MJSO

Malta Junior Science Olympiad

2024

GOVERNMENT OF MALTA
MINISTRY FOR EDUCATION, SPORT, YOUTH
RESEARCH AND INNOVATION
DIRECTORATE FOR STEM & VET PROGRAMMES

Acknowledgements

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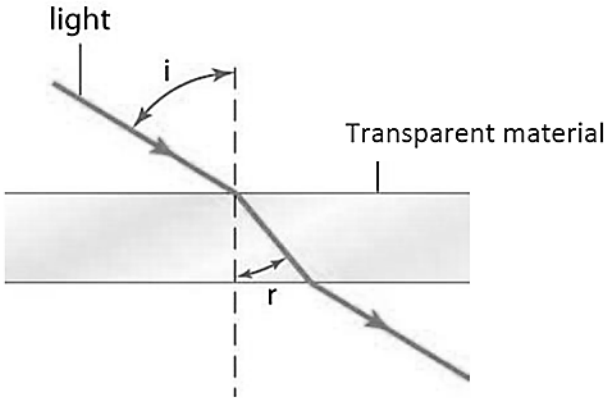
Instructions

- SAFETY FIRST – wearing a lab coat together with safety specs is mandatory at all times. Long hair must be kept tied.
- It is important that all laboratory equipment is handled carefully. In case of any breakages, report immediately to the lab supervisor.
- Each team is requested to clean the lab station adequately after handing in the script to the lab supervisor.
- You are asked to attempt all questions and to write your answers clearly in the spaces provided.
- You are also reminded of the necessity of good English and orderly presentation of your answers.

Section A: Physics

Refraction is an optical property and occurs when light rays in air hit a different medium at different angles (except for a right angle) resulting in a change of speed and direction.
The amount that the ray deviates depends on the refractive index (RI) of the medium which is a measure of the amount of refraction that the wave undergoes.



The refractive index can be found through Experiments A and B which follow below:

Experiment A: Finding the refractive index of Perspex using the real and apparent method.

The refractive index of a Perspex block can be defined as the ratio of the actual thickness of the block to the apparent depth.

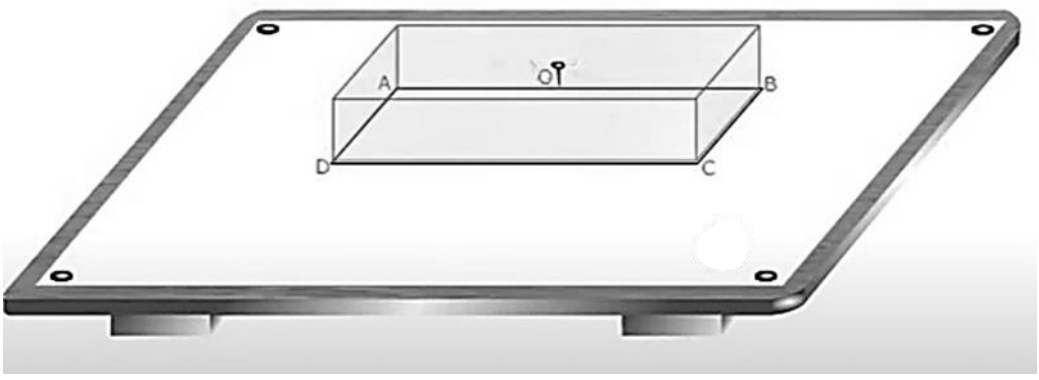
$$\textbf{Refractive index} = \frac{\textit{Actual thickness (real depth)}}{\textit{Apparent depth}}$$

You will require the following apparatus:

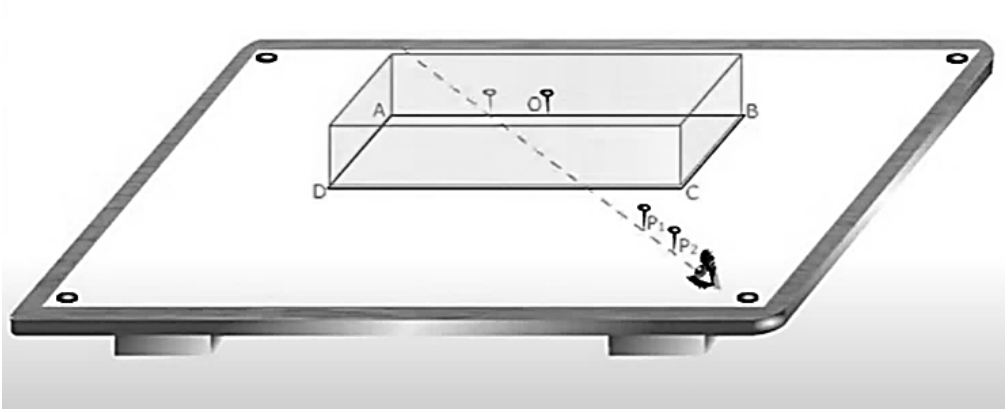
Apparatus: Perspex block, A3 sheet of paper, cardboard, glass head pins, and drawing pins.

Method:

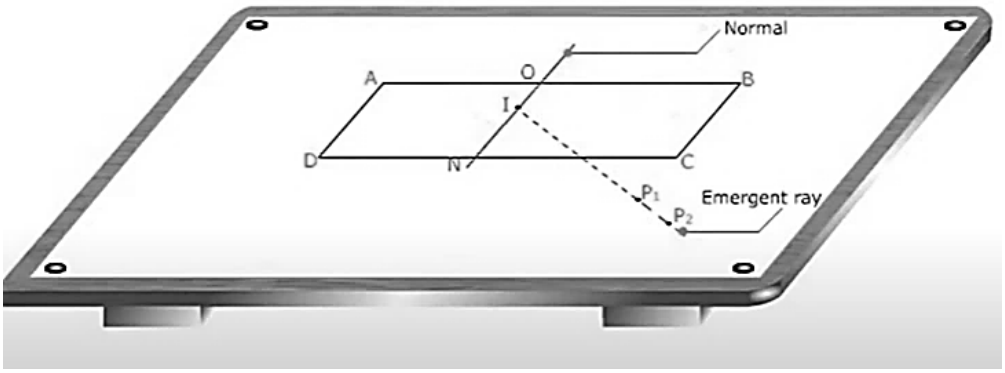
1. Place the A3 sheet of paper on the cardboard and secure it with drawing pins.
2. Place the Perspex block in the middle of the A3 sheet and draw the outline of the block.
3. Place a glass head pin in the position O as shown below.



4. Looking through the opposite face, place two glass head pins P_1 and P_2 such that these pins and the image of the glass head pin at O are along a straight line.



5. Remove the Perspex block and the pins and draw a normal at O. Join P_1 and P_2 and draw a line backwards such that it intersects with the normal ON at I. I is the image of the pin placed at O.



6. Repeat the procedure from the left-hand side of the block.

Results:

Complete:

a) Using the letters O, I, and N, state which distances represent real depth and apparent depth.

Real depth: _____, Apparent depth: _____ (2)

b) State the values of the real depth and apparent depth of the Perspex block.

Right-hand side try:

Real depth: _____ cm, Apparent depth: _____ cm (1)

Left-hand side try:

Real depth: _____ cm, Apparent depth: _____ cm (1)

c) Hence, using an average value of the real depth and apparent depth, calculate the refractive index of the Perspex block.

_____

_____

_____ (2)

IMPORTANT. After **writing your school code** onto the A3 sheet **insert it** into the booklet for reviewing when done.

d) A student is also studying refraction using a Perspex block. She is told that the refractive index of this Perspex block is 1.3 and that the speed of light in air can be taken as the same as that in a vacuum (3×10^8 m/s). Calculate the speed of light in the block.

_____

_____

_____ (2)

Experiment B: Finding the refractive index of glass using Snell's law.

This experiment must be completed in a dim lit room.

Since it is not easy to measure the speed of light in a material, there is another way to find the refractive index using the following equation:

$$\textbf{Refractive index (or n)} = \frac{\textit{the sine of the angle of incidence}}{\textit{the sine of the angle of refraction}}$$

Or in symbols

$$\mathbf{n} = \frac{\sin i}{\sin r}$$

This is called Snell's Law.

You are provided with the following:

Apparatus:

Rectangular glass block, ray box and suitable power supply, protractor, pencil, ruler, and three A3 papers.

Method:

1. Place the glass block in the middle of an A3 paper and draw around it using a pencil.
2. Align the ray box so that a single beam of light is incident on one surface of the glass block.
3. Observe the path of light, and using a pencil, trace over the light travelling into and out of the block onto the A3 paper.

4. Remove the glass block from the piece of paper and using a ruler, join the two lines that you have drawn with a single straight pencil line.
5. At the point where the incident ray reaches the glass block, draw a normal to the surface of the glass block using a protractor.
6. Measure the angle of incidence and the angle of refraction using a protractor and record your results in the table below.
7. Repeat steps 3 to 6 for another five times using different angles of incidence.

Use all provided A3 papers from both sides to trace the path of the rays.

a) In the space provided, draw a labelled diagram of the setup including:
   - An incident ray, a refracted ray through the glass block and an emergent ray.
   - Draw the normals at both surfaces.
   - Mark the angle of incidence and the angle of refraction at the air glass boundary.

(4)

Results:

b) Complete the table below:
Quote all numbers to 2 decimal places. (6)

Angle of incidence, i, in degrees	Angle of refraction, r, in degrees	sin i	sin r	n =sin i/sin r

c) Using the graph paper on **page 7**, plot a graph of sin (i) on the y axis and sin (r) on the x axis. (6)

d) Find the gradient of the line and use this to calculate the refractive index of the glass block.

_____

_____

_____ (3)

e) Using the graph you have just drawn; find the angle of refraction you would expect in the glass block for an angle of incidence of 42°.

_____

_____ (2)

f) Suggest a reason why it is better to calculate the refractive index using a graph, rather than just using one pair of values.

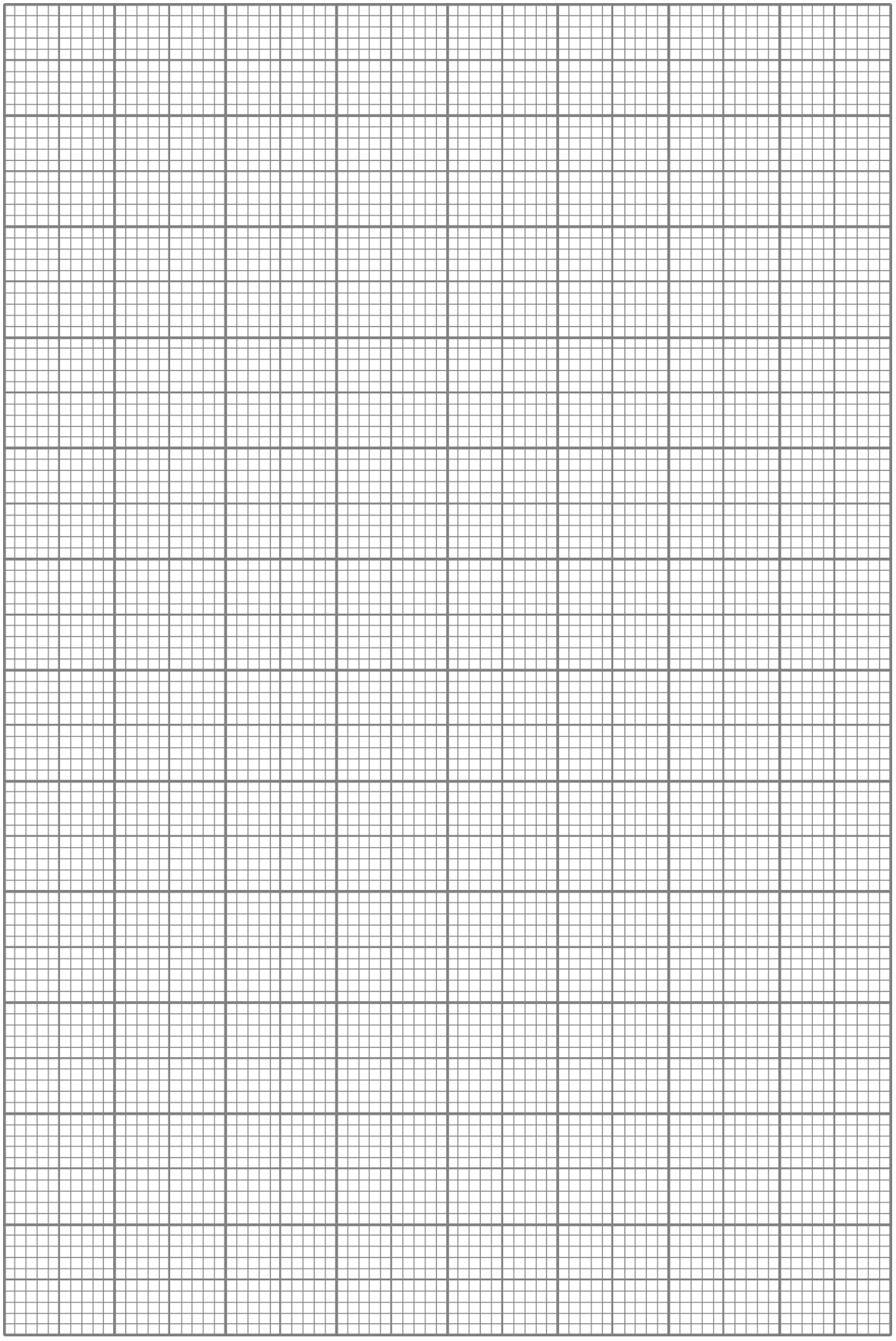
_____

_____ (2)

g) List TWO precautions taken in this experiment to ensure reliable results.

_____

_____ (2)

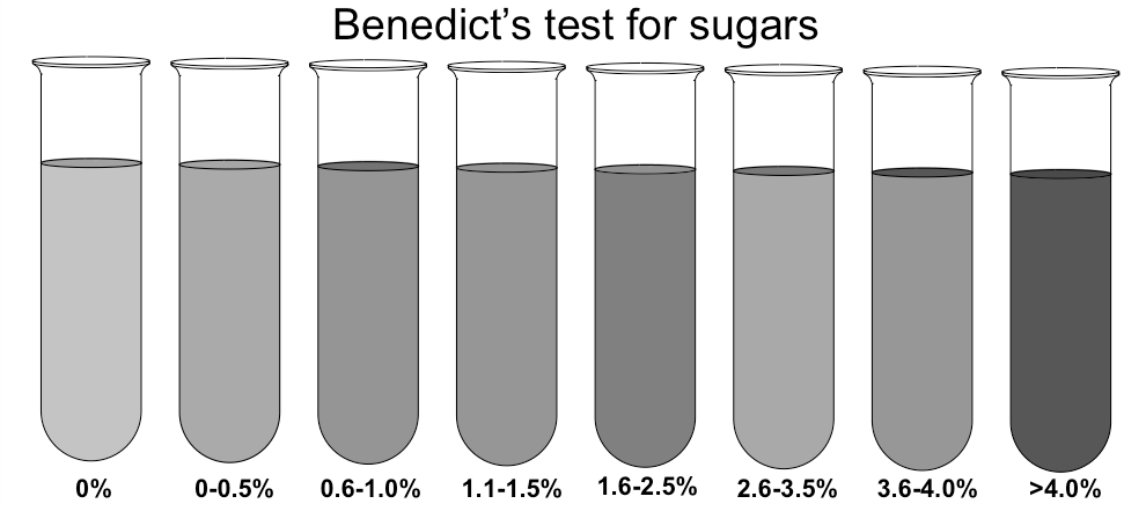


Sub-Total: 33 marks

"The Mediterranean pattern and Western-style pattern are two commonly practiced dietary patterns. The Mediterranean diet contains a high proportion of fruits and vegetables, legumes, whole grains, fish, and poultry with an emphasis on monounsaturated fats and antioxidants, whereas the Western-style diet is generally characterized by energy-dense foods like butter, high-fat dairy products, refined grains, as well as processed and red meat, leaving less space for other nutrients especially those coming from fruits and vegetables. Epidemiological studies have found that the Mediterranean dietary pattern has preventive and protective effects against cardiovascular diseases, whereas the Western-style dietary pattern is positively associated with dyslipidaemia, obesity, hypertension, atherosclerosis, and diabetes."

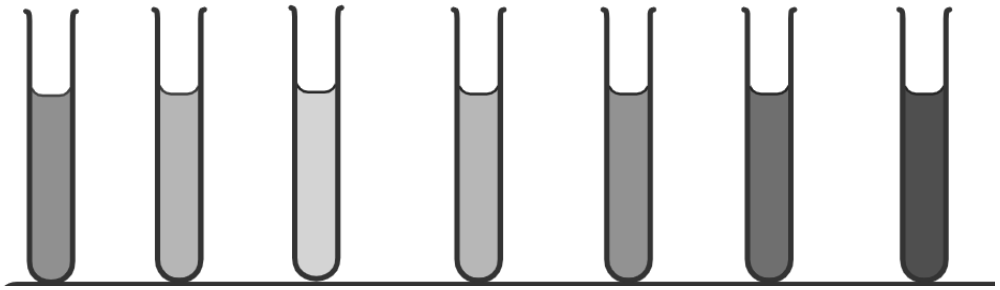
Taken from Chen Y, Michalak M, Agellon LB. Importance of Nutrients and Nutrient Metabolism on Human Health. Yale J Biol Med. 2018 Jun 28;91(2):95-103. PMID: 29955217; PMCID: PMC6020734.

Milk is the first food given after birth and provides the correct amount of nutrients until a child begins to eat semi-solid and solid foods. Milk is drunk by children and adults. In today's world, milk and its products can vary from cow's milk to several plant-based milks. The nutritional content of macronutrients of these different milks varies from one source to another. In this investigation you will need to determine the nutritional content of two macronutrients being sugars (simple carbohydrates) and proteins. Benedict's solution reacts with reducing sugars quantitatively. The colour of the precipitate produced from green to yellow to orange to reddish brown depends on the concentration of the reducing sugars present (refer to the A4 sheet provided in colour). In Figure 1 below, the values show the percentage (%) of reducing sugars found in the solution.



Taken from: https://malikeov.shop/product_details/16337532.html
Figure 1

Biuret solution (sodium hydroxide and copper (II) sulfate) also reacts with proteins quantitatively. The colour produced varies from blue to deep purple with several shades of violet and purple in between (refer to the A4 sheet provided in colour).



1. **Create a colour standard for the Benedict's test and Biuret test on reducing sugars and proteins respectively. Use the 5% glucose solution and the protein (albumen) solution on the main bench for these tests.**

2. **Design and conduct an experiment to determine the different concentrations of sugar and protein in the three milk samples provided.**

List of chemical and liquids:
Benedict's reagent, sodium hydroxide, copper (II) sulfate (or Biuret solution), milk solutions: A, B, and C, albumen, glucose 5%.

List of apparatus:
Bunsen burner, tripod, 2 beakers (250 cm^3 +1000 cm^3), 8 test tubes, test tube rack, test tube cleaner, pipette, stirrer, blank white sheet of paper, document showing colour changes and sugar/protein solutions of varying concentrations.

a) Write down the procedure you carried out to:
   i) Create a colour standard for Benedict's test and Biuret test using the 5% glucose solution and albumen respectively.

_____

_____

_____

_____

_____

_____ (2, 2)

ii) determine the % concentrations of sugar and the concentration of protein in the different milk samples A to C provided.

_____

_____

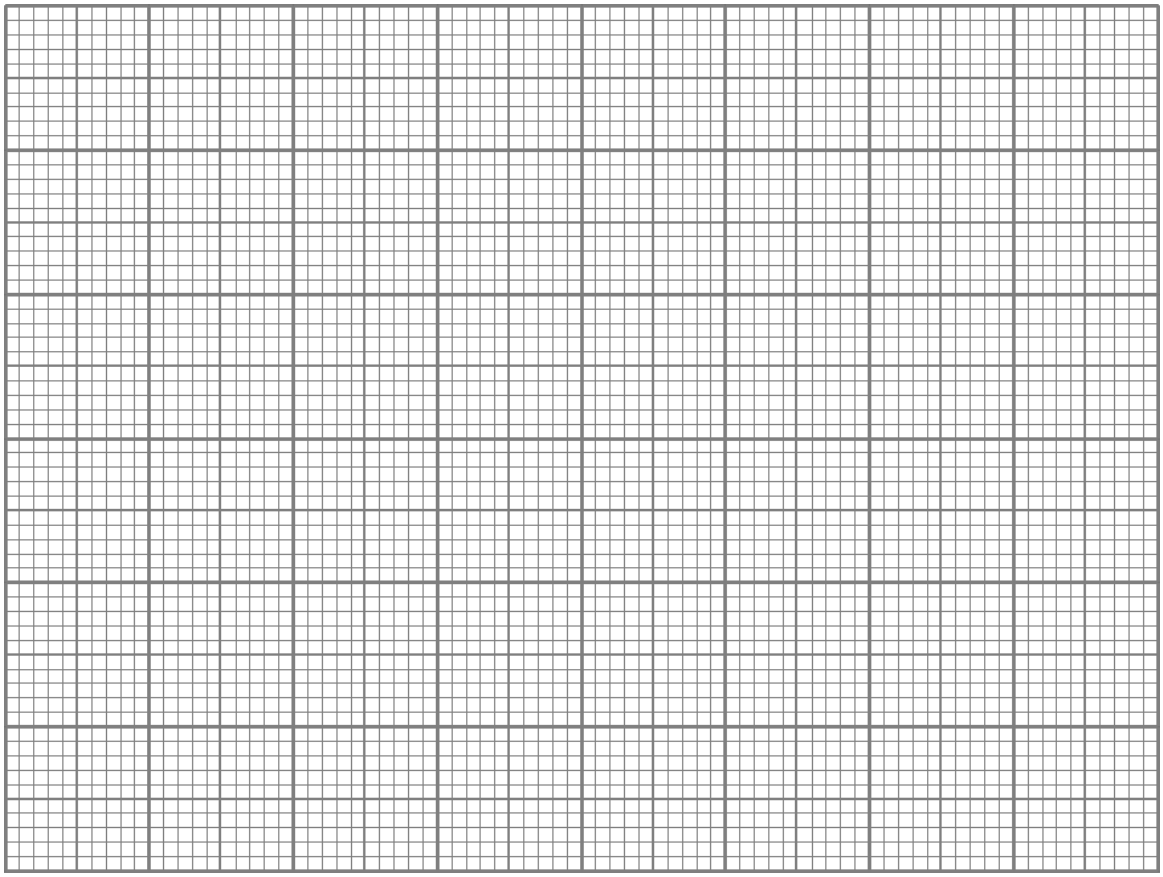
_____

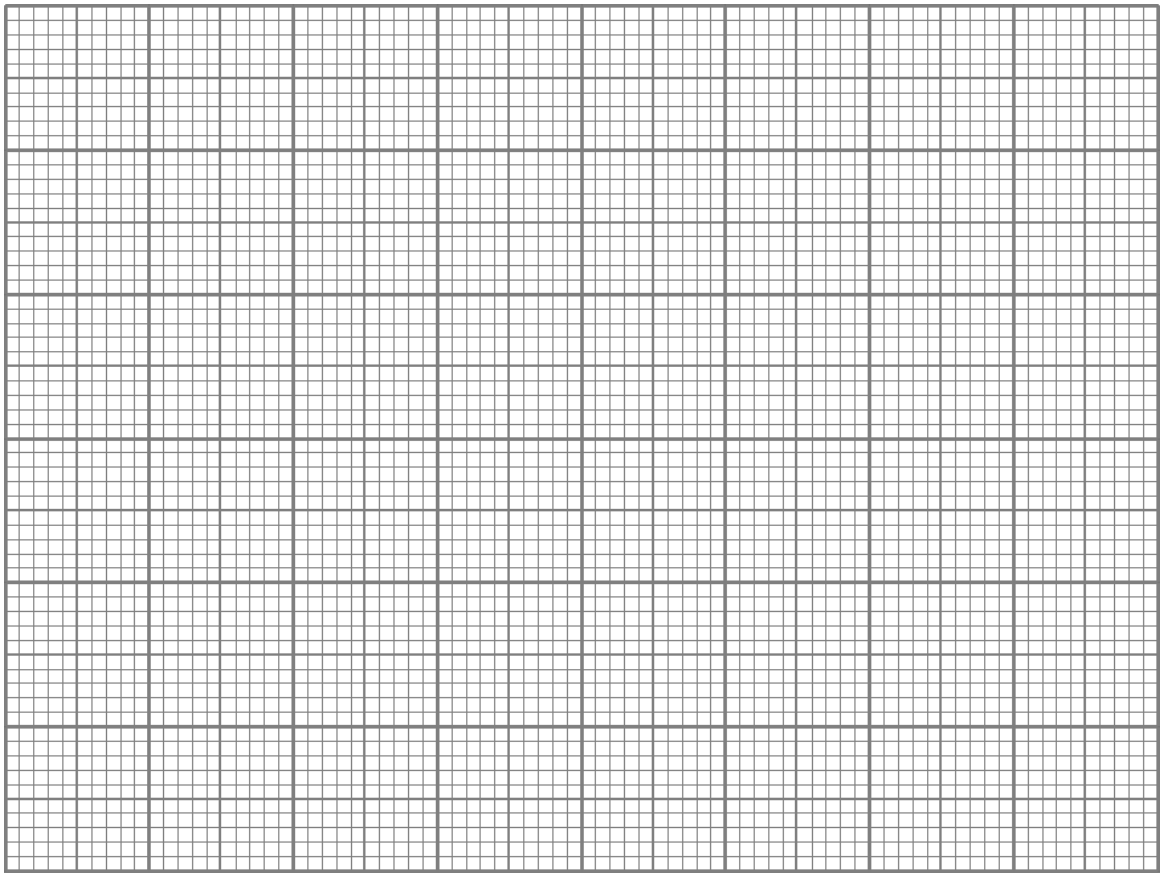
_____ (4)

b) Draw a table of results including:
- the colour change for each milk sample for each investigation,
- the relevant % concentration of sugar and concentration of protein in each milk sample,
- the colour standards.

(3)

c) Draw a bar chart of the % concentration of sugar of each milk sample and the type of milk. On separate axes, draw a bar chart of the concentration of protein of each type of milk sample and the type of milk. Use the graph paper provided on the following page. (4)





d)

i) Name the dependent variable for each experiment.

_____ (1)

ii) Name ONE precaution used for any of the two tests and justify the use of this precaution.

_____

_____ (1, 1)

iii) Give ONE source of error and explain why this is a source of error.

_____

_____ (1, 1)

e) From the results obtained, select the best milk sample, stating ONE reason, to give to a person suffering from:

i) diabetes type (II)

_____

_____ (2)

ii) anorexia

_____

_____ (2)

iii) obesity

_____

_____ (2)

f)

i) State which component of a diet might be present in a larger percentage in cows' milk rather than plant-based milk.

_____ (1)

ii) Explain the effects of large amounts of this component on the human body.

_____

_____ (2)

g) Given the differences between the Mediterranean and Western-style diets, what practical steps could individuals take to transition from a Western-style diet to a Mediterranean diet? Provide at least TWO actionable strategies.

_____

_____

_____

_____ (2, 2)

Sub-Total: 33 marks

Section C: Chemistry

Three samples of water labelled **A**, **B**, and **C** are being provided. These samples are distilled water, tap water and sea water. Your task is to design an experiment using the equipment and materials provided below to determine the identity of the water samples based on their hardness.

- Three samples of water labelled A, B, and C.
- Soap solution.
- 10 cm^3 measuring cylinder.
- 3 beakers.
- 3 stirrers.
- Bunsen burner.
- Tripod and wire gauze.

Your task also includes identifying the kinds of hardness that the water samples may or may not contain.

a) Describe the theoretical ideas behind the design of the experiment and how these ideas can be used to identify the unknown samples.

_____

_____

_____

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_____

_____ (5)

b) List the steps for the procedure of the experiment.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ (6)

c) List TWO precautions related to performing the experiment.

_____

_____ (2)

d) Present the results of your experiment in tabular format.

(3)

e) The identity of **A** is _____, **B** is _____,

and **C** is _____. (3)

f) State the kind/s of hardness, if any, that the following water sources may or may not have.

Distilled water: _____ (1)

Tap water: _____ (1)

Sea water: _____ (1)

g) Explain how the identity of the following water sources was determined.

Distilled water: _____

_____ (1)

Tap water: _____

_____ (1)

Sea water: _____

_____ (1)

h) Write a balanced chemical equation including state symbols to show how temporary hardness is removed by boiling.

_____ (3)

i) State what causes permanent hardness and how it can be removed by chemical means.

_____

_____ (2)

j) Write a net ionic equation including state symbols to show how permanent hardness can be removed by chemical means.

_____ (3)

k) State what causes both temporary and permanent water hardness.

_____

_____ (1)

Sub-Total: 34 marks