

# Unit 3 Case Studies

## GCE Physics

Pearson Edexcel Level 3 Advanced Subsidiary GCE in Physics  
(8PH01)

First certification 2014

Pearson Edexcel Level 3 Advanced GCE in Physics (9PH01)

First certification 2014



## Suggested case studies and associated practical work

Here are five suggested case studies involving an application of physics and a related practical that you can use with your students. Alternatively, you can choose one of your own.

### 1 Investigate quantum tunnelling composite materials

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*Case study brief:* Find out what sort of material a quantum tunnelling composite is. Why is its behaviour interesting and what is the significance of the phrase 'quantum tunnelling'? What uses could it be put to and what are its current limitations?

*Practical:* Candidates could do experiments such as investigating the relationship between the applied stress to a strip of material and its electrical resistance/resistivity. Specimens of QTC material can be purchased from [www.mutr.co.uk](http://www.mutr.co.uk). The material comes with a booklet with a number of interesting possibilities for experiments.

### 2 Investigate the physics of a 'tyrolean' traverse

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*Case study brief:* A tyrolean traverse is a rock-climbing term. Find out what it is and the circumstances in which this manoeuvre is used. What are the mechanics of this process? Discuss the forces acting on the climber and in the rope and justify them using your knowledge of resultant forces. Would you expect these forces to remain the same during the traverse?

*Practical:* Model a tyrolean traverse using two pulleys, cord and three weights. One of these weights is used to model the 'body'. Measure the distance from one pulley to the 'body' and the 'sag'. The sag is the distance of the position of the weight on the cord from the horizontal. Can you find an equation relating sag with distance by 'trying' various graphs? Does this experiment verify your research and findings for the case study?

### 3 Investigate electroplaques and suggest why an electric eel can kill its prey without injuring itself

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*Case study brief:* Electroplaques are cells within animals like the electric eel. They are stacked in series and parallel and this arrangement can generate large voltages and currents that can be used to kill or stun prey. Candidates can find out about the chemical processes which lead to the generation of an emf in these biological cells, revise ideas on parallel and series, consolidate ideas about internal resistance and explain why the electric eel doesn't injure itself.

*Practical:* Determine the internal resistance of a biological 'lemon' cell. What happens if you connect three lemon cells in series then in parallel? The electric eel has many electroplaques in series to produce a large voltage — why does it have many chains of electroplaques in parallel?

Students can create a lemon cell from a lemon, copper coin and zinc-coated screw. Three of these in series will create a battery with a reasonable emf. They should connect the battery to a variable load resistor and measure the terminal potential difference and current for an appropriate number of load resistor values. The load resistors need to be chosen so that their range reflects the internal resistance of the battery.



#### 4 Investigate the properties of spider silk

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*Case study brief:* Candidates can find out the properties of spider silk. They should specifically research typical breaking stresses and strains. They should then go on to compare the typical breaking forces for steel and spider silk, being careful to state the parameters for this comparison. Why is spider silk so strong?

*Practical:* How much energy is stored in an elastic band at full stretch? Compare the energy stored in an elastic band per unit volume at breaking point with that of spider silk at breaking point.

Students can use a typical elastic band. Use weights to establish a force–extension graph then determine the area under it. They test their answer by releasing the band and seeing how high it flies. They can revise ideas on gravitational potential and kinetic energy.

#### 5 Investigate the viscosity of ketchup

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*Case study brief:* Ketchup is more interesting than you might think. It needs to be treated so that it ‘pours’ in just the right way — not too runny and not too solid. It is known as a thixotropic material — what does this mean and how is it achieved?

*Practical:* Determine the viscosity of a material such as golden syrup.

Students can use the falling ball technique with a measuring cylinder of liquid (a 3mm-diameter ball bearing should suffice). Elastic bands make useful markers over which to determine terminal velocity. The change in viscosity with temperature of oil used in various machines could provide a different case study.

### Suggested visits and associated practical work

Here are five examples of a physics-based visit and a related practical that you can use with your students. Alternatively, you can choose one of your own.

#### 1 A visit to a sweet factory

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##### *Introduction*

Topics that may be covered by a visit to a sweet factory include viscosity, refractometry or polarimetry. The topic that you cover will depend on the part(s) of the factory you will be shown around.

*Viscosity:* Students should note that viscosity is an important property of some ingredients in sweets, considering that fluids that are used to make sweets need to be pumped around the factory. These fluids are often kept at relatively high temperatures — ask students why.

*Sugar content may need to be measured.* Two different techniques can be used to do this. The first technique, refractometry, uses the concept of critical angle. The second technique, polarimetry, uses the rotation of polarised light.

Students should make notes on the principals of these techniques and why they are important for the factory. They may also find it useful to note any relevant numerical values.

### ***Suggestions for practical work***

*Determine viscosity of a liquid such as golden syrup.* A straightforward method uses the falling ball technique with a measuring cylinder of liquid. A 3mm-diameter ball bearing should suffice. Elastic bands make useful markers over which to determine terminal velocity.

*How does the refractive index of a sugared water solution/Perspex vary with sugar content?* Prepare sugar solutions of different known concentrations. Students soak strips of sugar paper in these solutions to coat them and then stick each of the coated papers in turn onto the flat back of a semicircular Perspex prism. Students can find the critical angle for each sugar concentration by tracing rays of light through the prism from a light box (a good blackout will be essential). The refractive index for each of the different sugar concentrations can be calculated. Students could be asked to determine the concentration of a sugar solution prepared by the technician.

*How does the concentration of sugared water solution affect the angle of rotation of the plane of polarisation?* Students can make a simple polarimeter from a LED source, polarising filters and a plastic cell to contain the liquid which can be placed above the polarised light source.

## **2 A visit to a car maintenance garage or an 'exhausts, tyres and batteries' centre to explore sensor technology**

### ***Introduction***

Sensor technology is now very significant on most cars with light sensing, pressure sensing, temperature sensing, position sensing, etc. Students should note what a basic sensing circuit consists of and the quantity (in each case) that is being monitored by microprocessor. Numerical values should be noted if relevant.

### ***Suggestions for practical work***

Calibrate a position sensor using a rotary linear potentiometer. This is likely to involve the use of a linear potentiometer, some way of measuring angle, eg with a protractor and needle (through the arm of the potentiometer), a voltmeter and a power supply.

A nice extension is to ask candidates to decrease its sensitivity: full-scale rotation for 1V rather than, say, 5V.

## **3 A visit to any environmentally friendly ('green') site, eg an alternative energy centre or most modern building projects**

### ***Introduction***

A number of sites now profess to be 'green'. Students could discuss what this actually means in small groups and then each group could present their ideas to the whole class. At the 'green' site students may look for:

- features that reduce waste products, eg solar cells
- design features that reduce energy costs, eg insulation.



### ***Suggestions for practical work***

*Investigating a solar cell.* The efficiency of a solar battery depends, to some extent, on its internal resistance. Students could determine the internal resistance of a solar cell. These may be purchased cheaply from surplus suppliers. The internal resistance of a solar cell increases with light intensity, so students may not obtain the same values of internal resistance as each other for the same type of solar cell. Students will need to ensure illumination remains constant during their experiment and will need to use a sensible range of variable load resistance values.

*How does the thickness of insulating material change the rate of cooling?* Candidates will need a hot beaker of water, different thicknesses of material to wrap around the beaker, and a thermometer. They obtain a cooling curve for each thickness and then find the gradient at a particular temperature for each thickness.

## **4 A visit to a medical physics department at a hospital**

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### ***Introduction***

Most medical physics departments have three main applications of physics: X-ray imaging, nuclear medicine and ultrasound. It is probably best to concentrate on two of these during a visit.

- *X-ray imaging* Students should be able to explain: How are X-rays produced? How are images formed and what are X-rays typically used for? What are the risks? What safety precautions must be used? They should note any relevant numerical values.
- *Nuclear medicine* Students should be able to list medical applications that use radiation and explain: What radiation is used for and why? How is the radiation detected and an image produced? What are the risks?
- *Ultrasound* Students should be able to explain: What is it used for? What are the principles of ultrasound imaging?

### ***Suggestions for practical work***

While exploring the safety precautions involved with the use of ionising radiation, students could consider the importance of the inverse square law that relates the intensity of the radiation with distance from its source. Students could investigate this relationship using a light bulb to simulate a non-collimated source of ionising radiation. This will require a small 6V lamp and a light-intensity sensor, eg an ORP 12 light-dependent resistor.

An interesting variation is to use a 12V ('camping') strip light rather than a bulb — this tends to act as a line source and give more of a  $1/r$  variation.

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## 5 A visit involving an audio shop or stage production to investigate matching impedances, eg an amplifier with a speaker or an electric guitar with an amplifier

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### *Introduction*

The impedance of discrete systems have to be 'matched', eg an amplifier with a speaker or an electric guitar with an amplifier.

Students should be able to explain: What does this mean? Why is this important? What are the principles? Students should make a note of relevant numerical values.

### *Suggestions for practical work*

Students could do an experiment to find the internal resistance of a power supply by investigating how the electrical power delivered to a load varies with resistance.

Apparatus that students will need include a low-voltage supply or dry cell or solar cell and a variable resistance box which includes values either side of the internal resistance of the supply.