Session A:

Elementary Electricity and Magnetism:

Presented by
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Topics:

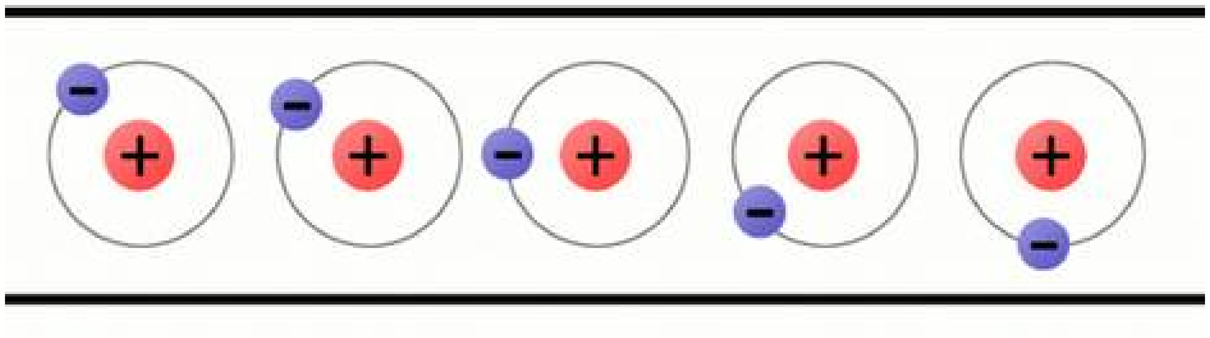
1. Elementary theory of electricity- Passive Devices (Resistors; Inductors, Transformers, Capacitors) and Active Devices (Diodes; Transistors).
2. Kirchoff's current and voltage laws- Simple applications of the law.
3. Conductors and Insulators — Properties; units of circuit elements, Ohm's Law.
4. Conductance — Definition of self and mutual inductance;
5. Power and energy- Definition, Units and simple applications.
6. Permanent magnets and electromagnets — Definition, properties and their use.

Elementary theory of electricity

Electricity deals with flow of charge (free flowing electrons)

Most people give credit to Benjamin Franklin for discovering electricity (electric fluid).

Some of the electrical terms which Franklin coined during his experiments include:
battery, charge, condensor, conductor, plus, minus, positively, negatively,

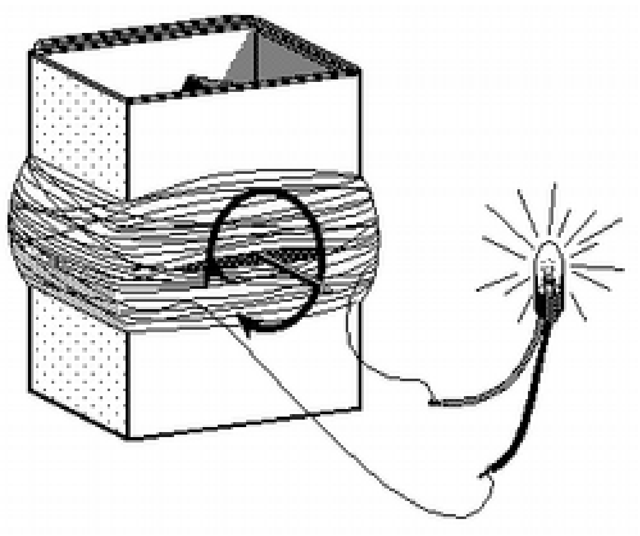


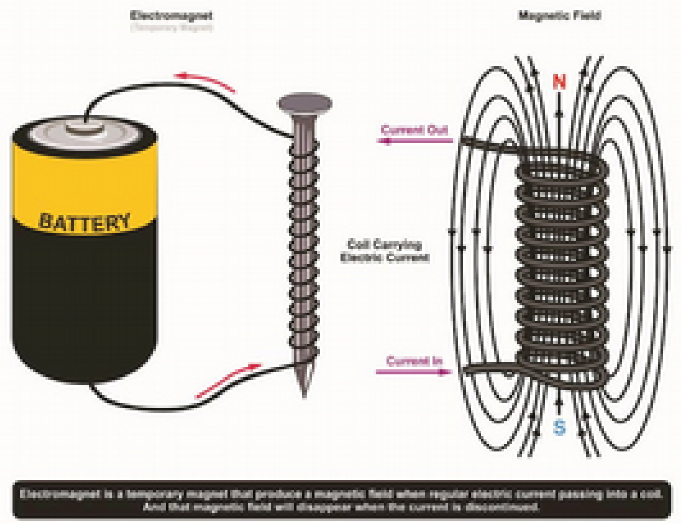
1. Static electricity: - electrons doesn’t flow through insulator, instead they form an electron cloud.
2. Dynamic (Current) electricity:- constant flow of electrons is possible in conductor
    a. Direct current (DC)
    b. Alternating current (AC)

Electromagnetism

1. Flowing electrons produce a magnetic field
2. Spinning magnets cause an electric current to flow.

Electromagnetism is the interaction of these two important forces.





Devices used to control the flow of electrons and magnatism

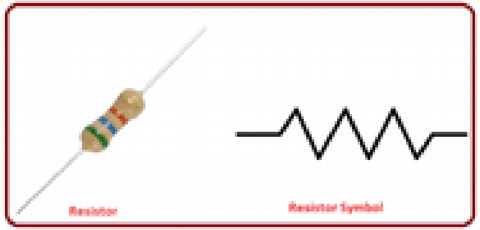
1. Passive Devices
   - Resistors
   - Capacitors
   - Inductors
   - Transformers
   - Antennas

2. Active Devices
   - Diodes
   - Transistors
   - Integrated Circuits

3. Electro mechanical
   - Piezoelectric crystal
   - Switches
   - Circuit breaker

4. Electro magnetic
   - Relays
   - Solenoid
   - Electric bell
   - Loudspeaker

Resistors



- Resistors are used to resist the flow of electricity

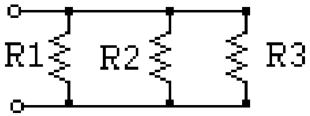
Resistor Types	Resistive element	Resistance range	Tolerance	Use
Carbon composition	Slug of carbon	2.7Ω to 22M Ω	±5%, ±10%, ±20%	ability to withstand high energy pulses. Used in high freq ckt and it has low temperature coefficient
Carbon film	Thin layer of carbon film	1Ω to 100M Ω	±1%, ±2%, ±5%	in high voltage and temperature applications
Metal film	film of metal/alloy/oxide	0.0025 Ω to 500G Ω	±0.05 to ±5%	in circuits where tight tolerance, low temperature coefficient and low noise properties are important
Wirewound	wire wound a insulating core	0.1Ω to 200KΩ	General & precision	Higher order of stability and reliability. Not suitable for high freq ckts

Resistors Cont…..

Resistors in series, just add them up.

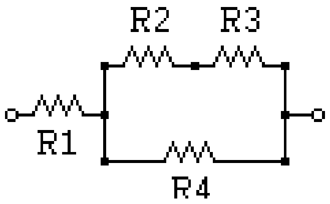
$R_S = R1 + R2 + R3$

Resistors in parallel.

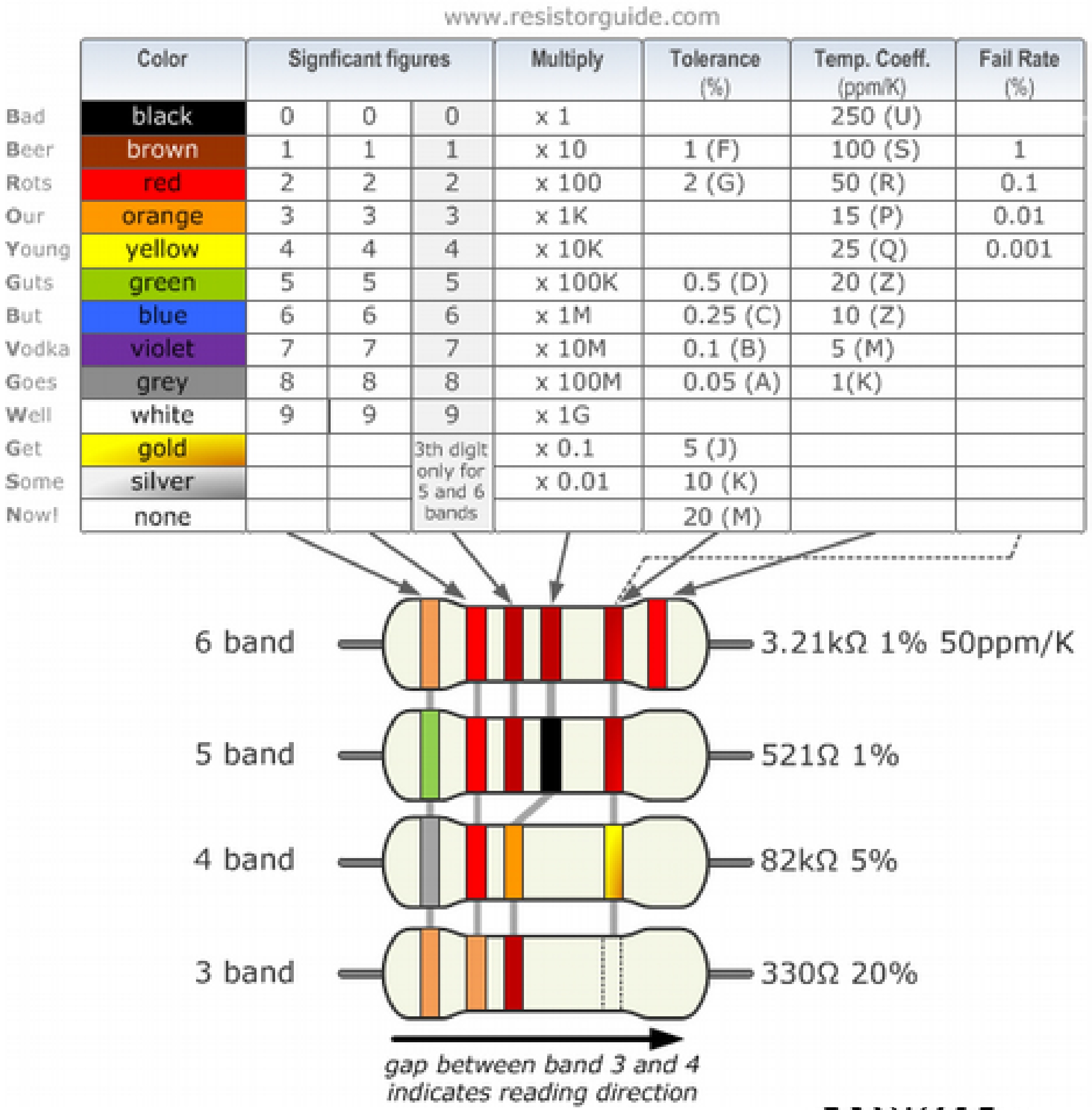


$$R_P = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}}$$

Example

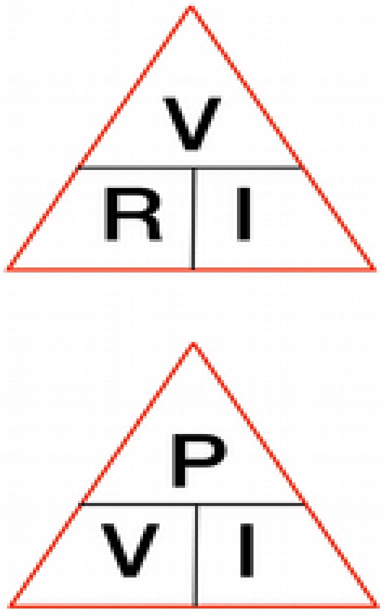


$$R = R1 + \frac{1}{\frac{1}{R2+R3} + \frac{1}{R4}}$$



	Color	Signficant figures			Multiply	Tolerance (%)	Temp. Coeff. (ppm/K)	Fail Rate (%)
Bad	black	0	0	0	x 1		250 (U)	
Beer	brown	1	1	1	x 10	1 (F)	100 (S)	1
Rots	red	2	2	2	x 100	2 (G)	50 (R)	0.1
Our	orange	3	3	3	x 1K		15 (P)	0.01
Young	yellow	4	4	4	x 10K		25 (Q)	0.001
Guts	green	5	5	5	x 100K	0.5 (D)	20 (Z)	
But	blue	6	6	6	x 1M	0.25 (C)	10 (Z)	
Vodka	violet	7	7	7	x 10M	0.1 (B)	5 (M)	
Goes	grey	8	8	8	x 100M	0.05 (A)	1(K)	
Well	white	9	9	9	x 1G			
Get	gold			3th digit only for 5 and 6 bands	x 0.1	5 (J)		
Some	silver				x 0.01	10 (K)		
Now!	none					20 (M)		

Resistors Cont…..

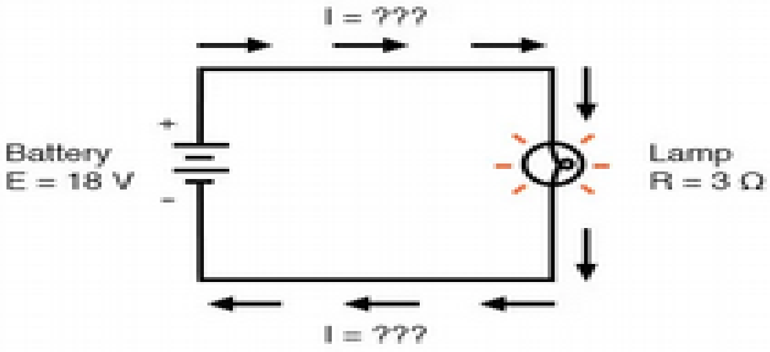


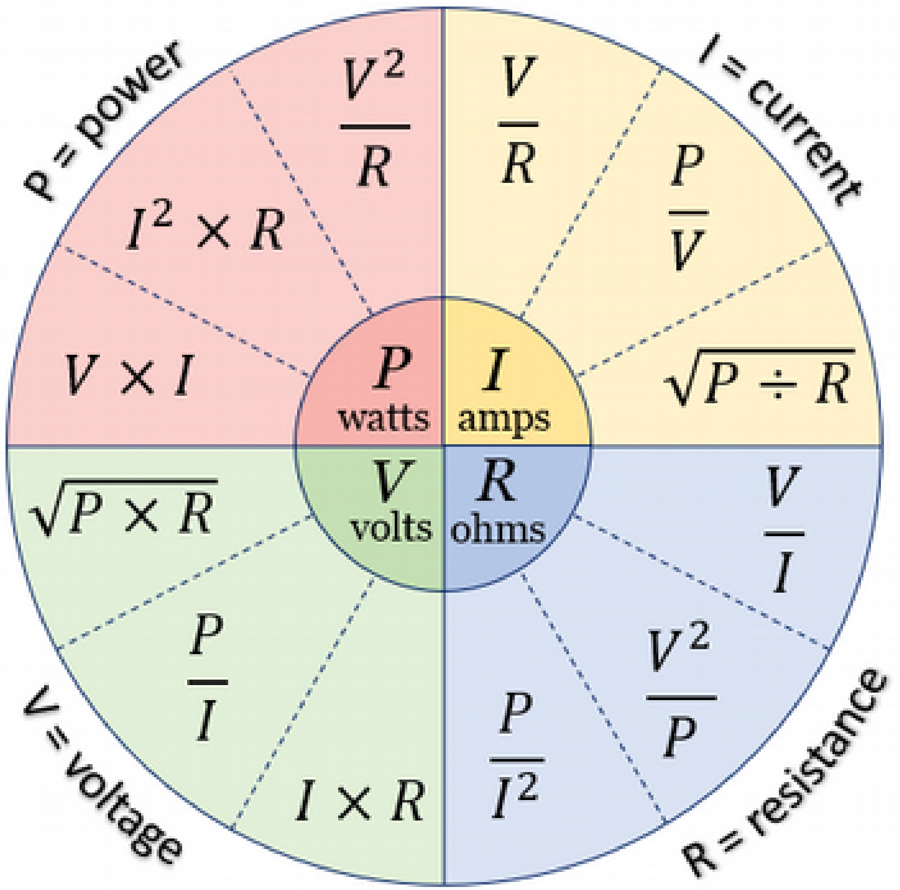
$\frac{V}{R} = I$ $\frac{V}{I} = R$

$R \times I = V$

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

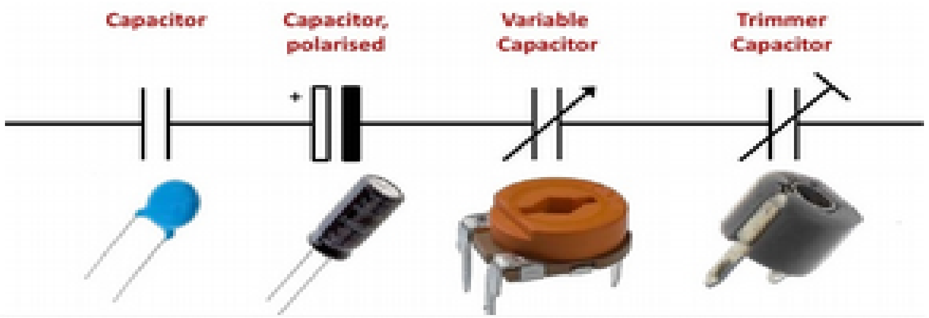
$V \times I = P$





Capacitors

- Capacitors are used to store energy in the form of electric field.
- Capacitor usually opposes the change in voltage

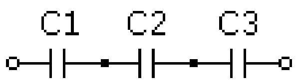


Types of Capacitor	Preferred Applications	Not Suitable For
Paper Capacitors	Motor Starting	-
Mica Capacitors	RF Circuits, High Frequency Filters	-
Polycarbonate (PC) Film Capacitors	Replaced by PP Capacitors	-
Polyester (PET) Film Capacitors	DC, Low Power, Low Frequency AC Applications	-
Polypropylene (PP) Film Capacitors	DC and AC Power Applications	-
Polystyrene (PS) Film Capacitors	Replaced by PET Capacitors	-

Types of Capacitor	Preferred Applications	Not Suitable For
Foil Capacitors	Size Constraint Applications	-
Glass Capacitors	Military Grade Applications	-
Class-1 Ceramic Capacitors	High Frequency Applications	-
Class-2 Ceramic Capacitors	Coupling, Decoupling and Bypass	Precision Applications
Aluminium Electrolyte	Power Supply Filters, Audio Circuits	Coupling, Decoupling, Attenuation
Tantalum Electrolyte	Military Audio and DC Circuits	Coupling, Decoupling, Attenuation
Niobium Electrolyte	High Capacitance DC Applications	Coupling, Decoupling, Attenuation
Variable Capacitors	Audio and RF Tuning Circuits, Variable capacitance in electrical devices	

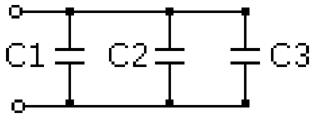
Capacitor Cont.

Capacitors in series.

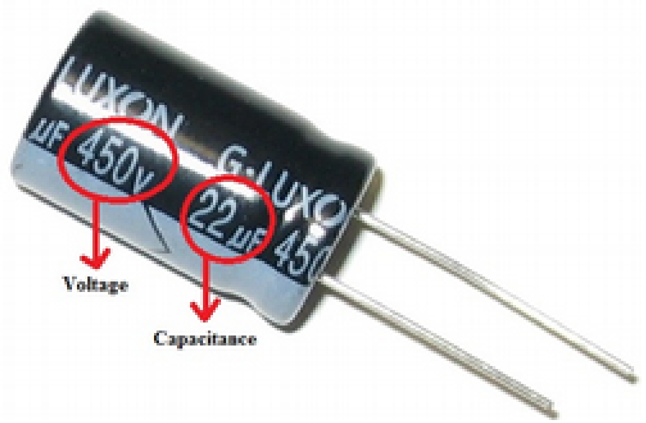


$$C_s = \frac{1}{\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}}$$

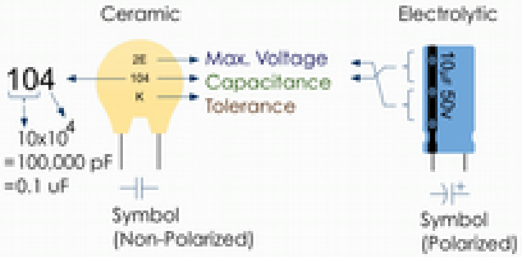
Capacitors in parallel, just add them



$$C_p = C1 + C2 + C3$$



Reading Capacitor Values



Max. Voltage	
Code	Max. Voltage
1H	50V
2A	100V
2T	150V
2D	200V
2E	250V
2G	400V
2J	630V

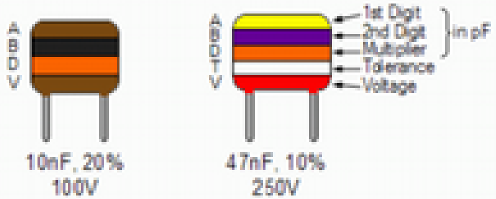
Capacitance Conversion Values		
Microfarads (μF)	Nanofarads (nF)	Picofarads (pF)
0.000001 μF	0.001 nF	1 pF
0.00001 μF	0.01 nF	10 pF
0.0001 μF	0.1 nF	100 pF
0.001 μF	1 nF	1,000 pF
0.01 μF	10 nf	10,000 pF
0.1 μF	100 nF	100,000 pF
1 μF	1,000 nF	1,000,000 pF
10 μF	10,000 nF	10,000,000 pF
100 μF	100,000 nF	100,000,000 pF

Tolerance	
Code	Percentage
B	± 0.1 pF
C	±0.25 pF
D	±0.5 pF
F	±1%
G	±2%
H	±3%
J	±5%
K	±10%
M	±20%
Z	+80%, -20%

Color Code Table

Band Colour	Digit A	Digit B	Multiplier D	Tolerance (T) > 10pf	Tolerance (T) < 10pf	Temperature Coefficient (TC)
Black	0	0	x1	± 20%	± 2.0pF	
Brown	1	1	x10	± 1%	± 0.1pF	-33×10^{-6}
Red	2	2	x100	± 2%	± 0.25pF	-75×10^{-6}
Orange	3	3	x1,000	± 3%		-150×10^{-6}
Yellow	4	4	x10,000	± 4%		-220×10^{-6}
Green	5	5	x100,000	± 5%	± 0.5pF	-330×10^{-6}
Blue	6	6	x1,000,000			-470×10^{-6}
Violet	7	7				-750×10^{-6}
Grey	8	8	x0.01	+80%,-20%		
White	9	9	x0.1	± 10%	± 1.0pF	
Gold			x0.1	± 5%		
Silver			x0.01	± 10%		

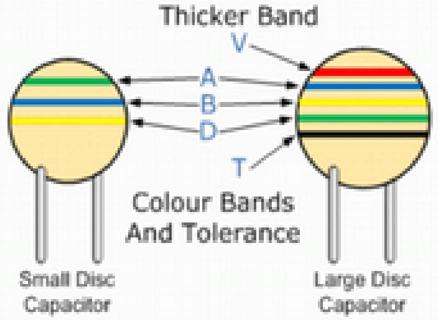
Metalised Polyester Capacitor



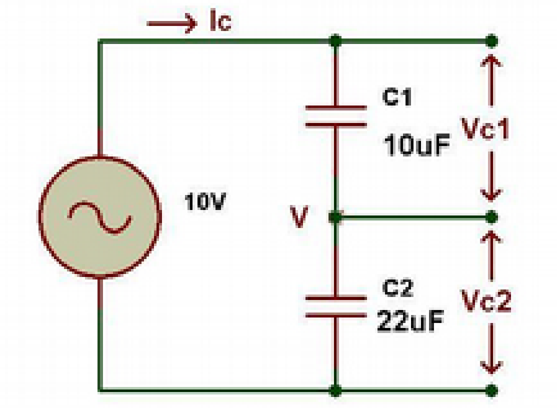
Voltage Color Codes

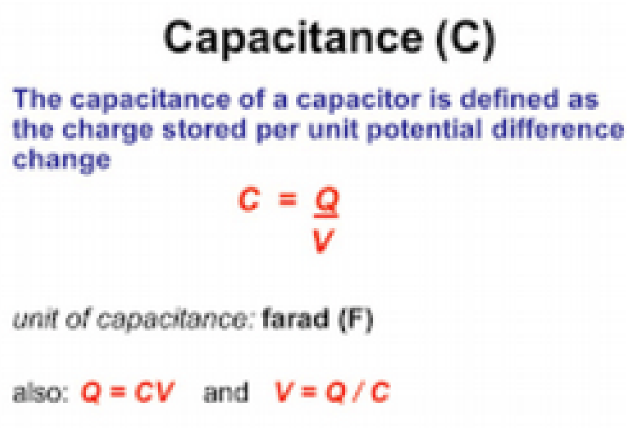
Band Colour	Voltage Rating (V)				
	Type J	Type K	Type L	Type M	Type N
Black	4	100		10	10
Brown	6	200	100	1.6	
Red	10	300	250	4	35
Orange	15	400		40	
Yellow	20	500	400	6.3	6
Green	25	600		16	15
Blue	35	700	630		20
Violet	50	800			
Grey		900		25	25
White	3	1000		2.5	3
Gold		2000			
Silver					

Disc & Ceramic Capacitor

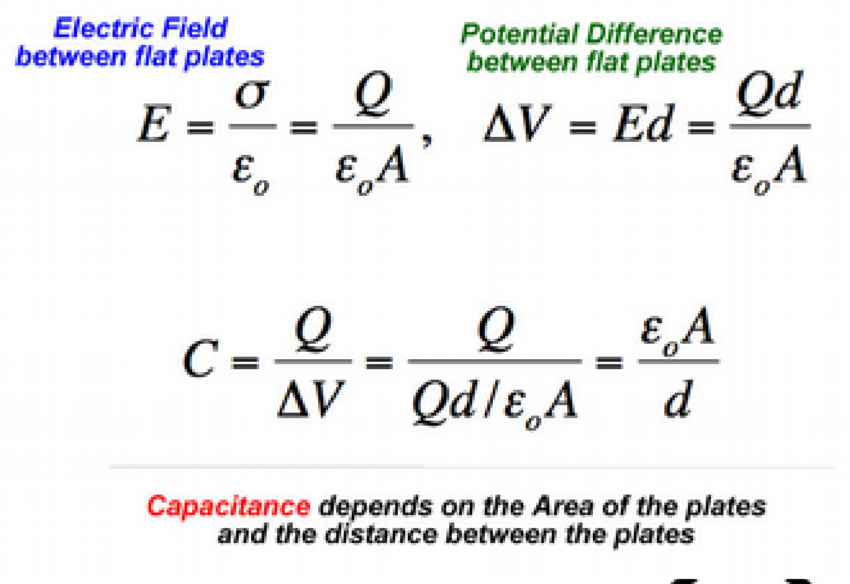


Capacitor Cont…





Now we will calculate the voltage distribution to the capacitors 10uF and 22uF
which are given in the above figure which have 10V supply voltage with40HZ frequency.



Reactance of 10uF capacitor, XC1 = 1/2πfC1 = 1/(2*3.142*40*10*10-6) = 400Ω
Reactance of 22uF capacitor, XC2 = 1/2πfC2 = 1/(2*3.142*40*22*10-6) = 180Ω
Total capacitive reactance of a circuit is, XC = XC1 + XC2 = 400Ω + 180Ω = 580Ω

CT = C1C2/(C1+C2) = (10*22*10-12)/(32*10-6) = 6.88uF
XCT = 1/2πfCT = 1/(2*3.142*40*6.88*10-6) = 580Ω

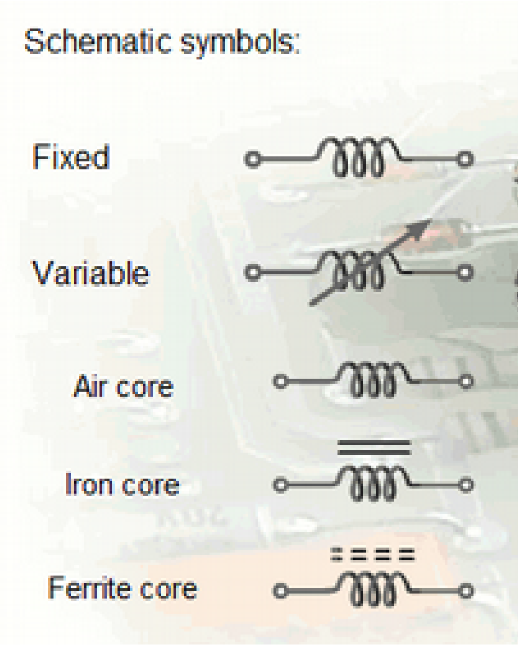
The current in the circuit is, I = V/XC = 10V/580Ω = 17.2mA

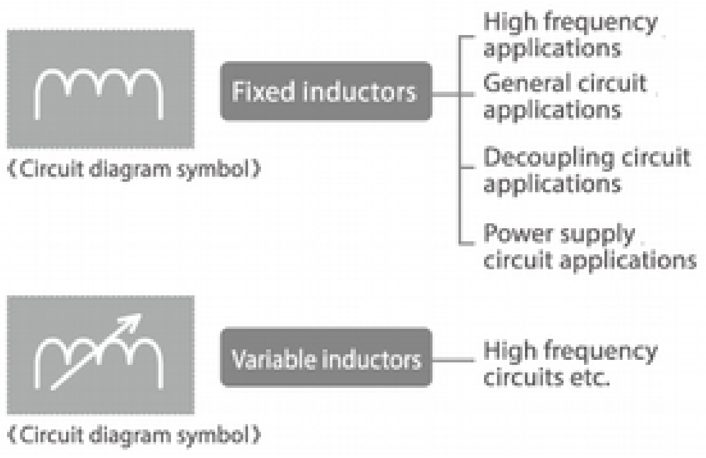
Now, the voltage drop across each capacitor is,
VC1 = I*XC1 = 17.2mA*400Ω = 6.9V
VC2 = I*XC2 =17.2mA*180Ω = 3.1V

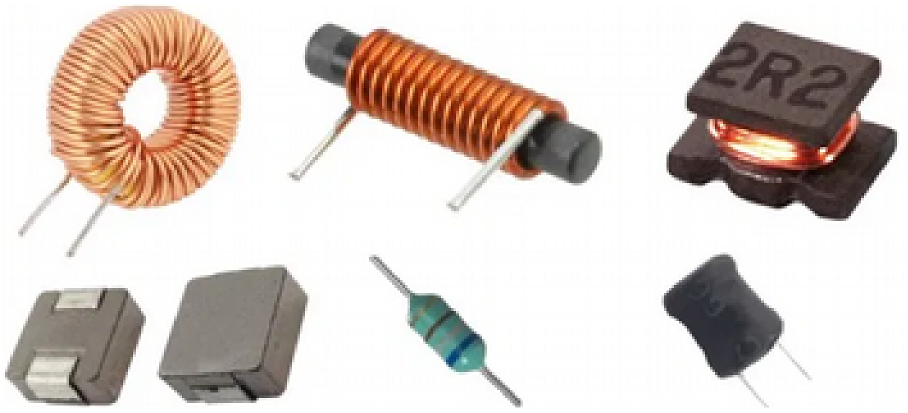
If the frequency is either 40HZ or 40KHZ, the voltage drops across capacitors will remain the same. The current flowing through the circuit changes depending on the frequency. The current will increases with increasing the frequency, it is 17.2mA for 40HZ frequency but it is 1.72A for the frequency 4KHZ.

Inductors

- Inductors are used to store energy in the form of Magnetic field.
- Inductor usually opposes the change in Current





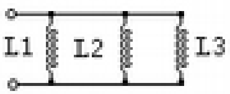


Inductor Cont…..

Inductors in series, just add them up.

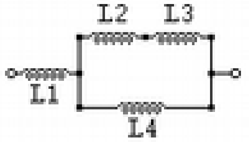
$L_S = L1 + L2 + L3$

Inductors in parallel.



$$L_P = \frac{1}{\frac{1}{L1} + \frac{1}{L2} + \frac{1}{L3}}$$

Example



$$L = L1 + \frac{1}{\frac{1}{L2+L3} + \frac{1}{L4}}$$

Four Band Standard EIA Colour Code For Inductors.

Therefore value = 27 x10 = 270μH +/-20%

Band	1	2	3	4
Meaning	1st Digit	2nd Digit	Multiplier (No. of zeros)	Tolerance %
Gold			x 0.1 (divide by 10)	+/-5%
Silver			x 0.01 (divide by 100)	+/-10%
Black	0	0	x1 (No Zeros)	+/-20%
Brown	1	1	x10 (0)	
Red	2	2	x100 (00)	
Orange	3	3	x1000 (000)	
Yellow	4	4	x10000 (0,000)	
Green	5	5		
Blue	6	6		
Violet	7	7		
Grey	8	8		
White	9	9		

Note: If no Band 4 is used, tolerance is also +/-20%

For values less than 10μH:

Bands 2, 3 and 4 indicate the value of inductance in μH
A gold band might be used in either band 2 or band 3.
In either of these two bands, gold indicates a decimal point ;
and band 4 is used as a digit instead of a multiplier band.
When no gold band is present in bands 2 or 3, band 4 is a multipier band.

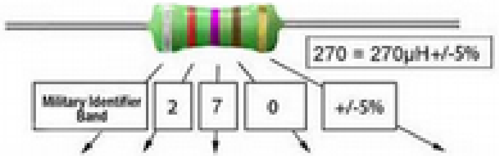
For example:

If bands 2,3 and 4 are red, gold, red the value would be 2.2 μH

If bands 2,3 and 4 are gold, yellow, violet the value would be 0.47 μH (470nH)

Band 5 indicates the tolerance between 1% and 20%

Five Band Military Standard Inductor Colour Code

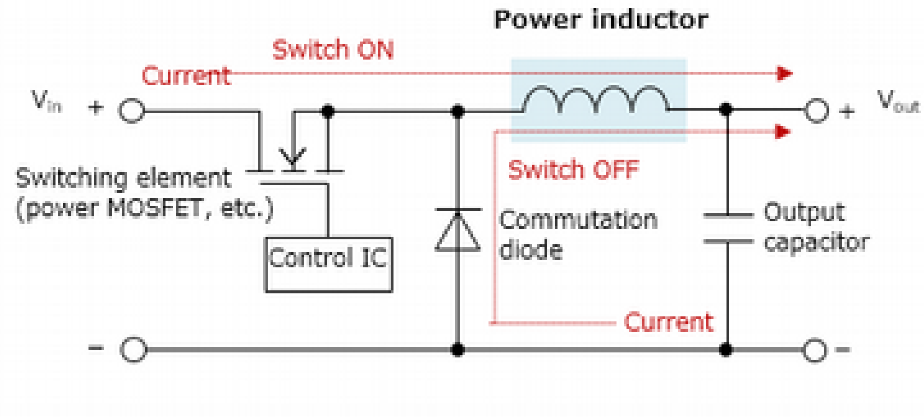


Band	1	2	3	4	5
Meaning (See Notes)	Mil. Spec.	Digit or Dec. point	Digit or Dec. point	Digit (or Multiplier)	Tolerance %
Gold		Decimal point	Decimal point		+/-5%
Silver	Always Silver double width				+/-10%
Black		0	0	0 (or x 1)	+/-20%
Brown		1	1	1 (or x 10)	+/-1%
Red		2	2	2 (or x 100)	+/-2%
Orange		3	3	3 (or x 1,000)	+/-3%
Yellow		4	4	4 (or x 10,000)	+/-4%
Green		5	5	5	
Blue		6	6	6	
Violet		7	7	7	
Grey		8	8	8	
White		9	9	9	

Notes:

The military standard for cylindrical inductors specifies 5 coloured bands
The same colours are used as in the EIA 4 band code, but:
For band 1, a **double width** sliver band is used to signify Military Standard.

Inductor Cont…..

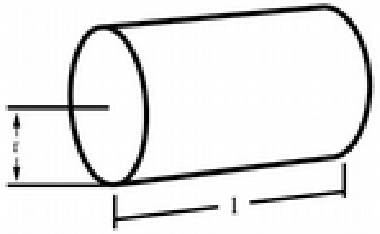


When the switching element is ON, the power inductor accumulates energy, and when it turns OFF the energy is discharged and the current is transmitted. The voltage can be decreased to the required value by setting the duty ratio (ratio of ON time to switching cycle).

Vout = Vin × Duty

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

$$\mu = \mu_r \mu_0$$



Where,

L = Inductance of coil in Henrys

N = Number of turns in wire coil (straight wire = 1)

μ = Permeability of core material (absolute, not relative)

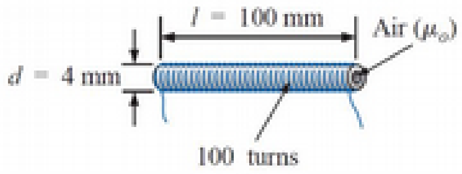
μ_r = Relative permeability, dimensionless (μ_0 = 1 for air)

μ_0 = 1.26x10^{-6} T-m/At permeability of free space

A = Area of coil in square meters = πr^2

l = Average length of coil in meters

exercise



Use equation for inductance of the coils

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

Find the inductance of the air-core coil

$$\mu = \mu_r \mu_o = (1)(\mu_o) = \mu_o$$

$$A = \frac{\pi d^2}{4} = \frac{(\pi)(4 \times 10^{-3}\ \text{m})^2}{4} = 12.57 \times 10^{-6}\ \text{m}^2$$

$$L_o = \frac{N^2 \mu_o A}{l} = \frac{(100\ \text{t})^2 (4\pi \times 10^{-7}\ \text{Wb/A·m})(12.57 \times 10^{-6}\ \text{m}^2)}{0.1\ \text{m}}$$

$$L = 1.58\ \mu\text{H}$$

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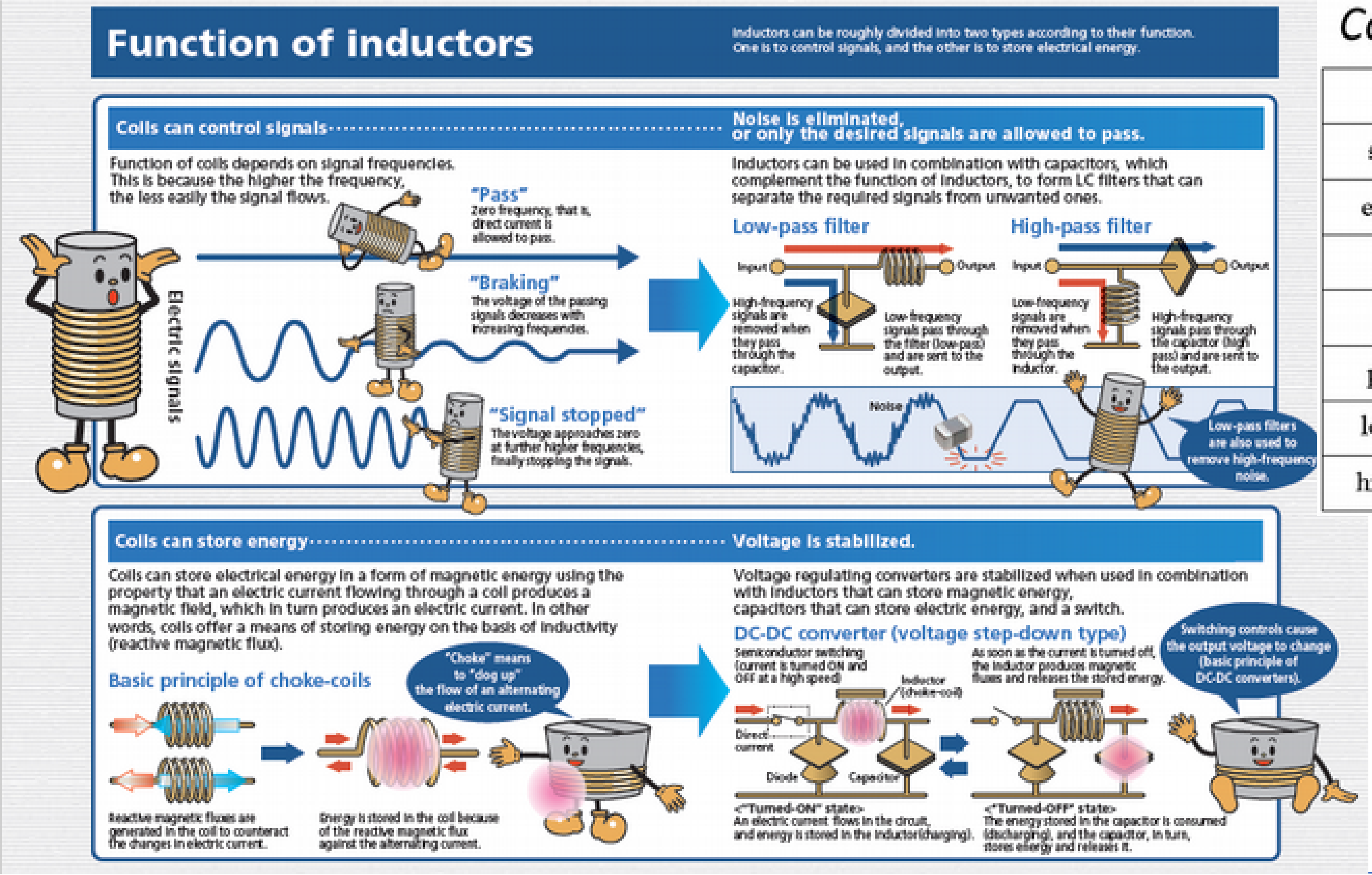
Inductor Cont…..



Comparison of Components

	resistor	capacitor	inductor
symbol	R	C	L
equation	$V_R = I_R R$	$I_C = C\frac{dV_C}{dt}$	$V_L = L\frac{dI_L}{dt}$
icon	(resistor icon)	(capacitor icon)	(inductor icon)
series	$R_T = R_1 + R_2$	$C_T^{-1} = C_1^{-1} + C_2^{-1}$	$L_T = L_1 + L_2$
parallel	$R_T^{-1} = R_1^{-1} + R_2^{-1}$	$C_T = C_1 + C_2$	$L_T^{-1} = L_1^{-1} + L_2^{-1}$
low freq	R	*open circuit*	*short circuit*
high freq	R	*short circuit*	*open circuit*

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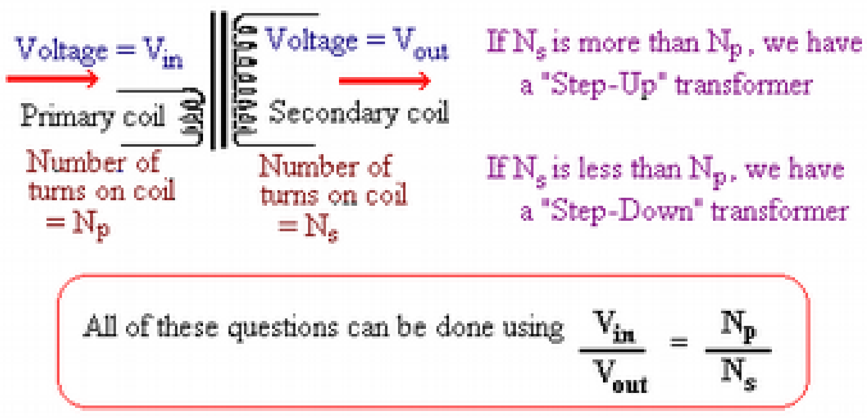
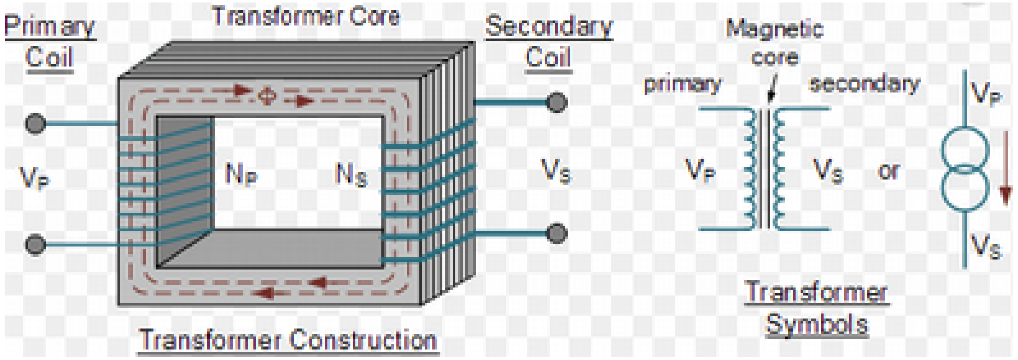
Transformer

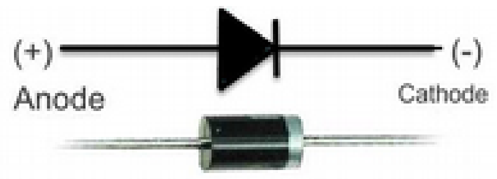
- Transfers electrical energy from one circuit to another through the process of electromagnetic induction.
- It is most commonly used to increase ('step up') or decrease ('step down') voltage levels between circuits

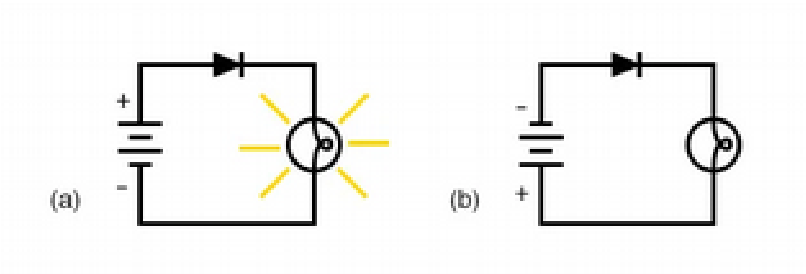


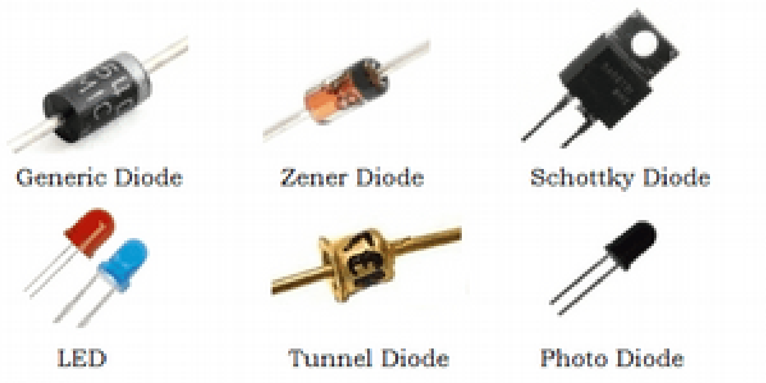


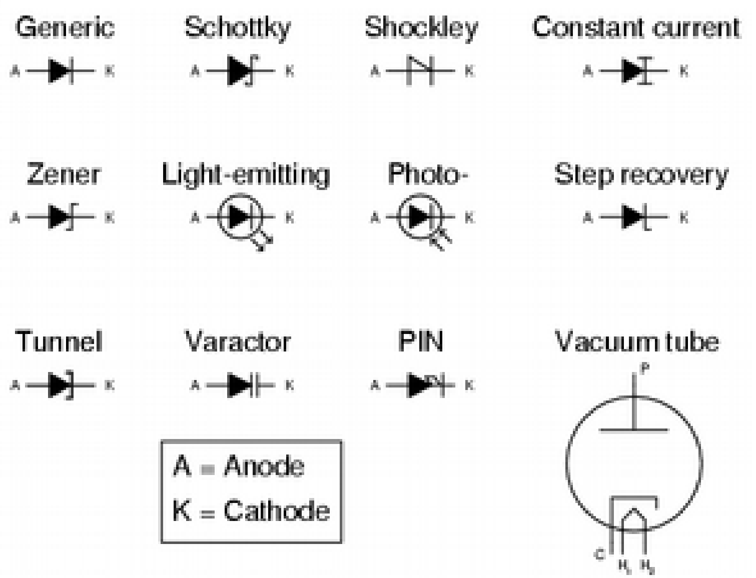
Diode

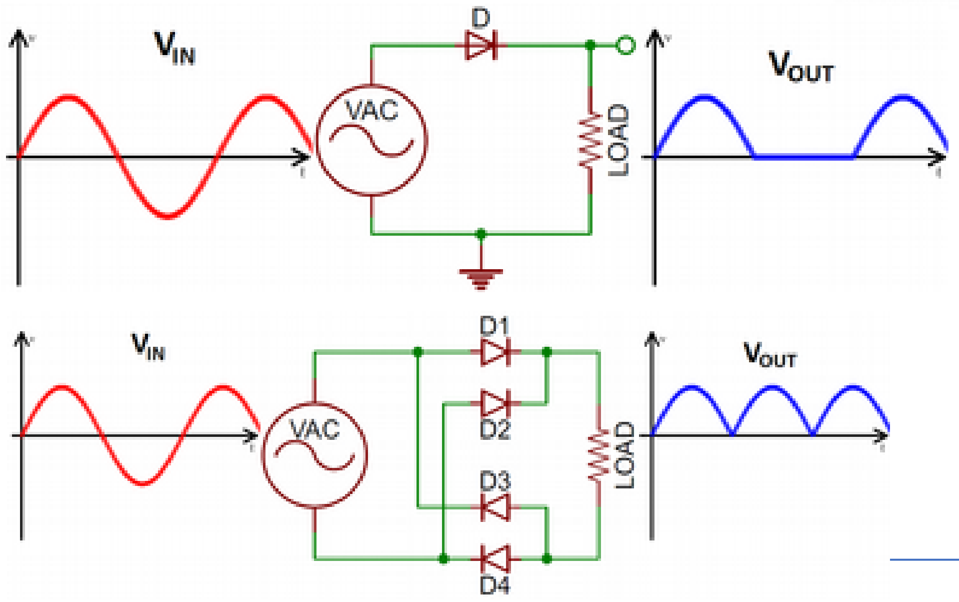
- semiconductor device which conducts in one direction only





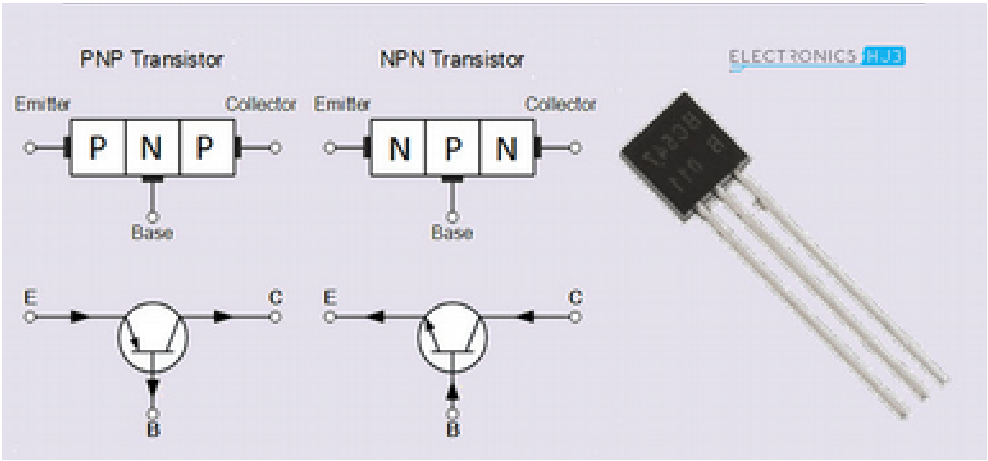






Transistor

- miniature electronic component that can do two different jobs. It can work either as an amplifier or a switch: When it works as an amplifier, it takes in a tiny electric current at one end (an input current) and produces a much bigger electric current (an output current) at the other

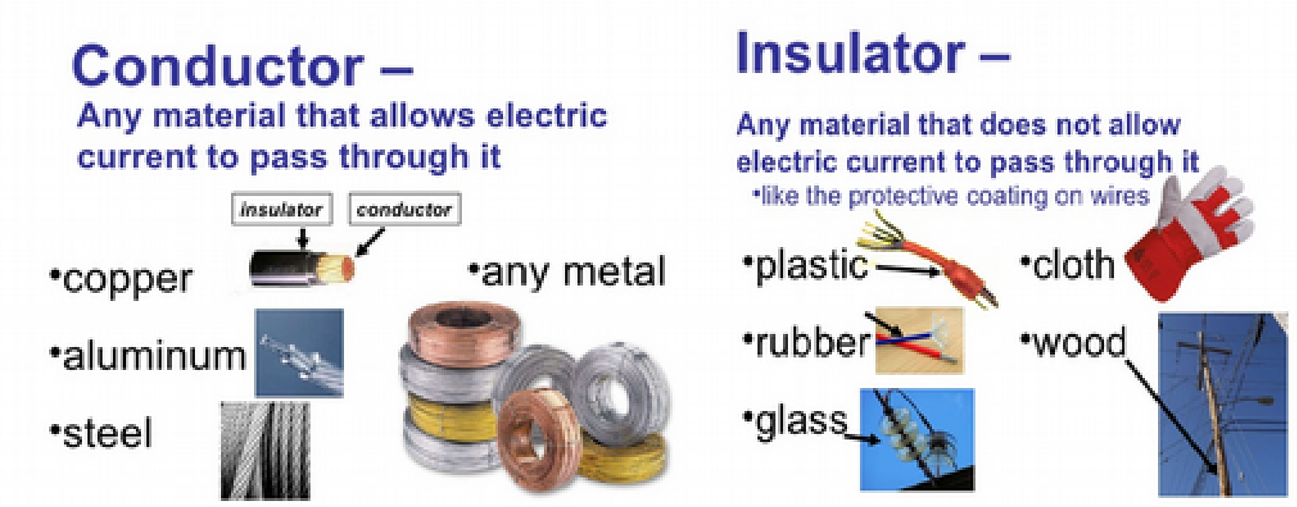


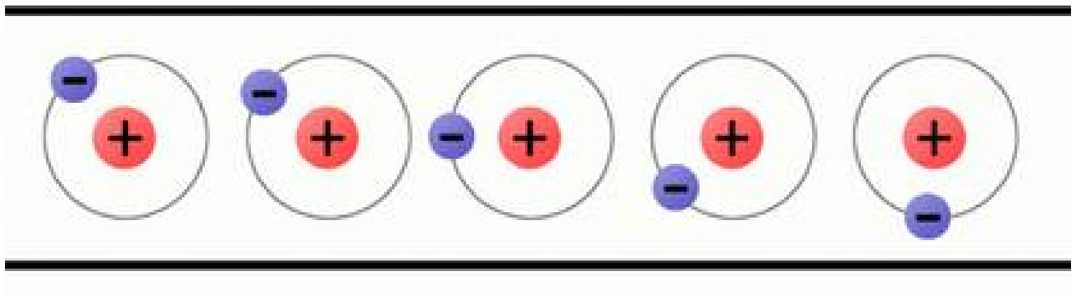
Transistors are basically classified into two types; they are Bipolar Junction Transistors (BJT) and Field Effect Transistors (FET). The BJTs are again classified into NPN and PNP transistors. The FET transistors are classified into JFET and MOSFET

Will be continued

SIARS

Conductors and Insulators





Conductance

Conductance is an expression of the ease with which electric current flows through a substance.

The standard unit of conductance is the siemens (abbreviated S)per meter (S/m),
formerly known as the mho

The mho is the reciprocal (also known as inverse) of the ohm.

To calculate the conductance of any circuit or component (including a single resistor), you just divide the resistance of the circuit or component (in ohms) into 1.

Thus, a 100 Ω resistor has 1/100 mho of conductance

Inductance

A current generated in a conductor by a changing magnetic field is proportional to the rate of change of the magnetic field. This effect is called INDUCTANCE and is given the symbol L. It is measured in units called the henry (H)

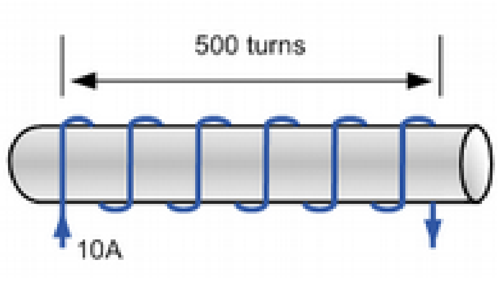
Self-induction:

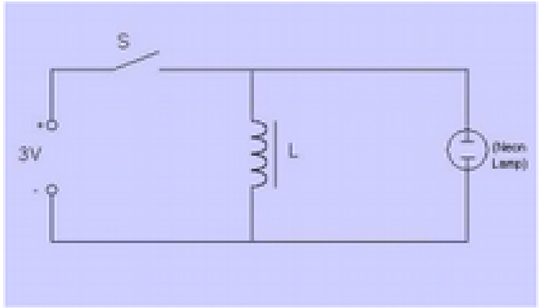
Inductors do this by generating a self-induced emf within itself as a result of their changing magnetic field. In an electrical circuit, when the emf is induced in the same circuit in which the current is changing this effect is called Self-induction, (L) but it is sometimes commonly called back-emf as its polarity is in the opposite direction to the applied voltage.

$$L = N\frac{\Phi}{I}$$

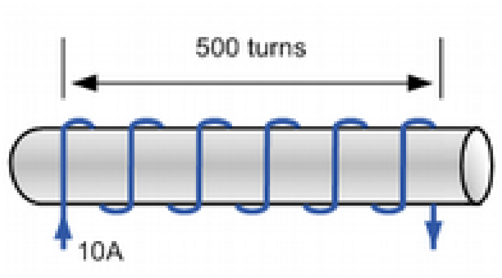
Where:

- L is in Henries
- N is the Number of Turns
- Φ is the Magnetic Flux
- I is in Amperes





Inductance



A hollow air cored inductor coil consists of 500 turns of copper wire which produces a magnetic flux of 10mWb when passing a DC current of 10 amps

$$L = N\frac{\Phi}{I} = 500\frac{0.01}{10} = 500mH$$

the value of the self-induced emf produced in the same coil after a time of 10mS

$$emf = L\frac{di}{dt} = 0.5\frac{10}{0.01} = 500V$$

Inductance

Mutual Induction:

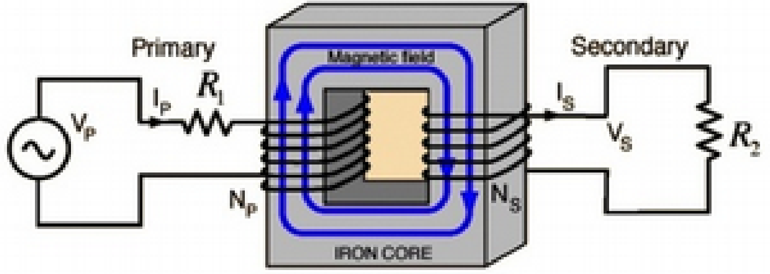
When the emf is induced into an adjacent coil situated within the same magnetic field, the emf is said to be induced magnetically, inductively or by Mutual induction, symbol (M). Then when two or more coils are magnetically linked together by a common magnetic flux they are said to have the property of Mutual Inductance

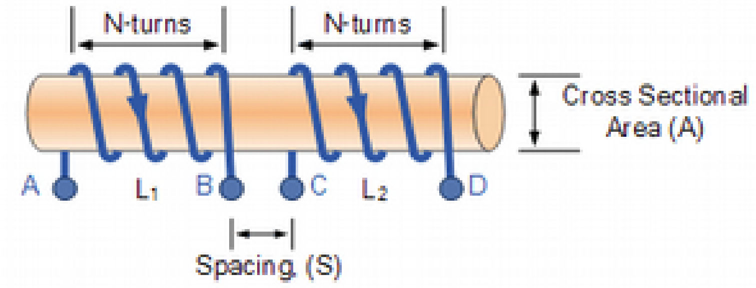
The mutual inductance term in the primary circuit represents the load of the secondary. It has the negative sign because it helps the source to produce more current in response to increasing load in the secondary circuit.

$$V_P = I_P R_1 + \frac{L_1 \Delta I_P}{\Delta t} - M\frac{\Delta I_S}{\Delta t}$$

The mutual inductance term in the secondary represents the coupling from the primary and acts as the voltage source that drives the secondary circuit.

$$M\frac{\Delta I_P}{\Delta t} = I_S R_2 + \frac{L_2 \Delta I_S}{\Delta t}$$





$$M = \frac{\mu_o \mu_r N_1 N_2 A}{\ell}$$

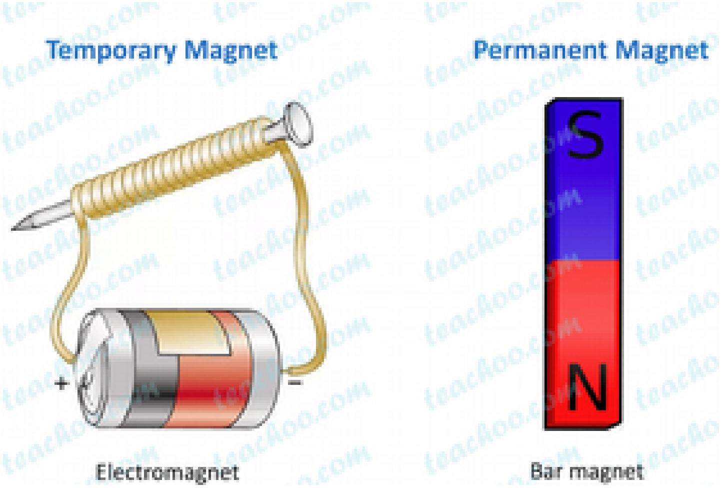
Where:

- μ_o is the permeability of free space ($4.\pi.10^{-7}$)
- μ_r is the relative permeability of the soft iron core
- N is in the number of coil turns
- A is in the cross-sectional area in m^2
- ℓ is the coils length in meters

SIARS

Magnetism

property of certain substances which pull closer or repel other objects



Permanent magnet:

It is a ferromagnetic material that possesses permanent magnetic properties, even when it is not located within a magnetic field. One end of the magnet is called the north pole, the other the south pole

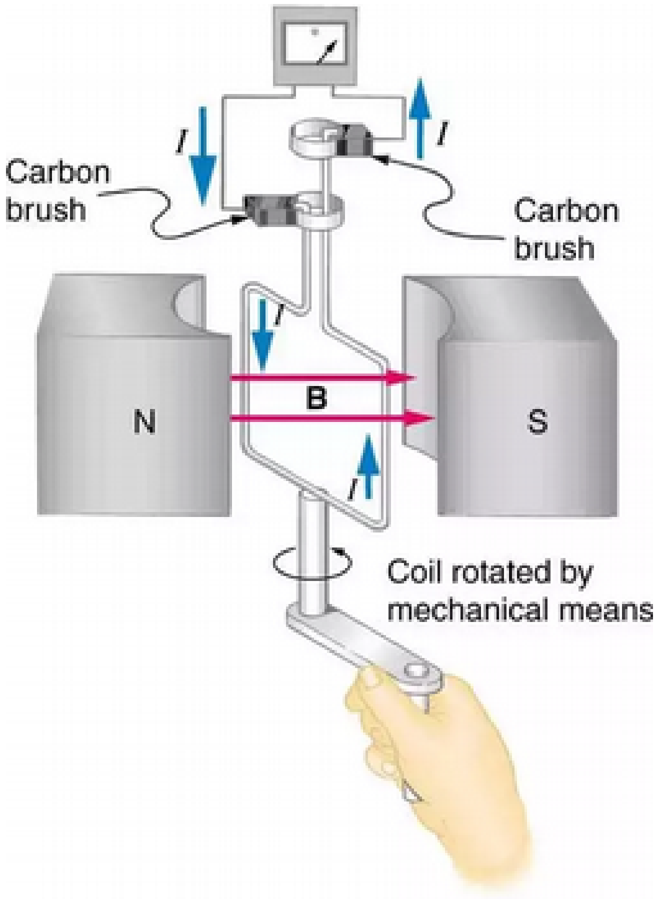
Electromagnet:

It is a type of magnet in which the magnetic field is produced by an electric current. Electromagnets usually consist of wire wound into a coil. A current through the wire creates a magnetic field which is concentrated in the hole, denoting the centre of the coil.

Electromagnet	Bar Magnet or Permanent Magnet
It is a temporary magnet	It is a permanent magnet
They are usually made of soft materials	They are usually made of hard materials
It can produce very strong magnetic force	It produces comparatively weak magnetic force
It's magnetic strength can be changed	It's magnetic strength can not be changed
It's polarity can be changed.	It's polarity can not be changed.
Example - Solenoid - A wire wound across a nail connected to a battery	**Example** - Bar Magnet

SIARS

Magnetism



I
I
Carbon
brush
Carbon
brush
I
B
N
S
I
Coil rotated by
mechanical means

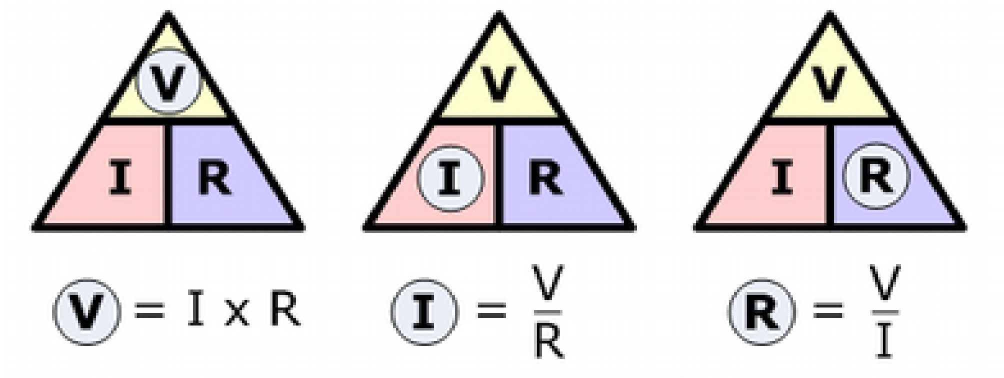
Units of electrical elements

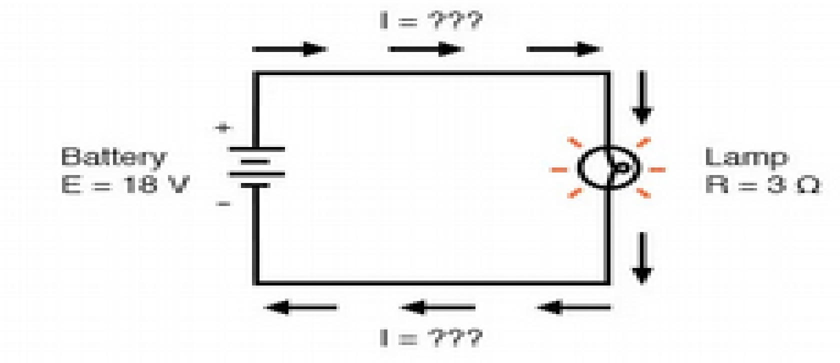
SI DERIVED BASIC ELECTRICAL UNITS

power, radiant flux	watt	W	J/s
electric charge, quantity of electricity	coulomb	C	-
electric potential difference, electromotive force	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
electric conductance	siemens	S	A/V
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A

Ohm's law

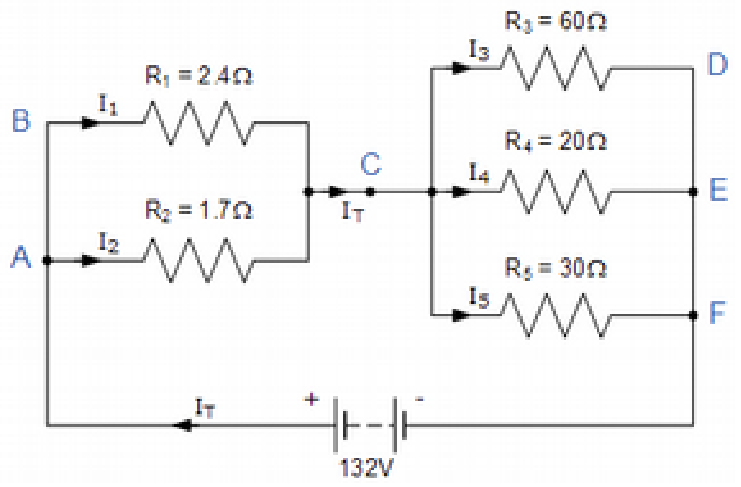
Ohm's law states that the electrical current (I) flowing in an circuit is proportional to the voltage (V) and inversely proportional to the resistance (R). Therefore, if the voltage is increased, the current will increase provided the resistance of the circuit does not change.





When E = 18V ; then current I = 6A
When E = 9V; then current I = 3A

Kirchhoff's circuit laws



First law / Nodal rule: -for current

For any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node.

$$\frac{1}{R_{(AC)}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{2.4} + \frac{1}{1.7}$$

$$\frac{1}{R_{(AC)}} = \frac{1}{1} \qquad \therefore R_{(AC)} = 1\Omega$$

$$\frac{1}{R_{(CF)}} = \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} = \frac{1}{60} + \frac{1}{20} + \frac{1}{30}$$

$$\frac{1}{R_{(CF)}} = \frac{1}{0.1} \qquad \therefore R_{(CF)} = 10\Omega$$

$$R_T = R_{(AC)} + R_{(CF)} = 1 + 10 = 11\Omega$$

$$I_T = \frac{V}{R_T} = \frac{132}{11} = 12\,\text{Amps}$$

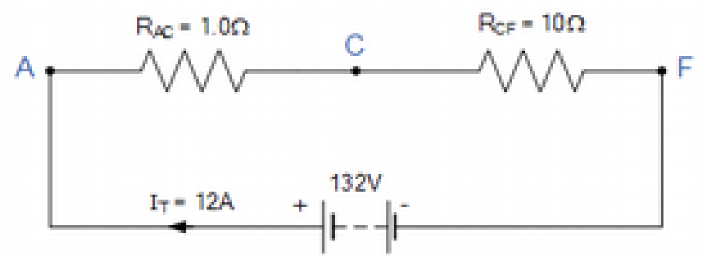
$$I_1 = \frac{V_{AC}}{R_1} = \frac{12}{2.4} = 5\,\text{Amps}$$

$$I_2 = \frac{V_{AC}}{R_2} = \frac{12}{1.7} = 7\,\text{Amps}$$

$$I_3 = \frac{V_{CF}}{R_3} = \frac{120}{60} = 2\,\text{Amps}$$

$$I_4 = \frac{V_{CF}}{R_4} = \frac{120}{20} = 6\,\text{Amps}$$

$$I_5 = \frac{V_{CF}}{R_5} = \frac{120}{30} = 4\,\text{Amps}$$



$$V_{AC} = I_T \times R_{AC} = 12 \times 1 = 12\,\text{Volts}$$

$$V_{CF} = I_T \times R_{CF} = 12 \times 10 = 120\,\text{Volts}$$

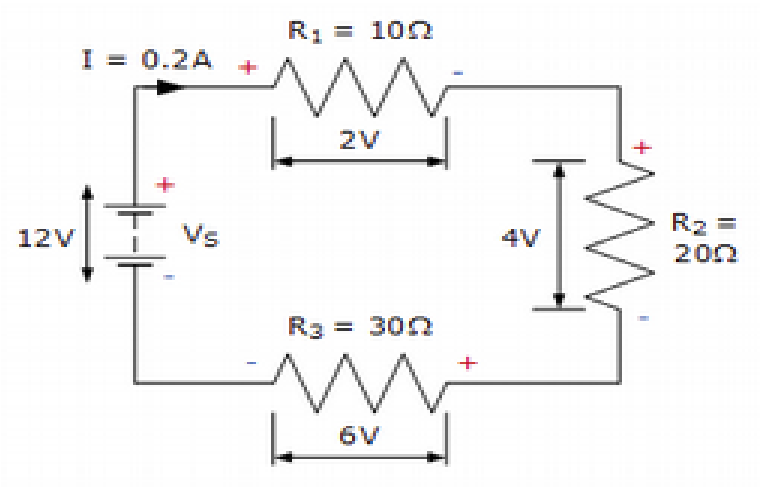
At node C

$$I_1 + I_2 = I_3 + I_4 + I_5$$

Kirchhoff's circuit laws

<u>Second law / Mesh rule</u>: -for voltage

The directed sum of the potential differences (voltages) around any closed loop is zero.



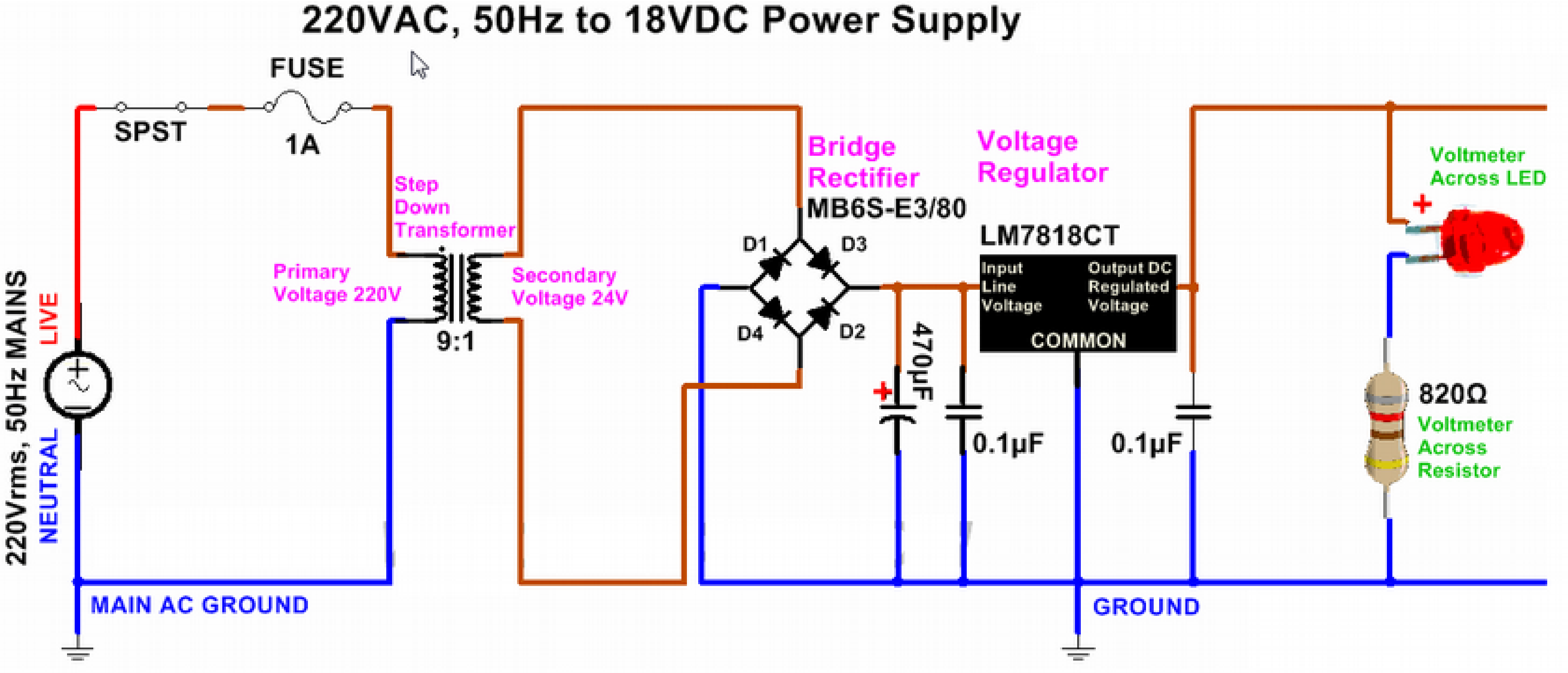
RT = R1 + R2 + R3 = 10Ω + 20Ω + 30Ω = 60Ω

$$I = \frac{V_S}{R_T} = \frac{12}{60} = 0.2A$$

VR1 = I x R1 = 0.2 x 10 = 2 volts
VR2 = I x R2 = 0.2 x 20 = 4 volts
VR3 = I x R3 = 0.2 x 30 = 6 volts

Vs-VR1-VR2-VR3 = 12-2-4-6 = 0

Simple Circuit



Thank You