Teaching The New GCSE Physics Content
I.O.P day
@ Rugby School 2017

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Blowing Balls

A qualitative approach to F=ma.
Pupils blow through the straws (with a comparable force!) and see which travel faster. This works very well with the ESA video clip provided on the pen drive.
For less able students this is found to be a better approach than a full F=ma practical approach with trolleys or as a lead in to the activity.
Discussions leading on from this can discuss why lorries find it hard to brake and motorbikes can accelerate easily.
**F=ma with constant mass**

This is a standard set up with a double mask to measure accelerations directly. It is also about shuffling the masses from the trolley to the mass holder to ensure that the **total mass of the system remains constant**: an idea that may be forgotten by some students!

The track has already been Friction compensated for you (ASK if unsure what this means!), First set the QED to S - Acceleration

- D – Select number
- S – Reading= 1
- D – Mask size
- S – Size in cm =5(press 5 times)

Press the yellow button, it will have “Waiting…”

Measure the acceleration with 50g pulling down (0.5N). Put the remaining three 50g masses on the cart. Then do the same with 100g pulling down (1.0N), each time ensuring the total mass of the whole system is the same.

Continue until you’ve measured all 4 accelerations, recording your results.

Light gate clamped so that the mask cuts the beam twice.

Mass – stays the same, as the mass is only moved from the cart to the mass hanger, and not added/subtracted.

Force – Changes, as more mass is added to the hanger and taken off the cart.

Acceleration – is measured using the lightgate.

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F=ma with a constant mass system continued…
The whole system which is accelerating is the cart plus the string and mass hanging off the end. Find the total mass of the cart plus string and masses.

Total mass of the system = __________________ grams
= __________________ kilograms

You are keeping the mass of the whole system the same. The pulling force is altered by changing the mass hanging off the end of the string by removing individual masses from the trolley. Remember that you are keeping the mass of the whole system the same.

<table>
<thead>
<tr>
<th>Mass Hanging (g)</th>
<th>Weight of Hanging Mass (Pulling Force) (N)</th>
<th>Acceleration of System (m/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What happens to the acceleration when the weight (pulling force) increases?
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
Using balloons, fishing line, straws and some sellotape students can be introduced to the ideas of Newton’s 2nd and 3rd laws by racing inflated balloons – one with added mass.

Our technicians have come up with a method of using bulldog clips so that both balloons can be released simultaneously; clothes pegs would also do the trick!
Specific Heat Capacity of Metals (Using a Method of Mixtures)

Experiment instructions:
Record the temperature of the water bath and note the metal mass (see table below). Measure 50ml (50g) of cold water and pour into the thermal drinking mug. Take a reading of the temperature of the water. Quickly and carefully remove a metal block from the water bath using the tongs and place in the drinking mug, replacing the lid. Allow the temperature of the water to adjust and note the new equilibrium temperature. The method can be used to find the SHC of the metal block using the idea that the energy lost by the metal cube is equal to the energy gained by the water:

Energy Lost by Metal Block = Energy Gained By Water

Mass of Block X SHC of block X temp drop of block = Mass of Water X SHC of water X temp rise of water

Safety notes:
Please take care when handling hot objects and boiling water.

<table>
<thead>
<tr>
<th>Product</th>
<th>Mass (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass</td>
<td>64.452</td>
</tr>
<tr>
<td>Copper</td>
<td>71.052</td>
</tr>
<tr>
<td>Iron, 20°C</td>
<td>63.021</td>
</tr>
<tr>
<td>Lead</td>
<td>85.4770</td>
</tr>
<tr>
<td>Tin</td>
<td>74.874</td>
</tr>
<tr>
<td>Zinc</td>
<td>53.052</td>
</tr>
</tbody>
</table>
Specific Heat Capacity of Water

Safety notes:-
- Please turn off the Power Supply unit after use.
- Refrain from taking the immersion heater out of the water as it becomes very hot.

This is a simple and cheap set up to determine the specific heat capacity of water using an electrical immersion heater and a well-insulated container to reduce heat losses to the surroundings. The energy supplied is measured using a meter power output and a stopwatch.

NB as the resistance of the heater will increase with temperature it is advisable for students to take an average power from the initial and final power readings.

Average power x time = mass of water x c x temperature rise

Mass of water can be found from volume with density of water taken as 1g/cm³

Discussions could involve what effect heat losses could have on the value of specific heat capacity they obtain.
Specific Heat Capacity of Aluminium

Safety notes:-
- Please turn off the Power Supply Unit after use.
- Refrain from taking the immersion heater out of the block as it becomes very hot.

Experiment instructions:-

The apparatus has already been set up for you to use.
Firstly take a reading from the thermometer, which is inserted in the 1kg Aluminium block.
Switch the power on to the PSU, which will turn on the immersion heater inside of the Aluminium block and at the same time start the stopclock.

As the resistance of the heater will change with temperature the students should measure the initial and final power values and use an average value. A minimum temperature rise of 20 °C is recommended.

Average power x time = mass of aluminium block x c x temperature rise

Discussions could involve what effect heat losses could have on the value of specific heat capacity they obtain.
Leslie’s cube

Safety notes:

Please use the gloves provided to handle the cube after use as becomes very hot.

Experiment instructions:

First fill the kettle and switch on to boil the water. Turn the dial on the Ed-spot galvanometer to read X.01 and ensure that the centre scale line is set at zero. Fill the cube full of boiling water and replace the lid. Rotate the cube by gently turning it on its turntable, to view the different readings given on the galvanometer for each of the different sides of the cube i.e. Cu, White, Black and silver.
Alternatively you can use the Infrared thermometer instead of the galvanometer.
Thermos flask V Beaker Cooling Practical

Safety: Care must be taken when handling hot water.

We have 12 beakers and 12 thermos flasks and so do this as a whole class experiment.

Switch on the kettle ensuring it has water in. Pour 250ml of boiling water into both the flask and the beaker. Place a thermometer into each of them. Observe the different rate of cooling for each the beaker and the flask. Students can record the temperature at set time intervals and plot cooling curves on the same graph axis.

We usually just get students to take a reading at the start of the lesson, go through the theory, and then look at the temperature at the end of the lesson. The students are often surprised by how large the differences are – and it is much better than just discussing it!
IR Heater and IR Absorption

Safety notes:
- Please take extreme care as the heater and glass plate become very hot.

Experiment instructions:
Switch on the heater, and the IR thermometer, point the thermometer at the glass plate in front of the heater, and take a reading. Remove the glass plate and take a second reading, compare your readings.

Now place the coins which have been stuck to the metal sheets with wax in front of the heater. One has a black coating the other silver – this is a nice demo of the absorbing properties of different coloured surfaces of infrared radiation.
I always show this picture to discuss William Herschel’s discovery of infrared before showing this demonstration. I was surprised many years ago when one pupil put up his hand and said ‘sir her was my ancestor’!

Project a spectrum from the glass prism onto the screen. Move the infrared detector slowly through the spectrum from violet to red and past red you should see the meter register a large response to the infra red.
Pepper’s Ghost

**Experiment instructions:-**

The apparatus is ready for you to use. Using the small grey remote control provided, switch **on** the background (picture of chairs and table in garden) by pressing **Number 1 on**. To make the ghost appear in the picture (next to the chair) press **Number 2 on**. **Pepper's ghost** is an illusion technique used in theatre, haunted houses, dark rides and in some magic tricks. Using plate glass, Plexiglas or plastic film and special lighting, it can make objects seem to appear or disappear, to become transparent, or to make one object morph onto another. It is named after **John Henry Pepper**, who popularized the effect.

**Safety notes:-** Please ensure that you turn the apparatus off, by pressing **Number 2 off** and **Number 1 off** on the small grey remote control.
Pepper’s Ghost continued…

How Does It Work (with an IGCSE Exam Question)?

2. Pepper’s Ghost is a theatre effect used to make it appear that there is an image on stage. The diagram shows a theatre viewed from above.

   A sheet of glass is placed on the stage. A brightly lit actor stands behind a curtain at the side of the stage.

   The audience sees the reflection of this actor in the glass.

(a) Add a ray diagram to show how light from the actor appears to come from the image. (3)

(b) The image formed by the glass is a virtual image.

   State what is meant by the term virtual image. (1)
SNELLS LAW Refraction of Light Rays by a Glass Block

In the following experiment you will use a photocopied protractor. Notice that all angles are measured from the NORMAL.

Place the glass block on the sheet of A4 paper with its frosted face downwards. It should be positioned so that one edge of the block is one the line marked "interface" (see below).

You have sent rays of light towards one side of the glass block at various angles indicated in the table and measure the angles of the rays of light passing through the glass.

Copy the title Refraction of Light Rays into your notes. Copy and complete the table of results shown below.

The ray of light sent towards the glass block is called the INCIDENT RAY. The ray of light passing through the glass is called the REFRACTED RAY.

Point the incident ray along the angles indicated below and then records the angle of refraction.

<table>
<thead>
<tr>
<th>Angle of incident ray</th>
<th>Angle of refracted ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°</td>
<td></td>
</tr>
<tr>
<td>30°</td>
<td></td>
</tr>
<tr>
<td>40°</td>
<td></td>
</tr>
<tr>
<td>50°</td>
<td></td>
</tr>
<tr>
<td>60°</td>
<td></td>
</tr>
</tbody>
</table>
1. What do you notice about the angle of incidence compared with the angle of refraction?

2. What happens to the angle of refraction when the angle of incidence increases?

3. Check to see if the angle of refraction is directly proportional to the angle of incidence. Show clearly how you did this (do NOT use a graphical method)

4. Plot a graph of the angle of refraction against the angle of incidence for light going from air to glass. Is it slightly curved? Does it show direct proportion?

5. The following diagrams show rays of light entering a glass block from air. Only two of them are correct. Copy the correct diagrams.

6. As well as refraction, what else does light undergo when it hits the glass?
Two versions of a light pipe using water jets are set up using lasers. Using a light coloured bowl allows the colours to be seen more vividly and students love to put their fingers in the colourful water stream!

A video clip of the beautiful horsetail falls (Yosemite USA) where this effect occurs under the right conditions is on your pen drive.
Determining the Speed of Waves in a Solid aka standing waves in a string!

Please take care when using the strobe as flashing lights may cause dizziness. (Do not use if you suffer from epilepsy).

**Experiment instructions:-**

The apparatus will be set up as in the picture. Turn the power to the Signal generator on, you may adjust the dial on the Signal generator to observe the different wave formations using different frequencies. A strobe can be used to freeze the wave. In physics a **standing wave** – also known as a **stationary wave** – is a wave that remains in a constant position.

By recording the frequency from the signal generator and the wavelength of the standing wave you can determine the speed of the wave using $v = f \times \lambda$. 

![Standing Waves](image)
Refraction Frog Demo
Please DO NOT attempt to move the camera attached to the bucket.

Experiment instructions:-
You will find the apparatus as in the picture.
Slowly fill the black bucket containing the frog with water, watch the computer screen and see frog appear, and reverse, if you empty the water out the frog will disappear.
Candle under Water

This is a classic illustration of the idea of the virtual image in a mirror i.e. the fact that the light rays only appear to be coming from the image point! By carefully positioning the 2 candles at equal distances from the class plate and lighting the candle hidden in the box its image appears in the beaker full of water!
Longitudinal and Transverse Waves on a Slinky

Slinkies are useful for illustrating not only transverse and longitudinal waves but also standing waves and interference. Try doubling the rate of vibration of the slinky and then tripling it. A slinky pulse can also be timed and this is an opportunity to use with speed=distance/time calculations; a fuller investigation could be made into how the amplitude of the pulse affects the speed of the pulse. You could even consider the problem below!
Apparent Depth and Refraction

Use the tube to locate the fish with your eye. Now try to spear the fish!
Diffraction of a microwave

Experiment instructions:-
Begin with the two metal plates together, Turn the power supply and the amplifier on, gently pull the plates apart to see the max signal, when gap size is equal to the wave length of the 2.8cm microwave, beyond this gap size the signal decreases and there is less diffraction.

Safety notes:-
Please ensure to turn off the power supply and the amplifier.
Ripple Tank

**Experiment instructions:**

The ripple tank is already set up and levelled for you to use, plug the other lead into the battery pack that runs the motor, and turn on the lamp (switch at the front) of the overhead projector. You can adjust the waves by speeding up or slowing down the motor. With the ripple tank you will find a basket of accessories (feel free to use them) to encounter different wave formations.

**Safety notes:**

Please ensure to turn off the lamp on the overhead projector and unplug one lead to the motor.

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**Observing Refraction:**

The waves travel more slowly in shallow water because of friction with the bottom. With the glass edge parallel to the vibrating beam, students should notice that the wave speed is reduced and wavelength becomes smaller as waves cross the boundary.

With the glass edge at various angles to the incoming waves, students should notice that the waves change direction as they cross the boundary.
Practical Guidance

The tank and the glass plate need to be very clean and free from grease.

To get sufficient change in wave speed at the boundary with the glass:

- Make the water on top of the glass very shallow.

- Pour water into the tank until it just covers the glass and then drain off a little of it. It may be necessary to re-level the tank to ensure that the film doesn’t break up into puddles.

- Use a low frequency, long wavelength (about 10 rev / second).

To get sharp waves, adjust the height of the vibrator so that it is just below the mean water level. The vibrator should just ‘hold up a film of water’ when it is still.

This simple stroboscope enables students to 'freeze' repetitive motions – or to slow them down for closer study. For example, continuous ripples are easier to see by using a stroboscope, especially those ripples with higher frequencies.
Density of regular and irregular objects

In addition to using a mass balance and ruler to calculate the density of regular solids pupils should know about displacement methods using measuring cylinders or Eureka cans.

<table>
<thead>
<tr>
<th>Object</th>
<th>Mass (g)</th>
<th>Volume of Water Before Object Added (cm(^3))</th>
<th>Volume of Water After Object Added (cm(^3))</th>
<th>Volume of Object (cm(^3))</th>
<th>Density (g/cm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This is a good opportunity to discuss precision of different measuring cylinders and accuracy; zero errors on mass balances, parallax and eye level readings, using a horizontal surface etc. Also it may give you the chance to introduce Vernier scales to more able pupils.

**Question:** How can we find the density of a floating solid?
**Vernier caliper**

Instructions on use

- The Vernier caliper is an extremely precise measuring instrument; the reading error is $1/20 \text{ mm} = 0.05 \text{ mm}$.
- Close the jaws **lightly** on the object to be measured.
- If you are measuring something with a round cross section, make sure that the axis of the object is perpendicular to the caliper. This is necessary to ensure that you are measuring the full diameter and not merely a chord.
- Ignore the top scale, which is calibrated in inches.
- Use the bottom scale, which is in metric units.
- Notice that there is a fixed scale and a sliding scale.
- The boldface numbers on the fixed scale are centimeters.
- The tick marks on the fixed scale between the boldface numbers are millimeters.
- There are ten tick marks on the sliding scale. The left-most tick mark on the sliding scale will let you read from the fixed scale the number of whole millimeters that the jaws are opened.

![Diagram of Vernier caliper](image)

- In the example above, the leftmost tick mark on the sliding scale is between 21 mm and 22 mm, so the number of whole millimeters is 21.
- Next we find the tenths of millimeters. Notice that the ten tick marks on the sliding scale are the same width as nine tick marks on the fixed scale. This means that at most one of the tick marks on the sliding scale will align with a tick mark on the fixed scale; the others will miss.
- The number of the aligned tick mark on the sliding scale tells you the number of tenths of millimeters. In the example above, the 3rd tick mark on the sliding scale is in coincidence with the one above it, so the caliper reading is $(21.30 \pm 0.05) \text{ mm}$.
- If two adjacent tick marks on the sliding scale look equally aligned with their counterparts on the fixed scale, then the reading is half way between the two marks. In the example above, if the 3rd and 4th tick marks on the sliding scale looked to be equally aligned, then the reading would be $(21.35 \pm 0.05) \text{ mm}$.
- On those rare occasions when the reading just happens to be a "nice" number like 2 cm, don't forget to include the zero decimal places showing the precision of the measurement and the reading error. So not 2 cm, but rather $(2.000 \pm 0.005) \text{ cm}$ or $(20.00 \pm 0.05) \text{ mm}$. 
Density of Air

Experiment instructions:-

Withdraw the plunger of the syringe to a volume of 20 ml. with the tap closed to remove the air. The pre-cut plastic trunking can be used to hold the syringe barrel in place. Find the mass of the syringe without air.

Turn the tap through 90 degrees, you will hear air entering the syringe. Find the mass of the syringe again. Subtract the mass of the empty syringe to get the mass of the air.

This experiment not only shows that air ‘weighs something’ but can give a remarkably accurate value for the density of air 1.02kg/m³

With A level students I do this as an activity on combining uncertainties:

<table>
<thead>
<tr>
<th>Value</th>
<th>Actual Uncertainty</th>
<th>Percentage Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of Syringe without Air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of Syringe with Air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of Air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of Air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density of Air</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Density of Air = ___________ g/cm³ +/- ___________ g/cm³

Density of Air = ___________ kg/m³ +/- ___________ kg/m³
A curious phenomenon to get students thinking

Density of a water/ethanol mix: Add an equal volume of ethanol to the water carefully using a syringe so they don’t mix. Mark the meniscus with a marker pen.

Seal the tube with a rubber bung and observe the new volume. What is going on?

There is in fact a 4% difference in density due to the way the ethanol and water molecules pack differently.
Bunjee Challenge: Aimed at the More Able Students

In this activity students use a lego man on a stretchy cord. They can find the stiffness using \( F = kx \) from a Hook’s Law experiment (or use a graph provided) and calculate elastic potential energy using \( \frac{1}{2}kx^2 \).

By measuring the mass of their lego man they can plot the gravitational potential energy lost with height dropped and where the graphs intercept (i.e. all gravitational potential energy is converted to elastic potential energy) they can calculate the maximum extension of the cord.

They can then estimate a safe drop height and release their bungee man from that height to see if they survive the fall!
Hooke’s Law Experiment

**Loading the Spring**

<table>
<thead>
<tr>
<th>Mass Added (g)</th>
<th>Force (N)</th>
<th>Pointer Position (cm)</th>
<th>Extension (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>300</td>
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<td>400</td>
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<td>500</td>
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<td>600</td>
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<td>700</td>
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<td>800</td>
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<td></td>
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<tr>
<td>900</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Plot a graph of Force against Extension

Calculate the **gradient** of the straight line part of your graph (using gradient = rise/run)

This is called the **SPRING CONSTANT** \( k \) and has units of N/m.

Hooke’s Law says that the extension is directly proportional to the force applied.

This can be written as \( F = k x \)

**Students can go on to investigate the effects of adding springs in series and parallel (and very able one might be able to work out a formula for combining spring constants!)**
This activity is to consider how using matched (i.e. same resistance) and unmatched bulbs can cause confusion to some students.

Set up a circuit with 2 matched bulbs in series and parallel and compare bulb brightness.

Now repeat this but using 2 unmatched bulbs.

Get pupils to discuss the differences they see between the 2 set ups – lots of potential for critical thinking!
Thermistor – Resistance v Temperature

Students can vary the temperature using hot water from a kettle or by using melted ice: the volume should be sufficient to fully submerge the thermistor bead but if the mass is too large it will take ages for the temperature to change!

Make sure you use a negative temperature coefficient thermistor where the resistance decreases with temperature to avoid confusion!

Pupils should record the resistance directly on a multimeter (or you may wish to use a voltmeter and ammeter with more able students) and temperature. Again with more able students get them to describe what the rate of change of resistance is doing with increasing temperature.
# Resistance and Wire Length Investigation

![Circuit setup](image)

This is a good exercise in getting pupils to correctly set up voltmeters and ammeters in a circuit and in calculating resistance.

Stress the importance of the need to repeat the procedure as they may position the crocodile clips in different places and the importance of taking averages.

You can also discuss methods of ensuring the temperature of the wire doesn’t change e.g. limiting current, switching circuit off between readings.

Students should plot a graph of resistance against length.

With able students you may wish to get them to determine the resistivity of the metal from the gradient of the graph. They will need to measure the diameter of the wire using a micrometer.  
\[ R = \rho l / A \]  
so the gradient \( X A = \text{resistivity} \)
Current and P.D. for a Filament Lamp

A worksheet we use with Year 11 students

We already know that: more p.d. (voltage) applied across something, means more current through that thing. However, the exact relationship between p.d. and current is different for different devices. This experiment is to find out how p.d. and current are related for a lamp.

Set up carefully the circuit shown below:

Tips for success:
- Don't confuse a voltmeter with an ammeter
- Vary the p.d. and current with the variable resistor. (You can also vary the voltage on the power pack.)

Results
Complete the table:

<table>
<thead>
<tr>
<th>P.D. (V)</th>
<th>Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Highest P.D. value</td>
<td></td>
</tr>
</tbody>
</table>

Now plot a graph on the graph axes provided. Draw a best-fit curve.

1. From the shape of your graph, explain what happens to the resistance as the p.d. is increased.

2. To check your answer to question 1, calculate the resistance when the p.d. = 1.0V, 3.0V and 4.0V.
Conservation of momentum only applies in a closed system where no external forces e.g. friction are going to exchange momentum to another object.

We get students to use a track to investigate a collision between a stationary cart and a moving cart which join together with a common velocity after the collision first without compensating for friction and then by applying friction compensation and calculating the % difference in momentum before and after the collision.

<table>
<thead>
<tr>
<th>Mass of A (g)</th>
<th>Vel. of A (m/s)</th>
<th>Momentum of A (g.m/s)</th>
<th>Mass of B (g)</th>
<th>Mass of A + B (g)</th>
<th>Vel. of A and B (m/s)</th>
<th>Momentum of A and B (g.m/s)</th>
</tr>
</thead>
</table>

**Friction Compensation** – the aim is to show pupils how we can compensate for the effects of friction when performing conservation of momentum experiments.
Adjust the level of the track by turning the foot.

To friction compensate the track, the readings from the two light gates must read the same when the cart passes. First set the QED to Speed

2 Readings
10cm mask

Using the two red buttons on the QED, press S–Speed

D – Select number
S - Reading=2
D – Mask size
S – Size in cm =10(press 10 times)

Press the yellow button it will have “Waiting...” then gently push the cart along the track.” Display” will appear on the screen, press the D, this will give you your first reading, press again for your second reading.

### With Friction Compensation

<table>
<thead>
<tr>
<th>Before Collision</th>
<th>After Collision – they stick together</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass of A</td>
<td>Mass of B</td>
</tr>
<tr>
<td>(g)</td>
<td>(g)</td>
</tr>
<tr>
<td>Vel. of A</td>
<td>Mass of A+B</td>
</tr>
<tr>
<td>(m/s)</td>
<td>(g)</td>
</tr>
<tr>
<td>Momentum of A</td>
<td>Vel. of A + B</td>
</tr>
<tr>
<td>(g.m/s)</td>
<td>(m/s)</td>
</tr>
<tr>
<td></td>
<td>Momentum of A and B</td>
</tr>
<tr>
<td></td>
<td>(g.m/s)</td>
</tr>
</tbody>
</table>

\[ \text{Table continues here with columns for Mass of A, Vel. of A, Momentum of A, Mass of B, and other values.} \]
The displacement of a vehicle is the distance moved in a particular direction. Use ticker tape to record the motion of a toy car and plot a graph of its displacement against time. Students usually work in groups of two and each of them needs to obtain their own ticker tape of the motion.

1. Attach approximately 1.0 metre of ticker tape to the roof of the car. Label this end of the tape “Start”.
2. Give the car a quantity of potential energy by pulling it backwards a certain distance. One of you must use a distance of 15cm. Your partner should use a pullback distance of 30cm. You will then compare your final displacement-time graph to see the differences in the motion.
3. Switch on the ticker timer just before releasing the car.
4. Divide the resulting tape into 5 gap sections (0.1 second) by drawing pencil lines as shown below. You should stop after the tenth strip.
Beetle Car with ticker Timer continued…

5. Use the resulting tape to complete the table below of total displacement against time.

<table>
<thead>
<tr>
<th>TOTAL DISPLACEMENT (CENTIMETRE)</th>
<th>TIME (SECONDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.10</td>
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<tr>
<td></td>
<td>0.20</td>
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<td>0.30</td>
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<td>0.60</td>
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<td>0.70</td>
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<td></td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
</tr>
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<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

6. Now plot the graph of displacement against time, labelling the graph as below:

![Graph of Displacement against Time]

Displacement (cm)

Time (seconds)

7. Draw your best fit line. What does your graph indicate about the speed of the car—was it constant, increasing or decreasing?

___________________________________________________________________________

8. Compare your graph with your partner’s
   a) Describe the differences.
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________

   b) Try to explain the differences.
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________
Measuring Latent Heat of Vaporisation

**Experiment instructions:**

The apparatus is ready for you to use. Pour water into the water bath sat on top of the balance until it reads 1000g. Switch on the power meter as indicated in Pic below; select the KWH (Yellow) button. Turn heater to 130°, simultaneously start the stop clock, after a few minutes take a reading using the balance and record the reading from the power meter. Compare with the actual value of 2250 kJ/kg.

**Safety notes:**

Please take care with hot water, ensure not to drop water onto electric sockets.

NB the resistance of the heating element and therefore power will change with temperature; students should record the power at the start and end and take an average.
Determining Focal Length of a Convex Lens

(i) The focusing method
A rough guide to the focal length of a lens can be obtained by focusing light from a distant object, such as the Sun, on to a screen.

(ii) The graphical method
A graph of 1/u against 1/v can be plotted and the focal length (f) found from this. The point where the line intersects either axis is 1/f.

Determining Focal Length of a Concave Lens

A convex lens (focal length f1) is used, in contact with the concave lens (focal length f2). It must be of greater power than the concave lens with one of its faces having the same radius of curvature as one of the faces of the concave lens. The focal length of the combination is then given by

\[ \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \]

The position of this initial image (I') is found, the concave lens is then placed in position and the final image position (I) is located. The focal length of the concave lens is then found using the lens equation.
**Lamps in series**

Aim:- This experiment provides an excellent introduction to the concept of potential difference (voltage). Students observe that two lamps with the same current give out quite different amounts of light and this sets off a discussion. The important point is that both current and voltage determine the brightness of a bulb rather than just the current as some students may think.

Turn ON all three digital multi-meters to measure 600V A.C. Voltage (green spot).

Turn circuit ON by pressing the ‘RESET’ button on the RCD.

Compare the different voltages on the meters.

Turn circuit OFF by pressing the ‘TEST’ button on the RCD.

Heat proof box in place to ensure pupils do not get burn, and also reduce glare on multi-meters display.

**This experiment should only be done by teachers with good knowledge of mains electricity and the dangers. Do remember that you are working with potentially lethal voltages and take extra care. Students should not come near the apparatus when it is being used.**
Fire Syringe

Experiment instructions:-

The instrument has been designed to demonstrate that pressure and temperature are related to each other. When we press down quickly on the plunger, air is compressed inside the tube, igniting a small cotton piece. The fire then instantly goes out, because all of the oxygen in the tube is exhausted.

Unclamp the cap from the upper side and remove the piston from the transparent tube. Take a small piece of cotton, place it at bottom side of the tube, place the piston inside the tube and fix the cap. Fix tightly the cap on the acrylic tube. Ensure that the piston move inside the transparent tube not freely. Keep the piston of the instrument on top most side.

Place the instrument vertically on a sturdy and balanced table. Hold the base of instrument firmly by one hand and push the plunger forcefully in the downward direction with another hand. A spark should produce in the cotton piece.

Safety notes:-

Hold the instrument properly to avoid any injury during performing the experiment.
Always perform the experiment in vertical direction and should not perform the experiment on a slipping surface.
If the plunger moves too tightly, rub some lubricant inside the transparent tube.
If the plunger moves too freely, then tighten the bolt holding the rubber piston or change it with another one.
Boyles Law

Experiment instructions:-

The apparatus has been specially designed to give quick, clear readings which the class can see. A sample of dry air is confined in a tall, wide glass tube by a piston of oil. The volume is found from the length of the air column, which should be clearly visible at the back of the class. The pressure is read from a Bourdon gauge connected to the air over the oil reservoir. This is calibrated to read absolute pressure and is also visible from the back of the class. The foot pump is attached to the oil reservoir and is used to change the pressure.

Safety notes:-

Please do not pump pass the red mark indicated on the Bourdon gauge. It has been known for the glass tube to fly upwards when the gas is at maximum pressure.
Marshmallow

Experiment: Marshmallow Fluff
Place three mini marshmallows in a syringe. Push the plunger down just until it touches the top of the marshmallows. Put your finger over the tip of the syringe to form a seal. Pull up on the plunger.

Marshmallows are basically a foam spun out of sugar, water, air, and gelatin. The sugar makes them sweet, the water and sugar combo makes them sticky and the gelatin makes them stretchy. But the air—which actually makes up most of the confection’s volume—makes marshmallows the tastiest way to encapsulate a gas in a solid. As you pump air out of the jar, the air inside the marshmallow expands and the marshmallow puffs up. Release the seal, and the marshmallows return to their normal size.

1. What happens to the marshmallows?
2. What is being decreased inside the syringe?
3. What is being increased?

Take your finger off the tip. Pull the plunger to the top of the syringe, seal the tip with your finger again and push the plunger down.

4. What happens to the marshmallows?
5. What is being decreased inside the syringe?
6. What is being increased?
7. Write a mathematical equation to show this relationship.
8. Who’s law is this?
The large U-tube manometer is made of clean transparent plastic tubing, secured to a board. It should preferably be attached to the wall. You may find it easier to avoid air bubbles in the manometer if the tube is filled before fixing it to the board. Make a preliminary estimate of the length of water column required. Immerse one end of the tubing in a beaker of coloured water and suck at the other end until there is the required length and finally fix the tube to the board.
Car jack & Evesham pressure box

The apparatus consists of a rectangular box made from melamine covered board, containing a flexible air bag within (which is replaceable should the need arise) and two lifetable platforms giving a 1:4 area ratio.

Procedure:
Connect one outlet to the foot pump
Pump air into the tube. The larger platform will rise
Repeat with two 0.5 kg masses on the larger platform, and still only one on the smaller platform. Again, the larger platform rises first. About twice the difference is obtained.
Repeat using three 0.5 kg masses on the larger platform, arranged as symmetrically as possible. Again, the larger platform rises first.
Finally put four 0.5 kg masses on the large platform with still the one 0.5 kg mass on the smaller platform. Both now rise together, showing that the pressure on each is the same.

Get a student to stand on the car jack board (with something to hold onto!) and get another student to pump the car jack; hydraulic pressure and moments are both involved here!
**Hydrostatic Pressure of different liquids**

*Hydrostatic pressure* is the pressure that is exerted by a fluid at equilibrium at a given point within the fluid, due to the force of gravity. *Hydrostatic pressure* increases in proportion to depth measured from the surface because of the increasing weight of fluid exerting downward force from below.

**Pressure Caused by a Liquid:**

\[ P = h \rho g \]

- Pressure
- Gravitational Field Strength
- Depth of Water
- Density of Water
On the metallic collector dome, the positive charges spread out due to electrostatic repulsion and become uniformly distributed due to the dome's spherical shape. At equilibrium, the potential difference between the collector dome and the generator housing can reach one-half million volts.

When it pointed to earth connected Bunsen burner metal barrel. The air between the collector experiences dielectric breakdown and the generator discharges the accumulated static charge in the form of a spark, and lit up a Bunsen burner.

A brave teacher can light the Bunsen by standing on an insulator touching the dome with one hand and using their finger to light it!
The aim of the experiment is to get students to put into practice the formula $v=2\pi r/T$ and investigate the relationship between the speed of the orbit and the centripetal force (by varying the number of washers); I usually use gravity and orbiting satellites as a context. There are a couple of practical difficulties students will encounter:

1. Maintaining a constant radius: students need to get the speed right which takes practice and make a mark on the string to try to maintain a constant radius orbit!

2. Maintaining a horizontal orbit: if there is a vertical component to the motion then a component of tension will affect the results.

---

When using the stopwatch to measure the time for one revolution, it is better to count the time for 10 revolutions and divide it by 10, thus minimize the error compared to just taking one or few revolutions.

Make sure that you swing the stopper in horizontal circles, not vertical circles.

Maintain the "3 cm" mentioned about during the swinging.

$V=2\pi r / T$

Look for a relationship between $F$ and $V$. 

---

The diagram shows a setup with a glass tube, a nylon thread, a paper clip, and a rubber bung of mass $m$. The setup is used to demonstrate circular motion, where a mass $M$ is swung in a circle using a string.
# Gravity Strength and Speed of Orbit

<table>
<thead>
<tr>
<th>Number of Washers</th>
<th>Time for 10 orbits (s)</th>
<th>Period of orbit T (s)</th>
<th>Speed ( V = \frac{2\pi r}{T} ) (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<td>5</td>
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<td>6</td>
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</tbody>
</table>
**Aquapods**

**Aquapod Bottle Rocket Launcher**
The AquaPod is a futuristic, one piece design plastic bottle launcher made of highly durable ABS plastic. The AquaPod requires no assembly and launches ordinary plastic 2-liter soda bottles up in the air. The AquaPod can launch a bottle up to 30 metres in to the air, and is the only launcher that has a built in safety-valve that prevent over-pressurization which releases pressure at 345kPa to help keep everyone safe from over-pressurising the entire system.

**To launch**
Partly fill a 2 litre plastic bottle with water and secure it upside down over the white launch tube. Using any bicycle pump, pressurise the AquaPod through the valve stem until the check valve inside the front leg releases pressure and water. Stand back and give the 4.5 metre release-string a short, quick tug to launch the bottle high into the air.

**Experiments:**
To run meaningful experiments you can:
- Use different launch pressures - requires a pressure gauge (not supplied) to monitor pressure
- Vary the amount of water used in the bottle

**Specifications:**
- Dimensions: 330mm x 195mm x 341mm
- Minimum age recommendation: 14+ Years
- Bottle launch height: up to 30 metres
- Bottle Size: 2 litre (not supplied)

The AquaPod Bottle Rocket Launcher was used as a 2015 PH5 Case Study for the WJEC syllabus (refer to Case Study sheets).
Aqua pods continued…

The AquaPod is a good demonstration to explore Newton’s third law and observe firsthand how every action has an equal and opposite reaction: the bottle pushes some its water downward and the water responds by pushing upward on the bottle, propelling the bottle upward. In that respect, the water-bottle rocket is like any other rocket. All a rocket needs is fuel and energy. Pushing the fuel backward is what propels the rocket forward-action and reaction. Energy is what allows the rocket to push that fuel backward. In many rockets, the fuel and the energy source are the same thing. Chemical reactions in the fuel release energy and this energy allows the rocket to push the fuel backward.

However, the water-bottle rocket uses two separate materials as fuel and energy source. The fuel is water and the energy source is compressed air. Having water as the fuel makes sense because water is dense and provides lots of inertia for the rocket to push against as it throws water backward out its tail. Having the compressed air as fuel is a good idea because it has little weight for the amount of energy it stores and doesn't load down the rocket.

At launch, most of the water-bottle rocket's mass is water. And with air packed tightly inside, the rocket has lots of energy. When you finally let water start streaming out of the bottle, the compressed air pushes downward hard on the water and the water pushes upward hard on the compressed air. The air conveys this upward force to the entire bottle and up it goes.

There is a copy of the 2015 WJEC A2 Case Study available on the desk for you to read, which uses data obtained from the launch of an Aquapod.
In mechanical engineering, a gear ratio is a direct measure of the ratio of the rotational speeds of two or more interlocking gears. As a general rule, when dealing with two gears, if the drive gear (the one directly receiving rotational force from the engine, motor, etc.) is bigger than the driven gear, the latter will turn more quickly, and vice versa. We can express this basic concept with the formula **Gear ratio = T2/T1**, where T1 is the number of teeth on the first gear and T2 is the number of teeth on the second.
Making Speakers

Experiment: Building working loudspeakers.

a) Turn on the radio at the mains.
b) Ensure that the volume is at its loudest point.
c) Place your ear close to the made card speaker.
d) Listen to the radio through the speaker.
e) If the noise from the room is too loud, you may also switch on the signal generator (Amplifier) provided.
f) Switch off the Signal generator if used.
g) Switch off the radio at the mains socket.

Class Experiment:

- Follow instructions on the worksheet.
- Please ensure your paper card cylinder fits over the magnet before continuing.
- Before testing your speaker, the insulated wire will need to be bared with sandpaper.
Key Stage 4-5: Another application of the motor effect. This is great as a whole class practical. I get each pair of students to build one and then test them at the front where I have a radio and a horseshoe magnet. A microphone and sig gen can amplify the quiet vibrations of the paper cone. Brighter students can apply Fleming’s Left Hand Rule to show how it works.
Making Motors

Experiment : Westminster motor kit.

a) Place the black plug into the centre of the battery pack to turn on.
b) Give the centre block of the motor a little nudge to get it going.
c) Ensure to unplug the black lead.
d) Please DO NOT take the demo motor apart.

Class Experiment :

- Refer to the student’s worksheet.
- Usually part of the motor is already made-up (see student motor box) – we only have 40 minute lessons
- For higher ability set students (or more time), the motor can be fully assembled by themselves.
- Students will be required to fix the brushes and axle to the motor.
- The trick is to make a cross with the brushes that can be seen through the split pin and then push the commutator up into the brush (ask, as it is easier to show than explain!)
- Connect the battery pack using the croc clips and leads provided.
Key Stage 4-5: Motor Effect and Fleming’s Left Hand Rule. On average over 90% of students (working in pairs) can get these working in a 40 minute lesson. They can go on to investigate the effect of reversing current/poles of magnets or size of current. Bright students can research the role of the split ring commutator in reversing the current every half turn and thus keeping the motor rotating in the same direction.

![Diagram of magnetic field and motor](image)

The origin of the motor effect explained in terms of a ‘catapult field’ where the field lines can be visualised as elastic bands.

Getting the brushes to touch both sides of the commutator without causing a short circuit is the key to success!
Slinko Seismic

A simple slinky setup to demonstrate some basic types of wave. The setup can show both longitudinal & transverse waves at the same time.

The setup consist of 4 small slinkies (£2 at amazon) connected to a plant pod mover (£2.99 at Home Bargains). When the plant pod mover is moved horizontally or vertically, a longitudinal wave vibrates parallel to (moves in the same direction of) wave travel can be seen on two slinky, and transverse wave can be seen on the other two.
Induction from Earth’s Magnetic Field

Experiment: Induction from Earth’s field using long wire and light spot Galvanometer.

a) Switch the Galvanometer on at the mains socket.
b) Turn the dial to measure direct.
c) Set to 0
d) Work in pairs and hold the wire like a skipping rope one at each end and rotate.
e) Observe what happens on the screen of the galvanometer.
f) Please ensure that the Galvanometer dial is pointing to the SHORT before leaving the apparatus.
g) Turn off at the mains supply.

Students are sometimes surprised to see electricity being produced out ‘of thin air’ and I discuss the potential use of EM induction in orbiting spacecraft to produce electricity.
Commutator

A commutator is a moving part of a rotary electrical switch in certain types of electric motors and electrical generators that periodically reverses the current direction between the rotor and the external circuit.

In case of DC generator, commutator is used to convert generated AC in armature into DC.

In case of DC motor, commutator is used to maintain unidirectional torque i.e. it only reverses direction of current flow.

The blue and red boxes represent the poles of the bar magnets: a good one for our visual learners and those bored (works!) of animations!
Charge the polythene rod by rubbing it with the cloth. Rub the charged rod on the top plate of the electroscope. Observe the movement of the gold leaf. Discharge the electroscope by touching it. Bring a charged polythene strip near to the top plate of the uncharged electroscope, but without touching it. Then touch the electroscope plate with a finger so that the leaf falls. Take away the finger, then take away the charged polythene strip and watch what happens. The electroscope has been charged by induction. The gold leaf electroscope is used for detecting electric charge and can also identify its polarity, if compared with a known charge.

Attracted balloons: Inflate a balloon and rub the top with a cloth, push it delicately to the wall, if the air is dry it can remain attracted

**Dancing Paper** Tear a sheet of paper into small pieces about the size of the fingernail. A polyethylene strip is charged by rubbing with wool. The charged strip is then used to make paper circles stand on their edges inside a petri dish. This introduced students to the charging of materials by induction as opposed to charging by contact.

Question for students: Why do we use gold?

Worth pointing out that although we use paper to stop alpha particles gold leaf was used in Rutherford’s alpha scattering experiment!
Electric Field Lines

Aim:- This shows the shape of electric fields, in much the same way that magnetic fields are demonstrated with iron filings.

SAFETY: BE very careful not to touch the apparatus – the HT supply is potentially lethal – ask Helen!!

Fill the electrode unit with a layer of liquid paraffin to a depth of about 0.5 cm. Sprinkle some lettuce seeds over the surface. It is better to start with too little lettuce seeds than to start with too much. You can always increase the quantity later.

Place the electrodes in the castor oil. Connect the positive and negative terminals of the EHT power supply to the electrodes. Adjust the supply to give 3,000 to 4,000 volts. When the voltage is switched on, the field lines will be clearly visible.

Try electrodes of different shapes. For example, one can be a 'point' electrode whilst the other is a plate, or two point electrodes can be used. A wire circular electrode with a point electrode at the centre will show a radial field. The field with two plates quite close together should also be shown.
A Van de Graaff generator can be used in place of the EHT power supply. If both these supplies are used in turn, students will see that electrostatic charges make the same field patterns as the charges provided by a power supply which can drive currents.

The ‘electric fields apparatus’ consists of two electrodes mounted in a glass dish – see the illustration. The electrodes can be made from aluminium sheet or can be purchased complete with dish. Apart from the care which needs to be taken with the insulation, this unit is readily improvised.
The ‘top pan balance’ is a straightforward way of investigating the factors affecting the force on a wire carrying a current in a magnetic field. The ‘wire’ is clamped so that it remains stationary and the balance measures the ‘change in weight’ of the Magnadur magnets placed on its pan. Also a good illustration of Newton’s 3rd Law!

Vary the current gradually up to about 5 or 6 A

To investigate how the length of wire in the field affects the force, you can select full length and half length of the wire by using the two way switch.

\[ F = BIl \]

Where:
- \( B \) = Flux Density
- \( I \) = Current
- \( l \) = Length
Lenz's Law

Experiment: Lenz's Law

a) There are two small metal cylinders provided in a plastic beaker.
b) Use these separately to drop into the copper pipe.
c) Observe each cylinder to see how they behave. Please leave both metal cylinders in the beaker provided after use.
Eddy Braking

Experiment: Eddy braking

a) The apparatus has been set-up ready for you to use.
b) Hold the metal wheel between your finger and thumb, and spin with a gentle force.
c) Turn the power supply on.
d) Observe what happens to the wheel.
e) Please ensure that the power supply has been turned off.
Rolling bar

Experiment 7: Rolling Rod and horseshoe magnet demo.

a) Turn on the power to the supply.
b) Use the switch to control the direction of the bar.
c) Ensure that the power is turned off.
d) Please leave all equipment intact.

Key Stage 4-5: Introduction to the Motor Effect and Fleming’s Left Hand Rule

Get students to predict what will happen if you use 50Hz AC
Jumping Ring

Experiment: Jumping ring.
   a) Switch the power supply on.
   b) Place the ring without a split over the metal rod part of the stand.
   c) Press the yellow button and watch the metal ring.
   d) Take the ring off the rod and replace it with the other ring that has the split.
   e) Press the yellow button again and see how this ring behaviour differs from the first.
   f) Please ensure that the power supply is turned off after use.

Key Stage 4-5: Demonstrating Lenz’s Law in Action. The basic argument is that an opposite pole is induced in the lower surface of the aluminium ring as the magnetic field grows in the coil (according to Lenz’s Law) and so it repels from the coil.

If you have any dry ice then you can do a more dramatic demo and discuss the effect of temperature on resistance!
Bicycle Dynamo

Experiment: Bicycle dynamo and Cathode ray Oscilloscope.

- a) Ensure that you have a straight horizontal line on the oscilloscope before you begin.
- b) Wind the handle on the bicycle dynamo clockwise.
- c) Observe the traces (lines) on the Oscilloscope.
- d) See what happens when you wind the handle at different speeds.
- e) Please leave the power to the Oscilloscope ON.
- f) I use this cartoon with my students, asking them to explain the Physics behind it. Needless to say they don’t find it that funny!

I use this cartoon with my students, asking them to explain the Physics behind it. Needless to say they don’t find it that funny!

Typical exam question:
The meter is now removed from the circuit.
The contacts at X and Y are then connected to the inputs of a cathode ray oscilloscope.

The grid below shows the trace on the oscilloscope when the coil is rotated at a steady rate in the magnetic field.

The speed of rotation of the coil is now doubled.

On the grid below sketch the trace which you would expect to see on the oscilloscope screen.
The controls of the oscilloscope have not been changed.
Slow AC

Experiment: Slow AC demo using plotting compasses and a signal generator.

a) Switch the power on to the signal generator.
b) Observe what happens to the plotting compasses.
c) Ensure the power is turned off on the signal generator.

Key Stage 4-5: Demonstrating the Time Varying Magnetic Field produced by an Alternating Current by slowing it all down to low frequencies with the signal generator. This is useful in explaining how a transformer works with the secondary coil sitting in the primary coil of the transformer.
Changing magnetic field → Induced Magnetic Field

Primary coil: 50 turns
Secondary coil: 100 turns

Voltage: 10 V, 20 V

Step-up transformer