93104

931040

S

SUPERVISOR'S USE ONLY

SCHOLARSHIP EXEMPLAR

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Scholarship 2016
Earth and Space Science

2.00 p.m. Friday 25 November 2016
Time allowed: Three hours
Total marks: 24

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

Pull out Resource Booklet 93104R from the centre of this booklet.

You should answer 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.

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

QUESTION ONE: SEAFLOOR METHANE HYDRATES AND GAS SEEPS

ASSESSOR'S USE ONLY

Use the information provided on pages 2 and 3 of your resource booklet to answer this question.

Recently, a vast amount of permafrost containing frozen methane hydrates plus numerous methane gas seeps has been discovered within the continental shelf sediments off the east coast of the North Island. Preliminary investigations have shown that methane gas is also reaching the ocean surface.

The continental shelf in this area has active, slow-moving, underwater landslides, up to 15 km long and 100 m thick. This is a phenomenon which is largely uninvestigated, and which may, at least in part, be caused by the presence of methane hydrates and methane gas seeps.

Much more research is needed to determine the extent and effects of these methane hydrates and gas seeps.

Justify the need for extra research considering the possible causes and implications of slow-moving underwater landslides, and the consequences of the release of methane gas. → GHG

↑°C

Well labelled diagrams may assist your answer.

ASSESSOR'S USE ONLY

~~Slow water~~ It is important that slow-moving underwater landslides are researched in greater detail, because more is needed to be determined about the possibilities of melting permafrost from these landslides. When methane hydrates are frozen in permafrost, they do not present a 'threat' to the outside world – that is, above the level of the ocean. However, the presence of methane gas seeps reaching the ocean surface means that the methane stored in the landslide permafrost is re-entering the atmosphere.

Methane gas in the atmosphere has the effect of being a '~~green house~~ gas' – this means that, when solar radiation heats Earth's surface ~~is reflected off the Earth~~, the gas can act as a sort of 'blanket' (i.e. absorbs radiation and re-radiates it as heat, back in the atmosphere (troposphere)). Thus, an increased concentration of methane in the atmosphere could lead to increased global atmospheric temperatures, due to the warming greenhouse effect.

Permafrost is not a 'new' addition to our Earth, and thus its presence is part of the dynamic equilibrium of methane storage. Over the last thousands of years, dead organic material releasing methane gas could be trapped in the permafrost, thus removing it from our atmosphere (creating, in effect, a methane sink). Then, through underwater methane seeps, this trapped gas could be steadily released back into the ocean, as well as the atmosphere above (should the gas seeps reach this far). Thus, a natural, negative feedback system would form if the rates of methane seeps leaking and methane 'sequestering' (in permafrost) were to reach a ~~constancy~~ constant point. However, this balance could be at risk of being upset. Permafrost formation and maintenance requires low temperatures. So, any changes to sea temperatures (due to an overall global rise in temperatures) could possibly melt this permafrost, and create a positive feedback.

If permafrost were to be melted, additional methane stores would be released, reaching both 250m above the ocean floor, as well as the ocean's surface. This could in turn lead to an increased greenhouse effect from the higher methane concentrations in the atmosphere, which could then cause increased temperatures, to melt yet more permafrost.

It is clear that additional research is needed in this area - from two research studies alone, it was found that a perceived methane seep prevalence was not 99 per 50 km², but 766. Thus, we need to continue finer-detailed investigation of greater areas of continential shelf, just like this, to see the extent of methane gas seeps (and so possibilities of methane hydrate stores). Only preliminary investigations have found that the seeps do, indeed, reach the surface - further research may find that a greater (or lesser) proportion of the gas could do so. The consequences of melting permafrost in these regions could be extraordinary, with the landslides covering up to 15 km in length (and 100m thickness). If the problem is not addressed, forecasts of future global greenhouse gas concentrations and therefore ~~to~~ global temperature estimates) ~~could~~ may well be invalid, without factoring in the added methane which could be brought by these melted permafrost methane stores.

The extent to which methane hydrates have the potential to change our climate could be massive. In fact, ~~in~~ one of the greatest mass extinctions of all time (~~during~~ preceding the Mesozoic Epoch), an estimated 80-90 % of living species ~~on the planet~~ were 'wiped out' - and it is ~~thought~~ theorised that this was due to ~~either~~ greenhouse gases increasing drastically in ~~concentrates~~ concentration (either CO_2 gas, or methane hydrates, just like is being investigated here). So, it is crucial that more research is done in ~~the arena of methane~~-hydrate-containing landslides, as it is within the realms of possibility that we are ~~being~~ faced with ~~the possibility of~~ ~~a~~ world-changing atmospheric ~~changes~~ conditions.

It is also provided in the evidence that methane can form gas seeps associated with large earthquake faults. While these do not affect landslides on the continental shelf, they present another possible problem. In the area of underwater region of the East Coast of New Zealand's North Island, we have an active ~~volcanic~~ earthquake zone due to the Kermadec Trench. This itself is a large fault line running ~~At~~ through north of New Zealand, and presents its own risks of underwater earthquakes ~~(and other~~ /tectonic activity). So, if methane gas seeps are also found in regions such as this, this indicates ~~that~~ the presence of methane hydrates possibly residing in this region. Due to tectonic activity ~~in~~ of this fault line,

(please see extra paper)

ASSESSOR'S USE ONLY

5

(8)

ASSESSOR'S USE ONLY

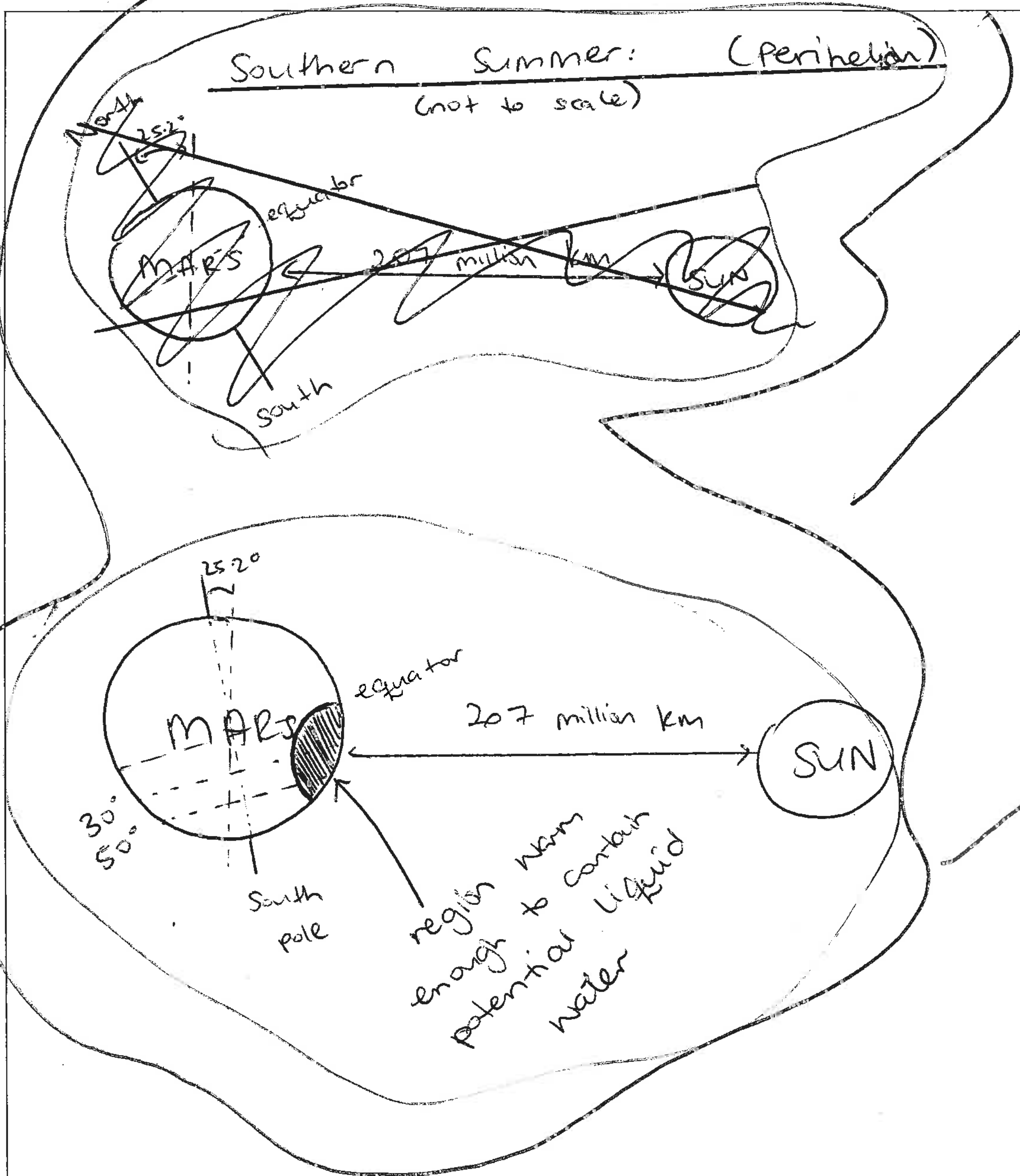
QUESTION TWO: LIQUID WATER ON MARS

Use the information provided on pages 4 and 5 of your resource booklet to answer this question.

There is no doubt that water exists on Mars as ice and water vapour, but recent evidence suggests that liquid water may be present just under, and occasionally on top of, the Martian surface.

Discuss in detail how and where liquid water could form on Mars, considering factors such as relevant geological features, and the axial tilt of Mars and its eccentric orbit around the Sun.

Well labelled diagrams may assist your answer.



ASSESSOR'S USE ONLY

For liquid water to exist on Mars, it would have to be at a temperature of 0 - 10°C (as below this it freezes, and above this it has surpassed the maximum boiling point so will only exist in a vapour (gaseous) state). However, in the regolith, perchlorates lowering the freezing point of water by as much as -70°C could mean that its boiling point (and melting point) could similarly be lowered. This would increase water's possibility of existing as a liquid on Mars, as ~~diurnal~~ ~~annual~~ annual temperature range means ~~average~~ temperature can be ~~from~~ ~~[illegible]~~ up to 35°C, which would be more than that needed to melt water. However, it is unlikely that water could exist in liquid state in the regolith, because of pressure inadequacies. Regolith is loose surface rock, so is under little pressure (likely close to the average 0.006 atmospheres on Mars). This is the region in which ~~watter~~ water will instantly sublime, surpassing the liquid phase from solid. So, for water to exist in liquid state, it would likely have to be in regions ~~nearer~~ under ice itself.

In polar ice caps, summer frozen CO_2 melts. Because liquid and solid water can co-exist like in Lake Vostok, it is possible that liquid water could be found under these polar caps. At the surface, sublimation of the water would still occur, but under greater pressures, at 0°C (for example), sub-polar-cap water could melt (looking at the "States of Water" graph). Despite this possibility, the location of the poles may

ASSESSOR'S USE ONLY

pose an issue for this liquid water. Even though the pole (southern) would tilt 25.2° towards the sun during the perihelion (southern summer), this may not be sufficiently close that temperatures of the polar caps are high enough to yield liquid water underneath the surface. ~~or, indeed, polar caps themselves~~

Therefore, another possibility for the location of liquid water could be under glaciers of the 30°/50° latitude. While dust might often cover the glaciers, reflecting solar radiation and reducing the glaciers' temperatures, variability of dust thickness changes due to dust storms. If there were to be a strong dust storm during the (southern) summer of Mars, this could sufficiently uncover the glacier to expose it to enough solar radiation that liquid water could occur. As with the possible liquid water at the polar caps, increased pressure from the glacier (under the surface) would aid in melting rather than subliming the water. The 30° latitude would likely have the highest chance of liquid-water-containing glaciers, because it would be more greatly exposed to solar radiation during the Southern summer (see diagram on the previous page). Of course, a southern summer would also have the greatest chances of 'creating' liquid water, because of the reduced distance to the sun (and axial tilt) meaning increased solar radiation (so heat) exposure to melt the ice. ~~In addition it~~

ASSESSOR'S USE ONLY

In addition to this, glaciers have the possibility of movement whereas polar caps are likely fixed in position. Hence, the glaciers may increase probability of containing sub-surface water even further because any possible movement makes the formation of ice crystals more difficult (so the liquid water chances greater).

0

Geological features (such as the Hellas Basin) could also make the possibility of liquid water greater ~~or smaller~~. If something akin to the ~~the~~ basin were to be the location for a glacier, or other frozen water body, it could increase the chances of liquid water because it would provide a suitably-located feature filled up to ~~2~~ 7 km deep (/2300 kms across) with water, which could (under the surface) be liquid. ~~As~~ So, the feature (located in the southern hemisphere for ideal temperatures during perihelion) might - if in conjunction with glacier formation - aid liquid water formation. Again, it would be unlikely to encounter water on the surface of such a feature, because the atmosphere (lacking humidity) would cause instant evaporation of the water. This also applies to adsorbed water on the surface of any regolith in a feature (such as Hellas basin), because of proximity to the thin unsaturated atmosphere.

0

Because the orbit of Mars around the sun is eccentric, liquid water would likely exist for only a small portion of the year. If southern hemisphere summers are the only time appropriately warm for liquid

(please see back paper)

6✓

(8)

QUESTION THREE: THE WARMING OCEAN AND THE EFFECT ON NEW ZEALAND

ASSESSOR'S USE ONLY

Use the information provided on pages 6 and 7 of your resource booklet to answer this question.

Over the next few decades, global warming will result in a warmer ocean and more energetic wind patterns in the South Pacific. As a result, sea temperatures around New Zealand may warm up by as much as 2°C, especially around the bottom half of the South Island.

By showing a comprehensive understanding of the factors that affect surface current flows around New Zealand, consider, in depth, the consequences of global warming on New Zealand and its surrounding ocean and ecosystems.

A well labelled diagram may assist your answer.

Surface current flows are primarily affected by two things - winds (above) influencing the surface flow, and deeper currents (below) influencing the surface flow. Both of these create 'pulling' (through friction) of the water meeting the air above it, thus forming surface currents.

Walker circulation strengthening indicates the possibility of a "La Niña" event. This is when the trade winds, from South America to Australia / Indonesia, strengthen, thus causing increased upwelling of cold water in South American (west) coasts and increased warm water piling up in Australia / Indonesia. The South Pacific Gyre is caused as the water moves westwards across the pacific, then is deflected downwards due to the coriolis effect (turning of the Earth causing an 'anticlockwise' force effect) as well as land masses in the Indonesian area. Then, with the ACC ~~Antarctic~~ flowing eastwards, this joins the gyre until it is deflected upwards once again as it encounters ~~to~~ South America. If Walker Circulation strengthens (because more energetic wind patterns spar a "La Niña" event), this will more strongly drive the SEC, and thus the south Pacific Gyre's path of ~~rotation~~ motion.

Global warming increasing South Island water temperatures, however, could ~~will~~ decrease the effects of the fronts. For example, when warm tropical water converges with cooler sub-tropical water, the 'wall' between their mixing is marked. If South Island water (sub-tropical) temperature's rise, the difference between its temperature and the tropical water's temperature will be lessened. This could then lead to a less marked front boundary, and so decreased plankton blooms and fish production. Without distinct differences in water temperature, the nutrient circulation could likely decrease, majorly affecting ecosystems in between Australia and New Zealand. Not only could this disrupt fishing industry off New Zealand's coast, but it could affect entire food webs. Plankton blooms are essential for the basis of marine food chains - as they provide basic sustenance for the fish / marine animals in lower trophic levels - so the filter-on effect could be to ~~drastically~~ reduce many species of different organisms relying on this. This would be due to the more 'muddled' exchange of water and matter, failing to create zones of nutrient-rich (front) waters like before.

The STF may well also be affected, depending on how subAntarctic waters change in temperature. If the water from the ~~sub An~~ ACC stays at a cool 1-2°C while the EAC water increases in temperature, the STF will likely remain clear and 'intact'. However, if the sub-Antarctic waters also increase in temperature, the STF could become less pronounced (depending on the extent of each water's warming). ~~This~~ The EAC then goes on to join the south

ASSESSOR'S USE ONLY

Pacific Gyre's flow. So, if surface currents are to possibly decrease with global warming's effect on the ~~S~~TF and STF (fronts), this could then disrupt the South Pacific Gyre's flow.

New Zealand's weather is dictated by differences in temperature of the North and South Island waters. The strengthening Walker circulation means that the EAC strengthening, combined with the ~~warming~~ of the South Island's waters, could ~~decrease~~ disrupt ~~the~~ the changeability ~~the effects of the~~ of our weather. Increased warmth in the currents surrounding New Zealand could lead to increased precipitation (rain). This is because, since warm water currents warm the air above them, (this creates low pressure zones as) the air expands (becomes less dense) and thus reaches its dew point higher in the atmosphere, releasing with it its latent heat and ~~for~~ condensing to form clouds/rain. ~~Of cours,~~ Of course, "increased" rain is a vast generalisation to the complexities of weather patterns for an entire country. More importantly, the surrounding ocean of New Zealand could become more uniformly warm, thus affecting delicate ecosystems.

Marine organisms adapted to New Zealand's South Island cooler) waters could be placed under more extreme selection pressures with global warming's heating of the water. Even if one species of fish, or other animal, were to decline in numbers, this could in turn disrupt the balance of the entire

5/6 (8)

(please see extra paper)

4 Eccentric (non-circular) orbit of Mars!). So, there may then be regions - perhaps at ~~small~~ higher latitudes in the southern Hemisphere, where sub-polar water could be present. However, this would rely on temperatures being at the appropriate level of warmth to promote melting (not subliming, as this could not occur under the (confined) pressure of under-polar-cap conditions). Conversely, a Northern summer at perihelion might have sufficient polar ice caps to provide similar conditions - and perhaps increased temperatures, too, due to increased proximity (of the entire Mars) to the sun. If this polar cap liquid water 'theory' were to be true, then it is possible that liquid water could exist for longer periods of time (as the polar ice would be present spanning multiple seasons). However, this is ~~still~~ highly unlikely in comparison to the glacier (Southern summer) probability, due to overly-low temperatures at the poles. So, in sum, water on Mars is most probably found in liquid states in regions around 30-50° latitude of ~~the southern~~ hemisphere, in perihelion.

Question 3.:

ecosystem. Warmer-adapted species might move southwards, out-competing the cold-adapted organisms which used to reside in the cool subtropical waters.

Changes to precipitation and evaporation in New Zealand could also affect the surrounding water's salinity. In tropical regions, for example, increased precipitation (due to warmer conditions' rainfall) is offset by increased evaporation due to the warmth of the waters. New Zealand lies at mid-latitudes, and so its salinity is generally ~~[illegible]~~ greater than that of the equatorial waters (while Antarctic waters' salinity is affected by polar ice formation and melting). If ~~precipita~~ warmer water's were to cause New Zealand's ocean conditions to become less saline (~~than~~ increased precipitation), then this could also affect certain organisms adapted to New Zealand's current conditions. Similarly, differences in salinity between fronts could

Extra space if required.
Write the question number(s) if applicable.

Question ①:

additional methane gas seeps could be released (further to the permafrost seeps of the continental shelf). This should be factored also into any forecasts of greenhouse gas effects on global temperature. Overall, it is obvious that extra research is required to find out more about the prevalence of methane (and methane hydrates) surrounding New Zealand. The changing environmental conditions above the oceans' waters could soon impact underwater areas containing permafrost, releasing previously unforseen greenhouse gas stores. To appreciate the effect this could have on our entire Earth in future years, the amount of methane stores - and its potential to infiltrate the atmosphere - is in need of investigation.

Question ②:

water to form, then the duration of its liquid state (under glaciers) would be a maximum of 4 months long. The rest of the year, the tilt of ~~the~~ Mars and its distance from the sun ~~would~~ well make these glaciers too cold for liquid water (especially at aphelion, when the southern hemisphere is tilted away from the sun (solar radiation) and the distance from the sun is greatest). So, liquid water could only exist with adequate (glacial) temperatures, most probably during Martian summer.

~~In saying this, it is also important to re-consider the possibility of polar cap (liquid) water at aphelion. While temperatures are ~~much~~ lower at this ~~time~~ of year (~~for~~ both hemispheres, due to increased distance from the sun), this expands ~~the~~ polar cap ice formation (as can be ...~~

Extra space if required.
Write the question number(s) if applicable.

Question (1):

additional methane gas seeps could be released (further to the permafrost seeps of the continental shelf). This should be factored also into any forecasts of greenhouse ~~gas~~ effects on global temperature. Overall, it is obvious that extra research is required to find out more about the prevalence of methane (and methane hydrates) surrounding New Zealand. The changing environmental conditions above the oceans' waters could soon impact underwater areas containing permafrost, releasing previously unforseen greenhouse gas stores. To appreciate the effect this could have on our entire Earth in future years, the amount of methane stores - and its potential to infiltrate the atmosphere - is in need of investigation.

Question (2):

water to form, then the duration of its liquid state under glaciers) would be a maximum of 4 months long. The rest of the year, the tilt of ~~the~~ Mars and its distance from the sun ~~would~~ well make these glaciers too cold for liquid water (especially at aphelion, when the southern hemisphere is tilted away from the sun (solar radiation) and the distance from the sun is greatest). So, liquid water could only exist with adequate (glacial) temperatures, most probably during Martian summer.

~~In saying this, it is also important to re-consider the possibility of polar cap (liquid) water at aphelion. While temperatures are much lower at this time of year (for both hemispheres, due to increased distance from the sun), this expands the polar cap ice formation (as can be ...~~

Earth and Space Science Scholarship (93104); 2016.

Panel leader comments

Scholarship paper:

Q1: (5) This is a scholarship answer because the candidate has discussed fully the consequences of the release of methane gas and partially justified the need for extra research by:

- recognising that methane is a potent greenhouse gas and understanding the role that methane plays in global warming
- justifying the need for extra research by recognising that the methane seeps need to be mapped in finer detail to determine the extent of the methane seeps.

This is not an outstanding answer because a greater breadth and depth in the answer was required. For example:

- not all aspects of the question were answered such as the causes and implications of slow-moving landslides
- the role of tectonic activity of the east coast of the North Island was not fully developed.

Q2: (6) This is a scholarship answer because the candidate has shown good integration of different pieces of information to show understanding of where liquid water may be found on Mars. For example:

- a good discussion on the conditions under which water could exist on Mars
- a well-developed understanding of the areas on Mars where liquid water may be found

The diagram also complemented the answer.

This is not an outstanding answer because there was little recognition that liquid water may exist in only small amounts for very short periods of time consequently expanding the range of conditions and places that liquid water could exist in.

Q3: (6) This is a scholarship answer because the candidate has shown:

- good understanding of stronger winds and the Coriolis Effect on the direction of surface currents around New Zealand.
- The conditions that could result in ecosystem changes due to water temperature changes resulting in some species migrating resulting in disrupted food changes.

This is not an outstanding answer because there was there was not a comprehensive understanding of the factors affecting surface current flows around New Zealand.