Wenzhou City, China 2024
International Mathematics and Science Olympiad

21st International Mathematics and Science Olympiad (IMSO)
Science Theory 2 Test

Wenzhou, China
03 October 2024

Instructions:

1. Do not turnover this page until you are told to do so.
2. Write your ID Number and Seat Number on the space provided.
3. Write your answer only on the separate answer sheet. There are 5 pages in the answer sheet.
4. Answer all the questions in English.
5. There are 9 questions printed on a total of 8 pages, excluding this cover page.
6. You have 90 minutes to complete this test.

1. **Figure 1** below shows a potometer, an instrument designed to measure the rate of transpiration. A plant is positioned in a sealed water-filled container, which is connected to a graduated capillary tube. A bubble is then introduced into the capillary tube. As transpiration takes place, water is drawn up by the plant, causing the bubble to move. The position of the bubble in the tube shows the volume of water taken up by the plant over time.

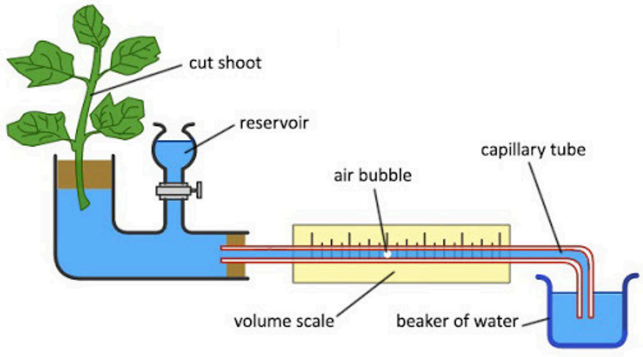


Figure 1

To investigate the transpiration rate of a specific spinach variety, scientists measured the water uptake by a young spinach plant at various temperatures. Water usage was recorded over the course of one hour for each temperature condition. Throughout the experiment, light intensity and humidity were maintained at constant levels. The results are presented in the table below:

Table 1

Temperature (°C)	Water usage (mL/h)
10	0.05
15	0.08
20	0.13
25	0.18
30	1.2
34	1.8
40	2.4

(a) Plot the data in **Table 1** in a graph in the answer sheet. [2.5 marks]

(b) Based from the graph you created, at which temperature would you expect the plant to use 1.5 mL of water per hour? [1 mark]

(c) Transpiration rates are often expressed as volume of water lost per unit time per unit leaf area (ie. mL/h/m^2). If the total leaf area of this plant was found to be 0.05m^2, calculate the transpiration rate of this plant at 30°C. [1 mark]

(d) Explain briefly the relationship between temperature and water usage. [1 mark]

2. An athlete competing in the steeplechase event (**Figure 2**) suffered a fall on the track, resulting in significant blood loss. Before the fall, his heart rate (HR) was 3 beats per second, and his stroke volume (SV) was 130 mL per beat. After the fall, due to the loss of blood, his stroke volume dropped to 80 mL per beat. In response, his body compensated by increasing his heart rate to 4 beats per second.

Figure 2

(a) Calculate the athlete's cardiac output (CO) before and after the fall. [2 marks]

Cardiac output is a measurement of how much blood the heart pumps per minute and can be calculated by the formula below,

$$\mathbf{CO} = \mathbf{HR} \times \mathbf{SV};$$

Where,
CO is the *cardiac output*,
HR is the *heart rate* (in **beats/min**) and
SV is the *stroke volume* (the measure of the amount of blood pumped per heartbeat, in mL/beat).

(b) Despite the increased heart rate after the fall, the athlete felt lightheaded and weak. Why might this occur even though the heart rate has increased? [1.5 marks]

(c) One of the medical interventions that could be given to the athlete after the fall is intravenous (IV) fluid therapy. Explain how this therapy can stabilize the athlete's cardiac output and overall condition after significant blood loss? [1 mark]

3. A student carried out an experiment by placing *Hydrilla* leaves of equal length in different beakers, each containing different concentrations of starch solutions, for 15 minutes. Each beaker contained one *Hydrilla* leaf immersed in starch solution. **Figure 3** shows the experimental set up.

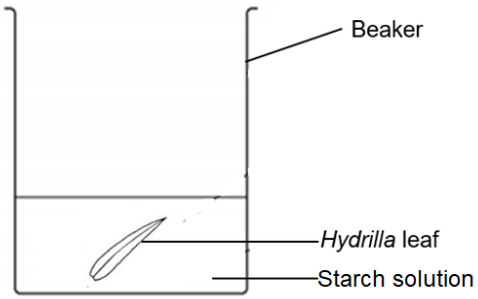


Figure 3

After 15 minutes, a drop of each liquid and the *Hydrilla* leaf were then placed on a glass slide with a coverslip and examined under a light microscope. **Table 3** below shows the results of the experiment.

Table 3

Type of liquid in each beaker with a *Hydrilla* leaf	Average length of protoplast (cells without the cell walls) in *Hydrilla* leaf cells (in micrometer)
20% starch solution	150
50% starch solution	90

After examining under the microscope, the *Hydrilla* leaves were then placed in a beaker containing distilled water for 15 minutes and examined under a light microscope again. The average length of protoplast (cells without the cell walls) in *Hydrilla* leaf cells was 225 micrometers.

(a) With reference to **Table 3**, explain the results obtained for *Hydrilla* leaf in 50% starch solutions. [1.5 marks]

(b) With reference to **Table 3**, compare and explain the extent of the condition of the Hydrilla leaf cells immersed in 20% starch solution and those immersed in 50% starch solution. [1.5 marks]

(c) Explain the results obtained after the *Hydrilla* leaves were placed in distilled water. [1 mark]

(d) A can of tuna contains very concentrated salt solution. If bacteria cells happen to be present in the can of tuna, explain what will happen to the bacteria cells. [1 mark]

4. **Figure 4** below shows a thermal bag which is used during pizza delivery to keep pizzas warm for a few hours. The inner layer is made of foam and lined with a layer of aluminium.

Figure 4

(a) Explain how the design features of the bag help keep the pizza warm for a long period of time. [2.5 marks]

(b) A man wants to keep the pizza in the refrigerator so he can reheat and eat it the next day. He placed the pizza with the bag into his refrigerator to keep the pizza fresh. Should he keep the bag open as shown or zip up the bag? Explain. [2.5 marks]

5. John conducts an experiment on fluids using the setup (**Figure 5**) below:

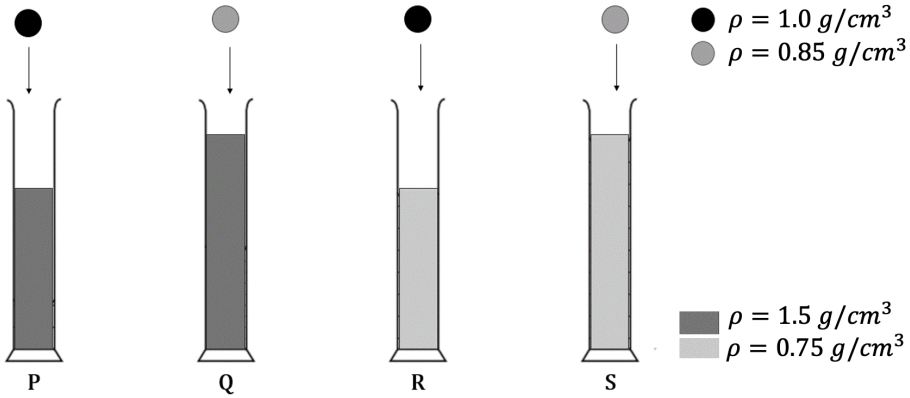
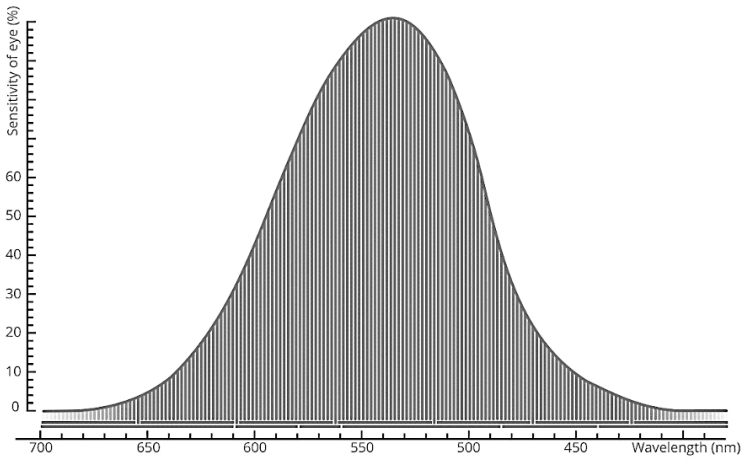


Figure 5

(a) Based on the densities of the balls and the liquids, describe whether each ball will sink or float after being dropped in the cylinder. [2 marks]

(b) Which ball experienced the most pressure after being submerged in the liquid? Explain. [2 marks]

6. **Figure 6** below shows the sensitivity of the human eye to the visible light.



Color	Wavelength	Frequency
violet	380–450 nm	668–789 THz
blue	450–495 nm	606–668 THz
green	495–570 nm	526–606 THz
yellow	570–590 nm	508–526 THz
orange	590–620 nm	484–508 THz
red	620–750 nm	400–484 THz

Figure 6

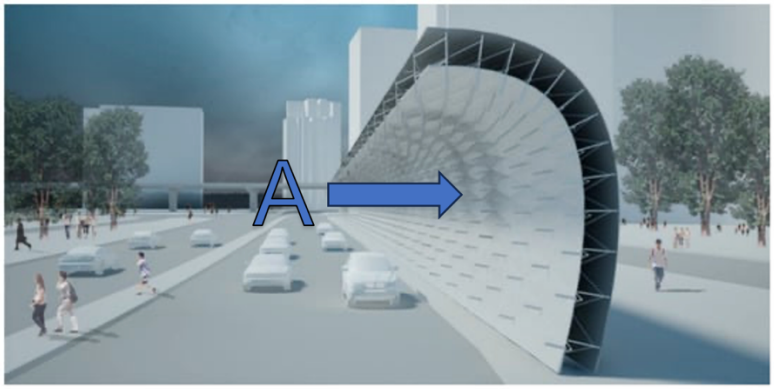
(a) With reference to **Figure 6**, which color is the human eye more sensitive to? [1 mark]

(b) With reference to **Figure 6**, state the relationship of the visible light's wavelength and frequency. [1 mark]

(c) Provide one example of electromagnetic radiation found in wavelengths (i) below 450 nm and (ii) above 700 nm. [2 marks]

(d) Explain why the human eye could not see spectral regions beyond visible light? [2 marks]

7. Study the structure labelled as 'A' as shown in the figure below and answer the following questions.



Taken OFL Architecture/Francesco Lipari, https://www.oflarchitecture.com/hknb, accessed on 18 June 2021, as cited in https://www.mdpi.com/2673-4931/8/1/11.

Explain the type of pollution(s) the structure is designed to address. [3 marks]

8. Asia is traversed by complex tectonic plate movements which makes the risk of megathrust earthquakes high in Asia. One example of this megathrust earthquake is the magnitude 7.1 earthquake that happened last April 2023 in Sumatra, Indonesia. Its intensity ratings are plotted on the map in **Figure 8.1** near the epicenter. Its epicenter is denoted by a star.

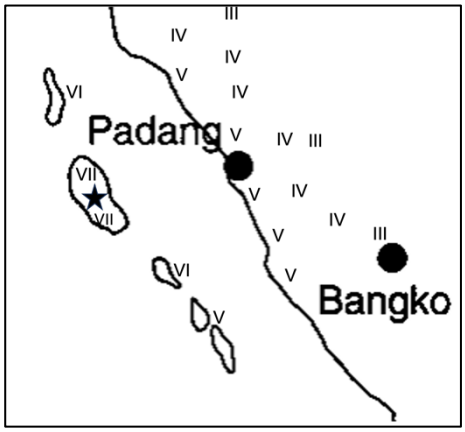


Figure 8.1

(a) A megathrust earthquake occurs in a subduction zone, which is an area where one of the Earth's tectonic plates is pushed under another tectonic plate.

(i) Identify the type of tectonic plate boundary that is located nearest to the epicenter of this earthquake. [0.5 mark]

(ii) Identify which layer of the earth does this plate movement occur. [0.5 mark]

(b) **Table 8** lists some of the observations that might be made during an earthquake according to the modified Mercalli scale. Place a check mark on the observations made in the city of Padang during the April 2023 Earthquake. [3 marks]

Table 8

I	Instrumental: detected only by instruments	VII	Very strong: noticed by people in autos Damage to poor construction
II	Very feeble: noticed only by people at rest	VIII	Destructive: chimneys fall, much damage in substantial buildings, heavy furniture overturned
III	Slight: felt by people at rest Like passing of a truck	IX	Ruinous: great damage to substantial structures Ground cracked, pipes broken
IV	Moderate: generally perceptible by people in motion Loose objects disturbed	X	Disastrous: many buildings destroyed
V	Rather strong: dishes broken, bells rung, pendulum clocks stopped People awakened	XI	Very disastrous: few structures left standing
VI	Strong: felt by all, some people frightened Damage slight, some plaster cracked	XII	Catastrophic: total destruction

__ parked cars rock
__ dishes and windows broken
__ buildings shifted off foundations
__ monuments fall
__ felt by Sumatrans who are sleeping
__ some heavy furnitures moved

(c) A magnitude 7.1 megathrust earthquake can generate a tsunami.

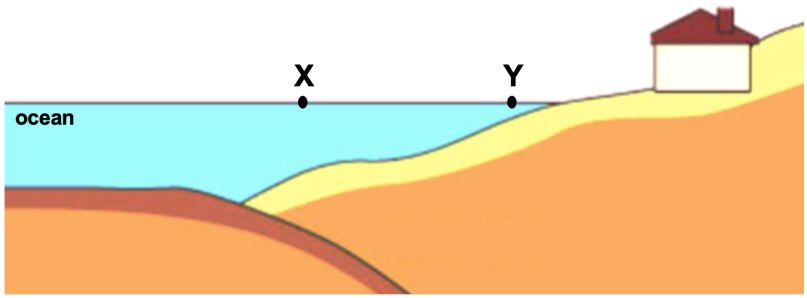


Figure 8.2

(i) On **Figure 8.2**, draw arrow(s) from the origin to show the direction of energy causing a tsunami. [1 mark]

(ii) Compare the velocity (faster or slower) and height (higher, lower) of the tsunami as it gets shallower from point X to Y. [2 marks]

9. The early Greeks thought that earth, fire, water and air were the four basic elements that made up the world. An early scientist, Georg Ernst Stahl first proposed that combustible substances contained a fire-like element called phlogiston, which was released when the substances burned (combustion) as in **Figure 9**.

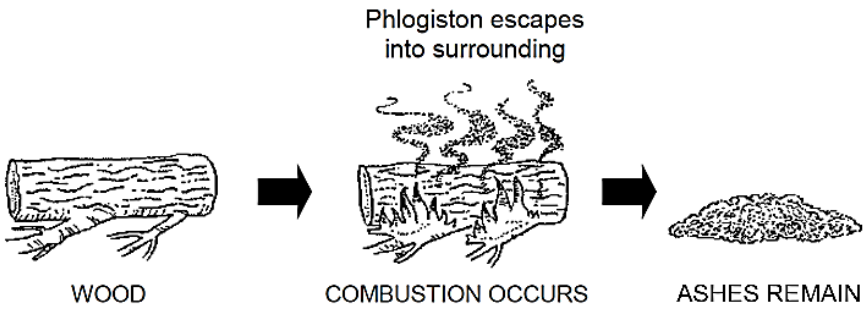


Figure 9

In 1774, scientist Antoine Lavoisier challenged the Phlogiston Theory when he carried out the combustion of mercury with air in a sealed container. He recorded the mass of mercury used, and mass of the product after combustion.

	Before combustion	After combustion
Mass of substance (g)	1.00	1.08

(a) Explain how Lavoisier's experimental results had disproved the Phlogiston theory. [1 mark]

(b) Lavoisier also showed that water was not an element. He reacted oxygen with an “inflammable air” to obtain water and concluded that water was a compound made up of oxygen and “inflammable air”.

What is the identity of this “inflammable air”? [0.5 mark]

(c) The modern-day idea of “combustion” is different from the Phlogiston theory. Complete the word equation below by naming the substances needed and formed during complete combustion. [1.5 marks]

combustible substance + ☐ $\xrightarrow{\text{combustion}}$ ☐ + ☐

(d) To cook soup noodles, a mountain climber heated pieces of ice (frozen at -15°C) in a pot until the water boiled for a few minutes. With an atmospheric pressure of 0.5 atm at his base camp, ice melts at 0°C and water boils at 81°C.

Sketch a graph to show how the temperature of water in the pot changed over time. Label your graph clearly with the various temperatures. [2 marks]

--- END OF SCIENCE THEORY 2 TEST ---