Pre-Lab Questions 2

Topic: Acceleration due to gravity, *g*

Learning Outcomes:

To enable the students to
(i) state the general pattern of variation of *g* on earth based on latitude.
(ii) state the reasons why g is larger at the poles.
(iii) linearize an equation.
(iv) set up a simple pendulum experiment to determine *g*.
(v) produce an appropriate table for the data.
(vi) calculate the uncertainties in the experiments.
(vii) calculate the percent difference between $g_{experiment}$ and $g_{standard}$.

Apparatus: Stopwatch, meter rule, a retort stand, clamp, string and pendulum bob.

Pre-Lab Questions 2

i) Different *g* at different latitudes on earth

Different locations on earth has slightly different acceleration due to gravity, *g*. The different values of *g* for several cities and places throughout the world is given in Table 1. The cities located near the equator have a slightly smaller *g* compared to those at higher latitudes.

Table 1: Acceleration due to gravity *g* at different places and cities of the world

No	*Place/Cities*	*Latitude*	*g* (m/s^2)
1	North Pole	90.0° N	9.832
2	Green Land	70.0°N	9.825
3	Helsinki	60.2°N	9.819
4	Amsterdam	52.4°N	9.813
5	Paris	48.8°N	9.809
6	San Franscisco	37.7°N	9.800
7	Kuwait	30.0°N	9.793
8	Bangkok	13.8°N	9.783
9	Kuala Lumpur	3.1°N	?
10	Singapore	1.2°N	9.781
11	Equator	0°	9.780

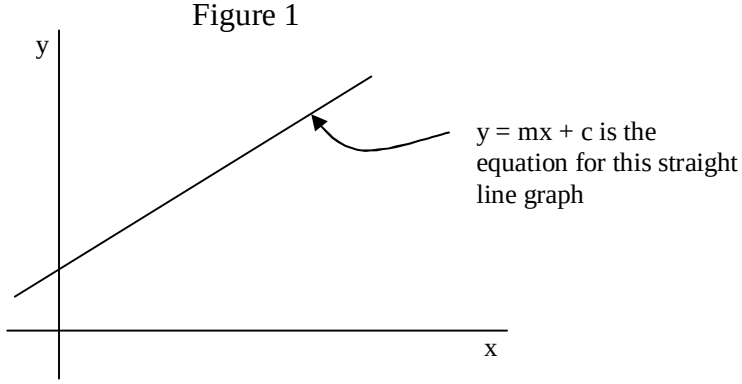
12	Jakarta	6.3°S	9.781
13	Rio de Janeiro	23.0°S	9.788
14	Sydney	34.0°S	9.797
15	Wellington	41.3°S	9.803
16	South Pole	90.0°S	?

1. Comparing the values of *g* at 16 places and cities in the world at various latitudes, what can you say about the trend of these values?
2. Can you guess the appropriate values of *g* for Kuala Lumpur and the South Pole?
3. Why *g* is larger at the poles?

ii) A straight line graph and its usage in data analysis

1. An equation for a straight line graph (linear graph) is y = mx + c, where y is the quantity on the vertical axis and x is the quantity on the horizontal axis as shown in Figure 1.

Figure 1



What is the meaning of m and c on the straight line equation y = mx + c?

2. The period of a simple pendulum (T) is related to its length (L) by the following equation:

$$T = 2\pi\sqrt{\frac{L}{g}} \quad \ldots\ldots\ldots(1),$$

where g is the acceleration due to the gravity.

(a) How do we transform equation (1) so that we can plot a straight line graph relating the variable T and L? [i.e. How do we linearize equation (1)?]

(b) How do we determine the value of *g* from this graph?

iii) Simple Pendulum

1. What is a simple pendulum?
2. How do we set up a simple pendulum in the lab?
3. What is the period of a simple pendulum?
4. What is the best way to determine the period of a simple pendulum?
5. What is the condition to use the equation $T = 2\pi\sqrt{\frac{L}{g}}$?
6. If we vary the length of a pendulum, the period will change. Make an appropriate table to record the data of L and T.
7. How do we determine the uncertainty (error) from a data that are plotted in a straight line graph?
8. How do we calculate the percent error between the value $g_{experiment}$ and $g_{standard}$?
   Take $g_{standard} = 9.81\ m/s^2$.

Experiment 2

Topic: Acceleration due to gravity, *g*

Objective: To determine the acceleration due to gravity, *g*, by means of a simple pendulum

Learning Outcomes:

To enable the students to

i) set up a simple pendulum experiment to determine *g*.
ii) produce appropriate table for the data.
iii) plot and extract appropriate information from a linear graph.
iv) calculate the uncertainties in the experiments.
v) calculate the percent error between $g_{experiment}$ and $g_{standard}$.

Apparatus: Stopwatch, meter rule, pendulum bob, string, retort stand and clamp.

Introduction

Different locations on earth has slightly different acceleration due to gravity, *g*. Table 1 shows the values of *g* at different major cities of the world.

Table 1: Slightly different magnitude of *g* at different cities.

City	*Latitude*	*g (m/s²)*	*City*	*Latitude*	*g (m/s²)*
Helsinki	60.2°N	9.819	Jakarta	6.3°S	9.781
Amsterdam	52.4°N	9.813	Rio de Janeiro	23.0°S	9.788
Kuwait	30.0°N	9.793	Sydney	34.0°S	9.797
Bangkok	13.8°N	9.783	San Francisco	37.7°N	9.800
Singapore	1.2°N	9.781	Wellington	41.3°S	9.803

The magnitude of *g* at the poles is bigger by about 0.5% compared to that at the equator. This difference is mainly due to:

1. The different linear velocity of earth rotation at the poles and at the equator. The linear velocity of the earth is bigger at the equator than at the poles.

2. The density of the earth's core which increases as we go deeper into the centre of the earth.

3. The equatorial bulge, where the poles are flattened and at a shorter distance to the centre of the earth.

Knowing the value of *g* is important in many applications such as *aerospace* fields to determine the load of aircraft and spacecraft and *automotive engineering* mainly in relation to cornering forces and collision analysis.

There are many ways to measure the gravitational acceleration of the earth. Two common ways to determine *g* in an introductory physics laboratory are carried out by:

(i) timing the freefall of an object going through certain measured vertical distance and then calculate *g* by using an appropriate equation of motion, and

(ii) timing the period of a pendulum for different length and then calculate *g* by using the formula that relates the period of oscillation (T) and Length (L).

The standard acceleration due to gravity for the earth at sea level is currently defined up to seven significant figures to be 9.806650 m/s^2. However, for comparison with our experimental results it is sufficient to take the value of *g* up to three significant figures only, 9.81 m/s^2.

Instructions

1. Set up a simple pendulum system by using a pendulum bob, a string, a clamp and a retort stand.

2. Determine the period of the pendulum for a certain length of the pendulum string with small oscillation angle.

3. Record the data in an appropriate table.

4. Repeat step 2 and step 3 for eight more readings for several different lengths of the string.

5. Determine *g* from an appropriate graph of the measured quantities based on equation $T = 2\pi\sqrt{\frac{L}{g}}$, where T and L are the period and length of the pendulum. Determine the uncertainty of *g*.

6. Calculate the percentage difference between the acceleration due to gravity determined in this experiment ($g_{experiment}$) and the standard acceleration due to gravity at sea level, $g_{standard}$ = 9.81 m/s^2.

What should be in your report :

1. Objective :

2. Apparatus : Equipments that you use in the experiment

3. Theory : State the physics concepts and equations used in this experiment.

4. Procedures : Steps that you take to perform the experiments

5. Data and Results:
   Organize your data into tables. Be consistent and correct in the use of significant figures. Give the quantity its units and uncertainties. Calculated values, calculated uncertainties, percent difference to the standard value and graphs should be included here.

6. Conclusions : State the results based on the objectives. Include the calculated uncertainties and state the possible sources of uncertainties.

References

Iona, M. (1978). Why g is larger at the poles? American Journal of Physics. 46(8):790-791.

Stumpf, F.B. et. al. (1979). Laboratory Experiments for General Physics 251, 252, 253. Ohio University.

Post-Lab Questions

1. Do you think the percentage difference between $g_{experiment}$ and $g_{standard}$ is acceptable in this experiment?

2. Do you think the experiment to determine *g* by using a pendulum can be improved? Describe the improvement.

3. Can you think of any other way to determine *g*?