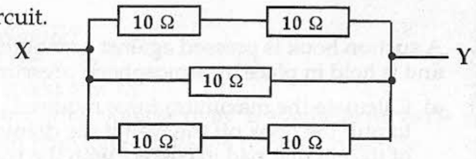
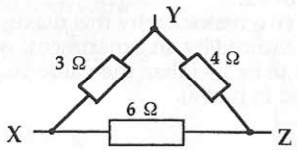
Resistors in Circuits

Exercise 4.1 Resistors

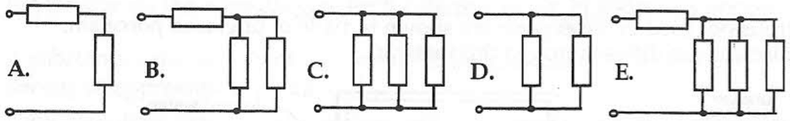
1. The diagram shows part of an electrical circuit.
   What is the resistance between X and Y?



2. Three resistors are connected as shown.
   Calculate the total resistance between
   a) XY,
   b) XZ,
   c) YZ.

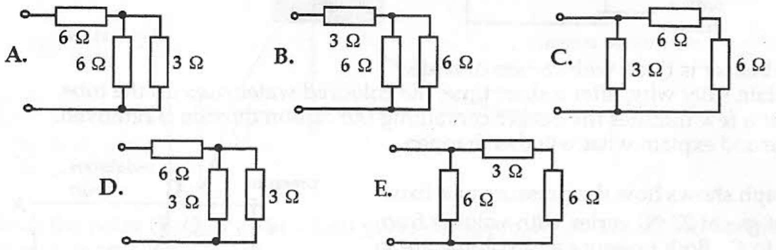


3. All the resistors in the diagrams shown have the same resistance.



Identify the arrangement which has
a) the least resistance,
b) the greatest resistance.

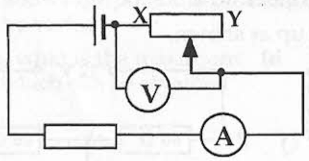
4.



Identify the arrangement which has
a) the least resistance,
b) the greatest resistance.

5. Three different resistors are available. Their values are 4 Ω, 6 Ω and 12 Ω.
   Describe how two, or all three, of the resistors might be combined to give each of the following resistances.
   a) 10 Ω
   b) 3 Ω
   c) 8 Ω

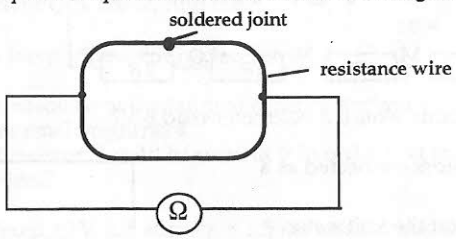
6. In the following circuit, the sliding contact of the rheostat moves from X to Y.



a) Explain whether the ammeter reading increases, decreases or stay constant.
b) Explain whether the voltmeter reading increases, decreases or stay constant.

7. The overhead cables used in a 132 kV grid system consist of 7 strands of steel wire and 30 strands of aluminium wire. The 7 strands of steel have a **combined** resistance of 3.0 ohms per kilometre and the 30 strands of aluminium have a **combined** resistance of 0.17 ohms per kilometre.
   a) Show that the resistance of the cable is 0.16 ohms per kilometre.
   b) Why should steel wire be used in the cable even though it has a much higher resistance than aluminium?
   c) A typical current in the cable is 400 A.
   Calculate the power loss per kilometre of cable for this current.

8. The resistance of a length of bare uniform resistance wire is 30 Ω. The length of wire is folded into the shape of a square and the ends soldered together as shown.



What value of resistance would the ohmmeter read if it is connected as shown at the mid-points of opposite sides of the square?
(You may ignore the resistance of the ohmmeter leads.)

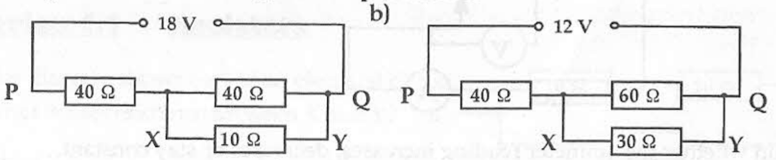
9. Some resistors are constructed by depositing a thin film of conducting material on top of an insulating base. The resistance depends on the breadth of the conducting film. The results show the resistance for various breadths of film of the same length and thickness.

Breadth/mm	150	87	67	60	55
Resistance/Ω	80	140	180	200	220

Find the relationship between the resistance and the breadth of the conducting film.
You must use all the data and show your working.

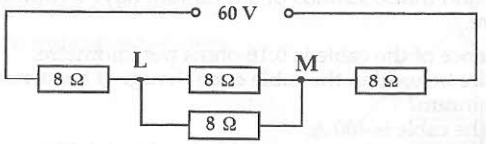
Exercise 4.2 Potential Dividers

1. Two potential dividers PQ are set up as shown.



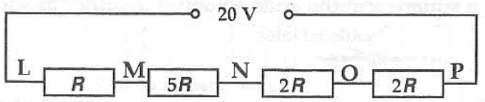
In each case, what is the potential difference across the resistor XY?

2. Four resistors each of value 8 Ω are connected across a 60 V supply of negligible internal resistance as shown.



Find the p.d. across LM.

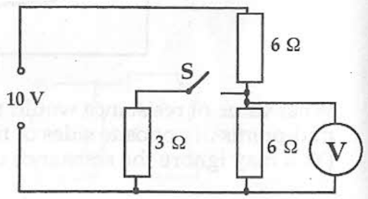
3. A 20 V supply is connected to a set of resistors in series as shown.



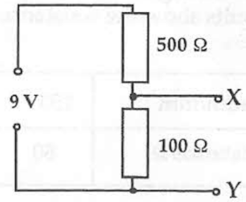
Between which two points would a voltmeter read 8 V?

4. The circuit shows resistors connected as a potential divider.

Calculate the reading on the voltmeter
a) when the switch S is open,
b) when the switch S is closed.

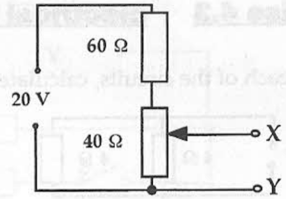


5. A potential divider is shown in the diagram.
   a) Calculate the p.d. between X and Y.
   b) A motor of resistance 50 Ω is connected across the terminals X and Y.
      i) Calculate the p.d. across the motor.
      ii) State the relationship between power, voltage and resistance.
      iii) Calculate the power supplied to this motor.

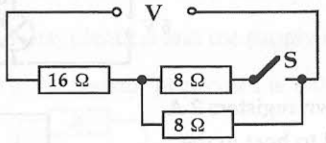


6. In the potential divider circuit shown, the variable resistor allows the potential difference between X and Y to be varied.

For the values given, what is the maximum potential difference which can be obtained across XY?

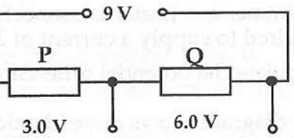


7. In the following circuit, the p.d. across the 16 Ω resistor is 40 V when switch **S** is **open.**



   a) What is the voltage of the supply?
   b) What is the p.d. across the 16 Ω resistor when the switch S is **closed?**

8. The circuit shown is used to provide output voltages of 3.0 V and 6.0 V from a 9.0 V battery of negligible internal resistance.



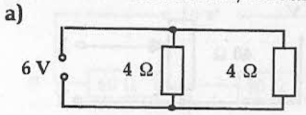
   a) If the resistance of Q is 100 Ω, find the resistance of P.
   b) A 6 V, 0.060 A lamp is now connected across resistor Q.
   Calculate the resistance of the lamp and hence explain why the lamp does not operate at its normal brightness.
   c) What value of resistor should be used at P in order that the bulb does work at its correct brightness?

9. You are given a fixed 10 V d.c. supply, a 1.5 kΩ resistor and a 1.0 kΩ variable resistor.
   a) Draw a circuit diagram which shows how you would connect these components to supply a variable voltage of up to 4.0 V.
   Label the output terminals in your diagram.
   b) When the variable supply is set at 4 V, a 1 kΩ resistor is now connected across the output terminals.
      i) Explain why the voltage across the terminals is now less than 4 V.
      ii) Calculate the new voltage across the terminals.

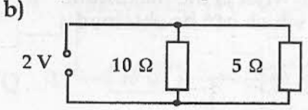
Exercise 4.3 Electrical Energy and Power

1. For each of the circuits, calculate the total power developed.

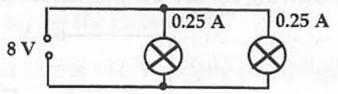
a)



b)

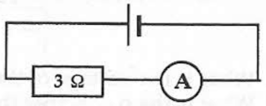


2. How much electrical energy is converted in the two bulbs in 16 s?



3. The ammeter in the circuit shown registers 2 A.

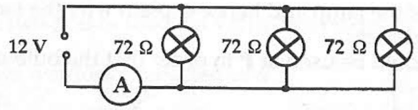
How much energy is converted to heat in the resistor in 1 minute?



4. An immersion heater is connected to a constant voltage supply. 2000 J of energy is required to supply a current of 2 A for 4 s through the immersion heater.

Calculate the potential difference, in volts, between the ends of the heater.

5. The diagram shows three identical light bulbs connected to a constant 12 V d.c. supply. Each bulb has a resistance of 72 Ω when operating at normal brightness. The ammeter registers 0.5 A and has negligible resistance.



A break occurs in the filament of one of the bulbs.

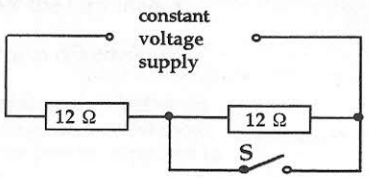
a) Calculate the new reading on the ammeter.

b) State what happens to the brightness of the other two bulbs.

6. An electrical heater has a power of 500 Ω when operated at 250 V.

If it were used on a 125 V supply, what would be its electrical power? (Assume that its resistance remains the same.)

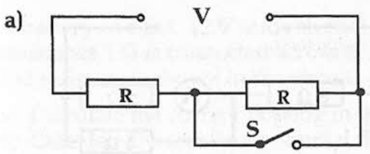
7. In the circuit shown, the power drawn from the supply, which has negligible internal resistance, is 30 Ω when the switch S is closed.



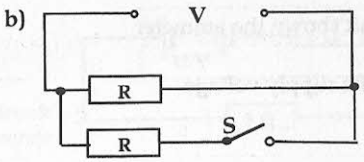
What power is delivered to the circuit by the supply when the switch is open?

8. When a single resistor R is connected, 400 Ω is drawn from the supply.

a)



b)



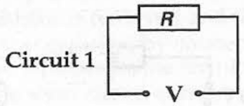
In each of the above circuits, calculate the power drawn from the same supply

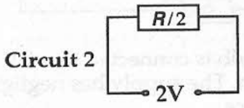
i) when S is open,

ii) when S is closed.

(Assume all the resistors are identical and the supply has negligible internal resistance.)

9. The power transferred to the resistor in circuit 1 is 100 W.





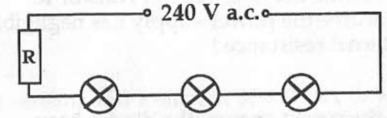
What is the power transferred to the resistor in circuit 2?

10. The resistance of one wire, **A**, is three times as great as that of another wire, **B**.

a) How does the power developed in the two wires compare when they are connected **in parallel** across the same source of supply?

b) How does the power developed in the two wires compare when they are connected **in series** across the same source of supply?

11. Three 12 V, 24 W bulbs are connected as shown.



a) Calculate the current in each bulb when operating at its correct power.

b) Calculate the resistance of resistor R which allows the three bulbs to be run at their correct power.

c) What fraction of the input power is used by the bulbs?

d) Give the reason why the power used by the bulbs is less than the input power.

e) Suggest another way of providing the correct voltage for the three bulbs.

12. A mains light bulb is 16% efficient. The current through the bulb is 0.261 A.

a) What is the power of the bulb?

b) How much energy is produced in the form of light in 5 minutes?

c) How much energy is produced in the form of heat in 5 minutes?

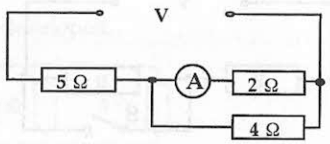
13. In the diagram plate A is at a potential of 100 V and plate B is at a potential of 300 V. A charge of 5 C was passed from A to B.

What was the energy, in joules, required for this?

Exercise 4.4 Circuits

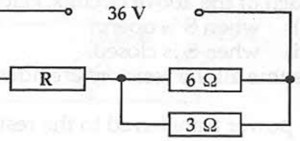
1. In the circuit shown the ammeter reads 2 A.

   Calculate the supply voltage.



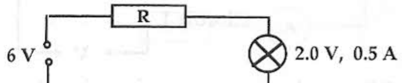
2. The current delivered by the power supply in the circuit shown is 3 A.

   Assuming the power supply has negligible internal resistance, find the resistance of resistor **R**.



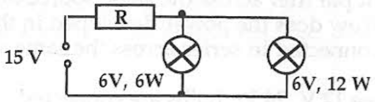
3. A 2.0 V, 0.5 A bulb is connected to a 6 V d.c. supply as shown. The supply has negligible internal resistance.

   If the bulb is to operate at its correct rating, calculate the resistance of resistor **R**.



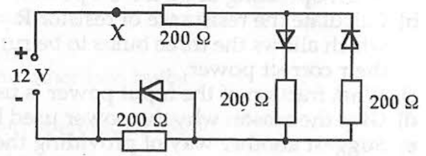
4. The two bulbs in the circuit shown operate at their correct ratings.

   Calculate the resistance of resistor **R**.
   (Assume the power supply has negligible internal resistance.)



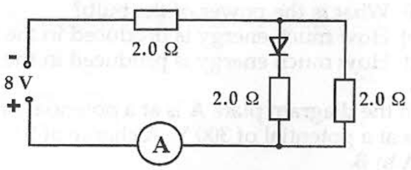
5. In the circuit shown, the diodes have negligible forward resistance and infinite reverse resistance.

   What is the current in the circuit at point X?



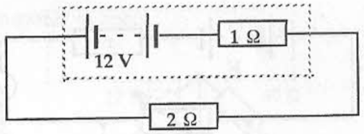
6. The circuit shown includes a diode which has negligible forward resistance and infinite reverse resistance.

   Calculate the reading on the ammeter
   a) with the diode as shown,
   b) if the diode is reversed.



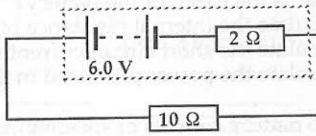
Exercise 4.5 E.m.f. and Internal Resistance

1. A battery of e.m.f. 12 V and internal resistance 1 Ω is connected across a 2 Ω resistor, as shown in the circuit.



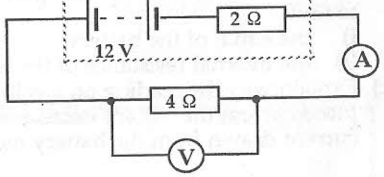
   a) Calculate the current flowing in the circuit.
   b) Calculate the terminal potential difference (t.p.d.) across the battery.
   c) What is the value of the 'lost volts'?

2. A battery has an e.m.f. of 6.0 V and an internal resistance of 2 Ω. It is connected to a 10 Ω resistor as shown.



   a) Calculate the p.d. across the 10 Ω resistor.
   b) The 10 Ω resistor is removed and the battery is short circuited by connecting a thick copper wire across the terminals. Calculate the short circuit current.

3. A battery has an e.m.f. of 12 V and an internal resistance of 2.0 Ω. It is connected to a 4 Ω resistor in the following circuit.



   a) Calculate the reading on
      i) the ammeter,
      ii) the voltmeter.
   b) The 4 Ω resistor is replaced by a 2 Ω resistor. Calculate the new reading on
      i) the ammeter,
      ii) the voltmeter.

4. A battery of e.m.f. 5.0 V is connected to a 10 Ω resistor and a current of 400 mA flows through the resistor.

   Calculate the internal resistance of the battery.

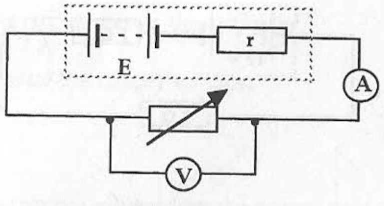
5. Three cells each of e.m.f. 2 V, and an internal resistance of 1 Ω are connected in series, to form a battery. The battery is connected across a 3 Ω resistor.

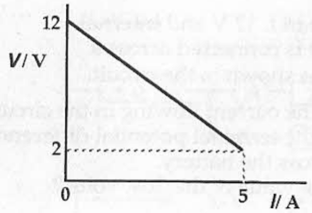
   Calculate the current in the circuit.

6. A voltmeter connected across a cell reads 1.5 V. The reading on the voltmeter drops to 1.0 V when the cell is connected to a 20 Ω resistor.

   Find the internal resistance of the cell.

7. The voltmeter and ammeter readings in the circuit shown are taken at various settings of the variable resistor and the graph plotted.

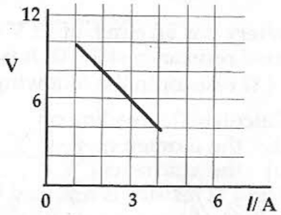




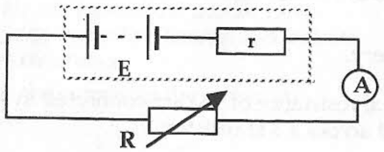
a) What is the e.m.f. of the battery?
b) Calculate the internal resistance of the battery.
c) Calculate the short circuit current for the battery.
d) Calculate the power produced in the variable resistor when it is set at 4 Ω.

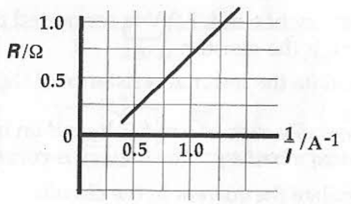
8. A radio battery consists of six identical 1.5 V cells in series. When the terminals of the battery are connected by a short piece of thick copper wire, the current is 0.5 A.
Find the internal resistance of **each** cell.

9. a) State what is meant by the e.m.f. of a battery.
b) Use the information from the graph shown to find
i) the e.m.f. of the battery,
ii) the internal resistance of the battery.
c) Explain why the reading on a voltmeter placed across the battery decreases as the current drawn from the battery increases.



10. A battery is connected to a calibrated variable resistor R and an ammeter as shown and a graph plotted of R against $1/I$.





a) For this circuit derive the expression:

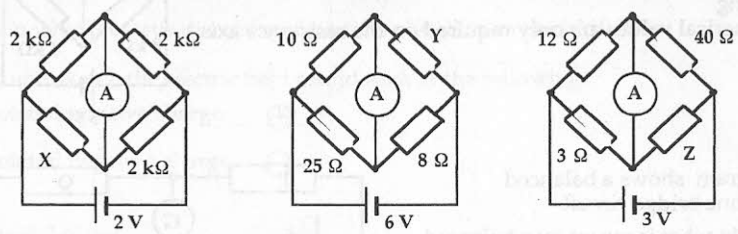
$$R = \frac{E}{I} - r$$

b) Explain why the graph of R against $1/I$ is drawn.
c) Use the graph to find the e.m.f. of the battery, the internal resistance and the short circuit current.

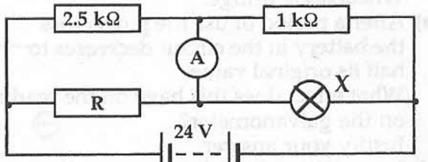
11. A heater of resistance 0.32 Ω is connected to a power supply of e.m.f. 2.0 V and internal resistance r. The power output of the **heater** is 8.0 W.
a) i) Calculate the current in the heater.
ii) Calculate the p.d. across the heater.
b) Calculate the internal resistance r of the power supply.
c) Another identical heater is connected in parallel with the original heater. The rest of the circuit is unaltered.
Calculate the total power output of the two heaters.

Exercise 4.6 Wheatstone Bridges

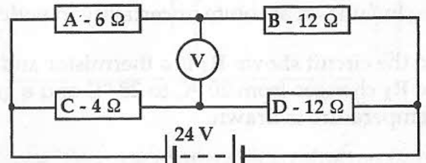
1. In the circuits shown the current in the milliammeter is zero. Calculate each of the resistances X, Y and Z.



2. Bulb X in the circuit shown has a rating 12 V, 24 W and is operating at its correct rating.
If the Wheatstone Bridge is balanced find the resistance of resistor R.



3. In the Wheatstone bridge circuit shown, there is a small potential difference on the voltmeter V.
a) State what change could be made to resistor A in order to balance the bridge.
b) Repeat for each of the other resistors B, C and D.



4. In the bridge circuit shown the variable resistor R is adjusted so that the bridge is balanced at 18 °C. The thermistor is now placed in a beaker containing melting ice.
a) How does the resistance of the thermistor vary when it is placed in the melting ice?
b) In order to rebalance the bridge, state the changes which could be made to
i) P (all other resistors unchanged),
ii) Q (all other resistors unchanged).