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AS and A LEVEL

Delivery Guide

PHYSICS A

H156/H556
For first teaching in 2015

Electricity

Version 2

AS and A LEVEL
PHYSICS A

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resources.feedback@ocr.org.uk

Curriculum Content	Page 3
Curriculum Content: Activities	Page 5
Thinking Conceptually	Page 7
Thinking Conceptually: Activities	Page 8
Thinking Contextually	Page 10
Thinking Contextually: Activities	Page 11
Learner Resources	Page 13

4.1 Charge and current

This short section introduces the ideas of charge and current. Understanding electric current is essential when dealing with electrical circuits. This section does not lend itself to practical work but rather to introducing important ideas. The continuity equation ($I = Anev$) is developed using these key ideas. This section concludes with categorising all materials in terms of their ability to conduct.

4.1.1 Charge

Students should be able to demonstrate and apply their knowledge and understanding of:

(a) electric current as rate of flow of charge; $I = \frac{\Delta Q}{\Delta t}$

(b) the coulomb as the unit of charge

(c) the elementary charge *e* equals 1.6×10^{-19} C

(d) net charge on a particle or an object is quantised and a multiple of *e*

(e) current as the movement of electrons in metals and movement of ions in electrolytes

(f) conventional current and electron flow

(g) Kirchhoff's first law; conservation of charge.

4.1.2 Mean drift velocity

(a) mean drift velocity of charge carriers

(b) $I = Anev$, where *n* is the number density of charge carriers

(c) distinction between conductors, semiconductors and insulators in terms of *n*.

4.2 Energy, power and resistance

This section provides knowledge and understanding of electrical symbols, electromotive force, potential difference, resistivity and power. The scientific vocabulary developed here is a prerequisite for understanding electrical circuits in **4.3**.

Electrical billing is done in kWh. This energy unit is easy to understand. There is a desire to use energy-saving devices, such as LED lamps, in homes. Students have the opportunity to understand the link between environmental damage from power stations and the impetus to use energy-saving devices in the home (HSW10) and how customers can make informed decisions when buying domestic appliances (HSW12).

There are many opportunities for students to use spreadsheets in the analysis and presentation of data (HSW3), to carry out practical activities to understand concepts (HSW4) and to analyse data to find relationships between physical quantities (HSW5).

4.2.1 Circuit symbols

(a) circuit symbols

(b) circuit diagrams using these symbols.

4.2.2 E.m.f. and p.d.

(a) potential difference (p.d.); the unit *volt*

(b) electromotive force (e.m.f.) of a source such as a cell or a power supply

(c) distinction between e.m.f. and p.d. in terms of energy transfer

(d) energy transfer; $W = VQ$; $W = EQ$

(e) energy transfer $eV = ½ mv^2$ for electrons and other charged particles.

4.2.3 Resistance

(a) resistance; $R = \frac{V}{I}$; the unit ohm

(b) Ohm's law

(c) (i) *I–V* characteristics of resistor, filament lamp, thermistor, diode and light-emitting diode (LED)

(ii) techniques and procedures used to investigate the electrical characteristics of a range of ohmic and non-ohmic components

(d) light-dependent resistor (LDR); variation of resistance with light intensity.

4.2.4 Resistivity

(a) (i) resistivity of a material; the equation $R = \frac{\rho L}{A}$

(ii) techniques and procedures used to determine the resistivity of a metal.

(b) the variation of resistivity of metals and semiconductors with temperature

(c) negative temperature coefficient (NTC) thermistor; variation of resistance with temperature.

4.2.5 Power

(a) the equations $P = VI$, $P = I^2R$ and $P = \frac{V^2}{R}$

(b) energy transfer; $W = VIt$

(c) the kilowatt-hour (kWh) as a unit of energy; calculating the cost of energy.

4.3 Electrical circuits

This section provides knowledge and understanding of electrical circuits, internal resistance and potential dividers. LDRs and thermistors are used to show how changes in light intensity and temperature respectively can be monitored using potential dividers.

Setting up electrical circuits, including potential divider circuits, provides an ideal way of enhancing experimental skills, understanding electrical concepts and managing risks when using power supplies (HSW4). Students are encouraged to communicate scientific ideas using appropriate terminology (HSW8). This section provides ample opportunities for students to design circuits and carry out appropriate testing for faults and there are opportunities to study the many applications of electrical circuits (HSW1, 2, 3, 5, 6, 9, 12).

4.3.1 Series and parallel circuits

(a) Kirchhoff's second law; the conservation of energy

(b) Kirchhoff's first and second laws applied to electrical circuits

(c) total resistance of two or more resistors in series; $R = R_1 + R_2 + \ldots$

(d) total resistance of two or more resistors in parallel; $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

(e) analysis of circuits with components, including both series and parallel

(f) analysis of circuits with more than one source of e.m.f.

4.3.2 Internal resistance

(a) source of e.m.f.; internal resistance

(b) terminal p.d.; 'lost volts'

(c) (i) the equations $\mathcal{E} = I(R + r)$ and $\mathcal{E} = V + Ir$

(ii) techniques and procedures used to determine the internal resistance of a chemical cell or other source of e.m.f.

4.3.3 Potential dividers

(a) potential divider circuit with components

(b) potential divider circuits with variable components e.g. LDR and thermistor

(c) (i) potential divider equations e.g.

$$V_{out} = \frac{R_2}{R_1 + R_2} \times V_{in} \quad \text{and} \quad \frac{V_1}{V_2} = \frac{R_1}{R_2}$$

(ii) techniques and procedures used to investigate potential divider circuits which may include a sensor such as a thermistor or an LDR.

Learner Activity 1

Current as the Flow of Charge

The students need to appreciate current as a flow of charged particles. The experiment described on the Institute of Physics website is a convenient starting point.

https://spark.iop.org/episode-102-current-flow-charge

The Georgia State University Hyper Physics website provides a suitable summary.

http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elecur.html

The Physics Classroom provides a bit more detail here.

http://www.physicsclassroom.com/Class/circuits/u9l2c.cfm

Physics Net has some nice worked examples to lead students into using the charge, current and time formula with the charge on the electron.

http://physicsnet.co.uk/a-level-physics-as-a2/current-electricity/charge-current-potential-difference/

Learner Activity 2

Kirchhoff's Laws

It is necessary here to develop the students' understanding from GCSE as they will all have encountered this in one form or another. The About Education and S-cool websites provide simple summaries.

http://physics.about.com/od/electromagnetics/f/KirchhoffRule.htm

http://www.s-cool.co.uk/a-level/physics/kirchoffs-laws-and-potential-dividers/revise-it/kirchoffs-first-and-second-laws

Learner Resource 1 provides a summary of Kirchhoff's first law and some sample questions. It is important to expose the students to the many different forms of electric circuits as many have had limited prior exposure. The All About Circuits website has some interesting questions on Kirchhoff's second law.

http://www.allaboutcircuits.com/worksheets/kvl.html

Learner Activity 3

$I = Anev$

Having looked at electron and ion flow, the drift velocity equation has some conceptual bedrock on which to stand.

P.F. Nicholls' School Science and Technology has this useful resource which leads through current to the description of the drift velocity equation with some sample calculations and answers.

http://www.pfnicholls.com/physics/current.html

This resource in the Physics Classroom also gives students the opportunity to think what changes in resistance or potential difference mean in terms of variables in the equation.

http://www.physicsclassroom.com/class/circuits/Lesson-3/Resistance

Learner Resource 2 supplies some notes and a few questions.

The School Science website also gives students a chance to check their understanding.

http://resources.schoolscience.co.uk/cda/16plus/copelech2pg3.html

Learner Activity 4

Ohm's Law

The link between current, potential difference and resistance should be intuitive for students if they have fully assimilated their model of electricity. The University of Colorado PhET site provides some interactive practice here.

http://phet.colorado.edu/en/simulation/ohms-law

This resource on the NASA website also provides some explanation and questions.

http://www.grc.nasa.gov/WWW/K-12/Sample_Projects/Ohms_Law/ohmslaw.html

The Quizlet app is readily available on all devices and computers. This resource provides flashcards and a test to reinforce the material.

http://quizlet.com/4851125/physics-chapter-34-chapter-assessment-flash-cards/

This experiment available on the IOPSpark website could also be used to reinforce this.

https://spark.iop.org/ohms-law

Learner Activity 5

Combining Resistances

The formulae for these can be seen to follow on from the work on Kirchhoff's laws, and deriving them can help reduce issues caused by parallel combinations. The Electronics Tutorials website has a nice introduction to this topic here.

http://www.electronics-tutorials.ws/resistor/res_5.html

This animation on the Walter Fendt site also illustrates series and parallel combinations.

https://www.walter-fendt.de/html5/phen/combinationresistors_en.htm

This presentation on SlideShare also covers the series and parallel combinations as well as recapping the concepts covered earlier.

http://www.slideshare.net/simonandisa/internal-resistance-power-combining-resistors

The Institute of Physics has an experiment described here to help reinforce this concept.

https://spark.iop.org/episode-114-components-series-and-parallel

Learner Activity 6

Potential Dividers

This brings together the work on Ohm's law and Kirchhoff's laws and leads into circuit theory. The resource on Physics Net provides a reasonable summary.

http://physicsnet.co.uk/a-level-physics-as-a2/current-electricity/potential-divider/

The Furry Elephant site has a nice animation.

http://www.furryelephant.com/content/electricity/series-circuits/potential-dividers/

The S-cool site has another summary of the theory with some sample calculations.

http://www.s-cool.co.uk/a-level/physics/kirchoffs-laws-and-potential-dividers/revise-it/potential-dividers

The Institute of Physics resource here has a practical approach to embedding this understanding.

https://spark.iop.org/episode-118-potential-dividers

There is a potential calculator available here on Georgia State University's Hyper Physics site.

http://hyperphysics.phy-astr.gsu.edu/hbase/electric/voldiv.html

Approaches to teaching the content

This theme builds on the students' knowledge and understanding of electricity developed from previous learning. Students should be given opportunities to integrate a model of electricity into their understanding in order to aid their explanation of what is happening in various processes. Experimental work is important here and the ultimate goal would be the understanding of how the potential divider is used in sensor circuits. The analysis of data and use of non-linear graphs give opportunities to reinforce and develop graph plotting skills. The discussion of how the resistance of materials depends on many different factors and the difficulty this creates in selecting materials to be used in varying environments allows links to be made to the materials theme.

Common misconceptions or difficulties students may have

Although earlier work will have covered the use of prefixes and standard notation, many students continue to find conversions difficult – for example, from mm^2 to m^2 and mm^3 to m^3. As in the materials theme it is useful practice to use a micrometer to measure diameter in mm and thus calculate cross-sectional area in m^2; thus the resistivity values calculated can be compared with book values. The use of multimeters allows for a discussion on the properties of the different meters and a deeper understanding of the concepts of current and potential difference.

Whilst the terminology is mostly familiar to the students, many will come with an incomplete conceptual model of the current, resistance and potential difference. In particular, potential difference is often a sticking point and continued emphasis on the definition of work done per unit charge can eventually yield results. Series and parallel circuits will be familiar to students but they may need practice in implementing Kirchhoff's laws to relatively simple circuits. Most students will use the equation $V = IR$ with relative confidence but its application to e.m.f., internal resistance and potential dividers often catches them out. Often students find it easier to work from the current flowing in the circuit to then calculate the p.d. between points or across components. The memorisation of the potential divider formula can often be detrimental to their deeper understanding of what is happening in the circuit and can leave the students struggling if there are more than two components in the circuit.

Conceptual links to other areas of the specification

The main thing to consider here is that this theme sets the foundations for much of the work which will be done on electric fields. Thus the overarching importance of building a strong conceptual understanding. The practical work allows for the reinforcement and further development of students' understanding of the limitations of results and data. The variety of data means that there are opportunities for using negative gradients and the *y*-intercept for internal resistance and e.m.f. Also students could be introduced to logarithmic charts to represent the range of resistivities of materials. This use of logarithms could be further enhanced by using the data from a sensor on a logarithmic scale. The work on electricity in specific electron flow is also significant in the understanding of quantum processes.

Learner Activity 1
Model of electricity

The topic usually starts by describing electricity in terms of a model or an analogy. This may involve a water model as illustrated on the Georgia State University's Hyper Physics website.

http://hyperphysics.phy-astr.gsu.edu/hbase/electric/watcir.html

There is similar material available on the Furry Elephants website here.

http://www.furryelephant.com/content/electricity/teaching-learning/electric-circuit-analogies/

More details of possible models are available here from the Nuffield Foundation.

https://spark.iop.org/models-electric-circuits

It is particularly important for the students to have some model or analogy that they can use for potential difference as this is the concept that causes the most significant difficulties. It is worth getting students to describe what is happening in simple circuits in terms of their model.

Learner Activity 2

Flow of ions

The appreciation that electricity is not just the flow of electrons is an important one, both in terms of conceptual understanding and in terms of linking together students' understanding of the physical world with processes that are covered in Chemistry and Biology. The IOPSpark and Institute of Physics have two interesting experiments that could be demonstrated.

https://spark.iop.org/ions-flame

https://spark.iop.org/episode-104-drift-velocity

The following animation shows how the flow of ions occurs in electrolysis.

https://www.youtube.com/watch?v=WM2QyKXd4NA

Learner Activity 3

IV characteristics

The measurement of dependence of current on applied potential difference for a variety of components provides a useful practical link to the earlier conceptual work. The IOPSpark website describes how this would be carried out for a lamp here.

https://spark.iop.org/iv-characteristic-filament-lamp

The Physics Net website provides some details on the diode, lamp and resistor.

http://physicsnet.co.uk/a-level-physics-as-a2/current-electricity/current-voltage-characteristics/

Learner Activity 4

Factors affecting the resistance of a wire

This is an area where the model of electricity developed by the students earlier can be used to build the familiar formula involving resistivity, resistance, cross-sectional area and length. The Cyber Physics website talks through the factors here.

http://www.cyberphysics.co.uk/topics/electricity/higher_electricity/resistance.htm

The IOPSpark website provides a suitable practical method here, although there are many others available.

https://spark.iop.org/investigating-resistance-wires

Using conducting putty or conductive paper are alternatives to the usual wire experiment and these are detailed in this Institute of Physics resource.

https://spark.iop.org/episode-112-resistivity

Learner Activity 5

Measuring the internal resistance of a cell

The e.m.f. and internal resistance of a cell are easily determined through a simple experiment. Whilst measuring p.d. and current is familiar to students, the nature of the data gathered in this exercise is unusual and helps reinforce concepts covered in the course. As well as comparing the equation for a straight line with the equation for determining the e.m.f. of a cell, the use of both a negative gradient and y-intercept helps further reinforce graph plotting skills. Learner Resource 3 describes one possible method for this experiment.

Learner Activity 6

Electric power

The link between mechanical power and electrical power can be usefully explored using experiments like the two listed below on the IOPSpark website; both of these use electric motors.

https://spark.iop.org/using-electric-motor-raise-load

https://spark.iop.org/measuring-power-motor

Alternatively the power output of a light bulb could be investigated using the experiment here.

https://spark.iop.org/measuring-power-lamp

There are a number of different takes on the bulb efficiency experiment but generally they measure the heat given out by the bulb. So it can be viewed as an extension exercise using the heat capacity formula.

Learner Activity 7

Potential dividers

The application of Ohm's law and Kirchhoff's first law to calculating the potential difference between two points really helps develop the students' ability to apply circuit theory. A useful summary is provided on the School Physics website here.

http://www.schoolphysics.co.uk/age16-19/Electricity%20and%20magnetism/Current%20electricity/text/Potential_divider/index.html

The potentiometer is another potential divider and this page from the All About Circuits website describes a possible experiment.

http://www.allaboutcircuits.com/vol_6/chpt_3/6.html

For extension work for the most able the Wheatstone Bridge provides a good challenge. This page from the Electronics Tutorials website explains how it works.

http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html

Alternatively, this YouTube clip does the same thing.

http://www.youtube.com/watch?v=qebl2kNsDZo

Learner Activity 8

Thermistors

The variation of resistance with the temperature of a thermistor is a useful concept to explore in terms of cementing students' understanding of the drift velocity equation. A simple summary of the properties can be found on the School Physics site here.

http://www.schoolphysics.co.uk/age16-19/Electronics/Semiconductors/text/Thermistor_/index.html

It is also possible to observe the change in this experiment from the IOPSpark website.

https://spark.iop.org/effect-temperature-thermistor

The Maths Physics site has a flash application that allows the experiment to be carried out virtually.

http://mathsphysics.com/RvsTempThermistor.html

It is also possible to combine this experiment with work on potential dividers.

Activities

Students will gain a deeper understanding of the physics of electricity by learning to apply their knowledge to a wide variety of contexts. Some examples follow which may be used to teach the content of the course within an interesting context. Some of the examples are also suitable for extension activities.

Learner Activity 1

Electric corn starch

The non-Newtonian fluid properties of corn starch are well known. This is an interesting extension to this and shows the effect a charge balloon can have on the fluid. A version of the experiment is detailed on Steve Spangler's website.

http://www.stevespanglerscience.com/lab/experiments/electric-cornstarch

The polarity of water molecules can easily be demonstrated with a stream of water and the applications to Chemistry and Biology can be discussed. Georgia State University has some information on its Hyper Physics website.

http://hyperphysics.phy-astr.gsu.edu/hbase/electric/diph2o.html

The orientation of liquid crystals is also controlled using electric charges. The worksheet from Nanoyou on Slideshare could be an interesting extension activity.

http://www.slideshare.net/NANOYOUproject/experiment-with-liquid-crystals-student-laboratory-worksheet-age-1418

Learner Activity 2

Resistance and resistivity

Resistance is used to measure our percentage of body fat in some sets of weighing scales. This resource from the All About Circuits website talks about body fat measurements before discussing the risks of electric shocks.

http://www.allaboutcircuits.com/vol_1/chpt_3/4.html

Resistance can also be used by archaeologists to look for features hidden underground. They carry out the survey before working out where to place trenches. The features show up because the remains have a different resistance from the soil. The following experiment from the IOPSpark website models a resistive survey.

https://spark.iop.org/modelling-resistive-survey

Learner Activity 3

Effect of temperature on resistance

In real life, wires warm up as the electricity passes through them. This experiment from the Nuffield Foundation allows students to measure the temperature coefficient of a wire.

https://spark.iop.org/temperature-change-and-resistance

Georgia State University has an explanation of the theory on its Hyper Physics website.

http://hyperphysics.phy-astr.gsu.edu/hbase/electric/restmp.html

There is a similar explanation on the All About Circuits website, along with the opportunity of applying some of the knowledge.

http://www.allaboutcircuits.com/vol_1/chpt_12/6.html

http://www.allaboutcircuits.com/worksheets/temp_r.html

If you have access to liquid nitrogen it is also possible to buy a cheap superconductor and demonstrate superconductivity, or you can try and make one by following these instructions.

http://www.futurescience.com/scpart1.html

Learner Activity 4

Internal resistance

Students may well be familiar with the idea that fruit can be used to make wet cells in conjunction with the correct metal electrodes. These experiments detailed by the Nuffield Foundation measure the internal resistance of homemade cells.

https://spark.iop.org/internal-resistance-potato-cell

https://spark.iop.org/internal-resistance-shoe-box-cell

This resource from the Institute of Physics looks at measuring the internal resistance of a number of common power supplies.

https://spark.iop.org/episode-121-emf-and-internal-resistance

Learner Activity 5

Measuring intensity using a LDR

When using a light dependent resistor as a light sensor it is necessary to calibrate the circuit. The experiment detailed in Learner Resource 4 allows students to use the flux equation to plot a suitable graph to calibrate their LDRs. The University of Reading has created this virtual version of a similar experiment.

http://www.reading.ac.uk/virtualexperiments/ves/ldr-full.html

Peter Vis has created a site here with an interactive potential divider incorporating a LDR.

http://www.petervis.com/GCSE_Design_and_Technology_Electronic_Products/Potential_Divider/Potential_Divider_with_LDR.html

Learner Activity 6

Measuring the thickness of paper

It is useful for students to see practical applications of the work they have studied on e.m.f. and understand how a calibration graph can be used to determine the optical transmission properties of an unknown piece of paper. There are different methods of carrying out experiments like this; the one described in Learner Resource 5 uses a solar cell although a LDR could be used instead.

The Science Buddies site details an extension project to look at how the output of a solar cell varies with light intensity.

http://www.sciencebuddies.org/science-fair-projects/project_ideas/Energy_p014.shtml#summary

Learner Activity 8

Sensor circuits

Many modern applications of electricity revolve around how the technology responds to external stimuli. From touch-sensitive screens to the accelerometer that is in so many modern phones, how sensors are used to create feedback circuits is an interesting application of potential divider circuits.

This resource from the Institute of Physics lists a series of potential divider experiments. The final one looks at putting a sensor in part of the potential divider. This could be extended by looking at how the output could be fed into simple digital circuits.

https://spark.iop.org/episode-118-potential-dividers

This water sensor from the University of California, San Diego would make an interesting extension project.

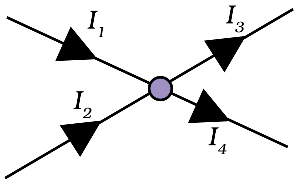
http://sailorgroup.ucsd.edu/research/sensorexperiments.pdf

The All About Circuits site gives details on how to make a static electricity sensor.

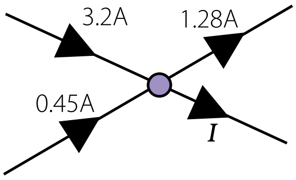
http://www.allaboutcircuits.com/vol_6/chpt_5/9.html

Kirchhoff's First Law

A simple way of viewing this is to think that whatever current enters a point must leave it (*what goes in must come out*). This is summarised in the following diagram:



$I_1 + I_2 = I_3 + I_4$



$3.2 + 0.45 = 1.28 + I$

$3.65 - 1.28 = I$

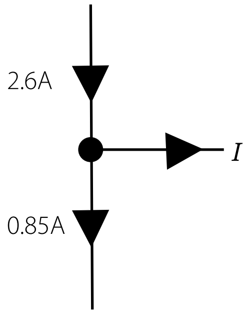
$I = 2.37\text{A}$

A more correct way of looking at this is too view the currents entering the junction as positive and the currents leaving it as negative. It basically rearranges:

$$I_1 + I_2 = I_3 + I_4 \text{ to become } I_1 + I_2 - I_3 - I_4 = 0$$

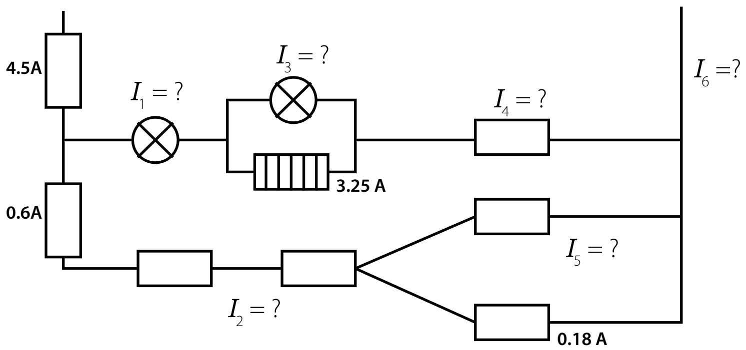
We say the sum of the currents entering a junction is zero.

$$\sum_{0}^{n} I_n = 0$$



What is the current leaving the junction?

1) Calculate the current at each point in this circuit.



I_1 = A

I_2 = A

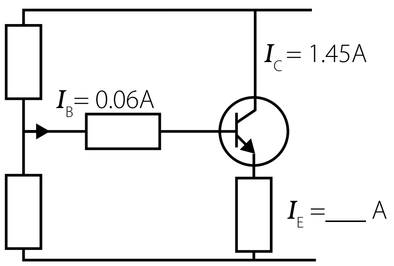
I_3 = A

I_4 = A

I_5 = A

I_6 = A

2) Calculate the emitter current for this transistor.



Flow of charge carriers

Electric **current** can be thought of as being a flow of **charged particles**. Normally these particles are **electrons**, however in electrolysis and in semiconductors **positively** charged particles flow. The **current** is equal to the *rate of flow of charge*, in other words how much **charge per unit time.**

$$\text{current} = \frac{\text{charge}}{\text{time}} = \frac{\text{number of charge carriers} \times \text{charge on each carrier}}{\text{time}}$$

n = number of charge carriers per unit volume

$$n = \frac{\text{number of charge carriers}}{\text{cross-sectional area} \times \text{length}} \quad \therefore \text{ number of charge carriers} = n \times A \times L$$

$$I = \frac{n \times A \times L \times q}{t} \quad \text{or for electrons } I = Anev$$

$$\boldsymbol{I = Anev}$$

Where v = drift velocity of the charge carriers

e.g. In a copper wire where the current is 0.4 A and the cross-sectional area is 2.2×10^{-7} m^2 and the number of electrons per unit volume is 6.5×10^{26} m^{-3}, what is the drift velocity of the electrons? ($e = 1.6 \times 10^{-19}$ C)

Anev worksheet

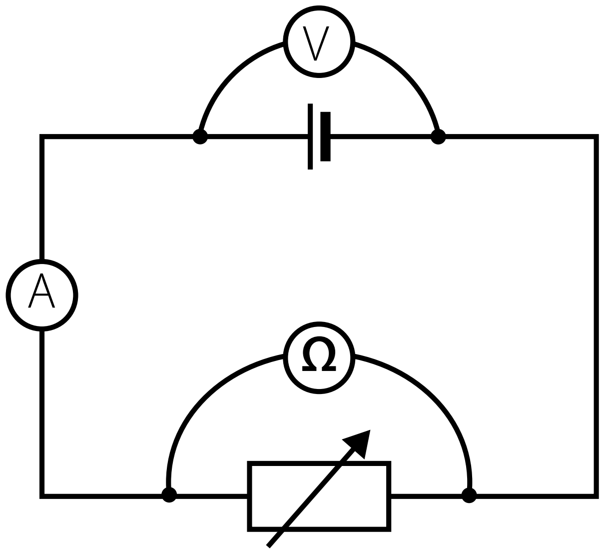
1) What is the current when the drift velocity in a copper wire is 0.1 m s^{-1}, the cross-sectional area of the wire is 4.5×10^{-6} m^2 and the number of conduction electrons per m^3 for copper is $n_{Cu} = 1.0 \times 10^{29}$ m^{-3}?

2) What is the number of electrons per unit volume in a metal when the drift velocity is 2×10^{-3} m s^{-1}, the cross-sectional area is 3.6×10^{-7} m^2 and the current is 12 mA?

3) A wire has a diameter of 0.32 mm and a current flowing through it of 0.04 A. What is the drift velocity of the electrons if the number of electrons per unit volume is 4×10^{28} m^{-3}?

Internal resistance and e.m.f.

Aim: To measure the internal resistance and electromotive force (e.m.f.) of a cell.



Instructions:

- Choose appropriate scales for the ammeter, voltmeter and ohmmeter.
- Start with the rheostat at its highest value; you will need to disconnect the cell to be able to check the value of the resistance.
- Each time you want to change the resistance, unplug the cell and the ohmmeter should now read the correct resistance so you can vary the slide accordingly.
- Vary the resistance from 3Ω to 0.6Ω in 0.2Ω intervals.
- Record values of potential difference (*V*) and current (*I*) for each of resistances.
- Take a repeat set of readings and find the average.

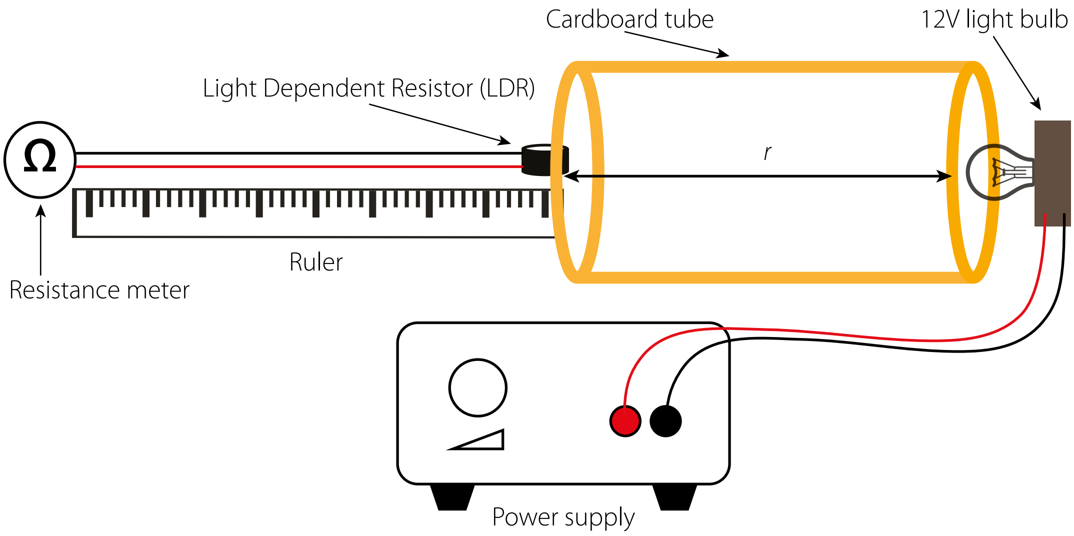
Analysis:

e.m.f. = $V + IR$

- Plot a graph of p.d. (y-axis) against current (x-axis).
- What is the relationship between the p.d. and the current?
- Determine a value for the y-intercept and gradient of the graph.
- How can you rearrange the e.m.f. equation so that the internal resistance and e.m.f. of the cell can be found from the gradient and y-intercept of the graph?

Light Dependent Resistor experiment

Aim: To investigate how the resistance of an LDR depends on the intensity of the incident light.



Instructions:

- Choose a suitable p.d. for the light bulb.
- Arrange the ruler so the LDR is 5cm from the bulb at the nearest point of approach. So r = 5cm. Record the value from the resistance meter.
- Take values of resistance every 5cm as you move the LDR away from the bulb.
- Repeat the experiment to improve accuracy.
- Try repeating the experiment using a different p.d. for the bulb.
- By using the flux equation below and $V = IR$ plot a suitable graph to show the relationship between the distance from the light bulb and the resistance of the LDR.

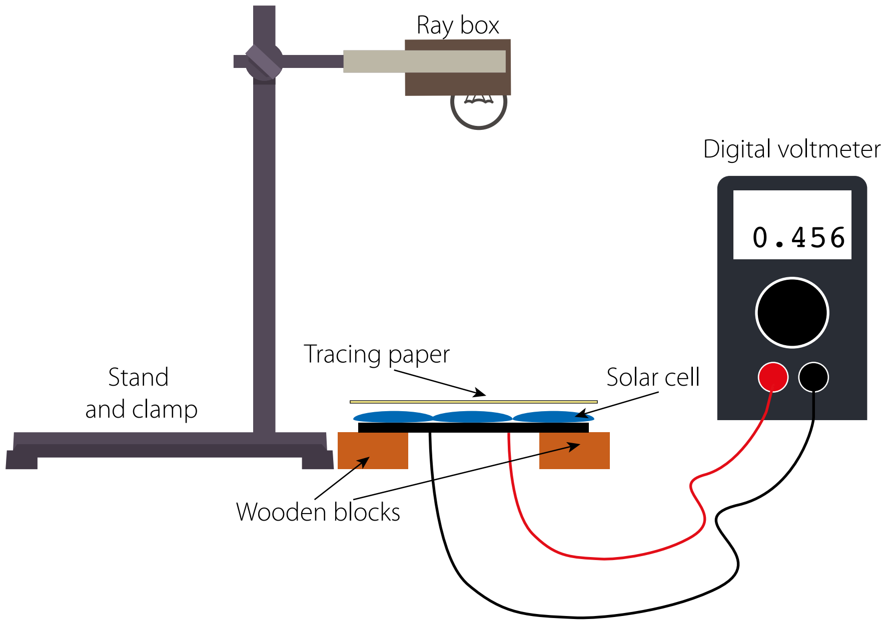
$$F = P/4\pi r^2$$

(F, incident light flux, P, power output of bulb, r distance of the LDR from the bulb)

Solar cell experiement

Aim: To demonstrate the ways in which a solar cell (or LDR) can be used as a sensor.

An experiment to see whether the potential difference (voltage) produced by a solar cell depends on the area of solar cell exposed.



Instructions:

- Add one sheet of paper at a time and record the reading on the digital voltmeter.
- Take repeat readings as appropriate.
- How does the e.m.f. produced by the cell vary with the number of sheets of tracing paper?
- Now take a reading for the unknown piece of paper.
- Using a suitable graph, find out how many sheets of tracing paper are equivalent to one sheet of the unknown paper.

Did you know?

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