

Victorian Certificate of Education
2019

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Letter

ENVIRONMENTAL SCIENCE

Written examination

Friday 8 November 2019

Reading time: 11.45 am to 12.00 noon (15 minutes)

Writing time: 12.00 noon to 2.00 pm (2 hours)

QUESTION AND ANSWER BOOK

Structure of book

Section	Number of questions	Number of questions to be answered	Number of marks
A	30	30	30
B	10	10	90
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied

- Question and answer book of 31 pages
- Answer sheet for multiple-choice questions

Instructions

- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination

- Place the answer sheet for multiple-choice questions inside the front cover of this book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Multiple-choice questions**Instructions for Section A**

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

Which one of the following is a non-fossil energy source?

- A. nuclear
- B. natural gas
- C. brown coal
- D. coal seam gas

Question 2

Which one of the following gases contributes the most to the natural greenhouse effect?

- A. methane
- B. water vapour
- C. sulfur dioxide
- D. carbon dioxide

Question 3

Which one of the following gases contributes the most to the enhanced greenhouse effect?

- A. ozone
- B. methane
- C. nitrous oxide
- D. carbon dioxide

Question 4

What is the approximate percentage of carbon dioxide in the atmosphere?

- A. 0.04%
- B. 0.3%
- C. 3%
- D. 21%

Question 5

Which one of the following statements about the atmosphere is correct?

- A. Weather occurs in the troposphere.
- B. The lowest layer is the stratosphere.
- C. Temperature rises with increasing altitude.
- D. Greenhouse gases maintain the temperature of the lithosphere.

Question 6

What does the term 'ecosystem diversity' refer to?

- A. the variety of different species within a particular ecosystem
- B. the number of and variation in ecosystem types within a region
- C. a community of organisms and their physical environment interacting together
- D. the collection of biological and physical requirements necessary for an organism to grow and reproduce within various habitats

Question 7

The King Island emu species existed only on King Island and was first identified by Europeans in 1802. Hunting and scrub fires caused by early European settlers led to the numbers of King Island emus dramatically declining in a very short time period. The last known examples of the species died in captivity in Paris in 1822.

What is the correct conservation category for the King Island emu?

- A. extinct
- B. endemic to only the King Island location
- C. critically endangered throughout Australia
- D. conservation dependent because the species was kept in a zoo

Question 8

Studies of fossil layers have found that a significant change occurred around 65 million years ago. Fossil records indicate that approximately 75% of all plant and animal species alive at that time died out in a relatively short time period.

This change in diversity would be described as

- A. a mass extinction event.
- B. evolution of some species over time.
- C. a period of rapid species diversification.
- D. a loss of genetic diversity due to inbreeding.

Question 9

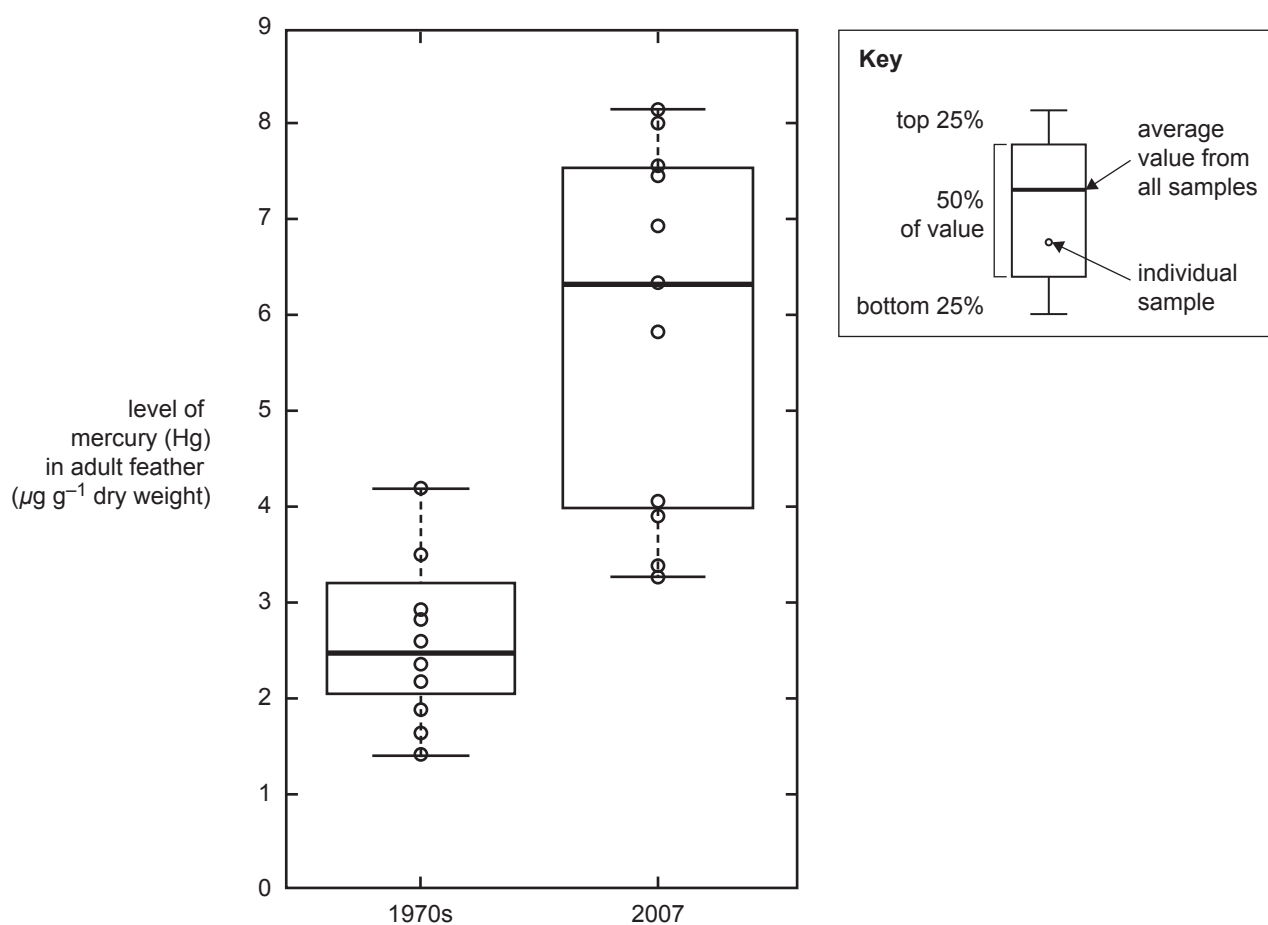
Although nitrogen is abundant in the atmosphere, it is not usable by plants in this form. Nutrient cycles enable nitrogen in the atmosphere to be converted into usable forms that can then be absorbed by plants.

What type of ecosystem service is provided by nutrient cycles in order to convert atmospheric nitrogen into more usable forms in soil?

- A. genetic service
- B. regulating service
- C. supporting service
- D. provisioning service

Use the following information to answer Questions 10–12.

Levels of mercury (Hg) found in samples of gentoo penguin feathers



Source: adapted from A Carravieri et al., 'Penguins as bioindicators of mercury contamination in the southern Indian Ocean: geographical and temporal trends', *Environmental Pollution*, vol. 213, 2016, Elsevier, p. 201

Gentoo penguins are a subantarctic bird species that consumes a diet of mainly fish and krill. Feathers are a good indicator of levels of mercury (a toxic heavy metal) absorbed into the body through diet. Feathers were collected from the nests of moulting animals in 2007 (the feathers fall out naturally when the penguins lose their winter coat), tested for mercury levels and compared with feather samples collected in the 1970s. Analysis of the feather samples indicated a level of mercury in these gentoo penguins that was higher than the organisms they fed on and much higher than background levels in their environment.

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Question 10

What do the high levels of mercury in the gentoo penguins' feathers compared to the organisms they fed on indicate?

- A. Penguins are able to excrete mercury.
- B. Mercury bioaccumulates within penguins.
- C. Mercury helps to create strong feathers in penguin species.
- D. Mercury will mainly be absorbed into the feathers of penguins through exposure to seawater.

Question 11

The graph indicates the levels of mercury (Hg), in $\mu\text{g g}^{-1}$ dry weight, found in feather samples from the 1970s compared to feather samples from 2007.

What can be concluded from these results?

- A. The results from the 1970s samples and the 2007 samples are similar because they overlap in the $3\text{--}4 \mu\text{g g}^{-1}$ range.
- B. There is a greater range of mercury levels in the samples tested from the 1970s compared to the 2007 samples.
- C. The results are inconclusive because the range in mercury levels is so wide in both the 1970s samples and the 2007 samples.
- D. There has been a large increase in the levels of mercury found in the feathers of gentoo penguins between the 1970s and 2007.

Question 12

A group of university scientists wants to investigate this issue further and plans to test the mercury levels in blood samples from gentoo penguins.

Why would these scientists need to have this sampling method approved by the university?

- A. Genetic swamping may occur if genetic material is being tested.
- B. The potential impacts of demographic variation need to be considered.
- C. Bioethical guidelines must be met when conducting experiments on animals.
- D. The scientists' research will not be able to be validated and the results might contain bias.

Use the following information to answer Questions 13 and 14.

A local government is planning a widening project along a main country road. Initial investigations of the area recorded patches of fragmented remnant vegetation mixed in among dairy farms along a creek system. A number of threatened species are thought to use the remnant habitat but additional fieldwork is required to collect more data and to confirm this.

When evaluating the issues related to developing the road, planners are considering three options:

- Option 1 – Do not proceed with widening the road.
- Option 2 – Use the existing path of the road but widen it to allow for traffic growth.
- Option 3 – Construct a new road path away from the remnant vegetation and through the dairy farms but at three times the cost of Option 2.

Question 13

A decision to accept Option 1 would be mainly based on

- A. the user pays principle.
- B. the precautionary principle.
- C. intragenerational equity issues.
- D. economic sustainability concerns.

Question 14

A decision to accept Option 3 would be mainly based on

- A. economic efficiency.
- B. stakeholder communication.
- C. sustainable development concerns.
- D. conservation of biodiversity and ecological integrity.

Question 15

A mining company is planning to develop a large-scale coal mine near the Australian coast. The planned mine site is adjacent to a wetland that provides a major habitat for nationally and internationally threatened waterbirds. The project could have potentially negative impacts on these threatened bird species, the water resources of the region and a protected Commonwealth marine reserve located off the coastline.

Before the project can proceed, approval is required under the

- A. *Flora and Fauna Guarantee Act 1988* (Vic).
- B. Convention on International Trade in Endangered Species (CITES).
- C. *Environment Protection and Biodiversity Conservation Act 1999* (Australia).
- D. International Union for Conservation of Nature Red List of Threatened Species.

Use the following information to answer Questions 16–18.

A regional council was studying the area that was cleared around a local lake and a river flat. The purpose of this study was to create a management plan to remove large items of rubbish and introduced plants from the site, and to replant the area with native species and, in doing so, form a parkland for use by local residents.

Question 16

This plan to develop the parkland is an example of

- A. bioremediation.
- B. risk assessment.
- C. the precautionary principle.
- D. ecologically sustainable development.

Question 17

Which two major investigations should the council undertake as part of the development of this management plan?

- A. relevant regulatory frameworks and stakeholder feedback
- B. consultations with local museums and galleries
- C. alternative site uses and pollution sources
- D. biological controls and local boundaries

Question 18

Creating the parkland for use by local residents would be regarded as an example of what type of value system?

- A. endemism
- B. biocentrism
- C. ecocentrism
- D. anthropocentrism

Question 19

There is an increasing demand for lithium-ion batteries for use in portable electronic devices and hybrid electric vehicles. A key technique being investigated involves a different method of extracting lithium, which aims to significantly reduce the time taken to complete the extraction process.

The focus of obtaining lithium by this method is

- A. bioremediation.
- B. ecological integrity.
- C. the application of new technologies.
- D. a risk assessment and risk management technique.

Question 20

A mining company is planning to extract tin from old mine waste left in tailings dumps 45 years ago. To carry out this plan, the company is required to follow strict government guidelines that limit pollutants being released and minimise harmful impacts on the local ecology.

These government guidelines would be described as

- A. a key feature of the user pays principle.
- B. regulatory frameworks that limit and control management plans for the site.
- C. an unnecessary limit on the plans to recycle waste material from an old mining site.
- D. an efficient way to collect relevant data related to the extraction of tin by recycling waste material.

Question 21

A group of students used a data logger to measure and record the level of dissolved oxygen in a freshwater sample at 20 °C for an experiment. The students repeated the measurement five times and recorded the following results.

	Measurement 1	Measurement 2	Measurement 3	Measurement 4	Measurement 5
Level of dissolved oxygen	8.5 ppm	8.4 ppm	8.5 ppm	8.6 ppm	8.5 ppm

The expected result, based on previous standard measurements at this location for freshwater at 20 °C, was 10.1 ppm. In scientific terms, the results collected by the students could be said to have

- A. low accuracy and low precision.
- B. high accuracy and high precision.
- C. high accuracy and low precision.
- D. low accuracy and high precision.

Question 22

A transformer converts high voltage to low voltage. The transformer has an input of 11.5 kW and an output of 10.0 kW. What is the percentage efficiency of the transformer?

- A. 15%
- B. 85%
- C. 87%
- D. 115%

Question 23

The residents of a small island are considering ways to provide electricity to the towns on the island. The residents consider using a small hydro-electric plant, a coal-fired power station or a natural gas station.

Which of the following sources of energy would give, in order, the least to most greenhouse gas emissions?

- A. natural gas, coal, hydro-electric
- B. natural gas, hydro-electric, coal
- C. hydro-electric, natural gas, coal
- D. hydro-electric, coal, natural gas

Question 24

Which one of the following groups of global measurements are all potentially influenced by human activity?

- A. level of solar radiation, sea level, volcanic activity
- B. annual average temperatures, sea level, ice coverage
- C. forest cover, flowering times, fluctuations in Earth's orbit
- D. carbon dioxide concentrations, annual average temperatures, level of solar radiation

Question 25

A climate model is a

- A. satellite view of global weather systems.
- B. forecast that accurately predicts weather.
- C. three-dimensional physical representation of Earth and the atmosphere.
- D. mathematical representation of the climate system, which uses powerful computers.

Question 26

The first law of thermodynamics is best stated as

- A. chaotic systems are hotter than their surroundings.
- B. force can be calculated by multiplying mass by acceleration.
- C. the total energy of an isolated system can never decrease over time.
- D. energy can be transformed from one form to another, but is unable to be created or destroyed.

Question 27

Large-scale tree planting is an example of

- A. increasing carbon storage.
- B. the hydrosphere effect.
- C. biosphere monitoring.
- D. palaeobotany.

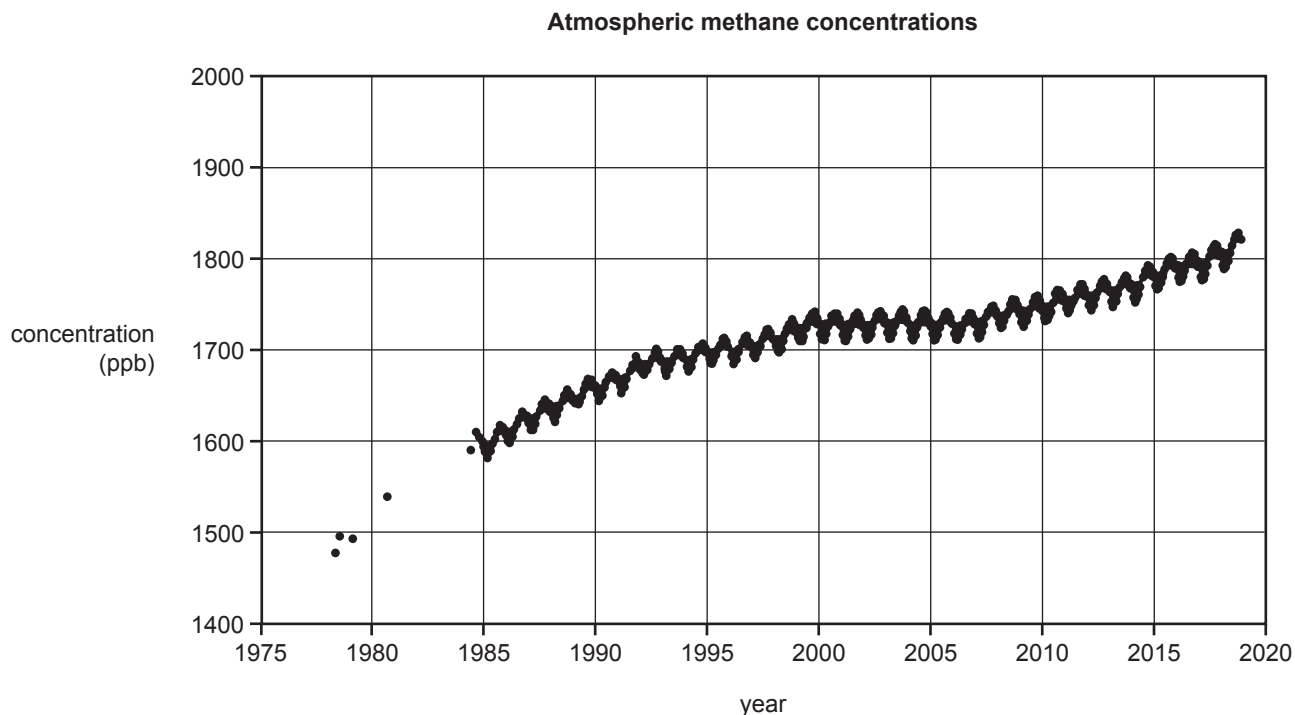
Question 28

Which of the following represents a significant source of atmospheric methane?

- A. spray cans
- B. use of fertiliser
- C. photosynthesis
- D. rice growing and cattle farming

Use the following information to answer Questions 29 and 30.

The graph below shows atmospheric concentrations of methane, in parts per billion (ppb), measured in air collected at the Cape Grim Baseline Air Pollution Station in north-western Tasmania.



Source: Commonwealth Scientific and Industrial Research Organisation (CSIRO),
<www.csiro.au/en>

Question 29

What is the approximate percentage increase in atmospheric methane concentration over the period 1985–2015?

- A. 7%
- B. 11%
- C. 15%
- D. 23%

Question 30

Which one of the following statements best describes the changes represented in the graph?

- A. a rising and falling seasonal cycle
- B. significant seasonal changes with a steady increasing trend
- C. seasonal changes with both periods of increase and periods of stability
- D. long-term changes with both periods of increase and periods of stability

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SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using blue or black pen.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (13 marks)

Short alpine herbfields are found on the plateau above 1500 m around Mount Kosciuszko. These are a mixed plant community of small, ground-hugging grasses and flowering plants. The community is found on gravel areas below large patches of snow that provide a flow of cold water as the snow melts. Sheep's sorrel is a European weed species that has spread into the alpine region.

Scientists used quadrats to record plant species data across three different short alpine herbfield sites: Q, R and S.

Simpson's Index of species diversity (D) was calculated by the scientists in order to compare the diversity of plant species across the three sites. The index (D) can be calculated using the following formula.

$$\text{Simpson's Index: } D = 1 - \frac{\sum[n_i(n_i - 1)]}{N(N - 1)}$$

Note: \sum refers to the 'sum of'

n_i means the total number of organisms of each individual species

N means the total number of organisms of all species

This formula should produce a value between 0 and 1. A higher index value (that is, a number closer to 1) indicates higher species diversity.

Species recorded at Site Q	n_i	$n_i - 1$	$n_i(n_i - 1)$
white purslane	7	$7 - 1 = 6$	$7 \times 6 = 42$
dwarf woodrush	4	$4 - 1 = 3$	$4 \times 3 = 12$
alpine plantain	7	$7 - 1 = 6$	$7 \times 6 = 42$
alpine wallaby grass	6	$6 - 1 = 5$	$6 \times 5 = 30$
snowpatch grass	6	$6 - 1 = 5$	$6 \times 5 = 30$
button sedge	4	$4 - 1 = 3$	$4 \times 3 = 12$
snow pennywort	3	$3 - 1 = 2$	$3 \times 2 = 6$
alpine marsh marigold	7	$7 - 1 = 6$	$7 \times 6 = 42$
sheep's sorrel	1	$1 - 1 = 0$	$1 \times 0 = 0$
N =	45		$\sum[n_i(n_i - 1)] = 216$
N(N - 1) =	1980		

Therefore
$$D = 1 - \frac{\sum[n_i(n_i - 1)]}{N(N - 1)}$$

$$D = 1 - \frac{216}{1980}$$

$$D = 1 - 0.109$$

$$D = 0.891$$

Simpson's Index (D) for Site Q is 0.891

- a. Use the figures in the table below and the spaces provided to calculate Simpson's Index (D) for Site R. 3 marks

Species recorded at Site R	n_i	$n_i - 1$	$n_i(n_i - 1)$
white purslane	3		
dwarf woodrush	3		
alpine plantain	4		
alpine wallaby grass	2		
snowpatch grass	2		
button sedge	1		
snow pennywort	1		
alpine marsh marigold	1		
sheep's sorrel	9		
N =			$\sum[n_i(n_i - 1)] =$
$N(N - 1) =$			

Therefore
$$D = 1 - \frac{\sum[n_i(n_i - 1)]}{N(N - 1)}$$

$$D = 1 - \frac{\quad}{\quad}$$

$$D = 1 - \frac{\quad}{\quad}$$

Simpson's Index (D) for Site R is .

- b.** What is a quadrat and why was this technique used to collect the species data for the short alpine herbfield plant community?

2 marks

- c.** The third site, Site S, was studied and a Simpson's Index of 0.844 was calculated for this site. However, a scientist noted that sheep's sorrel was not present.

Using the information provided and the Simpson's Index figures for each site, compare the species diversity and ecological quality of the three sites.

3 marks

- d.** Climate modelling has been carried out by various scientific organisations studying the Australian alpine environment. The worst-case scenario for 2050 predicted by scientists is a 2.8 °C temperature rise combined with a 22% decrease in precipitation, resulting in a 94% reduction in snow cover within the alpine region.

If this predicted climate change scenario occurs, outline the likely impact on the short alpine herbfield plant community.

1 mark

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- e. There is a high degree of confidence in the climate modelling carried out to develop the scenario predicted in **part d**.

How can the confidence in the projections provided by a climate model be assessed?

2 marks

- f. One option to help preserve the threatened short alpine herbfield plant community is to store material in a gene bank.

What is a gene bank and what is the purpose of creating one?

2 marks

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Question 2 (9 marks)

The barred galaxias (*Galaxias fuscus*) is a small, non-migratory freshwater fish endemic to a number of streams in the upper Goulburn River catchment in central Victoria. Twelve known populations of the fish currently exist in separate small streams in this region. These remnant populations now exist in stream habitats that are highly fragmented and isolated from each other.

The greatest threat to these remaining populations of barred galaxias is predation by and competition from two introduced fish species: the rainbow trout and the brown trout. As a result, conservationists have begun a program of constructing barriers in-stream to stop the movement of trout species into the remaining stream areas populated by barred galaxias.

An action statement for the barred galaxias has been prepared under the *Flora and Fauna Guarantee Act 1988* (Vic). Within the action statement the fish is described as ‘threatened’. Conservationists argue that the barred galaxias conservation category in Victoria should be considered as ‘critically endangered’.

- a. Explain what a change from the ‘threatened’ category to the ‘critically endangered’ category would indicate about how the species is considered in terms of conservation.

2 marks

- b. It has been suggested that, given the current isolation of the remaining populations of fish, the translocation of barred galaxias would be an effective management strategy.

Explain what ‘translocation’ refers to in this situation.

2 marks

- c. If translocation were to occur, explain **one** potential negative impact that this strategy could have on the genetic diversity of the barred galaxias.

2 marks

- d. A recreational fishing group is suggesting that the trout species should not be restricted by barriers and should be allowed to move into any stream throughout Victoria. This group believes that ecosystem resources should be available for human consumption and that it is important for humans to be able to catch fish in the wild.

Justify whether this view is based on an anthropocentric value system or on an ecocentric value system. In your answer, ensure that the difference between these two terms is clear.

3 marks

- b. Describe **one** impact that this proposal could have on the biosphere within the region, making clear the meaning of the term 'biosphere'.

2 marks

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SECTION B – continued
TURN OVER

Question 4 (12 marks)

A land developer is considering building a housing development on land surrounding a lake that is at the edge of a major city. The lake is fed by an underground spring that brings water to the surface at around 50 °C. The developer is considering marketing 1700 new home sites as ‘eco-friendly’ by combining a number of energy sources:

- System 1 – Based on using solar panel systems on the roofs of all houses (some panels producing electricity and a panel system heating water)
- System 2 – Based on using the naturally available hot water for hydronic heating (piping the hot water from the lake into each home, storing it and using this heat to warm the home) and taking hot water from the lake for home hot-water use

Water, coal-generated electricity and natural gas are available in the city. However, there would be significant costs related to upgrading and connecting the existing infrastructure to the development site. By using a combination of System 1 and System 2, it is believed that the development could be ‘cost neutral’ and not place any extra load on the existing services.

- a.** State one advantage and one disadvantage of using each system for the housing development. 4 marks

System 1

Advantage _____

Disadvantage _____

System 2

Advantage _____

Disadvantage _____

- b.** If a home used both systems described above (solar panels and hot water from the lake), what impact would this have on energy use and costs for the household? 2 marks

- c.** What would be the impacts on the resources of the city if all homes in the development used both of these energy supply systems? 2 marks

- d. Explain how the energy supply options in System 1 and System 2 consider both intergenerational equity and intragenerational equity. In your answer, ensure that the difference between intergenerational equity and intragenerational equity is clear.

4 marks

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SECTION B – continued
TURN OVER

Question 5 (10 marks)

Students are studying two of the major electrical energy sources that provide energy to Melbourne: brown coal generation in the Latrobe Valley, approximately 150 km east of Melbourne, and hydro-electric generation in the Snowy Mountains Scheme in southern New South Wales, about 600 km north-east of Melbourne. The students are comparing the energy sources in terms of accessibility, extraction, energy conversions, distribution, and their impact on the environment and society.

- a. What is **one** impact on the environment of accessing each energy source? Compare the relative impacts of accessing each energy source. 3 marks

- b. i. For brown coal generation, state each step in the process of converting the energy source to electricity. For each step, name the energy conversions involved. 3 marks

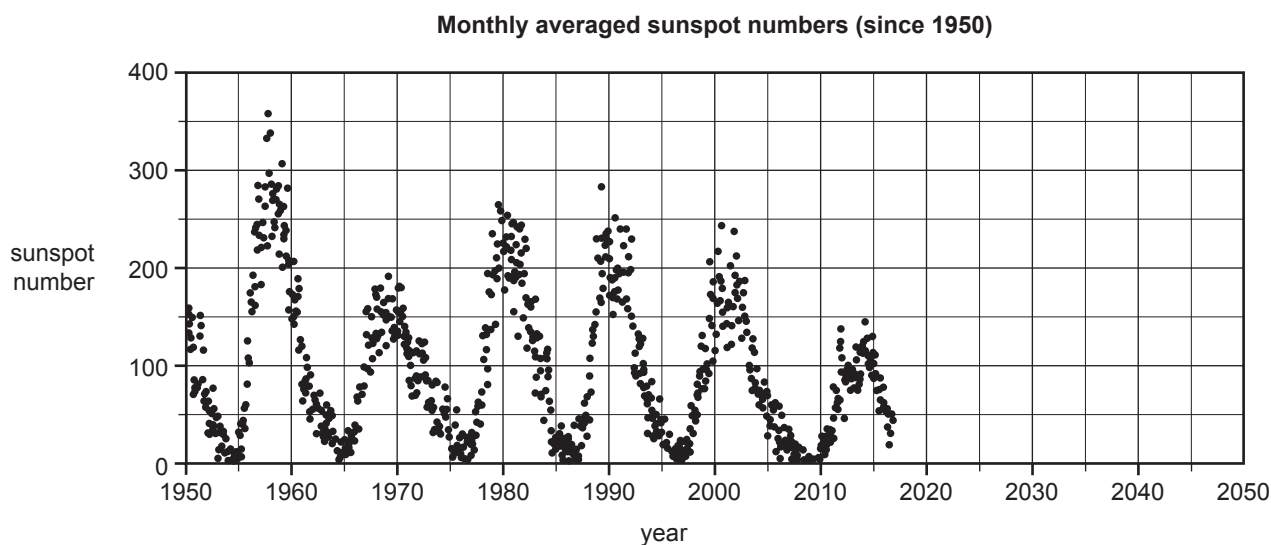
- ii. For hydro-electric generation, state each step in the process of converting the energy source to electricity. For each step, name the energy conversions involved. 2 marks

- c. Compare the relative efficiency of the distribution of energy from the Latrobe Valley with that of the Snowy Mountains Scheme, assuming that electricity is to be delivered to Melbourne. 2 marks

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Question 6 (3 marks)

The graph below shows the cycle of monthly averaged numbers of sunspots visible on the sun from 1950. The amount of solar radiation received on Earth is slightly greater when there is a peak in sunspot numbers.



Source: adapted from National Aeronautics and Space Administration (NASA), Marshall Space Flight Center, Solar Physics, <<https://solarscience.msfc.nasa.gov/>>

- a. What is the approximate time interval, in years, between the sunspot peaks? 1 mark

- b. Isabella claims that the global warming experienced since the 1950s is due to changes in the number of sunspots.

Assuming there has been global warming since 1950, use the graph provided to comment scientifically on Isabella's claim. 2 marks

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Question 7 (6 marks)

Earth's climate has varied dramatically over millions of years, with long-term natural cycles of 'ice ages' and 'warm periods'. Milankovitch was the scientist who discovered the link between the long-term changes in climate and variations related to Earth's orbit. A major contributor to these cycles are three cyclical variations related to Earth and its orbit around the sun, which affect the amount of solar energy received at Earth's surface.

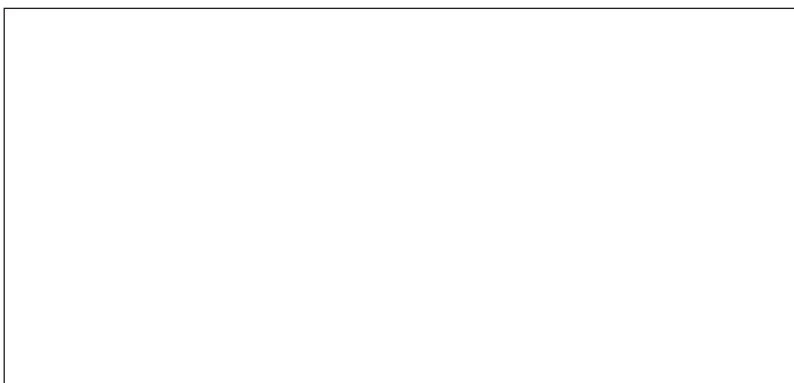
The three cyclical variations are Earth's eccentricity, its axial tilt and its precession.

Give a basic description of each variation and represent each variation with a simple diagram.

- Eccentricity

Description _____

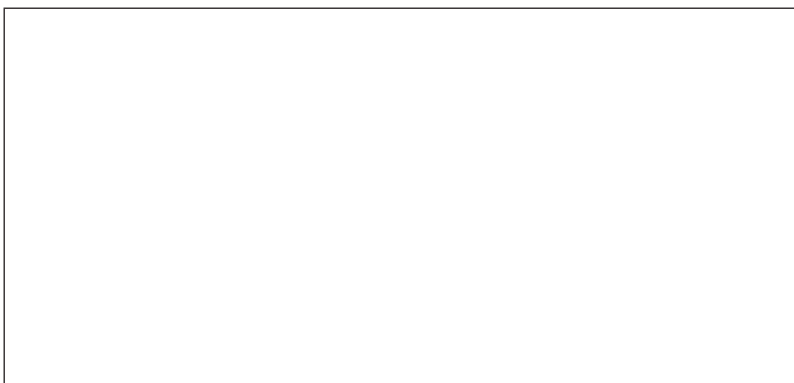
Diagram



- Axial tilt

Description _____

Diagram

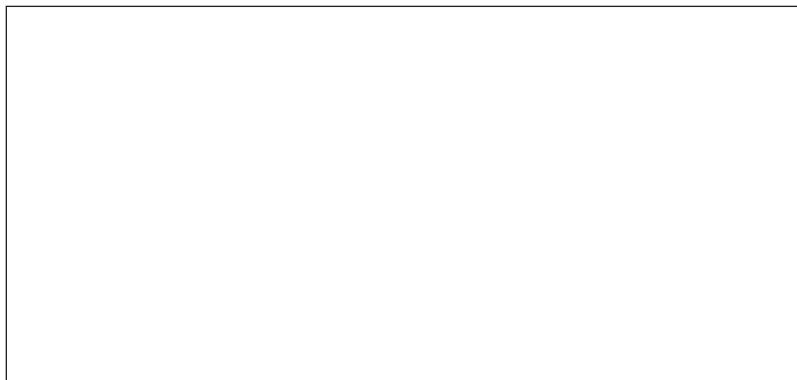


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- Precession

Description _____

Diagram



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SECTION B – continued
TURN OVER

Question 8 (12 marks)

The greenhouse effect influences the equilibrium temperature on Earth.

- a.** Outline the types of incoming radiation from the sun, describing their interactions as they pass through Earth's atmosphere.

3 marks

- b.** Describe the interactions of radiation at Earth's surface.

3 marks

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c. What happens to the radiation re-emitted from the surface of Earth?

2 marks

d. Describe the difference between the natural and enhanced greenhouse effects. In your answer, include the major causes and effects of each.

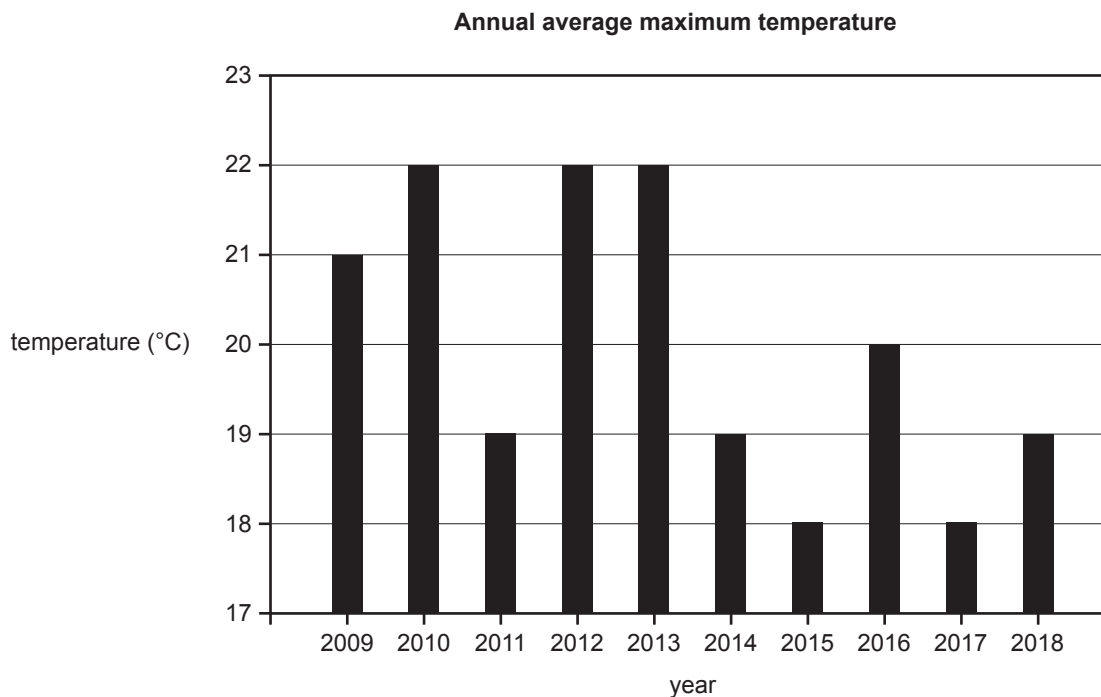
4 marks

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SECTION B – continued
TURN OVER

Question 9 (7 marks)

The graph below shows annual average maximum temperature measurements taken at a weather station in a suburb of Melbourne from 2009 to 2018.



- a. Calculate the average maximum temperature during the measurement period shown on the graph. 1 mark

- b. Leo states that the measurements are proof that climate change is not occurring.

State two scientific arguments that demonstrate that Leo's statement is incorrect.

2 marks

- ---

- ---

- c. Describe the main tool used by scientists to determine the likely future climate.

2 marks

- d. Scientists produce projections of future global warming based on various scenarios. Global warming is greater in some scenarios than in others.

List two factors within such scenarios that are likely to influence the extent of the projections of future global warming.

2 marks

- ---
- ---

Question 10 (11 marks)

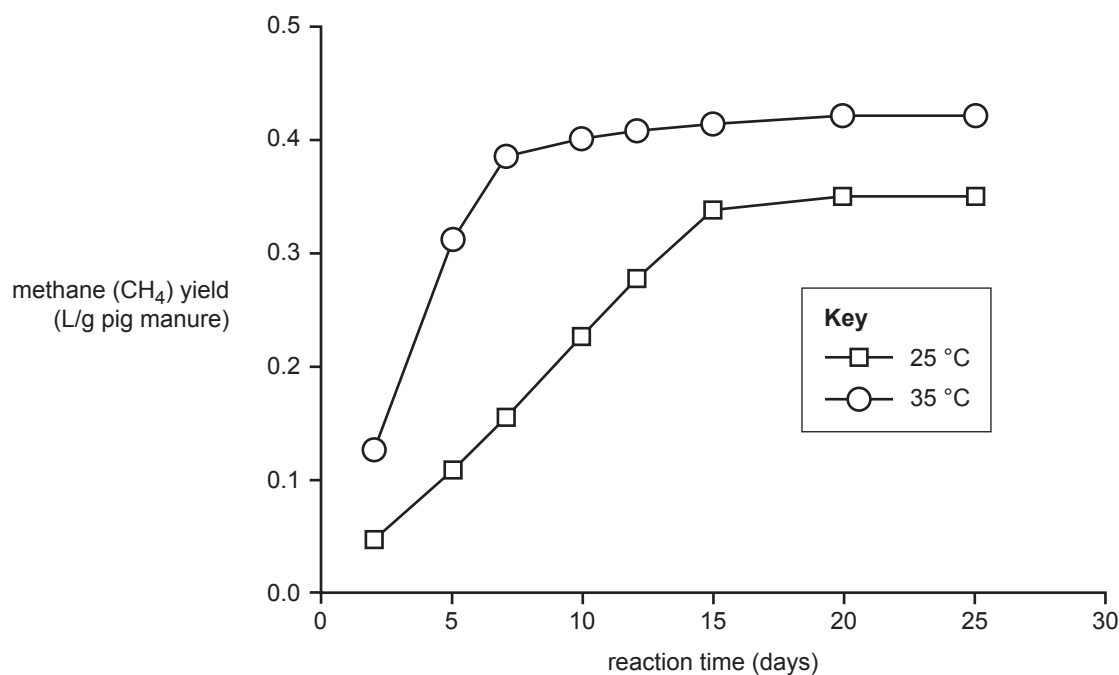
Biogas is created through the breakdown of organic matter, such as animal manures, by microorganisms in the absence of oxygen. These microorganisms are naturally found in animal manures. This process of anaerobic (without oxygen) digestion produces a flammable gas mixture, consisting mainly of methane, that can be stored and used as an energy source.

Two students wanted to investigate the effect of temperature on the volume of biogas generated from a digester system. Their hypothesis was that increasing the temperature of the mixture will allow for a greater volume of methane to be produced over time.

Disease pathogens and parasitic organisms that can pose a health risk to humans under certain conditions can be found in animal manures. Therefore, personal protective clothing, including dust masks and disposable gloves, were worn during the handling of the manure samples.

Two identical digester systems, which allow anaerobic digestion to take place in sealed conditions, were constructed in the school's laboratory. The gas produced by each system was collected and stored in a separate container, and analysed for its methane content.

200 g of fresh pig manure was accurately weighed and mixed with 1200 mL of a pH-controlled solution. The mixture was divided and one half was put into the first digester system, kept at a constant temperature of 25 °C, and the other half was put into the second digester system, kept at a constant temperature of 35 °C. The amount of gas produced was measured regularly over 25 days and the results graphed below. The pH of the mixtures was regularly checked throughout the experiment and kept constant at pH 7.3



Source: adapted from KJ Chae et al., 'The effects of digestion temperature and temperature shock on the biogas yields from the mesophilic anaerobic digestion of swine manure', *Bioresource Technology*, vol. 99, issue 1, January 2008, Elsevier, p. 5

a. What is the independent variable in this experiment?

1 mark

- b. What is a controlled variable? Indicate **one** example of a controlled variable in this experiment. 2 marks

- c. Was the experiment designed by the students collecting qualitative or quantitative data? Explain your answer, making clear the difference between the two terms. 2 marks

- d. Describe what happened to the volume of gas produced between days 20 and 25 for the mixture kept at 25 °C, and explain why this may have occurred. 2 marks

- e. Another student claims that the original hypothesis was refuted by the data.
Is this claim correct? Explain. 2 marks

- f. What are two potential environmental benefits of obtaining and using biogas from animal manures as an energy source? 2 marks

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