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93104

931040

SUPERVISOR'S USE ONLY

OUTSTANDING SCHOLARSHIP EXEMPLAR

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

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

Tick this box if you have NOT written in this booklet

Scholarship 2022
Earth and Space Science

Time allowed: Three hours
Total score: 24

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 answer ALL the questions in this booklet.

Pull out Resource Booklet 93104R from the centre of 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 (▨). This area may be cut off when the booklet is marked.

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

Question	Score
ONE	
TWO	
THREE	
TOTAL	

ASSESSOR'S USE ONLY

QUESTION ONE: WILDFIRE EFFECTS

Discuss the effect wildfires have on the climate, both short term and long term. Contrast this to a moderate volcanic eruption such as Mount Pinatubo.

Analyse how wildfires and volcanic eruptions can be affected by human interactions, including management of the environment and impacts of human populations.

Wildfires and volcano eruption both ~~cause large~~ have similar effects on the Earth's climate in the ~~long~~ short term and long term, with moderate volcanic eruptions generally having a greater impact on overall climate.

~~With the rise of wildfires~~ In wildfires, organic carbon ~~accumulated~~ stored in trees (trees undergo photosynthesis, converting atmospheric CO_2 gas into glucose and other organic ~~molecules~~ compounds, using energy from solar radiation - light -, thus acting as a carbon sink in the carbon cycle, as forests remove CO_2 from the air) undergo ~~carbon~~ partial combustion to form carbon monoxide, and complete combustion to form CO_2 gas: ~~$+ O_2$~~

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Both CO_2 gas and gaseous H_2O vapour are greenhouse gases. The ~~hot air~~ heat energy released from combustion heats up the surrounding air, causing the air containing smoke (carbon, ash) to rise by heat convection, as hot air is less dense than cold air. ~~This~~ Much of this smoke ~~enters the~~ stays ~~tropo~~ in the troposphere, ~~fallen~~ dispersed around the planet via ~~winds such as the~~ atmospheric circulation, for example in the trade winds. However,

the smoke plume from the Australian bush fire climbed to 32km, which is above the troposphere (usually ending at around 10km) and well into the stratosphere. Since stratospheric and tropospheric air do not mix well, smoke particles are able to remain in the stratosphere for more than a year.

A similar proces takes place during volcanic eruptions, as they liberate carbon stored in rocks and minerals such as limestone (from the compaction of dead organic matter, so is also a carbon sink), also as CO_2 gas, and eject a large amount of ash and pumice that rises into the stratosphere. In the short term
In both cases, the ash in the atmosphere acts as a planetary shade, blocking sunlight (as ash particles are opaque) from reaching the Earth's surface, reducing the amount of solar radiation absorbed and released as long-wave IR radiation (which carries heat energy), causing average global temperatures to decrease. In the case of the Australian bushfires caused a likely insignificant amount of cooling that contributed about a fraction of a degree, whereas volcanic eruptions caused far greater decreases (e.g. Mt Pinatubo causing ~1°C of cooling over two years and the 1783 Laki eruption causing average winter temperatures to drop by almost 5° in the following year). This is due to the

sheer quantity of smoke produced by eruptions being much greater than that released by wildfires. In the short-term, the cooling effect along with the decrease in sunlight reaching the Earth's surface may cause reduce the amount of heating of the ITCZ's, cooling air, possibly leading to a shrinkage of the Hadley cells, reducing its effectiveness in distributing heat over different the atmosphere leading to colder weather conditions at higher latitudes above the tropics. Oceanic circulation may also be affected; reduced strength Hadley cells and leads to weaker smaller trade winds, which combined with reduced sunlight leads to reduced could lead to the weakening of the El Niño oscillation, leading to colder climates in Oceania. However these effects are short-term; wildfire ash dissipates within about a year, and volcanic ash in a few years. In the long-term, the increased levels of CO_2 in atmosphere, a greenhouse gas, will more readily traps and return release long-wave radiation emitted by the Earth's surface back into the atmosphere, leading to an more enhanced greenhouse effect and an overall increase in global temperature. In the case of wildfires, this effect can be mitigated on the so long in the long-term through the recovery of affected forest areas within the timeframe of a few decades, to see re-establishing the carbon sink and re-absorbing the excess CO_2 via photosynthesis. In volcanic eruptions, this the excess CO_2

can not be readily returned to carbon sinks, as the process of ~~fixing~~ marine organisms converting CO_2 to calcium carbonate and compact it to limestone to return it to its carbon sink can take much longer, so eruptions are more likely to have a lasting impact on the Earth's climate through the greenhouse effect.

Human interventions are likely to increase the risk of wildfires, Human activity involving ~~fire,~~ fire, such as ~~as~~ cigarettes or campfires can act as the catalyst for wildfires, and this risk is greater around population centres, as increased human activity increases the probability that such an event would occur. Human-caused climate change can also increase this risk, through the burning of fossil fuels and the release of CO_2 ~~and~~ also contributing to an enhanced greenhouse effect. ~~Also~~ Changes in weather patterns causing a decrease in humidity and ~~also~~ increase in temperature might cause a wildfire to be sustained for longer durations and reach a greater extent (larger geographical area) than otherwise. Widespread deforestation means that once triggered, forests are unable to re-establish themselves, thus reducing the size of its carbon sink and allowing excess CO_2 to remain in the atmosphere ~~causing~~ exacerbating the effect of human-induced climate change. As volcanic activity is due to tectonic processes or 'hot-spots' formed by convection processes deep within the Earth's mantle, human activity is unlikely to affect the ~~po~~ or ~~also~~ the probability of eruptions.

↳ phot. → not shed
↳ imp: offset
↳ imp: greater coverage → res.
↳ future:

6

QUESTION TWO: AN UNEXPECTED BALANCE

Carbon dioxide and methane are the greenhouse gases with the largest worldwide focus. There is much research on the emission and absorption of the greenhouse gases carbon dioxide and methane.

Discuss possible reasons why New Zealand has higher than expected carbon absorption from intact mature native forest, and its importance. Analyse why the placement of the new monitoring stations is important for the study of New Zealand's carbon balance, and any future initiatives that might come from these placements.

Forests ~~are~~ are important carbon sinks in the carbon cycle, and ~~recent~~ recent measurements suggest that native forests in New Zealand absorb ~~upto~~ up to 60% more CO_2 than previously estimated. This could be due to native forests not shedding leaves during the winter, and highlights the importance of improved measurement ~~for~~ techniques ~~for carbon~~ to ~~build New Zealan~~ ascertain New Zealand's carbon profile.

Forests largely consist of photosynthetic vegetation, which as carbon sinks ~~through the~~ by absorbing atmospheric CO_2 gas and converting it to glucose ~~and the~~ and in turn other organic substances through photosynthesis using light energy ~~obtained~~ absorbed ~~by~~ in solar radiation:

$$6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_6 + 6O_{2(g)}$$

With previous ~~research~~ estimates of carbon absorption based largely on ~~the~~ research conducted in the Northern Hemisphere producing an underestimate for carbon dioxide absorption, this suggests that the increased absorption by native mature forests may be due to differences in ~~the periods~~ how native trees and exotic trees absorb carbon dioxide. ~~It~~ is ~~Northern hemisphere vegetation~~ Much of northern hemisphere vegetation sheds leaves during winter and regrow them during summer. As leaves are the sites of

photosynthesis, these trees are unable to absorb or very little CO_2 during the winter months. In contrast, native New Zealand vegetation does not undergo this process, being green year-round, allowing the absorption of carbon to occur throughout the year, including during winter, accounting for the extra 60% of CO_2 absorbed than expected.
This is evidence of the use of a dataset that does not apply to New Zealand vegetation, so we are unable to use or extrapolate findings from it, which may be unreliable. A control variable - weather or not the vegetation sheds its leaves during winter - was not controlled for. This highlights the necessity of collecting more data about New Zealand vegetation in particular in how much less (if at all less) CO_2 is absorbed in winter months in order to obtain a sample that is representative of New Zealand native vegetation. Previous estimates also used forest heights and land cover information to estimate carbon absorption, but this also produced underestimates, this may be due to higher density of native forests compared to exotic forests, leading to more CO_2 absorption per unit area.
The absorption of CO_2 is important, as it offsets excess carbon produced by greenhouse gas emissions, serving as a sink to counterbalance carbon sources. Human-caused

climate change has far-reaching consequences on the global climate, and thus disrupts the biosphere, hydrosphere, and atmosphere, through overall temperature increased due to the enhanced greenhouse effect caused by GHGs such as methane and carbon dioxcide absorbing outward bound long-wave infrared radiation and releasing it back to the Earth's surface. this makes it important to absorb the excess CO_2, and if native forests act as more effective carbon sinks than exotic forests, then their restoration may be necessary to maintain New Zealand's carbon balance and reduced net CO_2 emissions.

More frare monitering sites are required to obtain more accurate information about CO_2 absorption. These sites measure the amount of CO_2 and CH_4 in the air at their respective locations. Predictable wind patterns (south-westerly winds produced by the interaction of the southern Ferrel cell and the Earth's rotation through the Coriolis effect) allows scientists to compare the concentration of GHGs along the path the south-westerly winds take, and decline the amount of CO_2 absorbed between stations by taking their difference. However, this currently only gives us produces a low-resolution data about carbon absorption, as monitoring

sites are situated far apart, so it is unlikely that the ~~wind is not subjected to change~~ air flow is constant between stations. E.g. between Lauder and Wellington, winds need to pass over the rugged mountainous terrain at the northern ~~end~~ end of the Southern Alps, and interact with winds passing through the ~~co~~ Cook Straight, disrupting air flows, ~~and~~, possibly dispersing CO_2 in the air and reducing the ~~reliability~~ reliability of inferences made from the data taken. Similarly, the regions between established monitoring sites do not include a large amount of indigenous vegetation and may cover a large area of exotic ~~for~~ forest, such as to the south of the Mamaku Kā-karamea stations ~~further offshoring~~ making it difficult to ascertain the impact of native forests themselves. Therefore, it is necessary to place more monitoring stations situated closer to each other ~~to more so that~~ to increase the sample resolutions as well as produce more reliable data, as wind conditions are more likely to be constant over a small geographical area. Monitoring stations could also be established ~~on the~~ along the West coast of the South Island, where a large area of indigenous vegetation is not currently covered by current stations (as they as separated by the Southern Alps).

10 Alb. → unreliable
comb. → irregular surface → chaotic spin (Hyperion)
↳ atmosphere (hot) → const.
↳ comb.

QUESTION THREE: KUIPER BELT OBJECTS

Nept.: eccentric, tilt, eject?

The size and composition of the larger Kuiper Belt objects have been determined using changes in their albedos during their orbit.

Discuss how changes in albedo can be used to analyse the Kuiper Belt objects' surfaces and the shapes of their orbits. Furthermore, discuss the effect that Neptune has on the orbits of hot and cold classical Kuiper Belt objects.

Albedo is a measure of the reflectivity of a surface: the ratio of the amount of light reflected to the amount of light incident on the object. Albedo can be used to determine the ~~surfaces of distant objects~~ composition of distant objects ~~and~~ as different materials have different reflectivities.

The total amount of light reflected from an ~~a~~ astronomical object can be used to determine its size, as ~~the greater the~~ ~~it is reflected has~~ it is proportional to ~~the~~ its surface area of ~~a plate~~. However, this proved to unreliable ~~as~~ for determining the size of Eris, which was ~~much~~ thought to be larger than Pluto due to its brightness. This suggests that it reflects more light than ~~a~~ Pluto, and thus a higher albedo and different surface composition. Changes in albedo can provide further evidence ~~as to~~ for the composition of KBOs. A changing albedo such as that of Hyperion often suggest a ~~not~~ ragged, ~~surface~~ inconsistent surface and/or a chaotic spin, but this is unlikely for ~~KBOs they~~ Kuiper Belt dwarf planets, as they are ~~large~~ massive enough to ~~be~~ form into a spherical shape and have a

~~and~~ constant rotational period. Therefore, changes in albedo can suggest a changing surface composition.

Eris and Makemake are hot classical KBOs, having more elliptical and tilted orbits, so the distance from the sun changes drastically between aphelion and perihelion, leading to varying amounts of solar radiation reaching these Dwarf planets. ~~This may be as~~ The difference in the amount of energy absorbed by the surfaces may be enough to cause an ~~abo~~ atmosphere to ~~condense~~ condense and freeze at perihelion and ~~sot~~ melt or sublimate during aphelion.

Such a ~~composition for~~ Eris surface composition for Makemake and Eris can be suggested if they have changing albedos which vary periodically ~~correspondes~~ with a period corresponding to their ~~@~~ orbital period, as ~~frozen~~ a frozen ~~a atomo~~ atmosphere - with ice - has ~~a low~~ on average a higher albedo (0.5-0.7) than clouds (0-0.8). This can be further confirmed if a ~~spike~~ drop in surface albedo is observed ~~both~~ between aphelion and perihelion, as the atmosphere melts or ~~condenses~~ to ~~from~~ form a liquid ocean with an albedo of 0.07. This can happen ~~as~~ in Makemake as the frozen methane and ethane melts to form methane / ethane seas ~~betw~~ before boiling into ~~ga~~ gaseous methane / ethane. ~~The low albedos of~~ For this to occur, both conditions of

having ~~an or an~~ a relatively ~~a~~ eccentric orbit and an atmosphere must be met, so the changing albedo may be used to ~~deduce~~ deduce this about their orbits.

Conversely, ~~plut~~ Pluto has a less eccentric orbit, being a cold classical KBO as well as a relatively thin atmosphere of nitrogen, carbon monoxide and methane, which would allow most light to pass through and be reflected by ~~rock~~ its surface rock, having a generally lower albedo of 0-0.7 compared to ~~atmosphere~~ an atmosphere with clouds, ~~whic~~ with an albedo between 0 and 0.8. ~~This theory~~ therefore ~~be used to suggest that pl~~ plu Without ~~as~~ a changing albedo, it may be ~~suggested that~~ deduced that Pluto has a relatively circular ~~orbit~~ orbit with either no or a thin atmosphere.

~~Examples of~~ ~~Eris~~ While ~~more circular than~~ to the orbit of Pluto is more circular than that of Eris and Makemake, it ~~is is~~ is still relatively elliptical, passing within Neptune's orbit and ~~been~~ inclined compared to the rest of the solar system. the eccentricity of the orbits of hot classical KBOs may be explained by their relative proximity to Neptune, passing close enough for Neptune to exert a strong gravitational ~~influence~~ influence ~~one~~ on them. ~~When~~ these orbits may have been more circular ~~during~~ ~~on~~ immediately after their formation from planetessimals before

being disturbed by the outward migration of Neptune. The dwarf planets Eris, Makemake, and Pluto may be examples of KBOs large enough to avoid capture by Neptune (in contrast to some of the ice ~~giants~~ giants moons such as ~~Pluto~~ Triton), but still unable to escape its gravitational influence, ~~the~~ passing close ~~enough~~ enough that ~~Neptune~~ the force of Neptune's gravity is significant compared to the force exerted on them by the sun, ~~cold classical~~ coming close to the potential well of Neptune's gravity. KBOs further from Neptune ~~may be far~~ with longer orbital radii ~~so~~ are far enough that they never come within influence of.

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

QUESTION NUMBER

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QUESTION NUMBER

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Subject	Earth and Space Science scholarship	***Standard***	93104	***Total score***	21

Q	***Grade score***	***Annotation***
1	7	The candidate provided evidence for a 7 rather than a 8 because they did not discuss the effects of human interactions in enough depth to receive an 8. The rest of the answer is very well integrated, and they have done a thorough compare and contrast between the volcanic eruptions and wildfires.
2	7	The candidate provided some good explanations as to why New Zealand experiences higher than normal carbon dioxide absorption. However, they did not explore the importance of monitoring enough to be awarded an 8 for their answer.
3	7	The candidate had synthesised the information in the resource booklet to an outstanding level. However, they have not explained how Neptune's gravity effects the Kuiper Belt Objects and the subsequent result on changing albedo.