<u>Force and Torque on a Magnetic Moment:</u>

Several physical concepts and phenomena are going to be studied using the Teach Spin Magnetic Torque apparatus. They are :

A. Magnetic torque on a dipole in a uniform magnetic field
B. Magnetic force on a dipole in a non-uniform gradient magnetic field
C. Harmonic oscillation of a magnetic dipole in a uniform magnetic field
D. Precessional motion of a spinning dipole in a uniform magnetic field
E. Magnetic resonance

Much of the information about the experimental set up can be obtained on the Tech Spin website: **https://www.teachspin.com/magnetic-torque.**

The objectives of the experiment are to explore the effect of magnetic field on the magnetic dipole, more specifically determination of the magnitude of the magnetic dipole using given instrumentation and theoretical background learned in previous physics courses. In doing so students will explore the limitations and sources of error while discovering different aspects of the apparatus and the experiments. In particular students will consider the factors that are usually neglected in simple theoretical models. In addition to reporting results and analysis of their work, students should explain the limitations of the apparatus. They are also expected to explore sources of error and analyze any discrepancies in their data. Where feasible, students should include the error propagation in their work.

Get to know the Teach Spin Magnetic Torque apparatus :

At first, students will familiarize themselves with the apparatus and see how the instrumentally controllable parameter can be used in different experiment. The instrumental set-up shown in Figure 1 includes three major parts: Control box (on the right), Helmholtz loops base (on the left) and accessories

Figure 1

The white ball with a little knob is the cue ball that can be levitated by air on the base. The black piece on top of the base is the strobe light that will be used in experiment described below.

A. Magnetic torque on a dipole in a uniform field

In this experiment the magnetic torque exerted by uniform magnetic field on the cue ball balances the torque by gravity on a bead, which can be moving on the aluminum rod attached to the cue ball, as shown in Figure 2.

Figure 2

B. Magnetic force on a dipole in a non-uniform gradient magnetic field
Magnetic force will be studied using two independent balance kits, the balance beam (Fig. 3-left) and the plastic tower (Fig. 3-right). The first one is working with the cue ball again but the second one will be done using a permanent magnet hung by a spring.

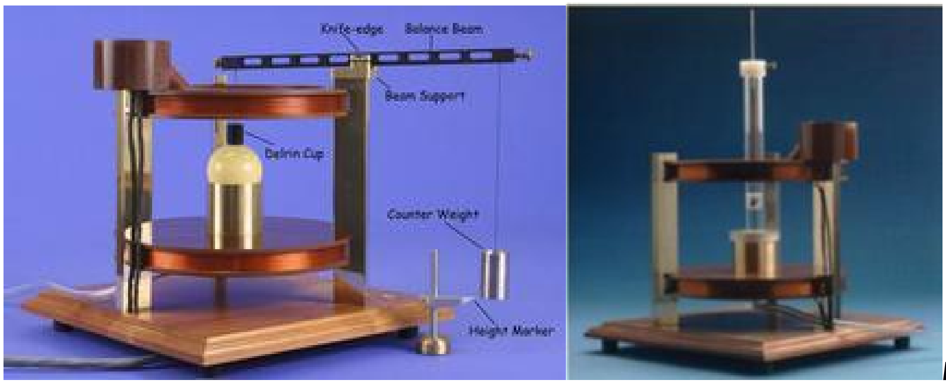

Figure 3

C. Harmonic oscillation of a magnetic dipole in a uniform field
The magnetic dipole (the cue ball) tends to line up with the magnetic field and oscillates around the balance point executing a SHO, if the initially displacement angle is small enough. Period of the oscillation is related to the magnetic field and the magnetic dipole moment of the cue ball. Hence this set-up can be used to measure the magnitude of the magnetic dipole. The SHO frequency can be measured using a stopwatch of multiple periods to achieve desired precision.

D. Precessional motion of a spinning dipole in a uniform field
The presessional motion happens when an object with an angular momentum (or spin) experiences an external torque. This is well understood by the rotational dynamics of angular momentum where the precession frequency (Larmor frequency) of the magnetic dipole (the cue ball) can be derived. By measuring the precession frequency students should be able to determine the magnitude of the magnetic moment of the cue ball. The challenging part of this experiment is spinning the cue ball and measuring its frequency. This can be done using a reflecting white dot on top of the knob of the cue ball and the strobe light with adjustable frequency.

E. Magnetic resonance
This part is a qualitative observation of a classical analogue of nuclear magnetic resonance (NMR), flipping of the nuclear spin in a steady magnetic field by absorption of a discrete amount of energy from an external source of oscillating electromagnetic field like RF. This descrete external energy must be equal to Larmor frequency of the precessional motion of the nuclear spin in the steady magnetic field. The classical analog of the NMR in this lab uses the cue ball and the magnetic field provided by the magnetization coils used in previous experiments. A saddle will be used to provide the external energy in an experimental set up, as shown in Fig. 4.

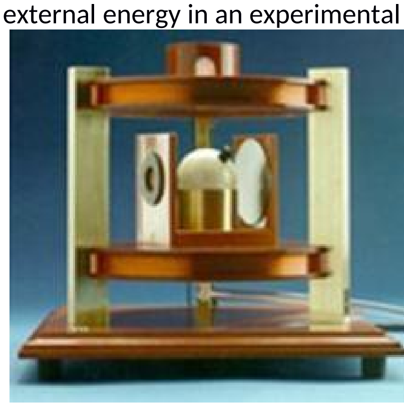
Figure 4