

# GCE

## Edexcel GCE in Physics

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Assessments for Unit 6

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# Introduction

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The material in this booklet is confidential and is intended only for use within centres. This document, or any part of it, must not be removed from the centre's premises.

This booklet contains five practical briefings and plans that may be used for the assessment of the Edexcel GCE in Physics Unit 6: Experimental Physics. The briefings and, where necessary, the plans, may be issued to students for the sole purpose of carrying out an assessment for unit 6 under supervised conditions. These materials must not be used for practice or any other purposes. Tutors must ensure that students do not remove any of these materials from the centre, even after completing their practical assessment, as the materials will be used by other centres, both this year and in subsequent years.

There are many suitable practical experiments that could be employed for the assessment of unit 6. It is important to realise that the practical experiments in this booklet are not intended to be either prescriptive or restrictive, and are provided as an illustration of the forms of practical assessments that would be acceptable.

Tutors should ensure that they are familiar with the requirements of the practical assessment as described in the Edexcel GCE Physics specification before their students commence any assessed work for unit 6. For guidance on the assessment of unit 6 and for practical assessments that may be used for training purposes please see the booklet: *Guidance for the A2 practical assessment*. This booklet is available on the Edexcel website.

# Briefings and Plans

## Briefing 1: Crossing the Tracks

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At a railway crossing the gates are lowered to keep the traffic and the train safely apart. When the train has passed there must be a time delay before the gates can be opened safely. Originally each crossing had a keeper whose job was to open and close the gates safely, by hand! He could see when the train had safely passed but all this is now done quite safely by electrical methods.

The gate machinery can be started by an electronic switch which can be set to come on and open the gates when the voltage across it has fallen to a certain value. One way of achieving this is to allow a capacitor to discharge through a resistor and to use the voltage across the resistor to trigger the switch. As the capacitor discharges the discharge current decreases and so the voltage across the resistor drops.

The current,  $I$ , through the resistor after a time  $t$  is given by

$$I = I_0 \exp^{-t/RC}$$

and so,  $V$ , the voltage across the resistor will be given by

$$V = V_0 \exp^{-t/RC}$$

where  $C$  is the value of the capacitor,  $R$  is the value of the resistor and  $V_0$  is the initial voltage used to charge the capacitor.

Plan an experiment to check the equation above and then to use your data to design a model of this system. Your model will use 6V as the charging voltage and you should find values for  $R$  and  $C$  so that the voltage across  $R$  falls to 3V in 15 seconds  $\pm$  2 seconds after the train passes, or in your model, after the switch is closed. You will then test your design to determine how closely your circuit fits the criterion. The product  $CR$  is called the time constant of the discharge.

# Plan 1: Crossing the Tracks

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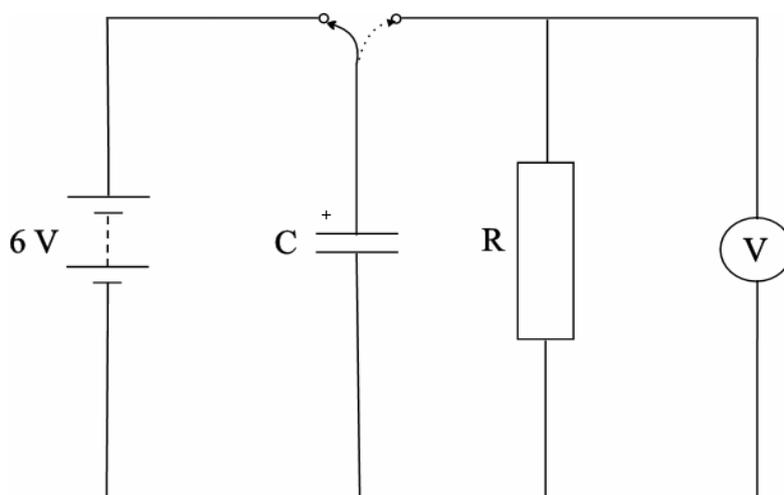
## Apparatus

- 6V dc power supply – this might be a battery pack
- Multimeter
- Stopclock
- Selection of resistors and capacitors
- Switch.

## Design

1. Choose a resistor that is at least an order of magnitude smaller in resistance than the resistance of the multimeter, but large enough to give a reasonable time constant with a moderate sized capacitor. A resistor of  $10\text{ k}\Omega$  would be suitable and with a  $6\text{ V}$  battery there will also be a suitable initial current. You can change this later on to get a better solution.
2. Use the equation for the time constant to show that a  $1000\text{ }\mu\text{F}$  capacitor with the  $10\text{ k}\Omega$  resistor will give a time constant of 10 seconds.
3. Connect the  $6\text{ V}$  supply,  $1000\text{ }\mu\text{F}$  capacitor and the  $10\text{ k}\Omega$  resistor as shown in the circuit diagram. The capacitor connections can be made by moving one end of an ordinary lead. Then switch the multimeter to a suitable scale and connect it in parallel with the resistor.

## Circuit



## Method

4. To charge the capacitor, briefly connect the capacitor to the power supply and then disconnect it.
5. As you connect the capacitor to the resistor, start the clock and record the voltage and time as the voltage falls.
6. Plot a suitable graph to test the equation  $V = V_0 \exp(-t/CR)$  and read from your graph the time taken for the voltage to fall from the initial value,  $V_0$  (ie approximately  $6\text{V}$ ) to  $3\text{V}$  by this combination of  $R$  and  $C$ .

7. Use this data to calculate suitable values of  $R$  and  $C$  so that when they are used as above the voltage falls from  $V_0$  to 3 V within the time interval stated. Now set up the circuit using your chosen values of  $R$  and  $C$ . Repeat the experiment above and measure the time it takes for the voltage to fall. Compare your measured time with the theoretical time.

### Analysis

8. Use the uncertainties in the component values to calculate the uncertainty in the time constant,  $CR$ . Consider other sources of uncertainty and compare the overall uncertainty with the variation in 7 and comment on whether your design is suitable.

### Safety

1. The capacitor should have a rated voltage of at least 6 V and must be connected with the correct polarity in the circuit.
2. The circuit arrangement should be checked before it is used.

## Briefing 2: Damped Pendulum

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A clock pendulum will lose energy because of drag as it passes through the air. This energy is usually replaced by a coiled spring or a falling weight. In order to design a clock that will run for the desired length of time without re-winding (or restoring the falling weight) it is necessary to determine the energy lost during that time.

To determine the energy loss it is necessary to find a value for the damping constant and this can be obtained by looking at an oscillating pendulum. When the pendulum is released the amplitude  $A$  is found to decrease exponentially and after  $n$  swings it is given by

$$A = A_0 \exp(-kn)$$

where  $A_0$  is the original amplitude and  $k$  is the damping constant.

You are to perform an experiment to determine the decay constant for a simple damped pendulum whose period is about 2 s. Your pendulum will need greater damping than a clock so that the experiment does not take too long. Damping can be provided by making a cone from an A4 sheet of paper and sliding it down the string to sit over the bob.

When you have measured the oscillations you should use your data to find a value for  $k$ . Use your value for  $k$  to find the number of oscillations it takes for the amplitude to halve, that is the number of oscillations for 75% of the initial energy to dissipate.

Compare this theoretical number with your data. Also compare the actual period with the theoretical value given by the simple pendulum equation.

Assuming that the pendulum will be wound up when it loses 75% of its energy you can find the time elapsed between windings.

# Plan 2: Damped Pendulum

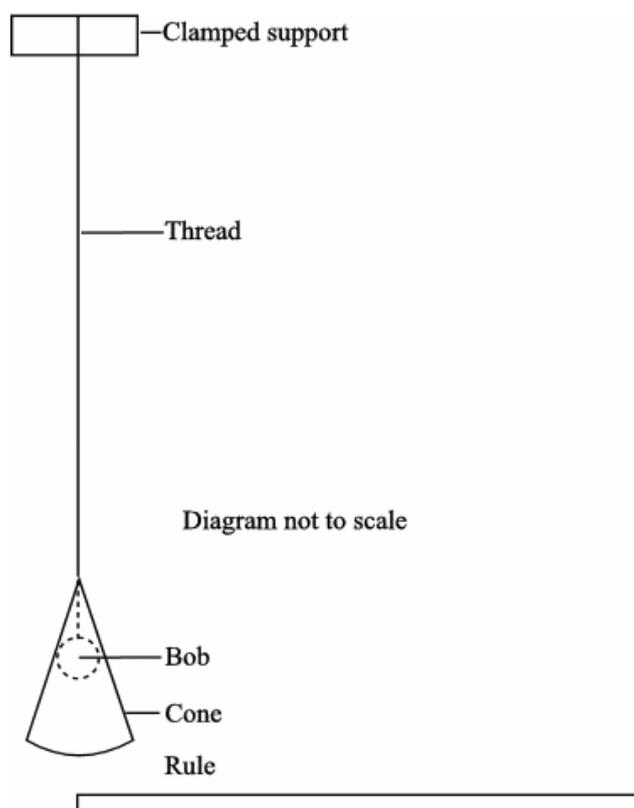
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## Apparatus

- Pendulum bob
- Thread
- Sheet of A4 paper
- Metre rule
- Access to all normal laboratory equipment.

## Design

1. Use the formula  $T = 2\pi\sqrt{l/g}$  to calculate the length of thread needed to give the pendulum a period of 2.0 s. Use a retort stand to suspend the bob with this length of thread and make an experimental determination of the period.
2. Make a cone using the A4 paper and Sellotape. Slide it down the thread and re-hang the pendulum at the same length as before, as shown in the diagram. Place the metre rule under the pendulum. Swing the pendulum and adjust the size of the cone if the damping is too great or too little. Fix the cone to the bob to ensure that the length remains constant.



## Method

3. Pull the pendulum to one side and record the initial amplitude  $A_0$  by looking vertically down past the pendulum to the metre rule below.
4. Release the pendulum and record the amplitude each time the pendulum returns to its maximum displacement on that side.

## Analysis

5. Plot a suitable graph so that you can determine  $k$ . Use error bars to determine the uncertainty in your value for  $k$ .
6. Find the percentage difference between the theoretical period given by the equation and the value you found by measurement. Comment on this difference with reference to the uncertainty in  $T$ .
7. Use the equation to find the theoretical number of swings for the amplitude to halve and compare this number with the number you found from your table of data. Hence find the time elapsed between windings.

## Safety

1. Secure the stand on the bench with a G-clamp or a heavy weight so that it does not topple over.

## Briefing 3: A Diode Thermometer

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In order to control an orbiting space probe, and to use it to best advantage, it is important to monitor the temperature of the probe's different parts. The temperature is subject to large fluctuations depending largely on whether the probe has sunlight falling on it or it is in the Earth's shadow. Weight is at an absolute premium and an electrical device provides a usable output directly. So a research student suggests that a diode be used as a thermometer since diodes can be very small and are stable over a wide temperature range. If a diode is connected so that it will conduct, with the voltage  $V$  kept constant, then the current  $I$  through the diode is given by

$$I = I_0 \exp(-eV/2kT)$$

where  $T$  is the Kelvin temperature and  $I_0$  is the theoretical current at absolute zero;  $e$  is the charge on the electron and  $k$  is Boltzmann's constant ( $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$ ).

You should plan an investigation into the behaviour of a diode to see if it can be used as a thermometer, with the current  $I$  giving a reliable indication of the temperature over as large a range as possible.

You are to connect a diode to a power supply, such as a battery, so that it conducts. Set the voltage across the diode to about 0.6 V by connecting a variable resistor in series with the diode. A 1 k $\Omega$  variable resistor is suitable and this will limit the current through the diode to a few mA. Record this voltage and use the variable resistor to keep the voltage at this value as you vary the temperature and take readings of the temperature and the current. Use your data to plot a graph from which you can determine a value for  $e$ , the charge on the electron.

In order to find out how good the diode will be as a thermometer you can do two tests. You could compare your value for  $e$  with the accepted value and also you could measure room temperature with a mercury-in-glass thermometer to see how it compares with the temperature as measured by the diode.

# Plan 3: A Diode Thermometer

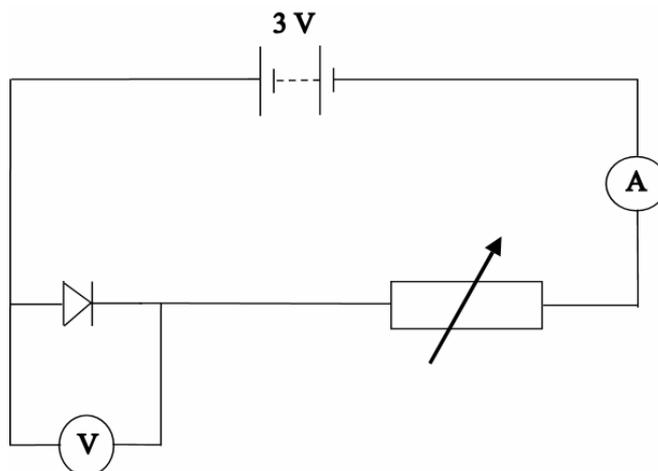
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## Apparatus

- 3V dc power supply – this might be a battery pack
- Ammeter
- Voltmeter
- 1 k $\Omega$  variable resistor
- Diode
- Mercury-in-glass thermometer range  $-10^{\circ}\text{C}$  to  $110^{\circ}\text{C}$
- Access to all normal laboratory equipment including ice.

## Design

1. Connect the diode in series with the power supply, ammeter and variable resistor as shown in the circuit diagram. Ensure that the diode is forward biased. If using multimeters you should check that one is set on a voltage range and the other on a current range. Connect the voltmeter across the diode. You might need an additional series resistor as the temperature rises - 470  $\Omega$  should be suitable.



2. Place the diode and a thermometer in a beaker or a boiling tube with some water and ice. Wait until the thermometer reads  $0^{\circ}\text{C}$  and adjust the variable resistor until the voltmeter reads about 0.63 V. Write down this voltmeter reading  $V_0$ .
3. Record your value of the current at  $0^{\circ}\text{C}$  and call it  $I_{ice}$ .

## Method

4. Remove the ice and raise the temperature of the water by about  $10^{\circ}\text{C}$ . Adjust the resistor until the voltmeter reads  $V_0$  and record the temperature and current.
5. Heat the water and repeat step 4 at suitable intervals up to  $100^{\circ}\text{C}$ . Let your value of the current at  $100^{\circ}\text{C}$  be  $I_{steam}$ .
6. Remove the diode and the mercury-in-glass thermometer from the water and allow them to cool to room temperature.
7. Adjust the diode voltage to  $V_0$  and record the current  $I_{room}$ . Use the mercury-in-glass thermometer to measure room temperature.

## Analysis

8. Take logarithms of the equation in the briefing and use the result to find a suitable graph to plot to obtain a value for  $e$ . Compare your value with  $1.6 \times 10^{-19} \text{ C}$ .
9. Find a value for room temperature from the equation

$$T = 100 \times \frac{(I_{\text{room}} - I_{\text{ice}})}{(I_{\text{steam}} - I_{\text{ice}})}$$

Compare this value with the thermometer reading of room temperature.

10. Use the results of both comparisons, in steps 8 and 9, to comment on whether the research student's idea will work on the spacecraft.

## Safety

1. Ensure that the beaker is stable on the tripod.
2. Keep the electrical leads away from any hot apparatus.
3. Ensure that the gas supply to the Bunsen burner is secure.

## Briefing 4: Measuring Mass in Space

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In order to determine the mass of an object it is usual to place the object on a top pan balance. In this way the Earth's gravitational field provides a force (proportional to the mass) that can be balanced by a known force. From the weight the mass can be calculated.

When a space vehicle is in flight all the objects inside are, in effect, falling freely so other means are required to measure the mass of an object. One such method might involve fixing the object between two opposing springs in a pull-push arrangement. When caused to oscillate, the period  $T$  depends on the mass  $m$  of the object and the combined spring constant  $k$  such that

$$T = 2\pi \sqrt{m/k}$$

You are to produce a calibration graph that would enable an astronaut to read off a value for mass from her measurement of  $T$ . The astronaut will also want to know how accurate her measurement of mass is likely to be.

First find the spring constant for a single spring from a force-extension graph.

You should then use the same single spring to produce the calibration graph for the astronaut. You can see to what extent both methods produce the same value for the spring constant and hence assess the reliability of this method in space.

You should test your calibration graph by 'weighing' an unknown object in this way and comparing your value with the value given by a top pan balance.

# Plan 4: Measuring Mass in Space

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## Apparatus

- Spring – such as 2 cm expendable spring
- 2 x Retort stand boss and clamp
- 1 x 50 g mass and 3 x 100 g slotted masses and one hanger
- Metre rule
- Stopclock
- Unknown mass of about 200g
- Access to all normal laboratory equipment including a top pan balance

## Design

1. Suspend the spring and mass hanger from one retort stand. Support the metre rule in a vertical position using the second retort stand. Place the metre rule close to the spring. Note the reading on the rule at the bottom of the hanger.

## Method

2. Add the 50 g mass to the hanger and measure the extension of the spring. Repeat for up to 350 g.
3. Measure the time period  $T$  for vertical oscillations of the hanger with the added 350 g.
4. Decrease the mass, in stages and measure the corresponding time period for vertical oscillations. Record your values for  $m$  and  $T$ .
5. Remove the hanger and secure the unknown mass on the end of the spring. Record the new time period  $T_x$ .

## Analysis

6. Plot a graph of force against extension and measure the gradient to find a value for  $k$ .
7. Plot a suitable graph of your readings for  $m$  and  $T$  to find a second value for  $k$ .
8. Determine the percentage difference between your two values of  $k$ .
9. From your second graph and your value of  $T_x$ , determine the mass of the unknown object.
10. Use the top pan balance to check your results and then draw a conclusion about this method of measuring mass.

## Safety

1. Since the values of mass in this experiment are small there is little risk involved in using them. Care should be taken to keep the amplitude of the oscillations within reason so that the masses do not fly off the spring.
2. The retort stand supporting the spring must be secure. Use a G-clamp or a heavy weight so that it does not topple over.

## Briefing 5: Low-Energy Light Bulbs

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It will soon be impossible to buy hot filament incandescent light bulbs; instead only low-energy ones will be on sale. Organisations like your school, which has a lot of light bulbs, are interested in the effect of this change.

The manufacturers claim that a low energy light bulb gives out as much light as a conventional incandescent one but draws less electrical energy from the mains. You are invited to try to come to a conclusion about this claim.

You are to use a light dependent resistor (LDR) to investigate how the light output from a conventional light bulb varies with distance from the bulb. You will then investigate the light output from a low energy bulb in the same way and use your results to comment on these claims. You may assume that the manufacturer's electrical power rating is an accurate measure of the power drawn from the mains.

An internet site suggests that the resistance of the LDR will be affected by the intensity of light from a point source such that the resistance  $R$  of the LDR at a distance  $d$  from the light source is given by

$$R = k d^p$$

where  $k$  and  $p$  are both positive constants.

You should take steps to ensure that it is only the light from the bulb that falls on the LDR.

Your teacher will provide you with access to a conventional light bulb and a low energy one. You are to plan an investigation that will provide scientific data to support your comments on the claim.

# Plan 5: Low-Energy Light Bulbs

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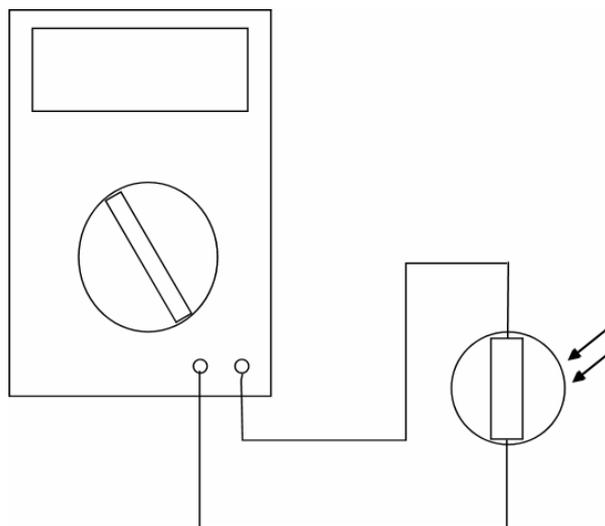
## Apparatus

- 60 W incandescent light bulb
- Low-energy light bulb of nominal equivalent output light power
- Light Dependent Resistor (LDR)
- Digital Multi Meter (DMM) with resistance ranges
- Paper for light shield
- Metre rules or measuring tape
- Access to all normal laboratory equipment.

## Design

1. It will be best to do this in a darkened laboratory. If this is not possible then use the paper to make a shield for the LDR such that it excludes any light other than that coming from the bulb. Place the bulb against a dull background to minimise the effect of background light.
2. Connect your LDR to the DMM as shown below and select a suitable resistance range. You could point the LDR at the bulb when it is off, move it over the range that you will use in the experiment and record a few DMM readings to investigate the effect of the background light.

## Circuit



## Method

3. Set up your LDR a reasonable distance from the light bulb and turn on the bulb. Select an appropriate scale on the DMM and record the resistance  $R$ . Make sure your shield does not exclude light from the bulb and allows in as little other light as possible.
4. Measure the distance  $d$  from the source to the LDR.
5. Vary  $d$  over as wide a range as possible and record  $R$  and  $d$ .
6. Repeat the experiment using the low-energy bulb.

## Analysis

7. Plot a suitable graph so that you can find a value for the constants  $k$  and  $p$  for both bulbs. Plot error bars and use them to determine an uncertainty for the values.
8. Use your two values for each of  $k$  and  $p$  to evaluate the claim that both lights give out the same light. Consider to what extent any difference between your graphs can be accounted for by the uncertainties in the investigation.

## Safety

1. The filament light bulb will become hot and should not be touched until it has cooled down, which will be a few minutes after being switched off.
2. Both lights are fragile and care should be taken that they cannot be easily dislodged during the experiment either by deliberate or accidental action. They should be mounted on a secure base.

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