**Lab 5: Measuring of the Acceleration Due to Gravity and Studying the Earth’s Magnetic Field**

**Geology 107: Plate Tectonics**

**PART 1: The Ball-Drop Experiment**

A ball is dropped between two infrared sensors (gates) A and B connected to a timer. This system yields:

1) the time the ball takes to pass through gate A, \( t_A \)
2) the time the ball takes to pass through gate B, \( t_B \)
3) the total time the ball takes to go from gate A to gate B, \( t_{AB} \).

The ball’s velocity at each gate is the diameter of the ball, \( D \) divided by the time it takes to pass through the gate. Thus, the velocity of the ball at each gate is:

\[
v_A = \frac{D}{t_A} \quad v_B = \frac{D}{t_B} .
\]

Because acceleration is the time derivative of velocity,

\[
a = \frac{dv}{dt} ,
\]

the ball’s acceleration due to gravity can be found by approximating the derivative with the differences:

\[
g = \frac{v_B - v_A}{t_{AB}} = \frac{\frac{D}{t_B} - \frac{D}{t_A}}{t_{AB}} = \frac{1}{t_{AB}} \frac{D(t_A - t_B)}{t_A t_B}
\]
Here are a few things to think about before performing the experiment:

i. Using two balls with different weights, which would fall faster?

ii. How would positioning the time gates further apart affect the estimate of g?

Experiment:
1. Measure and record \( t_A \), \( t_B \) and \( t_{AB} \) using the steel ball. Repeat for 3 trials. Record your results in the table below. Find and record the average for these measurements.

2. Repeat step 1. using the plastic ball.

The diameter, D, of both balls is 1.9 cm (0.75 in).

<table>
<thead>
<tr>
<th>Trial:</th>
<th>Steel Ball</th>
<th>Plastic Ball</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( t_A ):</td>
<td>( t_B ):</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Questions:
iii. How do the times for the two balls compare?

iv. Calculate \( g \) using the values from the average times for the steel ball. How well do your measurements of \( g \) agree with the accepted value of \( 9.8 \, \text{m/s}^2 \)?
PART 2: Pendulum Experiment

One day while attending Mass, Galileo noticed a chandelier above him was swaying in a draft. He noticed that for large and small swings the lamp had the same period of motion. The period, \( T \) is the amount of time taken for the swinging motion of the lamp to repeat. Galileo then confirmed his observation by noticing that the period of oscillation of any pendulum was dependent only on the length of the string used to suspend the mass, and not on the mass.

The arc-path of the mass, \( s \) is related to the product of the length of the string \( l \), and the angle \( \theta \), of the swing:

\[
s = l \theta
\]

The force acting on the pendulum tangential to the arc-path of the mass is:

\[
F = - m g \sin \theta,
\]

where \( mg \) is the weight of the mass.

Using Newton’s law of motion, this force is also equal to the product of the mass and the tangential acceleration, \( \frac{d^2s}{dt^2} \):

\[
F = - m g \sin \theta = m a
\]

By using the small angle approximation (when angle \( \theta \) is small, \( \sin \theta \approx \theta \)), we now have:

\[
a = - g \theta = - g \frac{s}{l}
\]

The square of the angular frequency \( \omega^2 \) is equal to \( g/l \). Using a relationship between the angular frequency \( \omega \) and the period, \( T \):
We can rearrange this equation to find the value of \( g \):

\[
g = \frac{4\pi^2 l}{T^2}
\]

Experiment:

1. Set the pendulum to a length of 0.5 meters.
2. Time how long the pendulum takes to make 10 oscillations. Record the time in the table below; repeat the trial five times.
3. Find the value of the period for each trial, average the values for time and period (period = \( T = \) Time/number of oscillations).
4. Using the formula above, calculate the acceleration due to gravity, \( g \) for the averaged value of the period.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Length</th>
<th>Time</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.5 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.5 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.5 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.5 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg.</td>
<td>0.5 m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

v. How well do your measurements of \( g \) agree with the accepted value of \( 9.8 \frac{m}{s^2} \)? List two possible explanations for the variations in your calculated value of \( g \) between the two methods used to calculate it.
PART 3: Looking at the field produced by a bar magnet

The magnetic field of the Earth is similar to that of a giant bar magnet. In this experiment we will look at the field produced by a bar magnet and compare it to that of the earth.

From Exploring Earth, fig 5.24

The magnetic field is not aligned with the Earth’s axis of rotation, which means that a compass does not point to geographic north, or the North Pole. The angle between the slight tilt in the "bar magnet" inside the earth and the North Pole is called the *declination angle*. This angle is sometimes given on maps so that geographic north may be found. Another angle, called the *inclination angle* is the angle between the horizontal and the magnetic field. This may be found by holding a compass vertically and measuring the downward angle off of the compass.

**Experiment**

1. On the next page, use the compass to mark the direction that arrow points.

2. Using the arrows you drew and the figure on the previous page, draw the field lines.