# CONTENT STATEMENTS associated with ELECTRIC FIELD & RESISTORS IN CIRCUITS

**Electric fields and resistors in circuits**

[1] State that, in an electric field, an electric charge experiences a force.

[2] State that an electric field applied to a conductor causes the free electric charges in it to move.

[3] State that work *W* is done when a charge Q is moved in an electric field.

[4] State that the potential difference between two points is a measure of the work done in moving one coulomb of charge between the two points.

[5] State that if one joule of work is done moving one coulomb of charge between two points, the potential difference between the points is one volt.

[6] Carry out calculations involving the relationship between potential difference, work and charge.

[7] State that the e.m.f. of a source is the electrical potential energy supplied to each coulomb of charge which passes through the source.

[8] State that an electrical source is equivalent to a source of e.m.f. with a resistor in series, the internal resistance.

[9] Describe the principles of a method for measuring the e.m.f. and internal resistance of a source

[10] Explain why the e.m.f. of a source is equal to the open circuit p.d. across the terminals of a source

[11] Explain how the conservation of energy leads to the sum of the e.m.f.'s round a closed circuit being equal to the sum of the p.d.'s round the circuit.

[12] Derive the expression for the total resistance of any number of resistors in series, by consideration of the conservation of energy.

[13] Derive the expression for the total resistance of any number of resistors in parallel, by consideration of the conservation of charge.

[14] Carry out calculations involving the resistances in a balanced Wheatstone bridge.

[15] State that for an initially balanced Wheatstone bridge, as the value of one resistor is changed by a small amount, the out-of-balance p.d. is directly proportional to the change in resistance.

[16] Carry out calculations involving potential differences, currents and resistances in circuits containing resistors.

[17] Use the following terms correctly in context: charge, current, p.d., resistance, terminal p.d., load resistor, bridge circuit, e.m.f., lost volts, short circuit current.

REVISION OF CIRCUITS

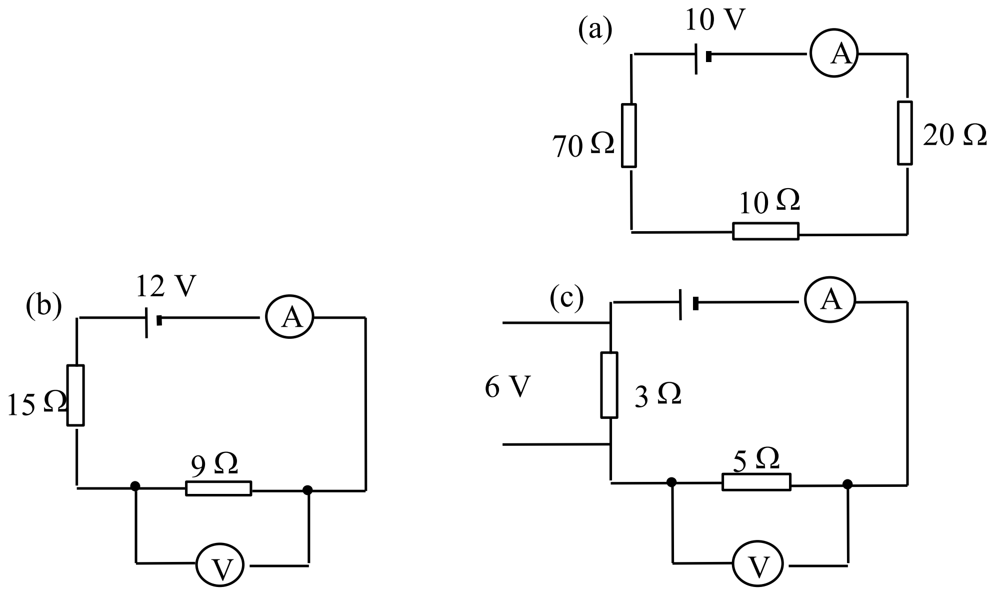
1. If a current of 40 mA passes through a lamp for 16 s, how much charge has passed any point in the circuit?

2. A lightening flash lasted for 1 ms. If 5 C of charge was transferred during this time, what was the current?

3. The current in a circuit is $2.5 \times 10^{-2}$ A. How long does it take for 500 C of charge to pass any given point in the circuit?

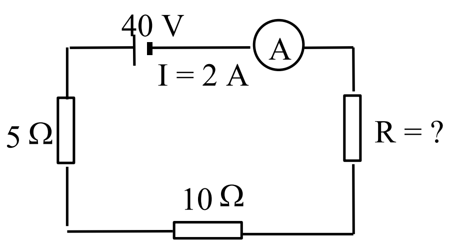
4. What is the p.d. across a 2 kΩ resistor if there is a current of 3 mA flowing through it?

5. Find the readings on the meters in the following circuits.




6. Find the unknown values of the following resistors.

(a)

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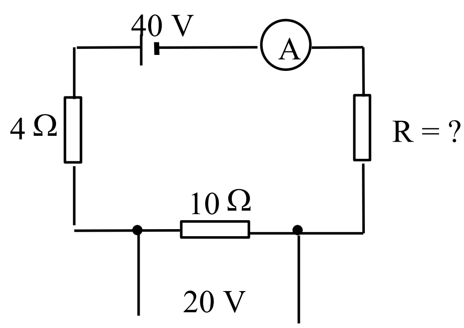
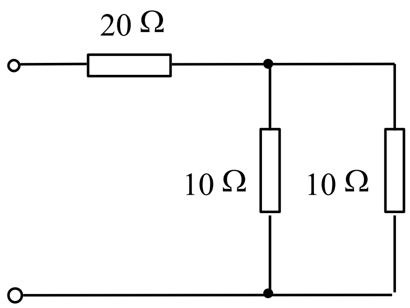


7. Find the total resistance of the following combinations.

(a)

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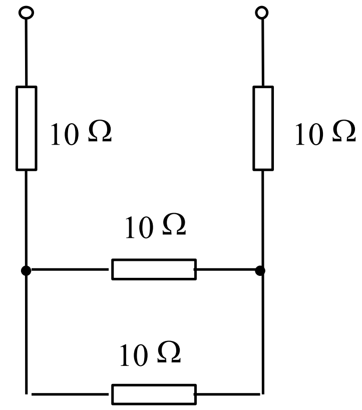
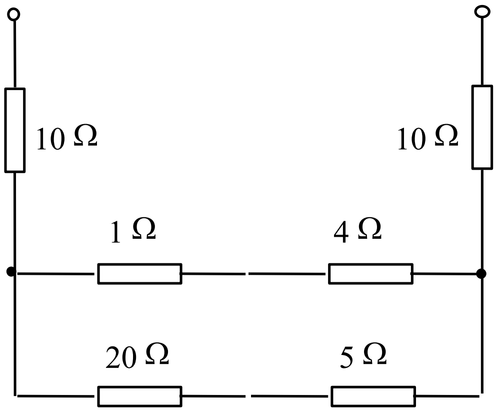
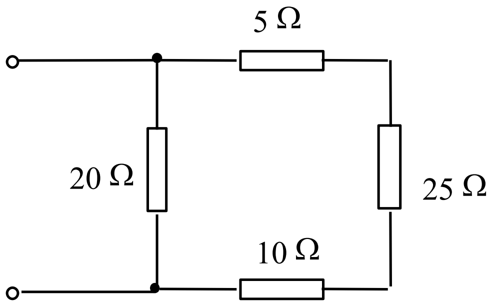


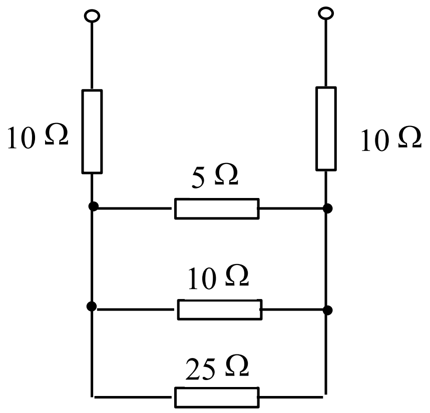

(c)



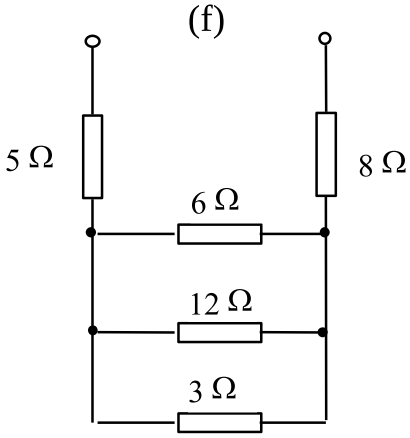

(d)



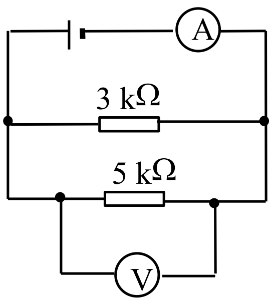

(e)




(f)




8. If the ammeter reads 2 mA, find the voltmeter reading.

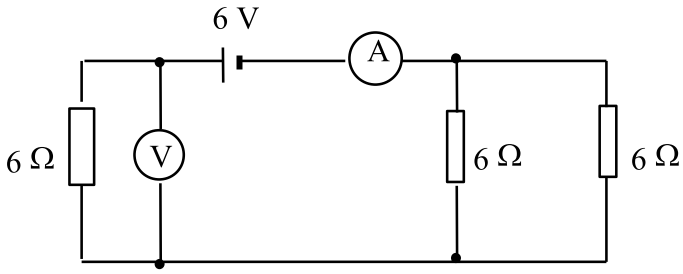


9. Calculate the power in each of the following cases.
(a) A 12 V accumulator delivering 5 A.
(b) A 60 Ω heater with a 140 V supply.
(c) A 5 A current in a 20 Ω heater coil.

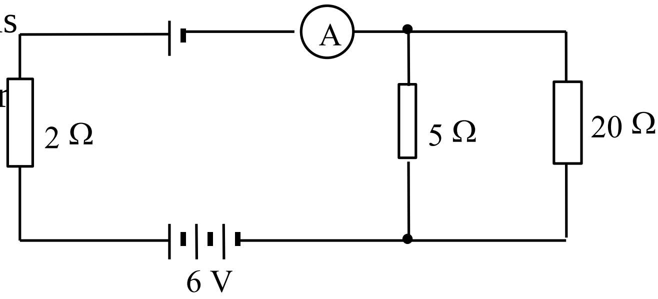
10. An electric kettle has a resistance of 30 Ω.
(a) What current will flow when it is connected to a 230 V supply?
(b) Find the power rating of the kettle.

11. A 15 V supply produces a current of 2 A for 6 minutes. How much energy is supplied in this time?

12. Find the readings on the ammeters and the voltmeter.




13. Assuming each of the four cells cell to be identical, find:
(a) the reading on the ammeter
(b) the current through the 20 Ω resistor
(c) the voltage across the 2 Ω resistor.

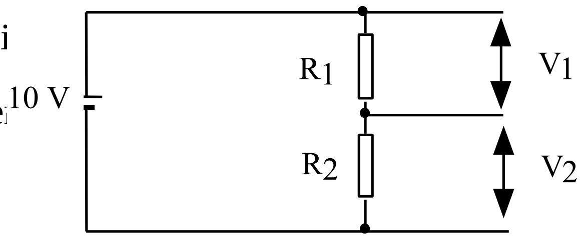



14. A coil has a current of 50 mA flowing through it when the applied voltage is 12 V. Find the resistance of the coil.

15. Write down the rules which connect the (a) potential differences and (b) the currents in series and parallel circuits.

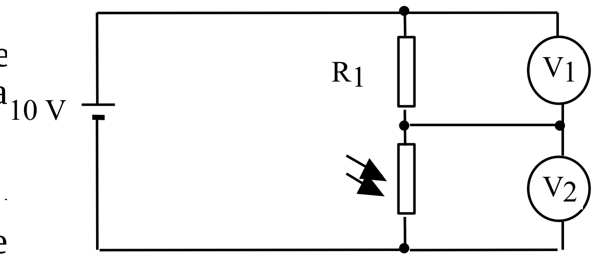
16. Draw the symbol for a fuse, diode, capacitor, variable resistor, battery and a d.c. power supply.

17. What is the name given to the circui opposite.
Write down the relationship betwee $V_1$, $V_2$, $R_1$ and $R_2$.



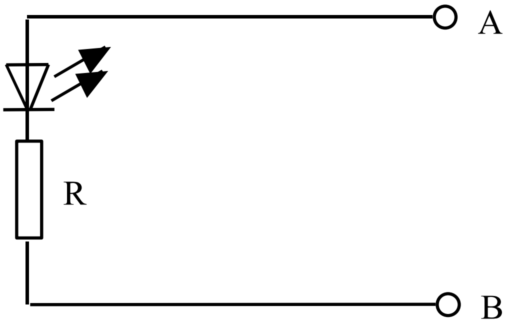

18. Find the values of $V_1$ and $V_2$ of the circuit in question 17 if:
(a) $R_1 = 1\ k\Omega$ $R_2 = 49\ k\Omega$
(b) $R_1 = 5\ k\Omega$ $R_2 = 15\ k\Omega$.

19. Explain what would happen to the readings on V1 and V2 if light wa shone onto the L.D.R.




Suppose the L.D.R. was replaced a thermistor which was then heate Explain the effect on the readings.

20. (a) What would be the polarity of A and B when connected to a 5 V supply, so that the LED would light?

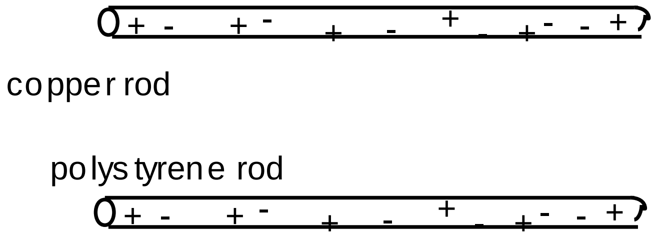



(b) What is the purpose of R in the circuit shown above?
(c) If the L.E.D. rating is 200 mA at 1.5 V, find the value of R.

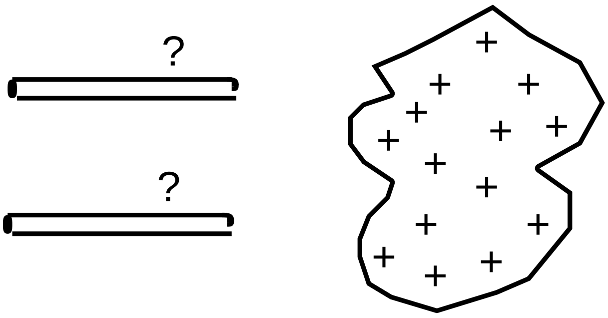
# ELECTRIC FIELDS & RESISTORS IN CIRCUITS/ TUTORIAL 1

[7]

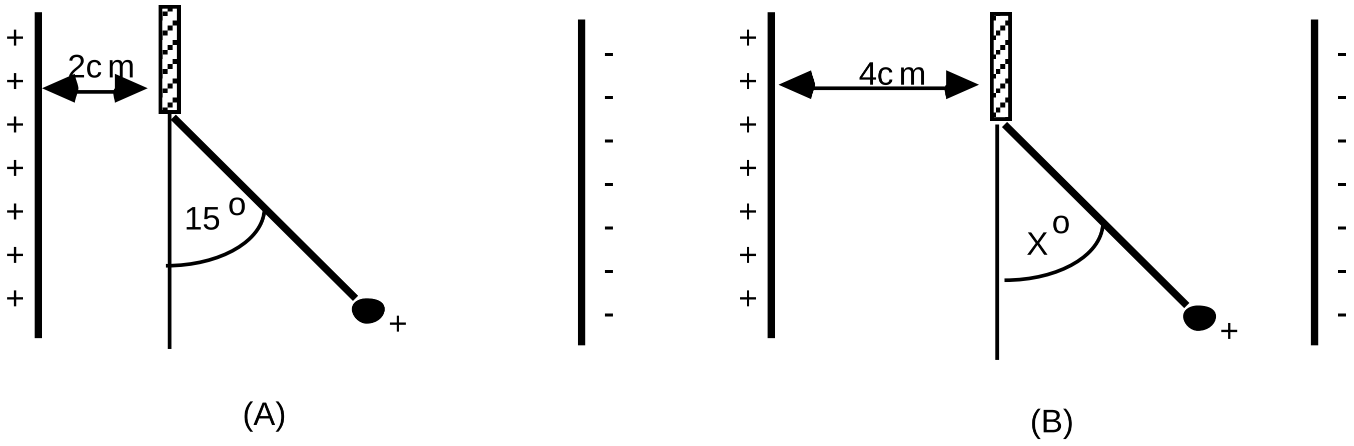
1.




Explain with the aid of a diagram, what effect we get when a positively charged object is brought near the right hand edge of these rods:-




2. What is the size of angle **X**?

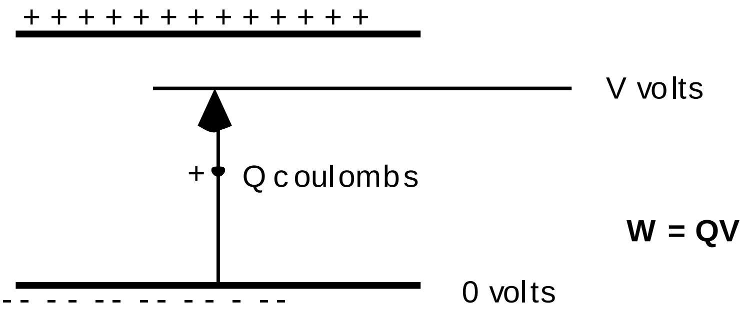


3. An oil drop with a charge of 3pC and a mass of $1.22 \times 10^{-8}$kg is placed in a uniform electric field of $4 \times 10^{4}NC^{-1}$. If the oil drop floats between the charged plates, what is its weight?

4. A small polystyrene sphere with a positive charge of 5pC is placed in a uniform electric field at the 10V level. If the sphere falls downwards to a place where the voltage level is 150V, how much work does the gravitational field do?

*[Help1]*

*We calculate work done in moving a charge of Q coulombs through a potential difference of V volts in a uniform electric field by using the relationship W=QV joules.*




*Write out some problems in which you have to calculate one of these variables given the values of the other two.*

*Ask your teacher to check your answers.*

# ELECTRIC FIELDS & RESISTORS IN CIRCUITS/ TUTORIAL 2

1. A lamp is rated at 48W 12V. When running normally,
   a) What is the current in it?
   b) What is the lamp's resistance while it is operating?

2. If a 2kΩ resistor has a p.d. of 9.6 V across it, what is the current in it?

3. A model power transmission line is 3m long and carries a current of 4A. What is the p.d. across it if the wire used has a resistance of 125 milli-ohms per metre?

*[Help2]*

*Combine Ohm's law, V = RI, with the fact that the electrical power delivered to a resistor is given by the product of the voltage across it and the current in it, P=VI, and we get a series of useful equations:-*

$$P = V \times I \cdots (1)$$
$$V = R \times I \cdots (2)$$

*Replace V in (1) by the I in (2) and we get*

$$P = (R \times I) \times I$$
$$= R \times I^2$$
$$\Rightarrow \quad P = I^2 R \cdots (3)$$

*Replace the I in (1) by the I in (2) and we get*

$$P = V \times \frac{V}{R} \quad \Rightarrow \quad P = \frac{V^2}{R} \cdots (4)$$

*Write out a few problems of your own which need knowledge of these equations to solve them.*

# ELECTRIC FIELDS & RESISTORS IN CIRCUITS/ TUTORIAL 3

1. a) If 15C of charge moves between two electrodes with 1200V between them, how much work is done?
   b) If the current in this device lasted for 600s, what is its power consumption?
   c) What is the current in this device?
   d) Using 'volts = joules per coulomb' and 'amps = coulombs per second', find what quantity we get by multiplying volts by amps.

2. A 12V 24W bulb is used in series with a 4 Ω resistor so that the bulb can run normally form a 20V supply. What is the resistance of the bulb?

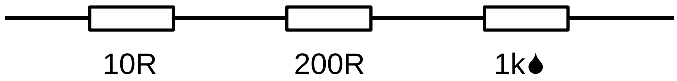
3. A battery of e.m.f. 12V has a terminal p.d. of 9V when connected to an external circuit drawing 3A. What is the internal resistance of the battery?

4. a) A 12V car battery has an internal resistance of 0.001Ω. What is its 'short circuit' current?
   b) What is the short circuit current of a 1.5V dry cell of internal resistance 1.25Ω?

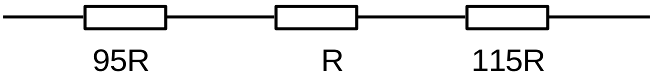
5. A power source has a terminal p.d. of 5.7V when its external circuit is receiving 1.5A from it. When the external circuit is changed so that the current drawn from the source is 2A, the terminal p.d. measurers 4.6V
   What is the source's e.m.f. and internal resistance?

# ELECTRIC FIELDS & RESISTORS IN CIRCUITS/ TUTORIAL 4

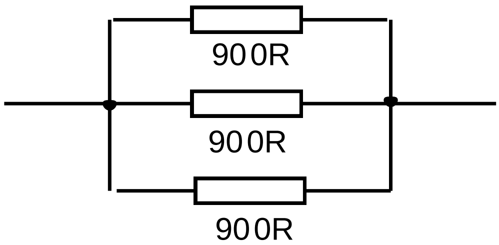
1. What is the total resistance of this arrangement?




2. If the equivalent resistance of the following arrangement is 250Ω, what is the value of the unknown resistor?




3. What is the equivalent resistance of this arrangement of resistors?

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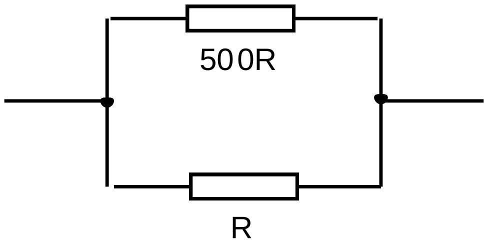



5. What is the equivalent resistance of 200Ω, 300Ω and 600Ω when they are all connected in parallel?

*[Help] Solving problems involving resistors in parallel requires manipulation of the formula* $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

*Since this is a routine operation, it is only necessary to practice the steps:*

6. *What is the equivalent resistance of three resistors, 4Ω, 4Ω and 2Ω in parallel?*

7. *What is the value of a resistor which gives an equivalent resistance of 18.75Ω when connected in parallel with a 75Ω resistor?*

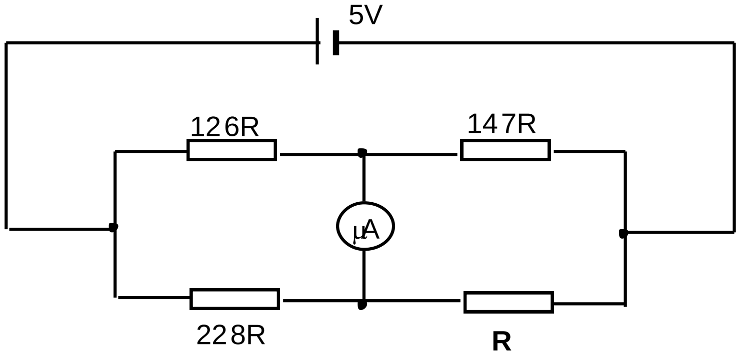
8. *Make up problems similar to number 6 above using your own values for the resistors.*

9. *Invent and solve problems similar to number 7 above.*

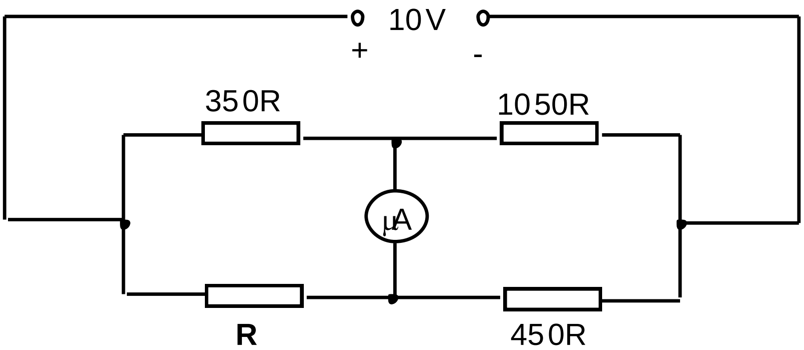
*Ask your teacher to check your answers.*

# ELECTRIC FIELDS & RESISTORS IN CIRCUITS/ TUTORIAL 5

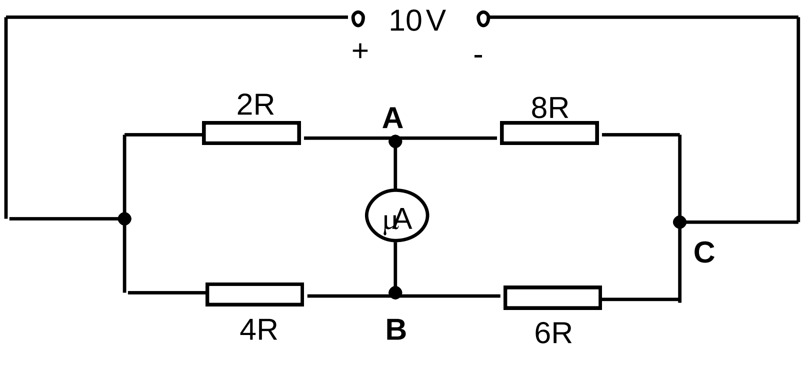
1. What is the value of the unknown resistor shown in this circuit when the micro-ammeter reads zero?




2. What value must **R** have in the following circuit for the micro-ammeter to read zero?




3. Is there a p.d. between **A** and **B** in the following circuit?



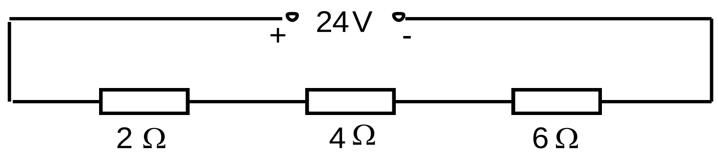

*[Help]*

*To get the necessary practice in manipulating the Wheatstone bridge equation, just put your own numbers in for any three of the resistors and then calculate the unknown value.*

[17]

# ELECTRIC FIELDS & RESISTORS IN CIRCUITS/ TUTORIAL 6

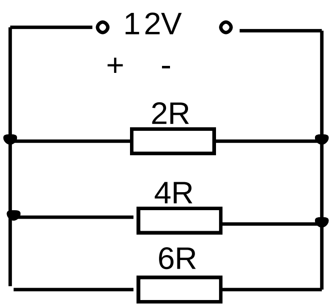
1. a) Calculate the total resistance shown in this circuit.




b) Calculate the current in the circuit.

c) Calculate the potential difference across each resistor in the circuit.

2.

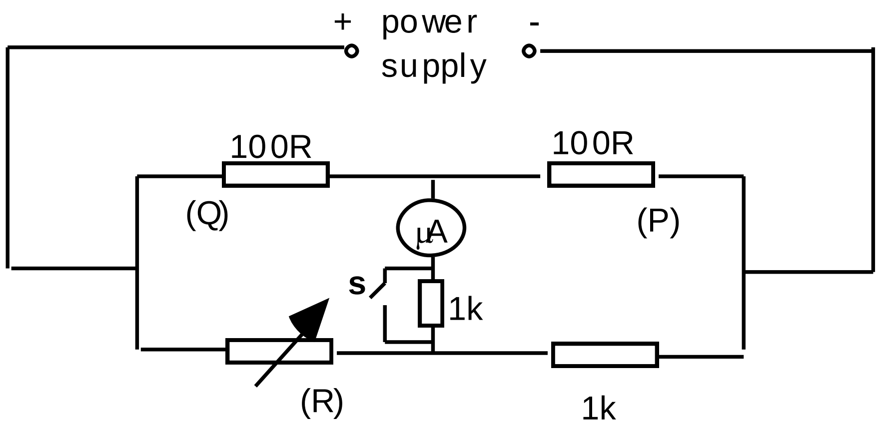



Examine this circuit, then calculate

a) Its total resistance.

b) The current in each of the resistors.

3.




a) **R** is adjusted until the micro-ammeter is nearly balanced and reads 10µA. What happens to this reading if switch **S** is closed?

b) **R** is adjusted until the micro-ammeter reads zero when the switch **S** is closed. If the power supply voltage is now doubled, what effect does it have on the current reading?

4. Here is a set of reading taken from an out-of-balance Wheatstone bridge:

| Current /**A** | $15x10^{-6}$ | $30x10^{-6}$ | $45x10^{-6}$ | $60x10^{-6}$ |
|---|---|---|---|---|
| Out-of-balance resistance /Ω | 12.5 | 25 | 37.5 | 50 |

What is the value of the out-of-balance resistance when the micro-ammeter reads 36μA?

5. A pupil wants to measure the connection between the weight hanging on a hacksaw blade and the amount of bending it causes. He intends using a strain gauge whose resistance varies in direct proportion to the angle through which it is bent.
Give an outline of how to set up the measuring system.

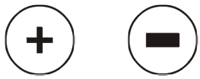
## ELECTRICITY AND ELECTRONICS PROBLEMS

### ELECTRIC FIELDS AND RESISTORS IN CIRCUITS

1. Draw the electric field pattern for the following charges:

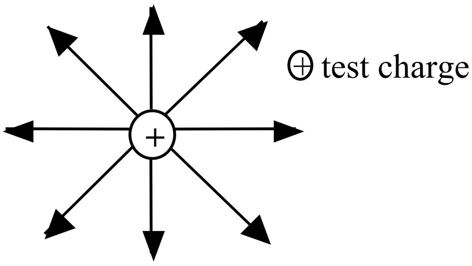
(a) 


(b) 

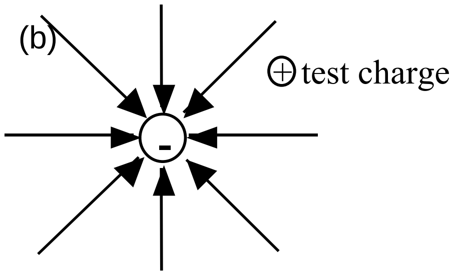

(c) 


2. Describe the motion of the small test charges in each of the following fields.

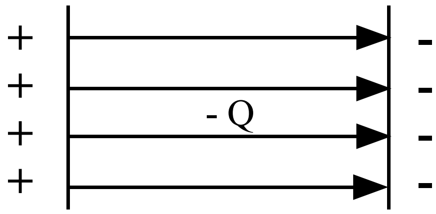
(a)



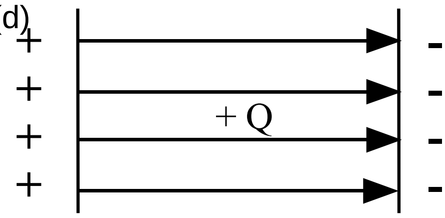

(b)




(c)



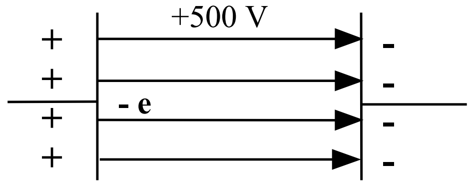

(d)




3. An electron volt is a unit of energy. It represents the change in potential energy of an electron which moves through a potential difference of 1 volt. If the charge on an electron is $1.6 \times 10^{-19}$ C, what is the equivalent energy in joules?

4. Mass of an electron = $9.1 \times 10^{-31}$ kg Charge on an electron = $1.6 \times 10^{-19}$ C

The electron shown opposite is accelerated across a p.d. of 500 V.

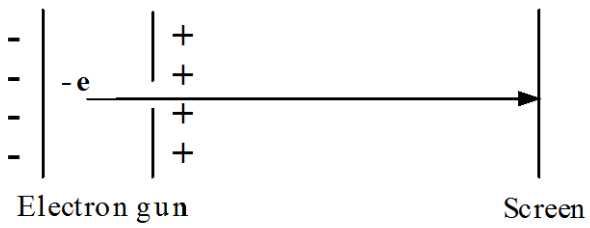



(a) How much electrical work is done?

(b) How much kinetic energy has it gained?

(c) What is its final speed?

5. Electrons are 'fired' from an electron gun at a screen. The p.d. across the gun is 2000 V. After leaving the positive plate the electrons travel at a constant speed to the screen. Assuming the apparatus is in a vacuum, at what speed will the electrons hit the screen?




6. What would be the increase in speed of an electron accelerated from rest by a p.d. of 400 V?

7. An X-ray tube is operated at 25 kV and draws a current of 3 mA.

(a) Calculate

(i) the kinetic energy of each electron as it hits the target

(ii) the velocity of impact of the electron as it hits the target

(iii) the number of electrons hitting the target each second.

(mass of electron = $9.1 \times 10^{-31}$ kg charge on electron = $1.6 \times 10^{-19}$ C)

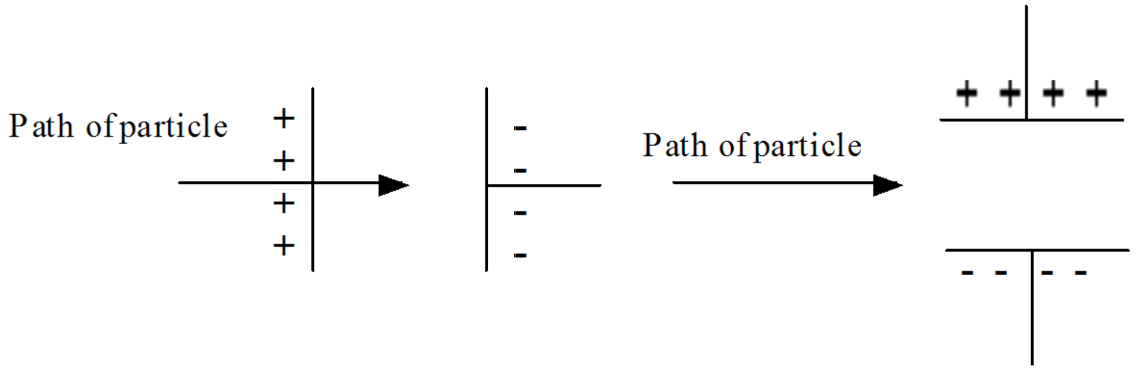
(b) What happens to the kinetic energy of the electrons?

8. Sketch the paths which (a) an a-particle,

(b) a b-particle,

and (c) a neutron,

would follow if each particle entered the given electric fields with the same velocity. (Students only studying this unit should ask for information on these particles).




9. State what is meant by (a) the e.m.f. of a cell

(b) the p.d. between 2 points in the circuit.

10. Prove the expressions for the total resistance of resistors in (a) a series and (b) a parallel circuit.

11. In the circuit below:

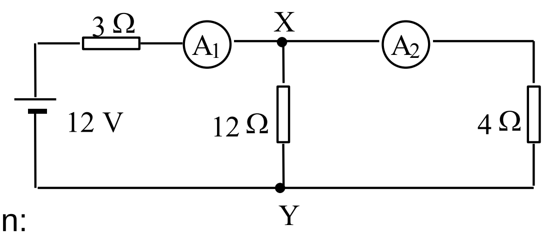
(a) what is the total resistance of the circuit

(b) what is the resistance between X and Y

(c) find the readings on the ammeters

(d) calculate the p.d. between X and Y

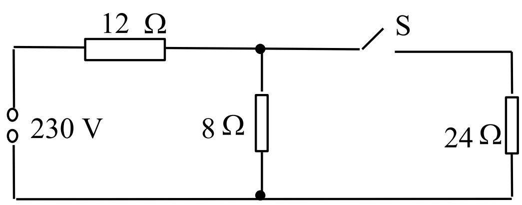
(e) what power is supplied by the battery ?



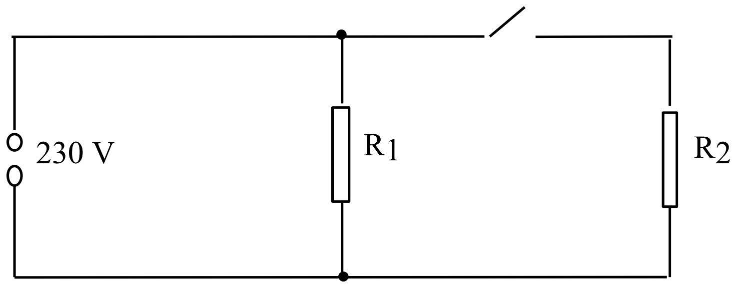

12. The circuit opposite uses the 230 V alternating mains supply. Find the current flowing in each resistor when:

(a) switch S is open

(b) switch S is closed.

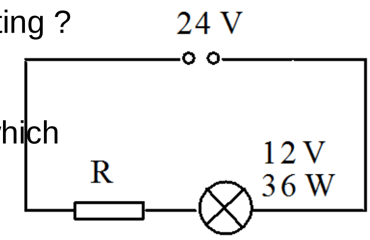


13. An electric cooker has two settings, high and low. It takes 1 A at the low setting and 3 A at the high setting.




(a) Find the resistance of $R_1$ and $R_2$.

(b) What is the power consumption at each setting ?



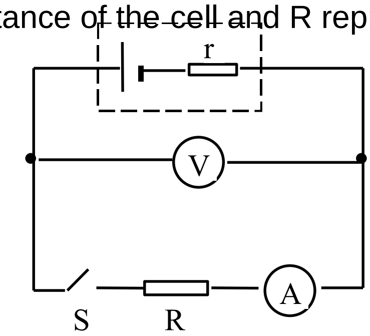

14. (a) Find the value of the series resistor which would allow the bulb to operate at its normal rating.

(b) Calculate the power dissipated in the resistor.

15. In the circuit below, r represents the internal resistance of the cell and R represents the external resistance of the circuit.

When S is open, the voltmeter reads 2.0 V.

When S is closed, it reads 1.6 V and the ammeter reads 0.8 A.



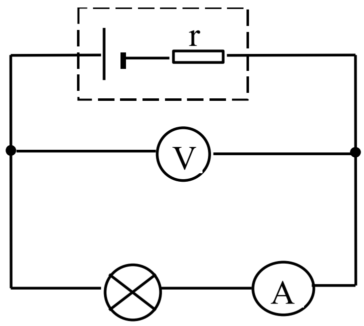

(a) What is the e.m.f. of the cell ?

(b) What is the terminal potential difference when S is closed?

(c) Calculate the values of r and R.

(d) If R was halved in value, calculate the new readings on the ammeter and voltmeter.

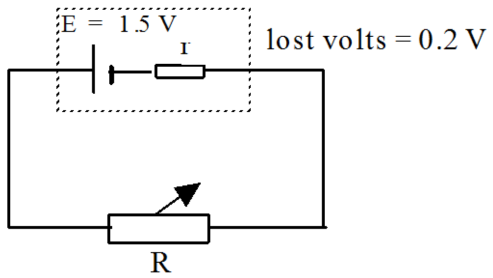
16. The cell in the diagram has an e.m.f. of 5 V. The current through the lamp is 0.2 A and the voltmeter reads 3 V. Calculate the internal resistance of the cell.




17. A cell of e.m.f. 4 V is connected to a load resistor of 15 W. If 0.2 A flows round the circuit, what must be the internal resistance of the circuit?

18. A signal generator has an e.m.f. of 8 V and internal resistance of 4 Ω. A load resistor is connected to its terminals and draws a current of 0.5 A. Calculate the load resistance.

19. (a) What will be the terminal p.d. across the cell in the circuit below.




(b) Will the current increase or decrease as R is increased?

(c) Will the terminal p.d. then increase or decrease ? Explain your answer.

20. A cell with e.m.f. 1.5 V and internal resistance 2 □ is connected to a 3 Ω resistor. What is the current?

21. A pupil is given a voltmeter and a torch battery. When he connects the voltmeter across the terminals of the battery it registers 4.5 V, but when he connects the battery across a 6 □ resistor, the voltmeter reading decreases to 3.0 V.

(a) Calculate the internal resistance of the battery.

(b) What value of resistor would have to be connected across the battery to reduce the voltage reading to 2.5 V.

22. In the circuit shown, the cell has an e.m.f. of 6.0 V and internal resistance of 1 □.

When the switch is closed, the reading on the ammeter is 2 A. What is the corresponding reading on the voltmeter ?

23. In order to find the internal resistance of a cell, the following sets of results were taken.

| Voltage (V) | 1.02 | 0.94 | 0.85 | 0.78 | 0.69 | 0.60 |
|---|---|---|---|---|---|---|
| Current (A) | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 |

(a) Draw the circuit diagram used.

(b) Plot a graph of these results and from it determine

(i) the e.m.f.

(ii) the internal resistance of the cell.

(c) Use the e.m.f. from part (b) to calculate the lost volts for each set of readings and hence calculate 6 values for the internal resistance.

(d) Calculate the mean value of internal resistance and the approximate random uncertainty.

24. The voltage across a cell is varied and the corresponding current noted. The results are shown in the table below.

| Voltage (V) | 5.5 | 5.6 | 5.7 | 5.8 | 5.9 |
|---|---|---|---|---|---|
| Current (A) | 5 | 4 | 3 | 2 | 1 |

Plot a graph of V against I.

(a) What is the open circuit p.d?

(b) Calculate the internal resistance.

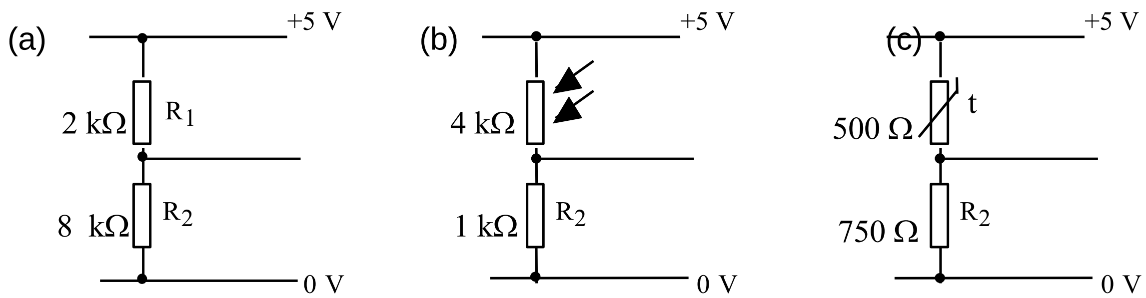
(c) Calculate the short circuit current.

(d) A lamp of resistance 1.5 Ω is connected across the terminals of this supply.

Calculate (i) the terminal p.d.

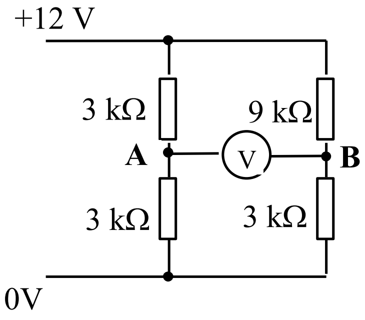
and (ii) the power delivered to the lamp.

25. Calculate the p.d. across $R_2$ in each case.

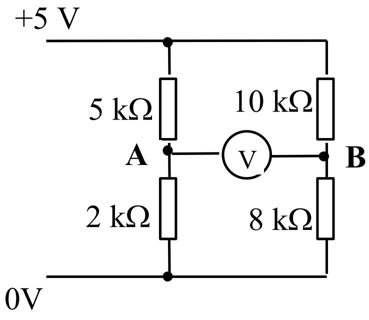


26. Calculate the p.d. across AB (voltmeter reading) in each case.

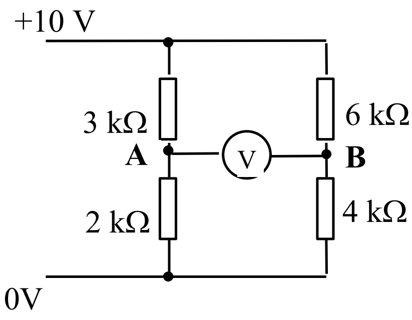
(a)



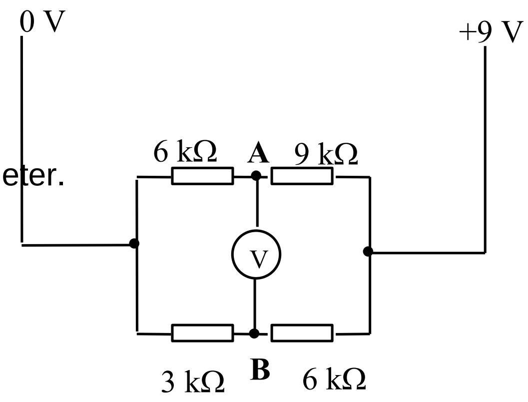

(b)




(c)



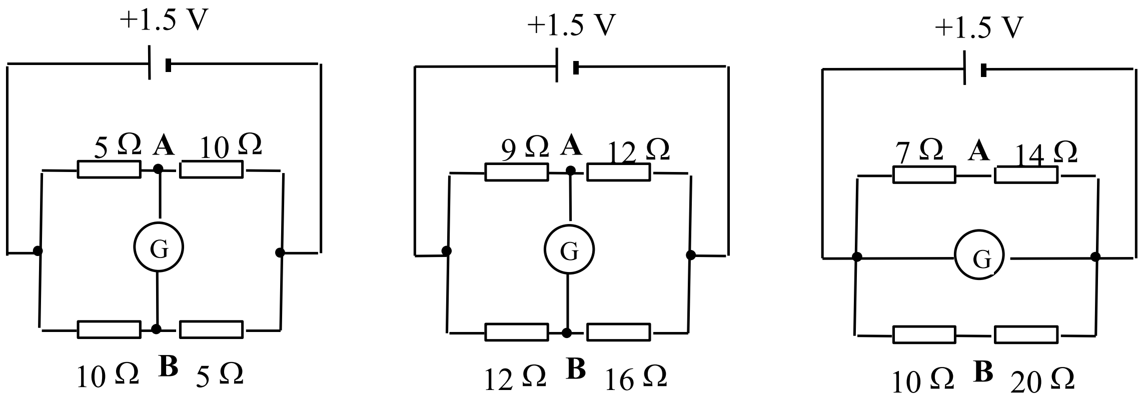

27. (a) Calculate the reading on the voltmeter.




(b) What alteration could be made to balance the bridge circuit ?

28. Three pupils are asked to construct balanced Wheatstone bridges.

Their attempts are shown.




**Pupil A** **Pupil B** **Pupil C**

One of the circuits gives a balanced Wheatstone bridge, one gives an off - balance Wheatstone bridge and one is not a Wheatstone bridge.

(a) Identify each circuit.

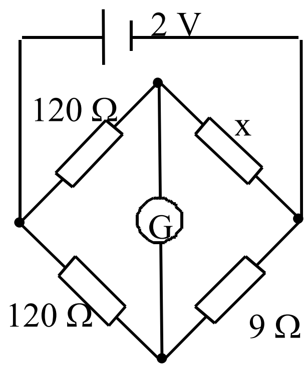
(b) How would you test that balance has been obtained ?

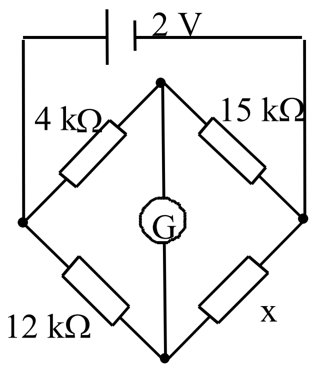
(c) In the off – balance Wheatstone bridge ;

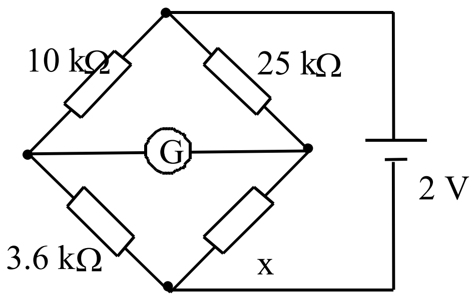
(i) calculate the potential difference across the galvanometer.

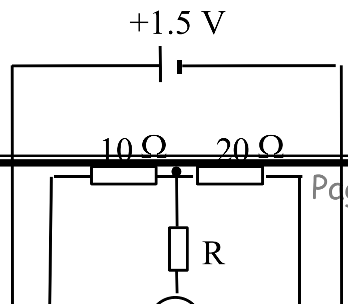
(ii) in which direction will electron current flow through the galvanometer.

29. Calculate the value of the unknown resistor × in each case.



30. The circuit shown opposite is balanced.

(a) What is the value of resistance ×?

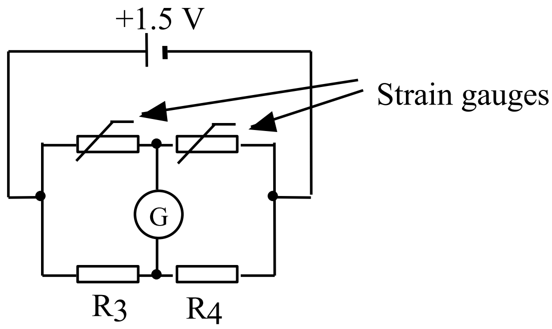
(b) Will the bridge be unbalanced if

(i) a 5 Ω resistor is inserted next to the 10 Ω resistor

(ii) a 3 V supply is used.

(c) What is the function of resistor R and what is the disadvantage of using it as shown ?

31. The following Wheatstone bridge circuit is used to monitor the mechanical strain on a girder in an oil rig.

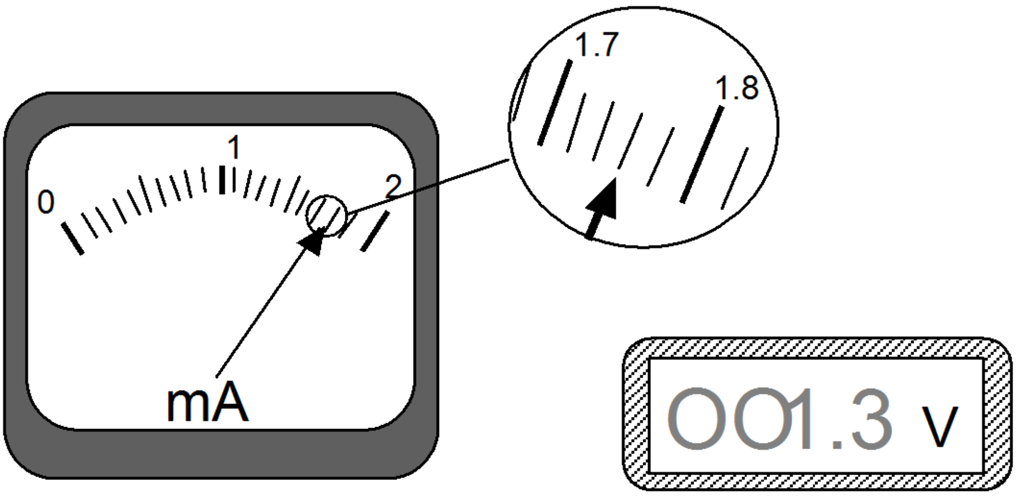



(a) Explain how the circuit can be used to monitor the strain.

(b) Sketch the graph of current through the galvanometer against the strain.

32. An automotive electrician needed to accurately measure the resistance of a resistor. She set up a circuit using an analogue milliammeter and a digital voltmeter.

The two meter readings were:




(a) What are the readings?

(b) What is the nominal resistance calculated from these readings?

(c) Which reading is likely to cause the greatest uncertainty?

(d) What is the smallest division on the milliammeter?

(e) What is the absolute uncertainty on the milliammeter?

(f) What is the absolute uncertainty on the voltmeter?

(g) What is the percentage uncertainty on the milliammeter?

(h) What is the percentage uncertainty on the voltmeter?

(i) Which is the greatest percentage uncertainty?

(j) What is the percentage uncertainty in the resistance?

(k) What is the absolute uncertainty in the resistance?

(l) Express the final result as “(resistance ± uncertainty)Ω”

(m) Round both the result and the uncertainty to the relevant number of significant figures or decimal places.

EXAM QUESTIONS

6.

a) A rechargeable cell is rated at 0.5 A h (ampere hour). This means that, for example, it can supply a constant current of 0.50 A for a period of 1 hour. The cell then requires to be recharged.

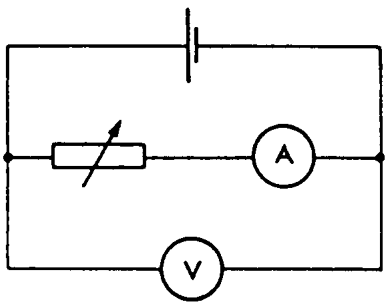
i. What charge, in coulombs, is available from a fully charged cell?

ii. A fully charged cell is connected to a load resistor and left until the cell requires recharging. During this time the p.d. across the terminals of the cell remains constant at 1.2 V.
Calculate the electrical energy supplied to the load resistor in this case **3**

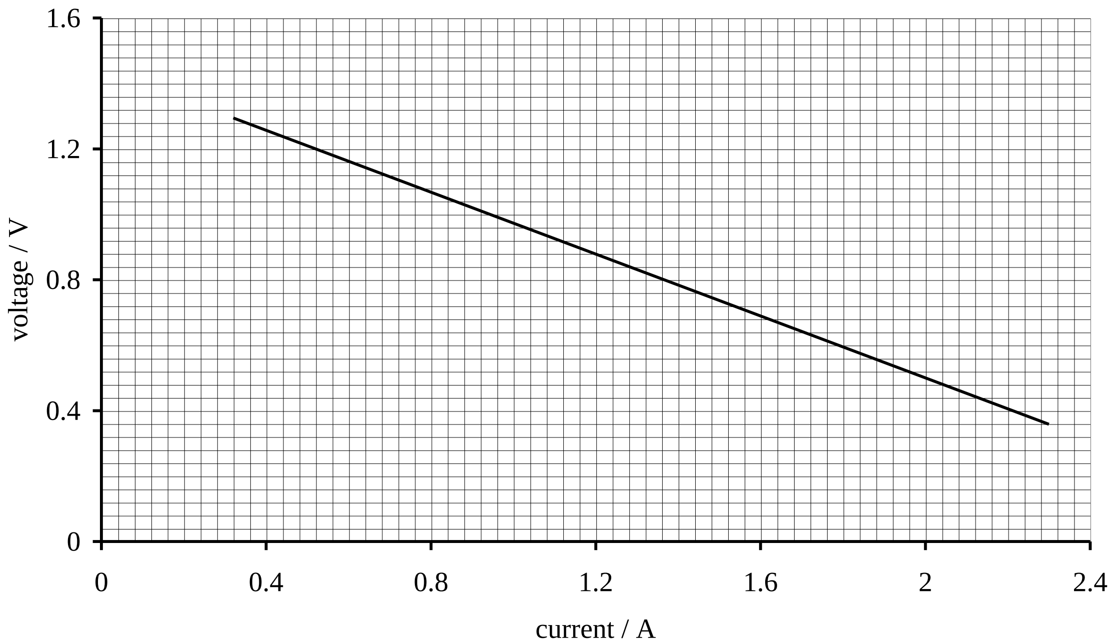
b)

i. State what is meant by the e.m.f. of a cell

ii. The circuit shown below is used in an experiment to find the e.m.f. and internal resistnce of the rechargeable cell.

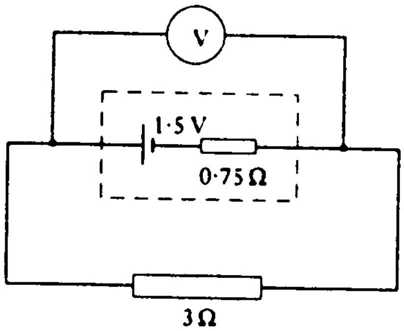



The voltmeter and ammeter readings for a range of settings of the variable resistor are used to produce the graph below.




Use the graph to find the values for the e.m.f. **and** internal resistance of the cell. **4**

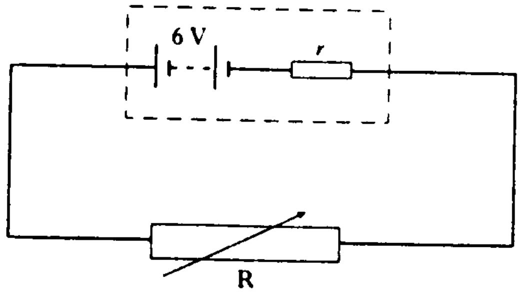
A cell of e.m.f. 1.5 V and internal resistance 0.75 Ω is connected as shown in the following circuit.



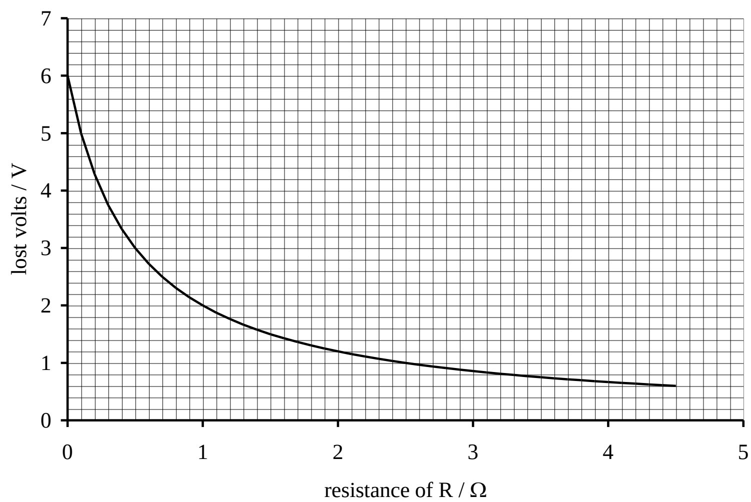

Calculate the value of the reading on the voltmeter.

What is the value of the "lost volts" in this circuit? **3**

A battery of e.m.f. 6 V and an internal resistance, r, is connected to a variable resistor R as shown in the following circuit diagram.



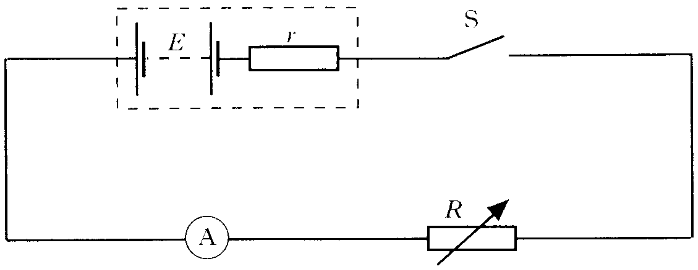

*The graph below shows how the "lost volts" of this battery changes as the resistance of R increases.*




Use information from the graph to calculate the p.d. across the terminals of the battery (t.p.d.) when the resistance of R is 1 Ω.

Calculate the internal resistance, r, of the battery. **4**

The Circuit below is used to determine the internal resistance r of a battery of e.m.f. E.

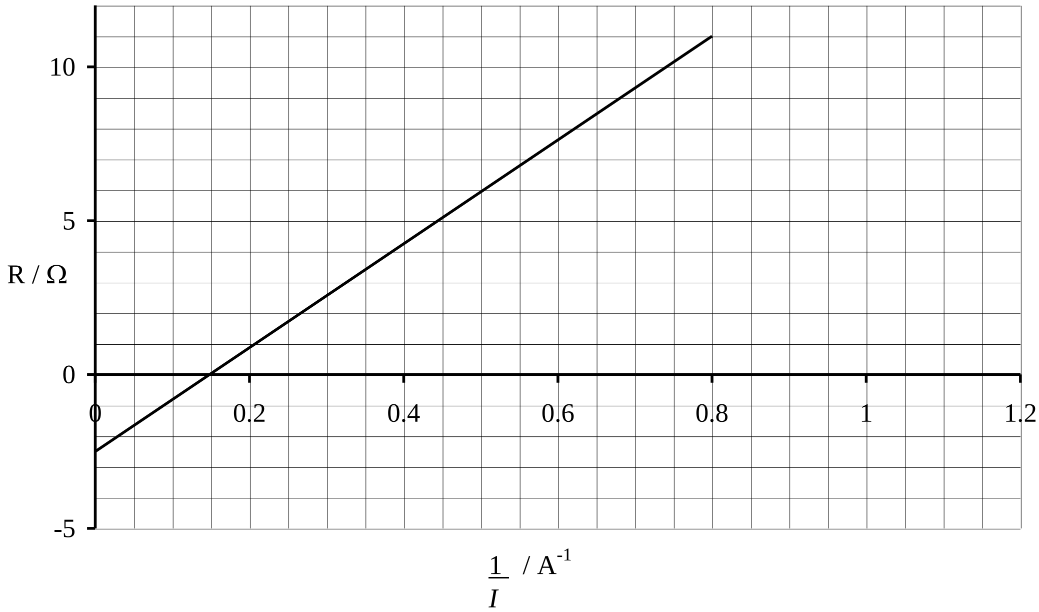



The variable resistor provides known values of resistance R.

For each value of resistance R, the switch S is closed and the current I is noted.

For each current, the value of $\frac{1}{I}$ is calculated.

In one such experiment, the following graph of R against $\frac{1}{I}$ is obtained.




a) Conservation of energy applied to the complete circuit gives the following relationship.

$$E = I(R + r)$$

**Show** that this relationship can be written in the form 1

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

b) Use information from the graph to find:

i) the internal resistance of the battery;

ii) the e.m.f. of the battery. 3

c) The battery is accidentally short-circuited.

Calculate the current in the battery when this happens. 2

# QUESTIONS.

1. What is the e.m.f. of a cell of resistance 3Ω which can produce a current of 0.2A in a wire of resistance 6Ω?

2. A cell of e.m.f. 1.2V and internal resistance 0.4Ω maintains a current in an external resistance of 2Ω. Find the p.d. between the terminals of the cell.

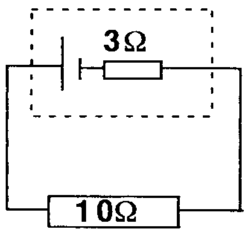
3. A voltmeter gives a reading of 2V when connected open circuit to an accumulator. When it lights a lamp of resistance 3.5Ω the reading on the meter falls to 1.4V. Find the internal resistance of the accumulator.

4. A cell has a resistance of 3Ω and an e.m.f. of 2V and another cell has a resistance of 1Ω and e.m.f. of 1.5V.

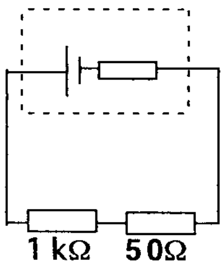
Calculate the resistance of the wire which, when connected to either cell, will produce the same current.

## Internal Resistance.

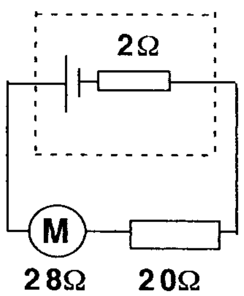
1. If the e.m.f. of the cell is 4V calculate




   a. The t.p.d.
   b. The lost volts.
   c. What would happen to these values if another 10Ω resistance was added in series?




2. If the e.m.f. is 16V and the current going through the circuit is 10 mA find the internal resistance.




3. Calculate the e.m.f. of the cell if the current is 0.4A.

**Revision of circuits**

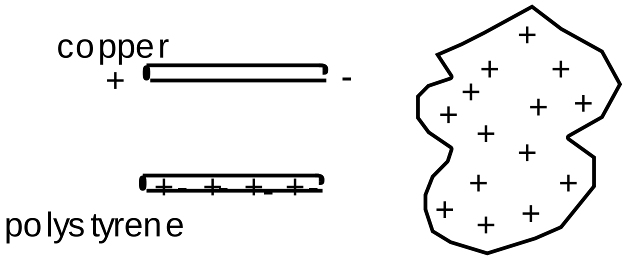
1. Q = 0.64 C
2. Q = $5 \times 10^3$ A
3. t = $2 \times 10^4$ s.
4. V = 6 V
5. (a) 0.1 A (b) 0.5 A, 4.5 V (c) 2 A, 10 V.
6. (a) 5 Ω (b) 6 Ω
7. (a) 15 Ω (b) 25 Ω (c) 24.2 Ω (d) 13.3 Ω (e) 22.9 Ω
   (f) 14.7 Ω.
8. $3.75 \times 10^{-3}$ V
9. (a) 60 W (b) 327 W (c) 500 W
10. (a) 7.67 A, (b) 1763 W
11. 9000 J
12. 0.67 A, 4 V
13. (a) 0.67 A (b) I (20 Ω) = 0.13 A, I (5 Ω) = 0.54 A (c) 13.4 V
14. 240 Ω
18. (a) $V_1$ = 0.2 V $V_2$ = 9.8 V (b) $V_1$ = 2.5 V $V_2$ = 7.5 V

20 (c) 17.5 Ω

**ELECTRIC FIELDS & RESISTORS IN CIRCUITS/ TUTORIAL ANSWERS**

**Tutorial 1**

1.




2. **X** = 15$^o$ since the field is uniform.

3. Since the drop is *floating*, the electric force, 1.2x10$^{-7}$N, is the same as its weight.

4. Since the motion is caused by the sphere's weight, the work done by the gravitational field is 7x10$^{-10}$J.

**Tutorial 2**

1. a) The current in the lamp is 4A
   b) The lamp's resistance is 3Ω
2. The current in the resistor is 4.8mA
3. The wire has a p.d. of 1.5V across it.

**Tutorial 3**

1. a) There are 18000J of work done.
   b) It is a 30W device.
   c) The current in the device is 25mA
   d) The product of *volts* and *amps* is *watts*.
2. The bulb has a resistance of 6Ω
3. The battery's internal resistance is 1Ω
4. a) The short circuit current is 12000A
   b) The short circuit current of a dry cell is 1.2A
5. The e.m.f. of the power supply is **9V** and its internal resistance is **2.2Ω**.

**Tutorial 4**

1. The total resistance is 1210Ω
2. The unknown resistance is 40Ω
3. The equivalent resistance is 300Ω
4. The unknown resistance is 500Ω
5. The equivalent resistance is 100Ω
6. The equivalent resistance is 1Ω
7. The unknown resistance is 25Ω

**Tutorial 5**

1. The unknown resistance is 266Ω
2. **R** has a value of 150Ω
3. Yes; the resistors do not have the same ratio in each branch and so the micro-ammeter registers a current which requires a p.d. across it. If you care to calculate the actual values, you find that **A** is at 8V and **B** at 6V. This gives a 2V p.d. between **B** and **A**.

**Tutorial 6**

1. a) The total resistance for this circuit is 12Ω.
   b) The current is 2A
   c) The p.d.'s are 4V, 8V and 12V across the 2, 4 and 6Ω resistors respectively.
2. a) The total is 1.09Ω
   b) The currents are 6A, 3A and 2A in the 2,4 and 6Ω resistors respectively.
3. a) The reading increases since the 1000Ω resistor which limits the ammeter current to 10μA has been removed.
   b) It doubles the current in each branch of the network which still leaves the micro-ammeter reading zero.
4. The resistance is 30Ω.
5. The strain gauge is made into one arm of a Wheatstone bridge which is then balanced with another identical strain gauge in an unstrained position. This means that any future strain on the working gauge causes an out-of-balance resistance whose size can be measured from the size of the out-of-balance current.

   We then apply different weights to the hacksaw blade and use the out-of-balance current as a measure of the amount of bending.

**Electric fields and resistors in circuits**

3. $1.6 \times 10^{-19}$ J

4. (a) $8 \times 10^{-17}$ J (b) $8 \times 10^{-17}$ (c) v = $1.33 \times 10^{6}$ m $s^{-1}$

5. v = 2.65 × 107 m $s^{-1}$.

6. v = 1.2 × 107 m $s^{-1}$

7. (a) (i) $4 \times 10^{-15}$ J (ii) 9.4 × 107 m $s^{-1}$ (iii) $1.875 \times 10^{16}$ electrons

11. (a) 6 Ω (b) 3 Ω (c) 1.5 A (ammeter 2), 2 A (ammeter 1) (d) 6 V (e) 24 W

12. (a) 11.5 A (b) 12.8 A (12 Ω), 9.6 A (8 Ω), 3.2 A (24 Ω)

13. (a) $R_1$ = 240 Ω $R_2$ = 120 Ω (b) Low - 240 W High - 720 W

14. (a) 4 Ω (b) 36 W

15. (a) 2 V (b) 1.6 V (c) r = 0.5 Ω, R = 2 Ω, 1.3 A, 1.3 V

17. 10 Ω

18. 5 Ω

19. 12 Ω

20. 19.(a) 1.3 V

21. 0.3 A

22. 3 Ω

23. 4 V

24. 23. (b) 1.1 V (Intercept), 4.2 Ω (-gradient) (c) 4.1 ± 0.02 Ω

25. 24. (a) 6 V (b) 0.1 Ω (c) 60 A (d)(i) 5.63 V (ii) 21.1 W

25. (a) 4 V (b) 1 V (c) 3 V

26. (a) 3 V (b) -0.8 V (c) 0 V

27. (a) 0.6 V

28. (c) (i) 0.5 V (ii) from B to A.

29. (a) 4 Ω (b) 45 Ω (c) 9 Ω

30. (a) 10 Ω

32. (a,e)1.76±0.01 mA, (b,f) 1.3±0.1V, (m) 740 ± 60 Ω