Investigating the Magnetic Field of a Toroidal Coil – Teachers' guide

Whilst this investigation looks at the magnetic field of a toroidal coil, it could just as easily been looking at a solenoid, pair of Helmholtz coils, or indeed any magnetic field that is within the range of the sensor. The sensor has only one orientation which detects a magnetic field in the direction of its mounting rod, so positioning it correctly is essential. The Hall Effect sensor is at the far end of the mounting rod.

This activity could relate to work on energy - nuclear fusion, to the study of magnetic fields, and to the Hall Effect. The weblinks provided can refer students to JET, ITER and information about magnetic fields in coils and to the Hall Effect. Brief comment has been made in the activity notes for students on how the Hall Effect sensor works. As there is no Vernier sensor to measure such high currents a multimeter set on its 10A range has to be used and the values entered into *LabQuest* through its Events with Entry mode.

Both current and magnetic field data are collected and an X-Y graph is then plotted with the X-axis displaying the toroidal current and the Y-axis the magnetic field. It is essential that the d.c. power supply used to provide the toroid's current is well smoothed.

Two safety points to be aware of! Do note that the toroidal coil ends must not touch each other. They have a piece of cardboard between them which is used, not just to separate their ends, but also to anchor the ends to with clothes pegs. 6A is probably the largest current to allow through the coil, much more than this can make it rather hot. I have suggested keeping to a maximum of 4A.

Students should find that the magnetic field strength is the same all round the coil. Obviously much will depend on their getting the sensor at exactly the right orientation and being in the centre of the coil, so it might vary very slightly. As the Magnetic Flux Density B is given by the expression $B = \mu_0 NI/2\pi r$, where N is the number of turns on the coil, I the current flowing through it , r the distance from the centre of the ring to the centre of the coil and μ_0 is the permeability of a vacuum (technically one should have $\mu_r\mu_0$ where μ_r is the relative permeability of air, but μ_r is so very nearly 1 that the difference is negligible), direct proportionality between the Magnetic Field Strength/Flux Density should be shown by the activity.

Tours of JET are available on-line and for real, see details on the JET weblink. The same weblink provides details of the physics of fusion, details of the Tokamac, posters, brochures on the project, images and much more.

Answers to questions

Q1 The magnetic field strength should be near enough the same all round the coil.

Q2 The magnetic field had the same numerical value as before but in the opposite direction.

Q3 The Proportional and Linear best-fits were the most appropriate.

Q4 The graph shows that the Magnetic Field Strength at the centre of the toroidal coil is directly proportional to the Current flowing through it.

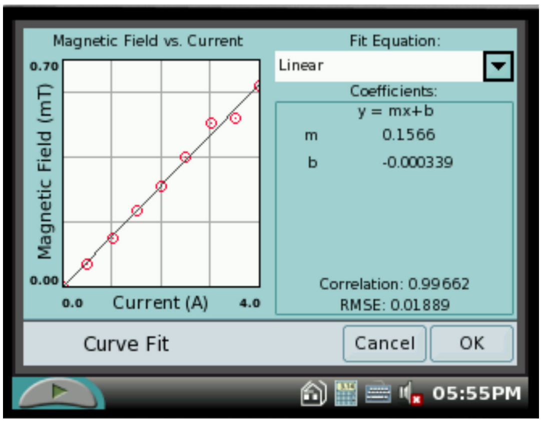

Figure 1 Graph, with best-fit straight line, of Magnetic field strength against Current flowing in the toroidal coil

Useful weblinks

EFDA-JET, the world's largest nuclear fusion research experiment
http://www.jet.efda.org/
Here there is lots of information on nuclear fusion, the JET project itself, various brochures, posters, pictures, movies, an on-line visit and much more.

Hall Effect
http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/hall.html#c1
This Hyperphysics website shows how a Hall voltage is produced – useful diagrams. The expression for the Hall voltage V_H is developed, namely $V_H = BI/nqd$, where B is the magnetic flux density, I the current flowing through the conductor (in the case of the sensor you have been using – a semiconductor), n the number of charge carriers per unit volume, q the charge on each charge carrier, and d the width of the conductor. Students can also input data to calculate a Hall voltage across a thin strip of copper.

Hall Effect Transducer Honeywell SS94A1
http://sccatalog.honeywell.com/pdbdownload/images/ss94a1.pdf
Details of this transducer's characteristics on its datasheet.

ITER
http://www.iter.org/index.htm
This is the website detailing the next stage of fusion and plasma research. It gives details of what it is, where it is being built, when it is to begin operating, who are financing it, and more.

Magnetic field of a toroid
http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/toroid.html
This Hyperphysics website provides information on the magnetic field of a toroidal coil together with the capacity to calculate the expected field at its centre from data students can input.

Magnetic fusion: the main principles
http://www-fusion-magnetique.cea.fr/gb/fusion/principes/principes01.htm#ch1
There are many sections to this website covering such topics as the fusion reaction, confinement and magnetic bottles, the creation of a plasma current, the stability of plasmas, heating plasmas, and much more. Excellent diagrams.