EXPERIMENT – 10

Aim of the experiment: Verification of Lorentz force relation using a mechanical balance for a current carrying conductor subjected to a magnetic field.

Apparatus required: Mechanical balance (beam balance), magnets and frame, long and slender conductor plated on epoxy boards, conductor holder and stand, dc power supply 0-3 A, connecting leads

Theory: The force $\vec{F}$ on a current element $id\vec{l}$ subjected to a magnetic field $\vec{B}$, is given by

$$\vec{F} = i\, d\vec{l} \times \vec{B} \qquad (1)$$

In this experiment we subject a straight current carrying conductor of length l, to a magnetic field B, in a direction perpendicular to it. If i is a steady current made to pass through it, we may write the force experienced by that segment of the conductor as,

$$F = i\, l\, B\, sin\left(\frac{\pi}{2}\right)$$

$$or, \qquad F = i\, l\, B \qquad (2)$$

That is,

$$\left.\begin{aligned} F &\propto i \\ &\propto l \\ &\propto B \end{aligned}\right\} \qquad (3)$$

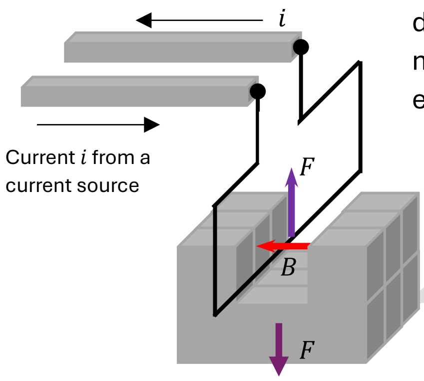

Fig-1: Schematic diagram of a setup for verification of dependence of Lorentz force on the current through the conductor, its length, and the magnetic field to which it subjected.

If we are able to experimentally establish the proportionalities mentioned above, the Lorentz force relation stands vindicated. To achieve this, we use a long and slender conductor plated onto an epoxy board, through which current of a desired magnitude is allowed, while it made to pass through a thin space between the magnet poles. We also ensure that the conductor epoxy plate which is held firmly in position between the magnet poles with the help of a holder, does not touch the magnet. A small air gap is carefully maintained so that the motion of the magnet that is placed on a beam balance pan, is in no way obstructed. This is key to performing the experiment, so we must be very careful while setting things up. Depending upon the direction of current and the magnetic field, there is a force on the conductor and the magnet. This force is the Lorentz force and is to be measured directly using the beam balance.

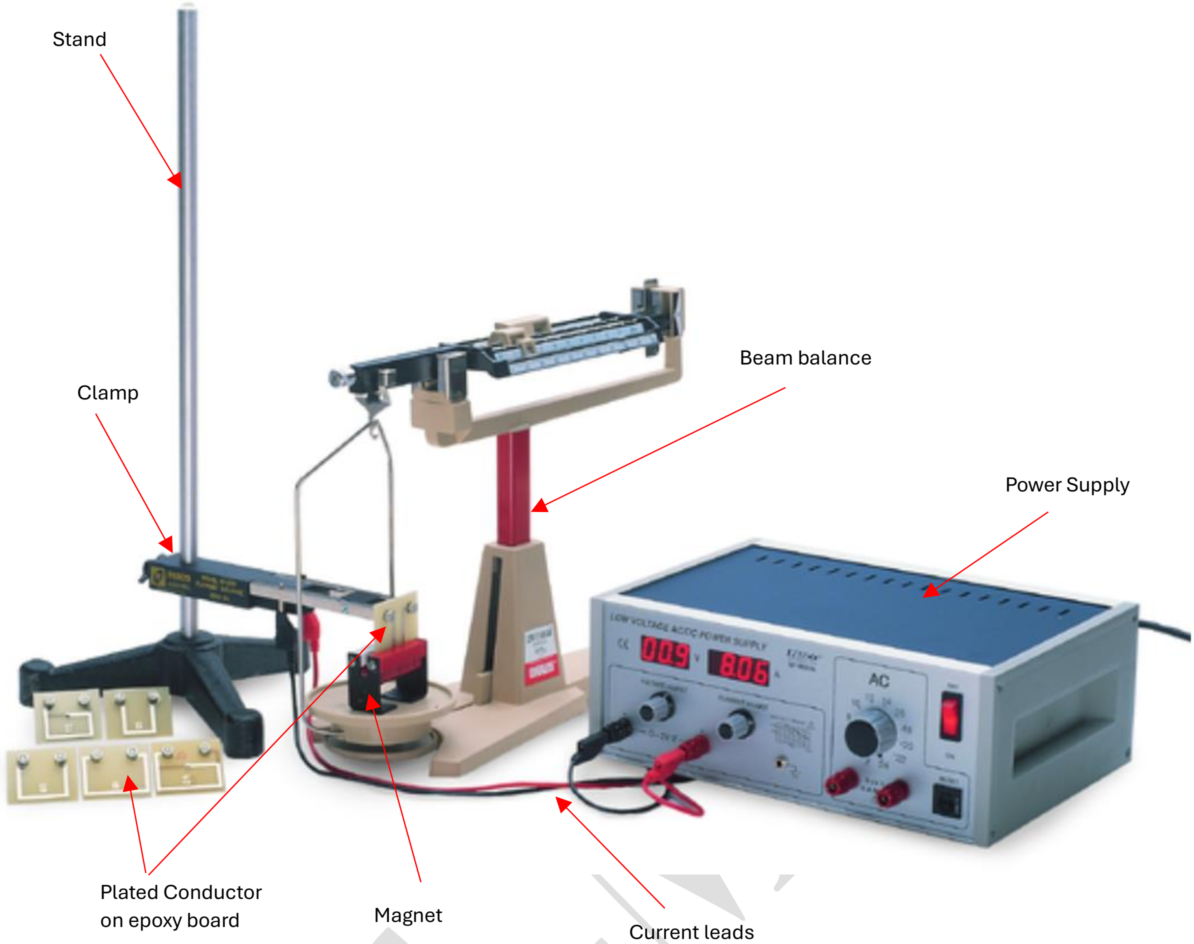

Fig-2: Picture of the setup for verification of dependence of Lorentz force on the current through the conductor, its length, and the magnetic field to which it subjected.

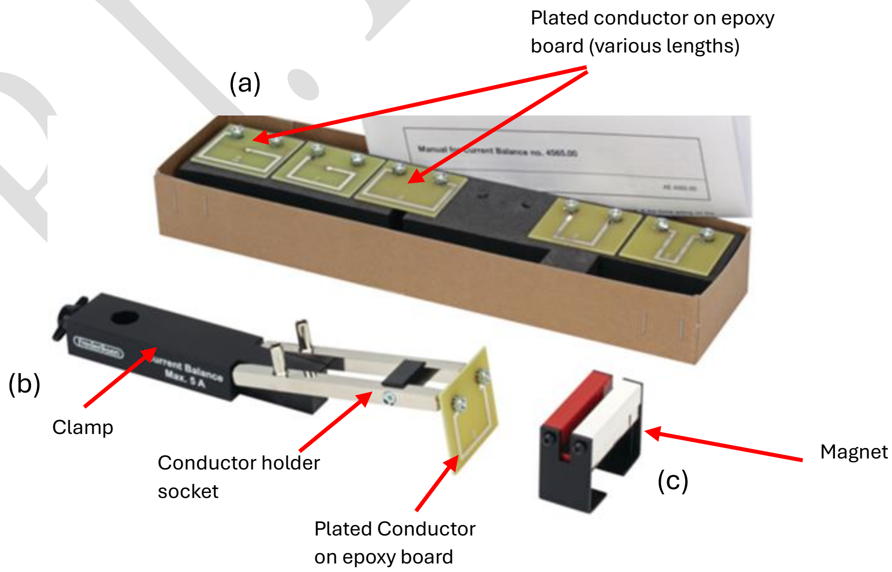

Fig-3: Picture of (a) conductor plated on epoxy boards, (b) conductor-board holder socket mounted on a clamp and (c) magnet holder with six magnet pieces.

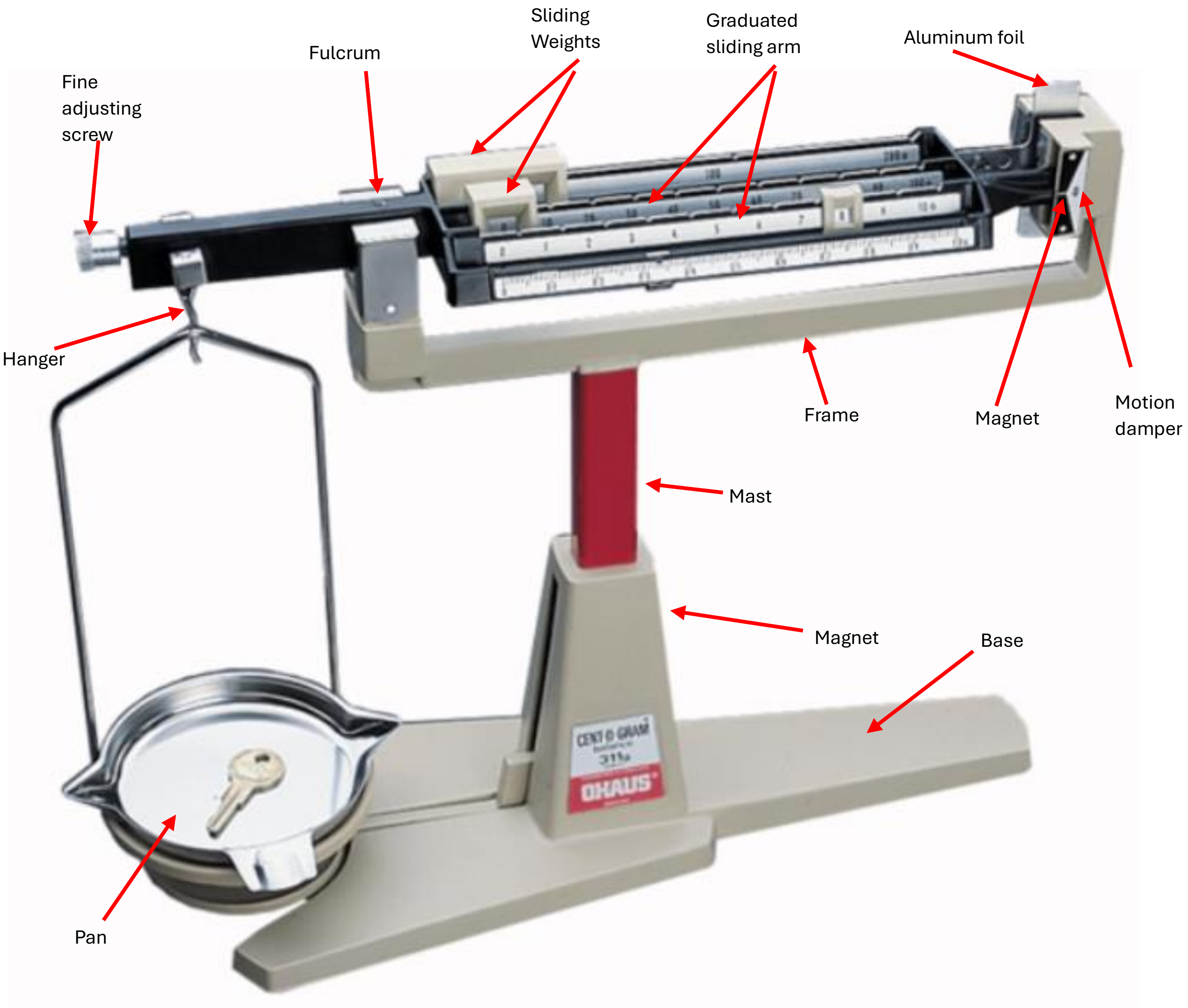

Fig-4: Precision beam balance for the determination of force on the magnet for verification of Lorentz force relation.

Procedure and precautions:

1. Chose the longest conductor-board and plug it in the holder socket, clamped onto a stand.
2. *It is to be noted that longest conductor is 6mm in length, 3mm on either side of the board.*
3. Arrange all the removable magnet pieces on the magnet holder such that like poles are on the same side. In this situation the total magnetic field between the poles is 1014 gauss approximately. *Please note that the values of magnetic field were measured using a Gaussmeter in our Solid-State Physics Lab (Physics Lab-I) of our department. However, these may vary a little for different setups. For all practical purposes the values given in this writeup may be used.*
4. Place the magnet holder on the beam balance pan, well centred, and balance it by shifting the weights on the graduated sliding arm. Note the initial reading. Not centring the magnet will have no perceptible effect on the weights recorded. Nevertheless, centring would definitely help avoid other associated difficulties.
5. Shift the plugged-in board with the stand so as to insert the board in the gap between the magnet poles. Make sure the horizontal part of the conductor lies exactly between the poles and the board doesn't touch the magnets even when the beam balance pan oscillates through its span.

6. Turn on the power supply and turn the voltage and current adjustment knobs to their minimum.
7. Connect the power supply output terminals to the board-holder terminals using the leads (banana jack terminated wires) provided (Refer to Fig. 2).
8. Rotate the voltage adjustment knob through a quarter turn and then adjust the current adjustment knob to allow a desired current through the conductor.
9. Notice that the equilibrium of the beam balance gets disturbed. Adjust the smallest sliding weight, a little to restore the equilibrium. Note the beam balance reading on the observation table.
10. Repeat the process for at least ten values of current in the range of 0 and 2 A.
11. Plot a graph of force against conductor current to show the proportionality.

12. Next, fix the current to 2 A and change the conductor-board one by one to record the dependence of force on the length of the conductor.
13. Plot a graph of force against conductor length to show proportionality.

14. Again, plug-in the longest conductor you have, into the conductor-board holder and fix the current to 2 A. Using all the six magnet pieces (1014 gauss), record the weight.
15. Remove one magnet piece and place it on the pan itself such that its field does not influence the force on the conductor. Record the weight.
16. Repeat this process till you exhaust all the magnet pieces.
17. Plot a graph of force against magnetic field, to show the proportionality.
18. If all the three plotted graphs show linearity, Lorentz force relation stands verified.

Observations:

Table-1: Readings for verifying the dependence of Lorentz force experienced by a conductor of length $l = 60\ mm$ due to a current i through it. We subject the conductor to a magnetic field, $B = 1014\ gauss$.

S.No.	Current through the loop i	Weight on the balance m	Force on the current loop $F\ (= mg)$
	(A)	(g)	(dyne)
1	0.0		
2	0.2		
3	0.4		
4	0.6		
5	. . .		
6	. . .		
7	2.0		

Table-2: Readings for verifying the dependence of Lorentz force experienced by a conductor carrying a current, $i = 2\ A$ through it. We subject the conductor to a magnetic field, $B = 1014\ gauss$.

S.No.	Loop length l	Weight on the balance m	Force on the current loop $F\ (= mg)$
	(mm)	(g)	(dyne)
1	10 (SF-8)		
2	20 (SF-18)		
3	30 (SF-28)		
4	40 (SF-38)		
5	60 (SF-58)		

Table-3: Readings for verifying the dependence of Lorentz force experienced by a conductor of length $l = 60\ mm$, carrying a current $i = 2\ A$, due to magnetic field B, to which it is subjected.

S.No.	Magnetic field B		Weight on the balance m	Force on the current loop $F\ (= mg)$
	No. of magnets	(gauss)	(g)	(dyne)
1	0	2		
2	1	204		
3	2	385		
4	3	565		
5	4	742		
6	5	844		
7	6	1014		

Plots:

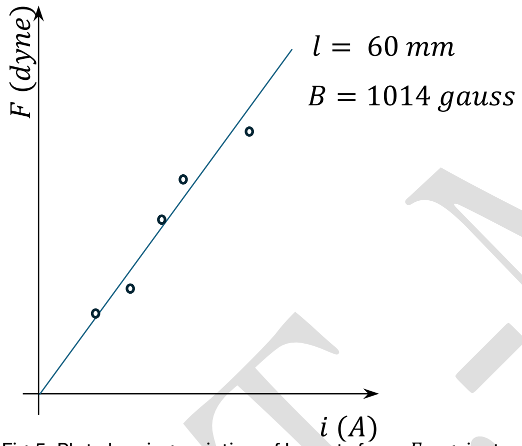

Fig-5: Plot showing variation of Lorentz force F, against current i, on a wire of length 60mm subjected to a magnetic field 1014 gauss.

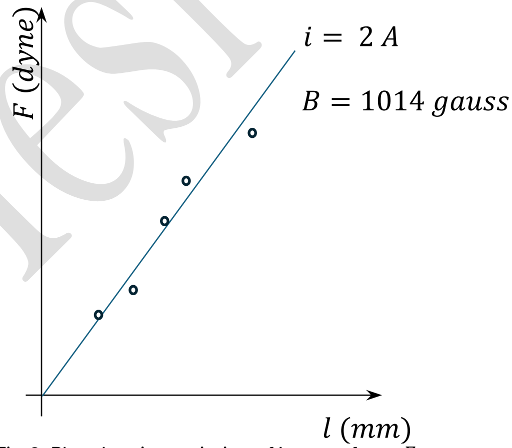

Fig-6: Plot showing variation of Lorentz force F, on a conductor of length l, bearing a current 2 A and subjected to a magnetic field 1014 gauss.

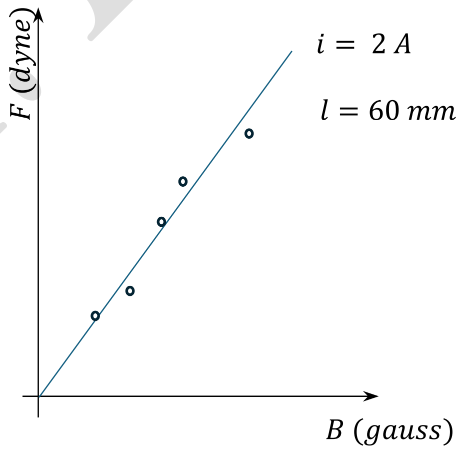

Fig-7: Plot showing variation of Lorentz force F, against magnetic field B, on a wire of length 60mm bearing a 2 A current.

Results and discussion:

The plots by and large show a linear dependence of Lorentz force on length of the conductor, the current through it and the magnetic field. Hence, we may safely conclude from a fairly direct measurement scheme that the Lorentz force relation holds.