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NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

New Zealand Scholarship
Science, 2004

2.00 pm Thursday 18 November 2004

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.

For all questions, the answers should be written or drawn clearly with all logic fully explained.

If you need more space for any answer, use the pages provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–22 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.

For Assessor's use only **Outcome Description** Students will use their knowledge of Science and its methodology to demonstrate higher level critical thinking by analysing and evaluating scientific information in a range of integrated contexts.
Scholarship Criteria The student will: • critically analyse integrated contexts using the knowledge and methodology of science.
Scholarship with Outstanding Performance Criteria In addition to meeting the Scholarship criteria, the student will: • consistently demonstrate perception in the critical analysis of integrated contexts.
Overall Level of Performance

You are advised to spend 3 hours answering the questions in this booklet.

QUESTION ONE: SUNSPOTS, RADIOACTIVE ISOTOPES AND EARTH'S CLIMATE CYCLES

The Earth is being continually bombarded by high-energy cosmic rays from space. The high-energy particles in cosmic rays interact with molecules in the Earth's atmosphere, producing radioactive isotopes. The two main isotopes produced are beryllium-10 (Be-10) and carbon-14 (C-14).

The Sun has a magnetic field that is able to deflect some of the cosmic rays from Earth. The greater the magnetic activity of the Sun, which strengthens the magnetic field, the greater the amount of cosmic rays that are deflected. The Sun's magnetic activity can be deduced from sunspot numbers, which follow an eleven-year cycle. More sunspots imply a more magnetically active Sun.

Beryllium-10 and carbon-14 can be used to measure solar activity.

- Beryllium-10 is either made in the atmosphere or produced within some minerals at the Earth's surface. Beryllium-10 made in the atmosphere falls with rain to the ground, where it is trapped in layers of ice. Polar ice cores from Greenland and Antarctica have been analysed for beryllium-10 atoms. Beryllium-10 decays to boron-10 with a half-life of 1.52 million years.
- Carbon-14 is incorporated into living tissue by photosynthesis and can be measured by analysing the amount of carbon-14 in the annual growth rings produced by trees. Carbon-14 decays to nitrogen-14 and has a half-life of 5730 years.

Beryllium-10 and carbon-14 are usually measured by a technique called mass spectrometry which counts the number of Be-10 or C-14 atoms.

Sunspot numbers have been calculated back to 850 AD by analysing the levels of these isotopes. Variation in both beryllium-10 and carbon-14 levels shows that the sun's activity is not constant. There is recent evidence that the Sun's magnetic activity has not only the eleven-year sunspot cycle but some long-term cycles as well. These longer cycles range from between 200 and 600 years, to 100 000 years.

Note: Both ice cores and tree rings show annual cycles.

- Tree rings: Each year a tree adds a layer of wood, forming the annual rings that can be seen when viewing a cross section of a tree trunk or branch. Cross correlation with different tree samples, living and dead, can mean that tree ring dating can extend back 10 000 years.
- Ice cores: Ice cores can be taken from depths of at least 2500 metres and can contain an uninterrupted, detailed record extending back up to 700 000 years ago.

(a) Evaluate the use of beryllium-10 and carbon-14 to determine the different solar cycles. Consider in your answer the significance of:

- the half-life of each isotope
- the advantages and disadvantages of using each isotope
- the samples that are necessary
- the cross checking of results required.

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Graph One: Sunspot activity as deduced from sunspot observations, beryllium-10 and carbon-14 levels

[For copyright reasons, this resource cannot be reproduced here. See below.]

The horizontal bars with attached arrows indicate the times of great minima (cooler temperatures) and maxima (warmer temperatures) of climate.

- MM – Medieval maximum
- Wm – Wolf minimum
- Sm – Sporer minimum
- Mm – Maunder minimum
- Dm – Dalton minimum

Adapted from: Usokin, I G, S K Solanki, M Schussler, K Mursula & K Alanko (2003) 'Millennium-scale sunspot number reconstruction: Evidence for an unusually active sun since the 1940s', *Physical Review* Letters 91(21).

The Earth is currently in a warm interglacial period called the Holocene that began about 11 000 years ago. Since the start of the Holocene, the Earth has gone through about seven major warming and cooling trends, some lasting as long as 3000 years, some as little as 400 years. The most recent warm period is the Medieval maximum period, from about 1150–1250 AD, during which average sunspot numbers are estimated to have been 44 per year. Telescopic observations of sunspots began in the early 1600s AD.

No sunspots were observed during an interval known as the Maunder minimum (1645–1715 AD). This was called the Little Ice Age and temperatures plummeted worldwide.

To account for the temperature changes, it has been proposed that ions produced by cosmic rays act as condensation nuclei for larger suspended particles. As a result, cloud coverage increases and temperatures on the Earth's surface fall.

There has also been a sharp increase in the number of sunspots since the beginning of the 20th century. While the average number was around 30 per year prior to 1900, and about 60 per year between 1900–1944, it is now around 76 per year.

(b) Discuss the relationship between temperature, sunspot numbers and the levels of carbon-14 and beryllium-10. Consider the implications for the Earth's climate of a more magnetically active sun.

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QUESTION TWO: THE TREATMENT OF OIL SPILLS

Oil spills can be cleaned up in marine environments in a number of ways. Two of these are

- the use of detergents
- bioremediation.

Detergents can be directly applied to oil spills in the open ocean. They assist with breaking up the oil slicks by removing oil from the surface of the water, so that the oil is dispersed as an emulsion in the water column.

(a) Discuss the chemistry involved in breaking up oil spills. Use a diagram if you wish. Include a discussion of the different types of detergent that might be used.

Bioremediation involves the application of nutrients to enhance the rate of growth and division of naturally occurring bacteria that can convert hydrocarbons from oil spills into less toxic compounds. Through the action of such bacteria, hydrocarbons are completely degraded to carbon dioxide, water and other simple non-toxic compounds. These bacteria are already in the environment because:

- bacteria break down a large amount of hydrocarbon contamination naturally found in the environment
- decades of small spills from leaky boats have selected for bacteria that can break down crude oil.

(b) Discuss the key factors that need to be considered in the design of an investigation to evaluate the effectiveness of different naturally occurring bacteria in breaking down crude oil.

You are not required to design an actual experiment, but examples of specific techniques can be used to illustrate the relevant points.

The natural ability of these bacteria may be enhanced by genetic engineering so that they can break down a wider range of hydrocarbons. However, many scientists question the release of genetically engineered organisms into the environment as they may be in competition with the naturally occurring organisms.

(c) Evaluate the use of genetically engineered bacteria as compared with naturally occurring bacteria for environmental clean-ups. Consider:

- the relative effectiveness of each type of bacteria
- the possible impact on the environment
- the risks of gene transfer
- ethical considerations.

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QUESTION THREE: GEOLOGY OF THE SEA FLOOR

Sonar mapping of the sea floor has important applications. Sonar can be used to work out the depth of the sea floor, but it is now also used to give accurate information about the nature of the sea floor by measuring the backscatter of the returned signals (see Diagram One A). Backscatter strength is the measurement of how strongly an acoustic pulse reflects from the sea floor and back to the transmitter. This scattering depends on the composition of the substrate, eg mud, sand, gravel, bedrock, or a mixture of these, and the angle at which the beam is emitted from the transmitter as shown in Diagram One B. Scattering also depends on the contours of the sea floor.

The strength (BS) of the pulse reflected back to the transmitter is measured and shown in Diagram One C.

This technique has been used to map the sea floor near the Kermadec Ridge, which is over 3000 m deep in places.

Diagram One: Showing the principle of sea floor acoustic backscattering

[For copyright reasons, this resource cannot be reproduced here. See below.]

Source: Y Le Gonidec, G Lamarche, I Wright. *NIWA Water and Atmosphere*. Vol 11 No. 4 December 2003

(a) Discuss factors that must be taken into account when sonar backscattering is used to determine the depth, the composition and the contours of the sea floor.

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The Kermadec Trench has formed where the Pacific plate is subducting under the Indo-Australian plate. Oceanic crust is subducting under oceanic crust. As a result, a number of active volcanoes are located along the Kermadec Ridge and sediments are accumulating from their eruptions. Many of these volcanoes are andesitic but some erupt dacite, an extrusive igneous rock rich in silica.

Map One: Geological map of the sea floor north of New Zealand

[For copyright reasons, this resource cannot be reproduced here. See below.]

Glen Coates, *The Rise and Fall of the Southern Alps*, Canterbury University Press, Christchurch, 2002

Photo One: An active volcano from the Kermadec ridge

[For copyright reasons, this resource cannot be reproduced here. See below.]

'Managing the seabed with multibeam mapping', *NIWA Water and Atmosphere* Vol 11 No. 4 p9

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The volcano in Photo One is 2000 m below sea level and 100 km to the west of the Kermadec Trench. Surprisingly it is an active caldera volcano and dredged samples from the volcano have revealed young rocks identified as dacite.

(b) Compare the processes that occur and the main rocks that are usually formed when:

- oceanic crust is subducted under continental crust
- oceanic crust is subducted under oceanic crust.

(Use diagrams in your answer if this will help.)

(c) Discuss reasons as to why some volcanoes in the Kermadec Trench, such as that shown in Photo One, erupt dacite and form calderas.

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QUESTION FOUR: ACCEPTABLE RISKS OF MEDICAL X-RAYS

Table One: The increase in the risk of cancer from the radiation doses from typical X-rays compared with radiation doses from natural sources

Table Two: Risks of daily living

Table Three: The risks of X-ray doses used in research compared with the research consequences

Tables from: http://www.ncht.org.uk/medphys/index.asp?nav=menu&page=rrir

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Low-level background radiation has always been present in our daily lives and can therefore be used as a means of assessing the risk from artificially produced radiation. The annual natural background dose in a city in England is about 2.7 milliSieverts (mSv), coming from cosmic rays (14%), food (12%), the ground (16%) and radon gas (58%). A chest X-ray is equivalent to about 10 days of background radiation and a dental X-ray about 4 days.

X-rays and gamma rays can cause the breakage of covalent bonds, leading to a variety of damaging effects on DNA, often resulting in cancer.

Medical X-rays are the biggest source of artificially-produced radiation exposure and are being used with increasing frequency. The growing use of CT (computed tomography) scans, which also use X-rays, is adding to exposure. One CT scan is equal to 100 chest X-rays. Researchers have found that medical X-rays are to blame for many thousands of fatal cancers worldwide each year. The problems arise when this technology is overused, without an accompanying appreciation of the risks.

However, X-rays have highly significant medical applications and have made a huge contribution to human health through their use in surgery, treatment of bone fractures, location of cancerous tumours, and diagnosis of internal diseases. But they do present quantifiable risks, and on many occasions the use of X-rays may not be required.

In medical research, patients may receive X-rays to help researchers obtain a general understanding of medical problems such as the progression of a disease or the effect of a drug. For example:

- bone scans may be given as part of a trial to determine the prevalence of osteoporosis in the population
- cancer patients trying a new chemotherapy treatment may be given multiple CT scans as a follow up.

Evaluate the information in the above paragraphs and Tables One to Three on page 16, and give an informed opinion on the safety levels of medical procedures involving radiation on people, and the circumstances under which these procedures should be used for research. You may wish to consider each of the four risk categories as a starting point.

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Extra paper for continuation of answers if required.
Clearly number the question.

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