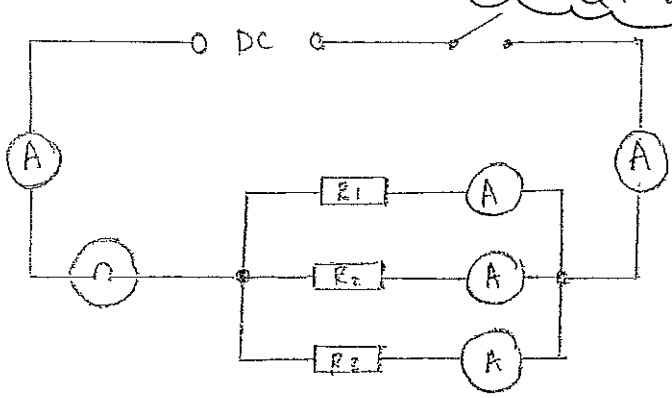
Chapter 10: Current and Voltage

Look in a book or on the internet to remind yourself about the rules for current in circuits.

Now try these questions.

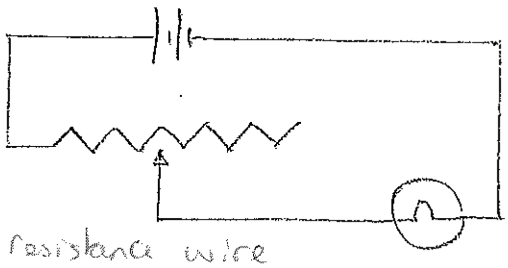
NOTE You will need to be able to recall and use the rules in Q1 & Q5

(1)

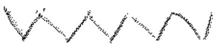


List 2 rules about current.

(2)

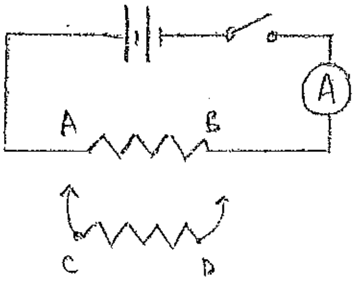


Explain the effect of moving the sliding contact to the right



represents resistance wire

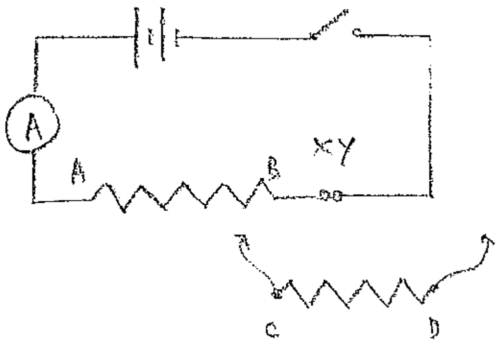
(3)



connectors to connect A to C and B to D

Explain the effect of adding wire CD in parallel.

(4)

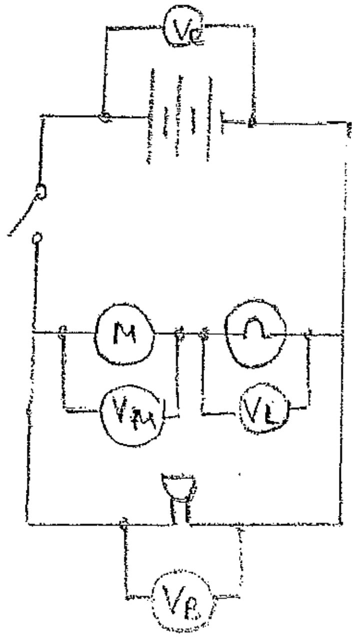


Separate XY
Explain the effect of adding wire CD at X-Y.

Look in a book or on the internet to remind yourself about the rules for voltage in circuits.

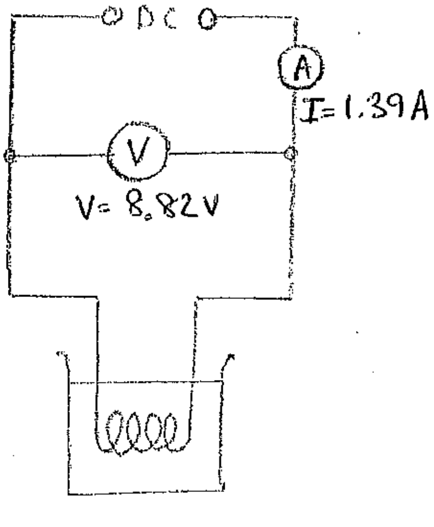
Now try these questions.

(5)



List 2 rules for the voltage in this circuit.

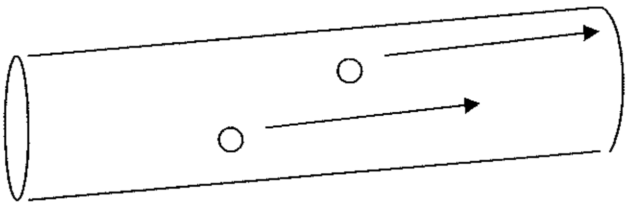
(6)



Calculate the power of the heater coil.

How much energy will it use in 5 minutes?

Current in a Wire



Current flows due to charged particles (e.g electrons in a wire) flowing. The current at a point in a circuit equals the **rate of flow of charge** passing that point i.e. the charge passing per second.

Current = $\frac{\textbf{Charge}}{\textbf{Time}}$ or in symbols $\mathbf{I = \frac{\Delta Q}{\Delta t}}$ (here the symbol Δ means 'change in')

or **Charge = Currrent x Time** $\mathbf{\Delta Q = I \times \Delta t}$

Current has the symbol I and is measured in amps (symbol A)

Charge has the symbol Q and is measured in coulombs (symbol C)

Time must be measured in seconds.

Example 1

Calculate the charge passing if a current of 0.24 A flows for 30s.

Answer

$\Delta Q = I \times \Delta t$

$= 0.24 \times 30$

$= 7.2$ C

Example 2

Calculate the current if a charge of 30mC passes in a time of 25s.

Answer

$I = \frac{\Delta Q}{\Delta t} = \frac{30 \times 10^{-3}}{25} = 1.2 \times 10^{-3}$ A

The flow of electrons

Each electron carries a charge of 1.6×10^{-19} C.

We can use the formula $\mathbf{Q = N \times e}$ to calculate the total charge that has flowed where:

N = the number of electrons that have passed by

e = the electronic charge (the charge on an electron i.e. 1.6×10^{-19} C)

Using the formula above we can calculate the number of electrons that have flowed when 1 coulomb of charge passes. $N = Q/e = 1/1.6 \times 10^{-19}$ i.e 6.25×10^{18} electrons have passed

We can use the formula $\mathbf{I = \dfrac{N \times e}{t}}$ to calculate current

Where:
I = current in A
N = the number of electrons that have passed
t = time in s

This rearranges to $\mathbf{N = \dfrac{I \times t}{e}}$ so now we can calculate how many electrons pass

Example 3

A current of 3.5 A flows through an ammeter.

a) Calculate how many electrons pass per second.

Answer
The number passing per second means that we can use a time of 1 s

$$\mathbf{N = \frac{I \times t}{e}}$$

$$= \frac{3.5 \times 1}{1.6 \times 10^{-19}} = 2.2 \times 10^{19} \text{ electrons per second}$$

b) Now calculate the amount of charge passing in 1 minute.

Answer
The time is 60 s
There are 2 possible methods

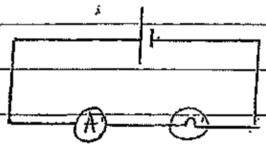
$\Delta Q = I \times \Delta t$
$= 3.5 \times 60$
$= 210$ C to 2 sig fig

or

$Q = N \times e$
$= (2.2 \times 10^{19} \times 60) \times 1.6 \times 10^{-19}$
$= 210$ C to 2sig fig

Now try the questions on the next page.

1a.



Current = 0.25 A

How much charge has flowed through the ammeter after 20s?

Formula:

Substitution:

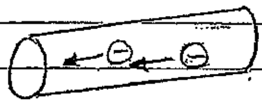
Answer: Units: [4]

(Give the correct number of significant figures)

b. How much charge has flowed through the bulb after 20s? [1]

c. How much charge has flowed through the ammeter after 1.5 minutes? [4]

d. In a wire, the electrons move causing a current (a flow of charge).



If each electron carries a charge of 1.6×10^{-19} C, calculate how many electrons have flowed if a total charge of 23 Coulombs has flowed. [2]

2a) A cell pushes 0.1 C of charge around a circuit in 5 seconds. Calculate the current. [4]

b) How many minutes would it take for a 0.300 A current to transfer 35.0 C of charge?

$t = \frac{Q}{I} = \frac{\quad}{\quad} = \ldots\ldots$ seconds

formula substitution

time in minutes $= \frac{\quad}{\quad} = \ldots$ minutes

Kirchoff's First Law for Current in a Circuit

This Law is based around the idea that electrons cannot 'jump out' of the wires in a circuit. It can be expressed simply as the following:

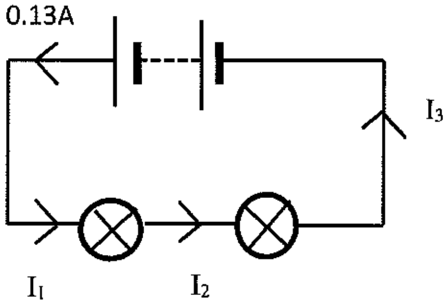
"The current is the same at all points in a series circuit"

and, for parallel circuits ...

"the total current entering a junction equals the total current leaving a junction."

Example 1

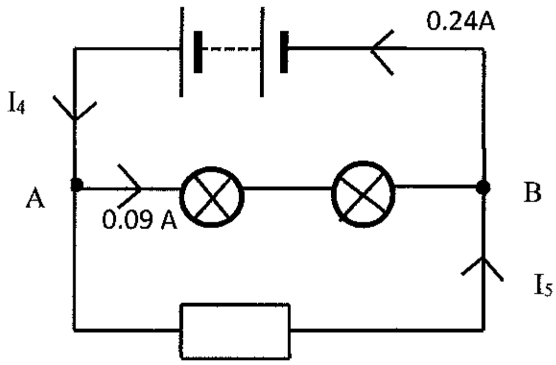
What are the values of the current I_1, I_2 and I_3?



Answer : The circuit is a series circuit so the currents must all be 0.13A.

Example 2

Calculate the currents I_4 and I_5?



Answer

The current returning to the battery (of cells) is 0.24A, so I_4 must also be 0.24A, since I_4 is in series with the 0.24A current marked on the circuit.

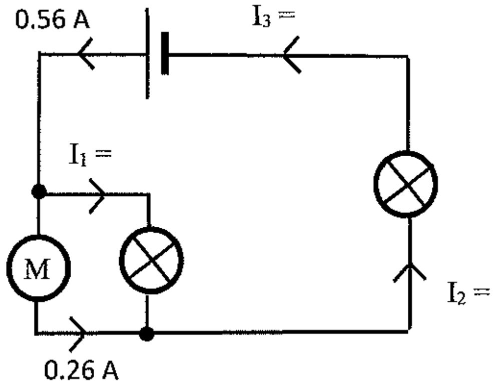
At Junction A, the total current entering the junction is 0.24A, and 0.09A leaves along wire AB through the 2 bulbs, so 0.15A must flow along the bottom branch through the resistor. So I_5 is 0.15A.

(At Junction B the 0.09A and 0.15A re-join to give a total current of 0.24A from B towards the negative side of the battery).

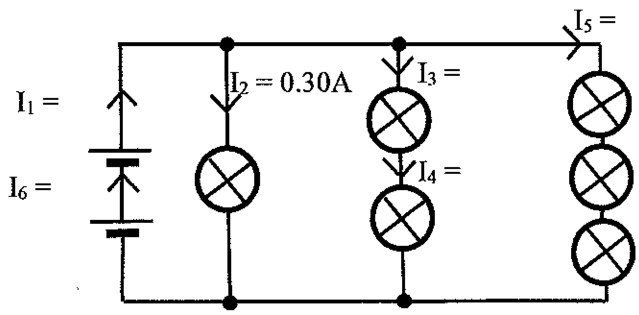
Exercise

Calculate the missing currents:

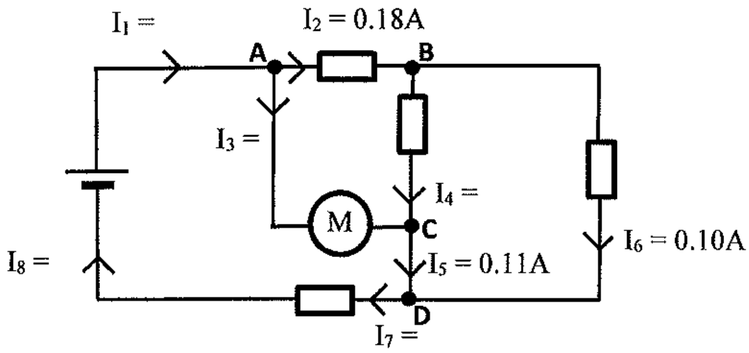
1.



2. In the circuit below the bulbs all have the same resistance. 2 bulbs in series will have twice the resistance of one bulb. Three bulbs in series will have 3 times the resistance of one bulb. Use these facts to predict the missing currents.



3. Predict the missing currents in the circuit below.



Kirchoff's Second Law for 'Voltage' in a Circuit

Firstly let us be clear about voltage – voltage is linked to the energy carried by a current.

The definition of voltage is **the energy carried by each coulomb of charge** or in symbol form **V = E/Q.** So **1 volt is equal to 1 joule of energy carried by each coulomb of charge.**

Kirchoff's Second law basically states that **for <u>any</u> route around a circuit, the 'voltage' given by the cell is all 'used up' by the devices in <u>that</u> route.**

At A level we replace the word 'voltage' with either:

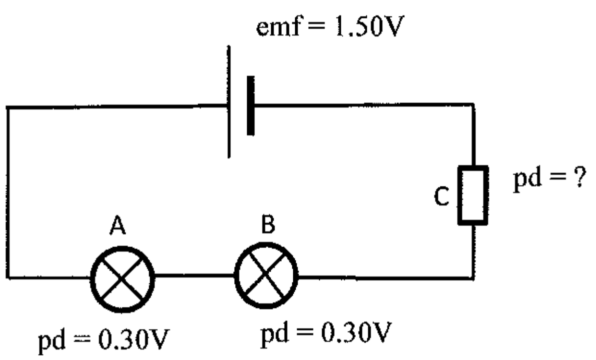
- the electromotive force of the supply (which we call the e.m.f.)
- the potential difference across a device (often shortened to p.d.)

The emf is the **energy per coulomb** given by the supply. The pd is the **energy per coulomb** transformed by a device in the circuit.

So Kirchoff's 2nd Law becomes:

Total supply emf = pd across 1st device in the route + pd across 2nd device in the route + pd across 3rd device in the route + ...

Example 1



Answer:

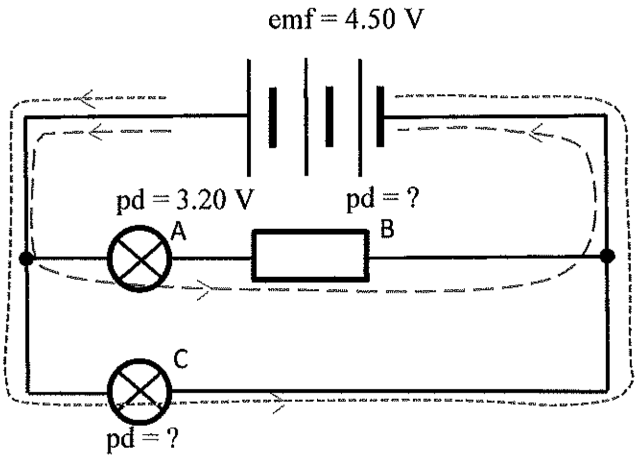
The total emf = 1.50 V

So using Kirchoff's 2nd Law $\quad$ Total emf = $pd_A + pd_B + pd_C$

$1.50\ V = 0.30\ V + 0.30\ V + pd_C$

$pd_C = 0.90\ V$

Example 2



Answer:

Firstly let's think about the route from the battery of cells around the top branch, through bulb A and resistor B and back to the battery (the larger dashed line).

Total battery emf = 4.50 V

So using Kirchoff's 2nd Law Total emf = $pd_A + pd_B$

$4.50\ V = 3.20\ V + pd_B$

$Pd_B = 1.30\ V$

Now let's think about the route from the battery of cells around the bottom branch, through bulb C and back to the battery (the smaller dashed line).

Total battery emf = 4.50 V

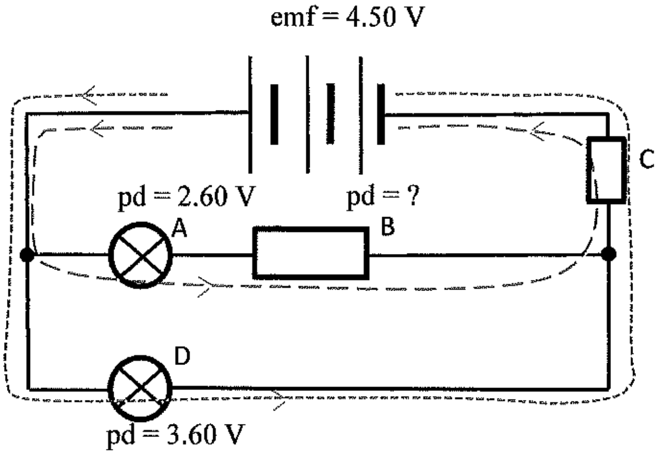
So using Kirchoff's 2nd Law Total emf = pd_C

$4.50\ V = pd_C$

$Pd_C = 4.50\ V$

It is VERY IMPORTANT to realise that each route must be considered separately. If you think about a single electron moving around a circuit, when that electron gets to a junction it will have to take one route or another, so it will 'give away' its 'voltage' to the devices in the route that it takes. Other electrons may take a different route and they will give away their voltage to the devices in their route.

Example 3



Answer:

Firstly let's think about the route from the battery of cells around the top branch, through bulb A, resistor B, resistor C and back to the battery (the larger dashed line).

Total battery emf = 4.50 V

So using Kirchoff's 2nd Law $\quad$ Total emf = $pd_A + pd_B + pd_C$

$4.50\ V = 2.60\ V + pd_B + pd_C$

Oh dear! We have 2 unknowns so we cannot calculate the answer!

So let's think about the route from the battery of cells around the bottom branch, through bulb D and through resistor C and back to the battery (the smaller dashed line).

Total battery emf = 4.50 V

So using Kirchoff's 2nd Law $\quad$ Total emf = $pd_D + pd_C$

$4.50\ V = 3.60\ V + pd_C$

$pd_C = 0.90\ V$

So now let's go back to the top route...

Total battery emf = 4.50 V

So using Kirchoff's 2nd Law $\quad$ Total emf = $pd_A + pd_B + pd_C$

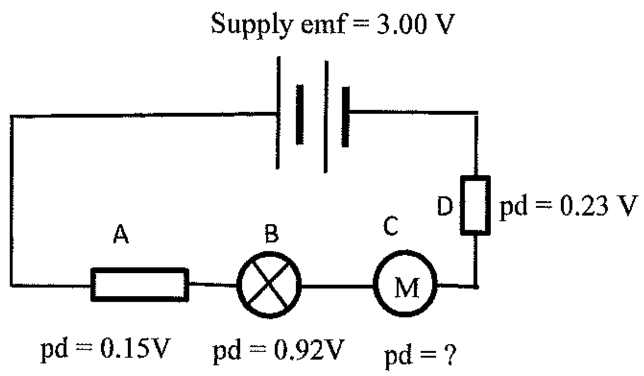
$4.50\ V = 2.60\ V + pd_B + 0.90\ V$

$pd_B = 4.50\ V - 2.60\ V - 0.90\ V = 1.00\ V$

Either way around the circuit the total pd is 4.50 V – just as it should be. Happy days!

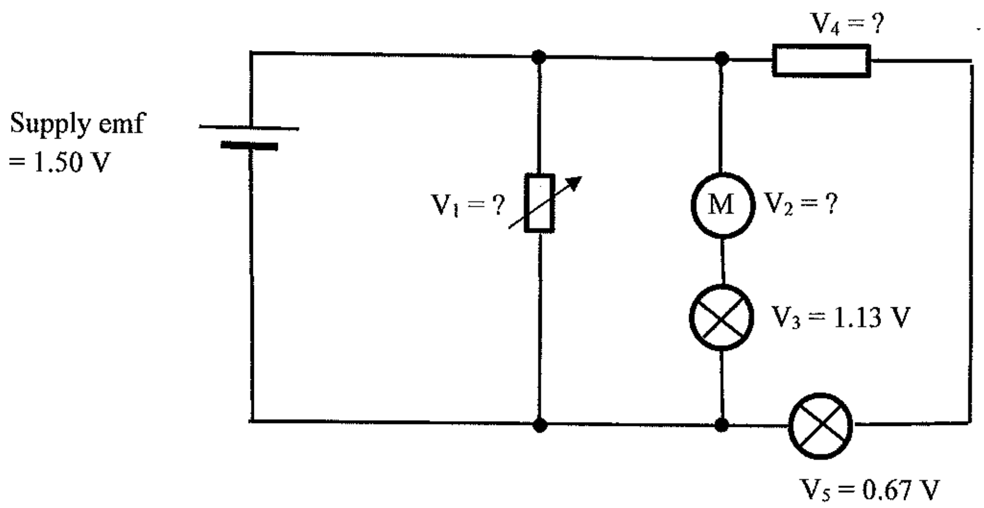
Exercise

1. Calculate the missing potential difference.



Answer:

2. Calculate the missing potential differences V_1, V_2 and V_4.



3. Calculate the missing supply emf and the potential differences V_2 and V_3 .