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NEW ZEALAND QUALIFICATIONS AUTHORITY
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Scholarship 2022
Earth and Space Science

RESOURCE BOOKLET

Refer to this booklet to answer the questions for Scholarship Earth and Space Science.

Check that this booklet has pages 2–7 in the correct order and that none of these pages is blank.

YOU MAY KEEP THIS BOOKLET AT THE END OF THE EXAMINATION.

Resource for
QUESTION ONE: WILDFIRE EFFECTS

New research has found Australia's disastrous 2019–20 fire season blew so much smoke into the atmosphere that it blocked sunlight from reaching the Earth's surface, potentially causing a brief global cooling effect comparable to a moderate volcanic eruption.

These raging wildfires in southeast Australia produced fire-induced thunderclouds, known as pyrocumulonimbus clouds, or pyroCbs; in one case climbing to an unprecedented altitude of more than 32 km into the stratosphere.

Figure 1
https://www.trendsmap.com/twitter/tweet/1410790896346578946

Pyrocumulonimbus clouds infuse the stratosphere with a number of chemicals. Most visible are the black clouds of carbon, but there are other products of the fires, such as carbon dioxide and sulfur dioxide.

Pyrocumulonimbus clouds and the large fires that create them can cause their own weather systems to form. These can be self-sustaining vortexes that can create abrupt wind shifts, which, due to their unpredictability, pose great danger to firefighters and property.

Findings published recently show that smoke acted like a planetary shade, reducing the amount of sunlight hitting Earth's surface for several months. A number of recent examples of large wildfires that have formed these clouds include the 2009 Australia Black Saturday, British Columbia 2017, and Siberia 2020.

After the Australian pyrocumulonimbus outbreak occurred, the largest of the smoke vortexes dissipated after a year in the atmosphere. Traces of the smoke from the event are still detectable via satellites. It's unclear how much longer it will take for that smoke to dissipate completely, but it's already taken much longer than anyone would have expected. How much the fires actually cooled Earth's surface during this time isn't known, although the effect likely amounted to a small fraction of a degree.

On 15 June 1991, there was the notable eruption of Mount Pinatubo in the Philippines. The large eruption pushed vast amounts of ash and other gases into the stratosphere, including around 15 million tons of sulfur dioxide gas. In the atmosphere, sulfur dioxide reacts with water to form a hazy layer of sulfuric acid droplets. Over the course of the next two years, strong stratospheric winds spread these aerosol particles around the globe. Data collected following the eruption showed that the mean world temperatures decreased by about 1 °C over the two years following the eruption.

Other large volcanic eruptions that led to subsequent years of cold climate conditions include:

Eruption	**Climatic effects**
1783 Laki, Iceland	Europe and eastern USA recorded the lowest ever winter average temperature in the following year, almost 5 °C below average.
1815 Tambora, Indonesia	Resulted in an extremely cold spring and summer in 1816, which became known as the year without a summer. Snowfalls and frost occurred during the summer months in the Northern Hemisphere.
1883 Krakatoa, Indonesia	Months after the eruption, the world experienced unseasonably cool weather and brilliant sunsets.

Figure 2

Figure 3

Adapted from: https://hondasxs.com/threads/yellowstone.14282/

Compared to the recent benchmark for large volcanic eruptions that alter the climate, the Mount Pinatubo eruption, the Australian bush fire event was considerably smaller.

Resource for
QUESTION TWO: AN UNEXPECTED BALANCE

New Zealand's forests and other land areas may be absorbing up to 60% more carbon dioxide than has been calculated, with much of this uptake likely occurring in native forests. Carbon uptake this strong is usually associated with peak growth of recently planted forests, and tends to slow as forests mature. This amount of uptake from relatively undisturbed forest land is remarkable, and may be caused by processes unique to New Zealand or be part of a wider global story.

Greenhouse gas emissions and uptake have traditionally been estimated using methods such as estimating carbon dioxide emissions from transport, based on the amount of fuel burnt by New Zealand vehicles. Also, forest carbon uptake has been estimated by measuring changes in the circumference of trees in a number of set locations. This is then combined with forest height and land cover information, and scaled up across the country.

In the last several years, a project (CarbonWatchNZ) has been launched to measure CO_2 and methane (CH_4) in the air above New Zealand at a network of sites around the country. By combining these atmospheric measurements with information about winds and air movement over our cities, forests, and farmlands, CarbonWatchNZ will measure the greenhouse gases we are emitting, and how much carbon our landscapes absorb.

When these "top down" atmospheric observations are added to existing estimates from the ground up, New Zealand will be able to build the world's first complete picture of a country's carbon profile.

Figure 1: The Baring Head station, which overlooks Cook Strait, has been operating since 1972, and the data collected there makes significant contributions to our global understanding of greenhouse gases.

https: / /kapitiindependentnews.net.nz/unique-chance-to-visit-the-historic-baring-head-lighthouse/

Prior to this study, there was a network of atmospheric monitoring stations: Baring Head near Wellington, Lauder in Central Otago, and Maunga Kākaramea near Rotorua. The research also reported that CO_2 absorption does not shut down completely during winter. This was in contrast to traditional thinking that there would be very little absorption in winter months. Research that has informed previous estimates had been conducted largely in the Northern Hemisphere.

The amount of carbon dioxide in the atmosphere is measured in parts per million (ppm). The datasets from these stations include some of the longest-running greenhouse gas measurements in the Southern Hemisphere.

Researchers can estimate how much carbon dioxide arrives in the country by taking measurements when the wind is arriving at the stations after travelling mostly over the ocean. When a south-westerly wind is blowing, as in Figure 2, Lauder and Baring Head measure essentially the same volume of air, but at different times. Any differences in carbon dioxide concentration reflect the sources and sinks of carbon dioxide between the two stations. And any difference between the measurement at Lauder and the amount of carbon dioxide arriving in the country reflect absorption and emission in the lower South Island. Overall, the absorption of carbon dioxide is stronger than expected. If so, this makes the amount of carbon dioxide uptake from relatively undisturbed mature forest with native plants and animals remarkable. Early findings have also found an unknown "additional strong sink" from Maunga Kākaramea.

The CarbonWatchNZ is looking at the four landscapes that are most important to New Zealand's carbon balance – our native and exotic forests, our farmland and cities. There are now new monitoring stations at key sites such as Fiordland, the central North Island, Canterbury, and across Auckland. These stations will enable CarbonWatchNZ to track greenhouse gas emissions and uptake across these four target landscapes.

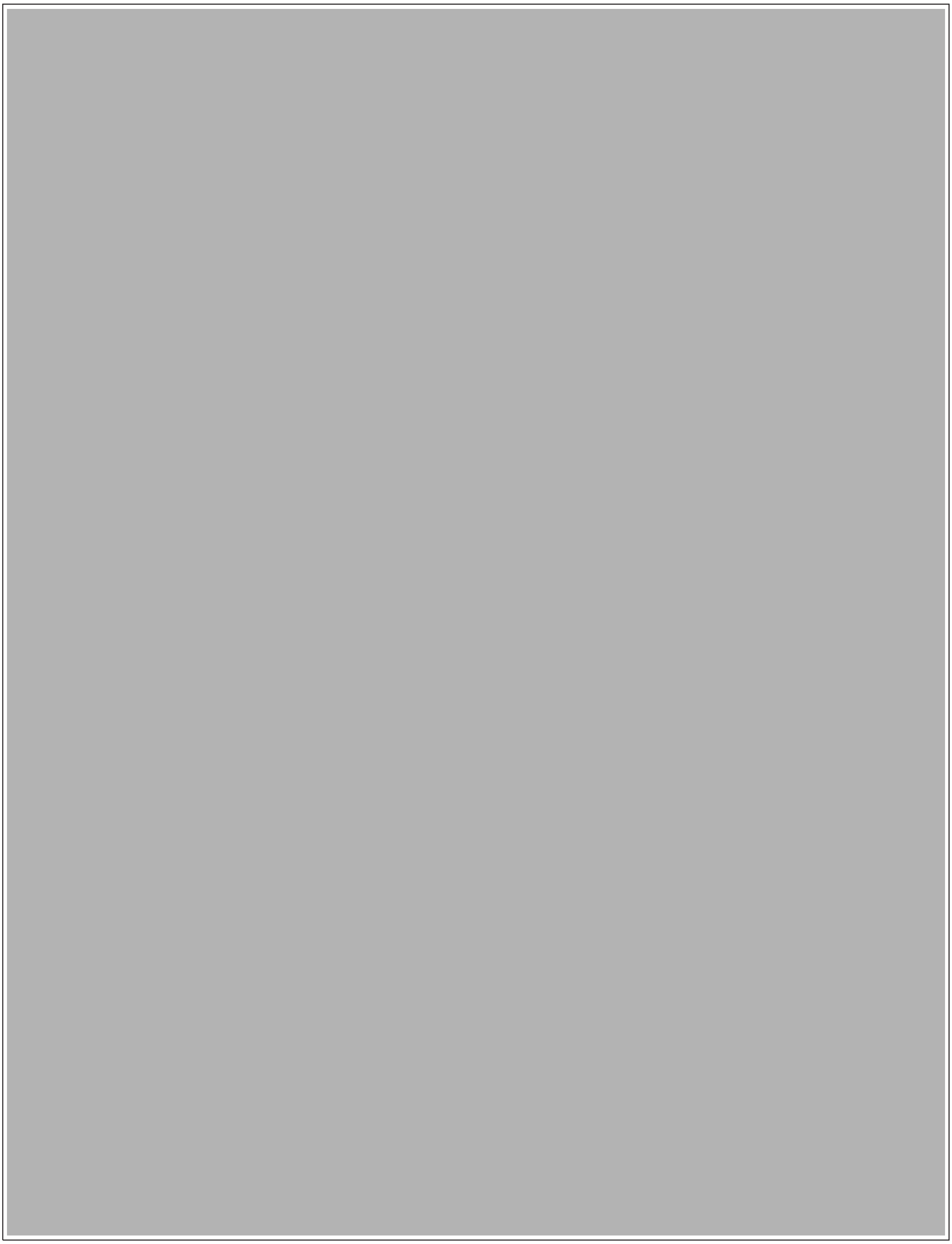

Figure 2
Adapted from: www.pce.parliament.nz/media/196926/land-cover-2012.png

Furthermore, a new station has been established at Winchmore, near Ashburton, which is considered to be a heart of dairy agriculture for the country. The station will measure carbon dioxide and methane emissions. The site benefits from a long-running weather station, providing an excellent dataset on precise local conditions and wind directions.

NIWA will also establish monitoring stations in urban environments such as Auckland. Cities are carbon dioxide hotspots, primarily from fossil fuels burned for transportation and industry. Urban green space absorbs some of the emissions, but more data is needed to ascertain how much.

Resource for
QUESTION THREE: KUIPER BELT OBJECTS

The Kuiper Belt is a large region of faint, icy objects beyond the orbit of Neptune. The Kuiper Belt is about 30–55 AU from the Sun. (1 AU, or astronomical unit, is the distance from Earth to the Sun, which is about 150 million kilometres.) This distant region is probably populated with hundreds of thousands of icy bodies larger than 100 km across, and an estimated trillion or more comets.

Figure 1

Source: https://solarsystem.nasa.gov/news/792/10-things-to-know-about-the-kuiper-belt/

Objects in the Kuiper Belt (KBOs) are presumed to be remnants from the formation of the solar system about 4.6 billion years ago.

Pluto may be the best known of the larger objects in the Kuiper Belt. It was discovered in 1930 and was controversially downgraded to dwarf planet status in 2006 after the discovery of Eris and Makemake in 2005. This is due to the International Astronomical Union creating a new class of objects called dwarf planets, and placing Pluto, Eris, and Makemake, as well as the asteroid Ceres, in this category. By definition, a planet has to clear its orbital pathway of large objects around it, and since Pluto could not do this, it was downgraded.

Figure 2

Adapted from: www.thegreatcoursesdaily.com/kuiper-belt-one-of-the-largest-structures-in-our-solar-system/

Because KBOs are so distant, their sizes and compositions are difficult to measure. The calculated diameter of a KBO depends on assumptions about how reflective the object's surface is.

When Eris was discovered in 2005, its brightness led scientists to suspect that it was larger than Pluto. In 2010, when Eris crossed in front of a faint star, astronomers watching were able to make a better estimate of its size and decided that it wasn't larger after all.

Astronomers use albedo to measure the reflectivity of a KBO's surface. The amount of light that strikes the KBO is calculated, and the reflected light measured. Because of the distance to the KBOs, the albedo of the whole surface is measured. An albedo of 1.0 indicates a bright object that reflects all of the light, whereas an albedo of almost zero means that most of the light is absorbed.

Surface on Earth	Typical Albedo
Charcoal	0.04
Deep shadowed cavities	0.01
Clouds	0–0.8
Ocean	0.09
Rock	0–0.7
Ice	0.5–0.7
Fresh snow	0.8–0.9

Figure 3

Although they are icy, KBOs do not reflect a lot of light, and have an albedo of about 0.05. However, Eris and Pluto both have atmospheres. Pluto's atmosphere is thin, and consists of nitrogen, carbon monoxide, and methane. Eris's atmosphere freezes and condenses during its orbit around the Sun.

Makemake has been found to have frozen methane and ethane on its surface, and has a reddish-brown colour. Makemake is also thought to develop an atmosphere during its orbit.

There are two main groups of objects in the classical Kuiper Belt, referred to as "cold" and "hot". These terms don't refer to temperature – instead, they describe the orbits of the objects, along with the effect of Neptune's gravity on them.

Cold classical KBOs have relatively circular orbits that are not tilted much away from the plane of the planets and have little interaction with Neptune's gravity. Hot classical KBOs have more elliptical and tilted orbits, due to gravitational interaction with Neptune. All classical KBOs have a similar average distance from the Sun of between about 40 and 50 AU.

Figure 4

Adapted from: www.quora.com/Do-the-planets-of-our-solar-system-orbit-the-sun-on-the-same-plane-and-do-they-orbit-in-the-same-direction

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