

EE1002 Principles of Electrical Engineering



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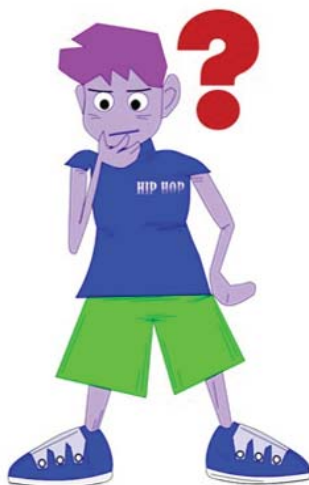
CILOs (Course Intended Learning Outcomes)

No.	CILOs [#]
1.	Consolidate mathematical concepts on differentiation, integration, trigonometry and complex numbers
2.	Describe the basic principles of electric charges and electrical conduction
3.	Apply Kirchhoff's laws to analyze circuits
4.	Apply differentiation and integration to analyze first-order transient circuits

As fundamentals, and for better preparation for level 2 courses.

Level 2 Courses	EE1002
EE2000 Logic Circuit Design	✓
EE2004 Microcomputer Systems	✓
EE2104 Introduction to Electromagnetics	✓
EE2108 Engineering Analysis	✓
EE2109 Electronic Circuits	✓
EE2301 Basic Electronic Circuits	✓
EE2331 Data Structures and Algorithms	CS1102, CS1302

3



Examination



4

- **Assessments**

- Examination: 50%
- **Course works: 50%**

- Note:

- Exam and course works are complement to each other.
- Course works may provide additional assessment to course/program outcomes (CILOs & PILOs).
- You need to score 30% from **BOTH** Exam and Course works.
- 75% laboratory attendance rate must be obtained.

5

Assessments

Assessment Tasks/Activities	CILO No.				Weighting	Remarks
	1	2	3	4		
Continuous Assessment: <u>50%</u>						
Quizzes/Tests (min.: 2)	✓	✓	✓	✓	30%	
3 Assignments (min.: 3)	✓	✓	✓	✓	10%	
Lab exercises and reports			✓	✓	10%	
Examination: <u>50%</u> (duration: 2hrs)						
Examination	✓	✓	✓	✓	50%	
Total					100%	

Class Schedule 1

Wk	Date	Topics	Activities
1	31/8	Introduction to electrical engineering, atom and electron, voltage and current, ohm's law	
2	7/9	<u>Engineering Math I</u> : Limits, derivatives, continuity, gradient, rate of change	
3	14/9	<u>Engineering Math II</u> : differentiation, product rule and quotient rule.	Lab 1
4	21/9	<u>Engineering Math III</u> : application of differentiation, maximum, minimum, partial derivatives.	
5	28/9	<u>Engineering Math IV</u> : Integration: area, integration techniques	Assignment 1
6	5/10	Test	
7	12/10	<u>DC Circuit analysis I</u> : Kirchhoff's law, power and energy; series and parallel networks; ammeter, voltmeter.	
8	19/10	<u>DC Circuit analysis II</u> : Kirchhoff's law, power and energy; series and parallel networks; ammeter, voltmeter; mesh and nodal analysis, Thevenin's and Norton's theorems; maximum power transfer	Assignment 2 Lab 2
9	26/10	Chung Yeung Holiday	

Class Schedule

Wk	Date	Topics	Activities
10	2/11	Test	Lab 3
11	9/11	<u>AC Circuit Analysis I</u> : Capacitor and inductor; sinusoid response; complex number, impedance;	
12	16/11	<u>AC Circuit Analysis II</u> : First-order transient circuit (RL and RC circuits); instantaneous and average power.	Lab 4
13	23/11	Revision/ Mock Test	Assignment 3

Texts (1 OR 2 plus 3):

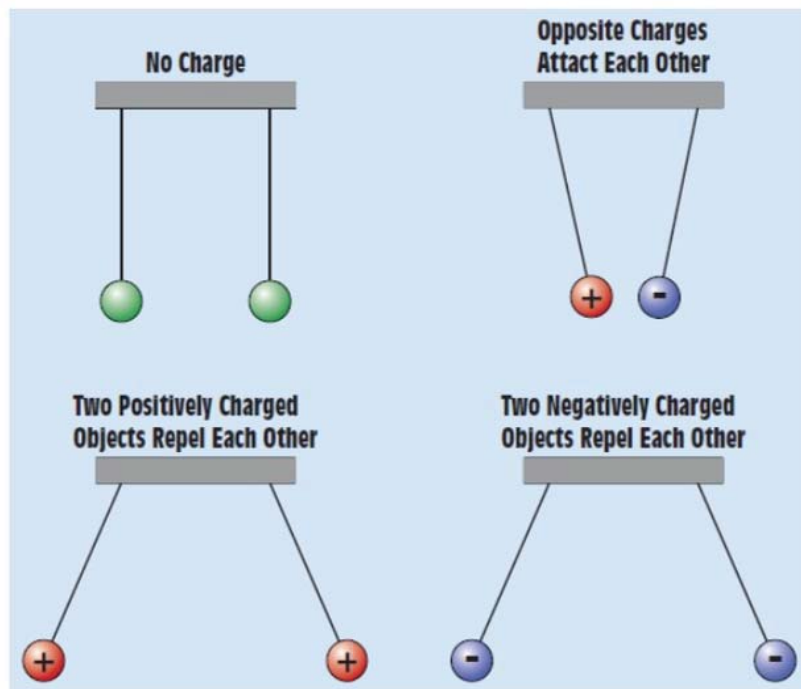
1. M. O. Sadiku, S. M. Musa and C. K. Alexander, Applied Circuit Analysis, McGraw Hill, 2012.
2. C. K. Alexander and M.O. Sadiku, Fundamentals of Electric Circuits, 5th Edition, McGraw Hill, 2012.
3. J. Stewart, Calculus Early Transcendentals, (any edition), Thomson Brooks/Cole

Outline

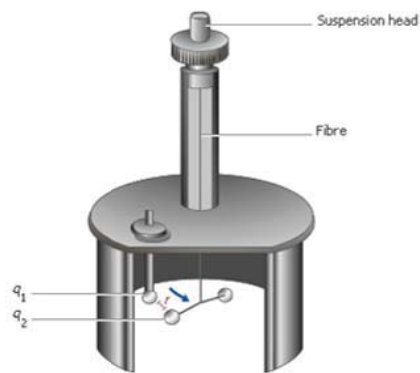
1. Coulomb's Law, Atomic Structure, and Electron
2. Conductor
3. Voltage and Current
4. Ohm's Law
5. Resistors
6. Resistors in Series and Parallel Connections
7. Ammeter and Voltmeter
8. Summary
9. Self-Assessment
10. Tutorials

9

Charge Action: Attract & Repel



Charge Action: Coulomb Force

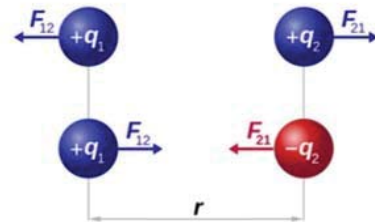


Based on careful experiments, Coulomb's law was published in 1785.

Coulomb force between two charges:

$$F_{12} = F_{21} = k \frac{|q_1 q_2|}{r^2}$$

Coulomb constant $k = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$

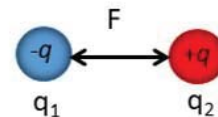


Coulomb's Law

Coulomb force between two charges:

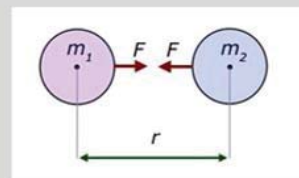
$$F = k \frac{|q_1 q_2|}{r^2}$$

Coulomb constant $k = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$



It is in a similar form to Newton's law of gravitation

$$F_{12} = F_{21} = G \frac{m_1 m_2}{r^2}$$

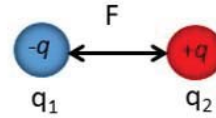


Coulomb's Law

Coulomb force between two charges:

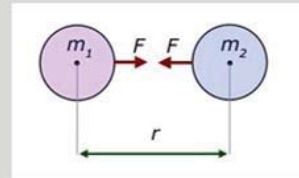
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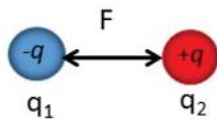
It is in a similar form to Newton's law of gravitation

$$F_{12} = F_{21} = G \frac{m_1 m_2}{r^2}$$

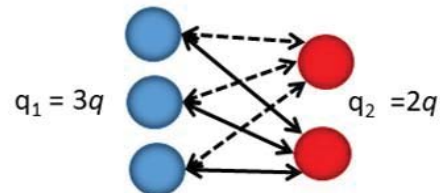
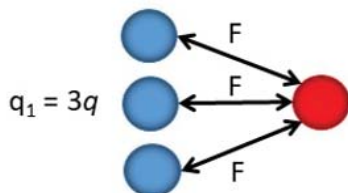
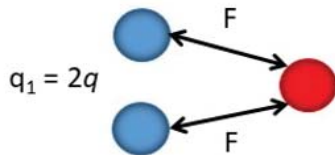


$$F = k \frac{|q_1 q_2|}{r^2} \quad \leftarrow \text{Why } q_1 \times q_2 ?$$

- Let force between two unit charges be F:

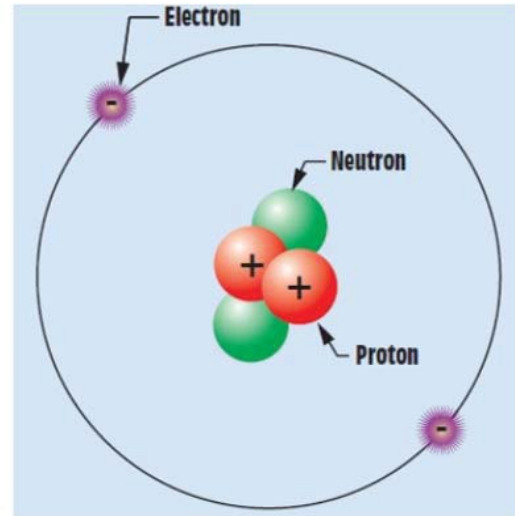
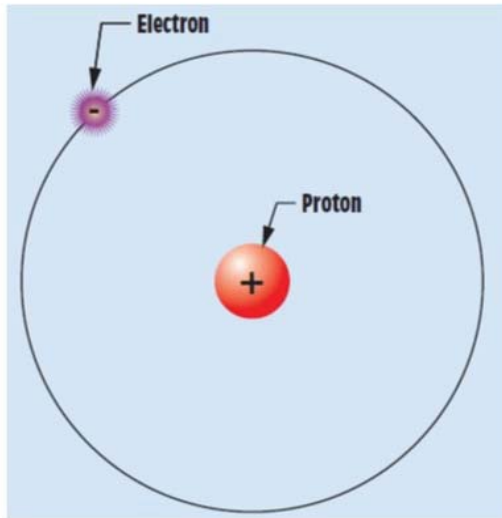


- Force with $q_1 = 2q$ and $3q$:



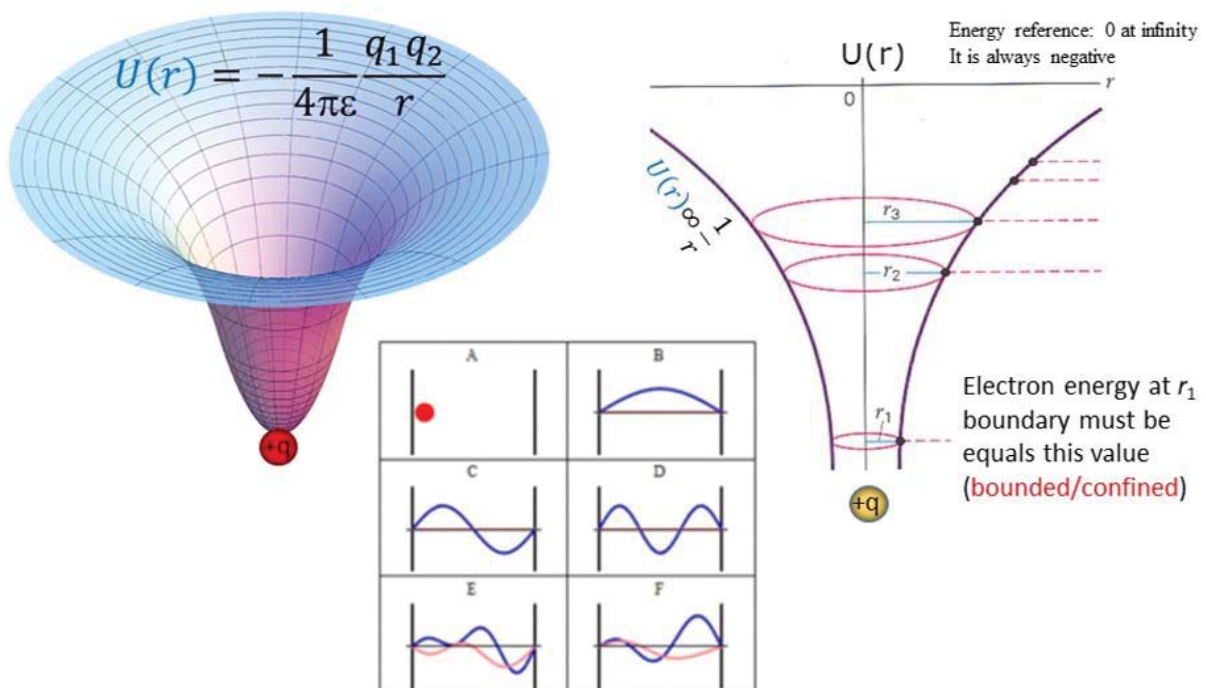
Atomic Structure and Electron

- Fundamental making of everything.



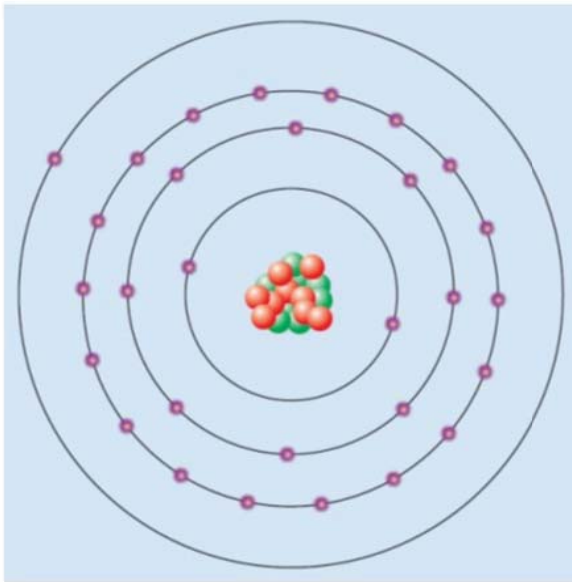
Electron is an elementary negative charge with charge value approximately equal to 1.602×10^{-19} Coulombs

Potential Well due to protons in nucleus

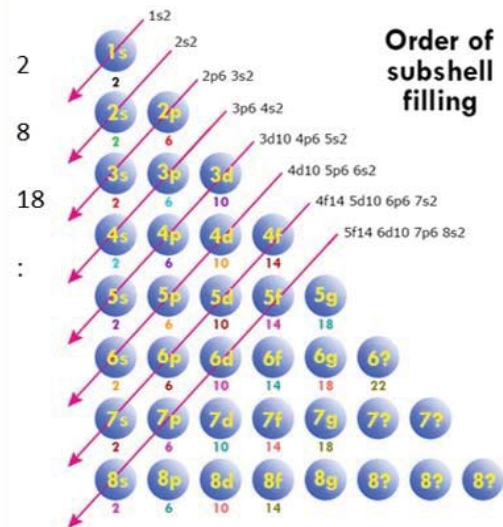


Electrons in bounded states → discrete energy levels → orbital/shells

Arrangement of many electron atoms



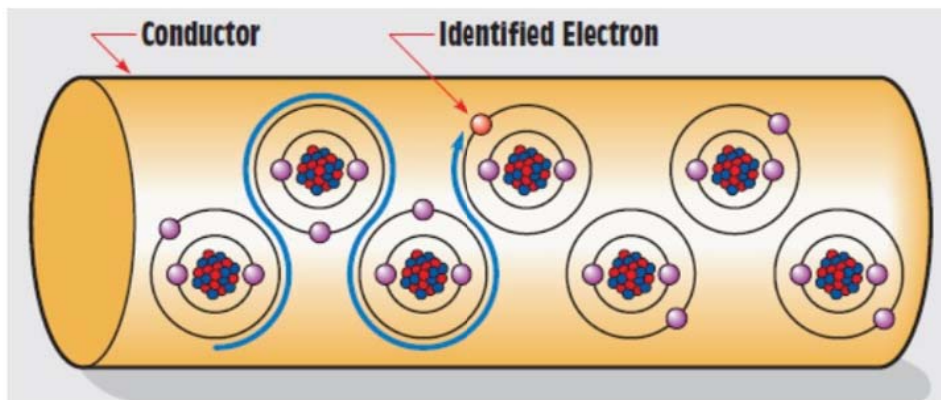
A copper atom contains 29 electrons and has 1 valence electron.



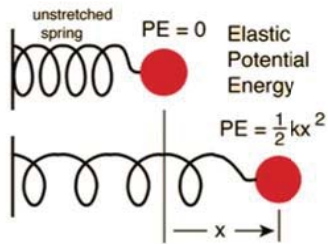
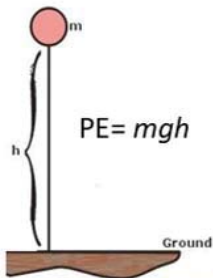
Cu 2, 8, 18, 1
1st shell 2nd shell 3rd shell

Conductor & Charge Transport

- Valence electrons are easier to “move” and governed most of the chemical and electrical properties of materials.



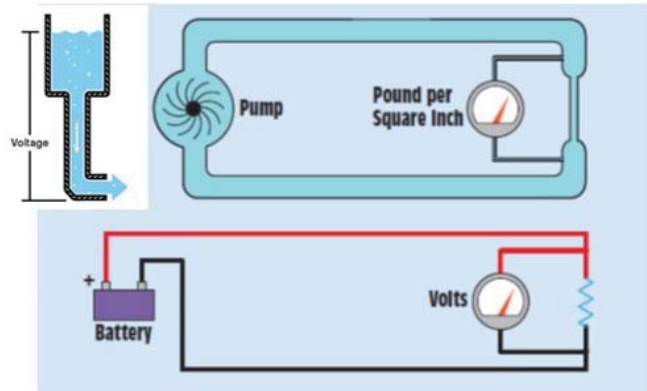
Potential: making charges “MOVE”



$$U = \frac{kQq}{r}$$

Diagram illustrating electrical potential. A positive charge Q is at a distance r from a point charge q .

Electrical potential can be generated by separating/inducing positive and negative charges.



Some Batteries



Li-ion batteries

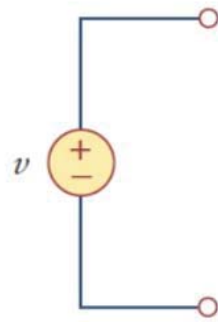


Alkaline batteries

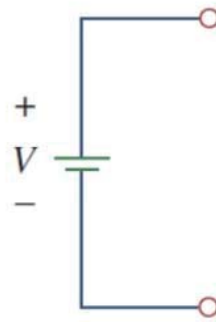


Capacity = current in mA x time in hour (@ specific voltage)
= # mAh

Voltage Source Circuit Symbols



AC Source

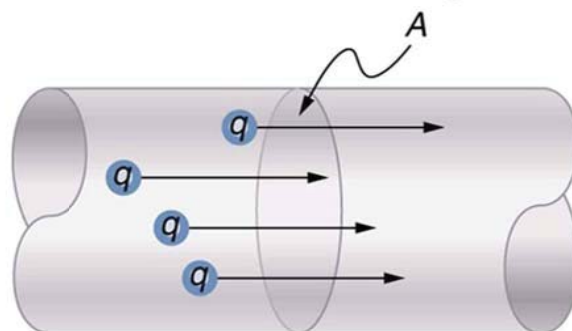


DC Source

Current: Amount of charge flow per second



Current = flow of charge

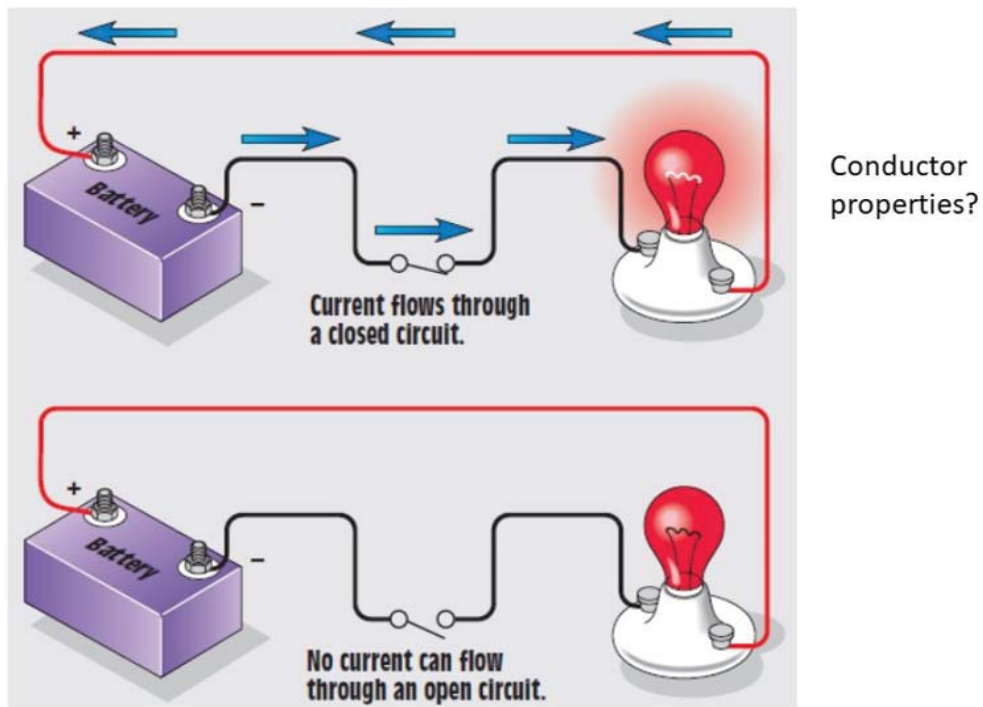


Rate, a fair way for comparison.

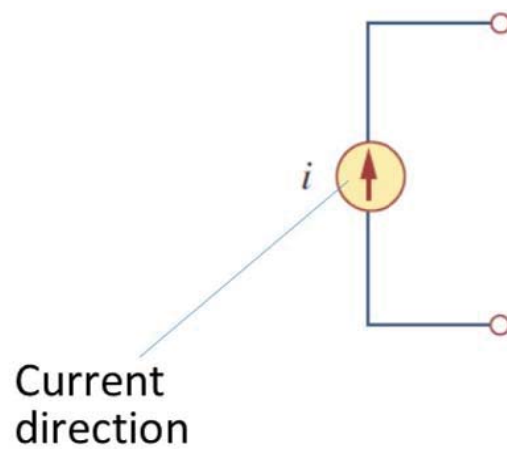
$$I = \text{Charge/time} = Q/t$$

Ampere = Coulomb/s

Circuit: Complete loop



Current Source Circuit Symbols



Resistance

- Current flow depends on the size and conductivity of a conductor.

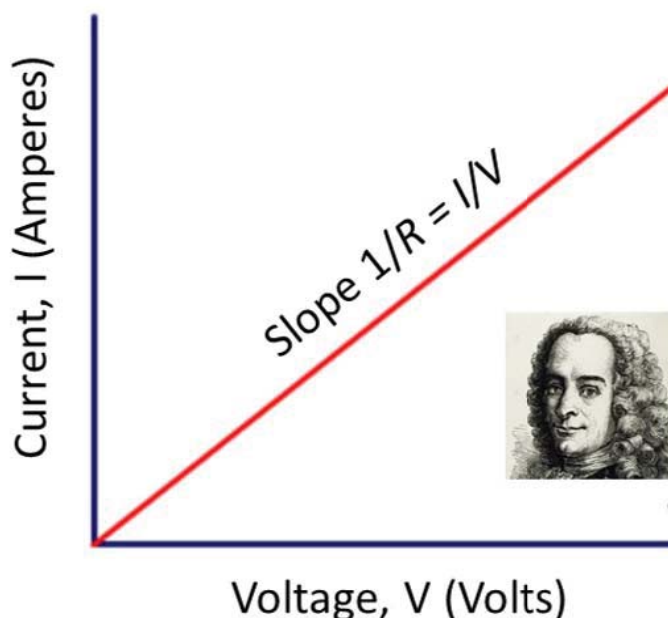


Ohm's Law $R = \frac{V}{I}$

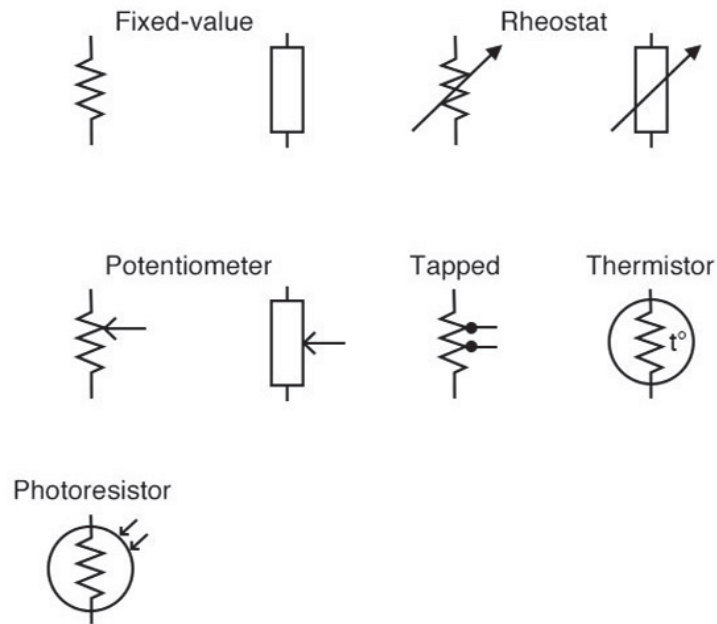
$$\text{Resistance } R = \frac{V}{I} \text{ (Ohm or } \Omega \text{)}$$

$$\text{Conductance } G = \frac{I}{V} \text{ (Mho or S)}$$

$$\text{Resistance} = \frac{1}{\text{Conductance}}$$



Resistor Circuit Symbols



More on Ohm's law



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

What governs the resistance of a conductor ?

Material and geometry !



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

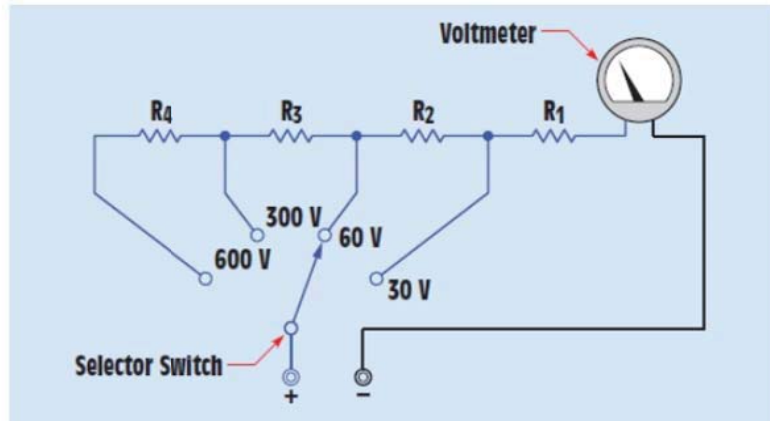
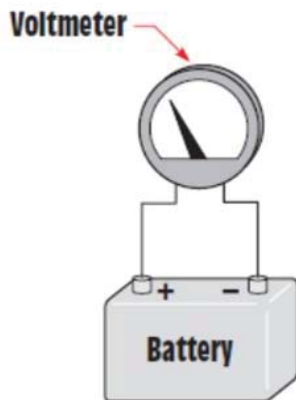
resistivity

length

cross-section area

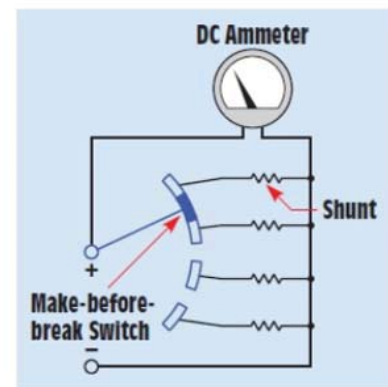
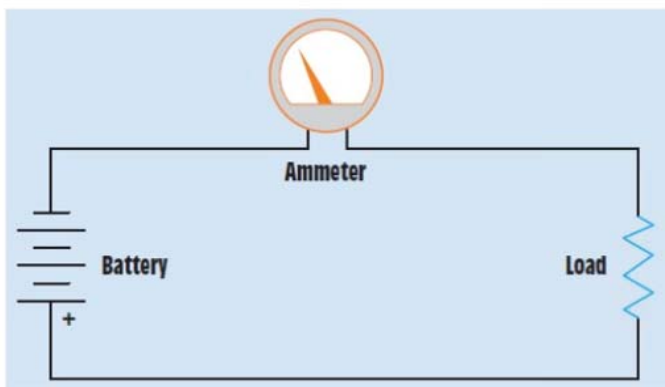
Voltage and Current Measurements

- Voltmeter: Potential different between two terminals.
- Larger ranges achieved by potential dividers.



Current flow needs to be measured by inserting the Ammeter into the circuit.

- High current can be measured by shunt connection.



Electric power

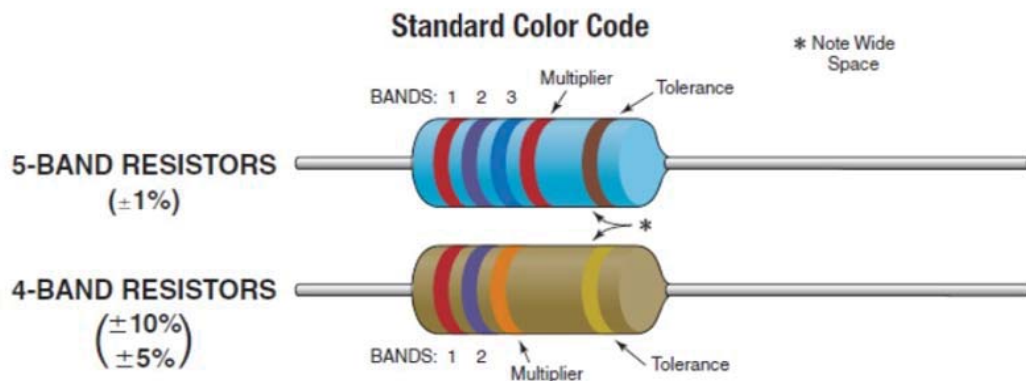
- **Electric power** is the rate, per unit time, at which electrical energy is transferred by an electric circuit. The SI unit of power is the watt (W), one joule per second.

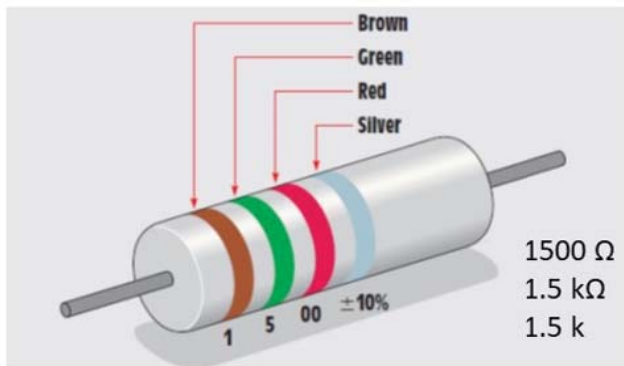
$$P = \frac{\text{Energy}}{t} = \frac{QV}{t} = IV$$

Resistors

- To limit the current, to divide the voltage;
- “Size” of resistor is measured with resistance in Ohm or Ω ;
- Commercially available resistors with resistance values shown in color bands.

Color	Value	Tolerance
Black	0	No color $\pm 20\%$
Brown	1	Silver $\pm 10\%$
Red	2	Gold $\pm 5\%$
Orange	3	Red $\pm 2\%$
Yellow	4	Brown $\pm 1\%$
Green	5	
Blue	6	
Violet	7	
Gray	8	
White	9	





223
= 22×10^3
= 22,000 Ohm
= 22K Ohm

Three-Digit Resistor

4R7
= 4.7 Ohm

Resistor With Radix Point

0
= 0 Ohm

Zero-Ohm Resistor

8202
= 820×10^2 Ohm
= 82,000 Ohm
= 82 KOhm

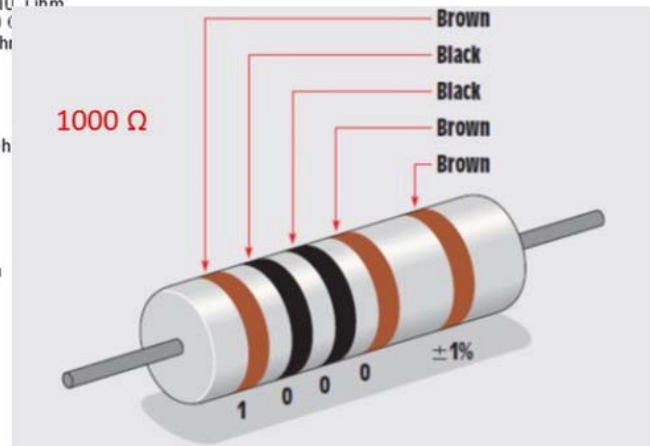
Four-Digit Resistor

0R22
= 0.22 Ohm

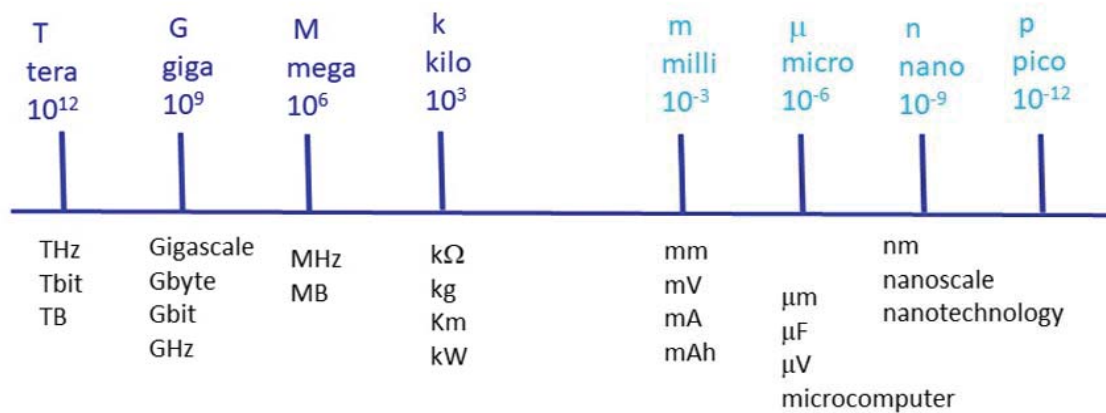
Resistor With Radix Point

000
= 0 Ohm

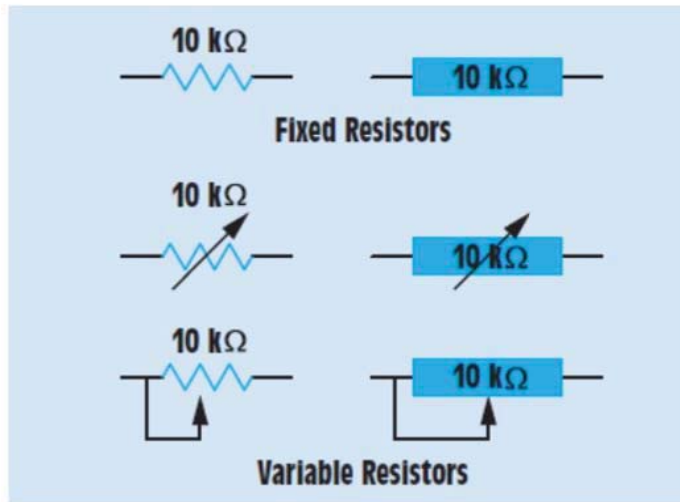
Precisely Zero-Ohm Resistor



Number and Prefix Scales



Variable Resistor



SMD (Surface Mounted Resistor)

223
 $= 22 \times 10^3$
 $= 22,000 \text{ Ohm}$
 $= 22\text{K Ohm}$

Three-Digit Resistor

8202
 $= 820 \times 10^2 \text{ Ohm}$
 $= 82,000 \text{ Ohm}$
 $= 82 \text{ KOhm}$

Four-Digit Resistor

4R7
 $= 4.7 \text{ Ohm}$

Resistor With Radix Point

0R22
 $= 0.22 \text{ Ohm}$

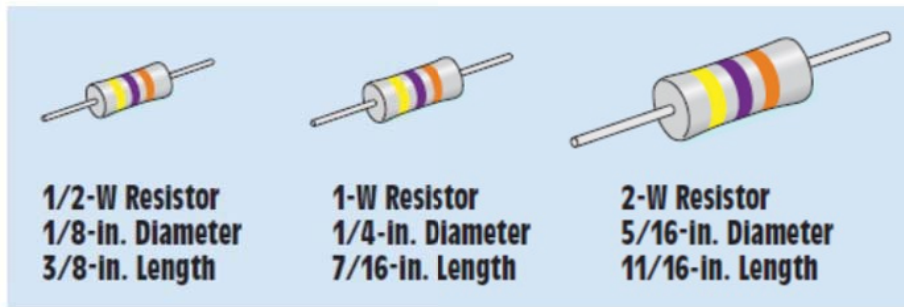
Resistor With Radix Point

0
 $= 0 \text{ Ohm}$

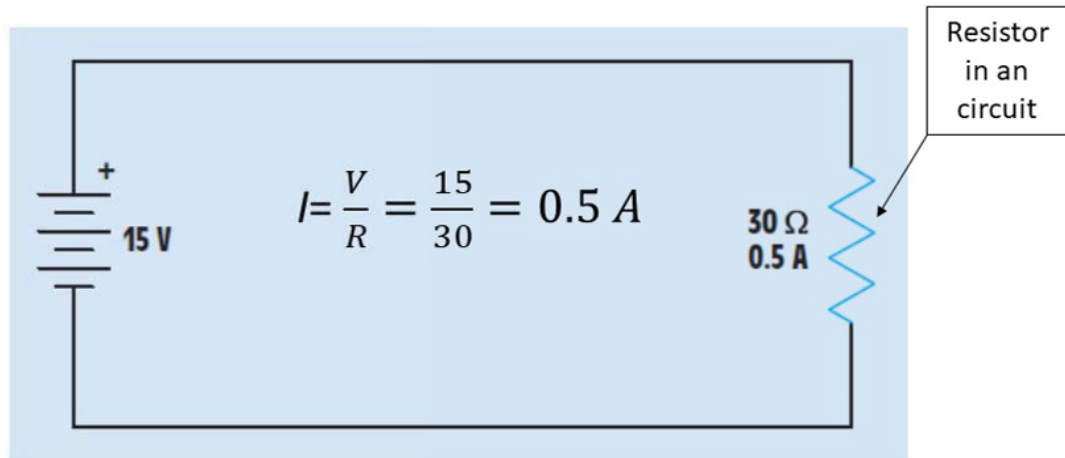
Zero-Ohm Resistor

000
 $= 0 \text{ Ohm}$

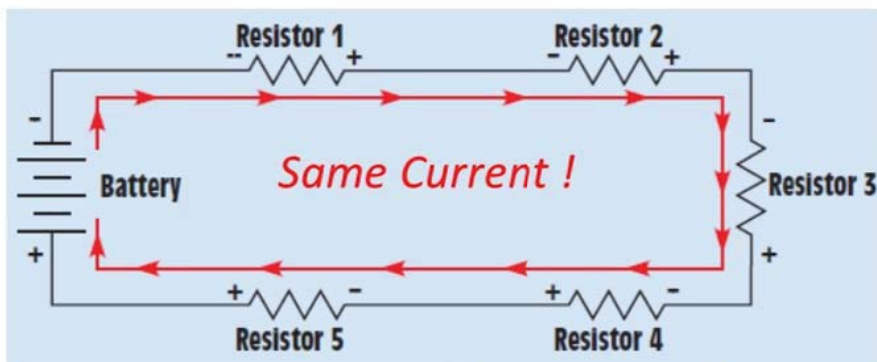
Precision Zero-Ohm Resistor



Resistors with different power ratings

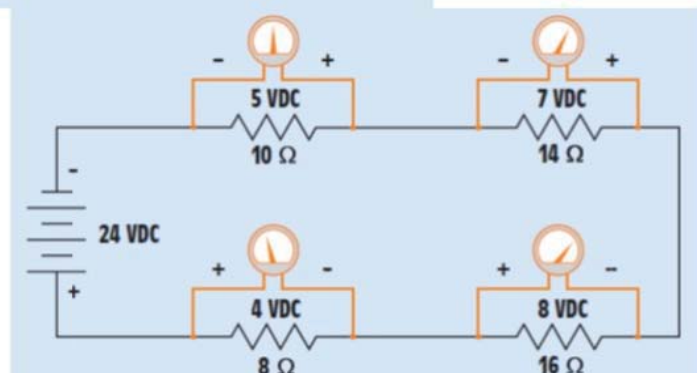


Resistors in Series



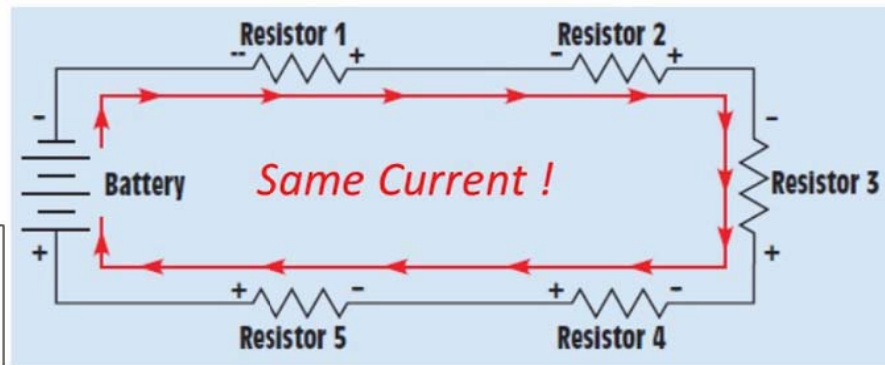
$$R = \frac{V}{I}$$

Larger R, Larger potential drop.



Resistors in Series

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



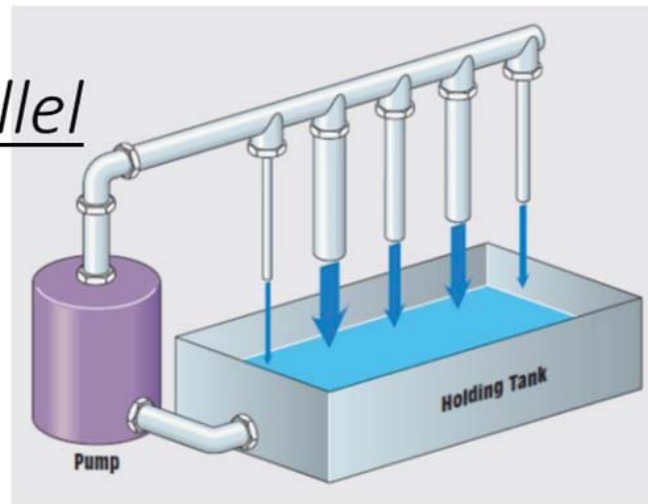
$$V_{tot} = IR_1 + IR_2 + IR_3 + IR_4 + IR_5$$

$$\frac{V_{tot}}{I} = R_S = R_1 + R_2 + R_3 + R_4 + R_5$$

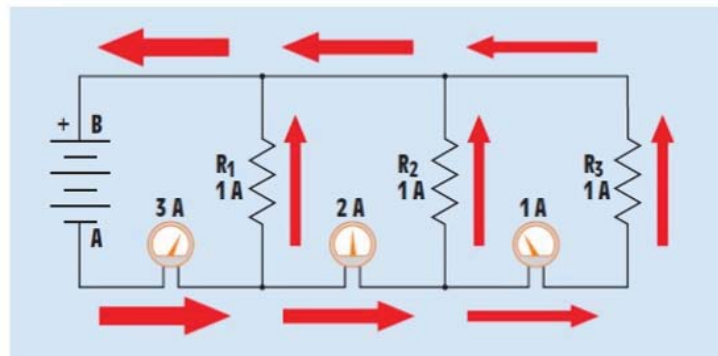
Resistors in Parallel

- Same Voltage

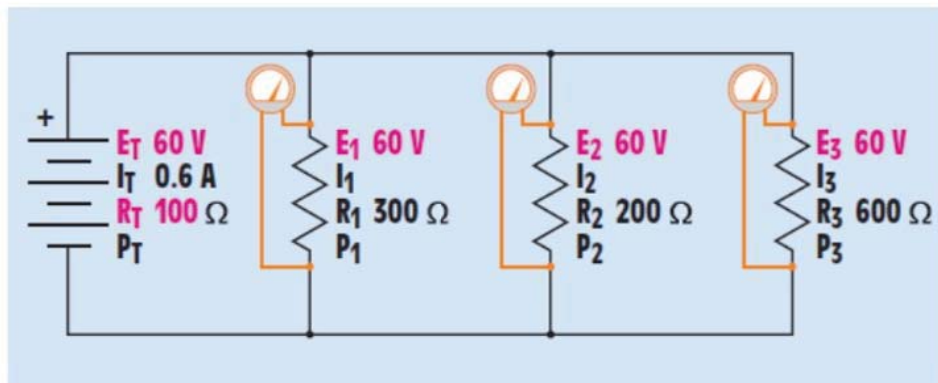
$$R = \frac{V}{I}$$



Larger R, smaller current.



Resistors in Parallel



$$I_1 = \frac{E_1}{R_1} = \frac{60}{300} = 0.2 \text{ A}$$

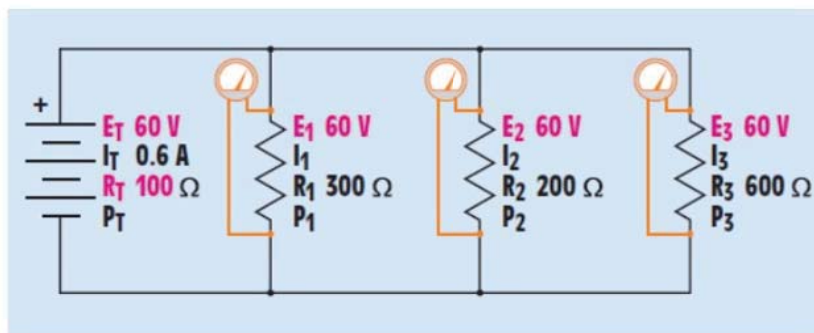
$$I_2 = \frac{E_2}{R_2} = \frac{60}{200} = 0.3 \text{ A}$$

Note:

$$I_T = I_1 + I_2 + I_3$$

$$I_3 = \frac{E_3}{R_3} = \frac{60}{600} = 0.1 \text{ A}$$

Resistors in Parallel



$$I_T = I_1 + I_2 + I_3$$

$$I_T = \frac{E_T}{R_1} + \frac{E_T}{R_2} + \frac{E_T}{R_3}$$

$$\frac{I_T}{E_T} = \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

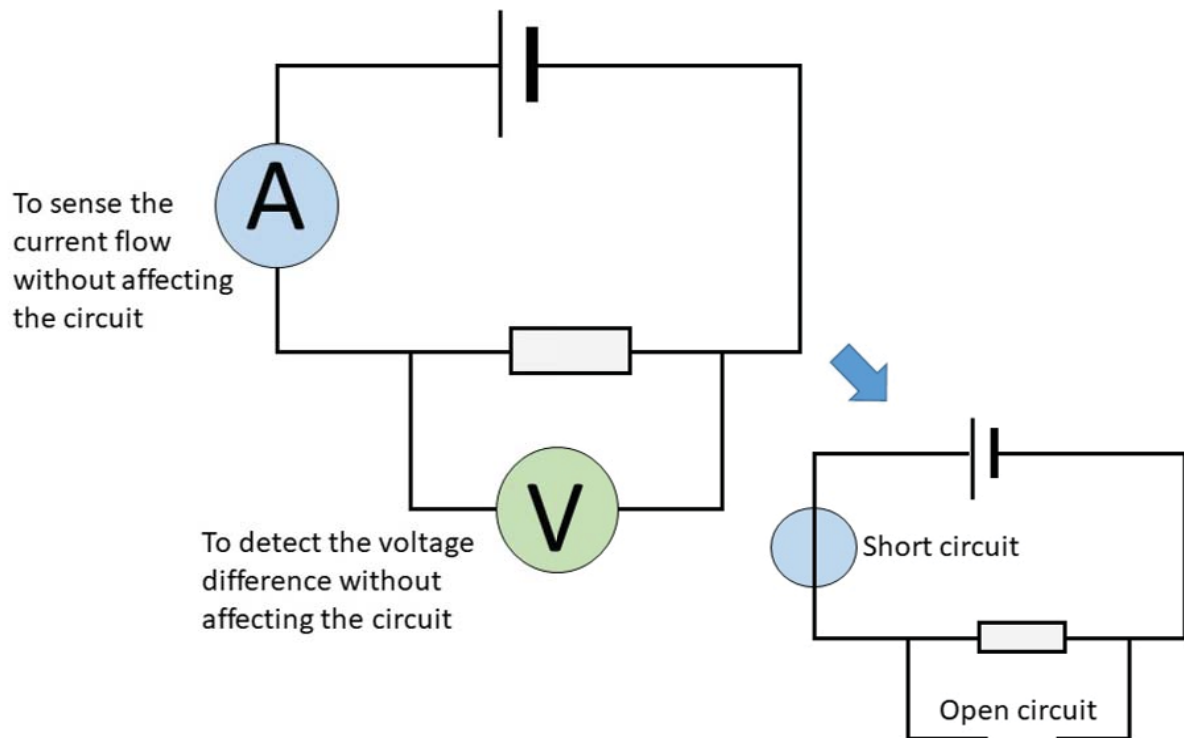
Two resistors in parallel:

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

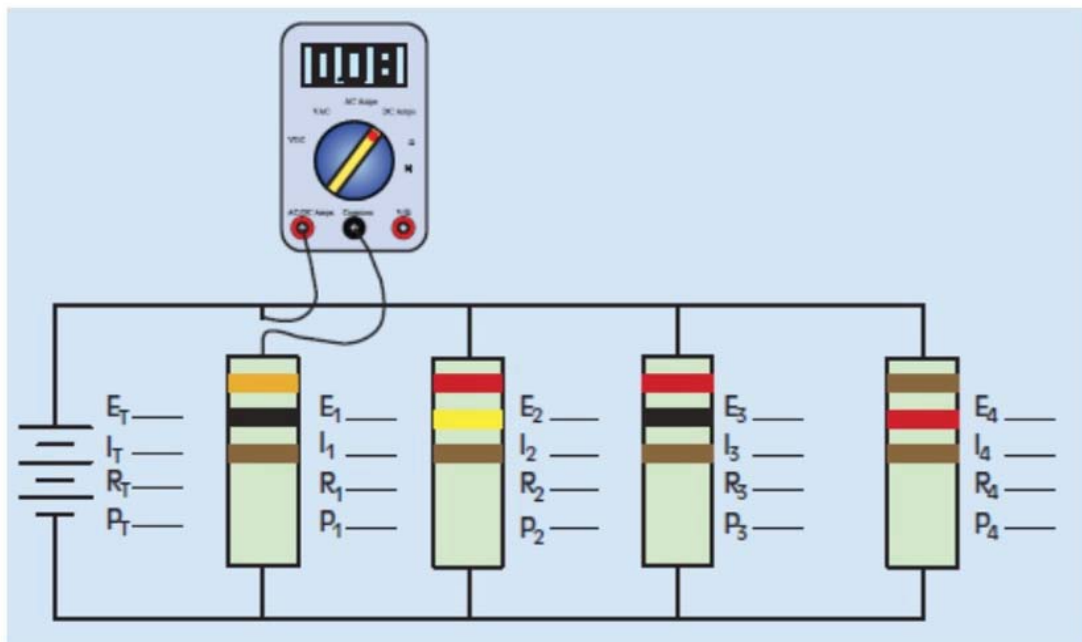
$$R_P = \frac{R_1 R_2}{R_1 + R_2}$$

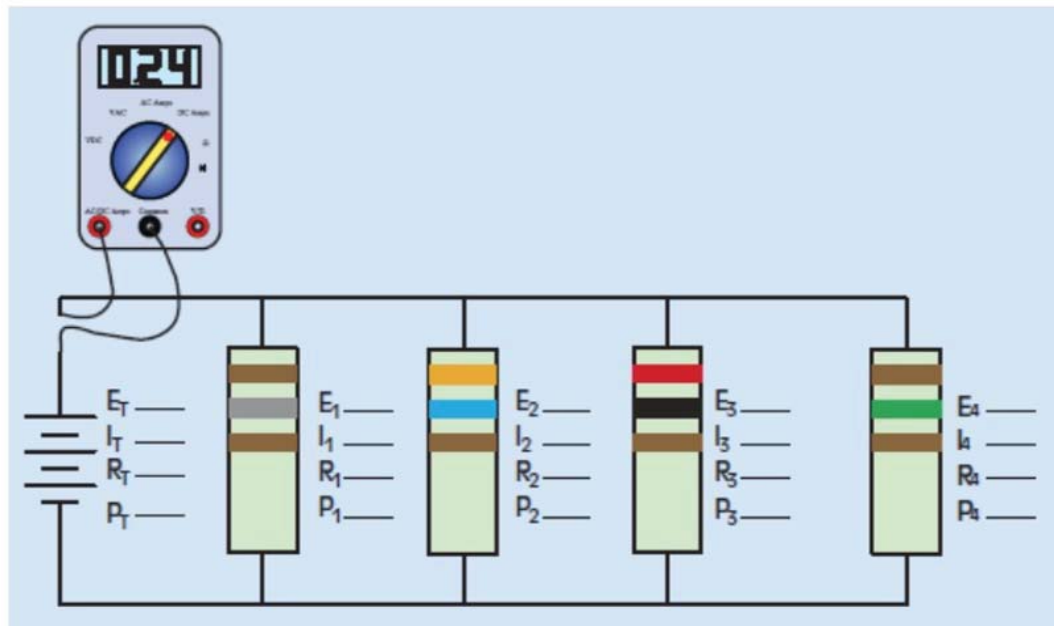
Note: $R_P < R_1$ & R_2

Ammeter and Voltmeter Connections

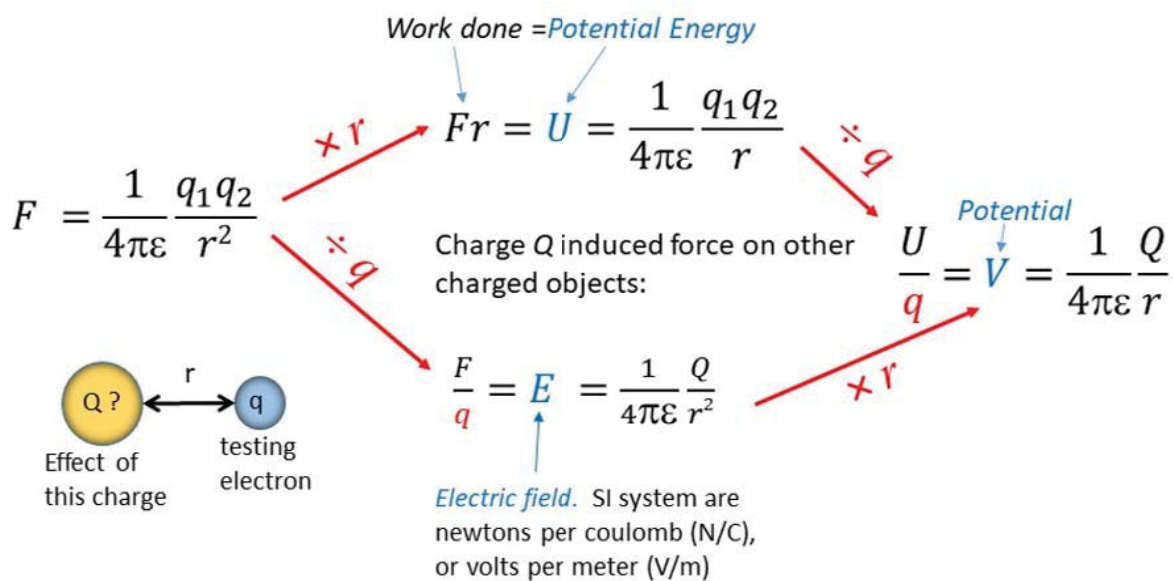


DIY





“Potential” of a Charge



Energy $U = qV \Rightarrow$ electron volt, eV
 Electric field and voltage relation: $V = rE$

Summary

- Key Concepts: Free electron, voltage, current, resistance, Ohm's Law.
- Current is the rate of charge flow past a given point in a given direction.
- Voltage is the energy required to move 1 C of charge through an element.
- Power is the energy supplied or absorbed per unit time. It is also the product of voltage and current.

- Current: $I = Q/t$ (Unit: Ampere, A, mA, μ A)

- Resistance: $R = \rho \frac{l}{A}$ (Unit: Ohm, Ω , k Ω , M Ω)

- Ohm's Law : $I = \frac{V}{R}$

- Electrical Power: $P = IV$ (Unit: Watt, W, mW, kW, MW)

Score: /10

Pay more effort if your score < 7

Self Assessment I

- One millivolt is one millionth of a volt.
(a) True (b) False
- The prefix *micro* stands for:
(a) 10^6 (b) 10^3 (c) 10^{-3} (d) 10^{-6}
- The voltage 2,000,000 V can be expressed in powers of 10 as:
(a) 2 mV (b) 2 kV (c) 2 MV (d) 2 GV
- A charge of 2 C flowing past a given point each second is a current of 2 A.
(a) True (b) False
- The unit of current is:
(a) Coulomb (b) volt (c) ampere (d) joule
- Voltage is measured in:
(a) watts (b) volts (c) amperes (d) joules per second
- The voltage across a 1.1-kW toaster that produces a current of 10 A is:
(a) 11 kV (b) 1100 V (c) 110 V (d) 11 V
- An electric heater draws 10 A from a 220-V line. The resistance of the heater is:
(a) $2200\ \Omega$ (b) $220\ \Omega$ (c) $22\ \Omega$ (d) $2.2\ \Omega$
- The voltage drop across a 1.5-kW toaster that draws 12 A of current is:
(a) 18 kV (b) 120 V (c) 125 V (d) 10.42 V
- The maximum current that a 2W, $80\text{ k}\Omega$ resistor can safely conduct is:
(a) 160 kA (b) 5 mA (c) 40 kA (d) 25 mA

ANSWERS: 1 (b) 2 (d) 3 (c) 4 (a) 5 (c) 6 (b) 7 (c) 8 (c) 9 (c) 10 (b)

Tutorials

Q1. A 60-W incandescent bulb operates at 120 V. How many electrons and coulombs flow through the bulb in one day?

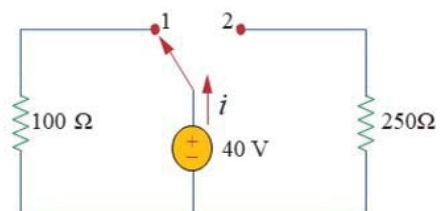
Q2. A battery has a rating of 0.8 ampere-hours (Ah) and a lifetime of 10 hours.

- How much current can it deliver?
- How much power can it give if its terminal voltage is 6 V?
- How much energy is stored in the battery in Wh?

Q3. Find the hot resistance of a light bulb rated 60 W, 220 V.

Q4. (a) Calculate current i in the Figure below when the switch is in position 1.

(b) Find the current when the switch is in position 2.



Additional

Materials for reference only

More on Ohm's law

-

Geometry independent form:

$$I = \frac{1}{\rho} \frac{A}{l} V$$

$$\frac{I}{A} = \frac{1}{\rho} \frac{V}{l}$$

$$\underset{\substack{\uparrow \\ \text{current density}}}{J} = \frac{1}{\rho} E = \underset{\substack{\uparrow \\ \text{conductivity}}}{\sigma} \overset{\substack{\downarrow \\ \text{electric field}}}{E}$$

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



$$\begin{aligned} I &= \frac{V}{R} & I &= GV \\ G &= \frac{1}{R} = \frac{1}{\rho} \frac{A}{l} = \sigma \frac{A}{l} \\ \sigma &= \frac{1}{\rho} \end{aligned}$$

What governs the conductivity?

$$J = \sigma E$$

← **Drift:** charge transport under the influence of an electric field.

$$\sigma = qn\mu$$

electron charge (points to q)
Charge density (points to n)
mobility (points to μ)

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Experiment on Resistance measurement (see Lab sheet EE1002LAB2 for details)

What are the different?

