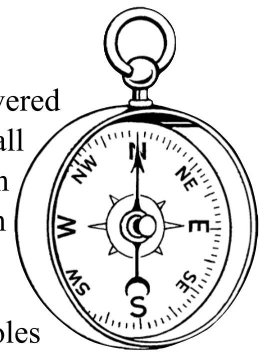
E&M Lab
Magnetic Dipole Force[1]

1. Objective:

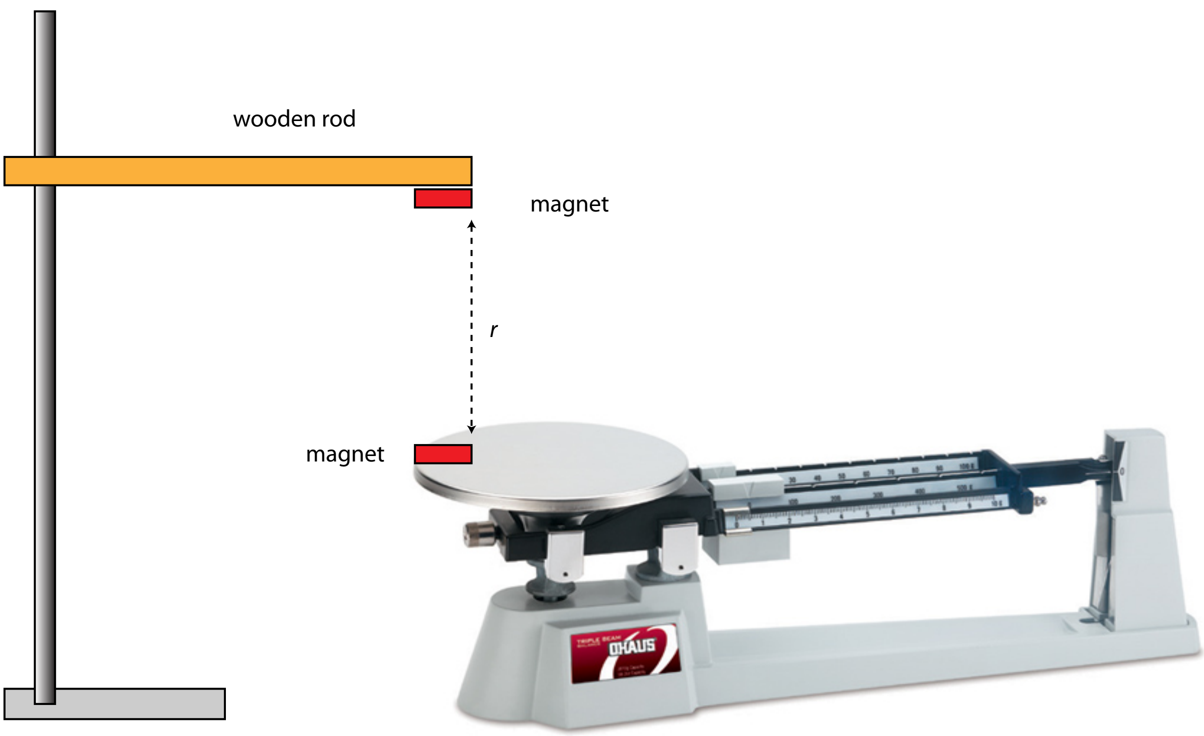
Determine experimentally the force as a function of distance between two permanent magnets.

2. Theory



A permanent magnet is a magnetic dipole. Magnetic dipoles were first discovered because they aligned themselves with the magnetic field of the Earth. We call the north pole of the magnet the one that aligns itself to the geographic north pole of the planet, and conversely the south pole of the magnet aligns with the south geographic pole.

We also observe an attractive force between north and south magnetic poles while there is a repulsive force between similar magnetic poles.



[1] The idea for this lab was taken from: ***Measuring the Forces Between Magnetic Dipoles***. *Lisa E. Gayetsky and Craig L. Caylor, Westminster College, New Wilmington, PA, in The Physics Teacher Vol. 45, september 2007*

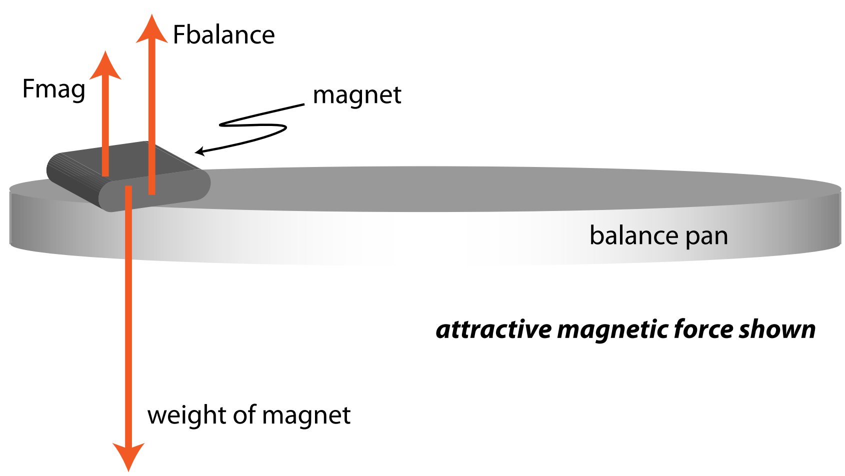
3. Procedure

You are supplied with two neodymium-iron-boron permanent magnets. This type of magnet is very strong but quite fragile, so be careful it does not hit another surface too hard, which could damage the magnet.

One magnet will be secured with tape near the edge of the triple-beam balance. The closer the magnet is to the center of the pan, the more it may interact with the magnetic damping system of the balance. The second magnet will be taped to the wooden rod attached to the universal stand. Make sure your magnets are secured in placed well enough so they can sustain a large force without moving.

We vary the distance *r* ***between the centers of the magnets*** by sliding the clamp on the universal stand and the distance is measured using a meter stick, or vernier calliper. For each separation distance, we can measure the force from the reading of the balance. The scale reports a mass based on the assumption that only the gravitational force and the normal force of the balance pan act on the object being measured. Since there is an additional magnetic force, the force applied by the balance pan to the object (F_{balance}) on the pan is given by

$$F_{\text{balance}} = mg \pm F_{\text{mag}}$$



The sign in the previous equation depends if the force between the magnets is attractive or repulsive. ***It is suggested to use a repulsive force between the two magnets***, because the equilibrium of the balance will be unstable when the attractive force is large.

Measure the mass (m) of the magnet on the pan in the absence of the second magnet, but including any tape used to secure the magnet on the balance pan.

Place the second magnet on the stand and approach it until you see an effect on the equilibrium of the balance. Move the sliders until the balance is back to equilibrium, record the apparent mass (m_{app}) and measure the distance (r) between the centers of two magnets. You can calculate the magnetic force later using the equation:

$$F_{\text{mag}} = (m_{\text{app}} - m)g$$

where g = 9.806 m/s^2 in Montréal, m is the real mass of your magnet and tape, and m_{app} is the apparent mass recorded at the distance r.

Start at a distance of about 15 cm and reduce the the distance until you have about 30 data points. Most of your data should be taken in a region where you have a significant magnetic force between the two magnets. If the force is too weak, your measurements will be more inaccurate.

4. Graph linearization

The graph should be a polynomial relationship called power law such as

$$F(r) = ar^n$$

where a is a constant and n is the exponent you need to identify. Inverse square laws such as gravitation or Coulomb's law (electrostatic force between two point charges) are such power laws, with n = –2. In order to linearize the function, you can take the log of both sides of the equation, which becomes:

$$\log F = \log a + n \log r.$$

So if you plot **log *F*** vs **log *r***, the function should be linear and the constant and exponent easily identified from the slope and intercept of the graph. It does not matter if you use either logarithm in base 10 or natural logarithm for this purpose.

5. Logbook

You must show the following before you leave the lab.

- ☐ Table of data.
- ☐ Graph of F vs r.
- ☐ Linearized graph; log F vs log r.
- ☐ The parameters of the power law, with uncertainties.
- ☐ A list of source of errors.
- ☐ A list of improvements to the lab.