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Oxford Cambridge and RSA

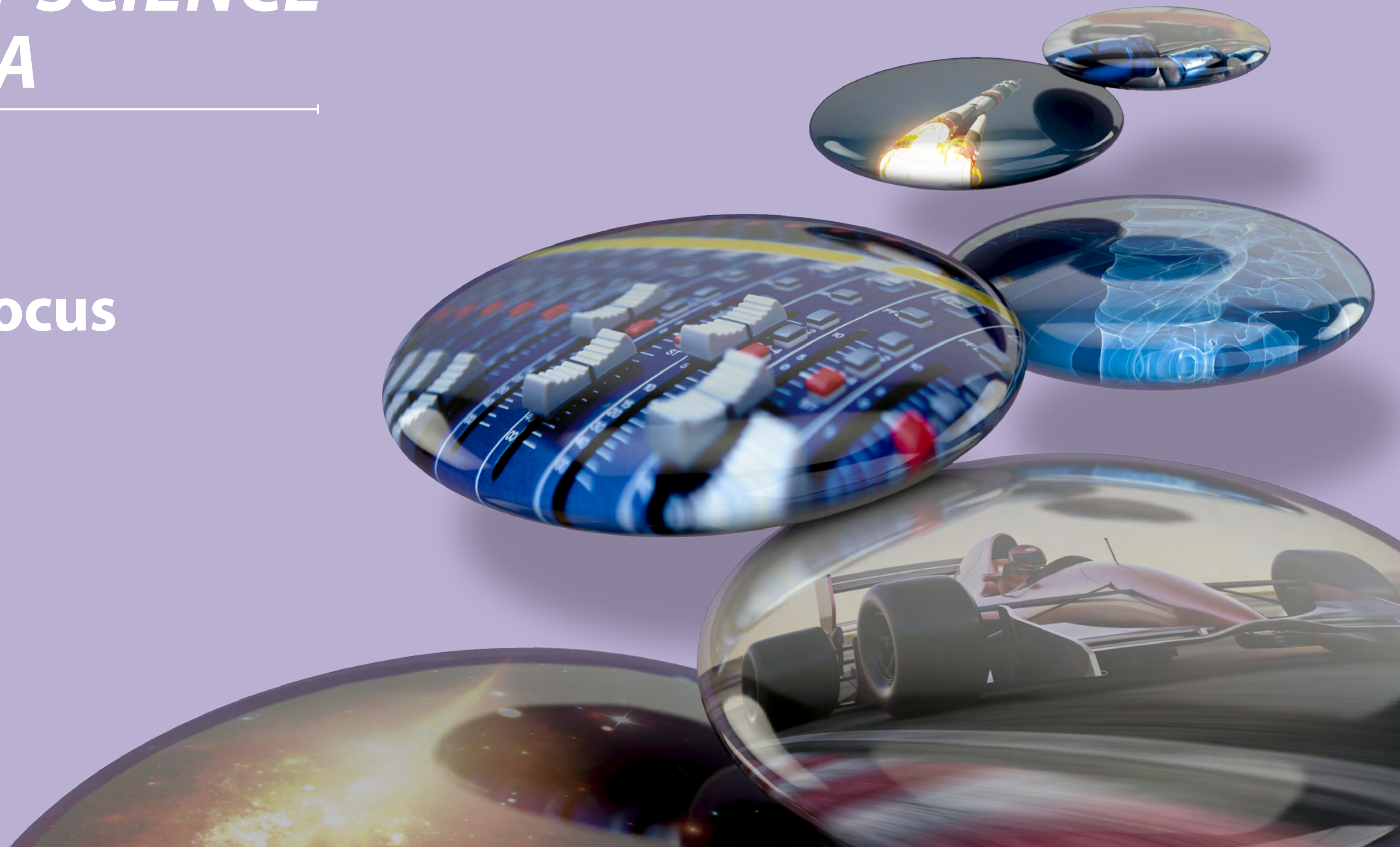
GCSE (9–1)
Transition Guide

GATEWAY SCIENCE PHYSICS A

J249
For first teaching in 2016

KS3–KS4 Focus
Electricity

Version 1



www.ocr.org.uk/physics

Introduction

GCSE (9–1)

GATEWAY SCIENCE PHYSICS A

Key Stage 3 to 4 Transition guides focus on how a particular topic is covered at the different key stages and provide information on:

- Differences in the demand and approach at the different levels;
- Useful ways to think about the content at Key Stage 3 which will help prepare students for progression to Key Stage 4;
- Common student misconceptions in this topic.

Transition guides also contain links to a range of teaching activities that can be used to deliver the content at Key Stage 3 and 4 and are designed to be of use to teachers of both key stages. Central to the transition guide is a Checkpoint task which is specifically designed to help teachers determine whether students have developed deep conceptual understanding of the topic at Key Stage 3 and assess their 'readiness for progression' to Key Stage 4 content on this topic. This checkpoint task can be used as a summative assessment at the end of Key Stage 3 teaching of the topic or by Key Stage 4 teachers to establish their students' conceptual starting point.

Key Stage 3 to 4 Transition Guides are written by experts with experience of teaching at both key stages.

Key Stage 3 Content

- separation of positive or negative charges when objects are rubbed together: transfer of electrons, forces between charged objects
- the idea of electric field, forces acting across the space between objects not in contact
- electric current, measured in amperes, in circuits, series and parallel circuits, currents add where branches meet and current as flow of charge
- potential difference, measured in volts, battery and bulb ratings; resistance, measured in ohms, as a ratio of potential difference (p.d.) to current
- difference in resistance between conducting and insulating components (quantitative)
- comparing power ratings of appliances in watts (W, kW)
- comparing amount of energy transferred (J, kJ, KW hour)
- other processes that involve energy transfers: completing an electrical circuit

GCSE Content

- P3.1a: describe that charge is a property of all matter and that there are positive and negative charges. The effects of the charges are not normally seen on bodies containing equal amounts of positive and negative charge, as their effects cancel each other out
- P3.1b: describe the production of static electricity, and sparking, by rubbing surfaces, and evidence that charged objects exert forces of attraction or repulsion on one another when not in contact
- P3.1c: explain how transfer of electrons between objects can explain the phenomena of static electricity
- P3.1d: explain the concept of an electric field and how it helps to explain the phenomena of static electricity
- P3.1e: recall that current is a rate of flow of charge (electrons) and the conditions needed for charge to flow
- P3.1f: recall that current has the same value at any point in a single closed loop
- P3.1g: recall and use the relationship between quantity of charge, current and time
- P3.2a: describe the differences between series and parallel circuits
- P3.2b: represent d.c. circuits with the conventions of positive and negative terminals, and the symbols that represent common circuit elements
- P3.2c: recall that current (I) depends on both resistance (R) and potential difference (V) and the units in which these are measured
- P3.2d: recall and apply the relationship between I, R and V, and that for some resistors the value of R remains constant but that in others it can change as the current changes
- P3.2e: explain that for some resistors the value R remains constant but that in others it can change as the current changes
- P3.2f: explain the design and use of circuits to explore such effects
- P3.2g: use graphs to explore whether circuit elements are linear or non-linear (M4c, M4d, M4e)
- P3.2h: use graphs and relate the curves produced to the function and properties of circuit elements (M4c, M4d, M4e)
- P3.2i: explain why, if two resistors are in series the net resistance is increased, whereas with two in parallel the net resistance is decreased (qualitative explanation only)
- P3.2j: explain why, if two resistors are in series the net resistance is increased, whereas with two in parallel the net resistance is decreased (qualitative explanation only)
- P3.2k: explain the design and use of such circuits for measurement and testing purposes
- P3.2l: explain how the power transfer in any circuit device is related to the potential difference across it and the current, and to the energy changes over a given time
- P3.2m: apply the equations relating potential difference, current, quantity of charge, resistance, power, energy, and time, and solve problems for circuits which include resistors in series, using the concept of equivalent resistance (M1c, M3b, M3c, M3d)

Comment

The transition from KS3 to KS4 in this area of the subject should be fairly smooth in most senses; the new topics and ideas are mostly clearly connected to those already introduced, and the difference is really of complexity and quantity of information rather than type. Learners should already have some grasp of the idea of charge, and energy, and ideally potential energy, although this concept can still confuse some. The main problems learners are likely to have are with the profusion of new terms and identities, many of which have confusingly similar names.

It is, at the earlier stages of teaching this topic, a good idea to remind learners that they can always go back to the basic fundamental concepts of charge, energy, time and so on, and use the basic identities of the terms to derive the equations they need. This can help avoid errors involving accidentally transposing terms in an equation and, for instance, trying to divide resistance by current to get voltage.

There are many well-known analogies that can be helpful when learners are trying to gain an intuitive understanding of the processes. They can visualise charge (or flowing electrons) as balls rolling down slopes, or water running through pipes, or traffic moving down roads. Of course all these analogies are flawed, but the basic idea of things experiencing a motive force that makes them "want" to move in a certain direction and experiencing a degree of resistance when doing so, which affects their average speed, is certainly useful.

One thing that is particularly helpful is to think of electricity as experiencing a sort of negative space in which air (or a vacuum) is a "solid" barrier to movement and electrical conductors are spaces that charge can move through. This kind of visualisation has a variety of explanatory uses: it helps explain static electricity; when there is a certain amount of attraction, the charge might squeeze up against the solid barrier of an insulator (such as air), but it cannot push through until the energy is sufficient to break the structure of the barrier (in this case, ionising the atoms in the air) and allow the charge to be conducted to where it "wants" to go. It also helps explain why resistors added in parallel do not increase the resistance in the circuit as a whole; any path that charge can take, however "narrow" or "wiggly" (or whatever analogy you want to use for resistance as something that slows the flow of charge), increases the amount of charge that can flow through the circuit, and thus cannot lower the current.

Some learners have difficulty when distinguishing between the direction of conventional current and flow of charge. They move in opposite directions and the former is a historic flaw in the model. The original naming of the particles of charge has meant the need to distinguish between the two terms. The majority of equations and theories, however, work regardless of direction.

Activities

Balloons and Static Electricity - Electricity, Static Electricity, Electric Charges

PhET – University of Colorado, Boulder

https://phet.colorado.edu/en/simulation/balloons-and-static-electricity

A simple interactive simulation in which users rub a balloon (or two balloons) against a jumper and stick it to a wall, or indeed to the jumper. Movement of dynamic negative charges and static positive charges is shown.

Ohm's Law - Ohm's Law, Circuits, Resistance

PhET – University of Colorado, Boulder

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

A simple interactive featuring Ohm's law, in which voltage and resistance can be altered to see the result on current.

How To Not Get Shocked Exiting a Car

Physics Girl

https://www.youtube.com/watch?v=4S0EBxT60pw

A short video about static electricity and how to avoid getting shocked; this features demonstrations of a Van de Graaff generator and various other standard examples of the effects of static electricity.

Conventional Versus Electron Flow : Basic Concepts Of Electricity

All About Circuits

http://www.allaboutcircuits.com/textbook/direct-current/chpt-1/conventional-versus-electron-flow/

A web page about the history of the convention of representing charge as flowing from positive to negative, and a suggestion that, instead of changing the direction we do equations in, we just redefine electrons as positive and protons as negative.

Overview

Since one of the problems a lot of learners have at this stage is remembering the relationships between quantities and the equations and rules for calculating quantities. The experience of working something out for oneself can often be a better way of remembering and understanding an equation and relationships between variables than simply learning and repeating it.

Learner task 1.1 features some basic calculation, plus a slightly guided derivation of the equation for power, voltage and current. Task 1.2 involves deciding whether to use series or parallel circuits in a selection of ordinary applications. The extension task contains an attempt to encourage learners to derive a rule for calculating the overall resistance of resistors in parallel.

Teacher Guidance:
The standard introductions to the topic should give most learners the information they need for the first two tasks. The third might require a little more help. The first question in the extension task is almost a trick, designed to confuse learners by referring to terms in ways that obscure the real processes. Some learners who are not as able as others in terms of calculations and memory retention may find this question easier than those who are better at manipulating the equations, because it does not require any calculation. The second question is more detailed. The maths is not especially hard, but the idea of deriving a relationship for themselves without being prompted may intimidate some learners, while potentially enthusing others. This is an opportunity for learners to feel that they have independently made a genuine scientific discovery of a sort.

No special materials are required, although obviously the availability of electrical circuits and components to experiment with would be useful.

Checkpoint task:
www.ocr.org.uk/Images/324530-electricity-checkpoint-task.doc

Activities

Battery-Resistor Circuit

PhET – University of Colorado, Boulder

https://phet.colorado.edu/en/simulation/battery-resistor-circuit

An interactive app in which users adjust the voltage and resistance in a circuit, watching the flow of virtual electrons (with ammeter) and the temperature change in the resistor in response to the adjustments.

Coulombs (C) To Electron Charge (e) Conversion

Rapid tables

http://www.rapidtables.com/convert/charge/coulomb-to-electron.htm

A simple convertor from Coulombs to electron charges. There are clickable links to other convertors, including the obvious one from electron charges to Coulombs.

How Voltage, Current, and Resistance Relate : Ohm's Law

Electronic Textbook

http://www.allaboutcircuits.com/textbook/direct-current/chpt-2/voltage-current-resistance-relate/

A fairly in-depth digest of the basics of resistance and ite relationship with basic quantities such as charge, energy and so on, featuring a few worked examples of calculations and some useful rules of thumb for reckoning SI units in terms of imperial measures.

Electric Potential: Visualizing Voltage with 3D animations

Physics Videos by Eugene Khutoryansky

https://www.youtube.com/watch?v=-Rb9guSEeVE&list=PLkyBCj4JhHt8DFH9QysGWm4h_DOxT93fb

The first of a set of videos which visualise electric circuits in terms of rolling balls, with gravity providing the potential energy instead of voltage. As with all analogies, there are some flaws; learners can be encouraged to discuss these.

Activities

Circuit Construction Kit (DC Only)

PhET – University of Colorado, Boulder

https://phet.colorado.edu/en/simulation/legacy/circuit-construction-kit-dc

A fairly comprehensive circuit simulator in which users can add or remove lengths of "wire" and various components to make series, parallel and combined circuits and measure and observe the effects of their adjustments.

Resistance and Resistivity

Hyperphysics

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

A more in-depth account of resistivity, resistance and associated quantities and concepts; this is useful is explaining that Ohm's law is reall not a law at all but just a convenient relationship between voltage and current that applies to some substances under some conditions.

Voltage Current Resistance and Electric Power General Basic Electrical Formulae

Sengpiel audio

http://www.sengpielaudio.com/calculator-ohm.htm

A succinct web page featuring a rather elegant "formula wheel" in which power, voltage, current and resistance are all expressed in terms of each other in all the possible permutations. More engaged learners may enjoy trying to work these out for themselves.

Charge

Sixty Symbols

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

A short video in which a theoretical physicist from Nottingham University explains the basics of charge, with a few amusing digressions, an element of history and a pleasingly adult and civilised feel; it is nice to see professors working in the subject at an advanced level still enjoying explaining and playing with the simpler and more fundamental elements of the subject.

Resources, links and support

Science Spotlight – Our termly update Science Spotlight provides useful information and helps to support our Science teaching community. Science Spotlight is designed to keep you up-to-date with Science here at OCR, as well as to share information, news and resources. Each issue is packed full with a series of exciting articles across the whole range of our Science qualifications: www.ocr.org.uk/qualifications/by-subject/science/science-spotlight/

Find resources and qualification information through our science page: http://www.ocr.org.uk/qualifications/by-subject/science/

Contact the team: science@ocr.org.uk

Continue the discussion on the science community forum: http://social.ocr.org.uk/

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To find out more about GCSE and A Level reform please visit: http://www.ocr.org.uk/qualifications/gcse-and-a-level-reform

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