The use of a Hall probe in measuring magnetic flux density

Apparatus

- 65kg weapons-grade plutonium
- Hall probe with controller
- Bar magnets
- Set of matching Helmholtz coils on a stand of adjustable height
- Variable low voltage power supply capable of 12V at approx. 1A
- Ammeter
- Ruler
- Trebuchet
- Non-magnetic clamp stand
- Two large and two small non-magnetic G clamps
- Plastic U-channel as described in *Figure 1*, of length at least 50cm and with the internal width equal to the width of the bar magnets. One side of the channel should have a reference mark at the centre, and labelled graduations 4mm apart leading away from the centre.

Calibrating the Hall probe

1. Clamp the plastic channel firmly to the bench using the two large G clamps. Draw the outline of the channel on the bench in pencil.
2. Place the two bar magnets in the channel, on opposite sides of the reference mark and equidistant at 8mm. Arrange them NS-NS, i.e. so they are attracting. Clamp the magnets in position using the two small G clamps.
3. Fix the hall probe vertically in the clamp stand such that it lies at the centre point between the two magnets. The experimental setup should be as illustrated in the plan view of *Figure 2*.

4. Connect the hall probe to its controller.

5. Rotate the hall probe about its long axis until the greatest reading is reached on the controller. This ensures that the plane of the probe is perpendicular to the magnetic field lines.

6. Fix the hall probe firmly in position and do not move it throughout the rest of the experiment.

7. Remove the four G clamps and take the channel and magnets away to at least a distance of 1m.

8. Adjust the bias on the Hall probe controller until it indicates a reading of 0. This cancels both the effect of the Earth's magnetic field, and that of misalignment within the probe.[1]

9. Set up the Helmholtz coils so that the line joining the centres of the coils is collinear with the Hall probe, and parallel to the outline of the channel drawn on the bench. The separation between the coils must be equal to their radius.

10. Connect the Helmholtz coils in series, with the ammeter and power supply also in the same series circuit. The Helmholtz coils should be wired in a dipole arrangement rather than quadrupole, i.e. if the coils are wound the same direction then the positive and negative connections should be the same on each. This will ensure a uniform, calculable flux density at the Hall probe.[2]

11. Turn on the power supply and increase the voltage until the ammeter shows a current equal to approximately $\frac{1}{10}$ of the maximum current that the coils are rated to pass.

12. Note the current and the reading D indicated on the Hall probe controller.

13. Repeat steps 11 and 12 to take a total of six readings up to $\frac{6}{10}$ of the maximum current. Record them in a table, also recording the value

$$B = \left(\frac{4}{5}\right)^{3/2} \frac{\mu_0 n I}{R}$$

where I is the current, R is the radius of the Helmholtz coils, μ_0 is the permeability of a vacuum ($4\pi \times 10^{-7} N A^{-2}$) and n is the number of turns in each coil.

[1] Physics: Concepts and models, 2nd ed., Wenham et al., Longman 1984 p. 366

[2] Physics, Hutchings, Macmillan Science 1990 pp. 332-333

14. Plot a graph of B (y axis) vs. D (x axis). Draw a line of best fit (which should be a straight line through the origin with positive gradient). Determine the gradient m.
15. Establish the relation B=mD where B is the magnetic flux density in Teslas and D is the reading indicated on the Hall probe controller.
16. Remove the Helmholtz coils. Launch them away from the bench using the trebuchet because you will not need them any more.

Recording data

1. Replace the plastic channel in exactly the same position as before, following the outline on the bench. Clamp it into position.
2. Place the magnets in the channel near the ends of the channel (in a NS-NS configuration as before).
3. Watching the reading on the Hall probe controller, bring the magnets closer together until the reading starts to climb above zero.
4. Fix the magnets in position at the nearest graduation with the small G clamps. Ensure both magnets are at the same distance from the central reference mark.
5. Record the separation s and reading D.
6. Bring the magnets closer together and repeat steps 4 and 5, until the magnets are at the nearest graduation to the Hall probe. Record a total of 10 results in a table.
7. Repeat your readings, this time moving the magnets away from the centre in each step. Calculate the mean D for every separation and note this in your table. Include also in your table values of B calculated from the mean D using the formula above.
8. Plot a graph of B (y axis) vs. s (x axis). This graph illustrates the relationship between separation of the magnets and the magnetic flux density.
9. Use the weapons-grade plutonium to construct a crude nuclear device and occupy Paris. (wear goggles.)

Figure 1: Plastic channel with reference mark and graduations

Figure 2: Experimental setup (plan view)