times (2.5 \times 10^{-4})^2} = 1.426 \approx 1.43 \Omega$

2. $W = Pt$

$W = 3000 \times 20 \times 60$

$W = 3600000J$

$W = 3600kJ$

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~~SUMMARY~~ ~~SUMMARY~~ SUMMARY

① Scientific notation → 0 − 10 × 10^{2} ← any number.

② Engineering notation → 0 − 1000 × 10^{21} ← multiple of 3

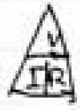
③ Charge → Q , & unit → ~~Columb (C)~~ Coulomb (C)

④ $V = \dfrac{W\,(J)}{Q\,(C)}$ (volt)

⑤ $I = \dfrac{Q\,(C)}{t\,(s)}$ (A)

⑥ $R = \dfrac{\rho l}{A}$ ← resistivity (Ωm), l (m), A (m^2), R (Ω)

⑦ $V = IR$ ← Ohm's Law



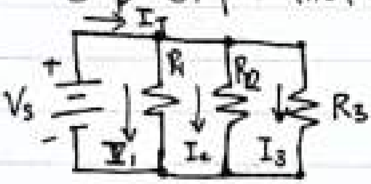
⑧ $P = IV$, $P = I^2R$, $P = \dfrac{V^2}{R}$

$\boxed{V \alpha I}$

$\boxed{R \alpha \dfrac{1}{I}}$

tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Chp 6. parallel circuit.



why? $R_1 \parallel R_2 \parallel R_3$?

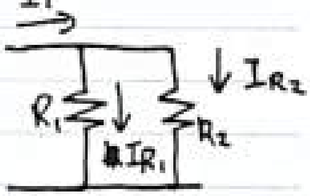
$V_{R_1} = V_{R_2} = V_{R_3} = V_s$

① $R_T = \dfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$

$R_T = \dfrac{R_1 R_2}{R_1 + R_2}$.

② $I_{R_1} = I_T \left(\dfrac{R_T}{R_1}\right)$

$I_{R_2} = I_T \left(\dfrac{R_T}{R_2}\right)$



$I_{R_1} = I_T \left(\dfrac{R_2}{R_1 + R_2}\right)$

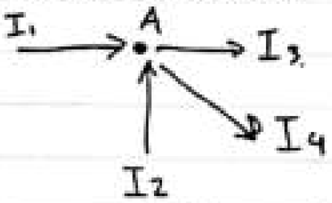
$I_{R_2} = I_T \left(\dfrac{R_1}{R_1 + R_2}\right)$

current divider law

$$I_x = \frac{V_s}{R_x} = \frac{I_T R_T}{R_x} = \left(\frac{R_T}{R_x}\right) I_T$$

③ KCL (Kirchoff's Current Law)

$\Sigma I_{in} = \Sigma I_{out}$



$I_1 + I_2 = I_3 + I_4$

KVL (Kirchoff's voltage Law).

$V_s - V_1 - V_2 - V_3 = 0$. ← All sum are equal to zero.

$V_s = V_1 + V_2 + V_3 + \ldots V_n$ ← The sum of all the voltage drops is equal to the sum of all the voltage rise.

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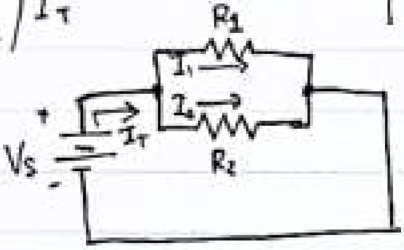
$R_T = \frac{R_1 R_2}{R_1 + R_2}$

$I_1 = \left(\frac{R_T}{R_1}\right) I_T = \left(\frac{\frac{R_1 R_2}{R_1 + R_2}}{R_1}\right) I_T$

$I_1 = \left(\frac{R_2}{R_1 + R_2}\right) I_T$

$I_2 = \left(\frac{R_T}{R_2}\right) I_T = \left(\frac{\frac{R_1 R_2}{R_1 + R_2}}{R_2}\right) I_T$.

$\therefore I_2 = \left(\frac{R_1}{R_1 + R_2}\right) I_T$.

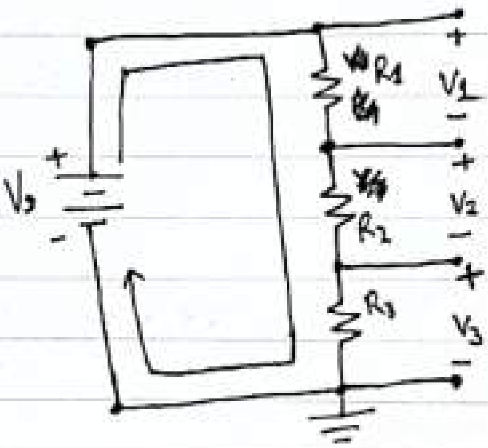


$I = \frac{V_S}{R_T}$

$V_1 = (I) R_1 = \left(\frac{V_S}{R_T}\right) R_1 = \left(\frac{R_1}{R_T}\right) V_S$

$V_2 = (I) R_2 = \left(\frac{V_S}{R_T}\right) R_2 = \left(\frac{R_2}{R_T}\right) V_S$

$V_3 = (I) R_3 = \left(\frac{V_S}{R_T}\right) R_3 = \left(\frac{R_3}{R_T}\right) V_S$



$\therefore$ In general, $V_n = \left(\frac{R_n}{R_T}\right) V_S$, when V_n is the voltage across resistor R_n

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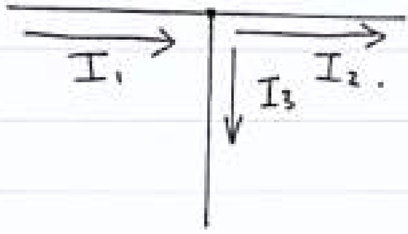
Kirchhoff's Junction Rule.

The sum of the currents flowing into a Junction is equal to the sum of the currents flowing out of said junction.

MATHEMATICALLY,

$\boxed{I_{in} = I_{out}}$

DIAGRAMMATICALLY,



$J_R(ji) = I_1 = I_2 + I_3$

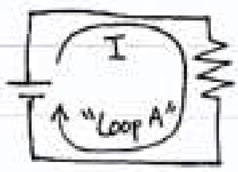
Kirchhoff's Loop Rool

For any closed loop the sum of the voltage "lifts" is equal to the sum of the voltage "drop".

MATHEMATICALLY,

$\boxed{V_{net} = 0}$

DIAGRAMMATICALLY,



$LR(A) = V_S - V_R = 0$

Conventions for KR:

* If we travel through a battery (while summing voltages) from LOW TO HIGH (negative to positive) the voltage is positive ("LIFT"); HIGH TO LOW (positive to negative) the voltage is negative ("DROP").
* If we follow current (while summing voltages) through a resistor, then $V = -IR$ ("DROP"); If we oppose current through a resistor, then $V = +IR$ ("LIFT")
* Loops and current directions are assigned and labeled arbitrarily with no preference in direction.

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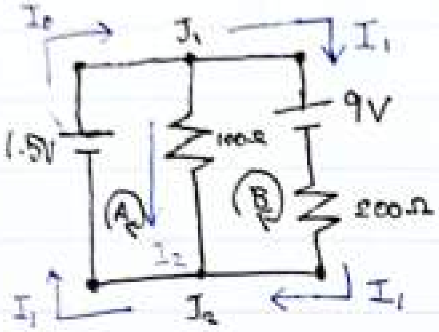
★ Typically ~~...~~ we'll use one more loop than the number of junction.



Junction Rule = $I_0 = I_1 + I_2$.

Sum of current into a junction is equal to going out.

In J_1 → I_0 going in ~~white~~, and the output is going 2 ways, I_1 (going straight) and I_2 (going down)

Loop Rule A = $-I_2(100\Omega) + 1.5V = 0$.

$-IR$. (voltage drop from $V = IR$)

~~Ex~~ $-100 I_2 + 1.5 = 0$.

$I_2 = \boxed{0.015A}$

Loop Rule B = $-9V - I_1(200\Omega) + I_2(100\Omega) = 0$

voltage lift.

$-9 - 200 I_1 + (0.015)(100) = 0$.

$-200 I_1 = 7.5$

$I_1 = \boxed{-0.0375A}$

direction is wrong (the opposite way).

~~Ex~~

$I_0 = 0.0375 + 0.015$

$I_0 = -0.0225A$

$V_{100\Omega} = (0.015A)(100\Omega)$

$V_{100\Omega} = \boxed{1.5V}$

$V_{200\Omega} = (0.0375)(200)$

$= \boxed{7.5V}$

$P_{100\Omega} = IV = (0.015)(1.5)$

$= \boxed{0.0225W}$

$P_{200\Omega} = IV = (0.0375)(7.5)$

$= \boxed{0.28125W}$

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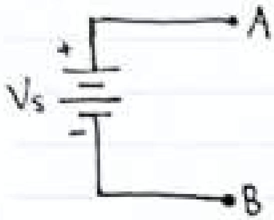
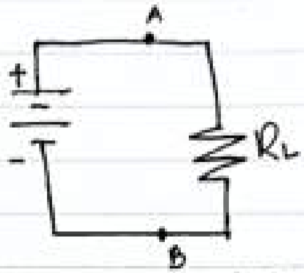
Unit 8.

☆ The ideal voltage source has:
- 0 internal resistance.
- Provides a constant voltage across its terminal A and B.
- $V_{AB} = V_s$ regardless of the load resistance.





☆ When a load is connected across the ideal voltage source:
- The voltage across termals AB remains the same.

$V_{AB} = V_{RL} = V_s$

☆ But in reality, no voltage is ideal. A practical voltage source can be represented by a resistor in series with an ideal voltage source

~~The terminal voltage value is higher than the source e.m.f.~~

To neglect the effect of a voltage source, the terminals across the source are ~~replaced~~ short circuited or replaced by a wire.

A practical ~~source~~ current source is one that has an extremely large internal resistance.

☆ To neglect the effect of a current source to a circuit, the terminals across the source are open circuited.

$V_s = I_s \times R_s$ & $I_s = \frac{V_s}{R_s}$

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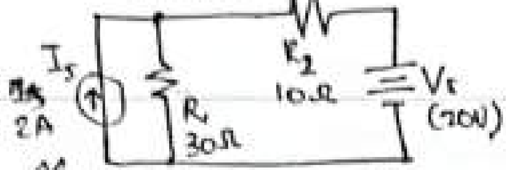
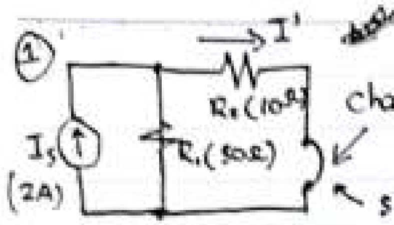
ORIGINAL.



Use superposition theorem to find ~~the~~ the current in R_2

①



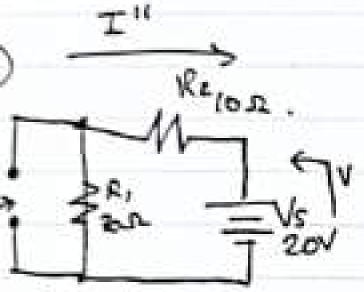
change a ~~Vs~~ 20V power supply (V_s (20V))

short circuit the voltage source V_s

I' ← I mine

$$I' = \frac{R_1}{R_1+R_2} I_s = \frac{30}{10+30} \times 2 = 1.5A$$

②

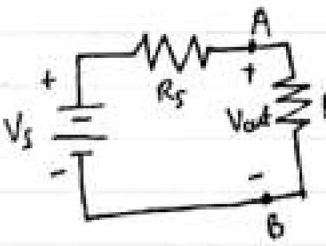
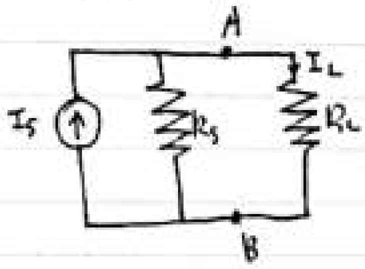


open circuit the ~~source~~ current source I_s

The negative indicates that the actual current flows in the opposite direction from the ~~a~~ direction of the assumed current

$$I'' = \frac{V_s}{R_1+R_2} = \frac{-20V}{\cancel{10+30}\ 10\Omega+30\Omega} = -0.5A$$ flowing in the opposite direction

③ Total current $I = I' + I'' = 1.5A + (-0.5A) = 1A$

	short	open
	Practical Voltage Source	Practical current source
Source resistor	in series with ideal voltage source	In parallel with ideal current source
Output voltage/current	(Based on voltage Divider Rule)	(Based on current divider rule)
Loaded circuit diagrams		
internal resistance	0 internal resistance	an extremely large internal resistance or ∞
neglect the effect of source	short circuited or replaced by a wire	open circuited
current	maximum/very high/∞	0

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Chp 9

Magnet

☆Properties:

- Magnet flux lines are only affected when ferromagnetic material is present within the field.
- Flux lines will concentrate near the ferromagnetic material and flow through it as it provides a far more easy path.

☆ How to magnetise.

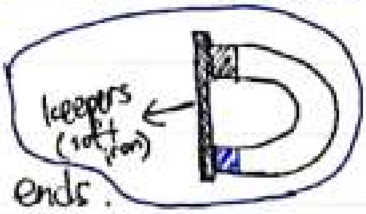
- Stroking → simple method but produces weak magnets.
- Induction → This method produces strong magnet. It uses a solenoid connected to a d.c. supply to magnetise the steel bar placed inside.

☆ How to demagnetize

- Heating → heat up till ~~curr~~ curie temperature
- Hammering → by hammering or ~~dropping~~ dropping the magnet, it will weaken it's strength.

- Solenoid / induction → Solenoid wrapped around the magnet with an a.c. current to eliminate it's strength.

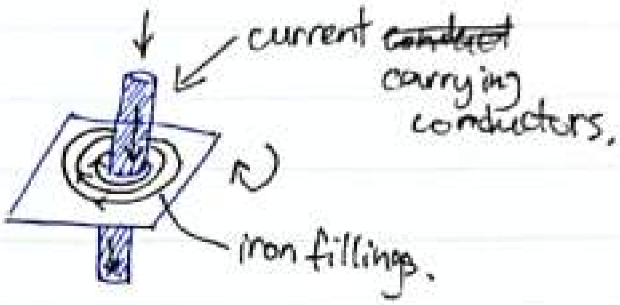
☆ Strong magnet.



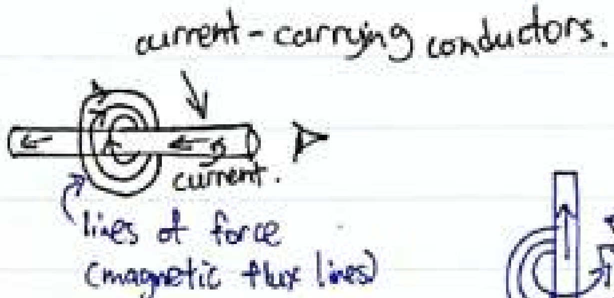
- Use keepers and put on the ends.
- They need to be stored properly as they will ~~lose~~ be weaker overtime.
- They are made of soft iron to provide best path for the magnetic field.

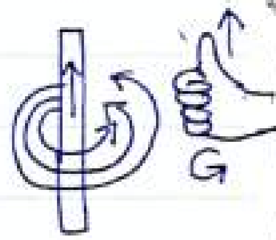
☆ Magnetic force

- ~~Lines are~~ of forces are in clockwise direction around ~~a~~ conductor that is carrying current away.



- Anticlockwise direction around ~~around~~ the conductor if viewed from the other end.



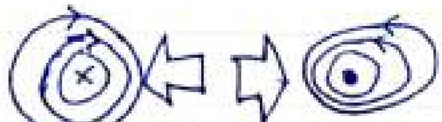


☆ Right hand grip rule

- The direction of the magnetic field can be rembered using the famous right hand grip rule.
- Thumb points along the direction of the current, and other fingers ~~w~~ will give the direction of the magnetic flux

☆ Force of Repulsion

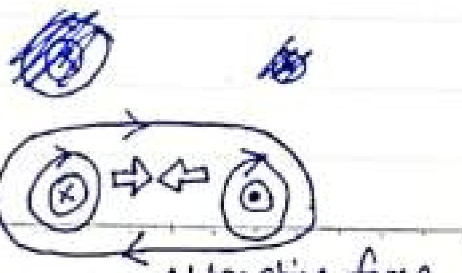
- ~~*~~ 2 parallel conductors with currents flowing in opposite directions.
- Magnetic field is additive. between the two conductors and exerts force of repulsion.



Repulsive force.

☆ Force of attraction.

- 2 parallel conductors with currents flowing in the same direction.
- Magnetic ~~磁~~ field is subtrative between ~~Aon~~ the two conductors and exerts force of attraction.



Attractive force.

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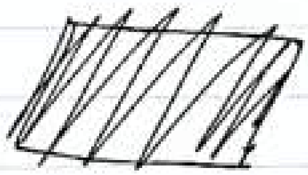
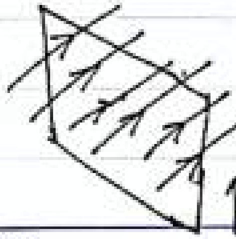
Chp 9.

☆ Magnetic Flux and Flux Density

Variable	Magnetic Flux	Flux Density
Unit	Weber (Wb)	Tesla (T)
Symbol	Φ	B
Definition	-The line of force in a magnetic field. -The higher the quanity, the stronger the magnetic field is	The amount of flux passing perpendicularly through a unit area in a magnetic field. $B = \frac{\Phi}{A}$ (where A is area at 90° to the flux).





↑ Area A, 90° to the flux.

☆ Electromagnet Properties.

These are related to the establishment of an electromagnetic field:

- Permeability of the core material selected (μ)
- Reluctance of the flux path (R_m)
- Magnetomotive force / MMF (F_m)

These parameters determine the field strength of an electromagnet, ease to establish flux flow and the force needed to establish the field.

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☆ Permeability of electromagnets.
①Permeability of the core material, (μ).
②Permeability values of ferromagnetic materials, (μ)
③Permeability of vacuum or air, (μ_0)
④Relative permeability, (μ_r)

①Permeability of the core material, (μ)
- The measure of the ease of establishing a magnetic field in the material:
  - The higher the permeability, the more easily a magnetic field can be established.
  - Unit: Wb/Atm or H/m.

③ Permeability of vacuum or air, (μ_0)
- Also known as permeability of free space
- formula: $\mu_0 = 4\pi \times 10^{-7}$ Wb/Atm

② Permeability values of ferromagnetic materials, (μ)
- Also known as 'absolute' permeability
- Typically hundreds of times higher: $\mu \gg \mu_0$
- Magnetic field can be established far more easily in ferromagnetic materials as compared to air or vacuum

☆ Reluctance of the flux path, R_m.
Definition:
- The opposition to the establishment of magnetic field in a material.
- Analogous to resitance R in an electric circuit.
- Value of reluctance R_m is:
  - Directly proportional to length (l) of the flux path.
  - Inversly proportional to both permeability (μ) and cross-sectional area (A) of material.

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Chp 9.

☆ Permeability of Electromagnets ℓ (flux path).

Magnetic circuit.

$R_m = \frac{l}{\mu A}$.

Electric circuit.

$R = \rho \frac{l}{A} = \frac{l}{\sigma A}$.

Magnetic circuit	Electric circuit
Reluctance (R_m).	Resistance (R).
Length of flux path (l).	length of current path (l)
Cross-section area (A).	Cross-section area (A).
Permeability (μ)	Conductivity (σ).

☆ Magnetomotive force / MMF (F_m)

- The force that produces the magnetic field. Current flowing ~~throu~~ in a conductor produces a magnetic field.

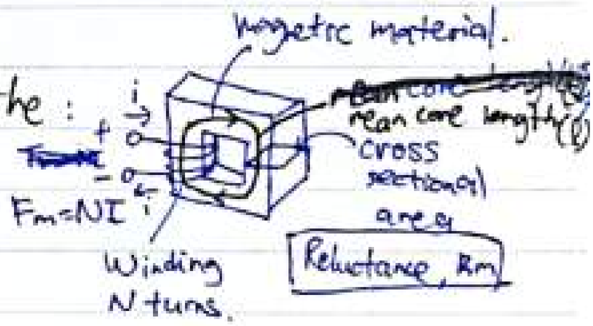
Unit: At.

Formula: $F_m = NI$

☆ The magnetic circuit

Amount of flux (Φ) depends on the:

- MMF (F_m).
- reluctance (R_m).



☆ The magnetic circuit.

Ohm's Law for magnetic circuit.

Formula: $\Phi = \frac{F_m}{R_m}$

MMF = magnetic flux × Reluctance.

↑ magnetomotive force.

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Electromagnet.

Wire coil around a magnetised core material, if current is applied in the coil, magnetic field is produced around it. The intensity of the ~~mag~~ magnetic field can be controlled by the amount of current. The pole can be reversed by changing current flow direction into it's coil.

Magnetic field and flux.

- Nature of magnetic field have flux flow across the air gap.
- Smaller gap between the poles lead to lesser reluctance.
- Magnetic permeability of air is ~~less~~ ~~that~~ much lower than in the magnetic body, due to the high magnetic resistance (relctance) of the core gap.

- Greater mmf is required to overcome reluctance of air gap.
- Basically the magnetic ~~flux~~ field can be easily establisted with smaller air gap because the reluctance is lesser.

Properties of electromagnet.

- Flux Density (B) can be enhanced by:
  1. Increase the number of coil turns.
  2. Increase the amount of current, I
  3. decreasing length of the coil, l.
  4. Increasing permeability, μ.
- MMF also depends on the number of turns (N), the strength of the current (I) as well as the length (l) of material
- Reluctance (Rm) is inversly proportional to the magnetic permeability.

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Chp 9.

☆ Properties of electromagnet. (continued)

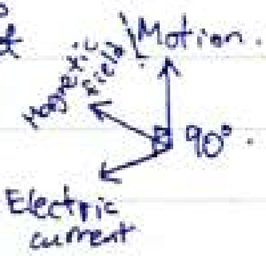
As F_m increase,

- B increase. (flux density).
- H increases (magnetising force).
- B proportional to H.

Flux density	Magnetising Force	Magnetic Flux.
$B = \frac{\mu NI}{l}$	$H = \frac{F_m}{l}$	$\Phi = \frac{F_m}{R_m}$
unit: T	unit: At/m.	unit: Wb

☆ B-H characteristics.

A simple method used to memorise the direction of the three variables:
- Field
- Motion.
- Current.



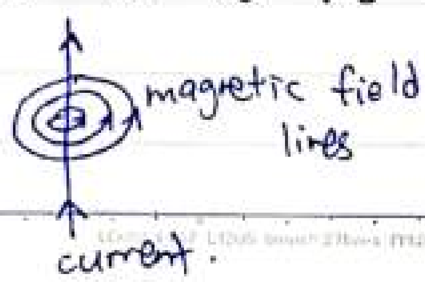
Fleming's Right Hand Rule.

- Rententivity
  - Symbol = ~~B~~ B_R.
- Definition:
  - Ability of a material to remain in magnetised state without magnetising force (H) Materials with:
  - ☆ High B_R are permanent magnets
  - ☆ Low B_R are temporary magnets.

☆ Conductor in Magnetic field.

The effect of placing a conductor in a magnetic field.
- Recall that a current-carrying conductor produces a magnetic field around it, perpendicularly to the current flow direction.

The electromagnet is a result of electromagnetism.



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☆ Faraday's Law.

- Definition & how it works:
  - When the switch is turned off and on, there is a deflection in the meter.
  - The switching action produced voltage and current.
- Faradays Law
  - It ~~conduct~~ concluded that the change of magnetic flux ($\Delta\phi$) induces electricity.
  - This phenomenon is called electromagnetic induction.

$$I = -\frac{N}{R}\frac{d\phi}{dt}$$

no. of turns → N; change in magnetic flux → $d\phi$; current → I; resistance → R

$d = \Delta$ (delta).

$V = IR$

$$\boxed{RI} = -N\frac{d\phi}{dt}$$

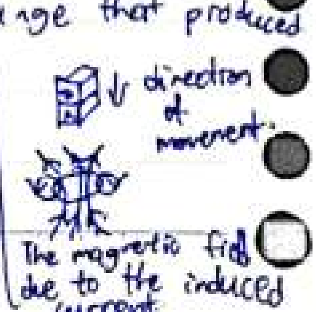
$$V_{emf} = -N\frac{d\phi}{dt} \Rightarrow V_{ind} = -N\frac{\Delta\phi}{\Delta t}.$$

Magnitude of induced emf (V_{ind}) in a coil is the rate of change in magnetic flux ($\frac{\Delta\phi}{\Delta t}$) through the coil multiplied by the number of turns (N).

☆ Lenz's Law.

- The direction of induced current is such as to oppose the change that produced it.
- Both Faraday's and Lenz's Law work together in explaining the magnitude and polarity of the induced voltage and direction of the induced current.

An induced current in a closed conducting loop will appear in such direction that it opposes the change that produced it.



Unit 10 PEEE

DATE 9 . 8 . 21

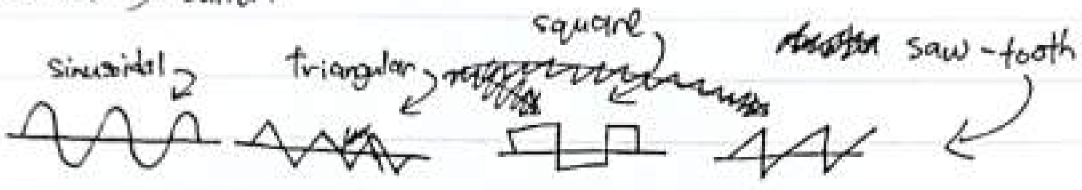
AC & DC

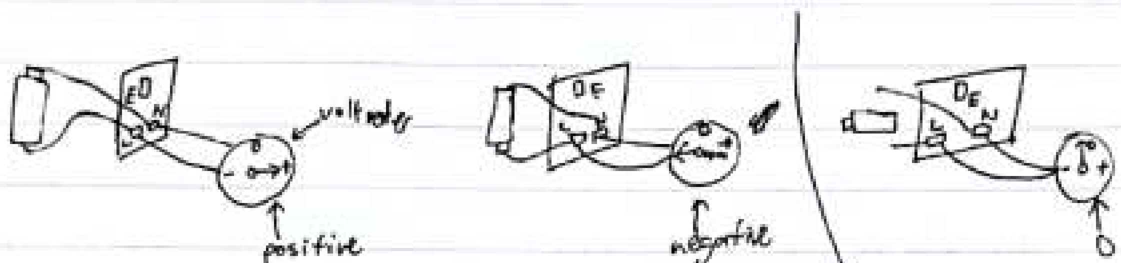
The voltage across 2 points of a circuit changes or alternates.

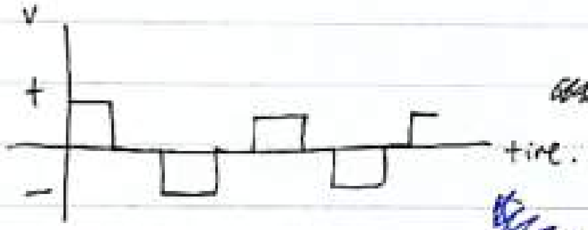
AC → electricity at home are found in AC

~~The voltage across each component of a circuit changes or alternates its polarity & repetitively and /or the current direction changes or alternates repetitively.~~

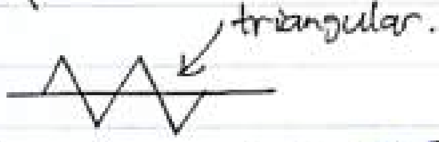
Alternating current







when plot



~~The voltage across 2 points of a circuit changes (alternates)~~

DC → Direct current.

→ polarities of the voltages remain the same throughout, and the current directions also remains the same.

The voltmeter is always positive even when the direction changes

---

AC → The electricity comes from power supply, it is generated by changing flux linkage through coils in a power generator.

Generating an ac waveform is achieved through the cutting of a magnetic flux lines by the rotating coils of wire called the rotors.

NO.

DATE

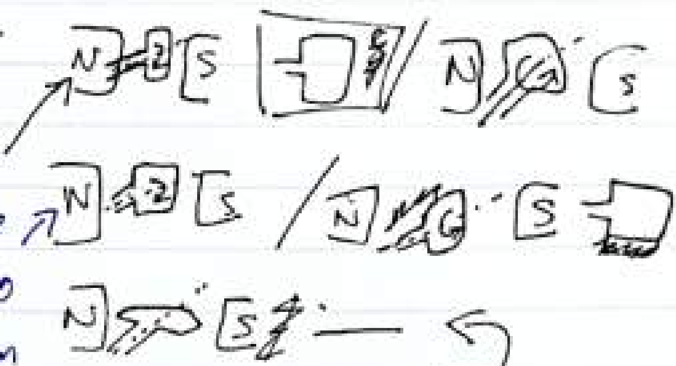
Generating ac ~~vol~~ voltage & current.

The effective rate of cutting flux lines depends on the instantaneous position of the coil conductor.

→ If coil is vertical, the conductor is moving in parallel to the flux lines and have zero cutting rate

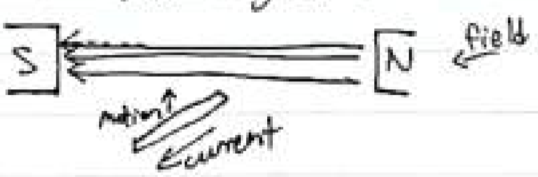
→ If the coil is positioned at an angle tilted to the flux lines, the cutting rate is between zero & maximum

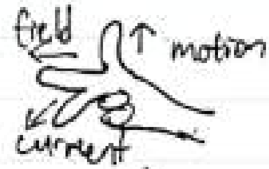
→ If the coil is positioned horizontally, the conductor is moving vertically to the flux lines and will have the maximum cutting rate.



☆. First finger is the magnetic field, direction is from north to south

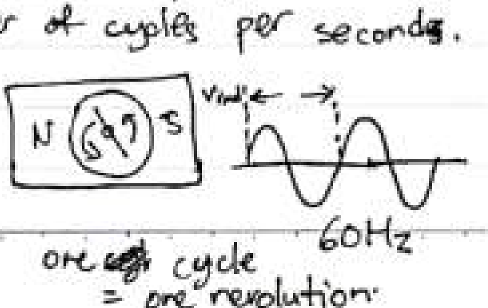
- Thumb points along with the motion direction of the conductor.
- Then second finger tells the direction of the current in the conductor.
- Induced current flowing towards you when the conductor bar cuts across the magnetic field.





☆ Frequency f and rotational speed n

- One revolution of conductor through magnetic field:
  ⇒ One cycle of induced sinusoidal voltage.
- Conductor's rotational speed determines time to complete of one cycle.
- Frequency of a periodic waveform, f = number of cycles per seconds.
- The unit of frequency is hertz (Hz)
- Faster conductor's rotational speed,
  → Higher frequency of induced voltage.



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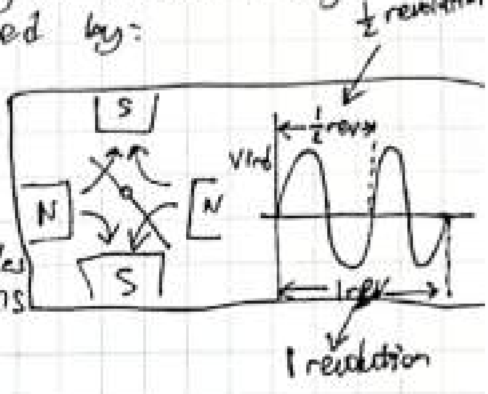
Frequency f and Rotational speed n.

- Faster conductors rotational speed, higher frequency of induced voltage
- Frequency of the ac voltage can also be increased by:
  - ☆ Adding the number of magnetic poles



Frequency $f = p \times n$.
where p = number of pole pairs.
→ one pole pair ⇒ a set of N and S poles
n = rotational speed, in number of revolutions per second (rps or rev/s)

Frequency f and rotational speed n

☆ By Faraday's Law, we can derive that the peak induced voltage, $V_p \propto nN$.
- where n is the rotational speed, and
- N is the number of turns of the coil.

☆ However, increasing n will increase the frequency f of the sinewave, which is undesirable. $f = n \times p$.

☆ The frequency of electricity supply is usually fixed at 50Hz or 60Hz

☆ Hence, we can generate high AC voltage by increasing the number of coil N.

Example:

* The conductor loop (rotor) of a simple two-pole generator rotates at a rate of 50 rev/s, what is the frequency of the output voltage

$f = p \times n = 1 \times 50 = 50\text{Hz}$

$p = 1$ pole pair $= 2$ poles (N and S)

* In order to produce a 400Hz sinusoidal voltage, at what speed must a four-pole generator be operate?

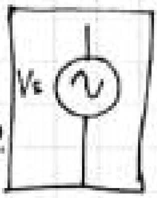
Rotational speed

$n = \frac{f}{p} = \frac{400}{2} = 200 \text{ rev/s}$.

$p = 2$ pole pairs $= 4$ poles.

Generating ac voltage and current.

- The symbol of an ac voltage source.
- It's voltage is in root mean square (rms).



Sinusoidal voltage source symbol.

★ If it is required, it be converted to peak value, V_P.

~~Source~~

Sources of AC waveform:

- AC generator. → supplies sinusoidal voltage & current to power up the home appliances (eg ~~lights~~ lights & etc).
- Function generator.

↓

can generate many types of waves like square wave, but ~~cannot output~~ the output signal is too weak to drive loads that require heavy current

↑

It is generated from 1. power plant.

2. stand by power generator

found in labs & repairing shops.

Terms describing a sine wave.

- ~~The~~ period (T) is the duration to complete 1 cycle of sine wave (unit → s)
- Frequency (f) is the number of complete cycles in one second (unit → Hz)

☆ waveform can be expressed in term of f

$f \Rightarrow V(t) = V_p \sin(2\pi f t) V$

In term of period (T)

$T \Rightarrow V(t) = V_p \sin\left(\frac{2\pi t}{T}\right) V$

- Peak voltage value (Vp) is the maximum positive value / amplitude of the waveform ; negative peak voltage value is ($-V_P$)
- Peak-to-peak voltage (V_{pp}) is the measurement between the two peaks $= 2V_P$

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

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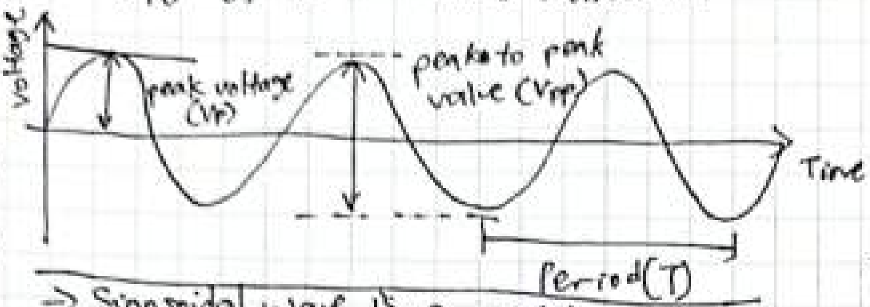
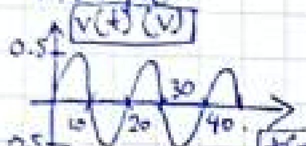
Parameter of a Sinosoidal waveform.



$V(t) = V_p \sin(2\pi f t)\, V$

→ Sinosoidal wave is a periodic wave.
→ A periodic waveform repeats itself. cycle after cycle.
→ A cycle starts anywhere. It ends when it reach the same level.

Example:



Period → 20ms, Frequency → $f = \frac{1}{T}$

Peak voltage → 0.5V $\quad f = \frac{1}{20\times10^{-3}} = 50Hz$

peak-to-peak voltage → $V_{PP} = 2 \times V_p = 2 \times 0.5 = 1V$

↓

The general waveform equation:

$$V(t) = V_p \sin(2\pi f t)\, V$$
$$= V_p \sin\left(\frac{2\pi f}{T}\right) V$$
$$= 0.5 \sin\left(\frac{2\pi t}{20\times10^{-3}}\right) V = 0.5 \sin(2\pi\times 50 \times t)\, V = 0.5 \sin(100\pi t)\, V$$

Describing a sinosoidal wave form.

$V(t) = V_p \sin(\underbrace{2\pi f t}_{\text{is in radian.}})$ $\qquad v(\theta) = V_p \sin(\theta)$

$2\pi f t$ is often lumped up as a single variable θ, so $\theta = 2\pi f t$.

Phase is an angular measurement ~~specyfing the~~ specifying the position of sine wave relative to a reference.

θ rad

Example:
a sine wave has a frequency of 200Hz. Determine the time to reach 36° after crossing zero level.

$\theta = 36° = 36 \times \frac{\pi}{180} = 0.2\pi$ rad.

$\theta = 2\pi f t$.

$t = \frac{\theta}{2\pi f} = \frac{0.2\pi}{2\pi\times200} = 0.0005s = 500\mu s$

Example:
- The general equation is

$v(t) = V_p \sin(2\pi f t)$

Given that $V_p = 300V$

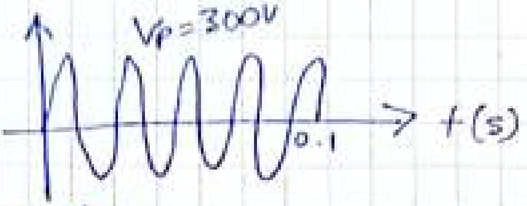
Time to complete 5 cycles = 0.1 s.

period $T = \frac{0.1}{5} = 20ms$

frequency $= \frac{1}{T} = \frac{1}{20\times10^{-3}} = 50Hz$.

$v(t) = 300 \sin(2\pi \times 50 \times t)$

$= 300 \sin(100\pi t) V$



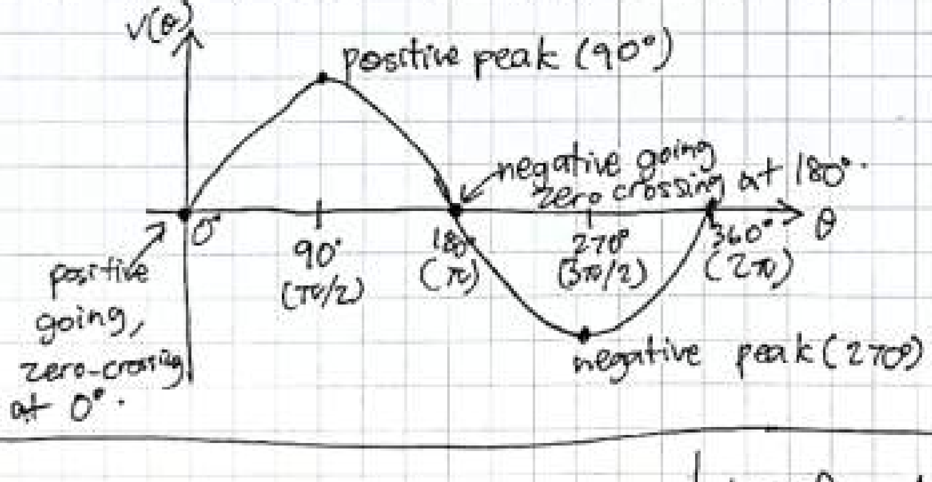
Phase ϕ of a sine wave

The general equation of sine wave with a phase angle of $\pm\phi$ is

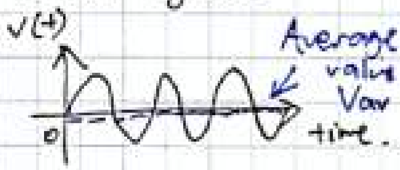
$v(\theta) = V_p \sin(\theta \pm \phi) V$

$0°$ is taken as the reference point.

If. $\phi = 0°$, $v(\theta) = V_p \sin(\theta)$, a sine wave.

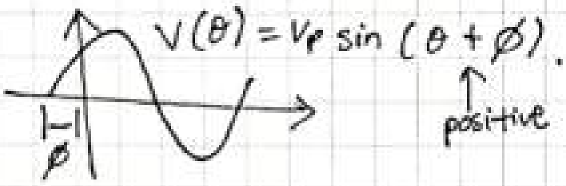


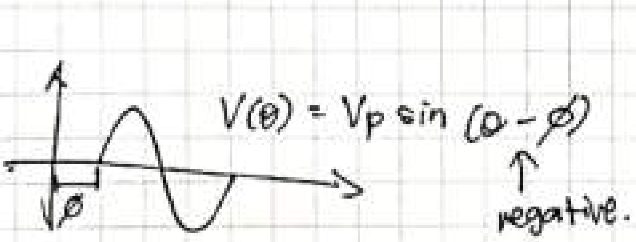
Average voltage over a full cycle.



$V_{av} = 0$.

The average value of a sinusoidal wave is always 0

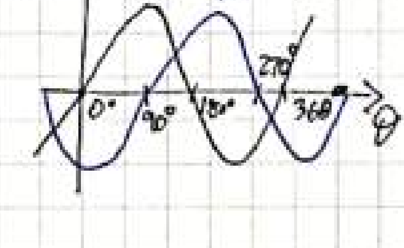




Waveform A rises above zero level 90° earlier than waveform B.

A Leads B by 90°

B Lags A by 90°.



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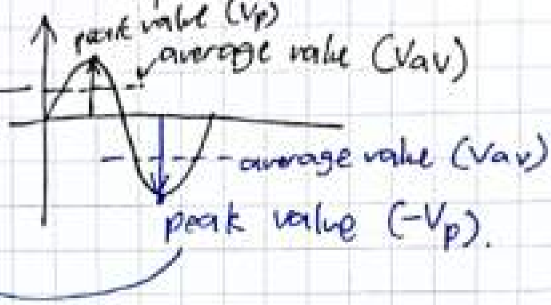
Values associated with sinosoidal waveform.

$$\boxed{V_{av} = \frac{2}{T}\int_0^{\frac{T}{2}} v(t)\,dt.}$$ ← mathematical equation.

where $v(t) = V_p \sin(2\pi f t)$

The average value over a positive or negative half cycle of a sinusoidal wave is

$V_{av} = \frac{2}{\pi} V_p$



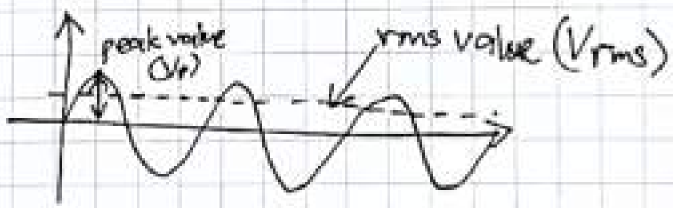
$V_{av} = -\frac{2}{\pi} V_p$

RMS.

Root mean square (rms) voltage.

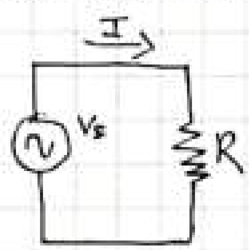
$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v(t)^2\,dt}$, where $v(t) = V_p \sin(2\pi f t)$

$V_{rms} = \frac{V_p}{\sqrt{2}}$



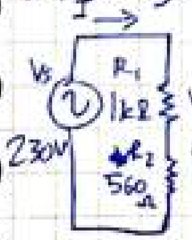
Circuit Laws & rules in AC circuits.

- All circuit laws & rules apply to AC circuits in the same way they apply to DC circuits
- For an AC circuit, all AC Voltages & currents are assumed to be rms values unless otherwise specified.



Example:

All voltage & current are in rms value



$R_T = 1k\Omega + 560\,\Omega = 1.56k\Omega$

$I = \frac{V_s}{R_T} = \frac{230V}{1.56k\Omega} = 147.4mA$

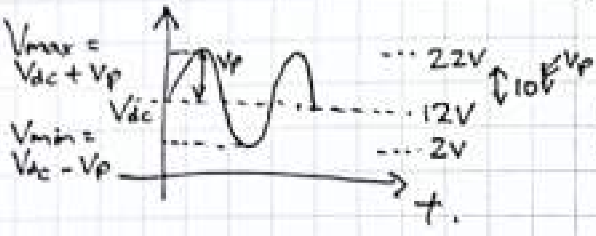
Voltage drop $R_1 = V_1 = I \times R_1 = 147.4mA \times 1k\Omega = 147.4V$

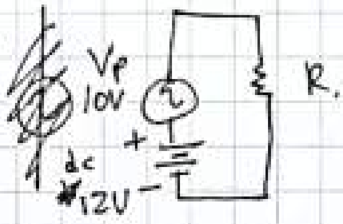
Voltage drop $R_2 = V_2 = I \times R_2 = 147.4mA \times 0.56\,k\Omega = 82.5V$

Superimposed DC & AC voltage.

If $V_{dc} > V_p$.

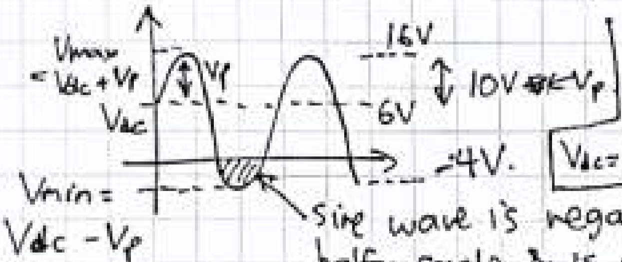
The combined voltage waveform shows that, sine wave don't reverse polarity & is non-alternating.

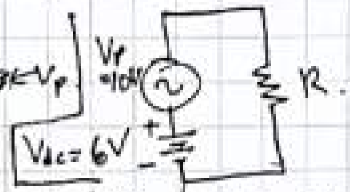




If $V_{dc} < V_p$.

The combined voltage waveform shows that.





sine wave is negative during certain portion of its lower half-cycle & is alternating

1

Unit 12 PEEE

Capacitors.

☆ Has the ability to store electrical energy.
☆ Made of 2 parallel conductive plates separated by an insulating material called dielectric

symbol

Capacitance:

The ~~higher~~ higher the charge (Q), the higher the voltage (V) across the capacitor.

$\therefore Q \propto V$

Hence → $Q = CV$ / $C = \frac{Q}{V}$

$\frac{Q}{C \mid V}$

charge stored.

voltage across the capacitor

capacitance
↳ unit → Farad (F)

A 1F capacitor exhibits 1V across it's plates when 1C of charge is being stored

The larger the capacitance (C), the higher the charge (Q) storing ability

overlap ~~area~~ $C \propto A$ ↓

overlap area

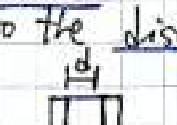
FACTORS AFFECTING CAPACITANCE.

☆ It is ~~directionally~~ directly proportional to the plate ~~&~~ area, A.
☆ It is indirectly proportional to the distance between the plates, d.

$C \propto \frac{1}{d}$

$\uparrow A = \uparrow C$ / $\downarrow d = \uparrow C$

$\downarrow A = \downarrow C$ / $\uparrow d = \downarrow C$



The absolute permeability in vaccum.
↓
$\varepsilon_0 \Rightarrow 8.85 \times 10^{-2}$ F/m.

☆ ~~Ik~~ It is also affected by the type of dielectric used.
- ~~Ik~~ ε (epsilon) is the permittivity of the dielectric
- Permittivity is a measure of material's ability to establish an electric field.

depends on the material → It is ~~directionally pro~~ directly proportional to the capacitance, C

$C \propto \varepsilon$

$$\boxed{\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}}$$

$$\boxed{C = \frac{\varepsilon A}{d} \; / \; C = \varepsilon \frac{A}{d} = \varepsilon_r \varepsilon_0 \frac{A}{d}}$$

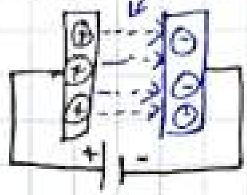
ε_r => relative permittivity.
ε_0 => absolute permittivity of vacuum
ε => permittivity of dielectric

C => capacitance → Farad.
A → area of overlap → m^2.
d = distance between plates → m

How A capacitor stores Energy.
→ It is stored in a form of an electric field established by opposite charges on both plates.
→ Electric field: line of force between ~~positive~~ +ve and −ve charges and is concentrated within dielectric

→ Energy stored in capacitor ⇒ $\boxed{W = \frac{1}{2}CV^2}$

electric field/ lines of electric force.



TYPES OF CAPACITORS

~~Max capacitors~~ Max DC voltage that can be applied to it.
Voltage rating: (can be called breakdown voltage/ working voltage).
Real capacitors can breakdown & start conducting ~~voltage~~ if the voltage applied to it is too high.

Dielectric Strength → of a dielectric determines breakdown voltage of a capacitor.

Leakage: Dielectric is not perfect electric insulator.
A very small amount of current is conducted between the 2 plates
↳ This can result, that any charge stored by a capacitor will eventually leak off.

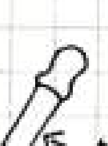
Capacitors are classified according → ① The material of dielectric.
→ ② If it is polarized or non-polarized.
→ ③ If the capacitor is fixed or variable

① ~~Materials~~ Tyically used Materials : - mica
- ceramic
- plastic film.
- electrolytic (aluminium oxide and tantalum oxides)

Fixed capacitors : Non-polarized.
→ Mica capacitos : 1 pF ~ 0.1 μF. ← capacitance value.
100V ~ 2500V ← voltage rating

→ Ceramic capacitors: 1pF ~ 2.2μF ← capacitance value
up to 6KV ← voltage rating.

→ Plastic film : up to 100μF ← capacitance value.
(poly carbonate capacitors)



positive lead.

~~Electrolytic capacitors~~:
Polarized capacitors: Tantalum capacitors
→ Electrolytic Capacitor → positive lead should be connected to the circuit lead with higher potential, while the negative to the lower potential

3.

Unit 12 PEEE

Variable capacitors

→ Used when capacitance value needs to be adjustable either manually or automatically.

→ Eg. Radio on TV tunners.

→ Capacitance is changed by adjusting plate overlap area.

← Symbol.

HOW IT STORES CHARGE?

① In neutral state, both plates contain equal amount of electrons

② Charging: → When connected to a Voltage source.

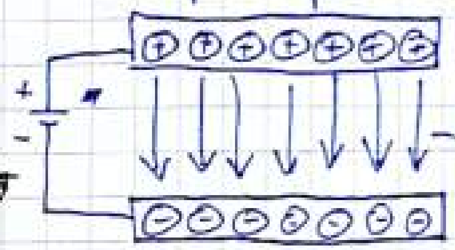
→ Upper plate : Electron ~~move~~ removed.

→ Lower plate : Electron deposited.

} Electron moved from +ve to -ve.

③ During the charging process, electrons flows from upper plate, through the connecting leads and the source, to the lower plate.

- parallel plate capacitor.



④ Upper plate loss electrons → becomes more positively charged.

Lower plate gains electrons → becomes more ~~negatively~~ negatively charged.

⑤ Movement of electrons stops at the plates because they cannot flow through the insulating dielectric, Voltage builds up across plates.

uniform electric ~~fie~~ field is produced

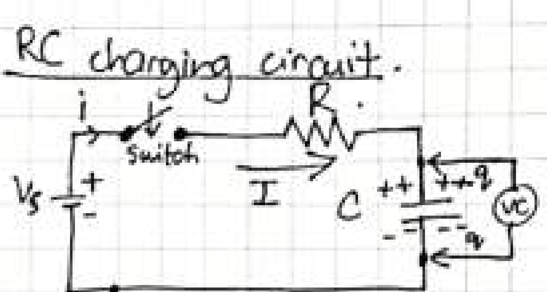
⑥ Movement stops when voltage across capacitor equals source voltage, V_s.

→ The external source cannot move charge anymore: the capacitor is now fully charged

→ If capacitor is now disconnected from source, it can retain the stored charge for a long time.

→ It can act as a temporary battery.

RC charging circuit.



Time Constant & Charging Curves

→ Time is required for a capacitor to charge or discharged fully.

→ Amount of time required depends on the time constant τ (tau) of the circuit.

$$\tau = RC$$

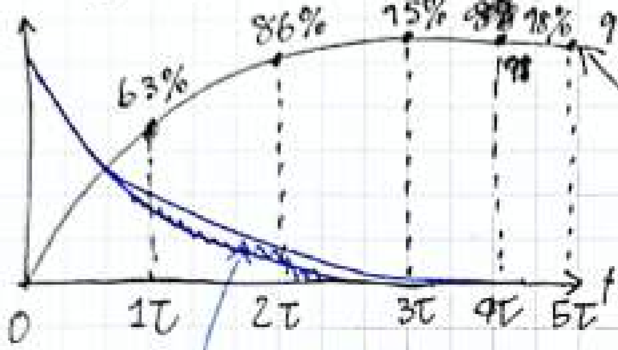
time constant (s)

resistance (Ω)

capacitance (F)

Time constant & charging curves

- τ is the amount of time needed to charge a capacitor to ~~appox~~ approximately 63.2% of it's final value.
- At 5τ, it is considered fully charged.
- Every capacitor circuit has same amount of Resistance (R), present.



$$V_c(t) = V_s\left(1 - e^{-\frac{t}{\tau}}\right)$$

$V_c(t)$ capacitor voltage during charge

$i_c(t)$ Capacitor current during charging

$$i_c(t) = \left(\frac{V_s}{R}\right) e^{-\frac{t}{\tau}}$$

- It take 5τ for the capacitor voltage to reach 99% of the final value (supply voltage)
- A fully charged capacitor appears as an open circuit.

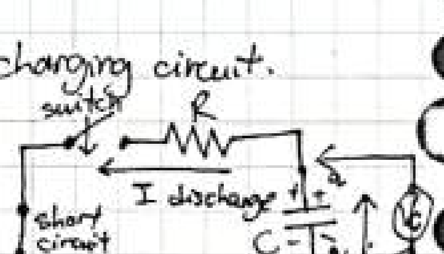
In a steady state $\rightarrow t > 5\tau$, $V_c(t) = V_s$, $i_c(t) = 0$.

An uncharged capacitor appears as a short circuit.

$$\boxed{\begin{array}{l} \text{At } t = 0. \\ V_c(t) = 0 \\ i_c(t) = \frac{V_s}{R} \end{array}}$$

RC Discharging Circuit.

Discharge current is opposite to that of the charging circuit.

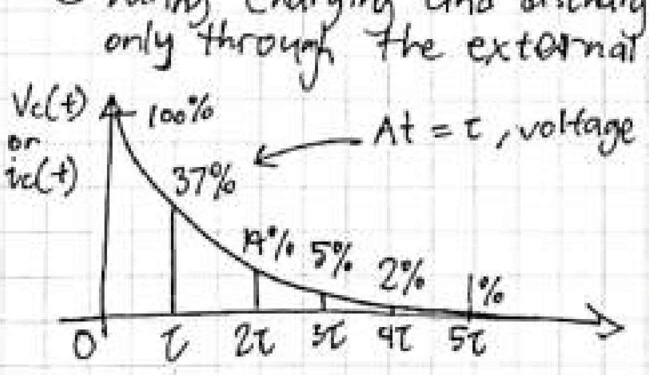


① When the switch closes, the excess electrons move from lower plate to upper plate (opposite to the conventional current flow) through the external circuit.

② Energy stored in an electric field by capacitor is converted back into discharging electric circuit.

③ During charging and discharging, current flows from one plate to another only through the external circuit.

equal or neutral



At $= \tau$, voltage / current is 63% of the journey to zero.

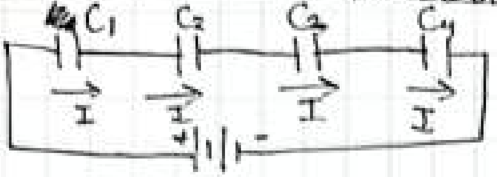
- It takes 5τ for the capacitor to decrease 99% of it's initial value.
- $t > 5\tau$, $V_c(t) = 0$, $I_c(t) = 0$
- $Q = 0$, $W = 0$,

Electrons stop moving when number of free electron on both plate are equal

5

Unit 12 PEEE.

Capacitors in Series ~~& Parallel~~



Like in series circuits, charging current I is same for all capacitors in the above circuits.
Since $Q = I \times t$ → all capacitors store same amount of charge

$$\therefore Q_T = Q_1 = Q_2 = Q_3 = Q_4 = Q_n$$

Equation → $C_T = \dfrac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_n}}$ ← Capacitance in series

The total series capacitance is always less than the smallest capacitance.

→ $C_T = \dfrac{C_1 C_2}{C_1 + C_2}$ ← 2 capacitor in series

→ $C_T = \dfrac{C}{n}$ ← capacitors of equal values.

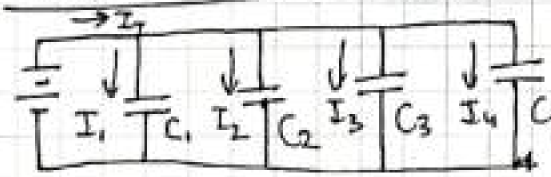
n: number / amount of capacitors.

Capacitors connected in series acts as a voltage divider.

Since $Q_1 = Q_T$
$C_1 V_1 = C_T V_T$ → $V_1 = \left(\dfrac{C_T}{C_1}\right) V_T$ / $\boxed{V_x = \left(\dfrac{C_T}{C_x}\right) V_T}$ ← General Equation

Largest value capacitor has smallest voltage, while smallest value capacitor has the largest voltage.

Capacitor in Parallel



By KCL → $I_T = I_1 + I_2 + I_3 + I_n$
so $Q = I \times t$, where t is common.
so $\dfrac{Q_T}{\cancel{t}} = \dfrac{Q_1}{\cancel{t}} + \dfrac{Q_2}{\cancel{t}} + \dfrac{Q_3}{\cancel{t}} + \dfrac{Q_n}{\cancel{t}}$
(cross out t)

$\boxed{C_T = nC}$

If all the capacitor have the same value C

$Q_T = Q_1 + Q_2 + Q_3 + Q_n$.
↓
$C_T V_T = C_1 V_1 + C_2 V_2 + C_3 V_3 + C_n V_n$
where $V_T = V_1 = V_2 = V_3 = V_n$

(Total capacitance)
Sum of capacitance in parallel → $\boxed{\therefore C_T = C_1 + C_2 + C_3 + C_n}$

Unit 13 PEEE

Inductors:

- A length of wire ~~is~~ is formed to a coil.
- Store energy in it's magnetic field.

symbol for inductor.

- Inductance is the property of a wire coil that opposes any change in current going through the coil.

A coil used in this way is called → an inductor / a 'choke'.

~~☆~~ Factors that determine inductance:

- The number of coil turns, N.
- The length ~~of~~ of the coil, l
- The cross sectional area of the coil, A.
- The type of material in it's core, μ.

☆ Formula that relates the factors

- Inductance is directly proportional to N^2. ← $L \propto N^2$
- A & μ ~~both~~ is indirectly proportional ~~to~~ to length, l ← $A \& \mu \propto \frac{1}{l}$

$$L = \frac{N^2 \mu A}{l}$$

μ → permeability of the material.

↳ In vacuum → $4\pi \times 10^{-7}$ Wb / At.m (weber / ampere - turn.meter)

↳ Air has same permeability as vacuum.

↳ ~~A~~ While all ferromagnetic core materials have higher permeability.

μ_r → relative permeability

↳ the ratio of absolute permeability to permeability of a vacuum is called relative permeability of a material.

↳ $\left(\mu_r = \frac{\mu}{\mu_0}\right)$ / $(\mu = \mu_r \mu_0)$ → For air - core inductors

↓

$\mu_r = 1$

Self inductance

← The measure of a coil's ability to establish an induced voltage, V_L as a result of a change in it's current

Inductance is 1H when current changing at a rate of 1A/s, flows into a coil and induces 1V across the coil.

$$V_L = L \times \frac{d_I}{d_t}$$

L ← Inductance (H) ← H → henries.

$\frac{d_I}{d_t}$ ← rate of change of the current in the inductor (A/s)

V_L ← Induced voltage ~~across~~ across an inductor (V)

Energy stored

An inductor stores energy in the magnetic field created by the current.

$$W = \frac{1}{2} L I^2$$

L ← Inductance (H)

I ← current ~~(I)~~ (A)

W ← energy (J)

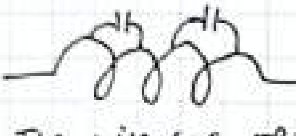
Winding Resistance

- Coil is made of a wire, an inherit resistance called winding Resistance R_w is present.
- Although this resistance occurs along the whole length of wire it can be represented as an R_w in series with L.

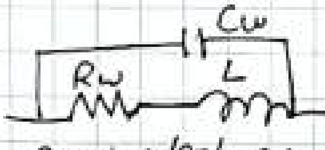
has R along it's length

Equivalent circuit.

R_w is usually small → can be ignored → so coil is considered as an ideal inductor.



The wire has resistance & capacitance distributed



equivalent circuit.

C_w = winding capacitance.

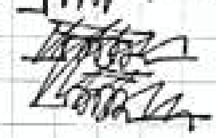
C_w → typically very small so no significant effect. but if high frequency, it can be important.

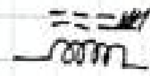
Types.

Fixed → 

Variable → 

air core → 

iron core → 

ferrite core → 

The polarity of the induced voltage is in a direction that opposes the change in current.

The Winding resistance & winding capacitance, fixed & variable inductors are some applications of inductors.

Example.

Determine the inductance of the coil assuming $N = 350$, $l = 1.5\text{cm}$, the radius of the cylindrical core material, $r = 0.25\text{cm}$, and μ of core is $0.25 \times 10^{-3}\ \text{H/m}$

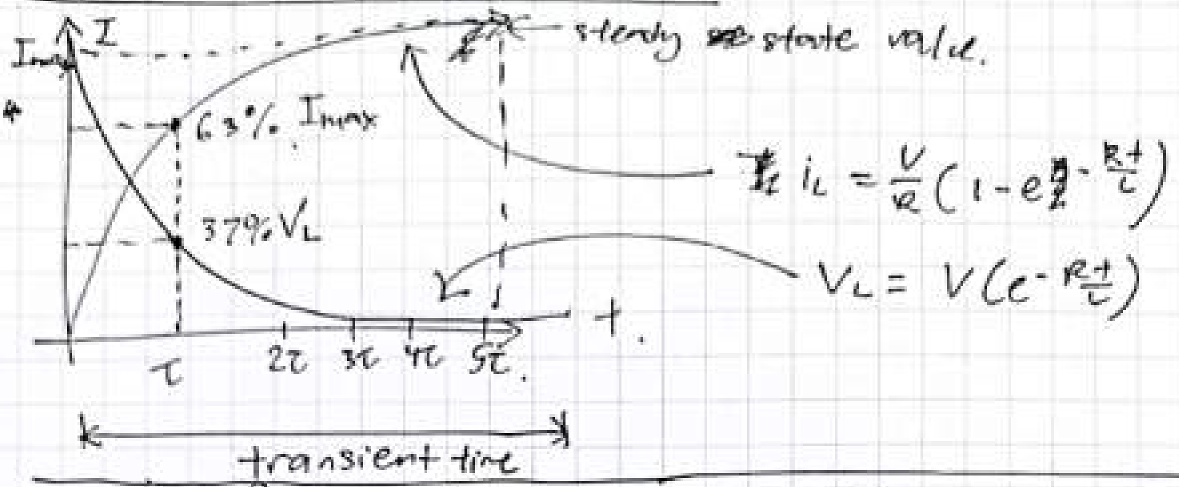
$$l = 1.5\text{cm} = 0.015\text{m}$$

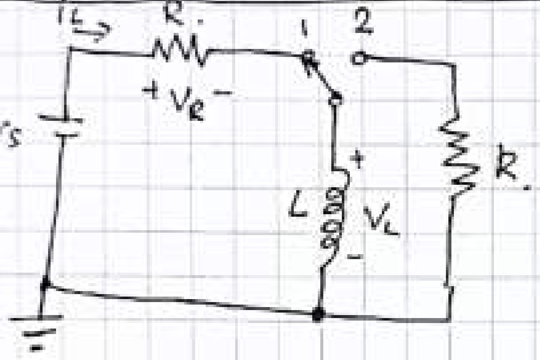
$$A = \pi r^2 = \pi(\underbrace{0.25 \times 10^{-2}}_{\text{convert to meter}})^2 = 1.96 \times 10^{-5}\ \text{m}^2$$

$$L = \frac{N^2 \mu A}{l} = \frac{350^2 (0.25 \times 10^{-3})(1.96 \times 10^{-5})}{0.015} = 40\text{mH}$$

Unit 13 PEEE

Charging & Discharging inductance.





When switch closes at $t = 0$ to position 1, inductor will prevent ~~~~ instant change of current due to induced voltage that opposes a change in current.

Time is required for ~~~~ inductor current, i_L to build up to it's maximum value.

$\tau = \frac{L}{R}$. τ = time constant (s) R = resistance (Ω)
L = inductance (H)

※ Time constant is the time taken by current to reach ~~app~~ ~~approx~~ approximattely 63% of it's final value I_F.

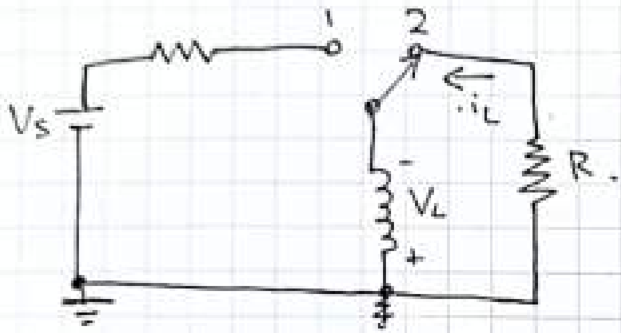
At $t = 0$, $i = 0$, $V = I \times R = 0V$
So, at $t = 0$, inductor behaves as an open circuit.
As time progresses, the inductor current, i_L, will rise ~~expone~~ exponentially from zero, as given by. $i_L = \frac{V_s}{R}(1 - e^{-\frac{t}{\tau}})$

At $t = \tau$, it will reach 63% of it's current.
final value of it's final current, I_F
At $t = 5\tau$, current will ~~read~~ reach about 99% of the max value.
$t = 5\tau$ is usually considered as the time taken by the current to reach it's final or steady state value $\rightarrow I_F = \frac{V_s}{R}$

At steady state, $i_L = \frac{V_S}{R}(1 - e^{-\frac{t}{\tau}})$

$V_R = V_S$ and $V_L = 0V$

At $t = \infty$, inductor behaves like a short circuit.



If the ~~swith~~ switch is ~~g~~ put on 2, the inductor current, i_L, will decrease exponentially to zero, as given by:

$$i_L = \frac{V_S}{R}(1 - e^{-\frac{t}{\tau}})$$

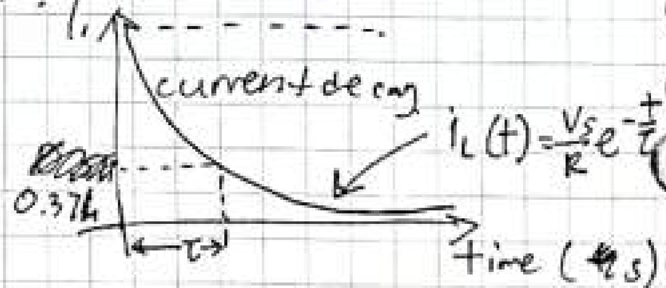
At the instant of opening the switch $(t=0)$: $i_L = \frac{V_S}{R}$.

~~If the switch is~~

At time $t = \tau$, the current, i_L, would have decreased exponentially by about 63% from it's ~~initial~~ initial value.

At $t = 5\tau$, the current, will decrease by about 99% from it's initial value.

$t = 5\tau$ is usually considered as the time taken by the current to reduce to 0A.



OPEN CIRCUIT

⇓

$t = 0$.

$t =$ infinity (∞)

⇓

SHORT CIRCUIT.

$t = 0$, $i_L = \frac{V_S}{R}$

$$i_L(0) = \frac{V_S}{R}e^{-\frac{0}{\tau}} = \frac{V_S}{R}e^0$$

$$= \frac{V_S}{R}.$$

At $t = \tau$, current drops by 64% from it's max value.

$$i_L(\tau) = \frac{V_S}{R}e^{-\frac{\tau}{\tau}} = \frac{V_S}{R}e^{-1}$$

$$= 0.37\frac{V_S}{R}.$$

$t = 5\tau$

drops by $\approx$ 99% of max.

$= 0.01\frac{V_S}{R}$

Unit 14 PEEE

Mutual Inductance

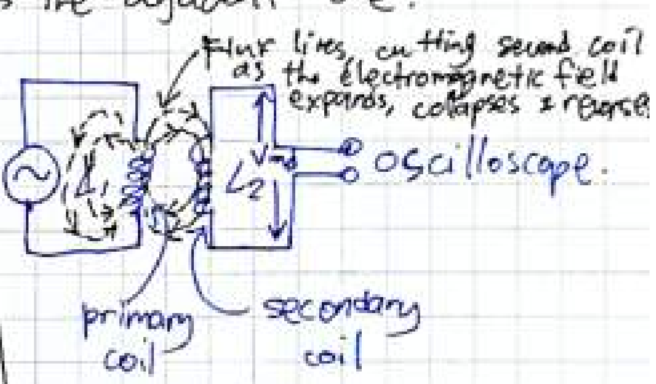
When the magnetic flux from 1 coil cuts an adjacent coil, a voltage is induced in the second coil. This is due to the presence of mutual inductance between the 2 coils.

A transformer works on the principle of Mutual Inductance.

A transformer has 2 coils: - Primary coil
- Secondary coil.

A voltage is ~~[illegible]~~ induced in the second coil when the Magnetic Flux from the first coil cuts the adjacent one.

~~REST~~
Mutual Inductance (L_M) ~~&~~
Dependent on self-inductance of each coil (L_1 & L_2) ~~each~~
Co.eff of coupling (k) between them.



↳ ratio of flux lines produced by primary coil that links to the secondary coil (ϕ_{1-2}) to the total flux produced (ϕ_1)

Formula ~~of~~ for coefficient of coupling:

$$k = \frac{\phi_{1-2}}{\phi_1}$$

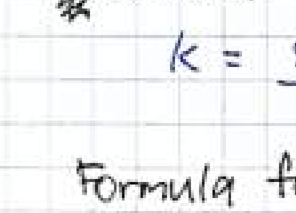
Formula for Mutual Inductance:

$$L_M = k\sqrt{L_1 L_2}$$

coefficient of coupling

k deppends on: → The physical closeness of the coils
→ The type of core material used.
→ construction ~~[illegible]~~ and shape of the core.

☆ Perfect coupling happens when $k = 1$.



$$V_{ind} = L_m \underbrace{\frac{di}{dt}}_{\text{rate of change of the primary current}}$$

$L_M = \frac{k N_p N_s \mu A}{l}$

$N_p \to$ turns in primary coil.
$N_s \to$ turns in secondary coil.
$k \to$ coeff of coupling between 2 coils ~~2 coil~~.
$\mu \to$ permeability of the ~~core material~~ core material.
$A \to$ cross-sectional area of the coil.
$l \to$ length of the coil.

function of core
core $\to$ a physical structure for the winding & a magnetic path so the flux is concentrated close to the coils.

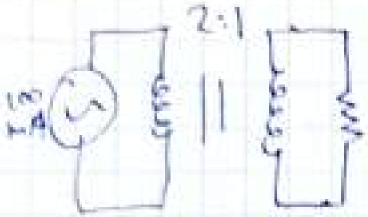
A basic transformer is an electrical device constructed of 2 coils wounded on a common core or frame
1 coil is primary & the other is secondary winding

Types of transformer	STEP UP	~~STEP~~ STEP DOWN.
DEPENDENT ON	Turn Ratio	~~Turn Ratio~~
Concept	$N_{pri} < N_{sec}$ $n = \frac{N_{sec}}{N_{pr}} > 1$	$N_{pri} > N_{se}$ $n = \frac{N_{se}}{N_{pri}} < 1$.
General Formula.	$n = \frac{N_{sec}}{N_{pri}} = \frac{V_{sec}}{V_{pri}}$	$n = \frac{N_{sec}}{N_{pri}} = \frac{V_{sec}}{V_{pri}}$
Secondary Voltage	$V_{sec} = \left(\frac{N_{sec}}{N_{pri}}\right) V_{pri} = n V_{pri}$ since $n > 1$, $V_{sec} > V_{pri}$	$V_{sec} = \left(\frac{N_{sec}}{N_{pri}}\right) V_{pri} = n V_{pri}$ Since $n < 1$, $V_{sec} < V_{pri}$

Unit 14 PEEE

Example

$I_s = \left(\frac{N_p}{N_s}\right) I_p = 0.1 \times 100mA = 10mA$



$I_s = \left(\frac{N_p}{N_s}\right) I_p = 2 \times 100mA = 200mA.$

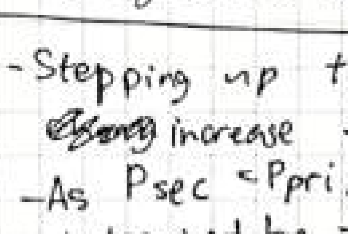
Direction of windings

- Another important transformer parameter is the direction which the windings are placed.
- The direction of the windings determines the polarity of the voltage across the secondary winding. (secondary voltage) with respect to the voltage across the primary winding (primary voltage).
- Phase dots are used on the schematic symbols to indicate the voltage polarities.

$P_{sec} = V_{sec} \times I_{sec} =$

$V_{pri} I_{pri} = P_{pri}$

voltages are in phase.



voltages are out of phase.

Power in transformers

power

$P_{pri} = P_{sec}$

$P_{pri} = V_{pri} \times I_{pri}$

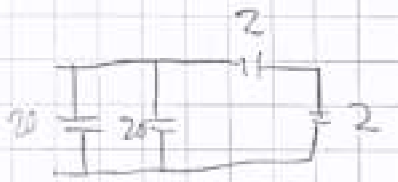
$P_{sec} = V_{sec} \times I_{sec}$

- Stepping up the output voltage will not increase the output power.
- As $P_{sec} = P_{pri}$, the output power is determined by the input power.
- If voltage is step up, the current will be step down. $n = \frac{V_s}{V_p} = \frac{I_p}{I_s}$

Power

- power transfed to the load can <u>never</u> be greater than the power in the primary winding.

- ~~[illegible]~~ When losses are ~~[illegible]~~ considered, some of the power is dissipated in the transformer rather than the load; therefore, the load power is always less than the power delivered to the primary.



$$\left(\frac{1}{2}+\frac{1}{2}\right)^{-1}=1$$

$$1+20+20$$