Ministry of high Education and Scientific Research
Al-Furat Al-Awsat Technical University
Al-Najaf Technical Institute

Electrical Circuits

Electronic and Communication Department
By
Dr. Anwer Sabah Ahmed

2023 / 2024

Inj.anw@atu.edu.iq

Week	Topics Covered
1	Unites system using in electricity , Measuring units (Multiples and Sub- multiples)- mathematics applications for values transformation by using units , define the basic units for (voltage , current , resistance) contents of electrical circuit - Ohm's Law – The factors that offered the resistance value – specific resistance for a conduction material and insulators- Effect of temperature on resistance value – temperature - coefficient for resistance .
2	In Dc circuits : - Resistances connected in Series with examples , - Resistances connected in Parallel with examples , - Compound connection for resistances . - Delta / Star connection for resistances and the transformation between them with examples .
3	Applications for series , parallel , compound circuits And Delta / star transformation .
4	Kirchoff's Laws - kirchhoffs law for current and voltage with applications .
5	Maxwells law with examples solution .
6	Thevenin‘s Theorem - definition of theorem - application in D.C circuits
7	. Norton's Theorem - definition of theorem - applications in D.C circuits
8	Applications examples for Thevenin's & Norton's theorems .
9	Superposition Theorem - Definition of theorem - The procedure for solving the theorem in D.C circuits which consisting more than one source -Solving example for current & voltage source and the transformation between them - Maximum power transfer theorem - Defination of theorem and the relationships derivative for it - Examples .
10	A.C quantities – definition of A.C current – generating a.c current & drawing the wave and the relations for it – definition of active value R.M.S & average value and the relationships between them to find the form & peak factor for non uniform waveforms with examples as applications .

Week	Topics Covered
11	A.C phasors quantities – definition –Phase and graphical representation – finding phase angle – finding the resultant phasor quantities consisting of division multiplication addition subtraction with examples as applications .
12	The effect of A.C current on circuit content resistance only - circuit content pure inductance only - circuit content pure capacitance only - Finding phase angle between current and voltage for each circuit with examples .
13	The effect of A.C current for circuit content (RL , RC , RLC in series) - Finding the relation between current and voltage in three cases – phase angle – total impedance for circuit with examples as applications .
14	The effect of A.C current for circuit content (RL , RC , RLC in parallel) - Finding the relation between current and voltage in three cases – phase angle – total impedance for circuit with examples as applications .
15	Using j – OPERATOR to find total impedance , and total admittance , current ,voltage and phase angle for circuits content impedances connected in series and in parallel with solution examples .
16	Resonance circuits (series resonance , parallel resonance) definition resonance case – The calculation at resonance for current ,voltage , impedance ,phase angle and frequency – Finding quality factor , bandwidth and draw relationship between reactance , capacitive , inductive with frequency - Tutorial problems .
17	Applications for theorems (Norton's , Thevenin's , Superposition) in (A . C) circuits .
18	Power in A .C circuits consisting of the calculations for the power for circuits content (resistances only – inductance only – capacitance only – resistances inductance and capacitance in series and in parallel) -The definition of active power and reactive power and their calculations .
19	The definition for total apparent power – Drawing power triangle – Definition of power factor and the effect of it in A . C circuits with application examples .
20	Maximum power transfer theorem in A.C circuit – Deriving the specified relationship for it with application examples .

Week	Topics Covered
21	The analysis for electrical network using voltage node method -Introduction - node voltages - Number of equations for node voltage - Equations for node voltage using test method .
22	Application examples for electrical networks analysis by using node voltage method .
23	Three phase A .C circuits – The define – Generation of A .C current (one phase , two phase and three phase) – Drawing each circuit - Star / delta Connections in three phase A .C circuits and its relations for calculating line and phase current and voltage , total power , line power , phase power – The advantages for each connection in balance and unbalance loads with application examples .
24	Solving application examples for three phase A .C current star / delta Connections for balance and unbalance loads .
25	Power measurement methods for three phase load – wattmeter instrument – the connection of it in circuit for measuring active power and determine reactive power and apparent power with solving example – measuring power by using wattmeter and voltage – finding total power in this method and in delta / star connection case by using wattmeter – three watt meters .
26	Transit cases for circuits - transit cases for D .C circuits - Circuits in transit case (RL- RC – RLC) circuits .
27	A.C transit currents – sinusoidal transit currents in (RL , RC , RLC) circuits – transfer currents .
28	Self induction for coil – definition – specified relations to find self induction for coil mutual induction between two coils – relations for finding mutual induction according to the connection type of the two coils.
29	Transformers- transforms drawing , the advantages – the basic of operation and the special relationships - types of transformers - examples.
30	Curves for rise and decay current for inductive circuit – its explanation and its affects in D.C current – general relations for grown and distortion current in coil – drawing current and determine time constant – examples solution – charging and discharging for capacitance by using capacitance in D.C current circuits – general relation for charging and discharging capacitance – drawing for current – the affect and calculation for time constant - examples .

References

1. **R. L. Boylestad, Introductory circuit analysis. Upper Saddle River, Nj: Pearson Prentice Hall, I.E, 2007.**
2. **F. J. Bueche and E. Hecht, Schaum's outline of theory and problems of college physics. New York: Mcgraw-Hill, 2006.**

Lecture 1

Unites system using in electricity , Measuring units (Multiples and Sub- multiples)- mathematics applications for values transformation by using units , define the basic units for (voltage , current , resistance) contents of electrical circuit - Ohm's Law – The factors that offered the resistance value – specific resistance for a conduction material and insulators- Effect of temperature on resistance value – temperature - coefficient for resistance .

3/ Pre test :-

Note

- Check your answers in key answer page 48.
- (1) degree for each .

Select the correct answer :-

1 – The unit of resistance is :-

a- volt . b- Ohm

c- Ampere d- haven't unit

2 – 1kΩ is equal to:-

a- 10 Ω . b- 100 Ω

c- 1000Ω d- 10000 Ω

3 – What is 100 mA in amps ?

a- 1A . b- 0.1A

c- 0.01A d- 0.001A

4 – the unit of resistivity is :

a- Ω . b- Ω.mA

c- Ω .m d- Ω \ m_

5 – 1μA means :-

a- 1 \ 1000000 A . b- 1 \ 100 A .

c- 1 \ 1000 A . d- 1 \ 10 A .

6 – The inverse of resistance is :-

a- Conductance . b- resistivity.

c- Conductivity . d- potential difference

7 – The resistance R = ?

a- V.I b- V / I

c- V+I d- V- I

8 –The power P = ?

a- V.I b- V / I

c- V+I d- V- I

9 – The inverse of resistivity is :-

a- Conductance . b- resistance .

c- Conductivity . d- potential difference .

10– When the voltage V is increases the current I according to Ohm's Law is :

a- not change b- constant

c- decreases d- increases

Key Answer

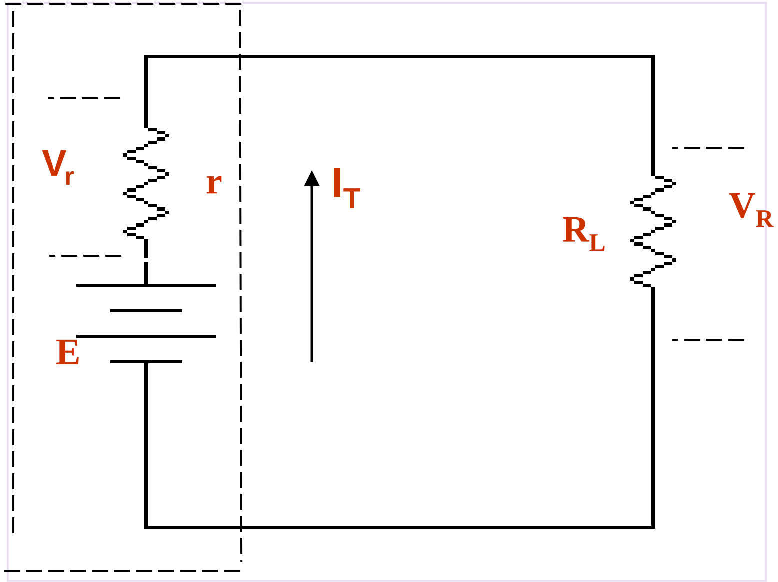
Menu

Simple Electrical Circuit

r : internal resistance of the source .

R_T : resistance Total for the circuit .

I_T : Total current for the circuit .



10

symbol	Unit	Defination	Quantity symbol	Quantity	
V	Volt فولت	$E = V_r + V_R$ Or/ $E = I_T . R._T$	e.m.f Or/ E	القوة الدافعة الكهربائية Electro motive force	1
A	Ampere امبير	$I = \frac{V}{R}$	I	Current التيار	2
V	Volt فولت	V = I . R	V	Potential difference فرق الجهد	3
Ω	Ohm أوم	$R = \frac{V}{I}$	R	Resistanc المقاومة	4
W	Watt واط	$P = V.I = I^2.R = \frac{V^2}{R}$	P	Power القدرة	5
S	Siemens سيمنس	$G = \frac{1}{R}$	G	Conductance التوصيلية	6
m	meter متر	______	L	length الطول	7
m	meter متر	$r = \frac{D}{2}$	R	radius نصف القطر	8
m	meter متر	D = 2r	D	Diameter القطر	9
m^2	Square meter مترمربع	$A = r^2.\pi$	A	Area المساحة	10
Ω . m	Ohm . Meter أوم . متر	$\varsigma = R\frac{A}{\ell}$	ρ	المقاومة النوعية (المقاومية) Specific Resistance (Resistivity)	11
S / m	سيمنس/متر Siemens/meter	$\sigma = \frac{1}{\varsigma}$	δ	التوصيلية النوعية(الموصلية) Specific Conductance (Conductivity)	12
C°	cent degree درجة مئوية	_____	t	Temperature درجة الحرارة	13
$/ C^{\circ}$	per cent degree لكل درجة مئوية	$\alpha = \frac{R_t - R_0}{R_t . t}$	α	معامل درجة الحرارة Temperature Coefficient	14

Electrical Units of Measure

The standard SI units used for the measurement of voltage, current and resistance are the Volt [V], Ampere [A] and Ohms [Ω] respectively. Sometimes in electrical or electronic circuits and systems it is necessary to use multiples or sub-multiples (fractions) of these standard units when the quantities being measured are very large or very small. The following table gives a list of some of the prefixes used in electrical formulas and component values .

Prefix	Symbol	Multiplier	Power of Ten
Voltage	V	1	10^0
Current	I	1	10^0
Resistance	Ω	1	10^0
Capacitance	F	1	10^0
Inductance	H	1	10^0
Frequency	Hz	1	10^0
Power	W	1	10^0
Impedance	Z	1	10^0
Giga	G	1,000,000,000	10^9
Mega	M	1,000,000	10^6
kilo	k	1,000	10^3
milli	m	1/1,000	10^{-3}
micro	µ	1/1,000,000	10^{-6}
nano	n	1/1,000,000,000	10^{-9}
pico	p	1/1,000,000,000,000	10^{-12}

Unit Modifiers for Reference

Smaller

- Deci = 10^{-1}
- Centi = 10^{-2}
- Milli = 10^{-3} m
- Micro = 10^{-6} μ
- Nano = 10^{-9}
- Pico = 10^{-12} p
- Femto = 10^{-15}

Larger

- Kilo = 10^{3} k
- Mega = 10^{6} M
- Giga = 10^{9} G
- Tera = 10^{15} T

Examples:

5mA = .005A

10kΩ = 10000 Ω

So to display the units or multiples of units for either Resistance, Current or Voltage we would use as an example:

1kV = 1 kilo-volt - which is equal to 1000 Volts.

1mA = 1 milli-amp - which is equal to one thousandths (1/1000) of an Ampere.

47kΩ = 47 kilo-ohms - which is equal to 47 thousand Ohms.

100uF = 100 micro-farads - which is equal to 100 millionths (1/1,000,000) of a Farad.

1kW = 1 kilo-watt - which is equal to 1000 Watts.

1MHz = 1 mega-hertz - which is equal to one million Hertz.

To convert from one prefix to another it is necessary to either multiply or divide by the difference between the two values. For example, convert 1MHz into kHz.

Well we know from above that 1MHz is equal to one million (1,000,000) hertz and that 1kHz is equal to one thousand (1,000) hertz, so one 1MHz is one thousand times bigger than 1kHz.

Then to convert Mega-hertz into Kilo-hertz we need to multiply mega-hertz by one thousand, as 1MHz is equal to 1000 kHz. Likewise, if we needed to convert kilo-hertz into mega-hertz we would need to divide by one thousand.

A much simpler and quicker method would be to move the decimal point either left or right depending upon whether you need to multiply or divide.

Current, Voltage, Resistance

- **Current is the rate of flow of electrons/charge**
  - **It is abbreviated as I**
  - **It is measured in amperes**
  - **One ampere is defined as one coulomb (Q; 6.28 X 10^{18}) of electrons flowing past a point each second (Q/s)**

- **Voltage is a force that pushes/drives the electrons/charge**
  - **It is also referred to as electromotive force or difference in potential.**
  - **It is abbreviated as E or EMF**
  - **Voltage is measured in volts (v)**
  - **Voltage source will have a polarity (negative and positive side)**
  - **Current flows from negative to positive (changing conventions)**
  - **AC/DC: Alternating current (polarity of source reverses) or Direct current (polarity is constant)**

- **Resistances are the barriers to the flow of charge**
  - **It is abbreviated as R**
  - **It is measured in ohms**

Voltage, Current & Resistance

In electronics we are dealing with voltage, current and resistance in circuits .

Voltage :

Voltage is the electrical force, that causes current to flow in a circuit. It is measured in VOLTS .

Electrical Current :

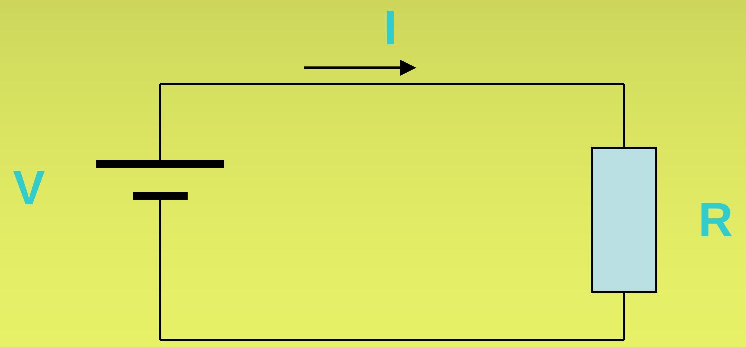
Current is the movement of electrical charge - the flow of electrons other charged particles through the electronic circuit. The direction of a current is opposite to electrons flow direction. Current is measured in AMPERES (AMPS, A) .

Resistance :

Resistance causes an opposition to the flow of electricity in a circuit. It is used to control the amount of voltage and/or amperage in a circuit. It is measured in OHMS .

Resistance of Conductors OHM'S LOW

- The Value of the resistance of a conductor Resistor
  - equal the Voltage across the resistor divided by the Current passing through it
- **R = V / I (OHMS) Ω**



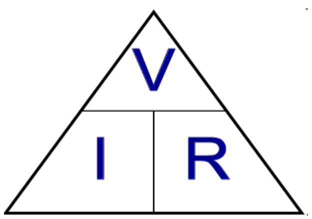
Resistance of Conductors

<u>OHM'S LAW</u>

Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference or voltage across the two points, and inversely proportional to the resistance between them provided the temperature remains constant

The mathematical equation that describes this relationship is :

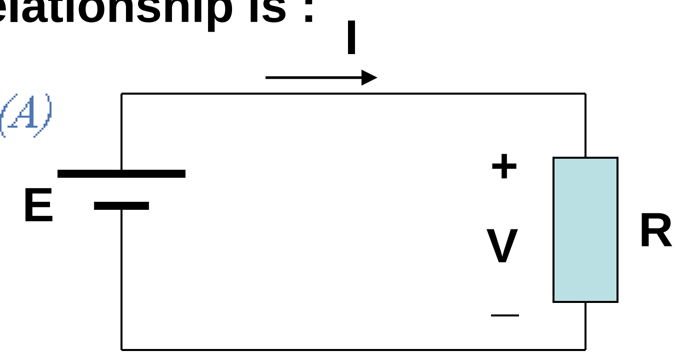
$$Current, (I) = \frac{Voltage, (V)}{Resistance, (R)} \; in \; Amperes, (A)$$



Ohms law triangle

V (volts) = I (amps) x R (Ω)

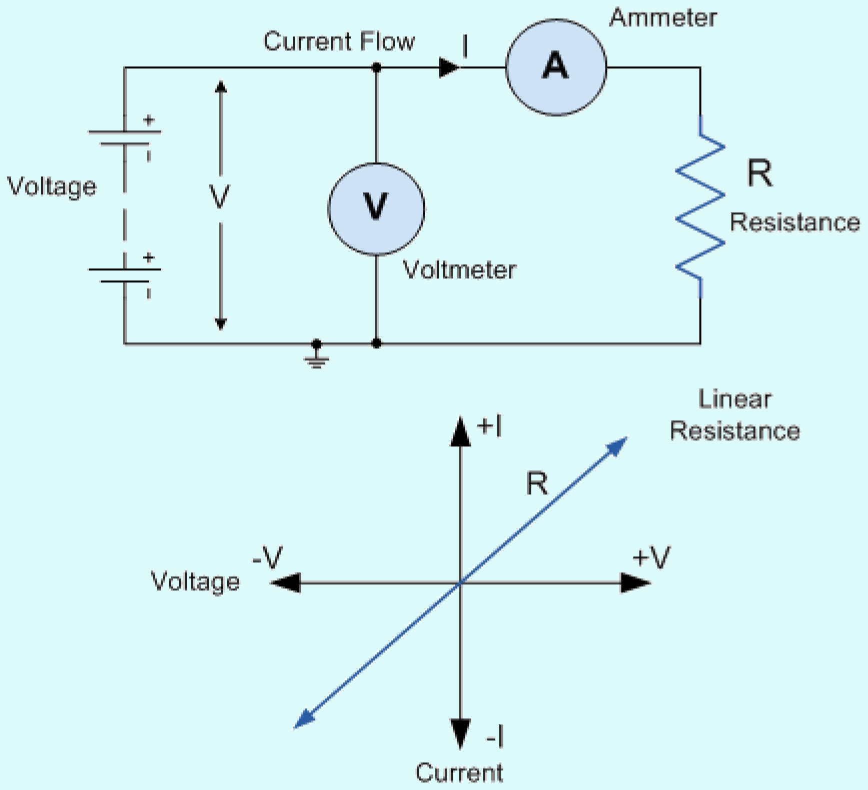
R (Ω) = V (volts) ÷ I (amps)



V, I, and R, the parameters of Ohm's law .

where *V* is the potential difference measured *across* the resistance in units of volts ;*I* is the current through the resistance in units of amperes and *R* is the resistance of the conductor in units of ohms .More specifically, Ohm's law states that the *R* in this relation is constant, independent of the current .

Relationship between Voltage and Current in a circuit of constant resistance .



Example No.1

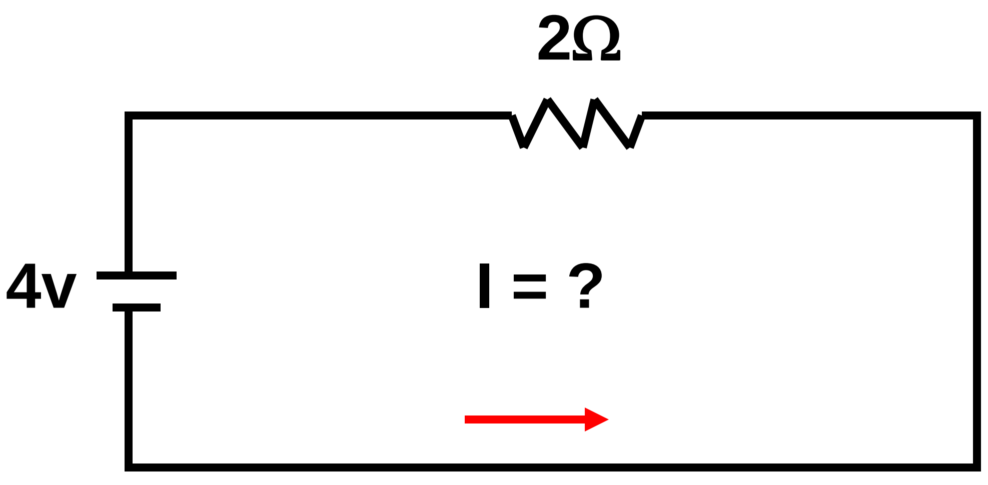
A 4v battery is placed in a series circuit with a 2Ω resistor.

What is the total current that will flow through the circuit?

$E = IR$

$4v = I * 2\ \Omega$

$I = 2A$



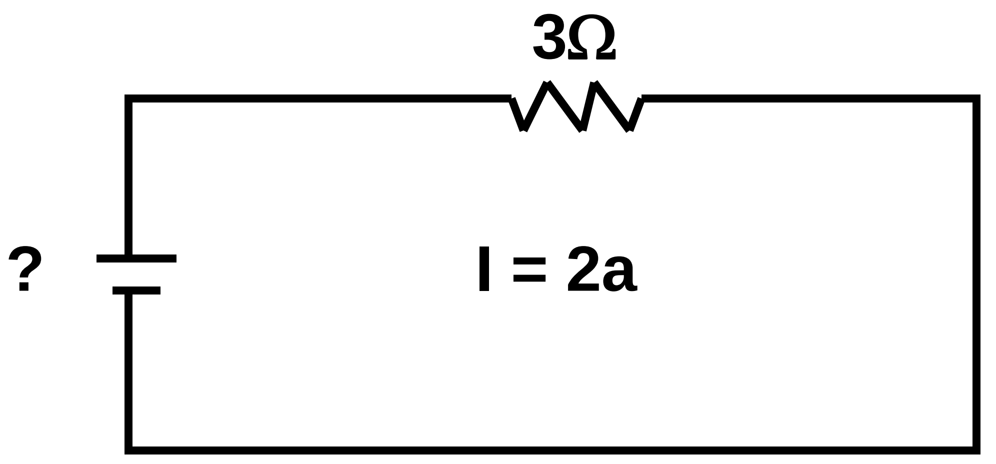
Example No.2

What voltage is required to produce 2A though a circuit with a 3Ω resistor.

E = IR

E = 2A * 3Ω

E = 6v



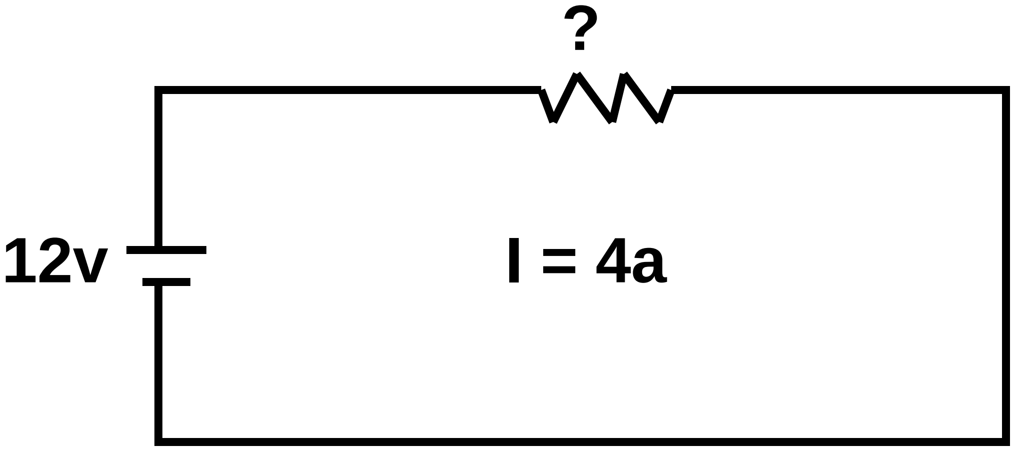
Example 3

What resistance is required to limit the current to 4A if a 12 v battery is in the circuit?

E = IR

12 = 4A * R

R = 3Ω



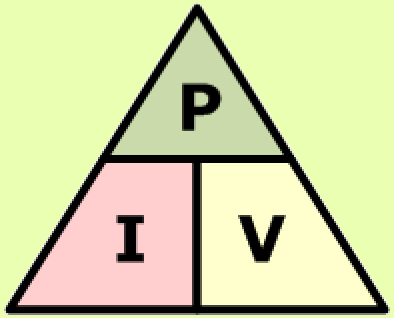
To find Power (P)

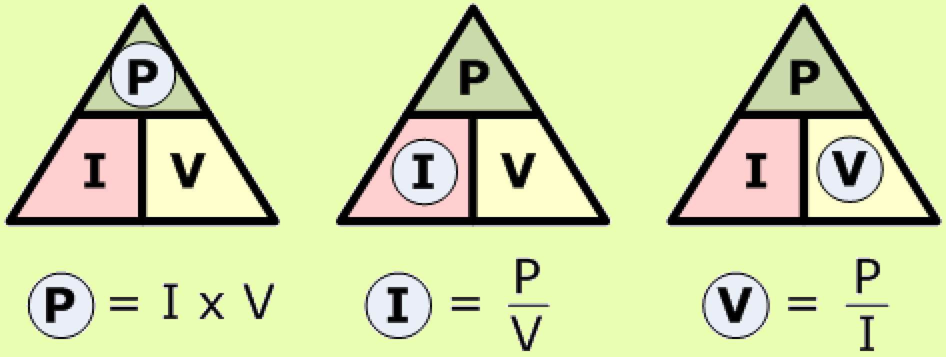
[P = V x I] P (watts) = V (volts) x I (amps)

,Also
(volts) ÷ R (Ω) 2R] P (watts) = V ÷ 2P = V]

,Also
(amps) x R (Ω) 2x R] P (watts) = I 2P = I]

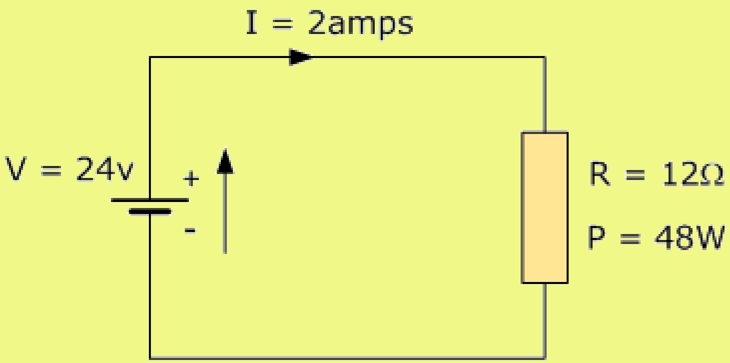
The Power Triangle





Example

For the circuit shown below find the Voltage V, the Current I, the Resistance R and the Power P .



Voltage [V = I x R] = 2 x 12Ω = 24V

Current [I = V ÷ R] = 24 ÷ 12Ω = 2A

Resistance [R = V ÷ I] = 24 ÷ 2 = 12 Ω

Power [P = V x I] = 24 x 2 = 48W

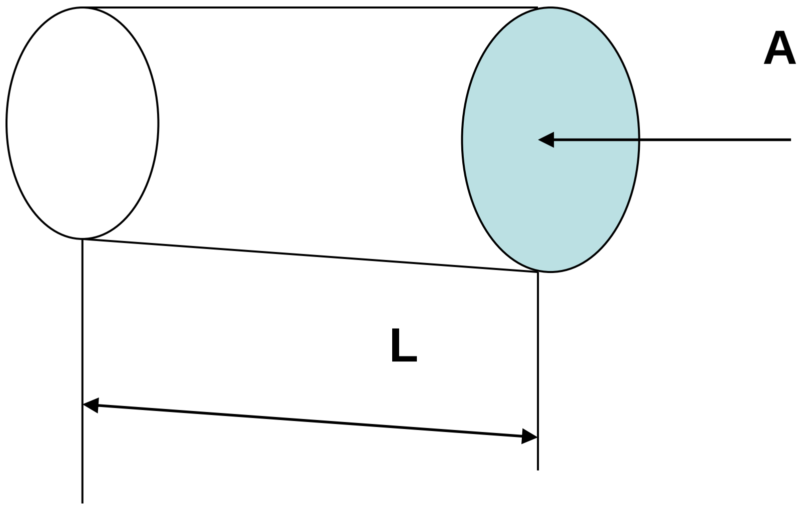
Conductance

The reciprocal of **resistance** is conductance (G), measured in siemens (S)

$G = 1/R$ (siemens, S)

Resistance of Conductors

- RESISTIVITY When electric charge flows through a circuit it encounters electrical RESISTANCE. The resistance of a metal conductor is a property which depends on its dimensions, material and temperature.
- Resistance increases with L
- Resistance decreases with A
- Resistance depends on the conductor's specific resistance



$$R = L \times \rho / A \ (\Omega)$$

where

R = resistance (ohms, Ω)

ρ = resistivity (ohm meter, Ω m)

L = length of conductor (m)

A = cross-sectional area of conductor (m^2)

Electrical resistance of an electrical conductor depends on :
- the length of the conductor
- the material of the conductor
- the temperature of the material
- the cross-sectional area of the conductor

Example

The resistance of a 10 meter copper wire with a cross sectional area of 0.8 mm^2 and resistivity of 1.7×10^{-8} Ω m can be calculated as:

$$R = (1.7 \times 10^{-8}\ \Omega\ m)\ (10\ m)\ /\ ((0.8\ mm^2)(10^{-6}\ m^2/mm^2))$$
$$= \underline{0.21}\ \Omega$$

Self Test

Problem 1 /

What are the unit of Resistivity (ρ) ?

Problem 2 /

A resistance of 1 M Ω is equivalent to a conductance of ?

Problem 3 /

If you have a 120 volt appliance and 2 amperes of current flow through it, what is the power used by it in watts? What is its resistance in ohms?

Key Answer

Menu

Conductivity (σ) :

The inverse of resistivity is called conductivity and can be expressed as :

$\sigma = 1 / \rho$ (2) ⟷ $\rho = \dfrac{1}{\sigma}$

Where :

σ = conductivity (1 / Ω m)

Temperature coefficient of resistance :

The temperature coefficient of resistance is a number used to predict how the resistance of a material changes with changes in temperature. Typically the units are either resistance per temperature or 1/temperature depending on which Equation is used for the calculations.

For example, in copper the temperature coefficient of resistance is about 0.0039 per change in degrees Celsius. A positive temperature coeefficient of resistance means that the resistance of the material will increase as temperature increases.

$$R = R_0[1 + \alpha(T - T_0)]$$

Resistance of Conductors Variations with Temperature

- Resistance of metal conductors increases with the temperature increase.
  - $Rh = Rc + \Delta R$
  - $Rh = Rc\ (1 + \alpha\ \Delta T)$
    - ΔT IS THE TEMERATURE INCREASE IN DEGREES

    α : is the Resistance coefficient (Ω / ° C)

    Equals the change in the resistance a conductor having a 1 OHM resistance When the temperature change equals 1 degree centigrade

- The resistance changes according to the equation:

$R_T = R_O\ (l + \alpha T)$

R_O is the resistance at some reference temperature such as 0 or 20 degrees

Resistance of Conductors
Temperature Effect Example

- If a copper wire resistance R =0.09 Ω
- Let Rc= .09 Ω at 20 degrees C.
  - At 55 degrees C.; R becomes
    - **With α = 0.0038 for copper**

      $Rh = Rc (1 + \alpha \Delta T)$

      $Rh = .09 (1 + .0038 (55 – 20))$

      $Rh = .09 (1 + .0038 \times 35)$

      $Rh = .09 (1.133) = 0.10\ \Omega$ …

      » **nearly 13.3% increase for 175% increase in temperature.**

      » **Similarly, for Constantan ALLOY the increase would be equal to 0.02% only.**

Resistance of Conductors
Temperature Coefficients (α)

- COPPER +0.0038 Ω/°c
- ALLUMINIUM + 0.004
- STEEL - 0.0045
- CONSTANTAN alloy -0.000005
- GRAPHITE -0.0004
- TANGESTIN +0.0041

Summary

** Voltage or potential difference is the measure of potential energy between two "**volt drop**" points in a circuit and is commonly referred to as its.

** When a voltage source is connected to a closed loop circuit the voltage will produce a current flowing around the circuit .

** In D.C. voltage sources the symbols +ve (positive) and -ve (negative) are used to denote the polarity of the voltage supply .

** Voltage is measured in" **Volts** "and has the symbol" V "for voltage or" E "for energy .

** Current flow is a combination of electron flow and hole flow through a circuit .

** Current is the continuous and uniform flow of charge around the circuit and is measured in" **Amperes** "or" **Amps** "and has the symbol" I ."

** The effective (rms) value of an AC current has the same average power loss equivalent to a DC current flowing through a resistive element

** Resistance is the opposition to current flowing around a circuit.

** Low values of resistance implies a conductor and high values of resistance implies an insulator .

** Resistance is measured in" **Ohms** "and has the Greek symbol" Ω "or the letter" R

5/ Post test :-

Note :
- Check your answers in key answer page 49 .
- (1) degree for each .

Problem 1 /

Define Ohm's Law ?

Problem 2 /

The current (2.5 μA) equal to --------- Ampere .

Problem 3 /

What are the unit of conductivity (σ) . Remember that :

$$\sigma = 1 / \rho$$

Problem 4 /

A resistance of 2 M Ω is equivalent to a conductance of ?

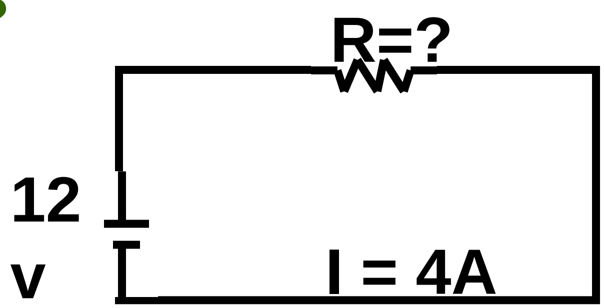
Key Answer

Menu

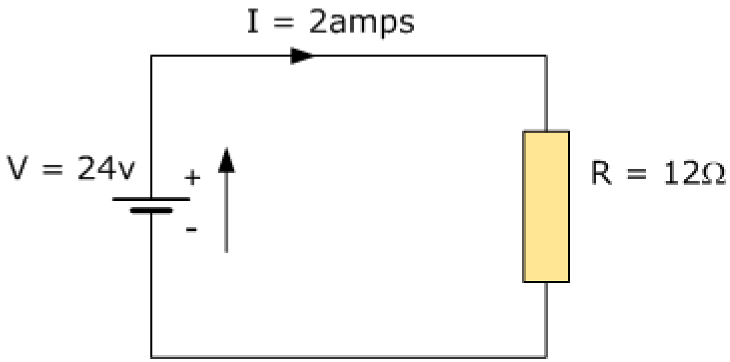
Problem 5 /

Define the conductivity (σ) ?

Problem 6 / **What resistance is required to limit the current to 4A if a 12 v battery is in the circuit?**



Problem 7 / **For the circuit shown below find the Power P which wouid be disspated in the resistance R .**



Key Answer

Menu

Problem 8 /

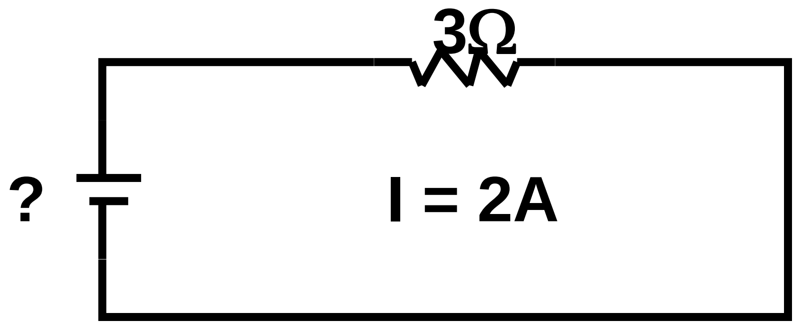
copper wire has a length of 10 meter and a cross sectional area of 0.8 mm2 and resistivity of *1.7 x 10-8 Ω m* , calculated its resistance ?

Problem 9 /

If a copper wire resistance R =0.09 Ω
Let Rc= .09 Ω at 20 degrees C.
what are the of resistance at 55 degrees C.
With α = 0.0038 for copper

Problem 10 /

What voltage is required to produce 2A though a circuit with a 3Ω resistor.



Key Answer

Menu

6/ key answer :-

1- Pre test :-

1. b
2. c
3. b
4. c
5. a
6. a
7. b
8. a
9. c
10. d

If you :-
got 9 or more you do not need to proceed .
got less than 9 you have to study this modular unit well .

Back To Pre Text

Menu

2- Self Test :-

Back To Self Test

1- Ω . m

2- 10-6 S

3- R = V / I = 120 / 2 = 60 Ω

3- Post Test :-

1- Ohm's law states that the current through a conductor between two points is directly proportional to the potential difference or voltage across the two points, and inversely proportional to the resistance between them provided the temperature remains constant (R = V / I) .

2- (2 * 10-6 A)

3- (1 / Ω . m) = (S / m)

Back To Post Test

Menu

4- (0.5 * 10-6 S)

5- Conductivity (σ) is the inverse of resistivity :

$\sigma = 1 / \rho$ *(So its unit is 1 / Ω m)*

6- R = V/ I = 12 / 4 = 3 Ω

7- P = V * I = 24 * 2 = 48 w

8- *R = (1.7 x 10-8 Ω m) (10 m) / ((0.8 mm2)(10-6 m2/mm2))*

= 0.21 Ω

9- Rh = Rc (1 + α ΔT)

Rh = .09 (1 + .0038 (55 – 20))

Rh = .09 (1 + .0038 x 35)

Rh = .09 (1.133) = 0.10 Ω …

10- V = R * I = 3 * 2 = 6 v

Back To Post Test

Menu