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Level 3 Earth and Space Science, 2019

91413 Demonstrate understanding of processes in the ocean system

2.00 p.m. Thursday 28 November 2019
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 and clearly number the question.

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

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

Excellence

TOTAL

22

ASSESSOR'S USE ONLY

QUESTION ONE:

- a) The word thermocline means (thermos-temperature) and (Cline-change) which basically means that the thermocline is a tool used to measure the temperature change within the ocean. The thermocline is located in the second layer within the ocean where the temperature quickly changes. The first layer of the ocean receives sunlight (Thermal energy) from the sun which heats up the water as heat is absorbed. However, in the lowest layer in the ocean no sunlight is able to reach it. This means that the water is very cold. This therefore causes a difference in temperature from the top and bottom layer. In the middle layer, this is when the temperature of the water quickly decreases or stays the same depending on the latitude. For example, in low latitudes there is more direct sunlight so therefore the water heats up more and the thermocline is greater and steeper, whereas in high latitudes around the poles the water doesn't receive much sunlight at all and is surrounded by ice which means that the water is already very cold so the thermocline is very minimal and the temperature tends to remain constant throughout the layers.

In low latitudes (Graph A), there is a lot of direct sunlight (Solar heating) from the sun onto the first layer of water in the ocean. This is because the sunlight is spread out over a smaller area so therefore the heat is more concentrated making it warmed. This therefore as a result heats up the water a considerable amount which is the graph is slightly above 25 degrees Celsius. The bottom layer of the ocean is always cold due to the absence of any solar heating from the sun as all of the light and heat from the sun has already been absorbed by the top layers. This means that because the temperature is much greater at the surface, there is a bigger difference in temperature between the top layer and the bottom layer in the ocean. Therefore, for the middle layer of the ocean the thermocline will be steeping and more drastic because of the bigger difference. This means that in the middle layer of the ocean where the thermocline occurs the change in temperature is more noticeable.

In mid-latitudes (Graph B), there is less direct sunlight and solar heating from the sun. This is because the sun rays are reaching the mid latitudes at greater angles meaning that the sunlight and thermal energy is spread out across a greater area. This results in the sun not heating up the ocean as much as it does in low latitudes areas around the equator. The result of this is that the temperature of the water on the surface layer of the ocean is slightly cooler compared to the low latitudes. For example, the graph has a temperature of over 25 degrees for the low latitudes and a temperature of roughly 21 degrees Celsius at the mid latitudes. The result of this is that the difference in temperature between the surface layer and the bottom layer of the ocean is not as great. Because the temperature at the bottom of the ocean remains constant, it means that the lower the temperature is at the surface layer, the less steep the thermocline is. Keeping this in mind, it means that at mid latitudes the thermocline is not as steep or aggressive as it is at low latitudes because the surface layer is not heated up as much. This causes then a gradual and gentler decrease in temperature of the water in the middle layer of the ocean where the thermocline is located.

In high latitudes around the poles (Graph A), the sun light rays are so spread out that not much thermal energy is provided by the sun and some areas do not even receive any light or thermal energy at all. The flow on effect of this is that the temperature of the water is

already extremely low around the temperature of the deep level water anyways at around roughly 2 degrees Celsius. This means that the thermocline at the high latitudes is nearly a linear line and goes straight down. This is because the difference in temperature between the surface and bottom layer of the ocean is so small. Therefore, the thermocline at the high latitudes around the poles is the weakest and smallest and there is any barely noticeable difference between the temperature as you go deeper into the ocean because it remains relatively consistent the whole way down due to the little difference between the top and bottom layer temperature of the ocean.

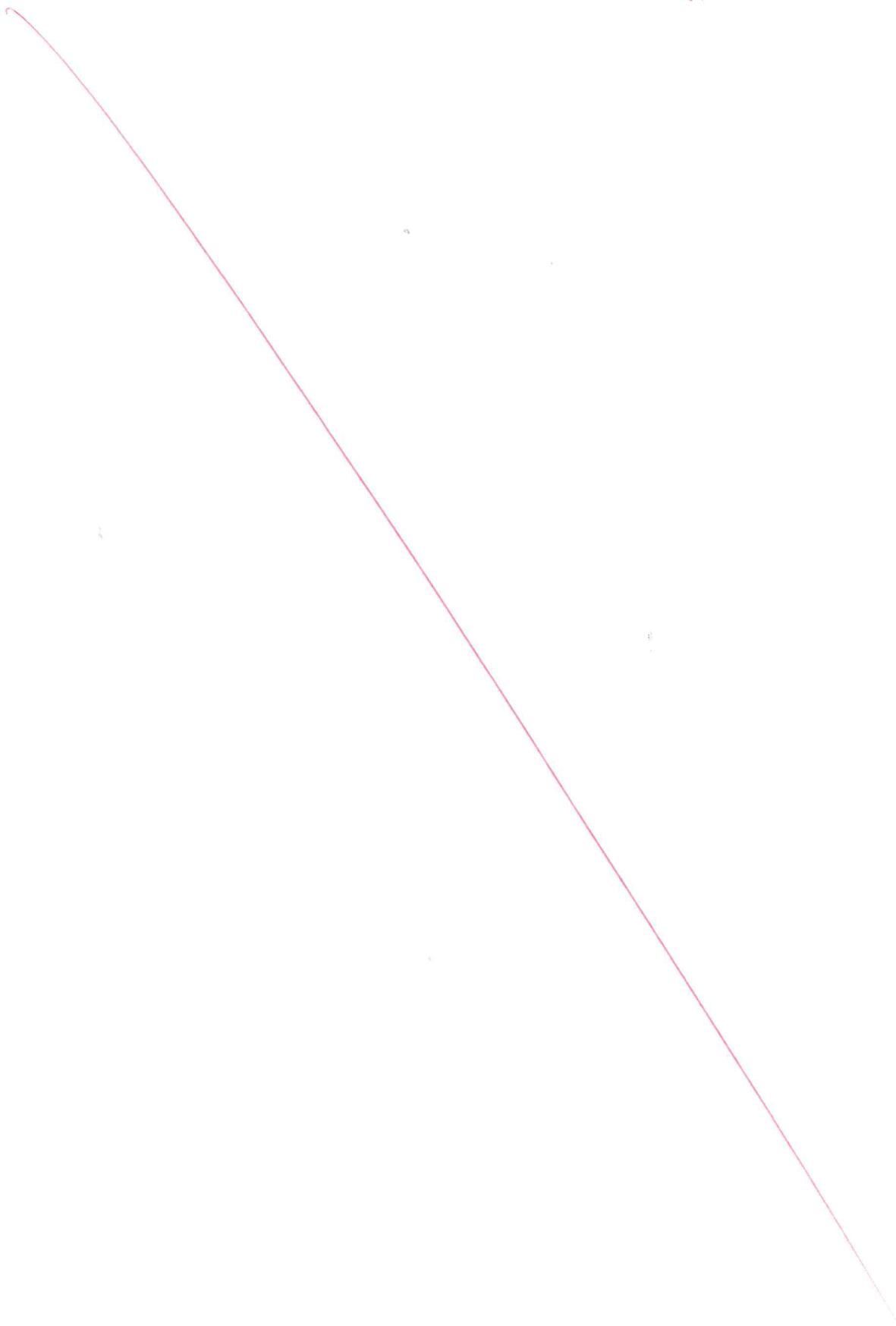
Seasonal heating can affect the thermocline. This is because the earth rotates on its axis which means that sometimes the mid latitudes get more or less direct sunlight from the sun because it is more around where the equator and most of the direct sunlight usually is on the earth. This means for example, that at mid latitudes, during the summer, the water at the surface layer will be warmer as it will be receiving more direct sunlight from the sun because of the earth rotating on its axis. This therefore means that at mid latitudes in the summer, the thermocline line will be steeper and more aggressive because of a larger difference in temperature. The same process applies to low latitude as the poles will be receiving more sunlight, however not much, but it is still enough to heat the water up to give a more curved thermocline line rather than a consistent temperature all the way down from the surface layer to the sea floor. In summer for the mid and low latitudes, at low latitudes it means that it has been moved further away from the direct sunlight from the sun and therefore there is not as much solar heating or thermal energy from the sun. The flow on effect of this is that the temperature of the water at low latitudes decreases slightly therefore resulting in a less aggressive thermocline curve and the temperature difference will be lower.

However, in the winter for mid latitudes, the earth will tilt them further away from the direct sunlight. This means that the temperature and level of thermal heating from the sun to the water will decrease meaning that the temperature at mid latitudes will decrease. Because the bottom layer of the oceans temperature remains consistent, it means that the thermocline curve will decrease and become less steep and there will be a smaller difference in temperature between the layers. At high latitudes near the poles the water is already extremely cold so there is barely any change in the thermocline so the curve stays relatively the same apart from being slightly cooler. At low latitudes, the water does not vary too far away from the direct sunlight meaning that the water will still remain warm but will ever so slightly be cooler meaning that the thermocline at low latitudes becomes slightly weaker and has a smaller temperature difference between the layers.

The effect of global warming (Climate change) has a huge and profound effect on the temperature of the water, especially in the surface layer. Due to the increased concentration of carbon dioxide within the atmosphere, it means that the sun's thermal and solar energy is absorbed more within the atmosphere and ocean due to the ocean absorbing more carbon dioxide. This is because the carbon dioxide molecule keeps infrared heat within the atmosphere by absorbing it and bouncing it back down into the atmosphere at the edges of the atmosphere. This results in the atmospheric region heating up. The result of this is that the temperature of the ocean will also increase leading to an effect on the thermocline. The result of a warmer ocean is, is that the thermocline at any latitude will become more aggressive and steeper due to a greater difference in temperature. However, the change will

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not be as strong at high latitudes because of the weakening of the thermohaline current which helps to distribute heat evenly around the globe. This also means that there will be an even more drastic change at the low latitudes because they will heat up even more and create an even stronger thermocline curve than it currently is.



QUESTION TWO:

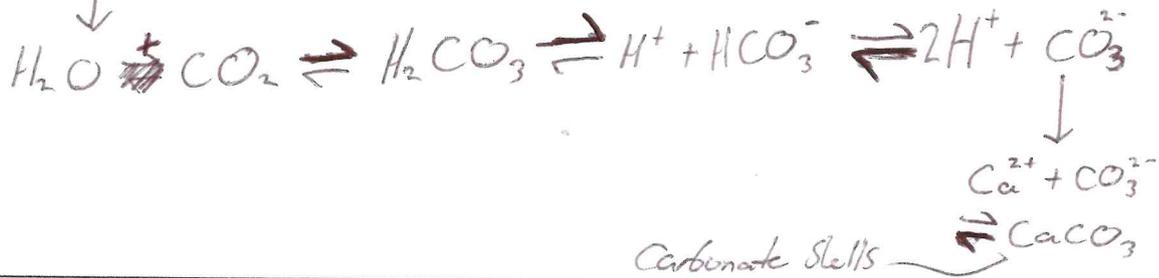
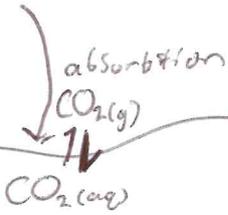
- a) As greenhouse gases by industrial human processes increases, the ocean will absorb more carbon dioxide from the atmosphere and the concentration increases. This is because the carbon dioxide concentration in the atmosphere and in the ocean is in equilibrium with each other. This means that if the concentration of carbon dioxide in the atmosphere increases, so will the concentration of carbon dioxide in the ocean. Because human industrial processes are releasing more and more carbon dioxide into the atmosphere, this therefore increases carbon dioxide concentration in the atmosphere. This therefore means that the carbon dioxide concentration in the ocean will also increase.

When the carbon dioxide enters the ocean, it changes state from a gas to an aqueous molecule. The carbon dioxide is essentially dissolving into the ocean water.

$(\text{CO}_{2(g)} \leftrightarrow \text{CO}_{2(aq)})$ The dissolved carbon dioxide then bonds with a water molecule which forms carbonic acid in a balanced equilibrium chemical equation

$(\text{CO}_{2(aq)} + \text{H}_2\text{O}_{(aq)} \leftrightarrow \text{H}_2\text{CO}_{3(aq)})$. The carbonic acid molecule can then dissociate one proton (H^+ ion) into the water which therefore forms a bicarbonate ion and a hydrogen ion. $(\text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-)$. The bicarbonate ion can then dissociate further once again into a carbonate ion and two hydrogen ions. $(\text{H}^+ + \text{HCO}_3^- \leftrightarrow 2\text{H}^+ + \text{CO}_3^{2-})$. The leftover carbonate ion from these equilibrium reactions can then bond with a calcium ion to form Calcium Carbonate which is what small sea creatures such as phytoplankton and zooplanktons shells are made out of. $(\text{Ca}^{2+} + \text{CO}_3^{2-} \leftrightarrow \text{CaCO}_3)$. This reaction is extremely important in making sure there is a strong aquatic ecosystem. However, due to the increase in carbon dioxide in the atmosphere and ocean, the equilibrium has shifted to compensate for this change and has moved the equation to form more bicarbonate and hydrogen ions. This as a result means that there is less carbonate ions in the water and more hydrogen ions in the water. These hydrogen ions can then bond with water molecules in the ocean to form hydronium ions $(\text{H}^+ + \text{H}_2\text{O} \leftrightarrow \text{H}_3\text{O}^+)$. With increased concentration of hydronium ions in the ocean, the more acidic it will become. This is because acidity in a solution is measured by the concentration of hydronium ions within it. Another problem is that with the increasingly acidified conditions, the carbonate ions prefer to bond with a hydrogen ion rather than a carbonate ion meaning that there are less available carbonate ions in the ocean for marine life to bond with to form their shells. This means that marine life is having to use more energy to come across more carbonate ions to build their shell and due to the fact that energy is conserved, they will have less energy left over to hunt for prey which could affect their likelihood of food and survival. Because the ocean will have less available carbonate ions and sea creatures such as phytoplankton and zooplankton are at the bottom of the food chain, if these sea creatures become too vulnerable and begin to die in massive quantities, it could cause the eventual collapse of the food chain in the ocean which means that the population of sea creatures in the ocean will be significantly reduced. This is because sea creatures nearer to the bottom of the food chain who eat the phytoplankton and zooplankton will not have as much food which means more of them will die due to starvation and there is a flow on effect straight through the entire aquatic food chain. Another effect which ocean acidification is having on sea creatures is that their bodies are going into equilibrium also with the ocean water which is becoming more acidic. The result of this

is that fish are beginning to have weakened prey identification and cannot direct themselves around easily and sometimes do not know how to get back home. This results are a much higher vulnerability for many fish species which could result in very decreased populations across the world. Also, with the increased acidity in the ocean, the already formed calcium carbonate shells on phytoplankton and zooplankton for example could literally be dissolved away due to the overall abundance of hydrogen ions in the water bonding to it because the water is so acidic. Once again, this could and will have huge implication into how to food chain works in the ocean and to the overall survival of sea creates and marine life in the ocean because coral reefs and exo-skeletons of many marine life creates have calcium carbonate in them. In the resource provided in the exam booklet, it shows the direct effect and correlation between decreasing pH levels (Acidity) in the ocean and the effect on a calcium carbonate shell. For example, at higher pH levels in the ocean like pH level 8, the calcium carbonate shell is at its thickest point at 4.09 micrometres due to there being more carbonate ions available in the water at that pH level. Then at lower pH levels like 7.7 there is less carbonate ions because of the change in equilibrium and less carbonate ions available in the ocean so the calcium carbonate shell is therefore not as well developed. The shell is at 3.43 micro meters which is 0.66 micro meters thinner than the shell at 8 pH level. However, in very low and acidic conditions such as 7.3 pH level, the shell is getting even thinner at 2.72 micro meters which is a 1.37 micro meters thinner than expected ocean condition at a pH level of 8. At this pH level, delocalised calcium carbonate ions are already increasingly difficult to find, however, the shell may even be dissolving due to the increased presence of hydrogen ions in the water meaning that the shell is further breaking down to a thinner size. With these thinner shells at lower pH levels, the coral reefs, zooplankton and phytoplankton etc. are all becoming under more considerable risk of extinction as there are not able to naturally protect themselves as well anymore which in the end results in the much more fragile aquatic eco-system which humans will pay the ultimate price for in the future if action is not taken soon.

$\uparrow \text{CO}_2$ Acidified conditions as
described in answer.

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

QUESTION THREE:

- a) The formation of the Chatham Islands and the Chatham rise is to do with tectonic plate movement and uplifting. For example, at plate boundaries, tectonic plates can push towards one another and cause them to bend upwards which is called uplifting. This is how the Chatham rise and islands were formed by the uplifting of land by the tectonic plates. This has caused a series of uplifted land under the ocean surface which means that the sea floor is much closer to the ocean surface. The origin of Chatham rise and islands is broken down sedimentary rocks off the coast of the historic "Gondwanaland" super-continent. These sedimentary fragments were these crushed together under extreme high pressure from the water above to form a sedimentary rock. These large rocks were then transported upwards above the sea floor as described before by tectonic plate movement.

The Antarctic circumpolar current originates from Antarctica and the west and east Auckland currents originate from lower latitudes around the equator. The Antarctic circumpolar current is formed by the prevailing westerly winds around the lower latitudes. These winds are strong and mainly remain consistent around the whole world. Also, because the current has a very long fetch, which is the distance the wind or water travels without being effected by exterior factors such as land, the current is extremely strong and is always moving in the same direction around Antarctica. The west and east Auckland currents are formed by the prevailing westerly winds through New Zealand. However, unlike the circumpolar current around Antarctica, there is land in the way effecting how the current flows. The waves from the current diffract around New Zealand and travel over to the east coast. The current strengthens towards the Chatham islands and over the Chatham rise because of the gravity of the lifted sea floor from tectonic activity and also the water is able to grow in amplitude due to the lifted up sea floor because there is less volume underneath the waves available to transport the energy. This means that the current does slow down however, but it does become stronger. The same factors apply for the strong circumpolar current surrounding Antarctica. The current is refracted across the lifted up sea floor which directs it towards where the Chatham islands are. This causes both the west and east Auckland currents as well as the Antarctic circumpolar currents to be directed towards the Chatham islands and rise. The temperature of the east and west Auckland currents is much warmer than the Antarctic circumpolar current. This is because the water has been transported down from low latitudes around the equator which have been heated up by more direct sunlight. Also, the sea level is a lot shallower so therefore the heat is not spread across a larger volume of water so therefore the water is more heated in that scenario. However, for the Antarctic circumpolar current, the water originates from the higher latitudes around the poles. This means that the water is receiving very little direct sunlight and thermal heating from the sun. Also, the water is around a lot of ice which cools the water down as well which means that the Antarctic circumpolar current water is much cooler than the west and east Auckland currents are.

As discussed earlier in my answer, the currents meet at the Chatham islands and rise because of refraction due to the differing sea levels which are caused by the tectonic plate movements. For example, the Antarctic circumpolar currents refract of the southern parts of the Chatham rise which bends the current towards the Chatham islands and the east and west Auckland currents because of gravity at the higher sea levels and also the diffraction around New Zealand. These factors therefore cause the water to be directed towards the Chatham islands and Chatham rise:

The result of this is that from the cold water from the circumpolar currents around Antarctica, nutrient water is surrounding the Chatham islands which is very appealing to fish so the concentration of fish in that area increases. Like described in the question, this is why there was a massive influx of phytoplankton in 2010 because of the fresh and cold and nutrient water from the Antarctic circumpolar current which refracted up to the Chatham islands which also bring a lot of fish and fishermen and therefore fish corporation (Human activity) along with in. Fish are also transported over from New Zealand through the east and west Auckland current over to the Chatham island. The result of this is that fish is more common around this area and this will significantly influence the presence of sea food and life around this area which therefore brings many fisherman and fishing corporation's over to the Chatham islands which is how it effects marine life and human activity in this area.

Excellence Exemplar 2019

Subject	L3 Earth and Space Science		Standard	91413	Total score	22
Q	Grade score	Annotation				
1	E7	The candidate uses the contextual evidence to advantage to discuss the nature and changes in the thermohaline in relation to solar heating, Earth's tilt and the seasons. A good understanding of the thermocline is shown.				
2	E8	The candidate provides a comprehensive discussion of the effect of cause of ocean acidification, chemistry and biological effects on shellfish using both the resource and application of concepts related to the context.				
3	E7	<p>The candidate provides a reasoned discussion on the effect of the Chatham Rise on deep and surface ocean currents in the region and the consequence of the meeting of the two currents.</p> <p>The discussion could have further developed by greater discussion as to the nutrient source that feeds the phytoplankton boom and its role in the ecosystem.</p>				

Confirmation of check	Y / N
This exemplar has been checked for similarities with current online exemplars.	Y