MINISTRY OF EDUCATION MALAYSIA
Matriculation Division

HOME-BASED EXPERIMENTS GUIDE

FOR
CHEMISTRY, PHYSICS AND BIOLOGY
(SEMESTER I)

FIRST EDITION

https://bit.ly/HomeBasedExperimentGuide

MATRICULATION DIVISION
MINISTRY OF EDUCATION MALAYSIA

Home-Based Experiments Guide

for

Chemistry, Physics and Biology

(Semester I)

MINISTRY OF EDUCATION MALAYSIA
MATRICULATION PROGRAMME

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FOREWORD

I am delighted to write the foreword for the Home-Based Experiments Guide for Chemistry, Physics and Biology (Semester I) First Edition, which aimed to equip students with knowledge, skills, and the ability to be competitive pre-university students.

This Home-Based Experiments Guide is written in such a way to increase the students' interest in Science, Technology, Engineering, and Mathematics (STEM). This guide also emphasises students' practical skills and their ability to read and comprehend instructions, make assumptions, apply learnt skills and react effectively in a safe environment despite being conducted at home. Science process skills such as making accurate observations, taking measurements in correct manner, using appropriate measuring apparatus, inferring, hypothesizing, predicting, interpreting data, and controlling variables are further developed during practical sessions. The processes which are incorporated to help students to enhance their Higher Order Thinking Skills (HOTS) such as analytical, critical and creative thinking skills. These skills are crucial to prepare students to face the upcoming challenges in the 21^{st} century era.

The manipulative skills such as handling the instruments, setting up the apparatus and drawing the diagrams correctly can be improved through practical sessions. These experiments are designed to encourage students to develop inquiry thinking. It requires students to participate actively in the science process skills before, during and after the experiment by preparing the pre-report, making observations, analysing the results and drawing conclusions.

It is my hope and expectation that this guide will provide an effective learning experience for all students. It will become a reference resource in equipping themselves with the skills needed to fulfil the prerequisite requirements in the first-year undergraduate studies.

Dr. HAJAH ROSNARIZAH BINTI ABDUL HALIM
Director
Matriculation Division

CONTENTS

SECTION 1

INTRODUCTION

INTRODUCTION

This Home-Based Experiments Guide is an extension of the Matriculation Programme Laboratory Manual for Chemistry, Physics and Biology. It is a guideline for students in conducting experiments at home. This first version was fully documented and applied effectively starting August 2021.

The objective of this guide is to help students to follow the learning process of scientific skills optimally and effectively even though the experiments are performed at home. Students' practical skills are also highlighted and their understanding of reading and following the procedures, making hypotheses, applying basic science manipulative skill in interpreting results in a safe environment.

The procedure of these home-based experiments has been designed closely related to the current laboratory manual practice which purposely to allow students' adaptation towards the home-based situations, using home appliances and household products. Combination of suitable websites, simulations and applications were also introduced to the students to support the new norm learning process.

The scientific process occurs naturally, spontaneously in our minds. Using this guide, students are derived to break down the steps of science process skills including observing qualities, measuring quantities, sorting/classifying, inferring, predicting, experimenting, and communicating. The experiments in this guide is to give the students a better understanding of the concepts of scientific skills throughout the learning process.

The aims of the experiments are to:

i. introduce students to laboratory work and to equip them with the practical skills needed to carry out experiments at home;
ii. choose suitable apparatus and, to use it correctly and carefully;
iii. handle apparatus, measuring instruments and materials safely and efficiently;
iv. identify the limitations and the accuracy of observations and measurements;
v. follow instructions and procedures given in this Home-Based Experiment Guide;
vi. observe, measure and record data by giving consideration to the consistency, accuracy and the units of the physical quantities;
vii. deduce logically and critically the conclusion based on observation, data analysis and data interpretation;
viii. present a good scientific report for the experiment;
ix. familiarise students with the standard experimental techniques; and
x. gain confidence through performing experiments.

SAFETY PRECAUTIONS FOR HOME-BASED EXPERIMENTS

i. Be careful when using sharp tools such as knives and scissors.
ii. Please keep your workspace clean and tidy. Cluttered workspace would cause errors in your experimental procedures and observations.
iii. Be careful when using chemicals and flammable solutions. Keep them at room temperature and away from fire.
iv. In any case of broken glass, injury, or other emergency cases, inform your parents or guardian immediately.
v. After completing the experiment, make sure all tools and the workspace are cleaned. Do not leave the remnants of materials and apparatus uncleaned.

GENERAL GUIDANCE FOR STUDENTS

i. Follow the Safety Precautions for Home-Based Experiments.
ii. Follow the experiment guide, do not perform any unauthorised experiments.
iii. Conduct the experiment by yourself, be responsible and honest to report the correct result gathered in each experiment. If the results are different from the theoretical value, state the possible reasons in your report.
iv. Seek advice from the lecturer if any problem arises during the experiment session through online communication.
v. Submit your complete reports online to the lecturer.

SECTION 2

CHEMISTRY EXPERIMENTS

GAS LAWS

LEARNING OUTCOMES

At the end of this lesson, students should be able to:
i. verify Boyle's Law by using graphical method; and
ii. verify Charles' Law by using graphical method.

INTRODUCTION

Boyle's Law
Volume of a fixed mass of a given gas is inversely proportional to its pressure at constant temperature.

$$V \propto \frac{1}{P} \qquad (n \text{ and } T \text{ constant})$$

Charles' Law
Volume of a fixed mass of a given gas is directly proportional to its absolute temperature at constant pressure.

$$V \propto T \qquad (n \text{ and } P \text{ constant})$$

Avogadro's Principle
All gases of equal volume will contain the same number of molecules at the constant temperature and pressure.

$$V \propto n \qquad (T \text{ and } P \text{ constant})$$

Ideal Gas Equation:

By combining the relationships governed by the gas laws, a general equation known as the ideal gas equation can be obtained.

Thus, combining the three laws, we get

$$V \propto \frac{nT}{P}$$

The above expression can be written as

$$V \propto \frac{RnT}{P} \quad \text{or} \quad PV = nRT$$

In this experiment, a gas law modeling and simulation tool come in the form of web application (developed by University of Texas) serves as a virtual lab that allows students to experiment with and develop a deeper understanding of gas laws. Students can also manipulate the volume of gas, pressure of gas and temperature of gas to verify Boyle's law and Charles' law. The gases used in the simulation are assumed to be ideal gases.

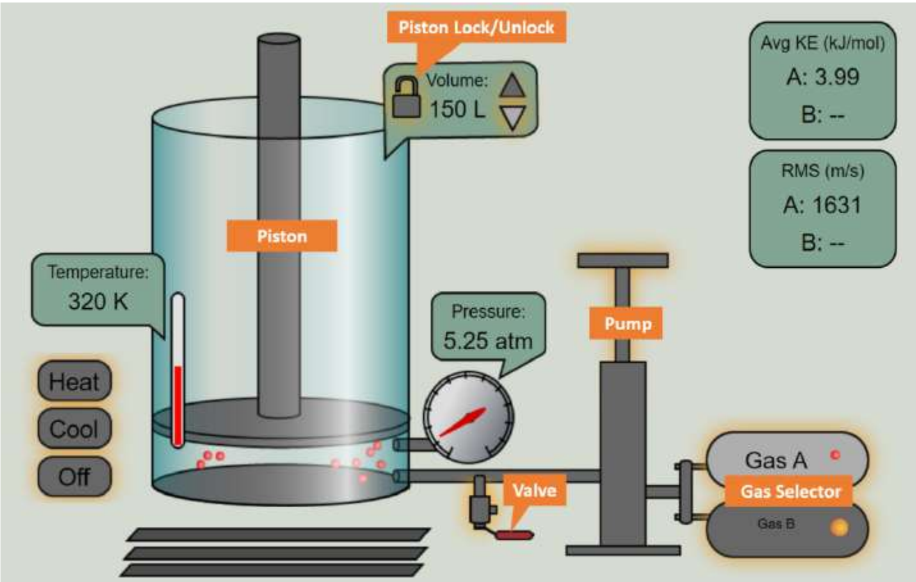


Figure 2.1 Gas Simulator (Copyright: University of Texas)

APPARATUS

Simulation Tool (Gas Simulator)
https://ch301.cm.utexas.edu/simulations/js/idealgaslaw/

PROCEDURE

(A) Boyle's Law

1. Click on the link or scan the QR code given.
   https://ch301.cm.utexas.edu/simulations/js/idealgaslaw/

2. Select a gas (Gas A or Gas B) using the searchable drop-down list on the bottom-right corner of the dashboard on the "Simulator" page.

3. Clear the gas container by tapping the gas valve until the container is empty.

4. Set a constant temperature (in a range of 250 to 300 K).

5. Press down the gas pump once. Record the readings of volume, temperature and pressure.

6. Change the volume of gas and record the respective pressure. Note: Make sure the temperature is constant throughout the process.

7. Repeat Step 4 for four times to obtain 5 sets of data.

8. Record the data obtained in **Table 2.1**.

(B) Charles' law

1. Click on the link or scan the QR code given.
   https://ch301.cm.utexas.edu/simulations/js/idealgaslaw/

2. Select a gas (Gas A or Gas B) using the searchable drop-down list on the bottom-right corner of the dashboard on the "Simulator" page.

3. Clear the gas container by tapping the gas valve until the container is empty.

4. Set the temperature in the range of 250 to 300 K.

5. Press down the gas pump once. Record the readings of volume, temperature and pressure.

6. Change the temperature of gas and record the respective volume and pressure.
   Note: Make sure the pressure is constant throughout the process.

7. Observe the speed of particles in the gas container and relate the speed with the average kinetic energy.

8. Repeat Step 4 for four times to obtain 5 sets of data.

9. Record the data obtained in **Table 2.2**.

10. Plot a graph of Volume of gas versus Temperature of gas (in degree Celsius) using the data obtained. Label the axis with appropriate units.

11. Extrapolate the graph line until V = 0, to obtain the absolute zero temperature.

12. By referring to the graph plotted, explain the relationship between volume of gas and temperature of gas using Kinetic Molecular Theory of gas.

13. Compare the speed of particles at two different temperatures in relation to average kinetic energy in **Table 2.3**.

ADDITIONAL INFORMATION

- University of Texas. (2018). *Ideal Gas Law Simulation*. https://ch301.cm.utexas.edu/

- simulations/js/idealgaslaw

DATA SHEET

EXPERIMENT GAS LAWS

NAME :
DATE :
OBJECTIVE :

RESULTS :

(A) Boyle's law

Table 2.1 Boyle's Law

Volume of gas	Pressure of gas

Constant Temperature = ___________________

1. Complete **Table 2.1**.
2. Plot the graph Volume of gas versus Pressure of gas. Label the axis with appropriate units.
3. Explain the relationship between volume and pressure of gas.

(B) Charles' Law

Table 2.2 Charles' Law

Volume of gas	Temperature of gas (K)	Temperature of gas (^{o}C)

Constant Pressure = ____________________

1. Complete Table 2.2.

2. Plot the graph Volume of gas versus Temperature of gas in degree Celsius. Label the axis with appropriate units.

3. Explain the relationship between volume of gas and temperature of gas using Kinetic Molecular Theory of gas.

4. Extrapolate the line until V=0, to obtain the absolute zero temperature.

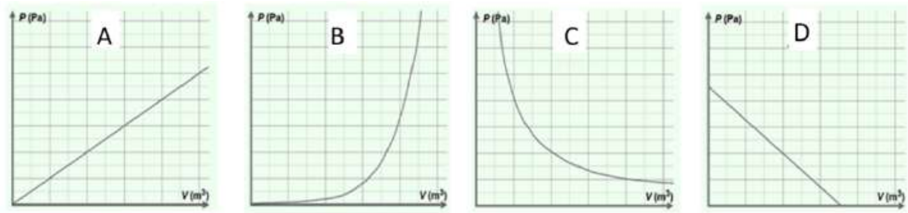
5. Complete Table 2.3 and compare the speed of gas particles at two different temperatures in relation to average kinetic energy.

Table 2.3 Speed of gas particles

Temperature (K)	Average kinetic energy ($kJ\ mol^{-1}$)	Speed of gas particles

ADDITIONAL EXERCISE

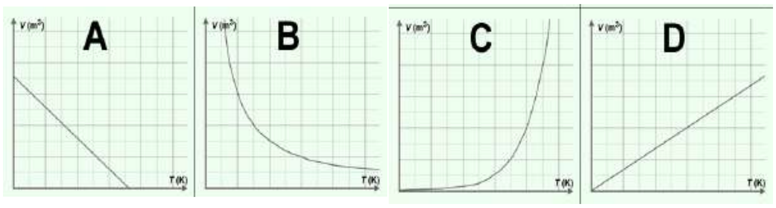
1. Which of the following graphs represents the correct relationship between the pressure and the volume of a gas at constant temperature?



A. Graph A
B. Graph B
C. Graph C
D. Graph D

2. Explain why the graph is shaped as it is and name the related gas law to support your answer.

3. Which of the following graphs represents the correct relationship between the volume and the temperature of a gas at a fixed pressure?



A. Graph A
B. Graph B
C. Graph C
D. Graph D

4. Explain why the graph is shaped as it is and name the related gas law to support your answer.

CHEMICAL EQUILIBRIUM

LEARNING OUTCOMES

At the end of this lesson, students should be able to:

i. study the effect of concentration, temperature and pressure on chemical equilibrium.

INTRODUCTION

How do you like your carbonated drink? With ice or with lemon? Below you are going to understand how to make the perfect carbonated drink using an understanding of chemical equilibrium.

Carbonated drinks are made by forcing carbon dioxide gas into the drink under high pressure. This process is called carbonation and causes CO_2 (g) to dissolve in the drink to form CO_2 (aq). Carbonated drinks 'taste' fizzy because of this dissolved carbon dioxide.

In an unopened bottle of carbonated drinks, the majority of the carbon dioxide molecules will be dissolved in the solution for example in the aqueous form. When carbon dioxide dissolves, the following equilibria are established.

$$CO_2(g) \rightleftharpoons CO_2(aq) + \text{Heat}$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

Change in one of the factors on a system that is already at equilibrium, will cause the reaction to move to the direction that minimizes the effect of change. The direction of the change can be determined by applying Le Chatelier's Principle.

Le Chatelier's Principle states that if a system at equilibrium is disturbed by a change in temperature, pressure or concentration of one or more components, the system will shift its equilibrium position in such a way so as to counteract the effect of the disturbance.

APPARATUS	**MATERIALS**
Clear drinking glass Syringe or teaspoon Suitable container	2 bottles of clear carbonated drinks 330 mL (e.g: *Sprite* / *Ice cream soda* /*100plus*) Ice cube Vinegar or lime juice or lemon juice Boiling water

PROCEDURE

(A) The effect of temperature

1. Label two carbonated drinks as A and B.
   Precaution: Both of the bottles must be at room temperature

2. Shake and observe bubbles formed in both bottles.

3. Place bottle A into the container filled with ice and bottle B into the container filled with boiling water for 5 minutes.

4. Observe the bubbles formed in bottle A and B.
   Precaution: Do not shake the bottles

5. Record the observation in **Table 2.4**.

EXERCISE
Discuss the observation in bottle B.

(B) The effect of concentration

1. Gently shake the carbonated drinks bottle A and observe bubbles formed.
   Precaution: Bottle A must be at room temperature

2. Open the bottle cap slightly.

3. Add 2.5 mL or 1 teaspoon of vinegar/lime juice/lemon juice into the bottle.

4. Close the bottle cap immediately and observe the bubbles formed.
   Precaution: Do not shake the bottles

5. Record the observation in **Table 2.4**.

EXERCISE
Use the equations stated in the introduction to explain why adding vinegar or lime juice to your carbonated drink may cause it to taste slightly flat?

(C) The effect of pressure (volume)

1. Gently shake the carbonated drinks in bottle B and observe bubbles formed.
   Precaution: Bottle B must be at room temperature

2. Open the bottle cap.

3. Fill the carbonated drinks into a clear drinking glass up to the brim.

4. Observe the bubbles formed in the clear drinking glass.

5. Record the observation in **Table 2.4**.

EXERCISE
Explain what will happen if the carbonated drinks bottle cap is open for a long time.

ADDITIONAL INFORMATION

- https://www.youtube.com/watch?v=x-Ny-ODz5BY

- https://thescienceteacher.co.uk/wp-content/uploads/2014/09/The-chemistry-of-coke-and-le-chateliers-principle-.pdf
  (Retrieve on 5 July 2021)

DATA SHEET

CHEMICAL EQUILIBRIUM

NAME :
DATE :
OBJECTIVE :

RESULTS :

Table 2.4 Effect of disturbances on chemical equilibrium

<table>
<tr><th rowspan="3">Experiment</th><th colspan="4">Observation</th></tr>
<tr><th colspan="2">Before</th><th colspan="2">After</th></tr>
<tr><th>Bottle A (cold)</th><th>Bottle B (hot)</th><th>Bottle A (cold)</th><th>Bottle B (hot)</th></tr>
<tr><td>(a) The effect of temperature</td><td></td><td></td><td></td><td></td></tr>
<tr><td>(b) The effect of concentration</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>(c) The effect of pressure (volume)</td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

pH MEASUREMENT & ITS APPLICATION

LEARNING OUTCOMES

At the end of this lesson, students should be able to:

i. prepare natural pH indicators from plants;
ii. determine the pH of household products using the natural pH indicator; and
iii. perform acid-base reaction using household products.

INTRODUCTION

pH is a measure of acidity or basicity of a solution. pH is defined as the negative logarithm of hydrogen ion concentration, $[H^+]$.

$$pH = -\log [H^+]$$

The pH scale ranges from 0 to 14. At 25 °C, a neutral solution has a pH of 7. An acidic solution has a pH of less than 7 while a basic solution has a pH greater than 7.

There are two methods to determine pH in the laboratory. The first method involves the use of indicators such as pH paper and the universal indicator. The second method is using the pH meter. In this home-based experiment, a natural pH indicator which can easily be prepared will be used to replace the indicators used in a laboratory.

Acid-base indicators are weak organic acids that change colour depending on the pH of a solution. Some plants contain highly coloured pigments that show colour changes with changes in pH. Thus this property makes them suitable to be used as acid base indicators. Two examples of plants with this property are red cabbage and butterfly pea flower (*bunga telang*).

In this experiment, extract from either one of these plants will be used as natural pH indicator. The pH of some common household products will then be tested using this indicator. This natural pH indicator is then further used to observe the change in pH in a neutralisation reaction of acid and base from household products.

Figure 2.1 shows the red cabbage and butterfly pea flower that can be used to prepare the natural pH indicators. Figure 2.2, 2.3 and 2.4 shows the pH chart for the natural indicator in acid and base solution.

(a) Red cabbage (b) Butterfly pea flower

Figure 2.2 Picture of red cabbage and butterfly pea flower that can be used to prepare the natural pH indicators.

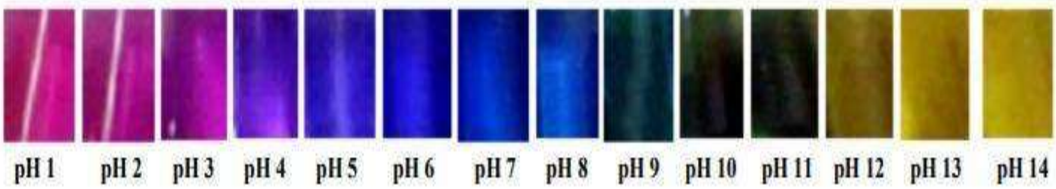


Figure 2.3 pH chart 1 showing the colour change of **butterfly pea flower** indicator
(Source: Nyi Mekar Saptarini et al. 2015)

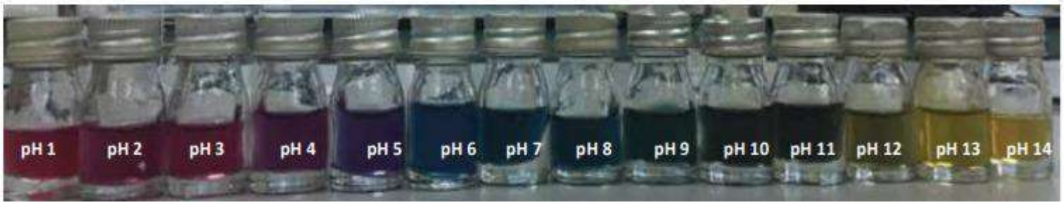


Figure 2.4 pH chart 2 showing the colour change of **butterfly pea flower** indicator
(Source: Nur Faezah Syahirah et al. 2018)

Figure 2.5 pH chart 3 showing the colour change of **red cabbage** indicator (Source: https://www.compoundchem.com/2017/05/18/red-cabbage/)

Scan here for pH chart

APPARATUS

Disposable transparent plastic cup
Knife
Syringe 5 mL
Syringe 10 mL
Bowl
Measuring spoon or teaspoon
Strainer
Measuring cup

MATERIALS

Red cabbage or butterfly pea flower
Water
Shampoo
Vinegar
Toothpaste
Laundry detergent
Sodium bicarbonate (baking soda)

Note:
Disposable transparent plastic cups can be replaced with watercolour palette or any other suitable containers. The amounts of materials used should be scaled down accordingly.

Instruction:
All procedures carried out and observations obtained must be recorded in the form of video or photos as evidence of your work and submitted together with your report.

PROCEDURE

(A) Preparation of natural pH indicator
[Remark: Prepare natural pH indicator either from red cabbage **OR** butterfly pea flower]

1. Cut into small pieces about 1 cup (250 mL) of red cabbage leaves (butterfly pea flowers does not require cutting and maybe can be used directly).

2. Transfer the red cabbage/butterfly pea flowers into a bowl.

3. Boil some water and pour the hot water into the bowl until it just covers the cabbage/butterfly pea flowers.

4. Stir the mixture for two minutes until the water becomes intensely coloured. Leave the mixture to cool for about 15 to 20 minutes.

5. Filter the red cabbage pieces/butterfly pea flowers by using a strainer to collect the coloured filtrate.

6. The natural pH indicator is ready to be used.

(B) Testing the pH of household products

1. Place 5 mL or 1 teaspoon of the following household products into separate disposable transparent plastic cups.
   i. toothpaste
   ii. vinegar
   iii. laundry detergent
   iv. shampoo
   v. sodium bicarbonate

2. Add 10 mL of water into each disposable transparent plastic cups and stir the mixture. Then add 10 mL of natural pH indicator.

3. Observe and compare the colour of the solutions with the pH chart provided and determine the pH range. Record the observation.

4. Repeat steps 1–3 using another two household products of your choice.

(C) Acid-base reaction

1. Measure ½ teaspoon of sodium bicarbonate and pour into a disposable transparent plastic cup. Add 15 mL of water and stir until the sodium bicarbonate is dissolved.

2. Add 5 mL of natural indicator to the sodium bicarbonate solution. Compare the colour of the solution to the pH chart provided and determine its pH. The sodium bicarbonate solution is ready to use.

3. Place 10 mL of vinegar into another disposable transparent plastic cup and add 5 mL of the natural indicator. Compare the colour of the solution to the pH chart provided and determine its pH. The vinegar solution is ready to use.

4. By using a syringe, add sodium bicarbonate solution slowly into the vinegar solutions until all sodium bicarbonate solution is completely used. By referring to the pH chart provided, record the pH for every 2 mL interval of sodium bicarbonate added.

EXERCISE

1. What is the reaction occur between vinegar and sodium bicarbonate?
2. What is the gas evolved during the reaction?
3. Write the chemical equation for the reaction in Part (C).
4. Based on your observation, what happens to the pH value vinegar when sodium bicarbonate is added? Explain.
5. What will happen to the pH of sodium bicarbonate if vinegar is added to it?
6. Predict what will happen if you blow (exhale) into some red cabbage indicator using a straw?

ADDITIONAL INFORMATION

- Nyi Mekar Saptarini, Dadan Suryasaputra and Hera Nurmalia (2015) Application of Butterfly Pea (Clitoria ternatea Linn) extract as an indicator of acid-base titration. *Journal of Chemical and Pharmaceutical Research*. 7(2): 275-280

- Nur Faezah Syahirah, L., Muhammad Umar Lutfi, M.Y., Atika, A., Muhammad Hafiz, R., Muhammad Zulhelmi, O.A., Mohd Ariff Adzhan, O. and Khor P.Y. (2018). A Comparative Analysis of Clitoria ternatea Linn. (Butterfly Pea) Flower Extract as Natural Liquid pH Indicator and Natural pH Paper. *Dhaka University Journal of Pharmaceutical Science* 17(1): 97-103.

- How to Make a Red Cabbage pH Indicator
  https://www.thoughtco.com/making-red-cabbage-ph-indicator-603650

DATA SHEET

pH MEASUREMENT & ITS APPLICATION

NAME :
DATE :
OBJECTIVE :

RESULTS :

(B) Testing the pH of household products

Household products	**pH in natural indicator**		**Acidic, Basic or Neutral**
	Red cabbage	**Butterfly pea flower**	
Toothpaste			
Vinegar			
Laundry detergent			
Shampoo			
Sodium bicarbonate			
Household product 1			
Household product 2			

(C) Acid-base reaction

Household products	**pH**	
	Red cabbage	**Butterfly pea flower**
Sodium bicarbonate		
Vinegar		

(i) Red cabbage

Volume of sodium bicarbonate added (mL)	0	2	4	6	8	10	12	14	16	18	20
pH											

(ii) Butterfly pea flower

Volume of sodium bicarbonate added (mL)	0	2	4	6	8	10	12	14	16	18	20
pH											

SECTION 3

PHYSICS EXPERIMENTS

MEASUREMENT AND UNCERTAINTY

LEARNING OUTCOMES

At the end of this lesson, students should be able to:

i. measure length of various objects; and
ii. determine the uncertainty of length of various objects.

THEORY

Measuring some physical quantities is part and parcel of any physics experiment. It is important to realise that not all measured values are exactly the same as the actual values. This could be due to errors that we made during the measurement, or perhaps the apparatus that we used may not be accurate or sensitive enough. Therefore, as a rule, the uncertainty of a measurement must be taken and it has to be recorded together with the measured value.

The uncertainty of a measurement depends on the type of measurement and how it is done. For a quantity x with the uncertainty Δx, its measurement is recorded as below:

$$x \pm \Delta x$$

The relative uncertainty of the measurement is defined as:

$$\frac{\Delta x}{x}$$

and therefore its percentage of uncertainty is:

$$\frac{\Delta x}{x} \times 100\% .$$

Single Reading

(a) If the reading is taken from a single point or at the end of the scale,

$$\Delta x = \frac{1}{2} \times \text{(smallest division from the scale)}$$

(b) If the readings are taken from two points on the scale,

$$\Delta x = 2 \times \left[\frac{1}{2} \times \text{(smallest division from the scale)} \right]$$

(c) If the apparatus uses a vernier scale,

$$\Delta x = 1 \times \text{(smallest unit from the vernier scale)}$$

Repeated Readings

For a set of n repeated measurements of x, the best value is the average value given by

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad 3.1$$

where n = the number of measurements taken

x_i = the i^{th} measurement

The uncertainty is given by

$$\Delta x = \frac{\sum_{i=1}^{n} \left| \bar{x} - x_i \right|}{n} \qquad 3.2$$

The result should be written as

$$x = \bar{x} \pm \Delta x \qquad 3.3$$

APPARATUS

Two books
A 30 cm ruler
A vernier callipers from *website*
A micrometer screw gauge from *website*
Two oval shape objects from *website*
Two dumbbells from *website*

PROCEDURE

1. Choose the appropriate instrument for measurement of the:
   (i) length of a book.
   (ii) diameter of an oval shape object.
   (iii) width of a dumbbell handle.

2. For task (i) to (iii), perform the measurement and record your data in the following table for at least 5 readings. Refer to **Table 3.1** as an example.

Table 3.1 Length of a book

No.	Length of a book, l $(\pm\, 0.1cm)$	$\lvert \bar{l} - l_i \rvert$ (cm)
1		
2		
3		
4		
5		
Average	$\bar{l} = \frac{\sum_{i=1}^{n} l_i}{n}$	$\Delta l = \frac{\sum_{i=1}^{n} \lvert \bar{l} - l_i \rvert}{n}$

3. Repeat step (2), for another one object with a different size.

4. Determine the percentage of uncertainty for each set of readings.

5. For task (ii) and (iii), use the following *websites:*
(for best experience, use computer/laptop)

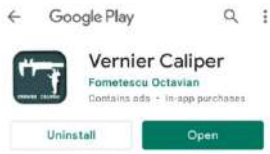
[*http://bit.do/MICROMETERSCREWGAUGE*](http://bit.do/MICROMETERSCREWGAUGE)

[*http://bit.do/VERNIERCALLIPER*](http://bit.do/VERNIERCALLIPER)

6. Screenshot the best picture of the measurement with one reading for each task. Attach the picture in your lab report.

***Alternative apps:**

http://bit.do/VernierCaliper (*Vernier Caliper*)



or

scan using QR code:

***Note**: This application available for *Android* only.

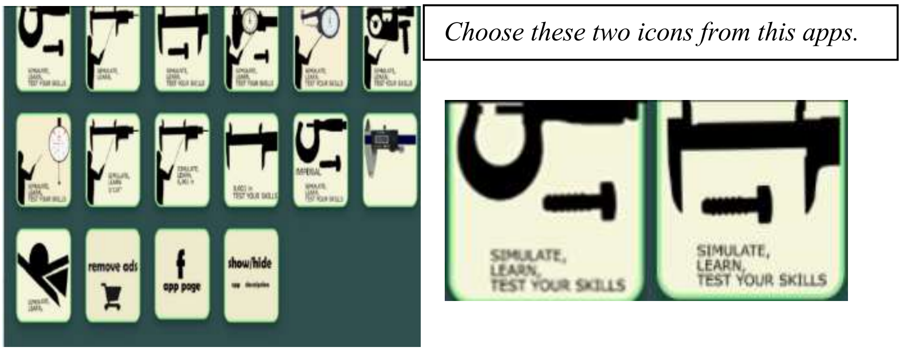


Figure 3.1 Application Vernier Calliper

ADDITIONAL INFORMATION

Measurement and Error Analysis, (2011), Retrieved from; *https://www.webassign.net/question_assets/unccolphysmechl1/measurements/manual.html,* College Physics Labs Mechanics, University of North Carolina

FREE FALL MOTION

LEARNING OUTCOMES

At the end of this lesson, students should be able to:

i. determine the acceleration due to gravity, *g* using free fall motion.

THEORY

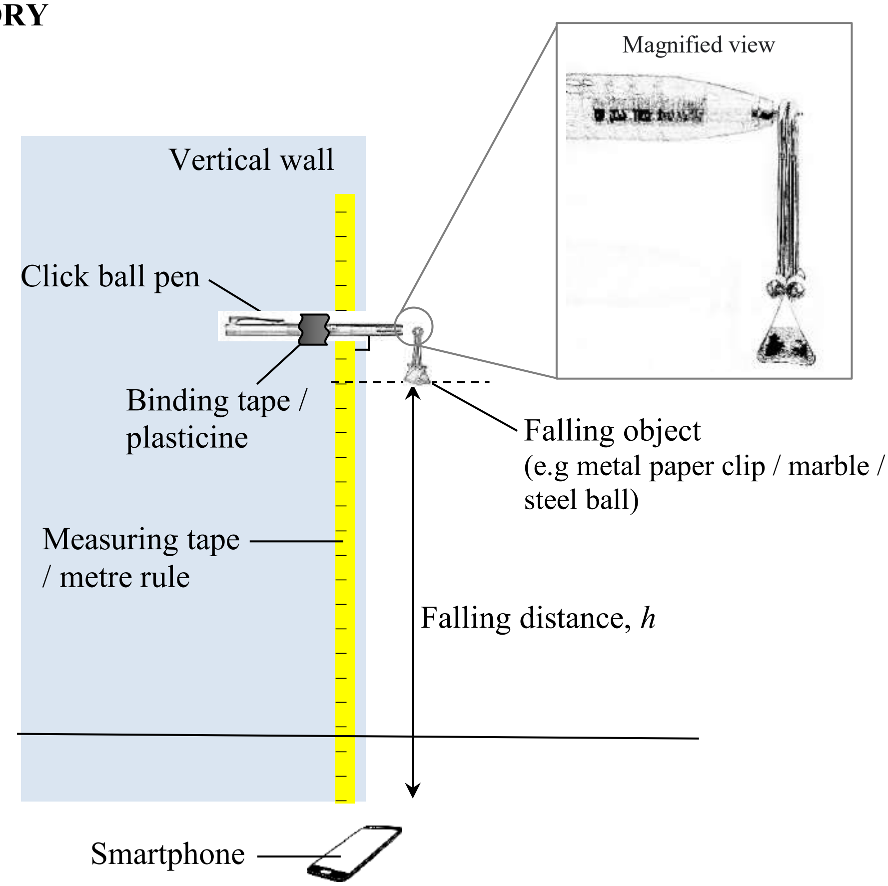


Figure 3.2 Experiment Free Fall Motion Set Up

When a body of mass, *m* falls freely from a certain height, *h* above the ground, it experiences a linear motion. The body will obey the equation of motion,

$$s = ut + \frac{1}{2}at^2 \qquad 3.4$$

By substituting the following into equation 3.4,

$s = -h$ (downward displacement of the body from the falling point to the ground)
$u = 0$ (the initial velocity of the body)
$a = -g$ (the downward acceleration due to gravity)

we obtain

$$h = \frac{1}{2}gt^2 \qquad 3.5$$

APPARATUS

A smart phone with Phyphox app
A measuring tape/metre rule
A click ball pen
Cellophane tape/binding tape/plasticine
A metal paper clip/marble/steel ball
A vertical wall
A pair of scissors or a cutter

PROCEDURE

1. Install Phyphox Physical Phone Experiments by RWTH Aachen University application from App Store (requires iOS 9.0 or later) https://apps.apple.com/us/app/phyphox/id1127319693 or Google Play store (Android) https://play.google.com/store/apps/details?id=de.rwth_aachen.phyphox

App Store (iOS) Play Store (Android)

2. Set up the apparatus as in **Figure 3.2**. Take a picture of your complete set up. (Attach the picture in your laboratory report)
Caution:
Place your phone slightly away from point of impact as the object hits the floor. Please be careful not to damage your phone during the experiment.

3. Launch the Phyphox application. In the main menu, scroll to Timers section and choose Acoustic Stopwatch.

4. Under tab SIMPLE, set Threshold value as 0.04 a.u. and Minimum Delay value as 0.2 s.
   Note:
   Change the threshold to be above the environmental noise level but below the trigger noise (you can try the audio scope experiment to check these). Also set the minimum delay to avoid triggers shorter than that time (for example due to echo or reverberation).

5. Set the falling distance h = 45 cm. Record h.

6. Tap on the play button  as shown in **Figure 3.3** to start the Acoustic Stopwatch.

Figure 3.3

7. Press the click ball pen and let the object fall.

8. Record the falling time, t measured by the Acoustic Stopwatch. Press RESET button to clear the reading. (refer **Figure 3.4**). Repeat the process to obtain the average falling time.

Figure 3.4

9. Repeat steps (5) to (8) for h= 55, 65, 75, 85 and 95 cm.

10. Tabulate the data.

11. Plot a graph of h against t^2.

12. Determine the acceleration due to gravity, g from the gradient of the graph.

13. Compare the acceleration due to gravity, g obtained from experiment with standard value. Write your comments.

SIMPLE HARMONIC MOTION (SHM)

LEARNING OUTCOMES

At the end of this lesson, students should be able to:
i. determine the acceleration due to gravity g using a simple pendulum; and
ii. investigate the effect of large amplitude oscillation to the accuracy of g obtained from the experiment.

THEORY

An oscillation of a simple pendulum is an example of a simple harmonic motion (SHM) if

(i) the mass of the spherical bob is a point mass
(ii) the mass of the string is negligible
(iii) amplitude of the oscillation is small (< 10°)

According to the theory of SHM, the period of oscillation of a simple pendulum T is given by

$$T = 2\pi\sqrt{\frac{\ell}{g}} \qquad 3.6$$

where ℓ is the length of pendulum
g is the acceleration due to gravity

Rearrange equation 3.6, we obtain

$$T^2 = \frac{4\pi^2\ell}{g} \qquad 3.7$$

Evidently, a graph of T^2 against ℓ is a straight line of gradient equals $\frac{4\pi^2}{g}$

Hence from the gradient of the graph, the value of g can be calculated.

APPARATUS

A piece of string or thread (≈105 cm)
A small padlock or key chain
A suitable place to hang the pendulum
A stopwatch or stopwatch function in smartphone
A meter rule or measurement tape or 30 cm ruler
A protractor with a hole at the centre of the semicircle
A pair of scissors or a cutter

PROCEDURE

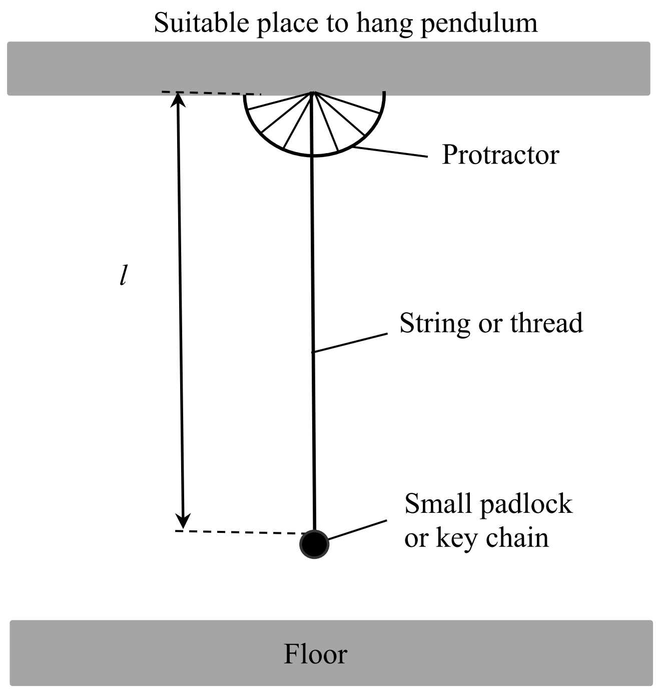


Figure 3.5 Experiment SHM Set Up

1. Set up a simple pendulum as in **Figure 3.3** and take the picture of your complete setup (attach in your laboratory report)

   Note: *Guidance by the lecturer when set up the pendulum.*

2. Measure the length l of the string about 40 cm.

3. Release the pendulum at less than 10° from the vertical in one plane and measure the time t for 10 oscillations. Record l and t.

   Note: *Start the stopwatch after several complete oscillations.*

4. Repeat step (3) and calculate the average value for t. Then calculate the period of oscillation T of the pendulum.

5. Repeat step (3) to (4) for length l of the string 50 cm, 60 cm, 70 cm, 80 cm and 90 cm.

6. Plot a graph of T^2 against l.

7. From the gradient of the graph, determine the value of g.

8. Fix the length of pendulum at 100 cm. Release the pendulum through a large arc of about 70° from the vertical. Record the time t for 5 complete oscillations. Repeat the operation and calculate the average value for t. Then calculate the period T of the oscillation of the simple pendulum.

9. Calculate the acceleration due to gravity, g using equation 3.1 and the value of l and T from step (8).

10. Compare the values of g obtained from step (7) and step (9) with the standard value. Write your comments.

SECTION 4

BIOLOGY EXPERIMENTS

TRANSPORT ACROSS MEMBRANE

LEARNING OUTCOMES

At the end of this lesson, students should be able to:
i. determine changes in length of potato strips in different sugar concentration.

INTRODUCTION

The cell membrane is a selective permeable structure because only selected materials can pass through it. Water molecules can easily pass through the membrane and the movement of water is called osmosis. The direction of movement of water molecules is determined by the concentration of the solutes of both sides of the membrane. The water potential inside and outside of the cell is said to be isotonic, that is the movement of water molecules in both direction is at the same rate. The vacuolar membrane is also a selective structure and the condition in the vacuole is isotonic to the cell environment.

In a hypertonic environment, water molecules will move out of the cell and the cell shrinks. The shrinking of cell is due to the hypertonic environment outside the plant and animal cells. The shrinking of plant cell is called plasmolysis while the shrinking of animal cell is called crenation.

When a plant cell is in a hypotonic environment, it will expand but the increase in size is restricted by the cell wall (turgid). On the other hand, animal cells which are in the hypotonic environment will expand and burst and this is called lysis or haemolysis.

APPARATUS

Knife and chopping board
Glass/any suitable container
Spoon
Cake chopstick/chopstick
Kitchen paper
Measuring cup/measuring cylinder/syringe/milk bottle (any suitable measurement tools for measuring volume)
Ruler and Digital kitchen scale

MATERIALS

Medium sized potatoes
Course Sugar
Water (ideally should use distilled water for this experiment. If don’t have any, tap water will work).

PROCEDURES

1. Cut 15 strips of potatoes with a length of 3 cm and the same thickness and remove the skin. (As alternative, you may use 3 ml syringe to cut strips of potatoes to produce same length and thickness)
   ***Note**: Syringe is readily available from pharmacy and pet shop.

2. Prepare sugar solution by mixing 40ml of tap water and 17g of course sugar. Stir sugar solution until you have a fairly concentrated solution.

3. Prepare 5 solutions of water with different sugar concentration as shown in **Table 4.1** and place the solution into the glass/any suitable container labelled A-E.

4. Put 3 potato strips into each of the glasses/any suitable container. (You may need to hold the potato strip into the solution with the cake chopstick/chopstick).

5. Leave the potato strips for about 40 minutes.

6. After 40 minutes, remove potatoes strips from the solution and dry carefully with kitchen paper.

7. Measure each potato strip and record their average length.

8. Record your observation and describe the changes of structure of each potato strip.

9. Based on your results, draw a graph to show the changes in length of the potato strips against the volume of sugar solutions.

Table 4.1 Water solution with different sugar concentration

Glass/any suitable container	A	B	C	D	E
Volume of sugar solution (ml)	2	4	6	8	10
Volume of water (ml)	18	16	14	12	10

Figure 4.1 Apparatus and materials

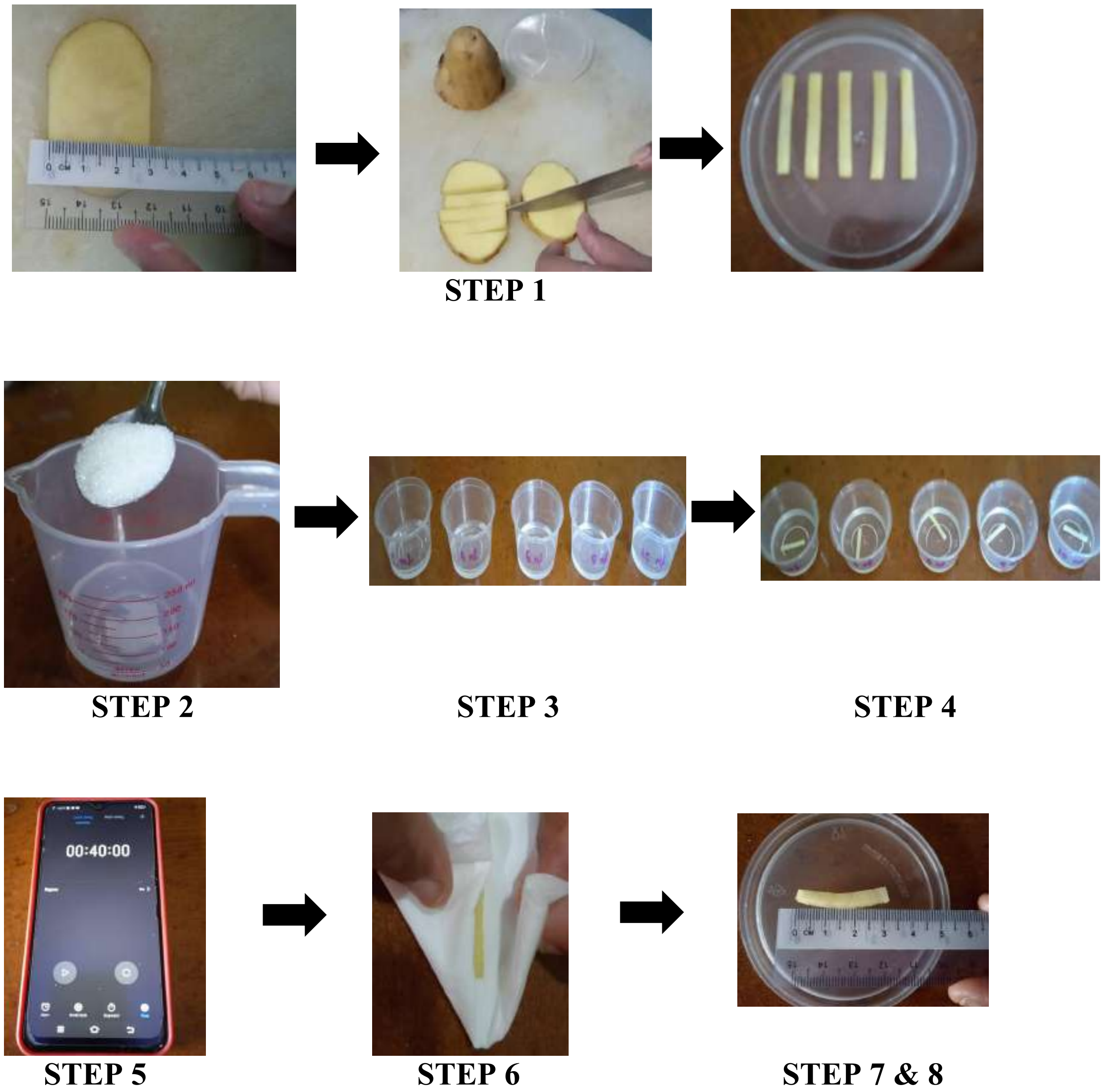


Figure 4.2: Steps of Procedures

INHERITANCE

LEARNING OUTCOMES

At the end of this lesson, students should be able to:

i. determine the inheritance of genetic traits controlled by single genes in human; and
ii. determine the inheritance of ABO blood groups.

INTRODUCTION

A number of human characteristics are determined by single genes. These characteristics include the shape of nose, earlobe, the ability of tongue rolling, the presence of dimple and left-handed (**Figure 4.3**). A single gene also determines pigmentation of iris and the ability to taste phenylthiocarbamide (PTC).

APPARATUS & MATERIALS

Google Form/Mentimeter/Survey Monkey/Telegram

PROCEDURES

(A) INHERITANCE OF GENETIC TRAITS IN HUMAN

1. Each class need to appoint the class representative to build a survey to collect the data for inherited characteristics from every student in the class by using Google Form/Mentimeter/Survey Monkey/Telegram

2. Below are six inherited characteristics in human:

   i. Shape of nose:
   Straight nose (E_) is dominant to curved nose (ee).
   ii. Earlobe:
   Free earlobe (P_) is dominant to attached earlobe (pp).
   iii. Tongue Rolling:
   Ability of tongue rolling into "U" shape (C_) is dominant to inability of tongue rolling into "U" shape (cc).

iv. Dimple:
Individual with genotypically (D_) dominant compared to those without dimple (dd).

v. Left-handed:
The right-handed characteristic (H_) is dominant to left-handed (hh).

vi. Hitch hiker thumb:
The ability to bend thumb at 60° angle or more are genotypically (tt) recessive compared to normal thumb-bending (T_).

3. Based on the above characteristics, fill in the information below in. **Table 4.2**.
   i. Determine your genotype for each of the six characteristics.
   ii. Calculate the observed and expected frequencies for each of the six characteristics.

Shape of nose

Curved nose

Straight nose

Earlobe

Free earlobe(detached)
https://www.users.rowan.edu

Attached earlobe
https://www.users.rowan.edu

Tongue rolling

Ability to roll tongue
https://askabiologist.asu.edu

Inability to roll tongue
https://askabiologist.asu.edu

Dimple

With dimple
https://www.news.makemeheal.com

Without dimple
https://www.sharewhy.com

Left-handed

Left handed
http://www.edquest.ca

Right handed
http://www.edquest.ca

Hitch hiker thumb

Normal thumb
https://askabiologist.asu.edu

Hitch hiker thumb
https://askabiologist.asu.edu

Figure 4.3 The six inherited characteristics in human

RESULTS

Table 4.2 Observed and expected frequencies of each genotype for six characteristics in the class

Characteristic	Phenotype	Genotype	Tick (√) our own genotype	Observed frequency of each genotype in the class	Expected frequency of each genotype in the class
Shape of nose	Straight nose	*E_*			
	Curved nose	*ee*			
Earlobe	Free earlobe	*P_*			
	Attached earlobe	*pp*			
Tongue Rolling	Ability of tongue rolling into "U" shape	*C_*			
	Inability of tongue rolling into "U" shape	*cc*			

Dimple	Have dimple	*D_*			
	Without dimple	*dd*			
Left-handed	Right-handed	*H_*			
	Left-handed	*hh*			
Hitch hiker thumb	Normal thumb-bending	*T_*			
	Ability to bend thumb at 60° angle or more	*tt*			

QUESTIONS

1. Individuals with certain heterozygous characteristics are usually called a carrier. What does a carrier mean?

2. A student inherited left handedness from parents who are both right-handed. Explain the pattern of inheritance.

3. What is the expected frequency for a person having tongue rolling ability and attached earlobe?

4. What is the expected frequency for a person to have all six recessive characteristics?

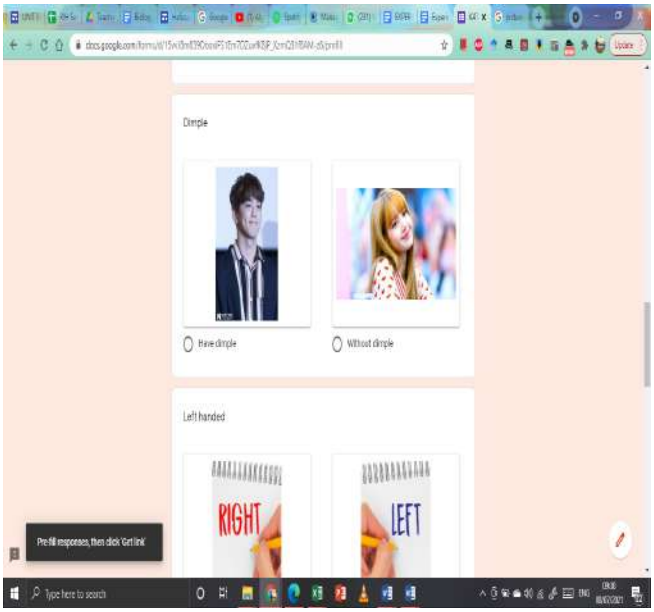


Figure 4.4 Example of a Google form for data collecting

(B) ABO BLOOD GROUP INHERITANCE

ABO blood groups in human are examples of multiple alleles of a single gene and also codominant alleles. Each individual inherited any one of four blood types, i.e. A, B, AB or O. Type A groups are determined by the presence of antigen A found on the surface of red blood cells (erythrocytes), while the blood plasma contains B antibody which agglutinates type B blood. Individuals with type B blood have antigen B and antibody A which agglutinates type A blood. Individuals with type AB blood have both antigens A and antigen B but without antibodies A or B. Finally, individuals with type O blood have antibody A and antibody B but without any antigen. **Table 4.4** shows individual characteristics for all ABO blood groups.

Table 4.3 Individual characteristics for all ABO blood groups.

Blood group (phenotypes)	Antigen present on erythrocytes	Antibodies present in blood plasma (serum)	Agglutinated blood group
A	A	Anti-B	B and AB
B	B	Anti-A	A and AB
AB	A and B	none	none
O	none	Anti-A and Anti-B	A and B

APPARATUS / MATERIALS

Google Form/Mentimeter/Survey Monkey/Telegram

PROCEDURES AND OBSERVATION

1. For blood type you can determine from your family history or previously medical history to determine your blood type. If you cannot determine your blood type, you may skip the experiment.

2. Your blood group: $\boxed{}$

Table 4.4: Frequency of blood group in the class

Blood group	Possible genotypes	Frequency of each blood group
A		
B		
AB		
O		

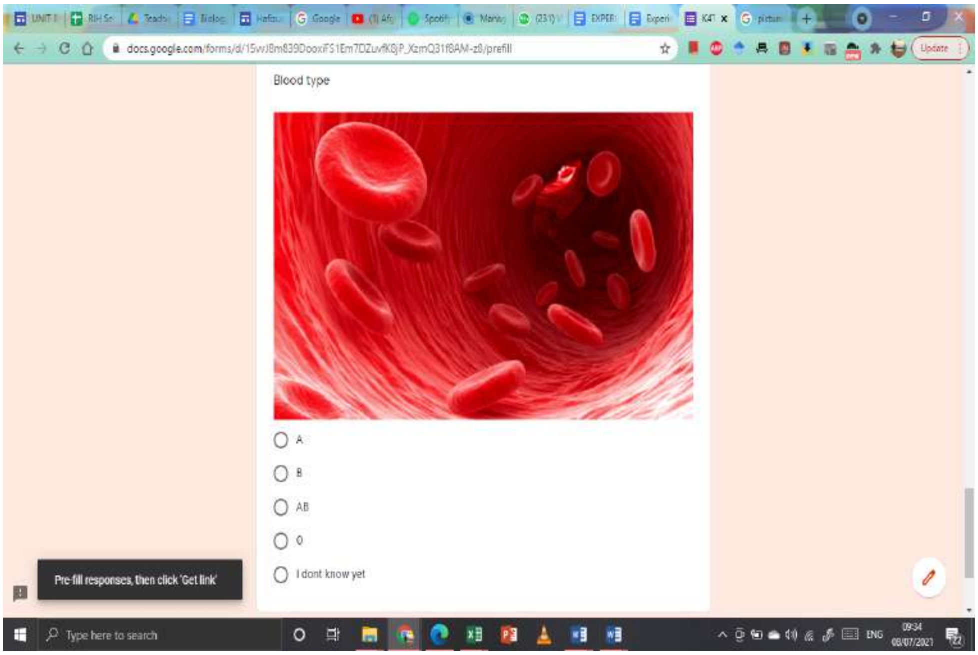


Figure 4.5 Example of a Google form for data collecting

QUESTIONS

1. Can an individual with O blood group donates his blood to an A blood group person? Give reasons to your answer.

2. A mother with O blood group gave birth to a baby girl having the same blood group. However, she is not convinced that the baby belongs to her because her husband has AB blood group. She claimed there might be swapping of babies in the nursery. Explain.

1.

2.

3.

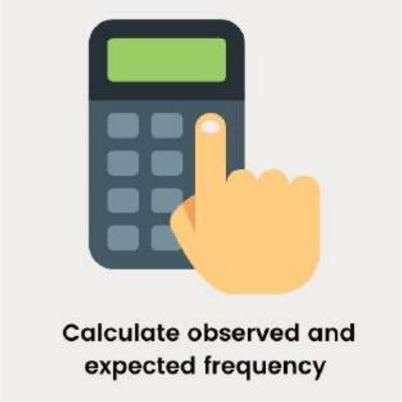


Figure 4.5 Task to be carried out

ISOLATING DNA

LEARNING OUTCOMES

At the end of this lesson, students should be able to:
i. isolate DNA from plant tissue.

INTRODUCTION

Each chromosome is a single thread-like structure made up of long molecules of DNA combined with histone protein. The DNA molecule is made up of many small sections called genes. Shortly before cell division occurs, each DNA molecule replicates itself. So, one thread of the chromosome becomes two identical chromatids. As the two chromatids are identical, they will have identical genes. These identical genes are known as allele. In this experiment, you will rupture fruit cells, thus releasing their contents such as protein, DNA, RNA, lipids, ribosomes and various small molecules. DNA is then suspended by alcohol as supernatant layer.

The purity of DNA will require further steps. After the isolation of nucleic acids, the solution is still contaminated with proteins which can be removed. To check the success of the removal, a purity determination is performed, which is based on the different absorption characteristics of the proteins and the nucleic acids using UV spectrophotometer.

APPARATUS

Blender/mortar and pestle
Measuring cup/glass container/syringe
Transparent glass/container
Tea strainer

MATERIALS

Kiwi Fruit/Onion/Tomato/Spinach/Broccoli/Carrot
Ice-chilled 95% alcohol (liquid based hand sanitizer-chilled in refrigerators for at least 4 hours or soak in ice cubes for 30 minutes before experiment)/ 75% alcohol in perfume/any alcohol beverages
***Do Not Use Gel Based Hand Sanitizer**
2 tablespoon (about 30 ml) liquid detergent dishwasher
Table salt
Cold water
Meat tenderiser/pineapple juice/contact lens cleaning solution/resin from papaya leaf stalk

PROCEDURES

1. Peel and slice kiwi/onion/tomato/ spinach/broccoli/carrot.

2. Put in a blender 1/2 cup of cut fruits/vegetable (approximately 100g), 1/8 teaspoon table salt (less than 1g) and 1/2 cup cold water (approximately 100ml; depends on types of fruit used)

3. Blend on high speed for 15 seconds (the blender separates the fruits cells from each other, so you now have a really thin fruit-cell soup).
   Note: You may use mortar and pestle to mash the fruits/vegetable finely.

4. Pour thin fruit-cell soup through a tea strainer into another container (like a measuring cup or transparent glass).

5. Add 2 tablespoons liquid detergent (about 30ml) and swirl to mix. Let the mixture sit for 5-10 minutes.

6. Then, pour the mixture into other small glass containers, each about 1/3 full.

7. Add a pinch of meat tenderiser/pineapple juice/papaya stalk resin to the mixture and stir gently.
   Notes: Be careful! If you stir too hard, you'll break up the DNA, making it harder to see (Meat tenderizer act as enzymes. If you can't find tenderizer, try using a teaspoon of pineapple juice or ½ teaspoon of contact lens cleaning solution).

8. Pour ice-chilled hand sanitizer (95% alcohol) into another small glass container, also about 1/3 full. You may replace the hand sanitizer with 75% alcohol perfume or any alcohol beverages (make sure the alcohol is ice-chilled)

9. Then tilt your small glass container and slowly pour ice-chilled hand sanitizer into the glass down the side so that it forms a layer on top of the fruit mixture (alcohol is less dense than water, so it floats on top).

10. The stringy stuff is DNA (DNA is a long, stringy molecule. The salt that you added in step one helps it stick together). So, what you see are clumps of tangled DNA molecules.
    Notes: DNA normally stays dissolved in water, but when salty DNA comes in contact with alcohol it becomes undissolved. This is called precipitation. The physical force of the DNA clumping together as it precipitates pulls more strands along with it as it rises into the alcohol. You can use a wooden stick or a straw to collect the DNA. If you want to save the DNA, you can transfer it to a small container filled with alcohol.

QUESTIONS

1. What is the purpose of using the following?
   i. liquid detergent
   ii. salt
   iii. meat tenderizer/pineapple juice/contact lens cleaning solution

2. Why do we need to finely blend the fruits?

Figure 4.6: Materials and Apparatus

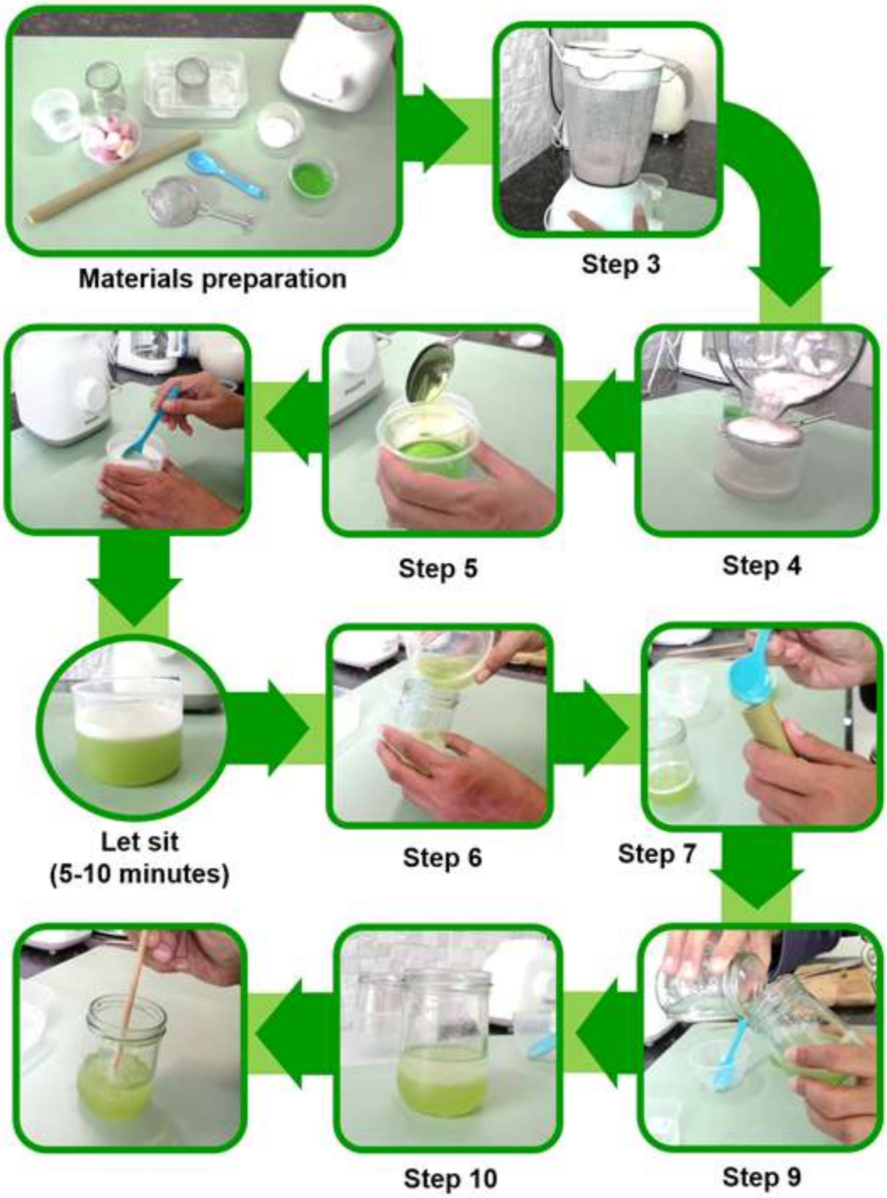


Figure 4.7 Steps of Procedures

SECTION 5

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