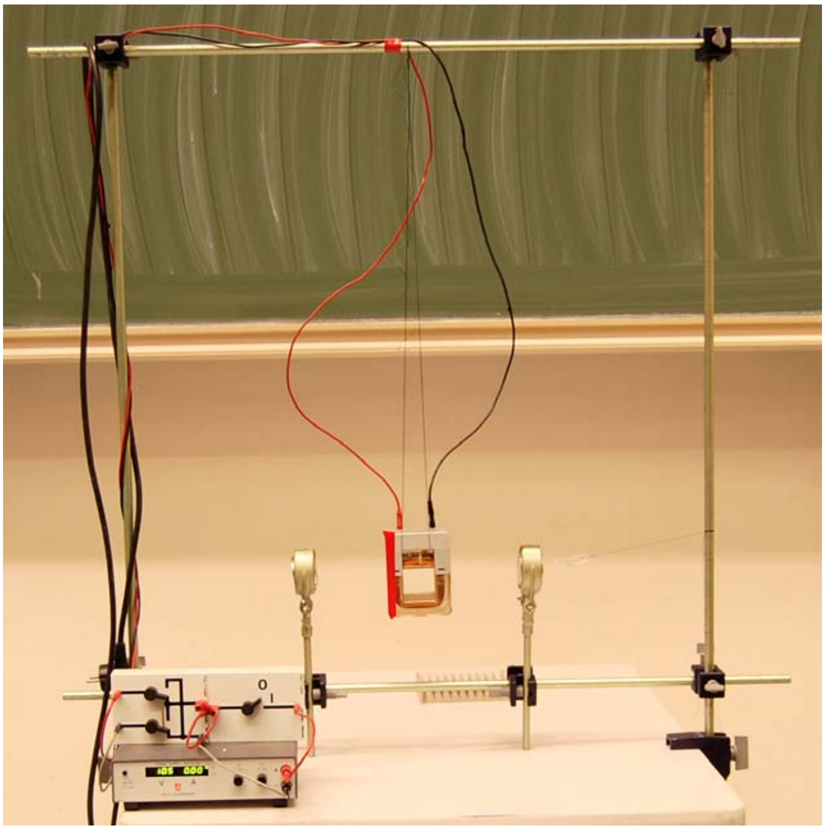
Current loop in magnetic field

Aim: To show torques and forces on a current loop in a magnetic field.

Subjects: 5H50 (Torques on Coils)

Diagram:



Equipment:

- Two Neodymium magnets fixed in clamps.
- Coil (n=500; I_{max} = 2.5A) with a piece of red tape at one side. The coil is suspended by thin thread, so it can rotate easily (see Diagram).
- Power supply, 30V/10A.
- Switch and Two-way switch.
- Array of compass-needles (Leybold Didactic 56061).
- Paperclip (to show the presence of a magnetic field).
- Camera and screen to show the demo to a large audience.

Safety:

- The Neodymium magnets are very strong. If these magnets are not handled carefully, there is risk of serious injury. The magnets are fixed in clamps and stored with a thick piece of sheet between them.
  -Carefully slide them apart when you use them, to prevent your fingers becoming trapped between them.
  -Keep them several meters away from magnetic information carriers.
  -Never operate the magnets in explosive environments, since they generate sparks!

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Presentation: Using the array of compass needles we show that there is a uniform magnetic field between the permanent magnets (see Figure 1).

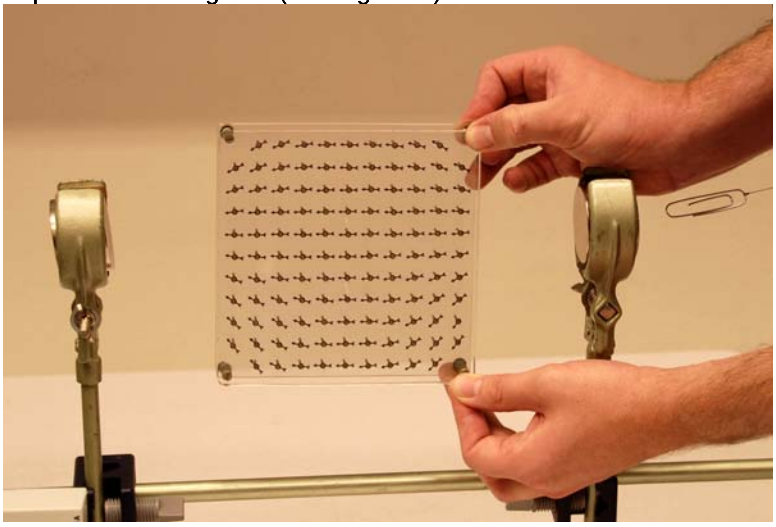

Figure 1

Close to the magnets the field is strongly divergent/convergent (see Figure 2).

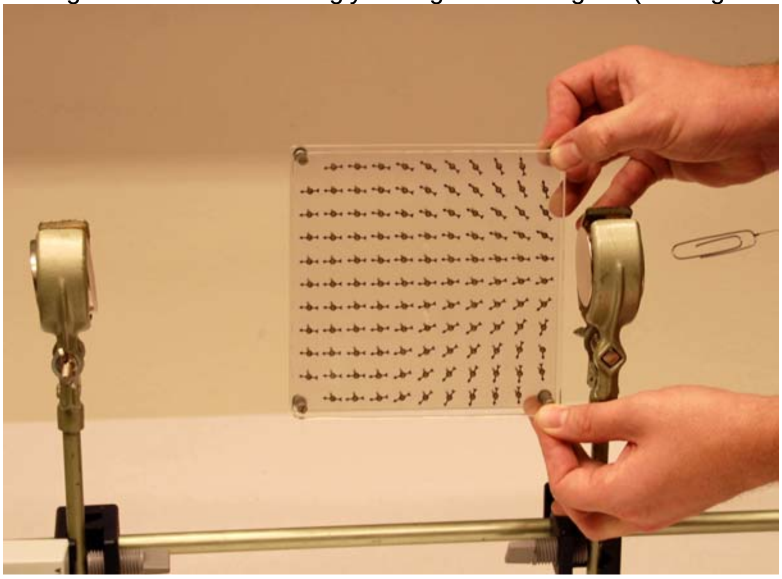

Figure 2

Then the coil is suspended between the two magnets (see Diagram). Connecting the power supply to the coil shows that the coil makes a rotation and lines up with the magnetic field (see Figure 3). There it remains at rest.
Conclusion is that in a homogeneous magnetic field a current carrying coil (a dipole) experiences a torque that lines up that dipole with the field. And in that uniform field there is no net force.

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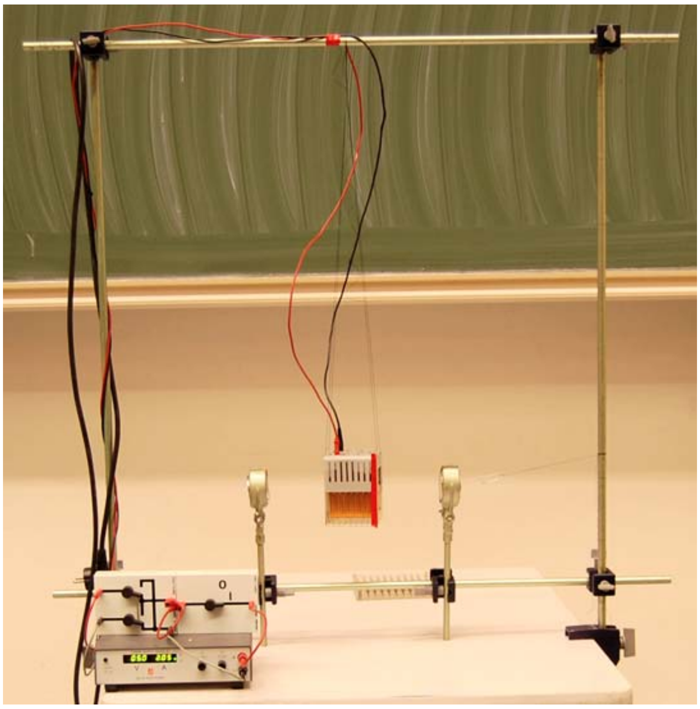

Figure 3

Then the coil is displaced a little from its central position: It attracts itself towards one of the magnets and sticks there (see Figure 4).

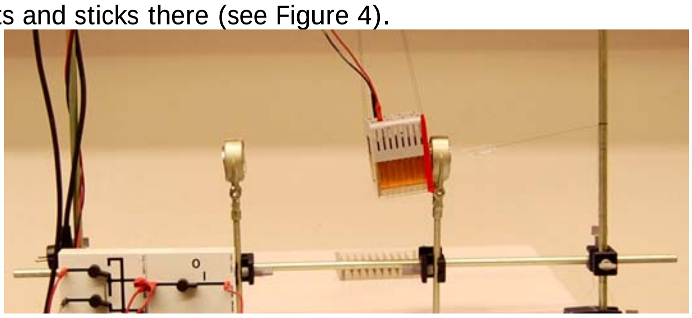

Figure 4

Conclusion is that in a non-uniform field there is a net force on a current loop (dipole).

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Explanation: There are Lorentz-forces on all sides of the coil. The forces on the bottom- and topside of the coil cancel (they only tend to stretch the coil). The two forces on the sides are also equal and opposite but they do generate a torque $\vec{N}$. $\vec{N} = \vec{m} \times \vec{B}$ ($\vec{B}$ is the magnetic field and $\vec{A}$, $\vec{A}$ being the area of the current loop).

When the field is non-uniform, there is a radial component of B and there will be a net force towards the magnet (see Figure 5).

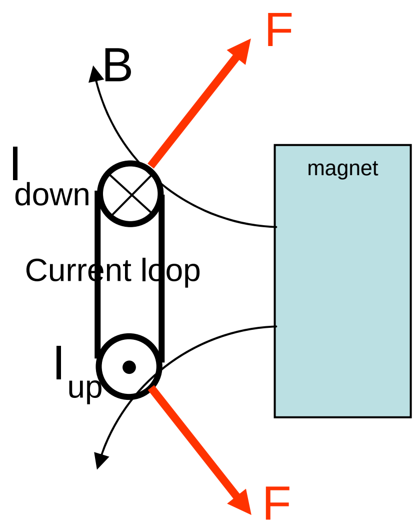

Figure 5

Remarks:

- The lining up of a current loop in a uniform field is an example of what dipoles do in a material. So it can be used as an example to present para-magnetism.

Sources:

- Griffiths, D.J., Introduction to Electrodynamics pag.255-258.