SERIES-PARALLEL CIRCUITS

PURPOSE:

This section introduces the series-parallel circuit and aims to develop systematic methods of applying Ohm's law for the determination of voltages, currents and resistances associated with series-parallel circuits.

TO ACHIEVE THE PURPOSE OF THIS SECTION:

At the end of this section the student will be able to:

- Reduce a resistive series-parallel circuit to a single equivalent resistance.
- Apply Ohm's law to series-parallel circuits to calculate the currents, voltages and resistances.
- Connect components to form a given series-parallel circuit.
- Calculate the total power consumed by a series-parallel circuit, and the power dissipated by each resistor within a series-parallel combination.

REFERENCES:

Electrical Principles for the Electrical Trades. 4th Edition. Jenneson J.R.
Pages 87-91.

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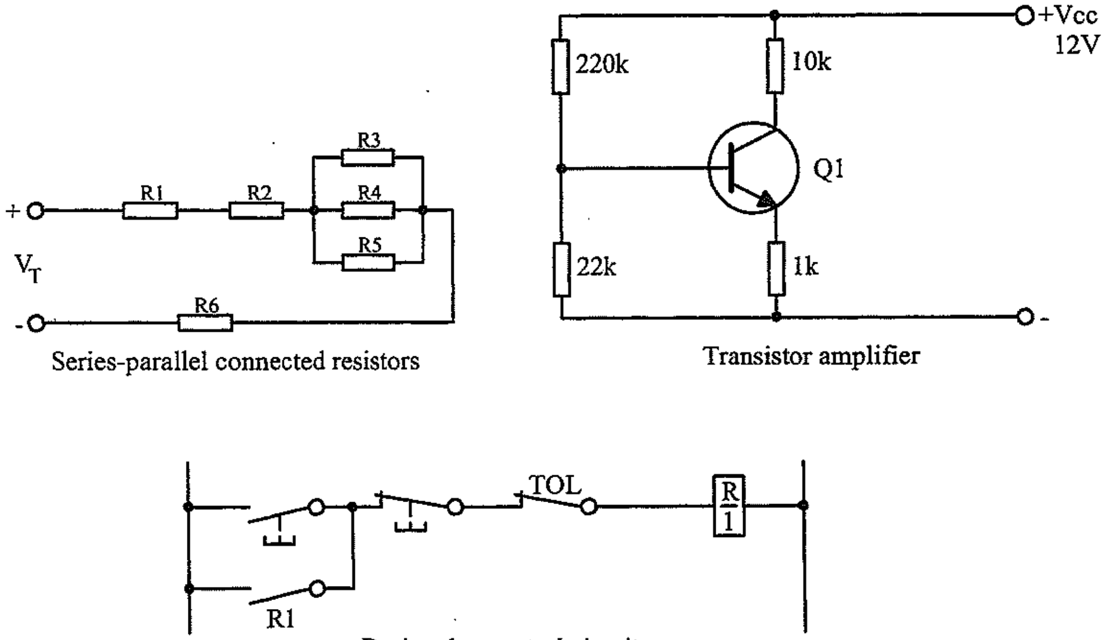
1. THE SERIES-PARALLEL CIRCUIT

In general, all electrical/electronic equipment is composed of a number of components that are interconnected to form a combination of series and parallel circuits. The most important point to learn is how to distinguish between the components that are connected in series and those components that are connected in parallel.

Figure 1 shows three examples of series-parallel circuits.



Series-parallel connected resistors

Transistor amplifier

Basic relay control circuit

Figure 1

When analysing series-parallel circuits, always remember that current flow determines whether a component is connected in series or parallel. Begin at the positive terminal of the supply and apply these two basic rules:

- if the total current has only one path to follow through a component, then that component is connected in series.
- if the total current has two or more paths to flow through two or more components, then those components are connected in parallel.

2. REDUCING A SERIES-PARALLEL CIRCUIT

Irrespective of how complex or involved the series-parallel circuit, there is a simple three step method to simplify the circuit to a single equivalent resistance, that is, to reduce or simplify the circuit.

Once the series-parallel relationships have been determined, the three step method may be applied. The three step method is:

- determine the equivalent resistances of all series connected resistors.
- determine the equivalent resistances of all parallel connected resistors.
- determine the equivalent resistances of the remaining resistances.

Example: 1

Determine the equivalent resistance for the circuit of figure 2.

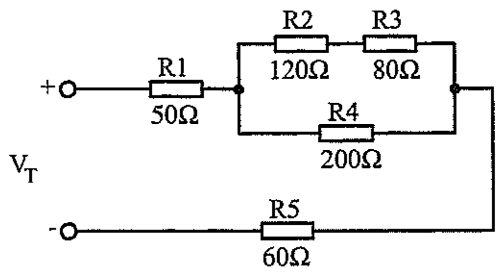


Figure 2

Example: 2

Determine the equivalent resistance for the circuit of figure 3.

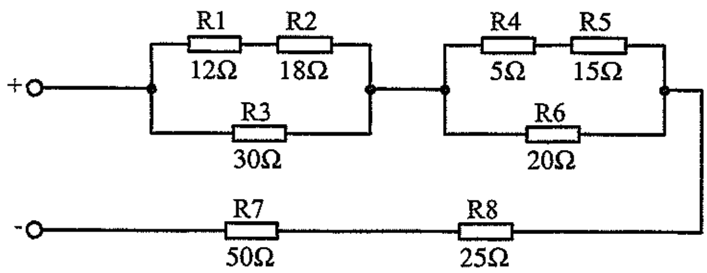


Figure 3

3. OHM'S LAW APPLIED TO THE SERIES-PARALLEL CIRCUIT

As is the case with series and parallel circuits, Ohm's law may be applied to all or any part of a series-parallel circuit.

$$I = \frac{V}{R} \text{ amperes} \qquad R = \frac{V}{I} \text{ ohms} \qquad V = I \times R \text{ volts}$$

Example: 3

For the circuit of figure 4 determine the:

(a) circuit equivalent resistance
(b) total circuit current
(c) voltage across R_{35}
(d) current through R_2

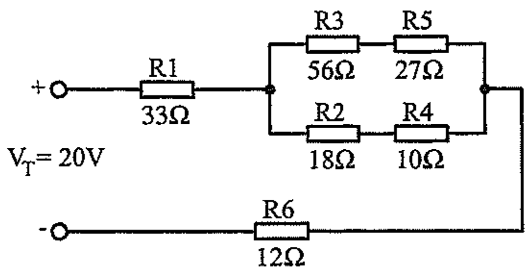


Figure 4

4. POWER IN THE SERIES-PARALLEL CIRCUIT

Each component in a series-parallel circuit consumes power and the amount of power consumed by each component depends on the resistance of the component.

As previously discussed, there are three equations which can be used to calculate power:

$$P = VI \quad \text{watts} \qquad P = I^2R \quad \text{watts} \qquad P = \frac{V^2}{R} \quad \text{watts}$$

The total power taken from the supply equals the sum of the powers taken by the individual components.

$$P_T = P_1 + P_2 + P_3 \quad \text{watts}$$

In addition to adding the individual component powers, the total power consumed by a series-parallel circuit can be calculated using the three power equations as follows:

- $P_T = V_T I_T$ watts
- $P_T = I_T^2 R_{EQ}$ watts
- $P_T = \frac{V_T^2}{R_{EQ}}$ watts

Example: 4

For the circuit of figure 5, calculate the:

(a) circuit equivalent resistance.
(b) total circuit current.
(c) voltage drop across each resistor.
(d) power taken by each resistor.
(e) total power consumed by the circuit.

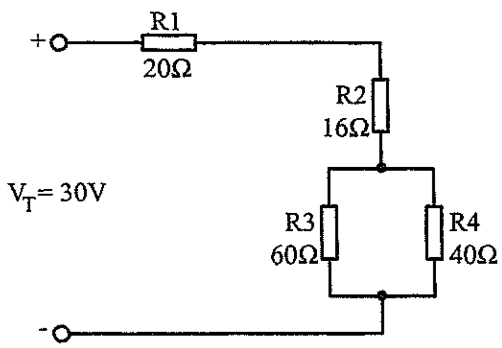


Figure 5

Example: 5

For the circuit of figure 6, calculate the:

(a) circuit equivalent resistance.

(b) total circuit current.

(c) voltage drop across each resistor.

(d) current through each resistor.

(e) power taken by each resistor.

(f) total power consumed by the circuit.

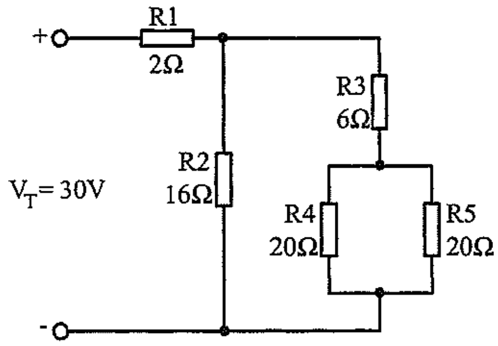


Figure 6

Example: 6

For the circuit of figure 7, determine the -

(a) voltage V_A

(b) voltage V_B

(c) voltage V_{AB}

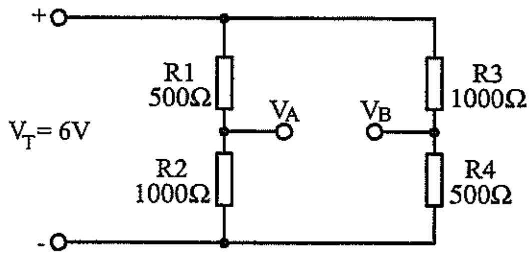


Figure 7

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SERIES - PARALLEL CIRCUITS

Please note the following requirements in relation to tutorial work -

- All tutorial work is to be completed on ruled A4 pad paper, with multiple pages stapled together. Write on one side only of the answer sheets.
- All work is to be completed in ink.
- In the case of multiple choice type questions, the question number and answer letter are to be written on the answer sheet.
- All relevant equations and working are to be shown in the case of calculation type questions.
- All diagrams are to be drawn using appropriate drawing instruments. Drawings are not to be freehand.

Section A
In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. The voltages in the parallel section of a series-parallel circuit:
   (a) are affected by the circuit equivalent resistance
   (b) are difficult to determine
   (c) are the same across the parallel components
   (d) decrease through the circuit from component to component

2. If one resistor in the parallel section of a series-parallel circuit goes open circuit, the circuit power dissipation will:
   (a) remain constant
   (b) decrease
   (c) increase
   (d) decrease to zero

3. The power dissipation of any circuit:
   (a) equal to the sum of the power dissipation of each resistor
   (b) equal to the product of the power dissipation of each resistor
   (c) equal to the supply voltage squared times the circuit equivalent resistance
   (d) depends on the circuit arrangement

4. In the circuit of figure 1, the supply current is equal to the:
   (a) value of branch currents
   (b) product of the branch currents
   (c) sum of the currents in each resistor
   (d) sum of the branch currents

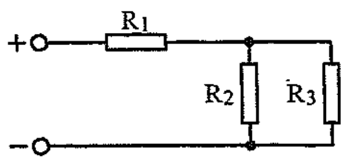

Figure 1

5. If the resistor R_1 in the circuit of figure 1 were to open circuit, the circuit current would:
   (a) remain unchanged
   (b) decrease
   (c) increase
   (d) become zero

6. If the resistor R_3 in the circuit of figure 1 were to short circuit, the circuit current would:
   (a) decrease
   (b) become zero
   (c) increase
   (d) remain unchanged

7. If the resistor R_2 in the circuit of figure 1 were to open circuit, the circuit power dissipation would:
   (a) become zero
   (b) remain unchanged
   (c) decrease
   (d) increase

8. If the resistor R1 in the circuit of figure 1 were to short circuit, the circuit power dissipation would:
   (a) become zero
   (b) remain unchanged
   (c) decrease
   (d) increase

9. If an extra resistor was added in parallel with resistors R_2 and R_3 in the circuit of figure 1, the equivalent circuit resistance would:
   (a) increase
   (b) decrease to zero
   (c) decrease to a lower value
   (d) increase to a much higher value

10. If the resistance of the resistor R_1 in the circuit of figure 1 was to be increased, the equivalent resistance of the circuit would:
    (a) increase
    (b) decrease to zero
    (c) decrease to a lower value
    (d) increase to an infinite value

Section B:

Blank spaces in the following statements represent omissions. Write the appropriate information.

Questions 1 to 17 relate to figure 2.

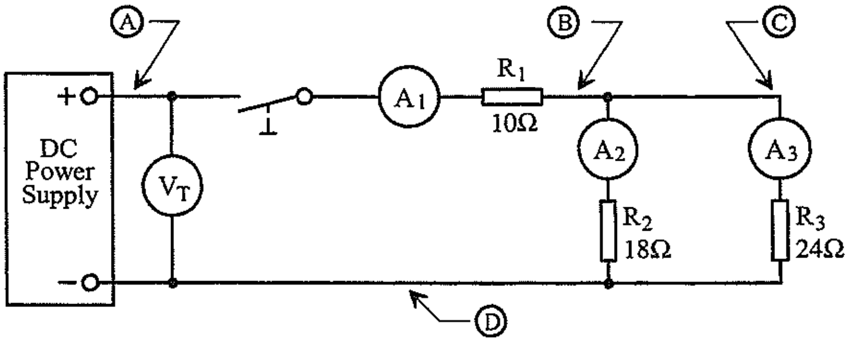

Figure 2

Using the negative terminal of the power supply as a reference, compare as either 'greater than', 'less than' or 'equal to' the voltages at the following points.

(a) the voltage at point A would be ______(1)______ the voltage at point C

(b) the voltage at point D would be _____(2)_____ the voltage at point B

(c) the voltage at point D would be ______(3)_____ the voltage at point A

(d) the voltage at point B would be _____(4)_____ the voltage at point C.

Compare as either 'greater than', 'less than' or 'equal to' the currents at the following points.

(a) the current through ammeter A_1 would be _____(5)_____ the current through ammeter A_2

(b) the current through ammeter A_3 would be _____(6)_____ the current through ammeter A_2

(c) the current through ammeter A_3 would be _____(7)_____ the current through ammeter A_1

(d) the current through ammeter A_1 would be _____(8)_____ the current at point D

(e) the current at point D would be _____(9)_____ the current through ammeter A_3

(f) the current in ammeter A2 would be _____(10)_____ the current at point D.

The power dissipated by resistor R_3 would be _____(11)_____ than the power dissipated by R_2.

If the value of the resistor R_2 was increased, the equivalent circuit resistance would ______(12)_____.

With the switch in the open position, the voltage across the switch would equal _____(13)_____.

The power dissipated by resistor R_2 would be ______(14)______ than the power dissipated by resistor R_1.

If resistor R_1 became open circuit, the equivalent resistance of the circuit would be _____(15)_____.

If resistor R_3 became short circuit, the circuit current would _____(16)_____ and the power dissipation would _____(17)_____.

SECTION C

The following problems are to be solved with the aid of a calculator. Answers are to be correct to two (2) decimal places. All equations and working are to be shown.

1. Determine the equivalent resistance for the circuit shown in figure 2. (20.29Ω)

2. For the circuit of figure 3, determine the -
   (a) equivalent circuit resistance (209.19Ω)
   (b) circuit current (0.478A)
   (c) voltage drop across resistor R_1 (57.36V)
   (d) voltage drop across R_2 and R_3 (42.63V)
   (e) currents in resistors R2 and R3 (0.284A, 0.193A)
   (f) total power dissipated (47.8W)

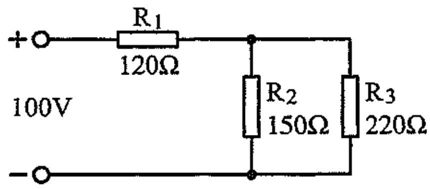

Figure 3

3. For the circuit of figure 4, determine the -
   (a) equivalent resistance (8.94Ω)
   (b) current in each branch (19.17A, 6.57A)
   (c) supply current (25.72A)
   (d) power dissipated by each component (4408W, 863.3W, 647.47W)
   (e) total power dissipation (5915.6W)

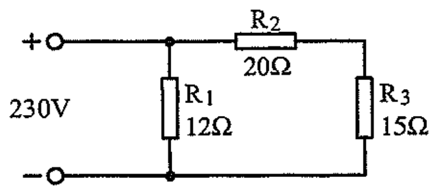

Figure 4

4. A circuit is made up of two resistors in parallel and has an equivalent resistance of 15.23Ω. If R_1 has a resistance of 25Ω determine the resistance of R_2. (39W)

5. For the installation shown in figure 5, determine the-
   (a) resistance of each branch (12.28Ω, 24.34Ω, 96.83Ω)
   (b) equivalent resistance (7.579Ω)
   (c) circuit current (32.32A)
   (d) voltage drop across the consumers mains (1.74V)
   (e) voltage drop across each final sub-circuit (243.26V)
   (f) current in each final sub-circuit (19.82A, 9.99A, 2.51A)
   (g) power dissipated in each load (4713.99W, 2395.2W, 604.8W)
   (h) total power dissipated (7918.4W)

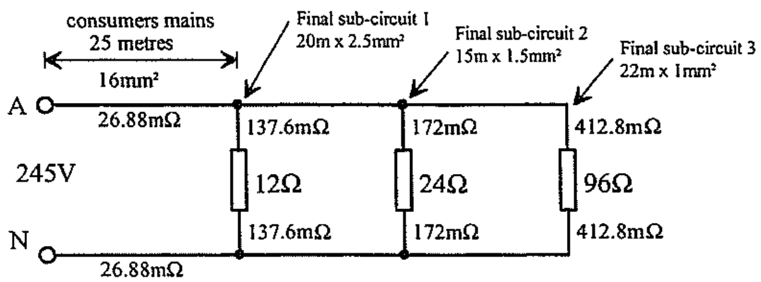

Figure 5

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