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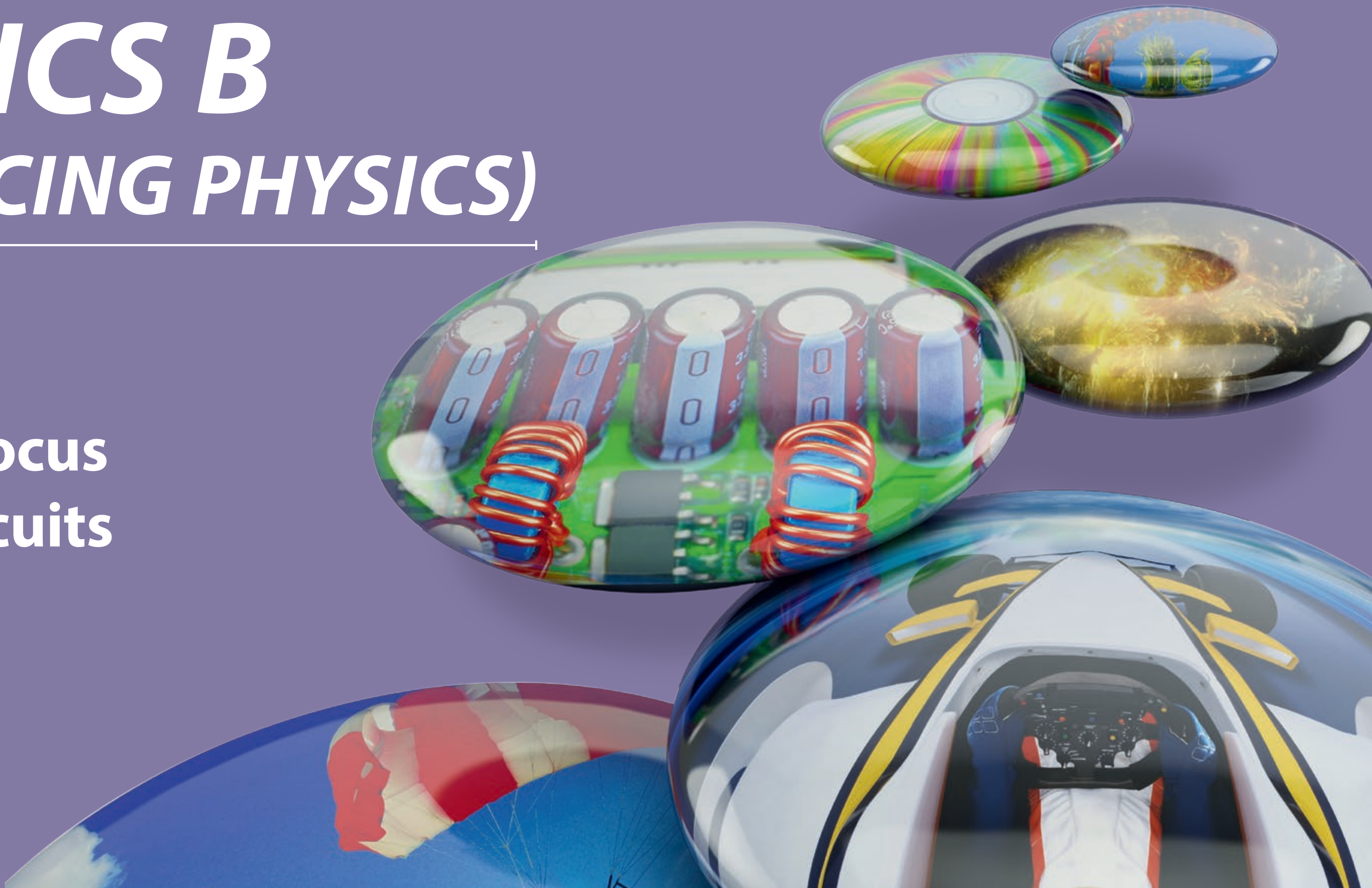
A LEVEL
Transition Guide

PHYSICS B (ADVANCING PHYSICS)

H557
For first teaching in 2015

KS4–KS5 Focus
Electric Circuits

Version 2



www.ocr.org.uk/physics

A LEVEL
PHYSICS B (ADVANCING PHYSICS)

Key Stage 4 to 5 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 4 which will help prepare students for progression to Key Stage 5;
- 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 4 and 5 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 4 and assess their 'readiness for progression' to Key Stage 5 content on this topic. This checkpoint task can be used as a summative assessment at the end of Key Stage 4 teaching of the topic or by Key Stage 5 teachers to establish their students' conceptual starting point.

Key Stage 4 to 5 Transition Guides are written by experts with experience of teaching at both key stages.

Key Stage 4 Content

GCSE content – Module P5 Electric Circuits

1. recall that mains electricity is produced by generators
2. recall that generators produce a voltage by a process called electromagnetic induction
3. understand that when a magnet is moving into a coil of wire a voltage is induced across the ends of the coil
4. understand that if the magnet is moving out of the coil, or the other pole of the magnet is moving into it, there is a voltage induced in the opposite direction
5. understand that if the ends of the coil are connected to make a closed circuit, a current will flow round the circuit
6. understand that a changing magnetic field caused by changes in the current in one coil of wire can induce a voltage in a neighbouring coil
7. describe the construction of a transformer as two coils of wire wound on an iron core
8. understand that a changing current in one coil of a transformer will cause a changing magnetic field in the iron core, which in turn will induce a changing potential difference across the other transformer coil
9. recall that a transformer can change the size of an alternating voltage
10. use the equation:
    (voltage across primary coil/voltage across secondary coil) = (number of turns in primary coil/number of turns in secondary coil)
11. describe how, in a generator, a magnet or electromagnet is rotated within a coil of wire to induce a voltage across the ends of the coil
12. understand that the size of this induced voltage can be increased by:
    - **a.** increasing the speed of rotation of the magnet or electromagnet
    - **b.** increasing the strength of its magnetic field
    - **c.** increasing the number of turns on the coil
    - **d.** placing an iron core inside the coil

Key Stage 5 Content

A Level Content – Electromagnetism

a (i) Describe and Explain:
- the action of a transformer:
- magnetic flux from a coil;
- induced emf = rate of change of flux linked

a (ii) Describe and Explain:
- the action of a dynamo:
- change of flux linked produced by relative motion of flux and conductor

a (iii) Describe and Explain electromagnetic forces;
- qualitatively as arising from tendency of flux lines to contract or interaction of induced poles;
- quantitatively, with calculation limited to force on a straight current-carrying wire in a uniform field

a (iv) Describe and Explain:
- simple linked electric and magnetic circuits:
- flux produced by current turns,
- the need for large conductance and permeance (understood as a magnetic equivalent to electrical conductance and with analogous dependence on the dimensions and nature of the magnetic medium)
- the effect of increasing the dimensions of an electromagnetic machine;
- the qualitative effect of iron and air gap

b (i) make appropriate use of the terms:
- B-field,
- Flux
- Flux linkage,
- induced emf,
- eddy currents

Key Stage 4 Content

GCSE content – Module P5 Electric Circuits

13. describe how the induced voltage across the coil of an a.c. generator (and hence the current in an external circuit) changes during each revolution of the magnet or electromagnet

14. understand that when the current is always in the same direction, it is a direct current (d.c.) e.g. the current from a battery

15. recall that mains electricity is an a.c. supply

16. understand that a.c. is used because it is easier to generate than d.c., and is easier and simpler to distribute over long distances

17. recall that the mains domestic supply in the UK is 230 volts.

Key Stage 5 Content

A Level Content – Electromagnetism

b (ii) including by sketching and interpreting:

- graphs of variations of currents, flux and induced emf
- diagrams of lines of flux in magnetic circuits & continuity of lines of flux

c) Make calculations and estimates involving:

c (i) $\theta = BA$, $\varepsilon = -\frac{d(\theta N)}{dt}$

c (ii) F = ILB

c (iii) V1 / V2 = N1 /N2

c (iv) I2 /I1=N1 /N2

Comment

The GCSE specification focuses predominantly on the concept of understanding, with purely qualitative responses with the minimum of recall and the use of the transformer equation relating the ratio of primary and secondary potential difference to primary and secondary turns. The operation of a transformer can be taught visually and students can observe the effect of the factors specified for themselves.

The mathematical calculations are limited to straightforward ratio of potential difference and number of turns on the primary input coil and secondary output coil.

The most obvious change at A level is the requirement to explain the operation of transformers and electrical machines linking the understanding of individual aspects of the specification. The A level topic includes a significant amount of mathematical calculation, including magnetic field strength, flux and hence flux linkage, and ultimately emf as the rate of change of flux linkage.

Calculations for transformer operation include the concept of conservation of energy, with the ideal transformer having no losses, and thus the inverse relationship between primary and secondary current with the turns ratio.

The A level specification extends the concept of electrical machines to electric motors, based on the force exerted on a current carrying conductor in a magnetic field. It also gives the opportunity not just to recall that a soft iron core increases the size of the induced voltage, but to also calculate the permeance of the magnetic circuit and contrast this to the electrical circuit.

The understanding at A level requires significantly greater conceptual understanding and the ability to infer directions of forces and current flow. The abstract notion of flux, flux density and idea that a finite amount of flux can have increased flux linkage due to the number of turns of wire gives rise to misconceptions, particularly as flux and flux linkage are represented by the same symbol with the same units of measurement.

Activities

Electromagnetic Induction

The topic follows on from that of electromagnetism at keystage 3 where students will have investigated the effect of current, number of turns and the use of a soft iron core on the efficacy of an electromagnet.

A typical lesson on this topic will include teacher demonstration of the notion of cutting flux generating an induced emf. Connecting a loop of wire to a spot galvanometer and then moving the wire between the poles of a Major Magnet will produce an emf. The demonstration can show the effect of direction, rate of movement and with some dexterity the effect of two or three coils in place of the single wire.

Students can then investigate these effects themselves using pre wound coils from a transformer kit (such as Sci-Chem SF8616) connected to an analogue multimeter with 500μA range (such as the Draper Pocket Alogue Multimeterreference 37317). If they move a standard classroom magnet into the coil and out of the coil they will observe the deflection of the meter. They can experiment for themselves with changing polarity, changing velocity and using coils with differing numbers of turns.

It becomes apparent that moving a magnet into and out of a coil is not practical for large scale generation. By rotating the magnet above the coil they should observe movement related to the sinusoidal wave of alternating current mains.

Hydroelectric generator
Resources: http://phet.colorado.edu/en/simulation/generator

There is a very good model of a hydroelectric generator which allows students to adjust the parameters of the generator and observe its output either as the effect in illuminating a lamp or on a voltmeter..

Turbine generator
Resources: http://turbinegenerator.org/

This provides much greater detail about a range of generators, including the steam turbine driven generator and wind generator.

Be aware that sites relating to power generation in the United States will have voltages and frequency which do not match the European standard of 230V at 50Hz.

Extension activities and possible research activities can include finding details of actual power ratings of generators in power stations, their operating speeds (most commonly given in revolutions per minute) and their physical size.

Transformers

Depending on lesson time this can be a continuation in a 100 minute lesson or follow on from an earlier one hour lesson.

The key concept of transformer operation is the transfer of power by means of a magnetic field with no visible connections.

Demonstrate that a signal generator gives out energy by connecting it to a loudspeaker. An oscilloscope can also be connected to show the waveform or if convenient a voltage probe connected to a data logger (such as the Data Harvest Easysense system) to allow projection onto interactive whiteboard, The loudspeaker is disconnected and in its place a transformer coil is connected. A second coil is connected to the loudspeaker, with possible second link to dual trace oscilloscope or datalogger. As the coils are brought together the loudspeaker will again produce sound. Varying frequency and amplitude on the signal generator will cause a change in the sound from the loudspeaker, demonstrating the link between energy source and conversion to sound. Inserting a soft metal rod (clamp stand upright) or transformer C core, will increase the efficiency of the transformer and thus amplitude of sound.

Students can again investigate the effect of turns ratio using standard lab power supplies.

For safety reasons limit the output to 5 volts and ensure that the possible turns ratios do not exceed 10:1.

Place the following statements in the correct order to describe how this transformer works:

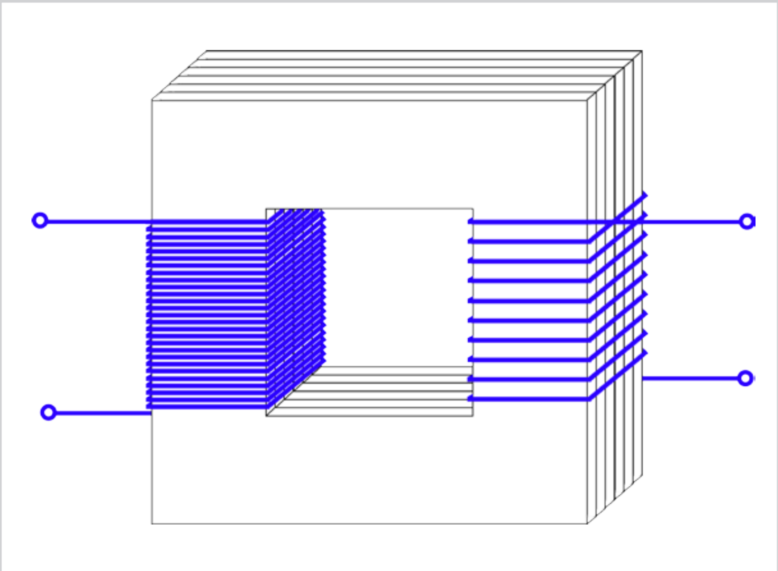


Diagram of a transformer. 200 turns primary, 50 turns secondary, 50V ac, 50Hz.

1 The primary current creates a magnetic field

2 The secondary coil cuts the flux

3 The input voltage to the primary coil causes a current to flow.

4 A voltage is induced which is less than the input voltage

5 The magnetic field creates flux which passes around the iron core

6 The induced voltage causes a current to flow in the lamp

Identify one key technical term which is missing from the bullet points and could improve the description of the operation of a transformer.

Give as much detail as possible to quantify the output from the secondary coil.

Notes for teachers:
Expect: 3,1,5,2,4,6
Technical term: alternating current,

Output : 12.5V, 50Hz

Activities

The teaching activities from Key Stage 4 can be repeated as revision and extended.

The motor effect can be demonstrated using a long length of wire connected to a power supply and suspended hanging through the field between the poles of a Major Magnet. When the power supply is turned on the wire will flick either into or out of the magnet. Reversing current flow reverses the direction.

The process of developing a hypothesis can be demonstrated by considering the effect of each variable on the outcome. Increasing field increases force so field is a multiple. Similarly increasing current and length will also increase force. Thus the formula can be hypothesised as F=BIL. [With pressure as area increases, pressure will decrease so area is a divisor, P=F/A]

The hypothesis can be proved using a magnet on an electronic balance. A non-magnetic rigid conductor (such as a length of copper pipe) is fixed in the space between the poles. As the current is varied the force experienced by the magnet changes. The balance gives equivalent "mass" which needs to be converted to force. Plotting force against current for a constant field and length demonstrates the validity of the hypothesis.

Points for discussion include the use of non-magnetic rod to avoid attraction between magnet and rod.

Be cautious and test the balance, as some balances are themselves affected by the magnetic field.

Next Time conceptual physics cartoons

Resources: http://www.arborsci.com/next-time-questions
http://www.arborsci.com/NTQ/NTQ_MAGNET_2QA.pdf
http://www.arborsci.com/NTQ/NTQ_MAGNET_4QA.pdf

The "Next Time" conceptual physics cartoons are a great free resource.

Printing the questions at A3 size and giving them to students to answer collaboratively provides a great learning opportunity coupled with embedded assessment.

If students then visit the work of other groups and comment on potential improvements it can support the skill of checking and revising written answers.

Rather than correcting the original work it can be left with annotations attached by post it notes.

Activities

Magnet breaking

Resources: http://www.coolmagnetman.com/magindex.htm
http://www.exo.net/~donr/activities/Eddy_Currents_and_Magnetic_Braking.pdf
http://demonstrations.wolfram.com/MagneticBraking/
http://adsabs.harvard.edu/abs/1993AmJPh..61.1096M

There are numerous experiments available which relate to the effects of magnetic braking, either of a pendulum, rotating disc or magnets falling through a non-magnetic, conducting metal tube. Practical applications of this include emergency braking on objects falling under the influence of gravity and as electronic retarders on buses and trucks. As the latter implies the devices will slow down objects which cut flux as they move, however the retarding force is related to speed and thus as speed approaches zero there is also negligible force.

Michael Faraday

Resources: http://lurnq.com/lesson/Michael-Faraday-Pioneer-of-Electricity/
http://www.bbc.co.uk/history/historic_figures/faraday_michael.shtml
http://www.studyphysics.ca/2007/30/06_forces_fields/20_em_induction.pdf

The topic of electromagnetism lends itself to a research project based on Faraday's work and its effect on modern life. Where would we be without the currents uses of electromagnetism?

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/

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Contact the team: science@ocr.org.uk

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

and follow us on Twitter, @ocr_science

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

The small print

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