

Problem Set Overview

The Youth STEM Cup (YSC) consists of two rounds: the **Preliminary Round**, and the **Final Round**. The questions in both rounds are designed for high school and pre-university students, and will test their knowledge across **six subjects** i.e. **Biology, Chemistry, Physics, Mathematics, Planetary Science** and **Social Science**. This sample problem set is created through the concerted efforts of the YSC Problem Selection Committee and the International Science Olympiad alumni. It gives an indication of the style of questions used in each round.

The general breakdown of paper in each round is described below:

- In **Preliminary Round**, the paper will consist of 36 questions - 6 questions from each subject mentioned above - to be sat in **one hour**. Participants can compete in **groups** or **individually**.
- In **Final Round**, the paper will consist of approximately 18 questions, with at least two questions from each subject. Each question is accompanied by a number of subquestions. The number of questions and subquestions in this round may change depending on the theme decided by the committee for that particular year. Participants will compete in **groups only** and have **two hours** to complete the paper.

To ensure fairness of the entire competition, participants will be divided into two different categories based on their academic level, which are **Junior category (SPM/O-level)** and **Senior category (STPM/Pre-U)**. Each category will have its own leaderboard and problem set.

For the paper in the Final Round, the theme changes every year and may influence the way questions are set. In general, there will be a few questions under a theme which may be arranged either in a sequence to form a storyline (shown below) or as individual questions related to the theme (see Final Round of YSC 2024).

The syllabus for all subjects will be at **SPM to Pre-U level** for **Junior category**, and at **Pre-U to University level** for **Senior category**. However, due to the lack of astronomy, astrophysics, planetary science and social science content in all three syllabi, the syllabus for these subjects will be stated and published on our official [AMISO website](#) to allow participants to prepare in advance. Any knowledge beyond the syllabus that will be tested will also be stated and published on our official website. To encourage self-studying on knowledge outside of curriculum, we have provided reading materials for every subject on our official website.

We hope this provides you with a clear understanding of how the questions are set and what to expect in YSC.

P.S. Not all of the problems in this sample problem set are cross-checked due to the fact that the problem setters are not proficient in all fields of science, do inform us if there are any mistakes and errors.

Acknowledgements

Special thanks to the YSC Problem Selection Committee and International Science Olympiad alumni for their contributions in creating this sample problem set:

Biology

Tan Hong Zher
Aaron Oong Zhu Wen

Chemistry

Joyton Fu Hung Li
Ng Ze Xian
Aaron Oong Zhu Wen

Physics

Teo Jia Quan

Mathematics

Vee Hua Zhi
Chuah Jia Herng
Leen Jun Khye

Planetary Science

Ng Kin Him
Cheong Kar Hin

Social Science

Tan Hong Zher
Ashwin Asokan
Lim Ming Wen

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Youth STEM Cup

Sample Problem Set

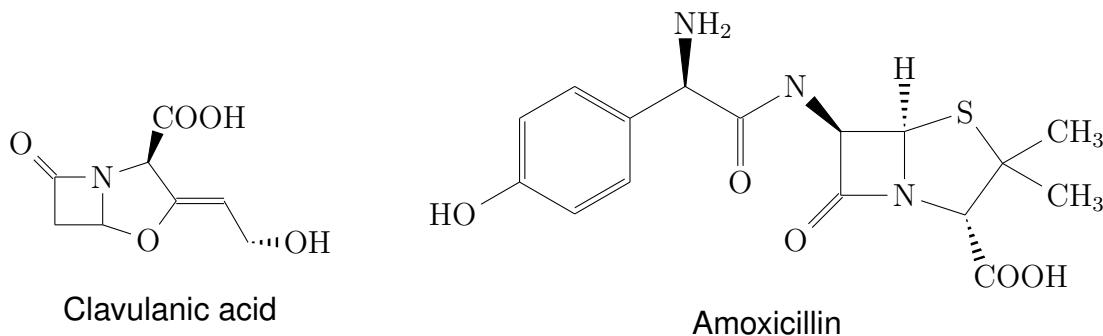
(Junior Category)

Preliminary Round

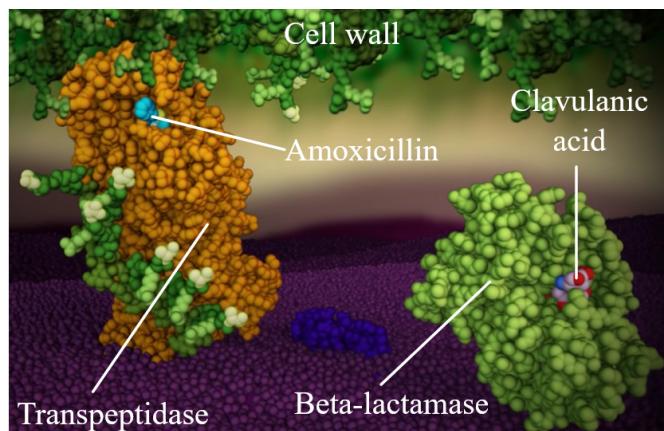
Problems

Biology

1. In 2005, two Australian researchers, Barry J. Marshall and J. Robin Warren jointly won the Nobel Prize in Physiology or Medicine for their discovery of the bacterium *Helicobacter pylori* and its role in the formation of peptic ulcers. More than half the population in the world harbors *H. pylori*, yet these pathological effects only affect around 10-20% of infected individuals. What is the most likely mechanism which protects us from *H. pylori*?
 - A. The high acidity of the gastric acid causes most *H. pylori* to be killed.
 - B. The mucus layer is too thick for *H. pylori* to penetrate.
 - C. Mucins in the gastric acid have antimicrobial activity.
 - D. *H. pylori* will be excreted through the digestive system.
2. Leaching is the loss of water-soluble plant nutrients from the soil due to rain and irrigation. If a soil undergoes excessive leaching, which of the following nutrients will the plant most likely have a deficiency in?
 - A. Magnesium
 - B. Potassium
 - C. Phosphate
 - D. Nitrate
3. The diagram below shows the structures of clavulanic acid and amoxicillin.



Clavulanic acid is often formulated with the antibiotic, amoxicillin to treat bacteria infections.



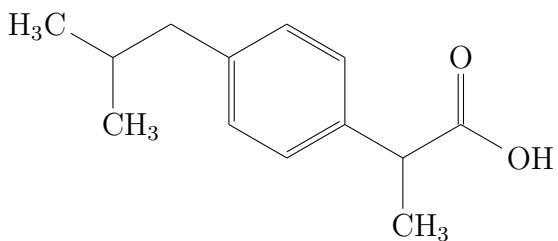
As shown in the diagram above, amoxicillin targets the transpeptidase on the bacteria by binding irreversibly to the active site of the enzyme and hence hampering cell wall synthesis while clavulanic acid targets beta-lactamase by binding irreversibly to the active site of the enzyme, thereby inhibiting the metabolism of amoxicillin.

Which of the following options best describes the type of inhibition that both molecules exert?

- A. Reversible competitive inhibition
- B. Irreversible competitive inhibition
- C. Reversible non-competitive inhibition
- D. Irreversible non-competitive inhibition

Chemistry

1. Scientists and engineers developed some solid rocket propellants to explore space. The fuel used is known as ammonium perchlorate (NH_4ClO_4). Given that the complete combustion gives nitrogen gas, chlorine gas, oxygen gas and water vapour, calculate the volumes (in dm^3) of the gaseous products if 1 mol of ammonium perchlorate is used.
(Use molar volume = 16 dm^3 under specific conditions)
 - A. 32
 - B. 64
 - C. 96
 - D. 128
2. A precipitate has the chemical formula $[\text{C}_9\text{H}_7\text{NH}]_3[\text{PMo}_{12}\text{O}_{40}]$. What is the oxidation number of molybdenum (Mo) in this precipitate?
 - A. +4
 - B. +5
 - C. +6
 - D. +7
3. Ibuprofen is a nonsteroidal anti-inflammatory drug that is used to relieve pain, fever, and inflammation. It has the chemical structure shown below.



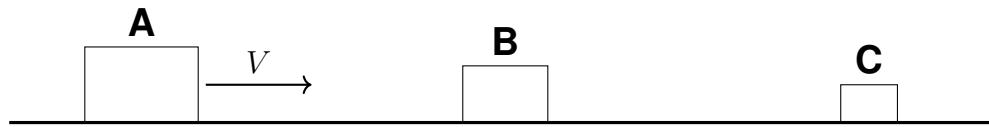
Ibuprofen

Identify how many chiral carbon centres are there in the ibuprofen molecule.

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

Physics

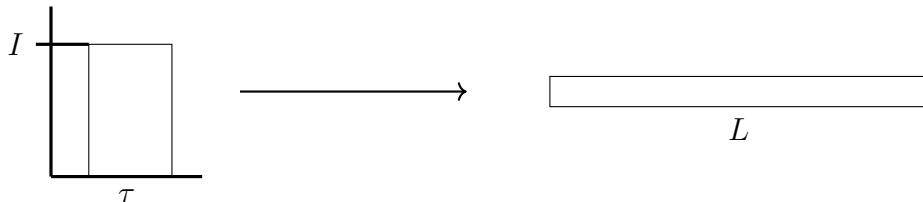
1. As shown in the figure below, small blocks **A**, **B**, and **C** are initially at rest on a frictionless horizontal surface.



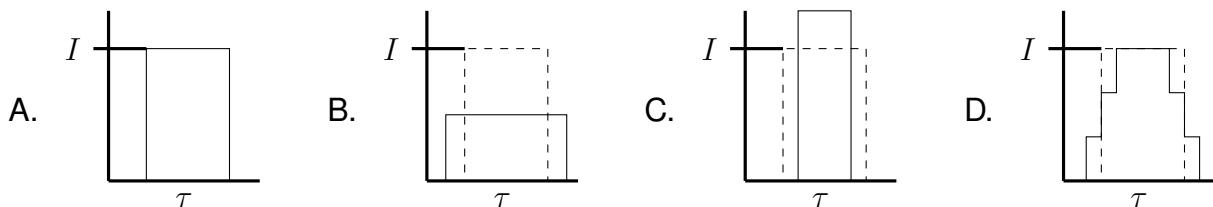
Block **A** is set in motion to the right with a velocity V and collides elastically with block **B**. Subsequently, block **B** collides elastically with block **C**. If the masses of **B** and **C** can be chosen arbitrarily, the maximum possible velocity of block **C** after the collisions is closest to _____.

- A. $2V$ B. $3V$ C. $4V$ D. $5V$
2. An object of mass M is dropped from a height H above the ground. The object bounces off a horizontal surface in a collision lasting time T . The object then rises upward to a maximum height $H/2$. What was the magnitude of the average net force acting on the mass during the collision with the surface?

- A. $(2 - \sqrt{2})\frac{M\sqrt{gH}}{T}$ C. $(\sqrt{3})\frac{M\sqrt{gH}}{T}$ E. $(\sqrt{2} + 1)\frac{M\sqrt{gH}}{T}$
 B. $\left(\frac{1}{\sqrt{2}} + 1\right)\frac{M\sqrt{gH}}{T}$ D. $(2\sqrt{2} - 1)\frac{M\sqrt{gH}}{T}$
3. There are three types of light with different wavelengths, each emitted and interrupted simultaneously, and the light intensity of each is the same. The total light intensity is I and the pulse width (duration of light emission) is τ . The variation of the light pulse intensity $I(\tau)$ with time is shown in the figure.



This light pulse is incident on a transparent glass rod of length L , with no consideration of transmission losses in the glass or reflection losses at the ends. What is the most likely graphical representation of the variation of light pulse intensity $I(\tau)$ with time after passing through the glass rod? (Note that the dashed part represents the waveform before incidence)



Mathematics

1. For all $x \in \mathbb{R}$, let $\lfloor x \rfloor$ be the floor function and $\{x\} = x - \lfloor x \rfloor$. Consider set $A = \{x \in \mathbb{R} \mid 0 < x < 10\}$, $B = \{x \in \mathbb{R} \mid \lfloor x \rfloor \{x\} = 5\}$, Jun Khye is curious about the value of $\max(A \cap B) - \min(A \cap B)$, help him to find out the answer.
 - A. $\frac{49}{18}$
 - B. $\frac{49}{8}$
 - C. $\frac{36}{18}$
 - D. $\frac{36}{8}$
2. Jun Khye's father was born on February 28, 1980. One day, Jun Khye decided to count how many prime numbers have their digit sum equal to 19800228. Can you help him find the answer?
 - A. 12
 - B. 13
 - C. 15
 - D. There exist infinitely many such primes
 - E. None of the above
3. Mr Leen is a functional inequality enthusiast. He created a problem to test his student:

Consider function $f : \mathbb{R} \rightarrow \mathbb{R}$, let f^k be the k^{th} iteration of the function, i.e. $f^1(x) = f(x)$, and $f^{k+1}(x) = f(f^k(x))$, $\forall k \in \mathbb{Z}_{>0}$.

Let $\mathcal{L}(k)$ be the number of solution for the following functional inequality:

$$f(x) + y \leq f^k(x), \forall x, y \in \mathbb{R}$$

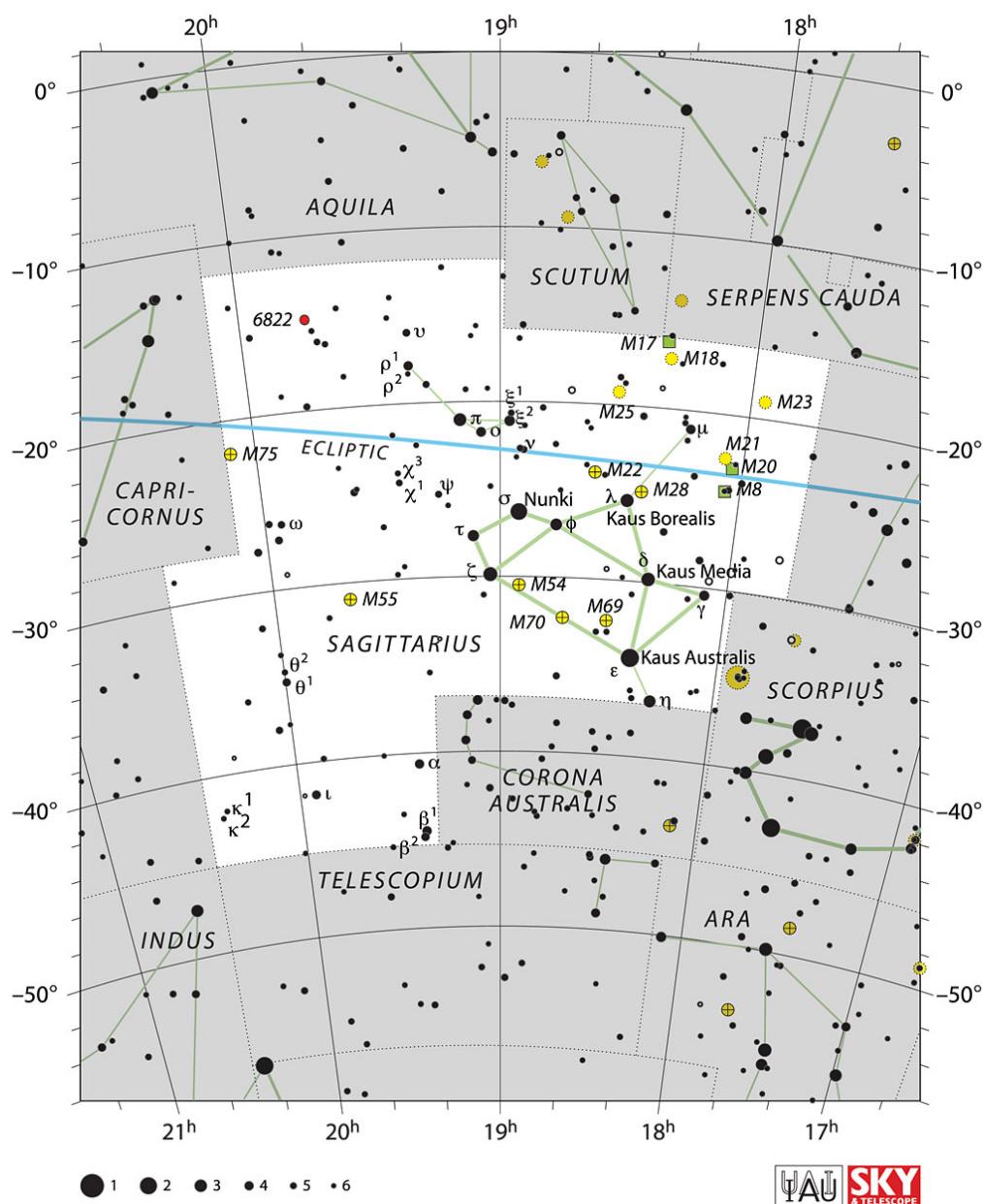
Find the value of $\max_{k \in \mathbb{Z}_{>0}} \{\mathcal{L}(k)\}$.

Can you solve this problem?

- A. 25
- B. 26
- C. 27
- D. Diverge
- E. None of the above

Planetary Science

1. This year, Santa Claus is vacationing at the South Pole. He sleeps during daytime so you would preferably call him when it's nighttime on his side. When should you call him on the 21st of June (assuming that Santa sets his clock to our time zone)?
 - A. 9 a.m.
 - B. It's going to be daylight the whole day so it doesn't matter at what time you call him.
 - C. 9 p.m.
 - D. It's going to be nighttime the whole day so it doesn't matter at what time you call him.
2. Astronomers often use a different system for locating objects in the sky, based on the idea of a celestial sphere. The following shows a map of the constellation Sagittarius.



What object can be found at RA = $18^{\text{h}}\ 31^{\text{m}}\ 23.10^{\text{s}}$ and Dec = $-32^{\circ}\ 20'\ 53.1''$?

- A. M69
 - B. Tau Sagitarii
 - C. Eta Sagitarii
 - D. M20
3. The total amount of energy released by an earthquake at its source, also known as _____ is its _____.
- A. Focus, Intensity
 - B. Hypocentre, Magnitude
 - C. Epicentre, Intensity
 - D. Epicentre, Magnitude

Social Science

1. There are 5 consumers who want to buy books in a market. Consumer 1 is willing to spend RM105 on a book, Consumer 2 is willing to spend RM95, Consumer 3 is willing to spend RM107, Consumer 4 is willing to spend RM110 and Consumer 5 is willing to spend RM99. If each consumer only wants to buy 1 book, and the market price for the book is RM100, what is the total consumer surplus?
 - A. RM16
 - B. RM22
 - C. RM30
 - D. There is not enough information to determine the consumer surplus.
2. Which of the following is generally considered a Veblen good?

Definition:

A Veblen good is a good for which demand increases as price increases.

- A. Books
 - B. Houses
 - C. Technological products
 - D. Wines
3. Here are some sentences in the Abma Language and their English Translations.

Abma	English Translation
Mwamni sileng.	He drinks water.
Nutsu mwatbo mwamni sileng.	The child keeps drinking water.
Nutsu mwegau.	The child grows.
Nutsu mwatbo mwegalgal.	The child keeps crawling.
Mwerava Mabontare mwisib.	He pulls Mabontare down.
Mabontare mwisib.	Mabontare goes down.
Mwelebte sileng mwabma.	He brings water.
Mweselkani tela mwesak.	He carries the axe up.
Mabontare mworob mwesak.	Mabontare runs up.

Extra Information:

Abma is an Austronesian language spoken in parts of the South Pacific island nation of Vanuatu by around 8,000 people.

In the Abma sentences you read above, there is no separate word for ‘the’ or ‘he’.

Translate “Mabontare keeps pulling him up” into English.

- A. Mwatbo mwerava mwisib.
- B. Mabontare mwatbo mwerava mwesak.
- C. Mwatbo mwerava Mabontare mwisib.
- D. Mabontare mwerava mwatbo mwesak.

Solutions

Biology

1. **C**

Let's understand why **C** is the answer:

- **A is not entirely correct.** While the gastric acid is highly acidic and kills most bacteria, certain strains of *H. pylori* have adapted to the acidic environment of the stomach by various mechanisms (refer to [National Cancer Institute](#)):
 - local neutralization by using ammonia it produces to prevent degradation by the gastric acid
 - avoid immune destruction by burrowing into the mucus layer and attaching to the cells that line its inner surface
 - interferes with local immune responses
- **B is not entirely correct** as well. Although the mucus layer can provide some physical barrier, *H. pylori* can still penetrate it, causing it to be not as effective.
- **C is correct.** Mucins are a family of glycoconjugates that can carry out antimicrobial and antifungal functions.
- **D is incorrect.** *H. pylori* typically is not excreted through the digestive system.

2. **D**

Nutrients exist as ions in the soil. As soil particles (such as clay and humus) are naturally negative in charge, the positive metal ions like Mg^{2+} and K^+ will be bound to the particles and held against the leaching action.

Between nitrate and phosphate, phosphate ions are more likely to form insoluble precipitates with iron, aluminium and calcium. Hence, nitrates are more likely to undergo leaching.

3. **B**

From the text given in the question, it simply means that transpeptidase is an enzyme that synthesizes bacterial cell wall while beta-lactamase is an enzyme that metabolises amoxicillin. Each enzyme is targeted by amoxicillin and clavulanic acid respectively by **binding to their active sites** (this is called **competitive inhibition**) and this process is **irreversible** which means that the inhibitor blocks the active site **forever** after binding. Therefore, both molecules exert **irreversible competitive inhibition** **B**.

Extra information:

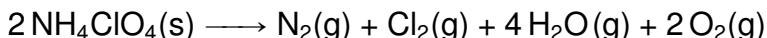
You may be wondering about the mechanism behind the irreversible competitive inhibition by amoxicillin and clavulanic acid on both enzymes. It occurs via the **formation of covalent bonds with the active sites** (this is **irreversible**), thereby inactivating them.

For better understanding, you can watch this video about how penicillins such as amoxicillin work: <https://www.youtube.com/watch?v=m0V6DRJBBGY>

Chemistry

1. **B**

The complete combustion of NH_4ClO_4 is represented by the following balanced chemical equation:



The above equation states that 2 moles of NH_4ClO_4 produce 8 moles of gaseous products. So, 1 mole of NH_4ClO_4 produces 4 moles of gaseous products which correspond to $4 \times 16 = 64 \text{ dm}^3$ i.e. **B**.

2. **C**

You may not have seen such complex formulae that often but it is generally quite easy to understand. There are two constituents in this formula, first $[\text{C}_9\text{H}_7\text{NH}]_3$, followed by $[\text{PMo}_{12}\text{O}_{40}]$, which resembles a salt formula. IUPAC dictates that, for all generalised salts, their formulae follow this principle: “all electropositive constituents precede all electronegative constituents” (refer to page 11 of [IUPAC Provisional Recommendations](#) or paragraph 2 of section 3.5 of chapter 3 of [Principles of Chemical Nomenclature](#)). This means that $[\text{C}_9\text{H}_7\text{NH}]_3$ is the cation, while $[\text{PMo}_{12}\text{O}_{40}]$ is the anion. Working backwards, we can ascertain that the cation has an overall charge of +1 while the anion has an overall charge of -3.

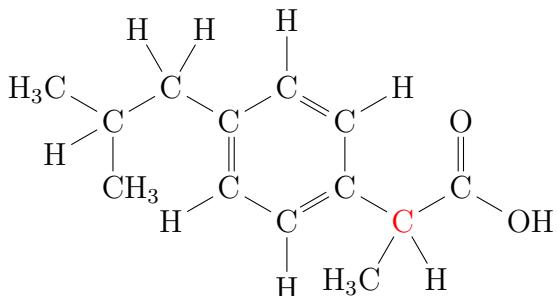
Since molybdenum (Mo) is present in the anion only, let’s just focus on the anion. It is well known that the oxidation number of P is +5 and that of O is -2. Then, we let the oxidation number of Mo in the anion be x and perform the following calculation:

$$\begin{aligned} +5 + 12x + 40(-2) &= -3 \\ 12x - 75 &= -3 \\ x &= +6 \end{aligned}$$

Therefore, the oxidation number of Mo in the precipitate is +6 i.e. **C**.

3. **B**

Converting the skeletal formula of ibuprofen to its structural formula will give us:



Chiral carbon centres are carbon atoms that are bonded to 4 different substituents. There is only one carbon atom that fulfills the above criteria i.e. the one next to COOH (coloured red). Thus, there is only 1 chiral carbon centre in ibuprofen which corresponds to **B**.

Extra resources:

This question requires participants to be familiar with the skeletal formula of a compound which can be a daunting and arduous task for those who are new to it. This resource from Cambridge Chemistry Challenge Lower 6th (C3L6) (a chemistry competition organised by University of Cambridge in the U.K.) provides a comprehensive guide to understanding skeletal formulae: https://www.c3l6.com/uploads/1661046848-C3L6_Understanding_Skeletal_Formulae.pdf

Physics

1. **C**

When block **A** collides with block **B**, by conservation of momentum, their final velocities (in terms of V'_a and V'_b respectively) would be:

$$V'_a = \frac{(m_a - m_b)V}{m_a + m_b} \quad V'_b = \frac{(2m_a)V}{m_a + m_b}$$

After the initial collision, block **B** moves with velocity V'_b and subsequently collides with block **C** which is initially at rest ($V_c = 0$). **After the collision**, the respective final velocities of blocks **B** and **C**: V''_b and V''_c are:

$$V''_b = \frac{(m_b - m_c)V'_b}{m_b + m_c} \quad V''_c = \frac{(2m_b)V'_b}{m_b + m_c}$$

In order to obtain the maximum possible velocity of block **C** (V''_c) after the collisions, the only possible way is to first **maximise** V'_b by letting $m_b \rightarrow 0$ (which means block **B** is much lighter than block **A**):

$$\begin{aligned} V'_b &= \frac{(2m_a)V}{m_a + m_b}; \quad m_b \rightarrow 0 \\ &\approx \frac{(2m_a)V}{m_a} \\ V'_b &\approx 2V \end{aligned}$$

Next, to **maximise** V''_c , just substitute $V'_b \approx 2V$ into the formula for V''_c , we'll yield:

$$\begin{aligned} V''_c &= \frac{(2m_b)V'_b}{m_b + m_c} \\ &= \frac{(2m_b)(2V)}{m_b + m_c} \end{aligned}$$

Lastly, by letting $m_c \rightarrow 0$ (which means block **C** is much lighter than block **B**) in the above formula, the maximum possible velocity of block **C** is:

$$\begin{aligned} V''_c &= \frac{(2m_b)(2V)}{m_b + m_c}; \quad m_c \rightarrow 0 \\ &\approx \frac{(2m_b)(2V)}{m_b} \\ &\approx 2(2V) \\ V''_c &= [4V] \end{aligned}$$

2. E

In this question, the concept that we're going to apply is Newton's Second Law which can be expressed as below:

$$F_{net} = ma = m \frac{\Delta v}{\Delta t}$$

In this equation, there are three variables we have to find out, of which two have been given in the question i.e. $m = M$ and $\Delta t = T$. So, we're left with Δv . To find Δv , we use the concept of conservation of mechanical energy for the object-Earth system both before and after the collision to determine the speed of the object when it reaches the ground:

$$\begin{aligned}\Delta KE + \Delta PE &= 0 \\ \left(\frac{1}{2}mv^2 - 0 \right) + mg\Delta y &= 0 \\ v &= -\sqrt{-2g\Delta y}\end{aligned}$$

The negative sign for the velocity indicates that it is moving downward when it reaches the ground. This results in $v_0 = -\sqrt{2gH}$ for the velocity of the object before hitting the ground with $\Delta y = -H$.

Likewise, for the trip upward, we write a similar expression to find the speed when it moves way from the ground:

$$\begin{aligned}v_f &= \sqrt{2g\Delta y} \\ &= \sqrt{2g \left(\frac{H}{2} \right)} \\ &= \sqrt{gH}\end{aligned}$$

So, by putting all of these together, we have:

$$\begin{aligned}F_{net} &= m \frac{\Delta v}{\Delta t} \\ &= M \frac{\sqrt{gH} - (-\sqrt{2gH})}{T} \\ &= \frac{M}{T} (\sqrt{2} + 1) \sqrt{gH} \\ &= (\sqrt{2} + 1) \frac{M\sqrt{gH}}{T}\end{aligned}$$

Therefore, the answer is E.

3. D

The initial light pulse has an intensity of I and a pulse width of τ . The light consists of three different wavelengths, which propagate at different speeds in the glass rod, leading to **dispersion effects**. As light propagates through the glass rod, absorption and scattering will cause the light intensity to decrease gradually. Different wavelengths travel at different speeds, causing the pulse to stretch and its width to increase. Reflection losses at the

glass rod's ends will further reduce the intensity of the light pulse. After passing through the glass rod, the **overall intensity decreases**, and the **pulse width becomes broader**. If dispersion is significant, light of different wavelengths will arrive sequentially, stretching the tail of the pulse. Answer is **D** because this diagram reflects the effects of dispersion (pulse broadening) and transmission losses (intensity reduction).

Mathematics

1. **A**

Since $\{x\} < 1$, $[x]\{x\} = 5$ means that $[x] \geq 6$. When $[x] = 6$, we have $\{x\} = \frac{5}{6}$ which means $x = \frac{41}{6}$; when $[x] = 9$, $\{x\} = \frac{5}{9}$ means that $x = \frac{86}{9}$, so the value of the desire is $\frac{86}{9} - \frac{41}{6} = \frac{49}{18}$ i.e. **A**.

2. **E**

The answer is 0.

We prove a useful result: $S(n) \equiv n \pmod{3}$, where $S(n)$ is the digit sum of n .

Let

$$n = \overline{a_k \cdots a_1 a_0}$$

be the base 10 representation of n , then

$$n = \sum_{i=0}^k a_i 10^i \equiv \sum_{i=0}^k a_i = S(n) \pmod{9}$$

and since $3 \mid 9$, we also have the congruence relation in $\pmod{3}$.

Back to the problem, clearly the only prime p that satisfies $p \equiv 19800228 \equiv 0 \pmod{3}$ is $p = 3$, but $S(3) \neq 19800228$.

3. **E**

The answer is 0.

If there exists such f , let $P(x, y)$ be the functional inequality $f(x) + y \leq f^k(x)$,

$$P(x, f^k(x)) \Rightarrow f(x) \leq 0$$

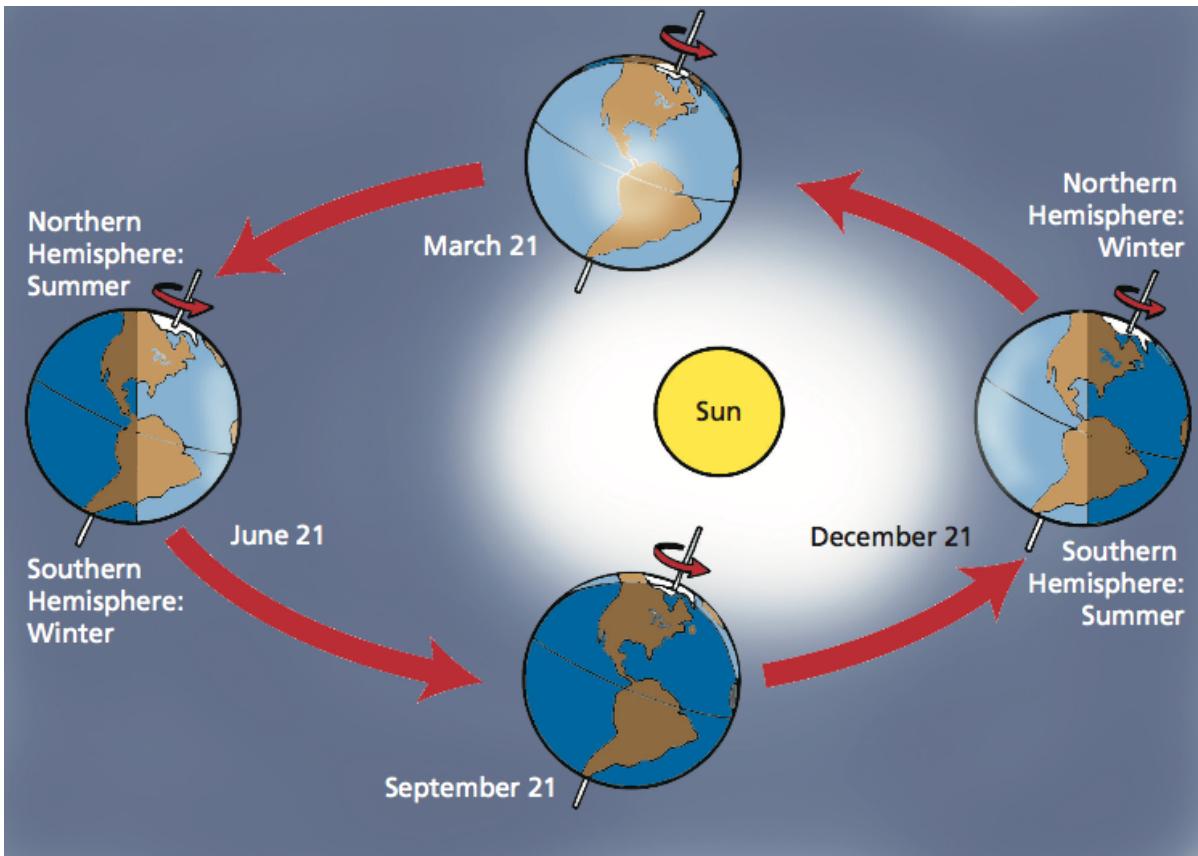
$$P(x, -f(x)) \Rightarrow f^k(x) \geq 0 \Rightarrow f^k(x) \equiv 0$$

$$P(x, -2f(x)) \Rightarrow -f(x) \leq 0 \Rightarrow f(x) \geq 0 \Rightarrow f(x) \equiv 0 \Rightarrow y \leq 0, \forall y \in \mathbb{R}, \text{ contradiction}$$

Planetary Science

1. **D**

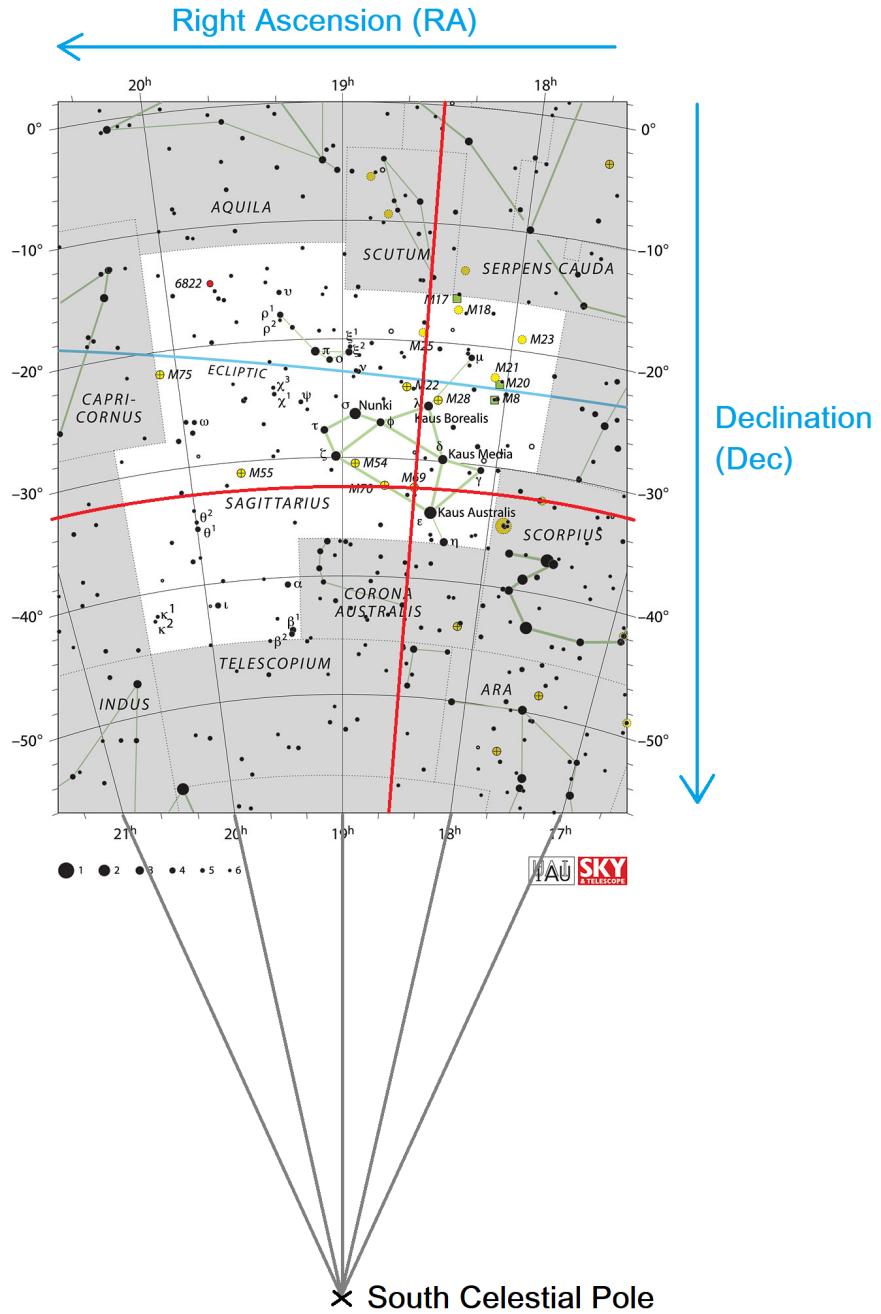
When it's summer solstice in the Northern hemisphere (June 21), it will be winter solstice in the Southern hemisphere due to the Earth's tilt (see image below). Thus, at any latitudes higher than $\pm 66^\circ 34'$, the sun does not appear to rise nor set.



Reference: [Smithsonian Science Education Center](#)

2. **A**

By looking at the graph on the next page, the right to left axis denotes right ascension (RA) while the up-down axis denotes declination (Dec). It's also good to note that the map is a section of the surface of the celestial sphere, meaning that the map is drawn curved. It can also be seen that the RA lines converge down to the south celestial pole.



Using the information given in the question and then drawing the lines as shown above (red lines), we arrive at M69 i.e. A.

3. B

Most people are confused about the differences between the terms. **Epicentre** refers to the point above the surface of the focus, a.k.a. the **hypocentre**. The **Magnitude** of an earthquake is a measure of the energy released by an earthquake while the **intensity** of an earthquake is dependent on the distance from the source and the subjective interpretation of what has happened as a result of the earthquake.

Social Science

1. **B**

Since the price of the book is RM100, Consumer 2 and Consumer 5 will not buy the book. Hence, the total consumer surplus is $(RM105 + RM107 + RM110) - 3(RM100) = RM22$, which is **B**.

2. **D**

Although books, houses and technological products can sometimes be considered Veblen goods, that only applies to luxury books, luxury houses and luxury technological products. Wines in general all follow the trend of Veblen goods.

3. **B**

As you look through the table, you may have been able to catch what each Abma word means in English:

mwamni	= drink
sileng	= water
nutsu	= child
mwatbo	= keep
mwegau	= grow
mwegalgal	= crawl
mwerava	= pull

mwisib	= down/go down
mwelebte	= bring
mweselkani	= carry
tela	= axe
mworob	= run
mwesak	= up

More importantly, by analyzing each sentence in Abma language, you may notice that all of them follow the same sentence structure i.e. Subject – Verb – Object, with either inclusive of all components or absence of the Subject or Object. For example:

Ø	Nutsu	mwatbo	mwamni	sileng
The	child (Subject)	keeps	drinking (Verb)	water (Object)

All components are included.

Ø	Mwerava	Mabontare	mwisib
He (Subject)	pulls (Verb)	Mabontare (Object)	down

Since there's no separate word for 'he', the sentence structure will be Verb – Object. The same applies to "Mwamni sileng", "Mwelebte sileng mwabma" and "Mweselkani tela mwesak".

Mabontare	mwisib
Mabontare (Subject)	goes down (Verb)

In this case, there is no Object, so the sentence structure will be Subject – Verb. The same applies to “Nutsu mwegau”, “Nutsu mwatbo mwagalgal” and “Mabontare mworob mwesak”.

Using the same concept, “Mabontare keeps pulling him up” can be broken down as such:

Mabontare (Subject)	keeps	pulling (Verb)	him (Object)	up
Mabontare	mwatbo	mwerava	Ø	mwesak

Therefore, the answer is **B**.

References

Biology

1. The image in **Q3** is adapted from:

RCSB Protein Data Bank. Penicillin and Antibiotic Resistance (from PDB-101) [video]. YouTube; 2019 [cited 2023 Nov 9]. Available from: <https://www.youtube.com/watch?v=m0\V6DRJBBGY>

Physics

1. **Q1** is sourced from Question 5 of :

Chinese Physical Society. 33rd Preliminary Test Questions and Answers [Internet]. China: Chinese Physical Society; 2016 [cited 2025 Jan 12]. Available from: <https://cpho.pku.edu.cn/info/1053/1136.htm>

2. **Q2** is sourced from Question 48 of:

American Association of Physics Teachers. PhysicsBowl 2012 [Internet]. College Park (MD): American Association of Physics Teachers; 2012 [2025 Jan 12]. Available from: https://aapt.org/programs/physicsbowl/upload/PhysicsBowl_2012.pdf

3. **Q3** is sourced from Question 4 of:

Chinese Physical Society. 34th Preliminary Test Questions and Answers [Internet]. China: Chinese Physical Society; 2017 [cited 2025 Jan 12]. Available from: <https://cpho.pku.edu.cn/info/1053/1135.htm>

Planetary Science

1. The image in **Q3** is sourced from:

International Astronomical Union, Sky & Telescope. Sagittarius [Image on the internet]. Paris (FR): IAU; 2015 [cited 2024 Dec 30]. Available from: <https://www.iau.org/public/images/detail/sgr/>

Social Science

1. **Q1** is adapted from:

International Economics Olympiad 2024.



Youth STEM Cup

Sample Problem Set

(Junior Category)

Final Round

Problems

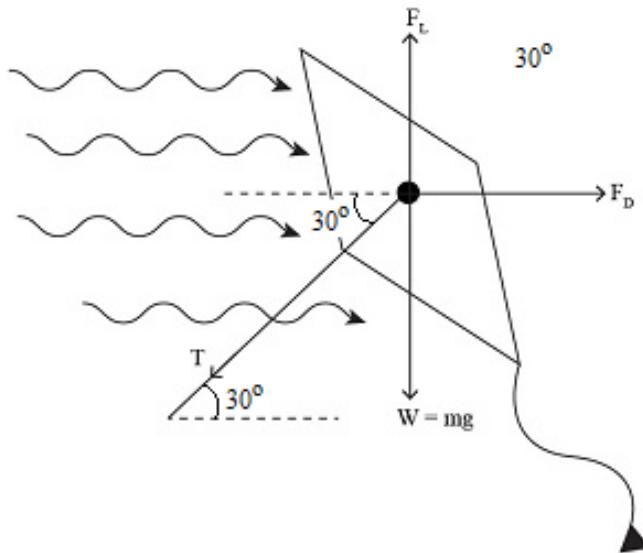
Section A: Beach

Je Qin decided to go for a holiday trip with his nerdy buddies! Because of the blazing hot tropical weather of Malaysia, the group decided to spend the day cooling down at a beach. Upon arriving at the site, they were greeted by a swarm of people, with a clear panoramic view of the ocean.

1. It is well known that seawater is salty, and the chemical formula of salt is NaCl. Joyton decided to measure the content of chloride ions in seawater, so he decided to use a mercurimetric titration method. The procedures are listed as follows:
 - I. 9.8×10^{-2} mol/dm³ of Hg(NO₃)₂ solution was prepared and placed in a burette.
 - II. 0.500 mL of seawater sample was collected and added into a small conical flask.
 - III. 2 mL of deionised water, 4 drops of 5 % HNO₃ and 3 drops of s-diphenylcarbazone (indicator) were added to the conical flask, the mixture was then titrated against the Hg(NO₃)₂ solution prepared above. 8.24 mL of Hg(NO₃)₂ solution was used.
 - IV. To improve the accuracy of this experiment, Joyton wanted to conduct a blank titration. He first treated the seawater to ensure that all chloride ions were removed and then performed the titration using water with ten times the volume of the treated seawater sample. 0.80 mL of Hg(NO₃)₂ solution was used.

It is known that Hg²⁺ reacts with chloride ions to form a white precipitate. The excess Hg²⁺ ions will form a purple complex with the indicator.

- a) Which of the following explains the purpose of blank titration in this experiment? Tick all reasons that apply.
 - To account for any impurities, other than Cl⁻ ions, in the seawater that may have reacted with Hg²⁺ ions.
 - To determine the amount of impurities in the seawater that may have reacted with Hg²⁺ ions.
 - To determine the concentration of chloride ions in the seawater sample.
 - To ensure that the reaction reaches completion.
 - b) Write the ionic equation for the formation of the white precipitate.
 - c) Calculate the concentration of chloride ions in mg/100 mL. Provide your answer up to three significant figures.
2. Zafri was flying his kite at the beach. The kite had a square shape with a surface area of 500 cm² and thickness of 50 mm. The air flows through the kite with speed 5 ms⁻¹ from the normal of the kite and the air density is 1.293 kg m⁻³. Assuming it is flying in equilibrium (the lift force is balanced by its weight) and the tension of the string is 50 N, what is the drag coefficient of the kite?



3. Hua Zhi and Tristan stumbled upon an uncle, who happened to be an ex-IMO coach for Malaysia, while walking along the beach. They had a fruitful conversation where they discussed about this problem:

You are the strategic planner for Karthik Vegetables Corporation, a Malaysian conglomerate with a fleet of merchant ships that frequently traverse the Red Sea. Recently, there have been increasing attacks on ships in this area, raising concerns about the safety and financial risk of continuing to use this route.

Each journey through the Red Sea is fraught with risk. With the danger of attacks looming and possible alternate routes, you need to decide if the risk is worth the reward.

Calculate the expected financial loss (**in millions of dollars**) per trip if you continue to use the current route through the Red Sea. Use the following simplified assumptions for your analysis:

- Daily traffic through the Red Sea includes 50 merchant ships.
- The value of each ship in your fleet is \$400 million.
- Over the past 200 days, there have been 20 attacks.
- The probability of attack is equal for all ships.
- Assume there is no human casualty, only financial loss from the attacks.
- This strategic decision will help determine the future operational routes of your shipping fleet.

Hua Zhi and Tristan got \$0.8 million dollars as the answer but weren't sure if it is correct. Did they get the correct answer? Please provide your solution.

4. Ming Wen was neither sunbathing nor chilling in the shade, but was trying to solve a linguistic problem under a coconut tree.

**GWASANAETH LLYFRGELL
GWYNEDD
LIBRARY SERVICE**

- Cyfrifiaduron at ddefnydd cyhoeddus am ddim – Free public use computers
- Ceisiadau llyfrau am ddim oddi fewn Cymru – Free book requests within Wales
- Llyfrau Llafar – Audio Books
- Llyfrau Print Bras – Large Print Books
- Cylchgrawn Which? – Which? Magazine
-  ancestry.co.uk
gwefan hel achau teuluoedd, ar gyfrifiaduron
y llyfrgelloedd yn unig
website to search family history, on
library computers only.

Gallwch ddefnyddio eich cerdyn llyfrgell yn unrhyw llyfrgell yng Ngwynedd, Conwy ac Ynys Môn
You can use your library card at any library in Gwynedd, Conwy and Anglesey

Am fwy o wybodaeth am eich llyfrgell leol a Gwasanaeth Llyfrgell Gwynedd
For more information about your local library and Gwynedd Library Service

www.gwynedd.gov.uk/llyfrgell
www.gwynedd.gov.uk/library

E-bost – llyfrgell@gwynedd.gov.uk
E-mail – library@gwynedd.gov.uk

The picture on the left is a leaflet in Welsh, with English translations, about the library service in the Welsh county Gwynedd.

After looking through the leaflet, he was given a question:

Use the leaflet to find the Welsh translations of “only request”.

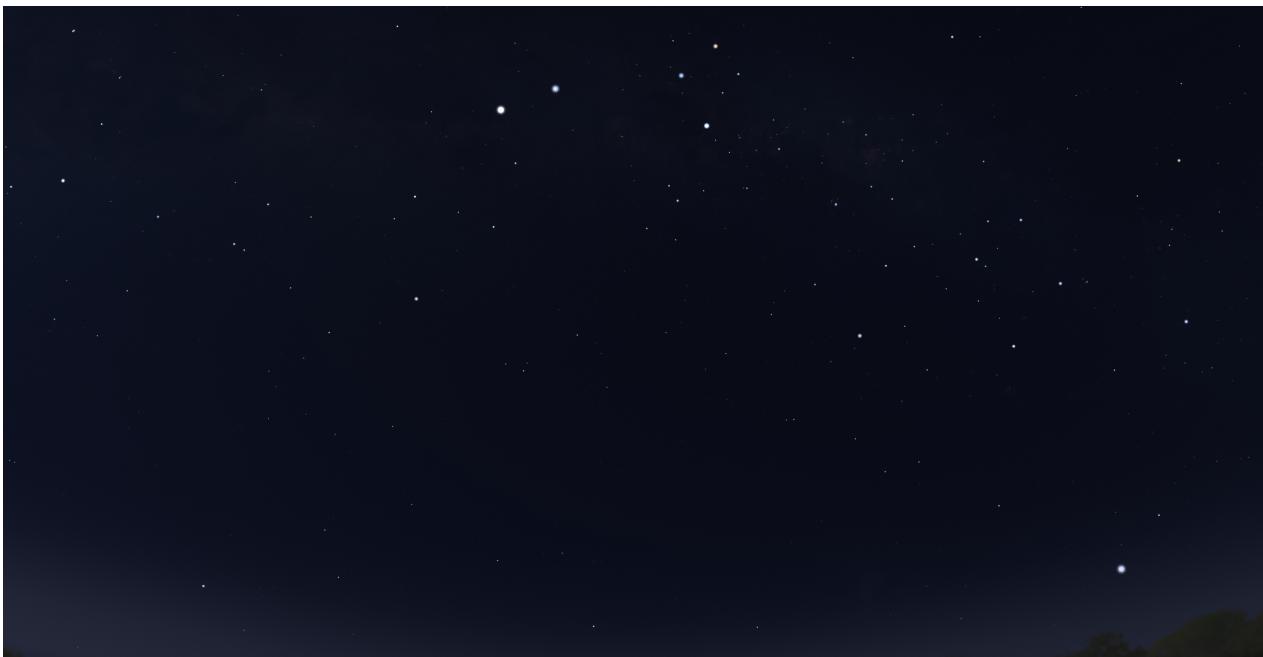
- A. ceisiadau unig yn
- B. yn unig ceisiadau
- C. ceisiad yn unig
- D. yn ceisiadau unig

Can you help him to solve this question so that he could enjoy his trip with his friends?



5. Ashwin was sipping his non-alcoholic cocktail when his father phoned him. He learnt from his father that he had just won an unbelievable lottery, which will pay him RM2,000 next year and then continue making regular annual payments to him (and his descendants) that increase by 3% each year forever. What will be the current fair price of these payments if the risk-free interest rate is 5%?

6. As the sun set, the group sat together to bask in the starlight. The diagram below shows their night sky at 8 pm.



While stargazing, Allister took out his compass to have a look.

- a) The compass showed that they were facing one of the cardinal points but the label of the cardinal points were too dim to be seen. By observing the constellations available, can you determine which direction they were currently facing?
 - b) Name THREE constellations that are partially/fully in their view.
 - c) Allister noticed the brightest object in his view. What do you think it is?
 - A. A plane
 - B. A star
 - C. A planet
 - D. A deep sky object
7. While the group was stargazing, they suddenly heard some noise nearby. A dark shadow was seen crawling out of the sea towards the beach. As they got closer with their flashlight turned on, they were surprised to find that it was a rare green turtle. Muthu remembered that it was the sea turtle nesting season and quickly asked his friend to wrap a red plastic bag around their flashlights if they wanted to continue observing sea turtle nesting in action.

Which of the following explains why Muthu advised his friends to wrap a red plastic bag around their flashlights? Tick all reasons that apply.

- Sea turtles are highly sensitive to white light at night.
- It allows them to spot and observe the sea turtle more easily at night.
- To prevent disturbing the turtles' natural behaviour.
- Sea turtles rely on red light to better navigate their surroundings.

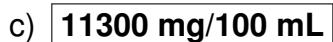
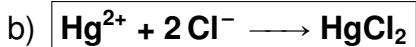
Solutions

Section A: Beach

1. a) To account for any impurities, other than Cl^- ions, in the seawater that may have reacted with Hg^{2+} ions.
 To determine the amount of impurities in the seawater that may have reacted with Hg^{2+} ions.
 To determine the concentration of chloride ions in the seawater sample.
 To ensure that the reaction reaches completion.

Let's review all options:

- Options 1 and 2 are **correct** because a blank titration is indeed performed to not only detect the presence of but also determine the amount of other impurities in a certain sample. In this case, it's the impurities, other than Cl^- ions, in the seawater that have reacted with Hg^{2+} ions to form unwanted precipitates. This helps to reduce titration errors, thereby ensuring the final result accurately reflects the reaction between Hg^{2+} and Cl^- ions only.
- Option 3 is **incorrect** because blank titration is conducted in the absence of an analyte (in this case, Cl^- ions), so it cannot directly determine its concentration. Instead, it accounts for external factors e.g. impurities that affect the titration.
- Option 4 is **incorrect** because a blank titration does not help to check if a reaction goes to completion but to correct for any non-analyte-related titrant (i.e. $\text{Hg}(\text{NO}_3)_2$ solution) consumption.



From the question, we ascertained that there are impurities, other than Cl^- ions, in the seawater that have reacted with the Hg^{2+} ions. For this reason, we have to subtract the volume of titrant (i.e. $\text{Hg}(\text{NO}_3)_2$ solution) used to precipitate the impurities from the initial volume of titrant used in order to determine the true amount of Hg^{2+} ions that reacted with Cl^- ions:

$$\begin{aligned}&\text{Volume of } \text{Hg}^{2+} \text{ ions that reacted with chloride ions} \\&= (8.24 - 0.8 \times 0.1) \text{ mL} \\&= 8.16 \text{ mL}\end{aligned}$$

From b), you should be able to get that Hg^{2+} ions reacts with Cl^- ions at molar ratio of 1:2. Using this information, the concentration of Cl^- ions in the seawater is calculated as:

$$\frac{n(\text{Hg}^{2+})}{n(\text{Cl}^-)} = \frac{1}{2}$$

$$\frac{(8.16)(9.80 \times 10^{-2})}{(0.50)([\text{Cl}^-])} = \frac{1}{2}$$

$$[\text{Cl}^-] = 3.199 \text{ mol/dm}^3$$

$$= (3.199 \times 35.45 \times 10^3) \text{ mg/1000 mL}$$

$$= 113000 \text{ mg/1000 mL}$$

$$= \boxed{11300 \text{ mg/100 mL}}$$

2. **53.5824**

Since the kite is in equilibrium, the tension of the string is equal to the drag force acting on it.

$$T \cos 30^\circ = F$$

$$T \cos 30^\circ = \frac{CA\rho v^2}{2}$$

$$C = \frac{T \cos 30^\circ \times 2}{A\rho v^2}$$

$$= \frac{50 \cos 30^\circ \times 2}{0.05 \times 1.293 \times 5^2}$$

$$= 53.5824$$

3. **Correct, it's \$0.8 million dollars**

$$\text{Chance of being attacked} = \frac{20}{50 \times 200} = \frac{1}{500}$$

$$\therefore \text{Cost (in million dollars)} = 400 \times \frac{1}{500} = 0.8$$

4. **C**

From the leaflet, you might have noticed that Welsh exhibits these characteristics:

- Notice from the passages above that Welsh has a **Verb – Subject – Object** sentence structure.
- There are some singular-plural differences. You can find *llyfrau* translating “books” in several places and *ceisiadau* translating “requests”, both of which bear the *-au* suffix – a plural marker for these words. However, in *Ceisiadau llyfrau*, it is translated as the singular: “book requests”. To understand what is going on here, it’s important to recognize that the English “book requests” means the same as “requests for books” (where “books” is plural). Therefore, the direct Welsh translation would adopt the plural form of “book requests” i.e. *ceisiadau llyfrau*.

On a side note, you may also notice that the singular form *llyfr* is found in *llyfrgell*,

“library” as well – i.e. a direct translation from the meaning of a library which is a book-place (*gell* in fact means “place”). (You might find it helpful to relate *llyfr* to the French *livre* or even to the *libr-* of English *library*.)

- Another aspect of all Celtic languages including Welsh is ‘mutation’ which is somewhat peculiar, whereby initial consonants mutate (change) from one sentence context to another. This is why some words have two forms (e.g. *llyfrgell* or *lyfrgell*; *cyfrifiaduron* or *gyfrifiaduron*). You can spot that in the phrase *unrhyw lyfrgell*, “any library”, where the *ll* of *llyfrgell* changes to *l*, and the same rule applies to constructing “any books”.

Let’s get back to the question. This question is straightforward, as you only need to translate “only request” into Welsh by considering the aspects of sentence structure and plurality as shown below:

request	only
<i>ceisiad</i>	<i>yn unig</i>

Hence, the answer is **C**.

5. **RM100,000**

To determine the current fair price of the lottery payments, we can use the formula for the present value of a growing perpetuity. The formula is as follows:

$$PV = \frac{C}{r - g}$$

where:

PV = Present Value

C = First payment

r = Discount rate (interest rate)

g = Growth rate of the payments

Given:

- The first payment, C = RM2000
- The growth rate, g = 3% = 0.03
- The discount rate, r = 5% = 0.05

Inserting these values into the formula, we get:

$$PV = \frac{2000}{0.05 - 0.03} = \frac{2000}{0.02} = 100000$$

Hence, the current fair price of these payments is **RM100,000**.

6. a) **South**

Since the Southern Crux can be spotted in the sky, and it is pointing to the South. Hence, they are facing the **south**.

- b) Any 3 of the following: Apus, Charmeleon, Carina, Crux, Centaurus, Musca, Triangulum Australis, Octans, Volans

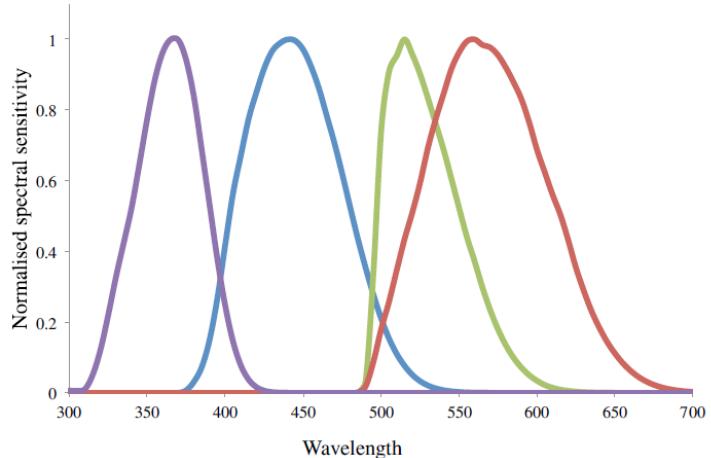
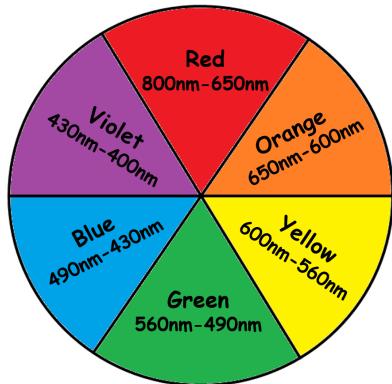
- c) **B**

The brightest object in the image is Rigel Kentaurus in the constellation Centaurus.

7. Sea turtles are highly sensitive to white light at night.
 It allows them to spot and observe the sea turtle more easily at night.
 To prevent disturbing the turtles' natural behaviour.
 Sea turtles rely on red light to better navigate their surroundings.

Let's understand why options 1 and 3 are correct:

- Option 1 is **correct**. The white light has wavelengths spanning from 400 nm – 800 nm, covering all colours visible to our naked eyes (see the colour wheel below). Sea turtles like green turtles are more sensitive to light in these wavelengths: 365 nm (ultraviolet), 440 nm (blue), 515 nm (green), and 560—565 nm (yellow), as shown in the graph below.



Since white light covers the blue, green, and yellow regions of the visible spectrum, sea turtles are highly sensitive to white light, especially at night. Therefore, the use of red light is necessary because they do not see red light as well as humans do.

- Option 3 is **correct** as well because white lights would deter adult females from nesting on the beach, resulting in fewer nests and cause disorientations which can often result in adult mortalities. Using red lights would help to prevent these from happening.
- Option 2 is **incorrect**. While red light helps the group observe sea turtle nesting without disturbing it, its primary purpose is to protect the turtle, not to improve human visibility.
- Option 4 is **incorrect**. Sea turtles do not rely on red light for navigation but rather using the natural light of the moon and stars. The red light only aids the group to observe sea turtle nesting without disturbing it.

References

Section A: Beach

1. The image in **Q2** is adapted from:

Study.com. Draw a free-body diagram to represent the forces acting on a kite on a string that is floating stationary in the air. Label the forces in your diagram [Internet]. 2025 [cited 2025 Mar 16]. Available from: <https://homework.study.com/explanation/draw-a-free-body-diagram-to-represent-the-forces-acting-on-a-kite-on-a-string-that-is-floating-stationary-in-the-air-label-the-forces-in-your-diagram.html>

2. **Q4 and its solution** are adapted from:

Hudson D. UKCLO Round 1 2012 [Internet]. United Kingdom Linguistics Olympiad (UKLO); 2014 [cited 2025 Feb 21]. Available from: <https://www.uklo.org/wp-content/uploads/2022/09/2012.3w-Welsh.pdf>

3. The image in **Q6** is sourced from:

Chereau F & Chereau G. Stellarium Web [Internet]. Bucharest (RO): Stellarium Labs SRL; 2024 [cited 2024 May 25]. Available from: <https://stellarium-web.org/>

4. The explanation and images in the solution for **Q7** are adapted from:

- Gates C. Color and Oxidation State — Overview & Examples [Image on the Internet]. Pittsburgh (PA): Expii Inc; 2019 [cited 2025 Mar 15]. Available from: <https://www.expii.com/t/color-and-oxidation-state-overview-examples-8411>
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- Sea Turtle Conservancy. What is wildlife friendly lighting? [Internet]. Gainesville (FL): Sea Turtle Conservancy; 2025 [cited 2025 Mar 16]. Available from: <https://conserveturtles.org/program-activity/finding-wildlife-lighting/>
- Witherington B. “Turtle-Friendly” Lighting: Is it as easy as that? [Internet]. Athens (GR): EuroTurtle; 2025 [2025 Mar 16]. Available from: [https://www.euroturtle.org/32.htm#:~:text=Pure%20red%20light%20\(light%20that,upon%20for%20our%20night%20vision.](https://www.euroturtle.org/32.htm#:~:text=Pure%20red%20light%20(light%20that,upon%20for%20our%20night%20vision.)