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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.

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Question	Score
ONE	
TWO	
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TOTAL	

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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 have a profound impact on the climate. Large wildfires release plumes of Carbon and smoke into the atmosphere, much like volcanic eruptions. The dense smoke and black Carbon effectively ~~x~~ increase the albedo of the Earth, reflecting away solar radiation. As a result, less radiation reaches and is ~~absence~~ absorbed by the surface, resulting in periods of cooling. ~~However, mo~~ However, moderate volcanic eruptions, particularly highly explosive ones such as those from caldera volcanoes with rhyolitic magma ~~will~~ will propel Carbon and other ashy particles high into the atmosphere as the gas trapped in the magma rapidly heats, expanding and throwing ash into the air. In comparison, wildfires transfer smoke up into the atmosphere through strong winds in the atmosphere. The lower ~~air~~ air is closer to the fire and thus warms, expanding and thus decreasing in density, causing the air to move upwards, taking Carbon and ash with it. This convection current carries wildfire smoke up into the atmosphere where it will block sunlight. In the troposphere, weather will ~~move most of the~~ get rid of most of the heavy smoke particles from the atmosphere through the water cycle as ash rains down onto the ground.* This will disturb ecosystems and organisms on the ground. Furthermore, as the sulfur dioxide reacts with water droplets in the atmosphere, sulfuric acid is formed, falling as acid rain. This will disrupt ecosystems as plants and organisms ~~who~~ that are not suited to living in the more acidic conditions die out. * Both ~~with~~ wildfires and eruptions will have this effect although eruptions like that of Mount Pinatubo likely releases more Sulfur dioxide, producing more acid rains. ~~Th~~ This will also contribute to ~~acid~~ ocean acidification, causing the ~~dissolution~~ dissolving of some calcium carbonate shells ($CaCO_3 + H^+ \rightleftharpoons Ca^{2+} + HCO_3^-$) which many organisms such as phytoplankton need to survive. The base of the foodchain, the death of phytoplankton due to both reduced sunlight for photosynthesis and scarcity of calcium carbonate will disrupt the entire foodchain, creating long-term impacts for the entire ecosystem. In contrast to the troposphere, smoke and Carbon ejected into the Stratosphere has a longer term impact as the air is stiller and there is little to no weather. As ~~volcanoes eject~~ most moderate eruptions eject soot particles up with more force than the wind currents of wildfires, it is likely volcanic eruptions cause a longer term and more widespread cooling effect as Carbon and other particles are ejected into the stratosphere and spread out, blocking sunlight for a long time. Huge force is required for this as Carbon is a heavy particle to get into the stratosphere. As the particles get into the stratosphere, they spread out across the globe, resulting in the world temperatures decreasing by an average of about 1°C over the two years after the Mt Pinatubo eruption. However, the Australian wildfires appear to have ejected smoke with more force than ~~suspected~~ expected as the fire-induced thunderclouds, created by the releasing of aerosols around which water ~~condense~~ droplets concentrate, forming clouds, climbed to an unprecedented altitude of over 32km into the stratosphere. Thus, it is likely the pressure differences in the air caused more violent wind shifts and smoke vortexes, carrying smoke higher into the atmosphere than predicted. This higher concentration of smoke particles in the ~~atmosphere~~ Streatosphere is likely why it has taken much longer for the smoke to dissipate than expected, with traces of smoke still detectable via satellites. This long-term effect will cause ~~so~~ more sunlight to be reflected away from the earth and more cooling. Although, the sheer volume of smoke ejected along with the force of the eruption is likely why moderate ~~erup~~ eruptions like Mt ~~Pinta~~ Pinatubo, ~~Tamb~~ Mt Tambora and Mt Krakatoa caused such dramatic cooling whereas the Australian wildfires ~~are~~ likely only cooled Earth by a small fraction of a degree. ~~In the long-term though, these events,~~ The positive feedback loop of the wildfires creating pyrocumulonimbus clouds which then create lightning, setting off further wildfires contributed to the large-scale impact of the wildfire, with the abrupt wind shifts helping spread the fire further.

In the long-term though, these events, ~~will~~ particularly the wildfires ~~not~~ will likely ~~cool~~ warm the earth as they accelerate global warming. Both wildfires and eruptions release mass amounts of greenhouse gases like carbon dioxide and sulfur dioxide. These may act as a negative feedback loop for climate change and wildfires by blocking sunlight and causing cooling, however, they also act as a positive feedback loop as they trap infrared radiation given off by the Earth in the atmosphere, warming the earth and increasing the risk of future wildfires. Volcanic eruptions operate in the slow Carbon Cycle, releasing CO_2 into the atmosphere which will then be absorbed by plants, organisms, the ocean and other Carbon sinks. When these organisms die, they ~~sk~~ sink ~~are~~ and are eventually compressed into rock which can then melt and become magma again. Meanwhile, ~~the~~ forest fires release Carbon stored in the biological Carbon reservoir into the atmosphere. By causing the huge reduction in trees, there are less plants available to absorb CO_2 from the atmosphere. ~~creating~~ Furthermore, as the ground is now exposed, the Earth's surface absorbs more solar radiation. The combination of both these positive feedback loops accelerating climate change will also ~~make~~ cause higher temperatures and greater risk for further forest fires. The CO_2 released into the atmosphere will be absorbed by the ocean, further acidifying the ocean and causing the death of phytoplankton. A key part of the

biological carbon sink, this will result in even less CO_2 absorbed from the atmosphere especially as warmer oceans absorb less CO_2.
Volcanic eruptions also cause these effects but are caused by the subduction of plates and outpouring of magma. Climate change has little effect on these so while wildfires will ~~becomes mo~~ become more common and impact us more in the future, eruptions will likely remain stable.
As humans have burned mass amounts of fossil fuels, we have released a lot of CO_2 into the atmosphere and accelerated climate change, ~~also~~ especially as we clear forests for methane-producing agriculture. ~~and~~ This warming of the Earth has undoubtedly increased the risk of forest fires as high temperatures make it easier for spontaneous fires to start. On the other hand, it is unlikely volcanic eruptions have been heavily impacted by human interactions as the subduction and melting of tectonic plates occurs deep within the Earth.
Human-caused climate change has also resulted in more extreme weather patterns, with drier summer seasons, further increasing the risk and potential damage from a wildfire.
* The clouds of smoke and chemicals released into the atmosphere will also reduce air quality in the short-term, negatively impacting animals, particularly larger animals with more air intake, affecting the functioning of ecosystems.

The warming of the atmosphere due to climate change caused by wildfires and eruptions also warms the ocean, slowing thermohaline circulation as the difference in water densities decreases and less CO_2 is stored in the deep water by downwelling, further accelerating climate change.

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.

* Carbon absorption estimates are estimated from measuring changes in the circumference of trees along with forest height and land cover ~~to~~ at research sites to extrapolate across the country. ~~It~~ It is possible these estimates are inaccurate, especially as research informing ~~the~~ previous estimates were conducted largely in the Northern Hemisphere. New Zealand forests have different species and may be different, with trees growing differently such that although the circumference of the tree may not have changed much, growth was still occurring and more CO_2 was absorbed than expected. Furthermore, New Zealand's largely warm climate also means a lot of our native forest continues growing in winter, unlike the many trees in the Northern Hemisphere that lose their leaves and halt growth in winter. Thus, CO_2 absorption continues in winter, ~~so~~ such that NZ forests absorb more CO_2 than expected. It is also possible NZ native forests, even when mature has higher rates of new growth with plant species dying and replenishing faster, such that CO_2 absorption is not like that of a standard ~~so~~ mature forest but closer to that of recently planted forests with peak growth. If this is the case, this discovery could be vital in the fight against climate change as New Zealand native forest trees could be planted elsewhere, creating new forests of rapid carbon absorption that could reduce net carbon emissions in other countries, decreasing the concentration of CO_2 ~~and~~ in the atmosphere and slowing climate change. Or, alternatively, it is possible this is part of a worldwide trend where environmental changes, such as the increased temperatures is causing more absorption of CO_2 by

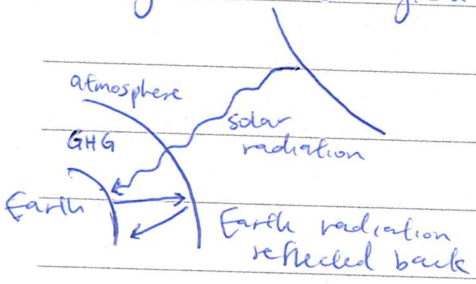
forests. This may be because the altered conditions are causing more plants to die, making space for new trees to grow, ~~and~~ absorbing more CO_2 as new plants undergo peak plant growth.
If this is the case globally, it would encourage revisions of current climate change models to account for the increase in Carbon absorption by forests.
While the existing monitoring stations have been valuable, the adding of new monitoring stations will allow the collection of more accurate data. By placing stations at the areas of high Carbon emission, we can get a more accurate estimate of NZ's Carbon balance. As the largest city and population centre by far, Auckland is expected to release a large portion of NZ's Carbon emissions. Thus, by establishing monitoring sites across Auckland, emissions from ~~to~~ urban processes like transportation and industry can be measured. ~~Furthermore,~~ This data could be applied to other high density urban areas such as central Wellington. It would also give a more accurate estimate of the Carbon absorption of urban green space in comparison to native forests. If it is much less, it would encourage the establishment of more protected wildlife reserves rather than the construction of manicured urban lawns and parks.
However, while traditional estimates of ~~Carbon~~ greenhouse gas emissions have used estimates from things like transport, New Zealand is unique in that a large portion of emissions come from our large agriculture industry. ~~Thus,~~ Thus, these traditional estimates are likely to be innaccurate. The establishment of a monitoring site at Winchmore will reveal more accurate estimates as this is at the ~~k~~ heart of the NZ dairy agriculture. With dairy being a huge NZ industry, livestock is a large source of methane emissions. Methane is much ~~better~~ more (about 25 times) effective at trapping heat in the atmosphere than CO_2 so accelerates climate change at a faster rate. By establishing the Winchmore monitoring site, the emissions of

dairy farms could be more accurately measured and extrapolated ~~acc~~ across the country to find ~~the~~ a more accurate measure of our greenhouse gas emissions. Furthermore, this could be compared to emissions from cities like Auckland to inform government policies and discern whether a majority of our emissions comes from urban infrastructure and transportation or rural agriculture.

The establishment of more monitoring sites in general will also be beneficial. As there is now less distance between monitoring sites, any difference in greenhouse gas concentrations in the air could be attributed to a smaller area, giving more accurate estimates on where NZs main carbon sinks and emitters are. For example, the station ~~at~~ in the central North Island could compare greenhouse gas concentration readings with the station in ~~the~~ Maunga Kākaramea to further ~~inv~~ investigate the 'strong sink' from Maunga Kākaramea. If it is indeed found to be a strong carbon sink, more investigation would be encouraged to find what is unique about Maunga Kākaramea that makes it so effective at ~~greeh~~ greenhouse gas ~~a~~ absorption and whether this could be applied across NZ and the world to absorb more greenhouse gases from the atmosphere and slow climate change. Furthermore, if native NZ plant species are more effective at absorbing carbon, research should be started into what specific species are the most effective so that this could be spread into other areas and into other countries.

The establishment of new monitoring stations at existing weather stations is also beneficial. With the added weather information, a more accurate assumption of where exactly the air came from can be ascertained such that the change in carbon concentration can be accurately attributed to the emission/absorption of precise areas. Prolonged monitoring will also allow us to predict how NZs carbon balance will change in the future, helping build an accurate climate change model and informing steps that must be taken to ~~meet~~ meet our climate emission goals. Overall, this ~~s~~ new estimate of NZ Carbon absorption rates is a positive sign that signals the need for more ~~is~~ research and more intensive protections for native forests.

* Greenhouse gases in the atmosphere trap infrared radiation such that less heat radiated from the Earth is able to escape to space. Thus, increased concentrations of greenhouse gases in the atmosphere ~~accelera~~ warm the Earth and accelerate climate change. Forests act as Carbon reservoirs, removing CO_2 from the atmosphere in photosynthesis and storing it as biological matter, slowing the rate of climate change.



QUESTION THREE: KUIPER BELT OBJECTS

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.

As changes in KBOs albedos are measured, hypotheses can be made about their surfaces and orbits.
~~As~~ Hot classical KBOs become closer or further away from the Sun ~~depending on~~ during ~~their orbit~~ due to their tilted elliptical orbit. When they move closer to the Sun, they receive more solar radiation and warm up. This will change the composition of its surface. For example, as Eris moves further away from the Sun, its atmosphere freezes, this will cover the surface with fresh snow (likely made up of methane and other gases instead of water), increasing its albedo. This decrease in albedo could be measured from Earth and used to find when - and the extent ~~to~~ to - Eris moves away from the Sun. If the change in albedo is dramatic it is likely surface compositions, temperatures and tilt of the orbit is also dramatic. However, the development of an atmosphere could also increase a planets albedo as clouds and a thick atmosphere reflects light away. Changes in albedo are not a very reliable measure of orbit shape as albedo can change for other reasons ~~too~~. ~~For~~ For example, impacts from other ~~k~~ KBOs or asteroids could leave the object scarred, with cavities and craters scattering light and decreasing albedo. These collisions could also deposit substances such as Carbon, changing the surface composition and changing albedo. Although most KBOs are cold enough to prevent geothermal activity, ~~it~~ it is possible volcanic eruptions and other natural processes could also deposit other substances onto the surface, with the formation of rock and soot from eruptions usually decreasing albedo.* Thus, ~~to~~ albedo changes alone could not discern the KBOs

surfaces but could aid in estimates. Changes in orbit shape would require measurements of albedo for an extended period of time. ~~Gradual~~ Cyclical, consistent changes in albedo will give the best estimate of orbit shape as these changes are unlikely to be due to 'random' events like collisions and eruptions.* Neptunes gravity has little effect on the orbit of cold classical KBOs. However, Neptune's strong gravitational pull will affect hot classical KBOs. These KBOs have an orbit affected both by the gravitational pull of the Sun and of Neptune. Although the sun has a much greater mass than Neptune, the much closer proximity of Neptune to KBOs mean both affect the movement of KBOs. The gravity of Neptune will distort the relatively circular orbit path and cause hot KBOs to have a tilted, more eliptical ~~ot~~ orbit. This will cause changing temperatures as the objects move closer and further from the Sun, changing the composition and processes of these KBOs. Furthermore, the gravity of Neptune may cause tidal flexing, 'squeezing' the KBO and causing friction, generating heat. Some smaller KBOs that pass close to Neptune may even be captured in Neptune's orbit, forming rings.

* KBOs observed with no consistent changes in albedo ~~and~~ are likely to have a circular orbit in plane with the planets as they likely have a fairly consistent surface ~~tem~~ and temperature. i.e. these are likely to be cold classical KBOs.

* Albedo is also especially difficult to use for KBOs as they are so far away. Thus, the albedo of the whole surface must be measured. If portions of the surface have a different composition or shape, the averaged-out albedo of the entire object could give confusing and innaccurate estimates as to ~~the~~ its surface. This is particularly true for smaller

KBOs that do not have enough mass and gravity to form a sphere and are misshapen, ~~with~~ changing how it will reflect light. Thus, a KBOs mass and diameter would be ~~to~~ very helpful in accurately ~~ascertaing~~ ascertaining its surface and orbit. However, albedo is an unreliable way to measure a KBOs size ~~mass~~, as seen when it was used to measure the size of Eris. Eris, with a higher brightness ~~albedo~~ than pluto was estimated to be larger. However, this increased brightness was mostly due to Eris' higher albedo, with an icier, more reflective surface than Pluto - Eris is actually similar in size to pluto.

However, if a KBOs ~~a~~ albedo could be determined, this could then be ~~used to~~ compared against the object's brightness to determine a more accurate estimate of its size. KBOs with a high brightness in comparison to its albedo are likely larger, and so able to reflect more light. The size of a KBO could then ~~tat~~ allow scientists to make assumptions about its surface and orbit. Larger KBOs like the dwarf planets have been shown to be hot classical KBOs with tilted eliptical orbits. Thus, if an object is determined to be smaller, ~~it is likely~~ with an albedo that doesn't change cyclically, it likely has a 'normal' orbit with a fairly circular orbit in plane with the planets.

The effect of Neptune ~~on~~ on KBOs will be greatest when objects are closest to it as its gravitational strength is proportional to the inverse square of the distance between ~~the~~ the objects' centre of masses. As the KBO passes closer to Neptune, it will be attracted more strongly to it, altering its orbit path. Neptune is a gas giant so has a high mass so the effect of this gravitational pull will be quite significant. However, as all classical KBOs have a similar average distance from the Sun of about 40 to 50 AU, it is unlikely that the distance from the sun is what separates hot and cold classical KBOs even though objects further away from Neptune will experience a weaker attraction to it and are less likely to become hot classical KBOs.

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