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91413



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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 3 Earth and Space Science 2025

91413 Demonstrate understanding of processes in the ocean system

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of processes in the ocean system.	Demonstrate in-depth understanding of processes in the ocean system.	Demonstrate comprehensive understanding of processes in the ocean system.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (X/X/X). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

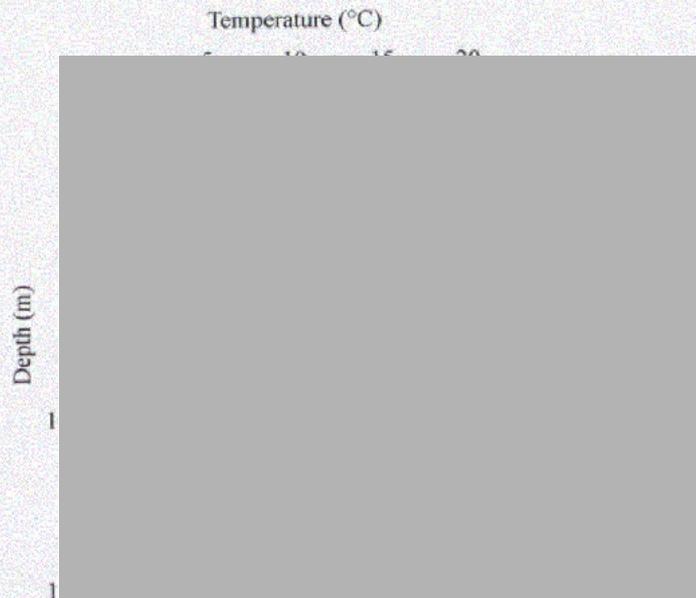
Merit

TOTAL 16

QUESTION ONE: NEW ZEALAND'S THERMOCLINE

New Zealand is in the mid-latitudes, where surface ocean temperatures vary widely between seasons. The gradient of the thermocline changes as surface temperature changes during the year. This also impacts formation of the pycnocline, which reflects changes in density of ocean water.

Seasonal thermocline changes



Adapted from: www.sciencedirect.com/topics/agricultural-and-biological-sciences/thermocline

Discuss seasonal changes in the thermocline and pycnocline near New Zealand.

In your answer, you should consider:

- how the thermocline forms
- formation of the three ocean layers
- reasons for seasonal variation in the thermocline at mid-latitudes
- how changes in the thermocline impact pycnocline formation.

An annotated diagram may assist your answer.

Thermocline is ~~the~~ a layer of water which rapidly changing temperature ^{with depth} in the ocean. This forms because the heat from the surface water molecules can ~~not~~ ^{be fully} radiated or conducted to the adjacent particles, there ~~is~~ must be energy loss during the transferring and resulting an overall decreasing in water temperature with depth.

The mixed surface layer is the top layer of the ocean. The surface water ^{molecules} absorb heat energy from the solar radiation and transfers to the near by particles by conduction and mixing (due to wind). This results the surface layer water are uniformly warm. Because the surface layer has the warmest water in ~~the~~ all three layers, the energy sufficient water will flow above the ^{colder} water will less energy. Therefore the lowest density.

The deep water is the layer where the water are uniformly cold, because the visible and UV lights from the sun have low penetration ability, so the water will not be able to absorb any heat from the environment. The water is cold and ~~is~~ with high salinity, making it ~~The most~~ the ~~deepest~~ ~~deepest~~ most dense layer and will always be under the other two layers. The water are mainly from the poles.

Transition layer is the layer of water which separates the warm, less dense surface layer ~~and~~ ~~from~~ from the cold, most dense deep waters. This is also where the thermocline and pycnocline are ^{at}.

There is more space for your answer to this question on the following pages.

Because NZ is in the mid latitude, so the thermocline ~~is~~ varies ~~seasonally~~ seasonally.

During winter, NZ experiences the least amount of sunlight hours so the surface water is relatively colder than other seasons, meaning the temperature difference between the surface layer water and the deep layer water are low. This results the lowest gradient / thermocline in all seasons.

At summer time, NZ experience the most amount of sunlight hours, making a great ^{temperature} difference between the surface ~~layer~~ layer water and the deep layer water. This creates the steepest thermocline. The surface water absorbs a longer period of solar radiation, so its warmer.

During spring and autumn, the sunlight hours are relatively constant, so the ^{temperature} ~~thermocline~~ is decreasing more gradually with depth, ~~so the~~ and the thermocline is higher than winter but ~~is~~ lower than summer.

Pycnocline is the layer of water ~~at~~ which rapidly changing density with depth. The density of water depends on the temperature and salinity. The colder the water, the easier to store more salt, and therefore the most dense. So the density is rely on the temperature of water. Pycnocline usually has the similar gradient to the thermocline.



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QUESTION TWO: SOUTHERN OCEAN CARBON SINK

The Southern Ocean plays a central role in moderating the rate of climate change, absorbing approximately 40% of the carbon dioxide (CO₂) that has been produced by humans until now.

Cumulative ocean CO₂ uptake since 1850



Adapted from: <https://scx2.b-cdn.net/gfx/news/hires/2022/improving-climate-mode.jpg>

Explain how the Southern Ocean absorbs large amounts of carbon dioxide from the atmosphere.

In your answer, you should consider:

- the biological and physical pumps that take CO₂ into the ocean
- the effects that storing increased amounts of CO₂ may have on ocean chemistry
- reasons why the Southern Ocean can absorb such large quantities of CO₂.

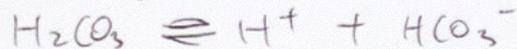
Physical pump is when CO₂ diffuse into the ocean due to the concentration gradient. Particles are tend to move from the place with high concentration to low concentration, where the ocean has lower concentration than the atmosphere.

Biological pump is when plants need to carry out photosynthesis to gain energy. The process requires CO₂ and water to produce oxygen and glucose.

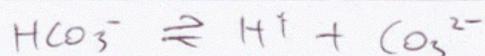
CO₂ from the atmosphere are absorbed by the plants to the ocean.



When CO₂ ~~gets in~~ ^{dissolves} into the ocean, it will react with water molecules forming carbonic acid H₂CO₃.



Carbonic acid dissociates in water forming ~~hydrogen~~ ^{hydrogen} ions (H⁺) and bicarbonate ions (HCO₃⁻).



The Bicarbonate ions will further dissociates to hydrogen ions (H⁺) and ~~carbonate~~ CO₃²⁻ ions.

When the amount of CO₂ storing in the ocean increases, the induced CO₂ will favour the forward reaction to produces ~~is~~ more H⁺ ions, resulting an increase of H⁺ ion concentration in the ocean.

The pH of ~~an~~ a solution depends of the concentration of H⁺ ions in the solution. Since the concentration of H⁺ ions in the ocean has increased, the pH will ~~is~~ be lower and therefore the ocean will be more acidic.

The ~~seather~~ southern ocean is near the ~~Ant~~ Antarctica, so the water will be colder than any other oceans. CO₂ are more likely to dissolve into colder water.

There is more space for your answer to this question on the following pages.



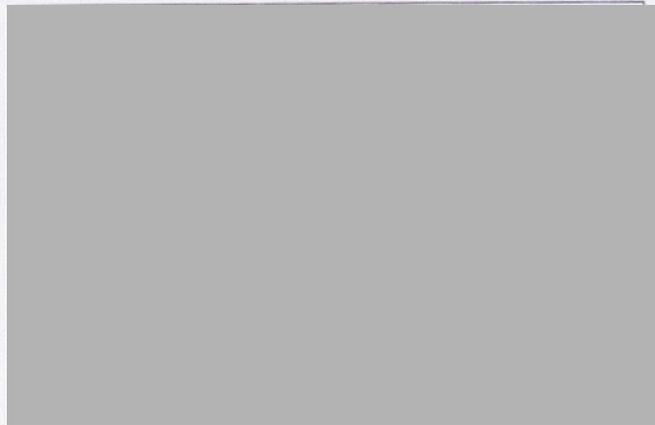
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QUESTION THREE: SOMALIA SEASONAL UPWELLING

Somalia is a country in East Africa. During the northern hemisphere summer, from June to September, a strong monsoon wind blows from the south-west along the coast. This causes upwelling and very good fishing compared to other seasons.

Surface currents in the western Indian Ocean

Adapted from: <https://www.mdpi.com/2073-4425/11/3/278>

Upwelling current at the Somali coast during southwest monsoon

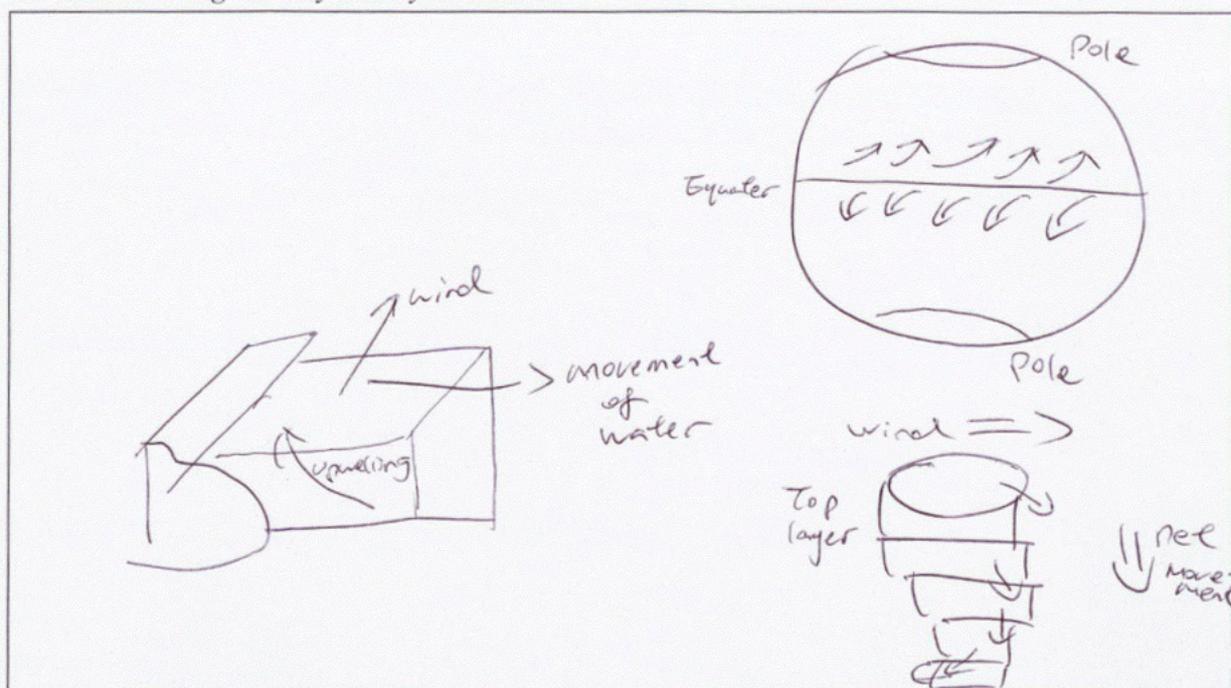
Adapted from: https://commons.wikimedia.org/wiki/File:Upwelling_current_at_the_Somali_coast_during_Southwest_Monsoon.png

Compare the seasonal fishing conditions off the coast of Somalia during the summer and winter monsoons.

In your answer, you should consider:

- the role of wind from the south-west and the Coriolis effect to create strong seasonal upwelling
- the source of nutrients
- the effect of strong seasonal upwelling in this area on productivity
- the conditions that lead to downwelling and poor fishing during the winter monsoon season.

An annotated diagram may assist your answer:



Coriolis effect is when the water near the equator travels the greatest distance and the slowest speed due to the radius of earth, and the water near the poles are travelling in the shortest distance thus the fastest speed.

The wind drives the ^{Surface} water movement (current) so the water tend to flow towards the poles. (low speed to high speed)

As the wind drags the surface layer of water to move, the ~~the~~ water will shift ^{a little bit} to either north and south (depends on the location). The top layer of water will also drag the lower layer of water to move due to friction. This creates a net movement of water which is 90° to the direction of the wind. This is the Ekman transport.

There is more space for your answer to this question on the following pages.

Because the summer monsoon wind is travel in a direction which parallel to the coast, so the net movement of the resultant current will be 90° to the coast, towards the opposite of the coast, due to Ekman transport. This results the lack of surface layer water ^{near the coast} as the water all been flow away, ~~causing~~ ^{causing} the ^{cold} deeper layer water to upwell, replace the loss of surface water.

The upwelling water brings the nutrients from the deep ocean which improves the ~~fish~~ ^{fishing} of Somalia.

During winter, the wind is travel at the opposite direction, making the net movement of the current towards the Africa coast line, the increase of ocean water causes the downwelling of the surface water, so the nutrients from the deep ocean are no longer available, therefore causes the poor fishing during winter monsoon season.

Merit

Subject: L3 Earth & Space Science

Standard: 91413

Total score: 16

Q	Grade score	Marker commentary
One	5	The candidate explained the formation of the different layers and how these are affected by seasonal changes such as amount and angle of sunlight. They did not explain the function of the thermocline as a barrier to preventing the surface and deep layers mixing.
Two	5	The explanation of the physical and biological pump processes was weak; however, the candidate demonstrated an in-depth understanding of ocean carbon chemistry in their use of chemical equations to explain ocean acidification.
Three	6	Explained the various processes involved in causing upwelling, but were not sufficiently linked together to demonstrate a comprehensive understanding for excellence.