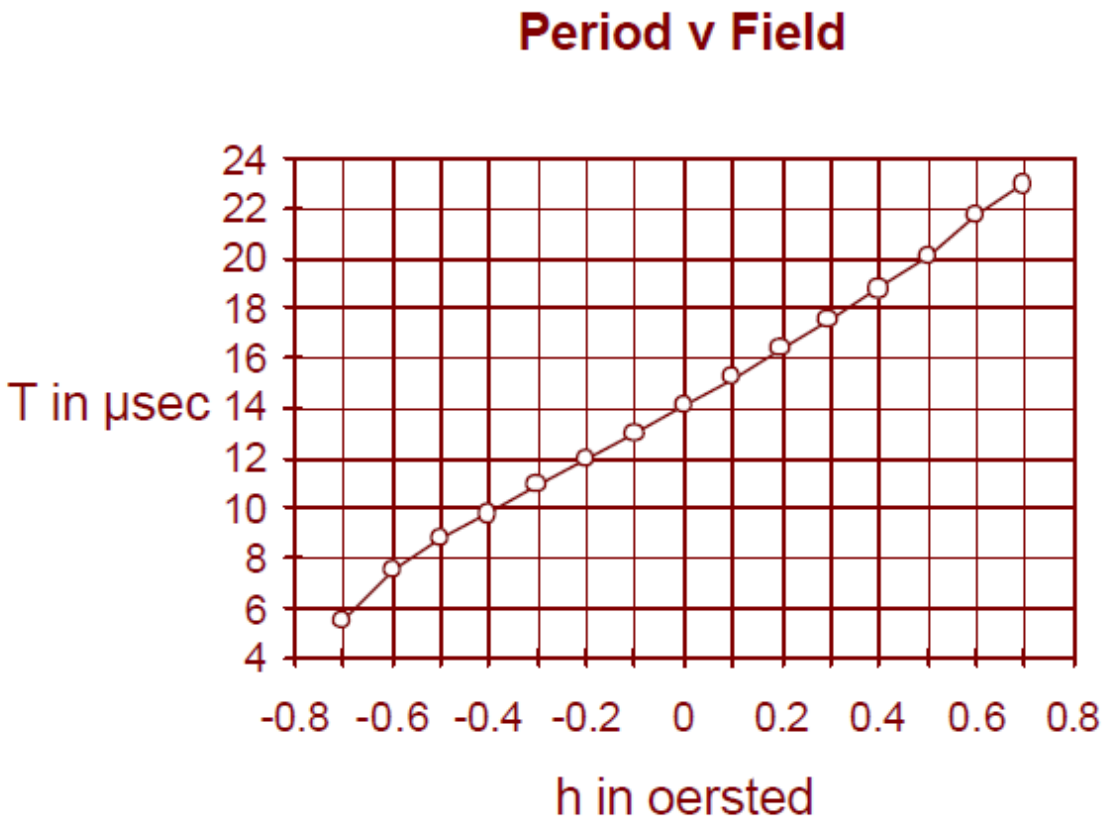
Measuring the Earth's Magnetic Field

The aim of this experiment is to measure fine variations over time as they occur in the Earth's magnetic field and to attempt to correlate this to measurements taken by other researchers.
A magnetometer has been produced using a simple FGM-3 magnetic sensor, full details of which may be obtained from the manufacturers website http://www.speakesensors.com/ .

The magnetometer is installed in the astronomy hut at Frongoch farm, to minimise interference from stray magnetic fields.

The output from the sensor is in the form of a 0 to 5 volt square wave, the period of which is proportional to the magnetic field, as shown in the graph below.



Please note: 1 oersted == $\frac{10^3}{4\pi}$ A/m. The magnetic field should be measured using S.I. units. In this graph the Field intensity h is measured in an old unit which is no longer in use.

There are a few snags with using an inexpensive sensor such as this. Firstly, given that in order to study fluctuations in the Earth's magnetic field a resolution in the order of nanoteslas is required, from the graph it can be deduced the period would need to be measured to a resolution of around 10 picoseconds; which is not easy (or cheap). Secondly, if the output from the sensor is observed on an oscilloscope it becomes clear that the period of the waveform is by no means stable enough to measure with any degree of accuracy due to noise produced by local electrical activity. Nevertheless, these problems can be overcome by taking an average of the period of the waveform over a relatively long time; in this instance 3 seconds. Over this period of time, the random noise will average out to something approaching zero, hopefully leaving just the original signal. The equipment that you will

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be using achieves the averaging process by means of a digital system, the internal workings of which it is not necessary for you to understand.
The Digital system interface with a computer via a minilab pod connected via USB. Data is collected via a Labview program installed on a dedicated computer used for the experiment. The data from the digital circuitry comes in the form of a 16-bit binary number at a rate of one sample every 3 seconds is saved to a computer by a LabVIEW program which is already provided. The data has been scaled so that the linear part of the field is covered within the range of the 16-bit number; where 0 equates to an output frequency from the sensor of 120 kHz and 65534 (216) to just under 50kHz. The program also provides a real time display of the raw field data as well as the temperature, which is recorded at the same time as each field sample.

Data logging

Recording to file is optional; if it is selected, data will be written into a .csv file in C:/magdata/<year>/. To keep the size of the files reasonable, a fresh file is created each midnight. The filenames are of the format "DATAxxx.csv", where xxx is the day of the year, with 001 being January 1st. the filename of the current output file is displayed on the front panel of the instrument.

The file format is as follows:
Each line of the file contains the readings from a single timepoint.
The values in the file are separated by commas. The fields within each line are:

1. A timestamp, indicating the number of seconds elapsed since 12:00 a.m., Friday, January 1, 1904.
2. An integer representing the observed magnetic field intensity in arbitrary units.
3. The temperature of the instrument, in °C

Data may be retrieved from the instrument by using WinSCP or some other FTP client. The instrument machine is at the address "ugexppc15.dph.aber.ac.uk" and logging in with the username "Magnetometer" and password "magnetometer".

Data may also be emailed to experimenters as each file is closed at midnight. To do this, simply put a list of email identifiers in the appropriate box on the "Setup" tab of the Labview instrument.

The instrument PC has been set up to allow remote desktop connection, with your usual username and password.

Temperature Compensation

Because the resolution is now in the nanoteslas range (the exact resolution is for you to determine), temperature drift within the sensor is much more significant. Thus the data which the magnetometer provides will need considerable postprocessing. In order to obtain the resolution from the instrument necessary to study variations in the earth's magnetic field, it is necessary to correct the output of the sensor for variations in temperature in the instrument's environment. In order to do this, data from several days' observations should be combined together and used to produce a plot of indicated field vs temperature is produced. If it is assumed that variations in the magnetic field will average out over time, this curve can then be used to produce a function which will enable the field data to be corrected for temperature. The magnetic sensor contains a single bipolar junction transistor and consequently the relationship between temperature and the raw field data is an inverse log law.
Once the data has been corrected for temperature, information from the manufacturer of the FGM3 magnetic sensor can be used to convert the arbitrary numbers indicating the output frequency of the sensor into conventional units, such as nanoteslas.
You should note that changes occurring in the data are more significant than the absolute value of the field at any time.

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Comparison with other data

There are a large number of stations around the world monitoring the earth's magnetic field and some of these produce data in a form suitable for download.

Suitable starting points for internet searches to find appropriate data are the World data centre for Geomagnetism (http://www.wdc.bgs.ac.uk/), the United States Geological Service National Geomagnetism Program (http://geomag.usgs.gov/) and Intermagnet (http://www.intermagnet.org)

You should find data from one of the ground stations closest to Aberystwyth (Hartland seems a good bet!) and try to get data in a format you can then process to find similar features to that shown in your local data.

Topics for Background Research in Report

In addition to carrying out the experiments detailed above, your experimental report should also contain some background research into some or all of the following topics: Flux gate magnetometer, geomagnetic field, magnetosphere, ionosphere, fluctuations in earth's magnetic field, SWARM.

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