



Pico Magnetic Induction Kit

Investigating Faraday's laws of electromagnetic induction

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Introduction



The Pico Magnetic Induction Kit provides a simple and effective method for students to investigate the concept of Faraday's laws of electromagnetic induction. A small bar magnet is dropped down the tube and, as it passes through the coil, an electromagnetic field (emf) is induced. The voltage pulse is monitored on an oscilloscope and its characteristics can be investigated as the rate of cutting of field lines are varied.

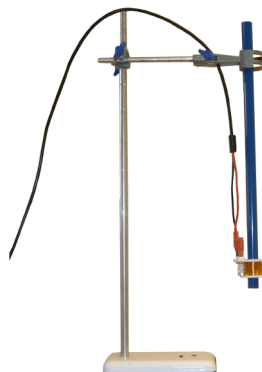
Applications

The system can be used to demonstrate electromagnetic induction, the direction of induced currents and variation of the size of induced emf with velocity. It can also be used as a student-based investigation, either with full instructions or as an open investigation where the students research the concepts.

Operation

Use a laboratory stand to clamp the main tube near its top so that it is in a convenient position for the magnet to be dropped down the tube and caught at the bottom. Slide the coil assembly on to the tube from below.

The output from the coil can be viewed using a Pico PC oscilloscope, a DrDAQ data logger or on most other digital storage oscilloscopes. The instructions vary slightly depending on the oscilloscope used:



1. Pico dual channel PC oscilloscopes / other digital oscilloscopes

Connect the output sockets to channel A on the oscilloscope
Set channel A to the 500mV/div and the timebase to 5ms/div. Set the trigger to 'repeat' so that the pulse is displayed each time the magnet is dropped down the tube. Set the trigger level to +50mV (rising) and the trigger delay to -50% (pre trigger.)

2. Pico ADC-40 or ADC-42

The ADC-40 and ADC-42 have a fixed 5V input range, so initially the waveform on the screen will appear very small. In PicoScope set the Y multiplier to x10 to zoom in on the signal.

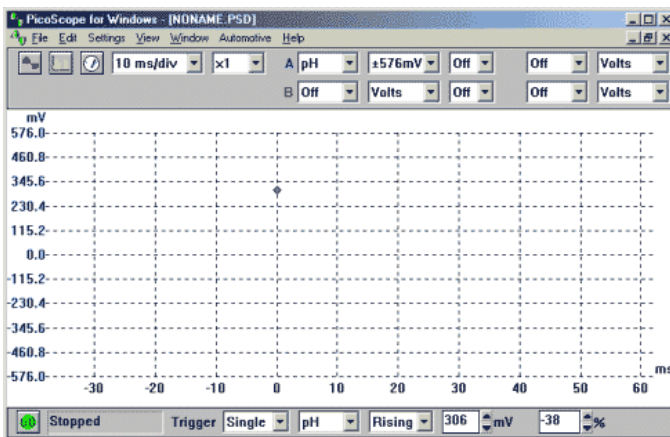
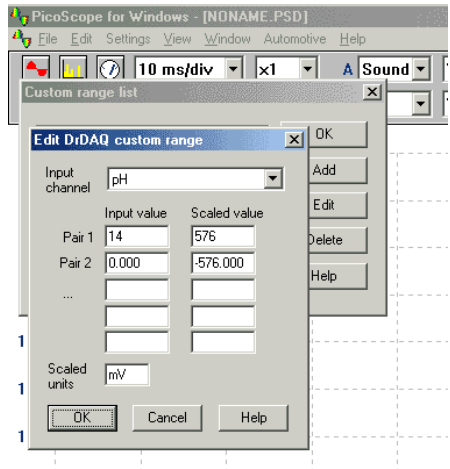
3. DrDAQ data logger

To use the magnetic induction kit with DrDAQ, connect to the BNC input. Normally this is calibrated to measure pH, however by adding a custom range, it can be made to read in mV.

Follow this procedure to configure the pH input for use with the Magnetic Induction Kit:

- 1) Select File| Settings| Custom ranges
- 2) Select Add in the custom range list
- 3) Enter the settings as shown in the image on the right.
- 4) Use the drop down menus for channel A to select pH and the range $\pm 576\text{mV}$

The DrDAQ screen should now look identical to the image shown below:



Please note that the DrDAQ BNC input is filtered to reduce noise pickup when measuring pH. This filtering may reduce the amplitude of the measured signal. For this reason whilst we recommend using

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DrDAQ for quick demonstrations, it is better to use one of the oscilloscope products for more detailed investigations.

Note that due to the variations in coil and magnet strength it may be necessary to adjust the settings of the oscilloscope you are using.

The velocity of the magnet is calculated using the formula:

$$\mathbf{v}^2 = \mathbf{u}^2 + 2\mathbf{a}\mathbf{s}$$

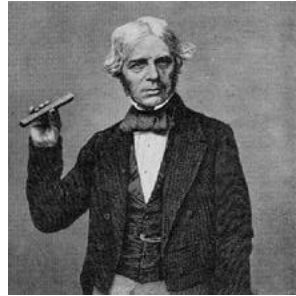
where \mathbf{v} is the velocity as it passes through the coil, \mathbf{u} is the initial velocity (assumed to be zero), \mathbf{a} is the acceleration due to gravity (g or 9.81m/sec^2) and \mathbf{s} is the distance from release point to the coil.

There are many points to note in the procedure and these can be explained to students or used in assessing their practical skills. The main points are:

- The pulse maximum occurs when the bottom end of the magnet passes through the middle of the coil. If the magnet is released with its mid-point level with the top of the tube, the distance fallen can be taken as the distance from the top of the tube to the top of the coil.
- If a graph of results is drawn (pulse amplitude against velocity) the intercept on the velocity axis i.e. velocity when amplitude is zero can be used to determine at which point in the coil the pulse maximum occurs.
- Multiple drops of the magnet for any given distance should be used to get the best estimate for the pulse amplitude.
- The pulse shape is asymmetric. The first maximum occurs as the lower pole enters the coil and the second peak occurs as the upper pole leaves the coil. The speed of travel will have changed during this process so that the second maximum is larger than the first. The effect is most obvious at small values of distance fallen since the percentage of change will be larger. When the coil is at the bottom of the tube the pulse is almost symmetrical. A very large distance between the release point and the coil is required for a truly symmetrical pulse. An imaginative student could explore this idea.

Michael Faraday

English scientist Michael Faraday's scientific work laid the foundations of all subsequent electro-technology. From his experiments came devices which led directly to the modern electric motor, generator and transformer. Faraday was also the greatest scientific lecturer of his day, and did much to publicise the great advances of nineteenth-century science and technology through his articles, correspondence and the Friday evening discourses which he established at the Royal Institution. The Royal Institution Christmas lectures for children, begun by Faraday, continue to this day.



On 29th August 1831, using his "induction ring", Faraday made one of his greatest discoveries - electromagnetic induction: the "induction" or generation of electricity in a wire by means of the electromagnetic effect of a current in another wire. The induction ring was the first electric transformer. In a second series of experiments in September he discovered magneto-electric induction: the production of a steady electric current. To do this, Faraday attached two wires through a sliding contact to a copper disc. By rotating the disc between the poles of a horseshoe magnet he obtained a continuous direct current. This was the first generator.

Faraday's three laws of electromagnetic induction state:

- 1) A changing magnetic field induces an electromagnetic force in a conductor.
- 2) The electromagnetic force is proportional to the rate of change of the field.
- 3) The direction of the induced electromagnetic force depends on the orientation of the field.

Visit the Pico Technology web site for educational applications and science experiments for PC oscilloscopes and data acquisition products.

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