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A LEVEL
Transition Guide

PHYSICS B (ADVANCING PHYSICS)

H557
For first teaching in 2015

KS4–KS5 focus Module 3 Physics in Action

Version 1

www.ocr.org.uk/physics

Introduction

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

- Understand that the higher the frequency of an electromagnetic radiation, the more energy is transferred by each photon.
- List the electromagnetic radiations in order of the energy transferred by each photon, or in order of frequency: radio waves, microwaves, infrared, red visible light violet, ultraviolet, X-rays, gamma rays.
- Recall that all types of electromagnetic radiation travel at exactly the same, very high but finite, speed through space (a vacuum) of 300000km/s.
- Understand that the energy arriving at a square metre of surface each second is a useful measure of the strength (or 'intensity') of a beam of electromagnetic radiation.
- Understand that the energy transferred to an absorber by a beam of electromagnetic radiation depends on both the number of photons arriving and the energy of each photon.
- Understand that the intensity of a beam of electromagnetic radiation decreases with distance from the source and explain why, in terms of the ever increasing surface area it reaches and its partial absorption by the medium it travels through.
- Understand that some electromagnetic radiations (ultraviolet radiation, X-rays, gamma rays) have enough energy to change atoms or molecules, which can initiate chemical reactions.
- Recall that high energy ultraviolet radiation, X-rays and gamma rays can cause ionisation.
- Understand that the electromagnetic radiations which are ionising are those with high enough photon energy to remove an electron from an atom or molecule (ionisation).Recall that when a force moves an object, it does work.
- Use the equation: work done by a force = force × distance moved in the direction of the force (joules, J) (newtons, N) (metres, m).
- Recall that electrons are negatively charged.

Key Stage 5 Content

A Level Content

- Describe and explain:
  (i) the formation of a real image by a thin converging lens, understood as the lens changing the curvature of the incident wavefront
  (ii) the storage of images in a computer as an array of numbers that may be manipulated to enhance the image
  (iii) digitising a signal (which may contain noise); advantages and disadvantages of digital signals.
- Make appropriate use of:
  (i) the terms: pixel, bit, byte, focal length and power, magnification, resolution, sampling, signal, noise, polarisation by sketching and interpreting:
  (ii) diagrams of the passage of light through a converging lens.
- Make calculations and estimates involving:
  (ii) power of a converging lens $P = 1/f$, as change of curvature of wave fronts produced by the lens
  (iii) use of $1/v = 1/u + 1/f$ (Cartesian convention)
  (iv) linear magnification = image height/object height = v/u.
- Describe and explain:
  (i) current as the flow of charged particles
  (ii) potential difference as energy per unit charge
  (iii) resistance and conductance, including series and parallel combinations
  (v) dissipation of power in electric circuits
  (viii) simple electrical behaviour of metals, semiconductors and insulators in terms of the number density of mobile charge carriers.
- Make appropriate use of:
  (i) the terms: e.m.f, potential difference, current, charge, resistance, conductance, series, parallel, internal resistance, load, resistivity, conductivity, charge carrier number density
  (ii) and recognise standard circuit symbols by sketching and interpreting:
  (iii) graphs of current against potential difference and graphs of resistance or conductance against temperature for ohmic and non-ohmic devices or components.

Key Stage 4 Content

- Recall that electric current is a flow of charge.
- Understand that in an electric circuit the metal conductors (the components and wires) contain many charges that are free to move.
- Understand that when a circuit is made, the battery causes these free charges to move, and that they are not used up but flow in a continuous loop.
- Recall that in metallic conductors an electric current is a movement of free electrons that are present throughout such materials.
- Recall that the larger the voltage of the battery in a given circuit, the bigger the current.
- Recall that the larger the resistance in a given circuit, the smaller the current will be.
- Understand that when electric charge flows through a component (or device), work is done by the power supply, and energy is transferred from it to the component and/or its surroundings.
- Recall that power (in watts, W) is a measure of the rate at which an electrical power supply transfers energy to an appliance or device and/or its surroundings.
- Use the equation: power = voltage × current (watts, W) (volts, V) (amperes, A).
- Recall that resistors get hotter when there is an electric current flowing through them, and understand that this heating effect is caused by collisions between the moving charges and ions in the wire.
- Describe how the resistance of an LDR varies with light intensity.
- Describe how the resistance of a thermistor (ntc only) varies with temperature.
- Recognise and use the electrical symbols for a cell, power supply, filament lamp, switch, LDR, fixed and variable resistor, thermistor, ammeter and voltmeter.

Key Stage 5 Content

- Make calculations and estimates involving: (i) $R=V/I$, $G = I/V$, $V=W/Q=P/I$, $P=IV=I2R$, $W=VIt$, $V=\epsilon-Ir$, $I=\Delta Q/\Delta t$, $1/G=1/G1+1/G2+\ldots$ $G=G1+G2+\ldots$. $R=R1+R2+\ldots$. $1/R=1/R1+1/R2+\ldots$.
- Demonstrate and apply knowledge and understanding of the following practical activities (HSW4):
  (iii) use of potential divider circuits, which may include sensors such as thermistor, LDR.
- Make calculations and estimates involving:
  (i) Hooke's Law, $F = kx$; energy stored in an elastic material (elastic strain energy) $=1/2\ kx2$; energy as area under Force– extension graph for elastic materials.

Key Stage 4 Content

- Understand that two (or more) resisitors in series have more resistance than either one on its own, because the battery has to move charges through both of them.
- Understand that two (or more) resistors in parallel provide more paths for charges to move along than either resistor on its own, so the total resistance is less.
- Use the equation: resistance (ohms, Ω) = voltage (volts, V) current (amperes, A).
- Describe in words, or using a sketch graph, how the current through a component varies with voltage across it when the resistance stays constant.
- Recall that potential difference is another term for voltage.
- Relate the potential difference between two points in the circuit to the work done on, or by, a given amount of charge as it moves between these points.
- Understand that when two (or more) components are connected in series to a battery:
  a. the current through each component is the same
  b. the potential differences across the components add up to the potential difference across the battery (because the work done on each unit of charge by the battery must equal the work done by it on the circuit components)
  c. the potential difference is largest across the component with the greatest resistance, because more work is done by the charge moving through a large resistance than through a small one
  d. a change in the resistance of one component (variable resistor, LDR or thermistor) will result in a change in the potential differences across all the components.

Key Stage 4 Content

- Understand that when several components are connected in parallel directly to a battery:
  a. the potential difference across each component is equal to the potential difference of the battery
  b. the current through each component is the same as if it were the only component present
  c. the total current from (and back to) the battery is the sum of the currents through each of the parallel components
  d. the current is largest through the component with the smallest resistance, because the same battery voltage causes a larger current to flow through a smaller resistance than through a bigger one.
- Describe how refraction leads to the formation of an image by a convex/converging lens.
- Understand and draw diagrams to show how convex/converging lenses bring parallel light to a focus.
- Draw and interpret ray diagrams for convex/converging lenses gathering light from distant point sources (stars), off the principal axis of the lens and extended sources (planets or moons in our solar system, galaxies).
- Understand that a lens with a more curved surface is more powerful than a lens with a less curved surface made of the same material.
- Calculate the power of a lens from: 1 /focal length power = (dioptres) (metres-1).
- Calculate the angular magnification of a telescope from the powers of the two lenses using: focal length of objective lens/focal length of eyepiece lens.

Comment

Digital Information

The GCSE specification contains many points relating to digital signals. The key concepts of what digital means and benefits of digital are covered.

It would be useful for students at GCSE to be aware of terms such as bits, sampling and noise, as well as how many bits are in a byte. A demonstration of how a sound and an image are digitised would be beneficial. The limiting factors on bandwidth and transmission rate would make good discussion points.

In the A Level specification, there is more detail on how to manipulate digital images, including varying brightness and contrast, reducing noise, detecting edges and using false colour. The concept of sampling is expanded upon, with minimum rates being calculated. Noise is addressed, in particular its impact on the quality of a signal. A good understanding of binary would help immensely, as would familiarity with powers and logarithms.

Students should be exposed to a variety of examples of digitisation. Sound digitisation is a good way to get started, and they could carry out a manual digitisation using the 'Digitising a Signal' activity. They should manipulate real images, using the filters in a package such as GIMP, and construct their own enhancement routines for simple diagrams, using a spreadsheet such as Excel.

A common misunderstanding is that digital sampling involves only two levels. This is a confusion between binary transmission and digital sampling in binary and needs to be clarified as early as possible. Discussion of four bit sampling, for instance, would be helpful – explaining how the signal is sampled into 16 different levels, and each level is then encoded using four binary digits. To act as a reminder of this, the students could be told that four bits is called a nibble (half a byte).

Lenses and Polarisation

The focus at GCSE is on ray diagrams, power and magnification. The context of telescopes is written into the specification, and proves a worthwhile application to study. It is also worth relating the work to optical prescriptions and corrective lenses, as this will strike a chord with many pupils. Electromagnetic waves are explained as waves made of electric and magnetic fields. The wave equation and the relationship between time period and frequency should be covered.

It is very important that the concept of focal length is strongly established at GCSE. Drawing ray diagrams for convex and concave lenses gives the opportunity to introduce the Cartesian convention.

This is one of the hardest things to get to grips with and every chance to use it should be embraced. Students should also see wavefront diagrams, not just ray diagrams, as these can be confusing if not met early enough. Students could carry out the 'Making Your Own Telescope' activity as either an introduction to the topic or as a summary at the end.

The basics are built upon at A Level, to include the concept of curvature and the Cartesian convention. The lens as a changer of curvature is a key thing to embed, accompanied by plenty of ray diagrams and wavefront diagrams showing the effects of different convex lenses. The concept of magnification is applied to optical systems.

The context of telescopes from GCSE could be built upon, perhaps combined with the work on digitising images. Satellite imaging is another application that could be used, or even simple digital photography. A demonstration of the polarisability of microwaves would be good, potentially combined with picking up the signal from pupils' mobile 'phones. Students should also examine the effects of polarising filters on visible light, including what happens when the filters are crossed.

The most common problem is getting all the signs correct in the lens formula. Coupled with this is the whole concept of curvature. It might help to play with balloons, as in the 'Curvature' resource. Some students get stuck on which way light is polarised – is it really like the rope and slatted fence analogy? Once they have covered work on electric and magnetic fields, it might be worth revisiting this to reinforce what is going on.

Energy Changes

At GCSE students are expected to be able to calculate work done when a constant force is used to move an object a set distance.

When the formula is introduced at GCSE, it would be helpful if the relevant force-distance graph were displayed (ie. a horizontal line at the constant force) and the area related to the formula. For the top students, the idea of 'average force' being half the maximum force (for a uniformly increased force) and this could lead to looking at the area under a triangular force-distance graph.

At A Level, they need to be able to relate the energy stored in an elastic material to the area under a force – extension graph. The concept of conservation of energy also crops up in relation to electrical energy and Kirchhoff's Laws.

Students should carry out experiments to plot the loading graphs for springs and elastic bands. They could then work out the areas using triangles and rectangles or trapezia.

One thing that some students find hard to believe is the conservation of energy. This is mostly to do with dissipated energy being effectively useless. The idea of a closed system needs to be explained, and that the total energy within such a system does remain constant. When it comes to calculating areas under graphs, students reach A Level with a wide disparity in the methods they have encountered, so be prepared to teach both counting squares and using trapezia as each has its own benefits.

Mechanical Properties

Very little is covered about this at GCSE. However, a good grounding in basic forces would be a big help. Certainly, meeting words such as tension and compressions would be valuable.

It would be beneficial if students carried out an experiment to determine the spring constant of a spring. It could be included with a focus on experimental technique and relating a formula to a line of best fit.

One of the key concepts introduced at A Level is the Young modulus. This brings with it the concepts of stress and strain. The behaviour under stress of a range of materials (metals, ceramics and polymers) needs to be studied, along with the matching stress-strain graphs. The behaviour must be explained in terms of microscopic properties of the materials, including dislocations.

Students ought to carry out a range of experiments related to Hooke's law and the Young modulus. They should, in particular, examine ways to improve the accuracy and precision of these experiments. The ways in which materials break should be studied through experiment; a couple of ideas are described in the 'Plastic Bag ' and 'Necking' resources. Bubble rafts and ball-bearing trays can be very useful for demonstrating the dislocations and inclusions on a large scale.

The concept of stress can be confusing. It can help to point out that it has the same units as pressure, and that it can be regarded as the tensional equivalent of this familiar quantity. Some students also find it hard to accept that strain has no units, and it should be made clear that it is a fractional/percentage change in the original length. Another problem had by many is that the Young modulus is a property of the material, not the object. Reminding them about density before introducing it would be a good idea, as this is an example they would have met before and are hopefully happy with.

Electrical Circuits

There is a large chunk of work on electricity at GCSE. This knowledge is assumed by the A Level specification, and is swiftly extended.

The key formulae of V=IR, Q=IT and P=VI must be fully understood. Rearranging them should be second-nature, and experience combining them is necessary. A discussion of why the IV plots have the shape they do would be worthwhile; not only will it pave the way for A Level study of components, but it will also make matching plot to component easier to remember at GCSE. When thermistors and LDRs are studied, it would be good if they were regarded as sensors; building practical circuits, for instance the 'Making a Qualitative Light Meter' resource, would give the topic some substance. All pupils should be very familiar with placing ammeters and voltmeters in circuits, and recognise the standard circuit symbols for a range of components. Able candidates at GCSE could be tasked with finding formulae for combining identical resistors in series and in parallel. It should be understood that electricity is the rate of flow of charge carriers; in particular that in a metal these are electrons. Whilst there is no need to mention drift velocity at GCSE, it is worth the students appreciating that the electrons move quite slowly. Terms such as potential difference and emf could be mentioned when looking at batteries, to avoid confusion later. Stressing the idea that potential difference is the work done per unit charge is vital – it comes up in so many areas and students frequently forget it.

The focus at A Level is on using electrical circuits as measuring devices. One key thing to grasp is the potential divider; in particular, why it allows for more sensitive measurements. The real-world complication of internal resistance is introduced and heavily applied. Combining resistances is covered, as is the concept of conductance.

Students should spend a lot of time working with circuits in this topic. At the very least, they should determine the resistivity of a wire, find the internal resistance and emf of a cell, verify the rules for combining resistances, and investigate potential dividers. There is room for extended practical work, such as making and calibrating their own sensor. Ideally, this would be set as a research project lasting several hours, though if closer guidance is required they could be shown the 'Making a Quantitative Light Meter' resource.

Internal resistance causes a lot of problems for students. It helps if they are drilled to represent a real cell as a perfect cell and a perfect resistor, and then apply the circuit laws as they already know them. Naming the parts of the internal resistance formula (E=emf, V=terminal pd, and Ir=lost volts) helps them understand what is going on. It is common for students to forget the final 1/ when combining resistances in parallel; they should be drilled to check that their answer is realistic, for instance it should be lower than all of the individual resistances.

Activities

Digitising
BravesirLeo
https://www.youtube.com/watch?v=UqyPqOeYFhQ

A fast-paced explanation of digitisation and binary.

Component cards
BBOP: School Physics Resources
http://www.archaeoroutes.co.uk/edphys/worksheets/Electricity/Component%20Cards.pdf

A card sorting activity matching component names and symbols.

Make your own telescope
Canada Science and Technology Museum
https://www.youtube.com/watch?v=uZeF1KETaU4

Instructions on how to make your own refracting telescope. Also explains how it works in terms of ray diagrams.

Making a qualitative light meter
Student Activity 1

Worksheet on making a light meter using an LDR.

Choose resistors suitable to your LDRs. You could allow them to investigate different locations outdoors, or just around the lab.

Ohm's Law
BBOP: School Physics Resources

http://www.archaeoroutes.co.uk/edphys/worksheets/Electricity/Ohm's%20Law.pdf

Worksheet with an experiment and questions on Ohm's Law.

Checkpoint task

The checkpoint tasks can be run before teaching Physics in Action at A Level as a method of checking prior learning and highlighting any misconceptions that have been carried through GCSE. They could also be used as an assessment tool when revising for GCSE exams or as separate tasks at appropriate points during teaching.

There are two main topics at GCSE that are assumed knowledge in the Physics in Action module. The first is optics and the second is electrical circuits.

Lenses can involve complex ray diagrams, and calculations involving a reciprocal frequently cause confusion. The first task is intended to assess whether pupils can apply the basic rules to a real-world example.

Designing a circuit to carry out a measurement is a fundamental task that many pupils struggle with. Once they have worked out what the variables to be measured are, they are often able to make more rapid progress.

The tasks below are designed so that they can be used in a number of ways:

- As individual checkpoint tasks during the teaching of the topics.
- As an 'experts' activity where groups of learners are assigned a different task and after completing the task, one person from each group forms a new group to share what they have learned.
- As the focus of a revision session.

Teacher Guidance:

Task 1

This covers P7.2 – Light, telescopes and images. Pupils must be familiar with drawing ray diagrams for lenses.

A common question is likely to be 'Where do we measure the focal length from?'. The centre of the lens is the best in a biconvex one as shown. You may also have to stress that the size and distance to the planet are not to scale with the lens.

Task 2

This covers P5.2 – What determines the size of the current in an electric circuit and the energy it transfers? Pupils must be familiar with using ammeters and voltmeters, and be able to apply Ohm's Law.

Each group will need access to the test resistor, an ammeter and a voltmeter (or two multimeters), variable power supply (or battery pack) and sufficient leads to connect them.

One key thing is to help the pupils decide what variables they need to measure. Pointing them towards Ohm's Law may be needed.

If they don't go straight for a graph, let them calculate a value using just one voltage and then discuss how they could improve the experiment – bring in ideas of repeatability etc.

Extension Tasks

The extension tasks are written questions building on the content of the main tasks.

Checkpoint Task:

http://www.ocr.org.uk/Images/310638-physics-in-action-checkpoint-task.doc

Making a Light Meter Activity:

http://www.ocr.org.uk/Images/310640-physics-in-action-activity-1-making-a-light-meter-activity.doc

Force - Distance Graphs Activity:

http://www.ocr.org.uk/Images/310641-physics-in-action-activity-2-force-distance-graphs.doc

Activities

Curvature

Discuss the concept of curvature. Blow up a balloon to demonstrate how the larger the radius (distance from point source) gets, the less the curvature of the surface (light).

How a digital camera works
Brit Lab

https://www.youtube.com/watch?v=lc0czeUJrGE

James May explains the details of taking a digital image.

Finding the power of a lens
BBOP: School Physics Resources

https://www.youtube.com/watch?v=_LbniV4KL7Q

Demonstration of finding the power of a lens using 1/v=1/u+1/f.

Seeing charge flow

Set up a microscope slide with a wide strip of filter paper attached to it by a metal bulldog clip at each end. Wet the paper with sodium chloride solution. Attach a power pack to provide 12-25V dc between the bulldog clips. Place a crystal of potassium permanganate in the centre of the paper. Watch the coloured ions drift towards one of the electrodes (they diffuse in all directions, but there is a definite preference towards the appropriately charged bulldog clip).

Making a quantitative light meter

Set the students the challenge to construct and calibrate a light meter using an LDR in a potential divider circuit. The calibration could be against a commercial light meter, or against distance from a known light bulb using inverse quare law. This task builds on the qualitative task suggested for GCSE.

Plastic bag see PAG activity 2.3

A technician should cut 1cmx15cm strips from plastic bags. One set should be cut horizontally and another set vertically. Students should ben progressively load the strips lengthways, using slotted masses and a hanger taped to the bottom of the strip. Due to the polymer alignment, one set should snap suddenly while the other set necks. The reasons for this could then be discussed.

A variation is to make up a set of ten strips for each student. One strip in each set is cut at 90 degrees to the other 9 strips. The students are asked to find the breaking force for the plastic. How they treat the anomaly is interesting.

Necking

http://image.slidesharecdn.com/wiredrawingbookletreducedsize-140423081219-phpapp01/95/rautomead-limited-wire-drawing-booklet-16-638.jpg?cb=1398241025

http://images.fineartamerica.com/images-medium-large-5/1-necking-in-copper-wire-martyn-f-chillmaid.jpg

A piece of wire (e.g. copper) is clamped and a large force progressively added until the wire breaks (safety!). A broken end should be compared to a cut end under a hand lens. The smooth area of necking and the rough area of brittle fracture should be visible. Micrograph images of broken wires could be projected for comparison.

Activities

Force-distance graphs

Student Activity 2

Worksheet that gets pupils to work out the work done by a force in the context of graphs.

Digitising a signal
BBOP: School Physics Resources

http://www.archaeoroutes.co.uk/edphys/worksheets/Communication/Digitising%20a%20Signal.pdf

Worksheet that gets pupils to encode and decode a signal.

Devilish Kirchhoff problems
BBOP: School Physics Resources

http://www.archaeoroutes.co.uk/edphys/worksheets/Electricity/Devilish%20Kirchhoff%20Problems.pdf

Demanding circuit problems to solve using a combination of Kirchhoff's Laws.

Resources, links and support

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