EDEXCEL NATIONAL CERTIFICATE/DIPLOMA
SCIENCE FOR TECHNICIANS

OUTCOME 2 - ELECTRICAL PRINCIPLES

TUTORIAL 2 – D.C. CIRCUITS

2 Electrical principles

Electrical energy: electric charge, charged conductors, conductors and insulators, resistivity and resistance, potential difference, electro-motive force, voltage, current

Dc circuits: Ohm's law, current, voltage and resistance in a simple circuit, series and parallel circuits, combined series/parallel circuits, Kirchoff's laws, elementary electrical power formulae

Magnetism: permanent magnets and magnetic fields, magnetic effect of a current, electromagnets, electro-magnetic induction, transformers, Lenz's and Faraday's laws, generator principle, motor principle

You should judge your progress by completing the self assessment exercises. These may be sent for marking at a cost (see home page).

On completion of this tutorial you should be able to do the following.

- Explain and use Ohm’s Law
- Explain and use Kirchoff’s Law
- Calculate electric power.
- Calculate the current and voltage in circuits made from resistors.

1 OHM'S LAW

Ohm discovered that the current 'I' flowing through a resistance is directly proportional to the voltage across it. The circuit shows how a voltmeter and ammeter may be used to prove this.

If the voltage V is varied and the current is I measured, it is found that V/ I = constant

The constant is the resistance R and has units of Volts per Ampere but this is commonly known as the Ohm (Ω).

$$V/I = R$$

2 ELECTRIC POWER

Electrons carry energy and this is given by Energy = Volts x Charge = VQ

Power is energy per second so the electric power is

P = E/second = V Q/Second

Charge per second is the current I Amperes. It follows that the power contained in an electric current is

$$P = VI$$

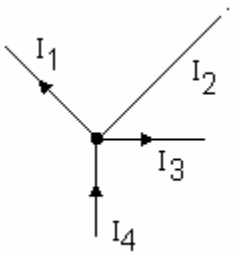
The formula may be presented in other ways by substituting Ohm's law into it. from Ohm's law we have V = IR and I = V/R.

Substituting for V gives $P = I^2R$

Substituting for I gives $P = V^2/R$

3 KIRCHOFF'S RULE

This rule concerns the currents flowing in and out of a junction. It simply states that the total current entering a junction equals the total current leaving the junction. Consider 4 conductors carrying currents into and out of a junction as shown.



Let current entering the junction be positive and currents leaving be negative. The rule then becomes

$$I_1 + I_2 + I_3 + I_4 = 0$$

Suppose $I_1 = -2$ Amps, $I_3 = -4$ Amps and $I_4 = 7$ Amps. Determine I_2 .

$$I_1 + I_2 + I_3 + I_4 = 0$$
$$-2 + I_2 - 4 + 7 = 0$$
$$I_2 = -1 \text{ Amp (i.e. leaving)}$$

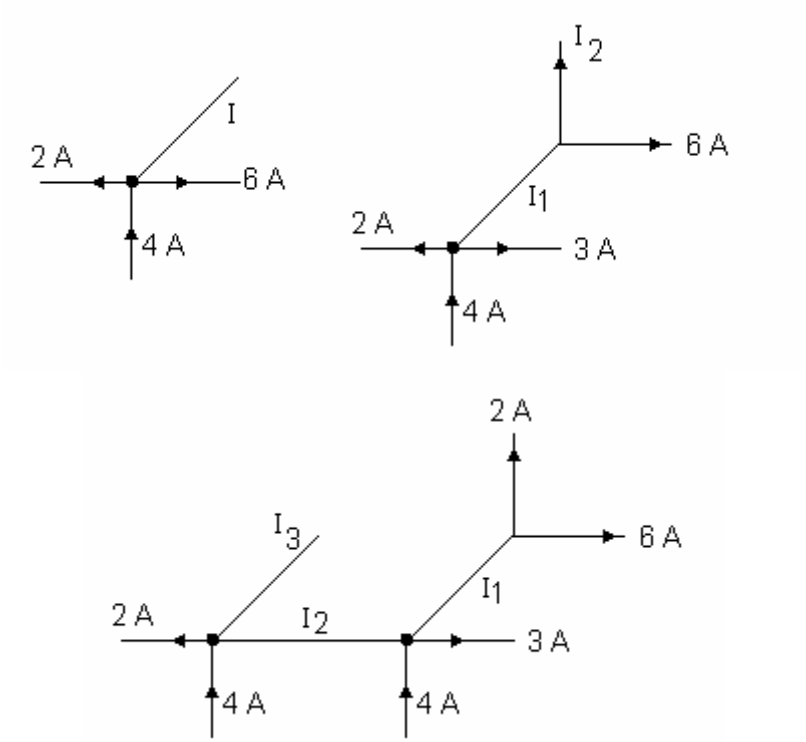
SELF ASSESSMENT EXERCISE No. 1

1. Calculate the resistance if a voltage of 10 V produces a current of 0.2 Amperes. Also calculate the power dissipated. (50 Ω)

2. Calculate the current which flows in a resistor 5Ω when 240 V is applied to it. Also calculate the power dissipated. (48 A and 11520 W)

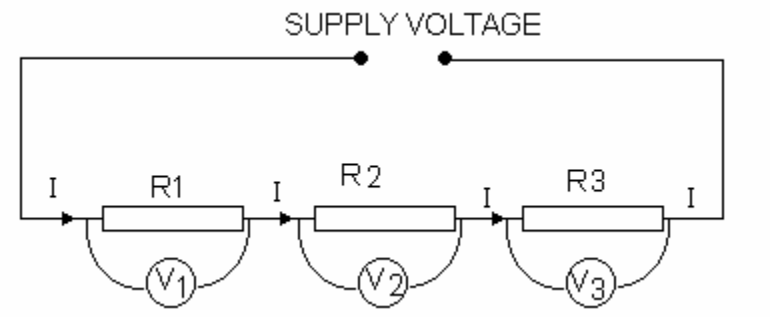
3. Calculate the voltage needed to make 20 mA flows in a resistor of 470kΩ . (9400 V)

4. Find the unknown current for each case shown.



4 RESISTORS IN SERIES –VOLTAGE DIVIDERS

Consider 3 resistors in series as shown.



The same current I flow through each of them. The voltage drop on each is given by Ohms' Law as follows.

$$V_1 = I R_1 \qquad V_2 = I R_2 \qquad V_3 = I R_3$$

In other words the voltage is divided according to the resistors. If the resistors were all equal, the voltage would be divided equally across each. The three voltages must add up to the supply voltage V.

$$V = V_1 + V_2 + V_3$$
$$V = I R_1 + I R_2 + IR_3$$
$$V = I (R_1 + R_2 + R_3)$$

If the 3 resistors were replaced by a single total resistor R_T then the supply voltage would be

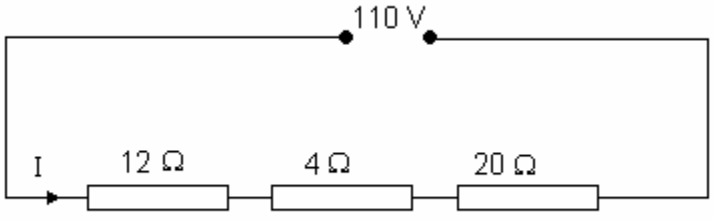
$$V = I R_T$$

Comparing the two equations it is apparent that $\mathbf{R_T = R_1 + R_2 + R_3}$

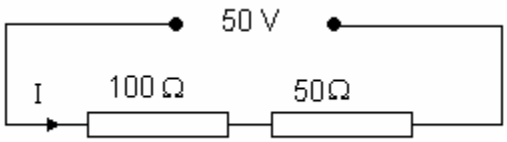
Resistors in series may be added to give one equivalent value.

SELF ASSESSMENT EXERCISE No. 2

1. Calculate the current flowing in the circuit below and the voltage drop over the middle resistor.

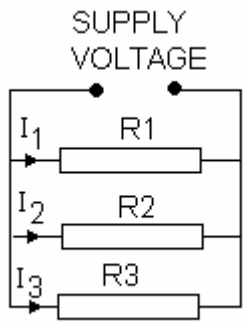


2. Calculate the total resistance of the circuit shown. Determine the current and the voltage drop over each resistor. (150 W), 0.333 A, 33.3 V and 16.67 V)



5 RESISTORS IN PARALLEL – CURRENT DIVIDERS

Consider 3 resistors in parallel as shown.



The voltage across each is the supply voltage V. The current flowing in each is given by Ohms' Law as

$I_1 = V/R_1$ $I_2 = V/R_2$ $I_3 = V/R_3$

In other words the current is divided according to the resistance. If the resistors were all the same, the same current would flow in each. The total current drawn from the supply is

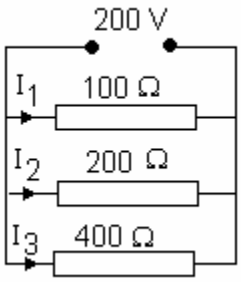
$I = I_1 + I_2 + I_3$
$I = V/R_1 + V/R_2 + V/R_3$
$I = V(1/R_1 + 1/R_2 + 1/R_3)$

If the same current was drawn from the supply by a single resistor R_T the current would be
$I = V/R_T$
Comparing the two equations it is apparent that

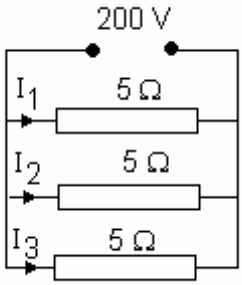
$1/R_T = 1/R_1 + 1/R_2 + 1/R_3$ $\qquad R_T = \dfrac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}}$

SELF ASSESSMENT EXERCISE No. 3

1. Calculate the total resistance for the circuit shown. Determine the total current drawn from the supply.

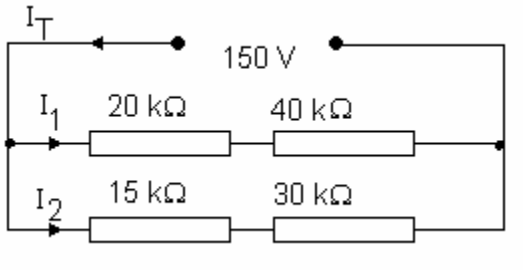


2. Calculate the total resistance for the circuit shown. Determine the current in each resistor and the total current drawn from the supply.
   (1.66Ω, 40 A 120 A)

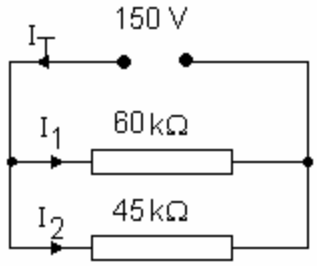


6 RESISTANCE NETWORKS

A network is a combination of parallel and series circuits. In order to find the total resistance, the circuit must be broken down step by step by identifying the series and parallel circuits and replacing them with a single resistor. The following example shows this.



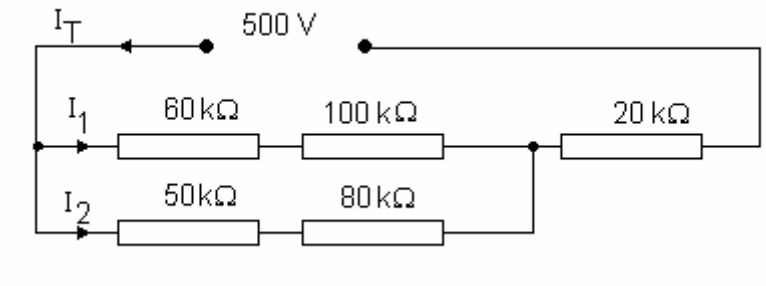
First identify two series circuits and replace them by single resistors.
20 + 40 = 60 15 + 30 = 45



Next solve the parallel circuit. $R_T = 1/\{1/60 + 1/45\} = 25.71$ kΩ.
The total current is $I_T = V/R_T = 150/25710 = 0.00583$ Amps or 5.83 mA.

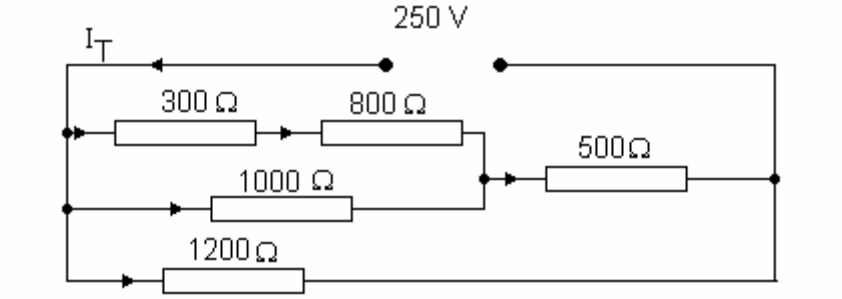
SELF ASSESSMENT EXERCISE No. 4

1. Solve the total resistance and current. Determine the voltage over the 20 K resistor.



(Answers 91.72 Ω, 5.45 mA and 109 V)

2. Solve the total resistance and current. Determine the voltage over the 800Ω resistor.



(Answers 552.46 Ω, 0.452 A and 93 V)