Youth STEM Cup 2024

Preliminary Round
(Junior Category)

Problems and Answers

13 April 2024

Contents

Committee and Contributions

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Problem Selection Committee

The Problem Selection Committee (PSC) is responsible for setting and selecting problems for the contest. It makes collaborative decisions on the suitability and format of the questions, and performs cross-checks to ensure the questions are valid, clear, and well-posed. It also produces the *Problems and Answers* document, the *Problems and Solutions* document and the question paper.

Special thanks to the PSC for contributing 36 problem proposals for the Preliminary Round:

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Earth Science
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Quincy Jules Tan Yi Liing, Hee Wen Kai

Social Science
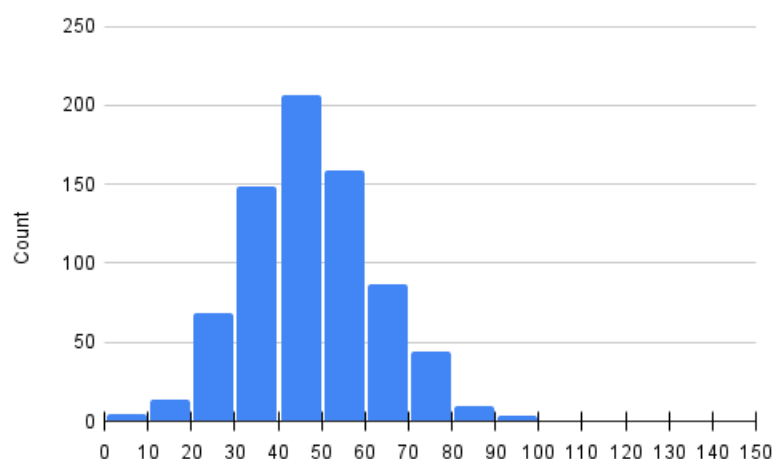Shee Yi Rong, Ashwin Asokan, Alex Chen Fan Hao, Lim Ming Wen

Preliminary Round Analysis

General Statistics

Duration	60 minutes
Full Score	150
Total Number of Responses (Individual participants + Teams)	669
Average Score	46.98
Median Score	46
Range	0 - 111
Standard Deviation	15.38

Score Distribution

Histogram of Score (Juniors)

Breakdown of Correct Responses

Bio		Chem		Phy		Maths		Earth		Social	
Q	Freq	Q	Freq	Q	Freq	Q	Freq	Q	Freq	Q	Freq
1	257	1	43	1	199	1	147	1	164	1	292
2	522	2	219	2	300	2	147	2	207	2	188
3	155	3	313	3	182	3	162	3	217	3	322
4	316	4	138	4	202	4	201	4	133	4	249
5	189	5	247	5	127	5	160	5	237	5	403
6	162	6	52	6	181	6	163	6	176	6	157
Σ	1601	Σ	1012	Σ	1191	Σ	980	Σ	1134	Σ	1611

Problems

Biology

1. Diagram 1 shows an experiment to study the effect of solution Z on the red blood cells.

Fresh chicken blood

Solution Z

Groove glass slide
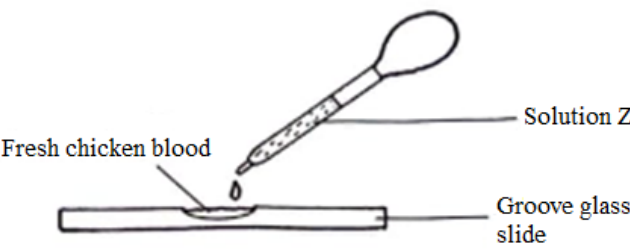
Diagram 1

Which of the following is the correct match? (3 marks)

	Solution Z	Condition of red blood cells
A.	0.15 M sodium chloride solution	
B.	Distilled water	
C.	0.15 M sodium chloride solution	
D.	Distilled water	

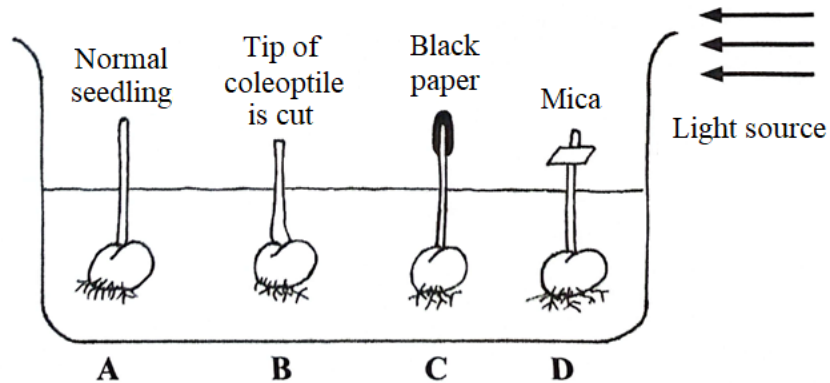2. Diagram 2 shows four seedlings being exposed to light from one direction.

Diagram 2

Which of the following A, B, C or D will show positive phototropism? (3 marks)

A. Seedling A

B. Seedling B

C. Seedling C

D. Seedling D

3. Animals possess mechanisms for maintaining their body temperature within permissible levels. For example, they show various responses to changes in room temperature. In addition, animals' body shapes are optimized to adapt to various climate changes, and their behaviours also regulate their body temperature.

Which of the following statements are **FALSE**? (4 marks)

 I. In each ordinary habitat, the body temperature of endotherms is always higher than that of ectotherms.

 II. In humans, the body temperature is elevated when the temperature of the hypothalamus is artificially increased.

 III. When a female Burmese python incubates eggs, her oxygen consumption in a cold room is less than that in a warm room.

 IV. Ectotherms require less energy than endotherms for homeostasis.

A. I, II and III

B. I, II and IV

C. I, III and IV

D. II, III and IV

4. In the motor end plate, there is a type of rapid chemical transmission, mediated by the neurotransmitter acetylcholine (ACh). ACh vesicles are concentrated in the area of the motor nerve closest to the muscle, the active zone, and are then released (via exocytosis) into the synaptic cleft. Botulinum toxin has a great impact at motor end plate and ACh-mediated chemical transmission.
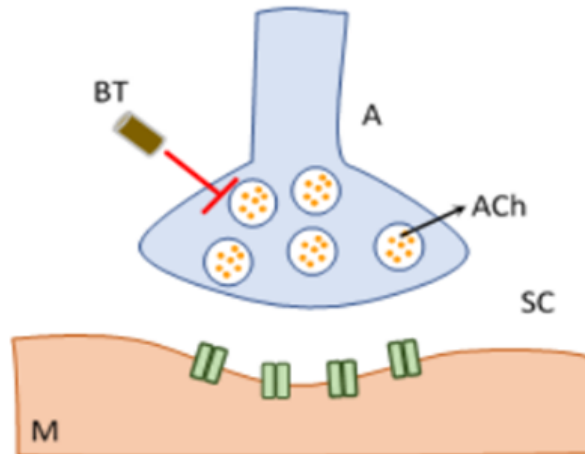

Diagram 3. Motor end plate. Impact of Botulinum toxin. BT − Botulinum toxin; M − muscle; SC − synaptic cleft; ACh − acetylcholine; A − motor axon.

Which of the following statements are **TRUE**?   (5 marks)

   I. Botulinum toxin blocks the release of ACh.

   II. Botulinum toxin promotes constant muscle contraction.

   III. Botox, the alternative name of botulinum toxin is produced by the fungus *Clostridium botulinum*.

   IV. Under steady-state conditions ACh release from the motor axon allows action potential.

   A. I and II

   B. I and IV

   C. II and III

   D. III and IV

5. For the three heritable features, Alfa, Baker, and Charlie, pedigree analysis was performed on pedigree A, pedigree B, and pedigree C, respectively, and the results in Diagram 4 were obtained. A subsequent detailed analysis revealed that all of the inheritance patterns of Alfa, Baker, and Charlie were due to recessive alleles on the autosome.
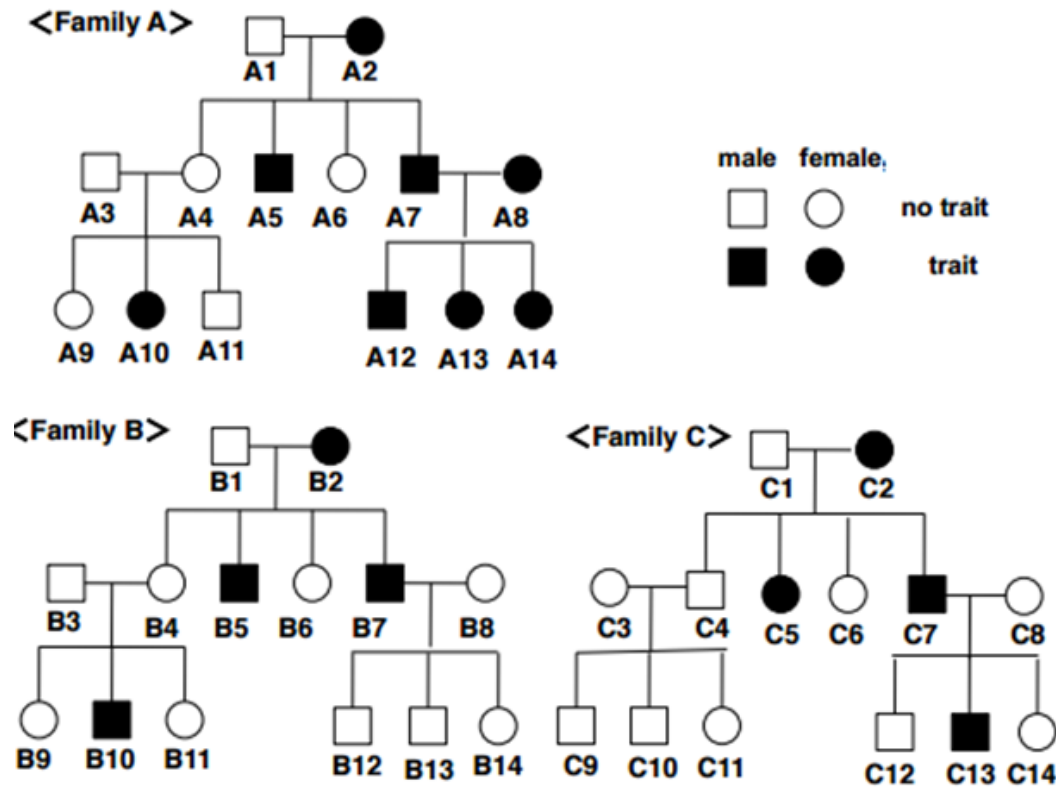

Diagram 5

Which of the following statements are **TRUE**? (6 marks)

I. An analysis of pedigree A suggests that the inheritance pattern of characteristic Alfa could be due to a dominant allele.

II. An analysis of pedigree C suggests that the inheritance of the characteristic Charlie could be due to a dominant allele.

III. B1 and B3 of family B are definitely carriers.

IV. C1 and C3 of family C are definitely carriers.

A. I and II

B. I and IV

C. II and III

D. III and IV

6. Hydrolases that degrade biopolymers can be categorized into two types: (1) endo-type that hydrolyzes the interior bonds of the polymer, and (2) exo-type that releases the end unit from the polymer. These exo-type and endo-type hydrolases are often linked to their biological roles. Which of the following enzymes are endo-type? (4 marks)

   I. Digestive proteases in stomach such as pepsin

   II. Proteases that cleave off the translocation signal peptide

   III. Proofreading nuclease in the DNA polymerase that removes misincorporated nucleotides during DNA replication

   IV. Cas9 nuclease of the CRISPR-Cas9 system for genome editing

   A. I, II and III

   B. I, II and IV

   C. II, III and IV

   D. All of the above

Chemistry

1. Which of the following represents hydrogen bonding? Choose one or more than one options.

A.

B.

C.

D.
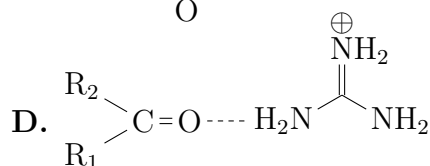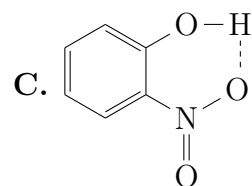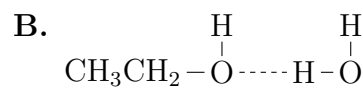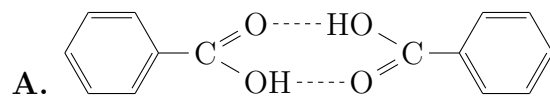
2. Consider the reactions below:

Which of the following statements is/are **incorrect**? (4 marks)
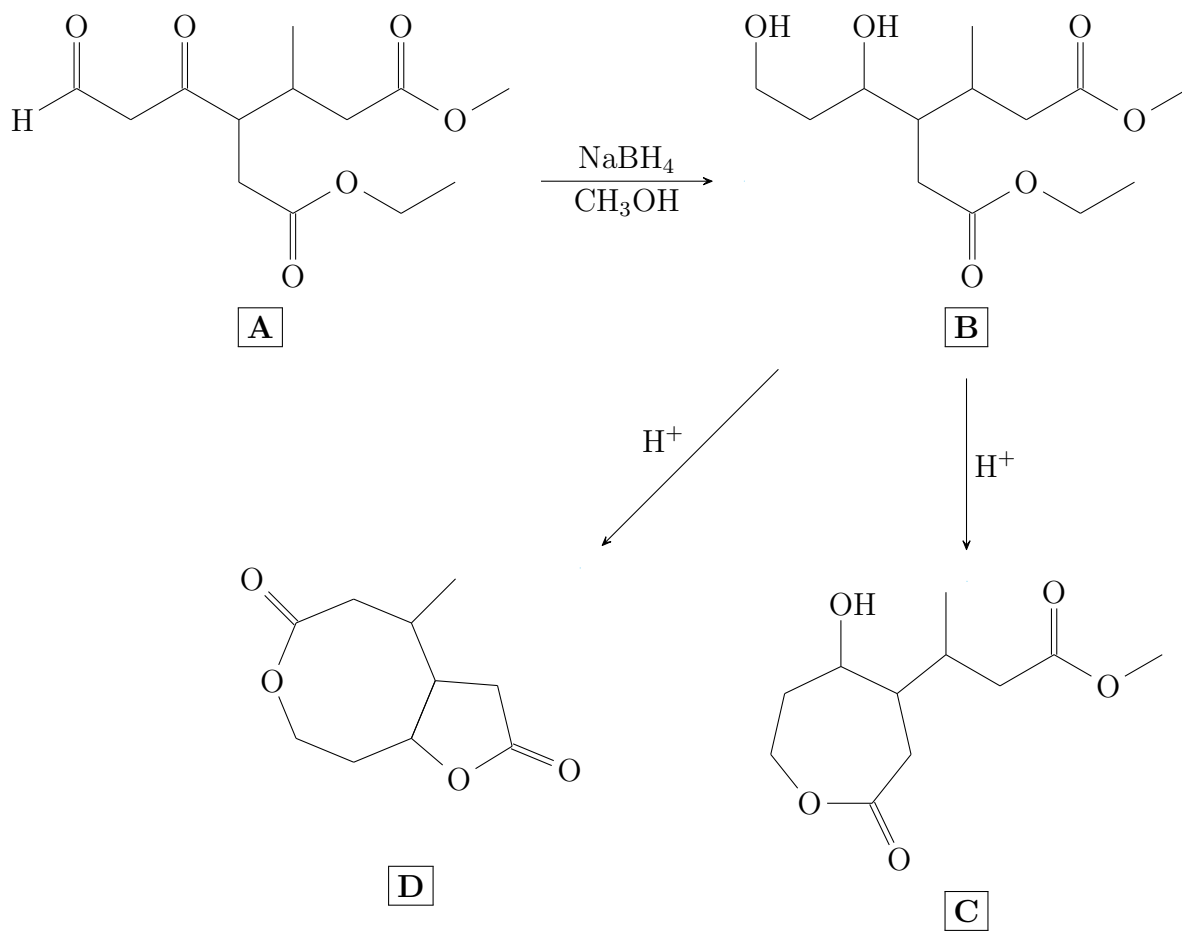
   I. The reaction involving the conversion of A to B is known as reduction.

   II. The reaction involving the conversion of B to C/D is called transesterification.

   III. A can be produced from B by using acidified potassium permanganate solution.

   IV. D can be produced from C without breaking the cyclic ester.

   A. II only   C. III and IV only

   B. I and II only   D. I, II, III and IV

3. Recently, Wand saw an interesting experiment on Instagram where a person dipped their finger with soap into a bowl of water containing pepper powder on top, causing the pepper powder to instantly disperse to the side. Which statement provides the best explanation for why this phenomenon occurs? (4 marks)

   A. Soap contains a hydrophobic tail, which disrupts the surface tension of water molecules and causes the water molecules to be pulled away from the soap in order to keep the surface tension intact.

   B. Soap contains a hydrophobic tail, which repels the pepper molecule to the side as molecules in pepper are mostly hydrophilic.

   C. Soap contains a hydrophobic tail, which repels the water to the side and causes the overall surface tension of water to decrease.

   D. Soap contains a hydrophilic head, which readily interacts with water and pulls water molecules towards itself, causing the pepper powder to be pushed to the side.

4. Billy is trying to react 0.500 g of impure magnesium strip, which contains only Magnesium (Mg) and Magnesium Oxide (MgO), with 25 mL of $1.0 \, \text{mol} \, \text{L}^{-1}$ hydrochloric acid to determine the amount of hydrogen gas released.

Which of the following is/are **TRUE**? (5 marks)
(Assume molar volume $= 24.0 \, \text{L} \, \text{mol}^{-1}$; A_r: H $= 1.0$; O $= 16.0$; Mg $= 24.3$; Cl $= 35.5$)

   I. The magnesium strip only becomes the limiting reagent if the oxygen content is at least 39.3(%) by mass.

   II. If Billy uses a measuring cylinder contaminated with sodium hydrogen carbonate to add the hydrochloric acid, the volume of Hydrogen gas released will increase as compared to using a clean measuring cylinder.

   III. The oxide content of the magnesium strip will not affect the rate of reaction.

   IV. Given that the reaction is exothermic, increasing the concentration of hydrochloric acid always leads to an increase in temperature rise (ΔT).
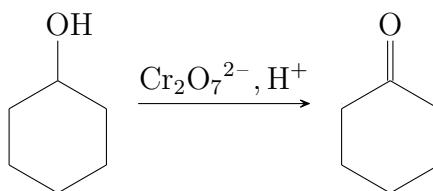
   A. I, II and IV only

   B. I and III only
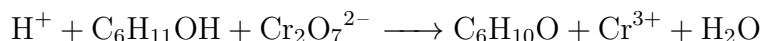
   C. II and IV only

   D. None of the above

5. Alcohols can be oxidized into ketones with $Cr_2O_7^{2-}$ in acidic solution, as shown below. Cr^{3+} is formed as a byproduct of the reaction.


The unbalanced chemical equation for the reaction is:

$$H^+ + C_6H_{11}OH + Cr_2O_7^{2-} \longrightarrow C_6H_{10}O + Cr^{3+} + H_2O$$

What are the stoichiometric coefficients for the above reaction?   (3 marks)

A. 8, 3, 1, 3, 2, 7   C. 8, 3, 1, 3, 1, 7

B. 20, 3, 5, 3, 10, 10   D. 0, 7, 1, 7, 2, 7

6. Hydrogen sulfide, H_2S, can be endogeneously produced in mammals *via* the transsulfuration pathway, which is responsible for the conversion of sulfur-containing amino acids. H_2S can be toxic at high concentrations, preventing energy production in the mitochondria.

Reduced glutathione (GSH), a three-amino-acid peptide, is involved in the mitochondrial sulfide oxidation pathway. This pathway is crucial as it prevents the buildup of H_2S by allowing for it to be oxidized into the sulfite ion, SO_3^{2-}. The **unbalanced** reaction for the oxidation of H_2S is shown below:

$$H_2S + O_2 + GSH \quad \xrightarrow{\text{Sulfide quinone oxidoreductase}} \quad GSSH + SO_3^{2-}$$
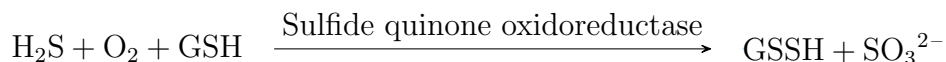
The chemical structure of GSH is displayed.
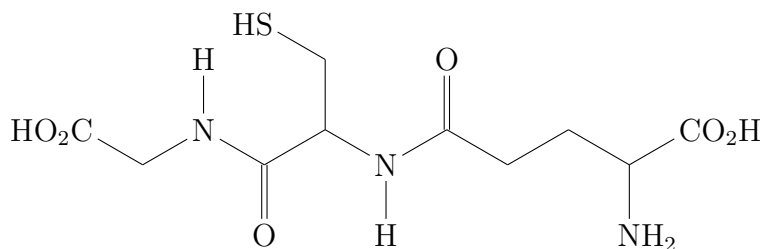
Reduced glutathione (GSH)

How many molecules of reduced glutathione are **directly** involved in oxidizing one molecule of H_2S into SO_3^{2-}?   (5 marks)
($N_A = 6.02 \times 10^{23}$ mol^{-1}; A_r: H = 1.0; C = 12.0; N = 14.0; O = 16.0; S = 32.1)

A. 0   B. 1   C. 3   D. 6

Physics

*In all the following problems, take the gravitational acceleration near Earth's surface to be $g = 9.81\,\mathrm{m\,s^{-2}}$.

1. A guy throws two balls with the same initial velocity as shown in the diagram. Which ball hits the ground first? (3 marks)
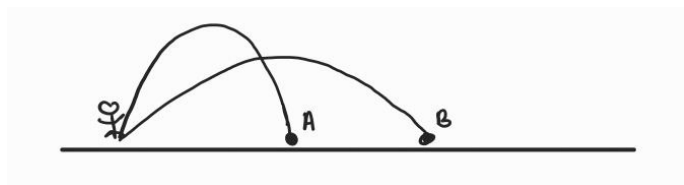

Figure 1

    A. Ball A

    B. Ball B

    C. Both balls reaches the ground at the same time.

    D. The balls collide in midair.

2. Two identical beakers are filled with equal amounts of pure water, and placed on two identical calibrated electronic balances in a stationary cart. On one side a ping pong ball is fully submerged in water, connected to the base of the beaker with a thin massless string; on the other side, a solid steel ball is fully submerged in water, connected to the rigid roof with a thin massless string as shown in Figure 2. The two balls have the same volume but different densities.
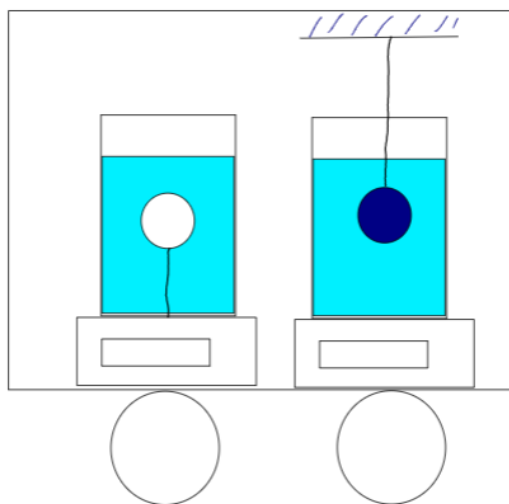

Figure 2

Which side of the beakers shows a larger weight reading? (3 marks)

    A. left   B. right   C. same reading   D. indeterminate

3. The setup for Question 2 is used in this question. Suppose the cart now accelerate rightwards with a positive acceleration $a = 5.0\,\mathrm{m\,s^{-2}}$. Which statement is correct? (4 marks)

   A. the ball on the left tilts leftwards, ball on the right tilts rightwards

   B. the ball on the left tilt rightwards, ball on the right tilts leftwards

   C. both balls tilt leftwards

   D. both balls tilt rightwards

4. Feeling adventurous, Nelson decides to try bungee jumping one day. He attaches himself to an elastic rope that has a relaxed length of $l = 18.0\,\mathrm{m}$. When it is stretched taut, it behaves like an ideal spring with spring constant $k = 40\,\mathrm{N\,m^{-1}}$. If Nelson starts falling from rest, at what point will his speed be maximised? Take y to be increasing downwards and Nelson's initial position to be $y = 0\,\mathrm{m}$. Nelson's mass is $60\,\mathrm{kg}$. (4 marks)

   A. $14.7\,\mathrm{m}$ B. $29.3\,\mathrm{m}$ C. $32.7\,\mathrm{m}$ D. $41.0\,\mathrm{m}$

5. A roller-coaster track is shaped as a parabola with an equation $y = 0.040x^2$ where y is the vertical distance from the ground; both x and y have units of metres. The roller-coaster starts off stationary at $(x, y) = (-50, 100)$. Find the normal force acting on the roller coaster when it reaches the lowest point of the track. You may assume that it is a point particle with mass $m = 80\,\mathrm{kg}$. (5 marks)

   A. $11\,900\,\mathrm{N}$ B. $12\,500\,\mathrm{N}$ C. $12\,600\,\mathrm{N}$ D. $13\,300\,\mathrm{N}$

6. A uniform metallic rod of mass $m = 0.75\,\mathrm{kg}$ and length $l = 0.56\,\mathrm{m}$ is free to slide along a vertical, infinitely long metallic frame.
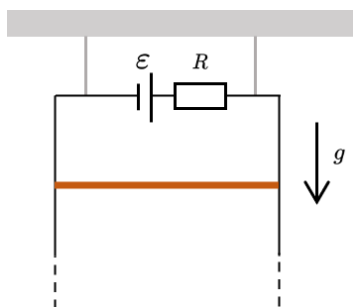

Figure 3

A uniform magnetic field with field strength $B = 80\,\mathrm{mT}$ and pointing directly out of the page permeates the space. It turns out that after the rod is released from rest for a long time, it moves downwards at a constant velocity v_m. Find v_m given that $\mathcal{E} = 1.2\,\mathrm{V}$ and $R = 17\,\mathrm{m\Omega}$. Assume that the metallic rod and frame have negligible resistance and friction.

(6 marks)

   A. $29.8\,\mathrm{m\,s^{-1}}$ B. $32.0\,\mathrm{m\,s^{-1}}$ C. $35.5\,\mathrm{m\,s^{-1}}$ D. $38.7\,\mathrm{m\,s^{-1}}$

Mathematics

1. Given $x \neq 0$, determine the range of x such that

$$\frac{2x + 2}{x} \leq x + 3$$

(3 marks)

   A. $x \leq -2$,   B. $x \leq -2$,   C. $-2 \leq x < 0$,   D. $-2 \leq x < 0$,
        $0 < x \leq 1$ $x \geq 1$ $0 < x \leq 1$ $x \geq 1$

2. Determine the sum of digits from 1 to 1001.   (4 marks)

   A. 13500   B. 13503   C. 500500   D. 500503

3. What's the smallest positive integer that has at least 5 digits and cannot be expressed as the sum of two perfect squares? (Note: 0 is considered a perfect square.)   (4 marks)

   A. 10001   B. 10002   C. 10003   D. 10005

4. Given triangle ABC, D is a point on side BC such that

$$\angle ABC : \angle ACB : \angle BAD : \angle CAD = 5 : 2 : 1 : 4$$

Determine $\dfrac{BC}{AD}$.   (4 marks)

   A. 1   B. $\sqrt{2}$ C. $\sqrt{3}$ D. 2

5. Let x be the number of ways to choose 4 distinct positive integers a, b, c, d, such that $a + b + c + d = 40$. Calculate the remainder when x is divided by 4. (Note: $a = 34, b = 3, c = 2, d = 1$ and $a = 34, b = 3, c = 1, d = 2$ are considered two different solutions.)   (5 marks)

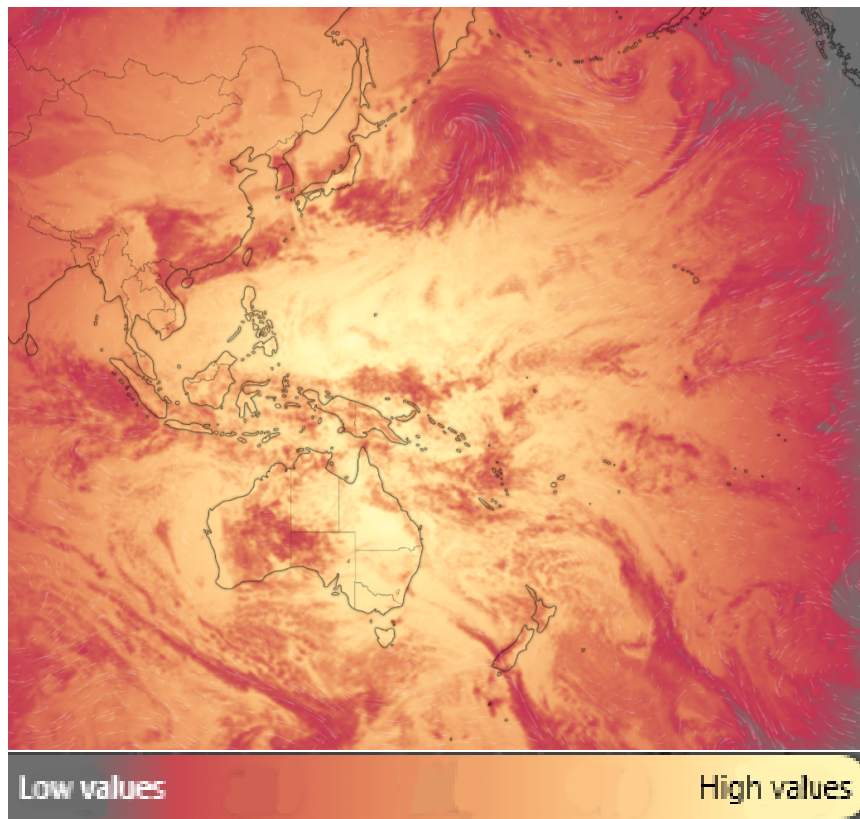   A. 0   B. 1   C. 2   D. 3

6. Let α be the largest root of the equation $x^2 - 5x + 1$. Determine the remainder when $\alpha^{48} + \dfrac{1}{\alpha^{48}}$ is divided by 101?   (5 marks)

   A. 25   B. 66   C. 78   D. 94

Earth Science

1. Consider the following map:

   What is shown by the map? (3 marks)

   A. Cloud distribution at a particular moment in time

   B. UV irradiance at a particular moment in time

   C. Solar power intensity at a particular moment in time

   D. Surface temperature at a particular time
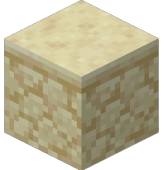
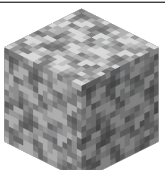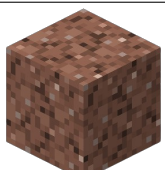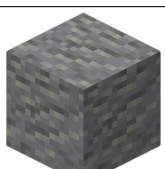2. Nitrogen fixation requires which of the following nutrients? (6 marks)

   A. Silicate

   B. Zinc

   C. Iron

   D. Nitrate

3. Choose the correct classification. (4 marks)

	Sedimentary	Igneous
A.	Sandstone	Slate
B.	Slate	Obsidian
C.	Diorite	Granite
D.	Coal	Andesite

4. Summer Solstice occurs on the 21st of June annually. During this day, the Sun has a declination of 23°26'N. What is the latitude at which the Sun does not rise? (3 marks)

    A. $23°26'N \leq \Phi \leq 90°N$

    B. $66°34'N \leq \Phi \leq 90°N$

    C. $23°26'S \leq \Phi \leq 90°S$

    D. $66°34'S \leq \Phi \leq 90°S$

5. Kepler's third law of planetary motion - sometimes referred to as the law of harmonies plays an important role in astronomy. After analysing the planetary data recorded by Tycho Brahe, Johannes Kepler eventually found out that, amazingly, every planet has the same T^2/a^3 ratio, where T is the orbital period of the planet and a is the orbital radius of the planet. Hence, he postulated that:
$$T^2 \propto a^3$$

Assume that astronomers discovered an asteroid in the solar system which has 0 eccentricity (the orbit is a perfect circle). Estimate the orbital period of the asteroid (in Earth years) if the diameter of the orbit is 1.196×10^9 km? (4 marks)

> **Tips:**
>
> - Astronomical Unit (AU) $\approx$ 149, 597, 871 kilometres (km)
>
> - The Earth has an orbital radius of 1 AU.
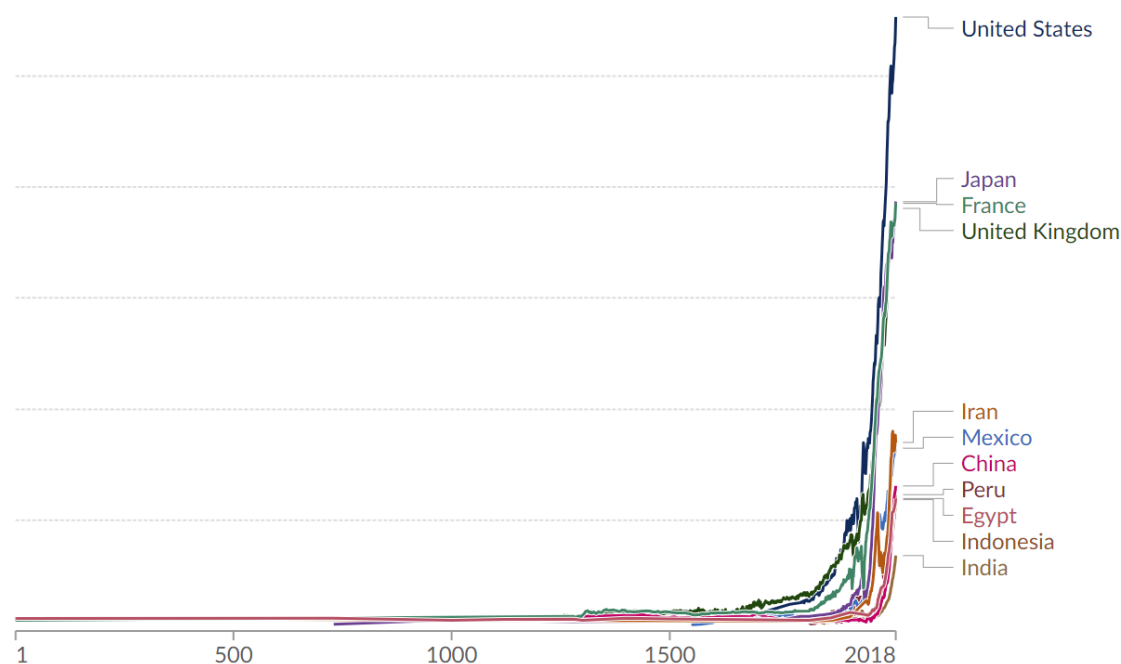
A. 2.5

B. 4

C. 8

D. 22.5

6. Zhi Qi will be representing Malaysia in the 17th International Olympiad on Astronomy and Astrophysics (IOAA) 2024 held in Rio de Janeiro, Brazil (Φ: 22°54′10″S, λ: 43°12′27″W) this August. Which of the following night sky is impossible to be observed by Zhi Qi?

(5 marks)

A.

B.

C.

D.

Social Science

1. Consider the following chart:

What does this chart most likely represent? The X-axis is time from 1 to 2018 AD.

(3 marks)

   A. Gross domestic product (GDP) per capita
   B. Level of inequality
   C. Gross domestic product (GDP)
   D. Level of freedom in the market

2. Country A has inclusive economic institutions. If a country has inclusive economic institutions, it has secure property rights. Therefore, Country A has secure property rights. Which of the following is a valid argument? (4 marks)

   A. Country B has secure property rights, therefore it has inclusive economic institutions.
   B. You believe that Country C has inclusive economic institutions. Therefore, Country C has secure property rights.
   C. Country D has extractive economic institutions. If I believe that a country has secure property rights if it has inclusive economic institutions, I must believe that Country D has insecure property rights.
   D. All of the above are invalid arguments.

3. Which of the following is the best example of a natural monopoly?   (3 marks)

> **Definition:**
> A natural monopoly is a type of monopoly in an industry with high barriers to entry that prevent any rivals from competing.

    A. A farm

    B. A residential power supply company

    C. A piano teacher giving private lessons

    D. A petroleum extraction company

4. The demand (Q_D) and supply (Q_S) curves of Good X are given by the following equations:

$$Q_D = 200e^{-0.1P}$$
$$Q_S = 50 + P^2$$

Calculate the supposed market equilibrium.   (6 marks)

    A. $P = 8.50$, $Q = 105$

    B. $P = 6.82$, $Q = 93.26$

    C. $P = 7.01$, $Q = 99.19$

    D. There is insufficient information provided to determine the market equilibrium.

Questions 5 and 6 are based on this dataset. Listed below are sentences in Language X and their English translations.

Language X	English Translation
utfàblortut	I will do my assignment.
lorditfabet	He has done your assignments.
udfàblortet	We will do his assignment.
etfablortut	She is doing my assignment.
edfablordud	They are doing our assignments.
itfàblorded	You will do their assignments.
lortetfabid	You all had done her assignment.

5. Translate "I am doing her assignments." into Language X.   (4 marks)

    A. itfablorded

    B. etfàblortit

    C. utfablordet

    D. udfàblordet

6. Translate "They had done your assignment." into Language X.   (5 marks)

    A. udfàblordud

    B. lortitfabed

    C. lorditfàbud

    D. lortidfabet

Answers

Biology

1. D
2. A
3. A
4. B
5. C
6. B

Mathematics

1. D
2. B
3. B
4. D
5. A
6. C

Chemistry

1. A, B, C, D
2. C
3. A
4. D
5. A
6. A

Earth Science

1. C
2. C
3. D
4. D
5. C
6. D

Physics

1. B
2. B
3. B
4. C
5. D
6. C

Social Science

1. A
2. D
3. B
4. C
5. C
6. B

References

Biology

1. **Q1 and Q2** are sourced from:
   Sijil Pelajaran Malaysia (SPM) 2021.

2. **Q3, Q5 and Q6** are adapted from:
   International Biology Olympiad (IBO) 2020.

3. **Q4** is adapted from:
   International Biology Olympiad (IBO) 2021.

Earth Science

1. The image in **Q1** is sourced from:
   https://www.windy.com

2. The image in **option A of Q6** is sourced from:
   Lorenzi M, Favretto G. The teapot [Image on the internet]. 2003 [cited 2024 April 10].
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3. The image in **option B of Q6** is sourced from:
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4. The image in **option C of Q6** is sourced from:
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5. The image in **option D of Q6** is sourced from:
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1. The image in **Q1** is sourced from:
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