2.Multiple path dc circuits

Introduction

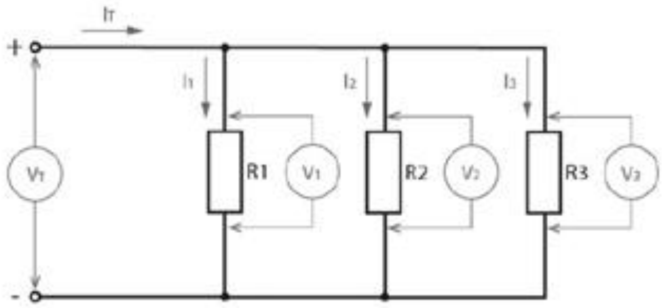
In this section, we will explore the characteristics of parallel circuits and the methods of determining parallel circuit operating parameters.

The voltages, currents and resistances in the different parts of a parallel circuit will always behave according to Ohm's Law, as discussed in Topic 3 Ohm's Law in UEECD0046.

In addition, the power dissipated in a parallel circuit can be determined by applying the Power Equation, as discussed in Topic 4 Electrical Power in UEECD0046.

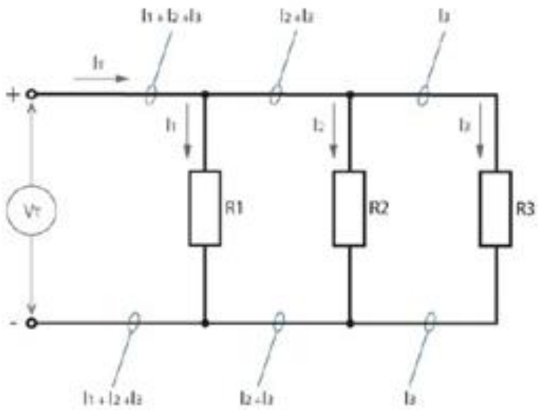
Circuit Characteristics

The diagram below shows three resistive loads connected in parallel.



By examining the circuit, it can be seen that ***a parallel circuit has several current paths***. When the current reaches a junction, it splits up according to the resistances offered by each path.

The following diagram shows the current that will be flowing in the various connecting wires of a parallel circuit.



Current in Parallel Circuits

When loads are connected in parallel, ***the sum of the individual branch currents is equal to the total circuit current***. This can be represented by the equation:

$$I_T = I_1 + I_2 + I_3$$

Where:

I_T = total circuit current

I_1 = current through R1

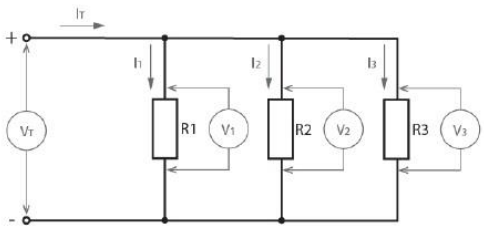
I_2 = current through R2

I_3 = current through R3

The value of current that flows in each branch of a parallel circuit is inversely proportional to the branch resistances.

Worked Example – Calculating Current

For the circuit pictured above, calculate the total current drawn from the supply, if each resistor draws a current of 10 amperes.



$$I_T = I_1 + I_2 + I_3$$
$$I_T = 10 + 10 + 10$$
$$I_T = 30 \text{ amperes}$$

Voltage in Parallel Circuits

Note that the supply terminals are connected directly across each load in a parallel circuit. ***The voltage across each component in a parallel circuit will be equal to the supply voltage***. This can be represented by the equation:

$$V_T = V_1 = V_2 = V_3$$

Where:

V_T = total circuit voltage

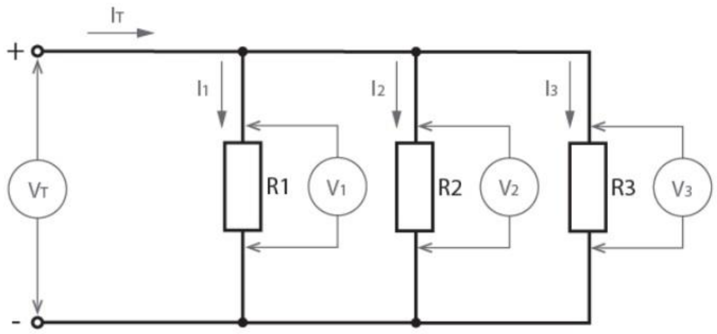
V_1 = voltage across R1

V_2 = voltage across R2

V_3 = voltage across R3

Worked Example – Calculating Voltage

For the circuit pictured above, calculate the voltage across each resistor if the supply voltage is 24 volts.



$$V_T = V_1 = V_2 = V_3$$
$$24 = V_1 = V_2 = V_3$$
$$V_1 = 24 \text{ volts}$$
$$V_2 = 24 \text{ volts}$$
$$V_3 = 24 \text{ volts}$$

Resistance in Parallel Circuits

When resistors are connected in parallel, ***the total equivalent resistance will be less than the smallest individual resistance***. This means that every time an additional resistance is connected to a circuit in parallel, the total circuit resistance goes down! This can be represented by the equation:

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

Where:

R_T = total resistance

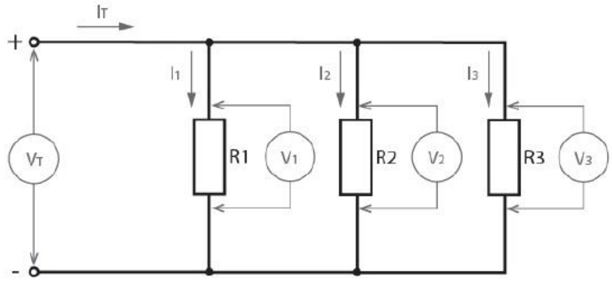
R_1 = resistance of R1

R_2 = resistance of R2

R_3 = resistance of R3

Worked Example – Calculating Resistance

For the circuit pictured above, calculate the total resistance if R1 has a resistance of 40 ohms, R2 has a resistance of 80 ohms, and R3 has a resistance of 200 ohms.



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

$$R_T = \frac{1}{\frac{1}{40} + \frac{1}{80} + \frac{1}{200}}$$

R_T = 23.5 ohms

Power in Parallel Circuits

The total power dissipated in a parallel circuit is equal to the sum of the individual powers. This can be represented by the equation:

$$P_T = P_1 + P_2 + P_3$$

Where:

P_T = total circuit power

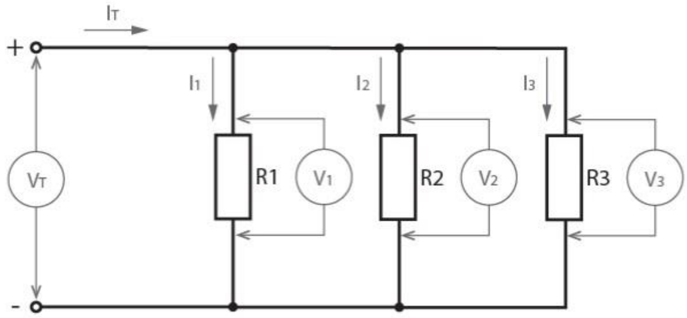
P_1 = power across R1

P_2 = power across R2

P_3 = power across R3

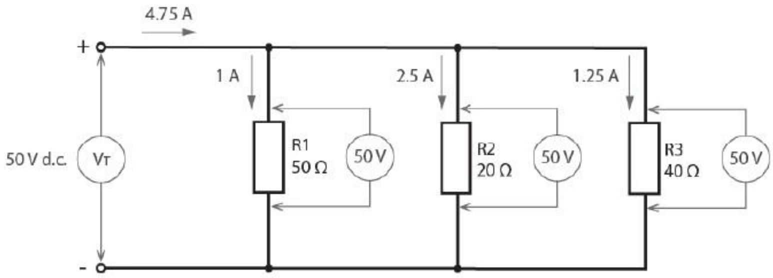
Worked Example – Calculating Power

For the circuit pictured above, calculate the total power if resistors R1, R2 and R3 are dissipating 200 W, 150 W and 400 W respectively.



$$P_T = P_1 + P_2 + P_3$$
$$P_T = 200 + 150 + 400$$
$$P_T = 750 \text{ watts}$$

To illustrate how all of these operating characteristics come together, consider the following parallel circuit:



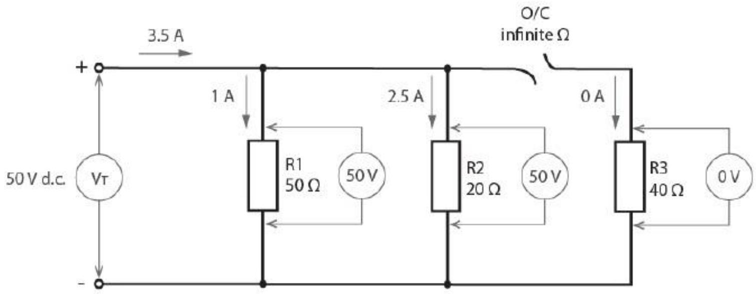
$R_T = 10.53\ \Omega$

Note that:

- the total resistance is less than the smallest individual resistance
- the voltage across each resistor is the same
- the current flowing in each branch is inversely proportional to the branch resistances
- the sum of the branch currents is equal to the total supply current
- the current, voltage and resistance values at each point in the circuit obey Ohm's Law

Open-circuits

The following diagram shows a parallel circuit with an open-circuit in a positive wire.



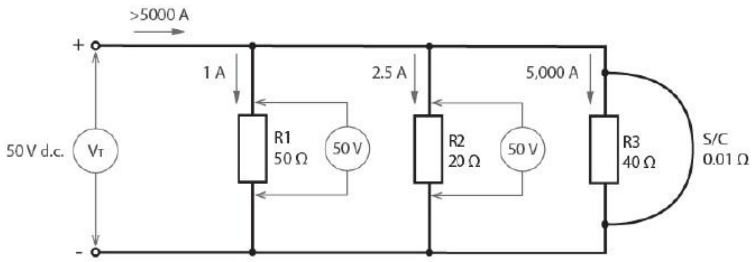
R_T = 14.29 Ω

When an open-circuit occurs in a parallel circuit the total current will be reduced. How much the current reduces depends on where the open-circuit occurs. For example, if an open-circuit occurred in the positive wire between the supply terminal and the junction of branch 1, then the total current would drop to zero. In this case, the location of the open-circuit has effectively removed the 40 Ω resistor from the circuit. The effect of this has been to:

- increase the circuit resistance from 10.53 Ω to 14.29 Ω
- decrease the total circuit current from 4.75 A to 3.5 A

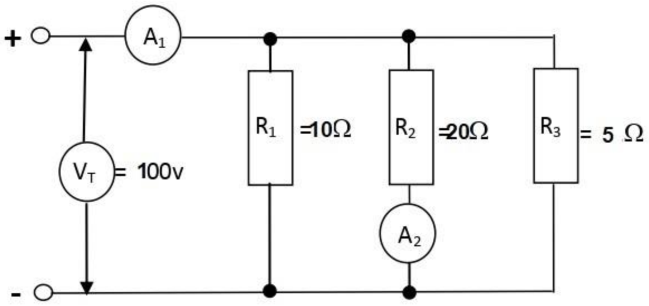
Short-circuits

The following diagram shows a parallel circuit where a short-circuit has developed across R3.



R_T = <0.01 Ω

When a short-circuit occurs in a parallel circuit, the total resistance is reduced to almost zero, causing a high fault current to flow. It is the role of a circuit protection device to automatically disconnect the circuit in the event that this occurs. This protects the circuit wiring and equipment from damage due to excessive heat caused by the high current. In this case, total circuit resistance has dropped to less than 0.01 Ω, resulting in a short-circuit current of over 5 kA.



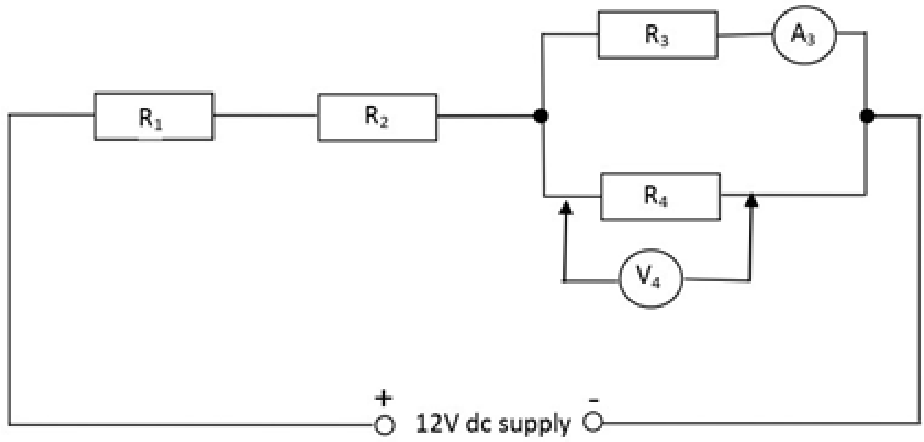
For the single source dc parallel circuit drawn above, and using the circuit values shown:

a. The reading on the ammeter A_2 will be = ____________ Amps

b. The resistance of the complete circuit will be = ____________ Ohms

c. The reading on the ammeter A_1 will be = ____________ Amps

Show your calculations here…

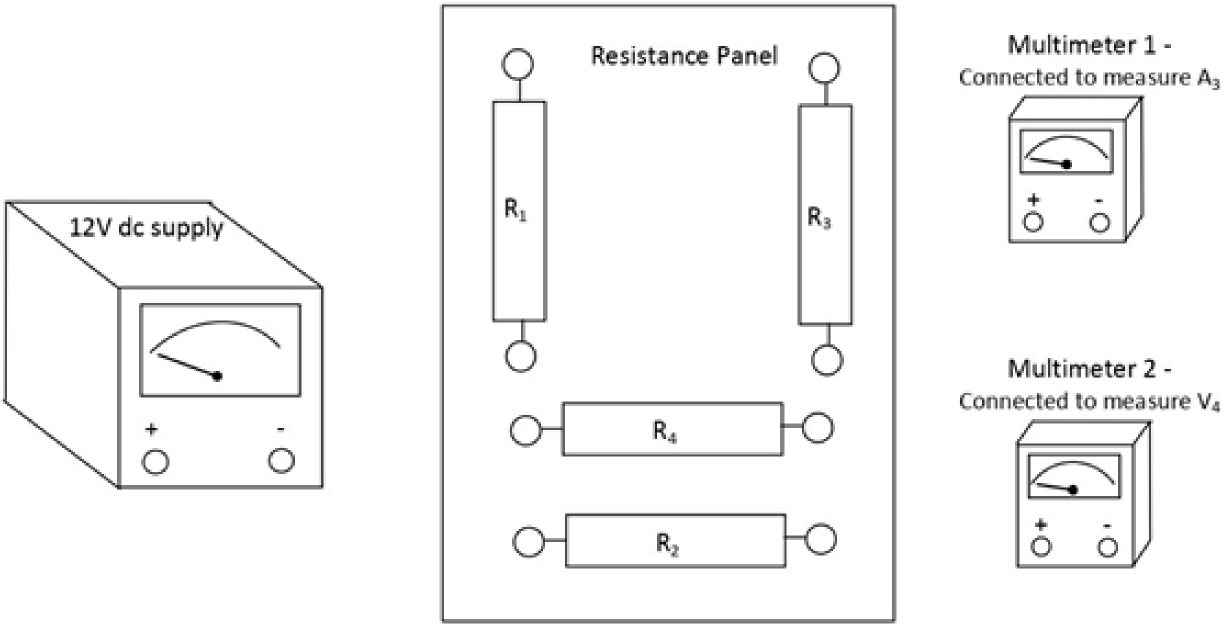


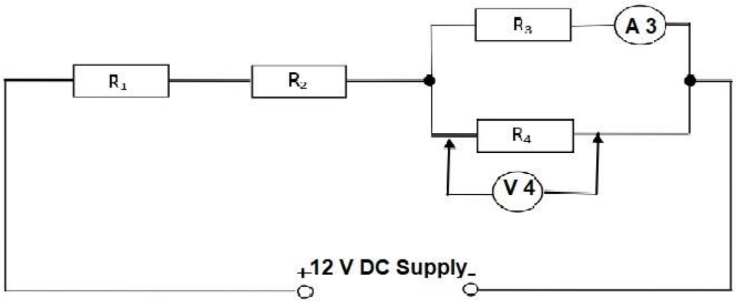
TASK:

a. From the dc series/parallel circuit schematic diagram above, **draw a wiring diagram** showing all connections on the equipment and meters below.

NOTE: Show your wiring diagram to the assessor **BEFORE** you turn to the next question.

Correct wiring diagram ☐





R1 = 3 ohm **R2= 2 ohm** **R3= 4 ohm** **R4 = 8 ohm**

TASK:

With the supply connected and power on:

a. The reading on the meter connected to measure A_3 is _____________ Amps

b. The reading on the meter connected to measure V_4 is _____________ Volts

c. **Use the meter readings** obtained and ohms law to **determine the resistance of R_3**

The resistance of R_3 is ___________ Ohms

Show your calculations here: