Thursday, April 28th, 2005

<u>Before attempting to assemble your equipment, read the problem text completely!</u>

Please read this first:

1. The time available is 5 hours.
2. Use only the pen and equipments provided. You may use your own calculator.
3. Use only the **one side** of the provided sheets.
4. In addition to "blank" sheets where you may write freely, there is a set of *Answer sheets* where you **must** summarize the results you have obtained. Numerical results must be written with as many digits as appropriate; don't forget the units.
5. Please write on the "blank" sheets the results of all your measurements and whatever else you deem important for the solution of the problem, that you wish to be evaluated during the marking process. However, you should use mainly equations, numbers, symbols, graphs, figures, and use *as little text as possible*.
6. **It's absolutely imperative** that you write on top of *each* sheet: your country ("**Country code**"), your student code (as shown on your identification tag, "**Student ID**"), and additionally on the "blank" sheets: the progressive number of each sheet (from 1 to *N*, "**Page n.**") and the total number (*N*) of "blank" sheets that you use and wish to be evaluated ("**Page total**"); leave the "**Problem**" field blank.
7. The students should start with a new page for each section. It is also useful to write the number of the section you are answering at the beginning of each such section. If you use some sheets for notes that you do not wish to be evaluated by the marking team, just put a large cross through the whole sheet, and don't number it.
8. When you have finished, turn in all sheets <u>in proper order</u> (answer sheets first, then used sheets in order, the unused sheets and problem text at the bottom) and put them all inside the envelope where you found them; then leave everything on your desk. You are not allowed to take anything out of the room.

1. DETERMINATION OF SHAPES BY REFLECTION

INTRODUCTION

Direct visual observation, is a method where human beings used their eyes to identify an object. However, not all things in life can be observed directly. For example, how can you tell the position of a broken bone? Is it possible to look at a baby inside a pregnant woman? How about identifying cancer cells inside a brain? All of these require a special technique involving indirect observation.

In this experiment, you are to determine the shape of an object using indirect observation. You will be given two closed cylindrical boxes and in each box, there will be an object with unknown shapes. Your challenge is to reveal the object without opening the box. The physics concepts for this experiment are simple, but creativity and some skills are needed to solve it.

EXPERIMENT

APPARATUS

For this experiment, you will be given two sets of cylindrical boxes consisting of:

1. An object with unknown shape to be determined (it is a simple geometrical object with either plane or cylindrical sides)
2. Closed cylindrical box with an angular scale on the top side (2a) and around its circumference (2b).
3. A knob which you can rotate
4. A laser pointer
5. Spare batteries for the laser pointer
6. A ruler

EXPERIMENTAL METHOD

The students are to determine the shape of the object inside a closed cylindrical box. The diameter of the cylinder can be measured by a ruler. ***Students are not allowed to open the cylindrical box or break the seal to determine the shape of the object.*** The object is an 8-mm thick metal with its sides polished so that it can reflect light likes a mirror. You can rotate the object using the knob on the top part of the cylinder. This will rotate the object in the same axis as the cylinders axis.

EXPERIMENTAL COMPETITION

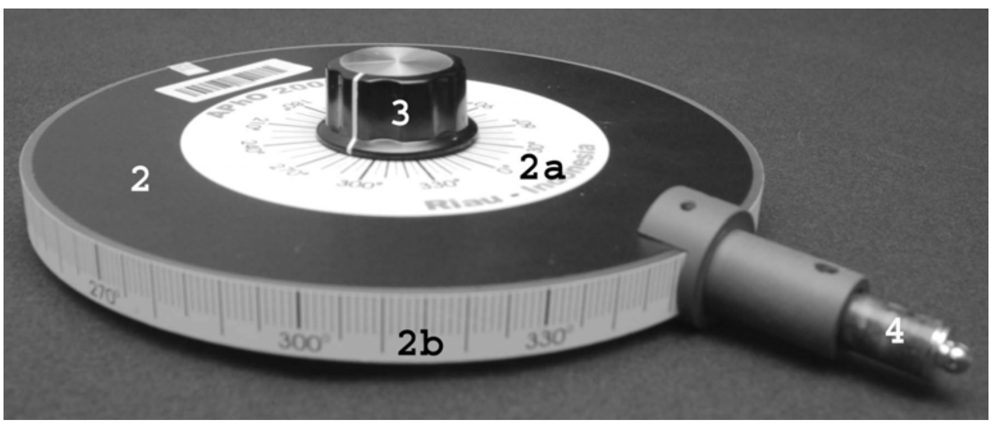
The laser pointer can be switched on by rotating its position. You can adjust the position of the light beam by rotating the laser pointer in either clockwise or anti-clockwise direction. The reflection of the laser beam from the laser pointer can be observed along the circumference of the closed cylinder. Measurement using the angular scale can be used. By rotating the knob on the upper part while the laser pointer is switched on, you will notice that as you rotate the object, the position of the reflected light from the object will change. ***If the light from the laser pointer dim or the laser pointer fail to work, ask the committee for replacement.*** By observing the correlation of the angular position of the object and the reflection of the laser beam, you should be able to determine the shape of the object.

For every object (the two objects are of different shapes):

A. Draw a graph of: ‘reflection angle of the laser beam against the angular position of the object’ (2×1 pt)
B. Determine the number of edges (sides) in each object (2×0.25 pt)
C. Use data from the graphic to sketch the shape of the object and find the angular positions of changing sides correspond with the top angular scale (2×1.5 pts)

For the object with fewer sides only:

D. Draw rotating axis of the object and determine the distance to every sides (3 pts)
E. Determine the length of sides without error analysis; determine also the angles between neighboring sides (1.5 pts)



You must present your result on graph papers and try to deduce the mathematical equations to determine the shape of the object.

Remarks:

1. One of the objects has only plane sides and the second object has one curved side.
2. Sometimes you may get two reflections of the beam from the object.
3. In case of a curved side the determination of the radius of curvature is not required but determination whether it is convex or concave with respect to the axis of rotation is necessary.

2. MAGNETIC BRAKING ON AN INCLINED PLANE

INTRODUCTION

When a magnet moves near a non-magnetic conductor such as copper and aluminum it experiences a dissipative force called magnetic braking force. In this experiment we will investigate the nature of this force.

The magnetic braking force depends on:
- the strength of the magnet, determined by its magnetic moment (μ);
- the conductivity of the conductor (σ_C);
- the size and geometry of both magnet and the conductor;
- the distance between the magnet and conducting surface (d); and
- the velocity of the magnet (v) relative to the conductor.

In this experiment we will investigate the magnetic braking force dependencies on the velocity (v) and the conductor-magnet distance (d). This force can be written empirically as:

$$F_{MB} = -k_0\, d^{\,p} v^n \qquad (1)$$

where

k_0 is an arbitrary constant that depends on μ, σ_C and geometry of the conductor and magnet which is fixed in this experiment.

d is the distance between the center of magnet to the conductor surface

v is the velocity of the magnet

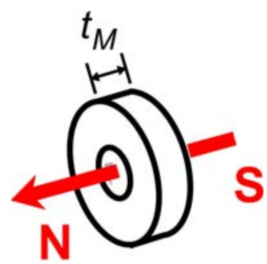
p and n are the power factors to be determined in this experiment

EXPERIMENTAL COMPETITION

EXPERIMENT

In this experiment error analysis is required.

APPARATUS



Magnetic poles

(1) Doughnut-shaped Neodymium Iron Boron magnet.
  Thickness: t_M = (6.3±0.1) mm
  Outer diameter: d_M = (25.4±0.1) mm
  The poles are on the flat faces as shown:
(2) Aluminum bar (2 pieces)
(3) Acrylic plate for the inclined plane with a linear track for the magnet to roll
(4) Plastic stand
(5) Digital stop watch
(6) Ruler
(7) Graphic papers (10 pieces)

Additional information:

Local gravitational acceleration: $\boldsymbol{g}$ **= 9.8 m/s²**
Mass of the magnet: $\boldsymbol{m}$ **= (21.5±0.5) g**
North-South direction is indicated on the table.
You can read the operation manual of the stopwatch

This problem is divided into two sections:
(A) Setup and introduction
(B) Investigation of the magnetic braking force

Remarks:
Make sure that the plane is clean before your experiment

EXPERIMENTAL COMPETITION

QUESTIONS

Please provide sufficient diagrams in your answers so that your work can be understood clearly

(A) Setup

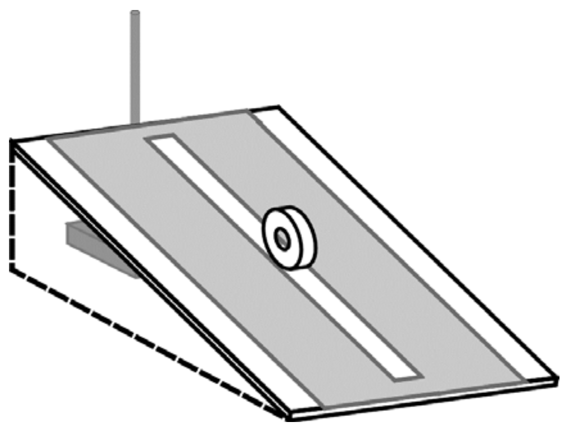


Figure 1. Inclined plane setup without aluminum bars

Roll down the magnet along the track as shown. Choose a reasonably small inclination angle so that it does not roll too fast.

[1] As the magnet is very strong, it may experience significant torque due to interaction with earth's magnetic field. It will twist the magnet as it rolls down and may cause significant friction with the track. What will you do to minimize this torque? Explain it using diagram(s).

[1.0 pt]

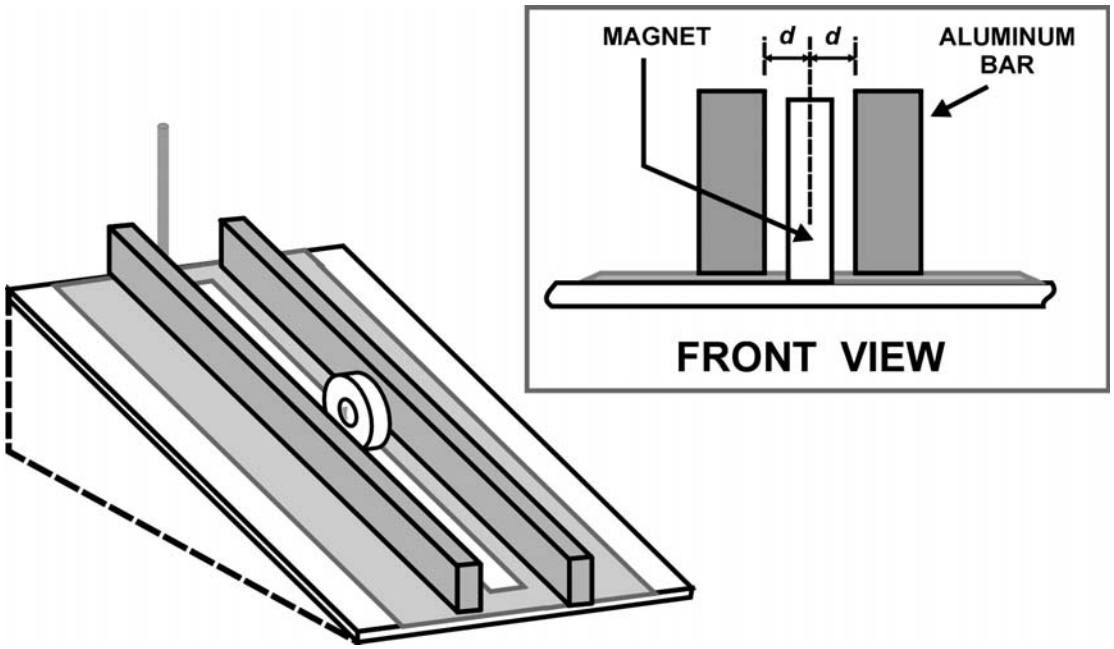


Figure 2. A complete setup with aluminum bars

Place the two aluminum bars as shown in Figure 2 with distance approximately d=5mm. **Remember that the distance *d* is to the center of the magnet as shown in the inset of Figure 2**.

Again release the magnet and let it roll. You should observe that the magnet would roll down much slower compared to the previous observation due to magnetic braking force.

[2]. Provide diagram(s) of field lines and forces to describe the mechanism of magnetic braking.

[1.0 pt]

(B) Investigation of the magnetic braking force

The experimental setup remains the same as shown in Figure 2 with the same magnet-conductor distance approximately d = 5 mm (about 2 mm gap between magnet and conductor on each side).

[1] Keeping the distance d fixed, investigate the dependence of magnetic braking force on velocity (v). <u>Determine the exponent ***n*** of the speed dependence factor</u> in Equation 1. Provide appropriate graph to explain your result.

[4.0 pt]

Now vary the conductor-magnet distance (d) <u>on both left and right</u>. Choose a fixed and reasonably small inclination angle.

[2] Investigate the dependence of the magnetic braking force on conductor-magnet distance (d). <u>Determine the exponent ***p*** of the distance dependence factor</u> in Equation 1. Provide appropriate graph to explain your result.

[4.0 pt]