OCR
Oxford Cambridge and RSA

AS and A LEVEL

Delivery Guide

PHYSICS B (ADVANCING PHYSICS)

H157/H557
For first teaching in 2015

Imaging and signalling

Version 2

Introduction

AS and A LEVEL
PHYSICS B

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.

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Curriculum content

The theme splits into two main concept areas.

Firstly there is the propagation of waves. The main focus of this is on lenses and their use in cameras and telescopes.

Secondly there is digitisation and the use of digital signals. The key point here is that digitisation takes something with an infinite number of possible levels and reduces it to a set number of levels which can then be encoded into binary. Sampling and encoding are covered in detail.

3.1 Communication

These sections are about waves, images, simple optics and electric circuits. The physics of the imaging and signalling section is approached through how information is gathered, processed, transmitted and presented. Learners have opportunities to develop IT skills through the use of image processing, data capture and data analysis software. The material can be taught using contexts such as smart phones, data streaming, medical scanning and remote sensing. There are opportunities to address human and social concerns, for example, consequences of the growth of worldwide digital communications (**HSW9**) and the ethical issues of sharing information (**HSW10**).

3.1.1 Imaging and signalling

(a) 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 wave-front (**HSW9**)

    (ii) the storage of images in a computer as an array of numbers that may be manipulated to enhance the image (vary brightness and contrast, reduce noise, detect edges and use false colour)

    Learners are not expected to carry out numerical manipulations in the examination; an understanding of the nature of the processes will be sufficient.

    (iii) digitising a signal (which may contain noise); advantages and disadvantages of digital signals (**HSW12**)

    (iv) evidence of the polarisation of electromagnetic waves.

(b) Make appropriate use of:

    (i) the terms: pixel, bit, byte, focal length and power, magnification, resolution, sampling, signal, noise, polarisation (**HSW8**)

    by sketching and interpreting:

    (ii) diagrams of the passage of light through a converging lens using both wave-fronts and rays

    (iii) diagrams of wave-forms.

(c) Make calculations and estimates involving:

    (i) the amount of information in an image = no. of pixels x bits per pixel

    (ii) power of a converging lens $P = 1/f$, as change of curvature of wave-fronts produced by the lens (**HSW10, M0.3, M1.1, M2.2, M2.4, M3.2**)

    (iii) use of $\dfrac{1}{v} = \dfrac{1}{u} + \dfrac{1}{f}$ (Cartesian convention).

Restricted to thin converging lenses and real images (**M0.3, M1.1, M2.2, M2.4, M3.2**)

    (iv) linear magnification

    (v) $v = f\lambda$ including the use of $f = 1/T$

    (vi) number of bits, b, provides $N = 2^b$ alternatives; $b = \log_2 N$ (**M0.5**)

    (vii) minimum rate of sampling $> 2 \times$ maximum frequency of signal (**M2.1**)

    (viii) rate of transmission of digital information = samples per second $\times$ bits per sample

    (ix) the graphical representation of the digitisation of an analogue signal for a given number of levels of resolution (**M3.1**)

    (x) Use of $b = \log_2 (V_{total}/V_{noise})$

(d) Demonstrate and apply knowledge and understanding of the following practical activities (**HSW4**):

    (i) determination of power or focal length of a converging lenses using 3.1.1c(iii) (**links to 3.1.1c(ii)(iii)**)

    (ii) observing polarising effects using microwaves and light (**links to 3.1.1a(iv)**)

Activities

Learner Activity 1

Sampling SHM

Learner Resource 2

A worksheet to illustrate the effect of different sampling rates on the data produced. A mass is set to oscillate on a spring (due to differing springs you may need to change the number or the mass to get a period of about 8s). The student is then asked to record the displacement at different sample rates and plot the results.

Learner Activity 2

Definitions

Learner Resource 3

A matching exercise to consolidate the meanings of key words.

Thinking conceptually

Approaches to teaching the content
This theme addresses ideas of light and digitisation. The main thrust should be on how these can be used for modern communications. The ability to explain how a TV programme is recorded, broadcast and displayed could be seen as an immediate goal. Discussion of the advantages and disadvantages of using digital signals should be encouraged.

Students should be given opportunities to become confident using terms such as pixel, bit, byte, focal length, power of a lens, magnification, resolution, sampling, sample rate, signal, noise and polarisation. They should also investigate image manipulation on a computer.

The primary practical goal would be to accurately determine the power of a lens by measuring the curvature of the light before and after. It is also worth building on previous work on experimental techniques by stressing the effect of sample rate and resolution on reliability of data.

Common misconceptions or difficulties students may have
The concept of curvature is quite tricky, especially the sign convention. It is worth spending some time building these ideas before introducing the lens formula.

There is not much in the way of direct experimental work on digitisation. Some students find it hard to grasp the intangible processes which happen far too fast to observe in real applications. However there are plenty of opportunities for modelling what is happening at human speed. Sampling often causes problems for students. With the common belief that digital is best for everything it is hard for some to grasp that information is lost when sampled.

Whenever it is met students find estimation to be hard, mostly because it appears to lack rigour. Some work on estimating and approximating values for calculations would help.

Conceptual links to other areas of the specification – useful ways to approach this topic to set students up for topics later in the course
The waves section provides an opportunity to consolidate work done at GCSE ready for when it is used in 4.1 *Waves and Quantum Behaviour*. Examples include mentioning refraction when dealing with lenses and making sure concepts of wavelength and frequency are solid when doing wave equation.

Treating cameras as sensors can help ease the way into 3.1.2 which is all about sensors.

Graphs from later on in the course, esp. exponential decay and simple harmonic motion, could be used as examples from which to sample. This will not only mean that they have seen them but also allow discussion about how taking results is sampling.

Activities

Learner Activity 1

Finding the Power of a Lens (BBOP School Physics Resources)

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

A video demonstrating how to find the power of a convex lens. Alternatively the teacher could demonstrate the experiment using a digitiser. Having watched, students should carry out their own measurements of lenses with a range of powers.

Learner Activity 2

Noisy Transmission (University of Auckland Computer Science Department)

https://www.cs.auckland.ac.nz/courses/compsci314s1c/resources/Coding/

An applet to work on encoding and transmitting a signal in the presence of noise.

Learner Activity 3

Digitising a signal

The following video is a good introduction to the basics of digitising a signal.

https://www.youtube.com/watch?v=f6-vd6p3Wl8

Here is a useful summary on digital processing with some example questions from Schoolphysics.

http://www.schoolphysics.co.uk/age16-19/Wave%20properties/Wave%20properties/text/Communication.pdf

Thinking contextually

Digital cameras provide a great way to put this topic into context. Firstly the lens must focus the image onto the CCD. Then the image is digitised and stored as an array of numbers. The size of the file will depend on the number of pixels and how many bits of information are stored for each.

This can be extended to the cameras used for remote sensing. You could work out the resolution and magnification of a camera on a satellite. This could be an infra-red device so you can bring in false colour.

DAB radios are useful for discussing sample rates and transmission rates. First the sound wave must be sampled, taking care to have a sample rate at least twice the highest frequency in the sound.

Another application is an optician. Firstly look at how the lens in the eye produces a real image. You can also examine how correcting lenses work. This would lead to interpreting the prescription which gives the power of the lens in dioptres. Finally you could look at the effects of polarising filters and why they are often used for driving or lifeguarding (they cut down glare because reflected light is polarised).

Activities

Learner Activity 1

Resolving Power

Learner Resource 1

Print out the two sheets. One has two dots, the other one. Gather the students at one end of a large space, eg. a football pitch. Walk away from them along a tape measure. Every 5m turn and hold up a card. They raise two hands if they think it has two dots, one hand if they think it has one dot or leave them down if they can't tell. Repeat until the majority can't tell or get it wrong – this can be taken as the limit of resolving.

The students should then measure the distance between the dots and the distance at the limit of resolving and work out the resolution of their eyes.

Relate this to an eye test chart (http://www.i-see.org/block_letter_eye_chart.pdf) or compare to telescopes.

Learner Activity 2

Satellite Imagery (various)

https://www.youtube.com/watch?v=fCrB1t8MncY

https://www.youtube.com/watch?v=fdxHAggOmB4

Watch the above videos as a starting point for discussion on resolution and false colour.

Learner Activity 3

Audio engineering

This site covers the basics of sampling.

https://www.izotope.com/en/learn/digital-audio-basics-sample-rate-and-bit-depth.html.

Sampling

Listen to the effects of sampling rate and bits per sample on the quality of a musical recording.

https://www.youtube.com/watch?v=fZzMXdxbOes&list=PL4dISychPQEtnZkzPUfstKVYsG0e5gwbt&index=1

https://www.youtube.com/watch?v=ubCMI3Jq6e4&list=PL4dISychPQEtnZkzPUfstKVYsG0e5gwbt&index=2

Learner Activity 4

The charge coupled device (CCD) camera

This Schoolphysics link has some concise examples of imaging with digital cameras.

http://www.schoolphysics.co.uk/age16-19/Optics/Optical%20instruments/text/CCD_camera/index.html

Resolution of the human eye

Resolution of the human eye

Learner Resource 1

Sampling SHM

When carrying out any experiment it is important to choose an appropriate interval between your readings. If your dependent variable is time the frequency of these readings is called the sample rate. If your sample rate is too low you will miss something.

This experiment will give you an idea of how to choose a sensible sample rate.

Set up a 1kg mass on a pair of springs as shown below. Find the frequency by measuring the time period and using

$$f = \frac{1}{T}$$

Make sure that the zeros on the two rulers are level with the bottom of the mass when it is hanging still (this is called the equilibrium position).
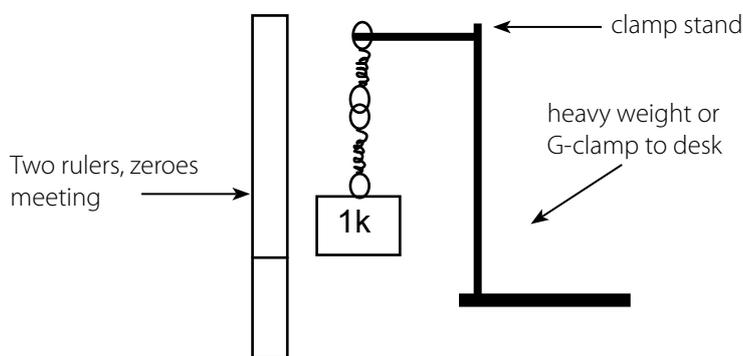
Pull the mass down 10cm and release, starting the stop watch at the same time. Record the displacement every 30s. Values on the top ruler are positive, values on the bottom ruler are negative.

Now repeat the experiment several times. Record the displacement every 20s, every 10s, every 5s and every 2s respectively.

Plot a graph of your results. Each set of data should be presented on the same axes; mark the points and curves in different colours.

Find the frequency of each curve by reading off the time period.

- What do you notice about the quality of the graphs as you went to shorter sample rates?
- At what point could you accurately measure the frequency of the oscillation from the graph?

In order to capture all the information the sample rate should be at least twice the frequency of the source. If there are multiple frequencies it needs to be at least twice the highest frequency.

Learner Resource 2

Definitions

Match the word to its definition.

pixel	The distance beyond a lens that parallel incident rays would meet.
bit	The smallest element of an image.
byte	The ratio of the size of the image and the size of the object.
focal length	Random, unwanted fluctuations added to a signal.
power of a lens	A binary digit.
magnification	Change of curvature to a wave front.
resolution	The smallest separation at which two objects can be seen as separate.
sampling	8 bits.
signal	Lining up the planes of oscillation of waves.
noise	The information being transmitted.
polarisation	Taking readings at set time periods.

Learner Resource 3

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