

STUDENT NUMBER           Letter

# ENVIRONMENTAL SCIENCE

## Written examination

Thursday 11 November 2021

Reading time: 3.00 pm to 3.15 pm (15 minutes)

Writing time: 3.15 pm to 5.15 pm (2 hours)

### QUESTION AND ANSWER BOOK

#### Structure of book

<i>Section</i>	<i>Number of questions</i>	<i>Number of questions to be answered</i>	<i>Number of marks</i>
A	30	30	30
B	9	9	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 32 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.

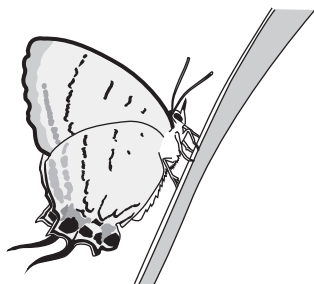
A correct answer scores 1; an incorrect answer scores 0.

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.

Use the following information to answer Questions 1–4.



*Jalmenus eubulus* is a critically endangered butterfly species that is found only in the wild within a small region that includes parts of Queensland and northern New South Wales (NSW). The geographic distribution of the species is estimated to be very highly restricted, with suitable habitat severely fragmented.

**Question 1**

Based on the information above, the butterfly

- A. was introduced to Queensland.
- B. has a range throughout Australia.
- C. has a fragmented but wide range.
- D. is endemic to NSW and Queensland.

**Question 2**

Which one of the following describes the likelihood of extinction in the wild of *J. eubulus*?

- A. certain extinction in the medium-term future
- B. high risk of extinction in the immediate future
- C. extremely high risk of extinction in the immediate future
- D. very high risk of extinction in the medium-term future

**Question 3**

What would be the most suitable strategy to reduce the impact of habitat fragmentation on this butterfly population?

- A. captive breeding
- B. culling of feral predators
- C. creating wildlife corridors
- D. maintaining remnant vegetation

**Question 4**

A population of *J. eubulus* is kept in a zoo overseas. Zoologists from different countries exchange butterfly specimens in order to broaden the diversity of their captive populations.

Such scientific exchanges require an exemption from which international agreement?

- A. World Heritage listing
- B. *Flora and Fauna Guarantee Act (Vic)*
- C. Convention on International Trade in Endangered Species
- D. *Environment Protection and Biodiversity Conservation Act 1999*

**Question 5**

Scientists study changes in the relative numbers of fossil species in adjacent rock layers.

Which one of the following would provide fossil record evidence for a mass extinction event?

- A. A small variety of fossils is found from a time period.
- B. A large number of different fossils is found from a time period.
- C. The fossils show evidence of damage from hunting or scavenging.
- D. A large number of fossils from one species is found from a short time period.

**Question 6**

Which one of the following increases the likelihood of survival of an endangered plant species after environmental change?

- A. widespread use of herbicides
- B. the presence of advantageous genetic traits
- C. a decreased number of pollinator species
- D. isolation of different populations and speciation

**Question 7**

Why is ecosystem diversity in a region important?

- A. because species richness is a measure of ecosystem diversity
- B. to provide nutrient-rich soil in areas undergoing urban development
- C. ecosystems provide provisioning, regulating and supporting services
- D. diverse ecosystems are the only source of purified water available to humans

**Question 8**

Which one of the following energy sources will not release carbon dioxide when combusted?

- A. petrol
- B. biodiesel
- C. hydrogen
- D. natural gas

DO NOT WRITE IN THIS AREA

**Question 9**

Which of the following are characteristics of nuclear energy?

- A. renewable, fossil resource
- B. renewable, non-fossil resource
- C. non-renewable, fossil resource
- D. non-renewable, non-fossil resource

**Question 10**

The first law of thermodynamics states that in a closed (isolated) system, heat energy

- A. is the only form of energy.
- B. cannot be created but it can be destroyed.
- C. cannot be created or destroyed.
- D. can be destroyed once used.

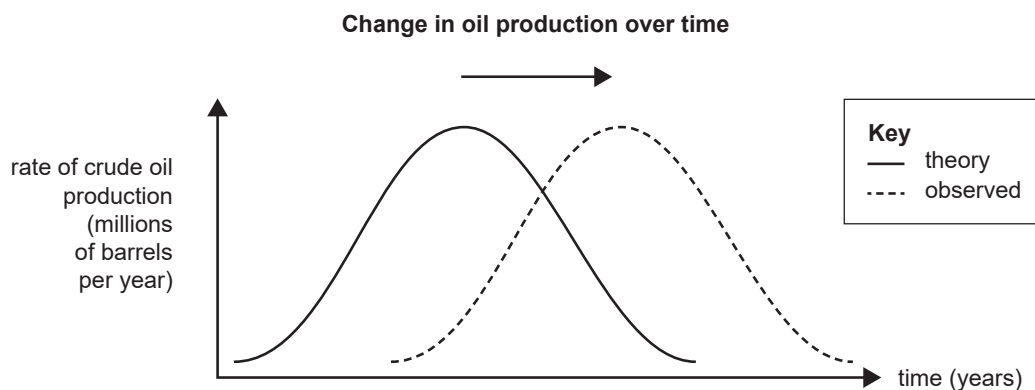
**Question 11**

Which of the following gives the correct order of energy conversions from wind by a wind turbine for human use?

- A. kinetic → mechanical → electrical
- B. chemical → mechanical → electrical
- C. kinetic → heat → potential → electrical
- D. mechanical → potential → electrical → heat

*Use the following information to answer Questions 12 and 13.*

The graph below shows the theoretical and observed rates of production of crude oil over a period of time.

**Question 12**

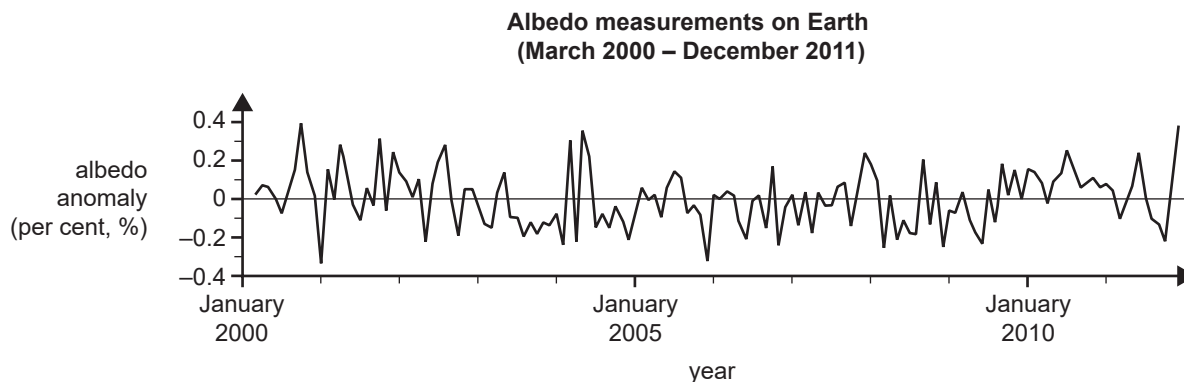
The shift to the right shown in the graph above indicates that

- A. oil reserves will not run out.
- B. oil reserves will continue to be found.
- C. peak oil will occur sooner than the theory predicts.
- D. peak oil will occur later than the theory predicts.

**Question 13**

The shift to the right shown in the graph on page 4 could be explained by

- A. new technologies having no effect on oil resource extraction.
- B. new technologies enabling access to less accessible oil resources.
- C. new technologies increasing the rate of use of oil resources.
- D. oil and other fossil fuel reserves having more time to renew themselves.

**Question 14**

Source: adapted from National Aeronautics and Space Administration (NASA), Earth Observatory, 'Measuring Earth's Albedo', <<https://earthobservatory.nasa.gov/images/84499/measuring-earths-albedo>>

On the graph above, a value of zero indicates the long-term mean albedo.

During which years was the albedo on Earth 0.35% lower than the long-term mean?

- A. 2001 and 2005
- B. 2002 and 2007
- C. 2004 and 2009
- D. 2005 and 2011

**Question 15**

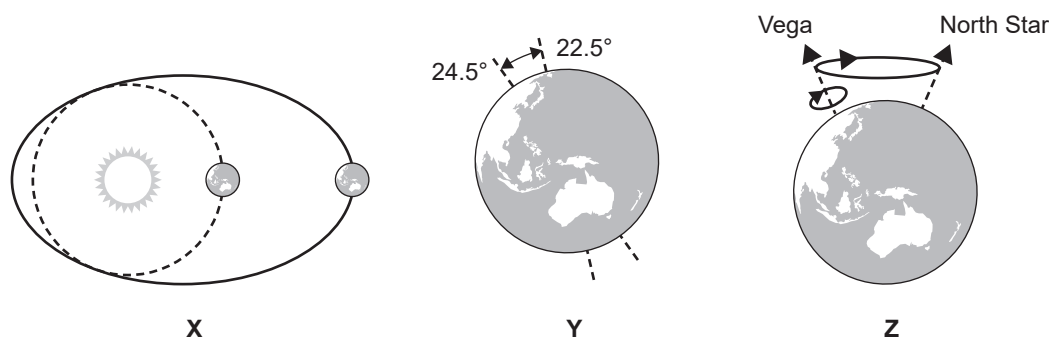
Which one of the following gives the approximate time period over which the change in the range of Earth's axial tilt occurs?

- A. 12 000 years
- B. 40 000 years
- C. 100 000 years
- D. 400 000 years

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## Question 16

## Milankovitch cycles



Source: adapted from University of Washington, College of the Environment, 'Program on climate change', <[https://uwpsc.ocean.washington.edu/file/Milankovitch\\_Cycles](https://uwpsc.ocean.washington.edu/file/Milankovitch_Cycles)>

Which of the following presents the diagrams for the Milankovitch cycles (X, Y and Z), shown above, in the correct order?

- eccentricity, precession, axial tilt
- eccentricity, axial tilt, precession
- axial tilt, eccentricity, precession
- precession, axial tilt, eccentricity

Use the following information to answer Questions 17 and 18.

An environmental scientist in western Victoria reviewed the latest long-term climate projections in the area to assist with tree selection for the local botanic gardens. These projections indicated that:

- maximum and minimum daily temperatures will continue to increase (very high confidence)
- extreme rainfall events will become more intense (high confidence)
- rainfall will decline in winter and spring (medium to high confidence)

Data: JM Clarke, M Grose, M Thatcher, V Round and C Heady, *Wimmera Southern Mallee Climate Projections 2019*, CSIRO, Melbourne (Australia); © 2019 State of Victoria

## Question 17

Long-term climate projections are generated by the use of

- palaeobotany data.
- climate modelling.
- records of species extinction.
- measurements of concentrations of greenhouse gases.

## Question 18

The levels of confidence for each of the projections would have been assessed

- using high-quality measuring devices.
- by comparing past and future climate data.
- by investigating the most accurate and current climate data.
- by analysing past climate data and considering a wide range of factors that have an impact on the global climate.

**Question 19**

The amount of heat absorbed by a greenhouse gas, taking into account its lifetime in the atmosphere, is referred to as its global warming potential. The table below provides examples of the global warming potential of different greenhouse gases.

Gas	Chemical formula	Lifetime (years)	Global warming potential (time period)		
			20 years	100 years	500 years
carbon dioxide	CO <sub>2</sub>	variable	1	1	1
methane	CH <sub>4</sub>	12 ± 3	56	21	6.5
nitrous oxide	N <sub>2</sub> O	120	280	310	170

Source: United Nations Framework Convention on Climate Change (UNFCCC) secretariat, UN Climate Change, 'Global warming potentials (IPCC Second Assessment Report)', <<https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials>>

Why does carbon dioxide have a global warming potential of 1?

- A. It absorbs 170 times less radiation compared to methane.
- B. It is the least common greenhouse gas in the atmosphere.
- C. It absorbs the greatest amount of infra-red radiation of all greenhouse gases.
- D. It is used as a baseline unit and it can remain in the atmosphere for a very long time.

**Question 20**

Which one of the following would not be an impact of the enhanced greenhouse effect?

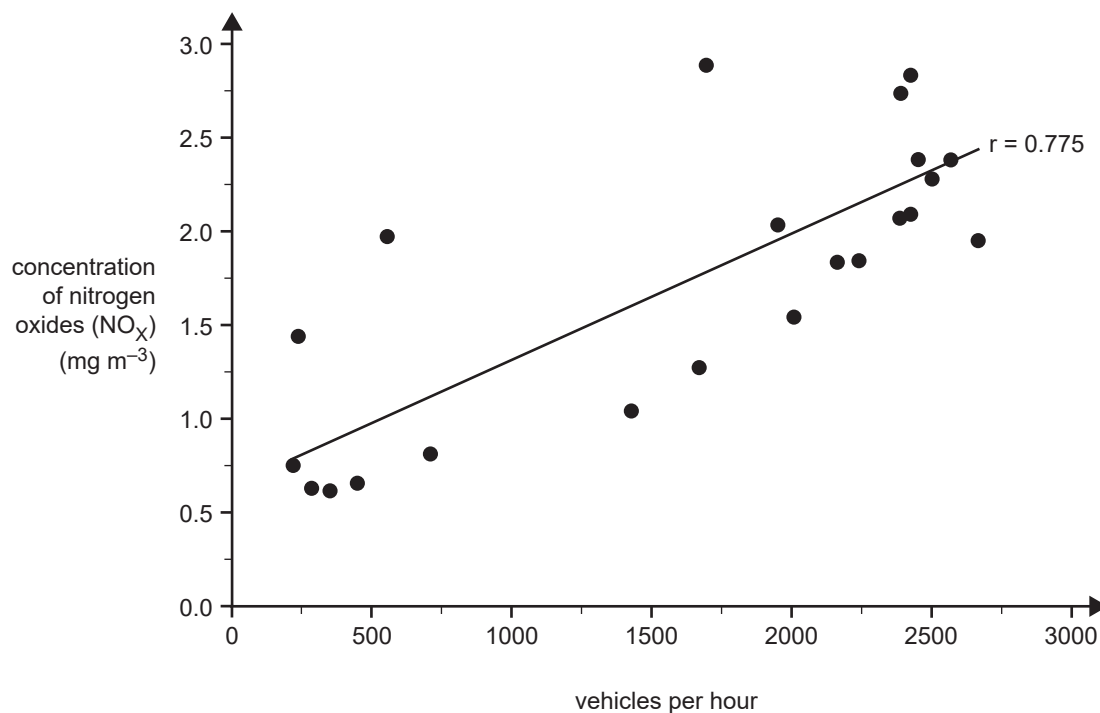
- A. climate refugees
- B. increased coastal erosion
- C. increased rate of species extinction
- D. reduced global average sea surface temperature

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Use the following information to answer Questions 21–24.

Scientists have investigated the concentration of nitrogen oxides inside a road tunnel.

**Correlation between concentration of nitrogen oxides ( $\text{NO}_x$ ) and amount of road traffic inside a road tunnel in Shanghai, China**



Source: Rui Zhou, Shanshan Wang, Chanzhen Shi, Wenxin Wang, Heng Zhao, Rui Liu, Limin Chen, Bin Zhou, 'Study on the traffic air pollution inside and outside a road tunnel in Shanghai, China', *PLoS ONE*, 9(11): e112195, <<https://doi.org/10.1371/journal.pone.0112195>>; licensed CC-BY 4.0 <<https://creativecommons.org/licenses/by/4.0/>>

### Question 21

What does the data shown in the graph above indicate about the correlation between the concentration of nitrogen oxides and the amount of road traffic inside the road tunnel?

- A. The concentration of nitrogen oxides fluctuates and increases over time.
- B. As the amount of road traffic increases, the concentration of nitrogen oxides also increases.
- C. The amount of road traffic does not affect the concentration of nitrogen oxides in the road tunnel.
- D. It is dangerous to human health to be in the road tunnel when levels of nitrogen oxides are high.

### Question 22

What type of data was collected during this investigation?

- A. biased
- B. random
- C. quantitative
- D. qualitative



**Question 23**

Nitrogen oxides released into the atmosphere can lead to the formation of tropospheric ozone in the presence of sunlight.

An increase in road traffic through the tunnel is expected in the future.

This increase is likely to

- A. further increase the daily concentration of nitrogen oxides inside the road tunnel and around the tunnel's entrance and exit.
- B. decrease concentrations of nitrogen oxides because more would be converted to ozone both inside and outside the road tunnel.
- C. be of concern because tropospheric ozone is a greenhouse gas and there would be climate change and a rise in temperature around the tunnel entrance and exit.
- D. be of benefit to the environment because this additional ozone will help to repair the hole in the ozone layer, thereby reducing climate change.

**Question 24**

For a similar road tunnel project in Australia, environmental scientists collected data on levels of nitrogen oxides multiple times using the same method and equipment.

They did this to

- A. reduce the sample size.
- B. increase the precision of the data.
- C. ensure the results are affected by a single independent variable and support the hypothesis.
- D. ensure the results obtained are repeatable and allow reasonable conclusions to be drawn.

**Question 25**

The terms 'sustainability' and 'ecologically sustainable development'

- A. refer to the same basic principle of not wasting any vital resources.
- B. have a similar major focus on not damaging the environment in which humans live.
- C. have a different focus, with sustainability focused more on meeting the needs of humans now and in the future, whereas ecologically sustainable development has a greater focus on environmental concerns.
- D. have a different focus, with ecologically sustainable development not focused on using vital resources but rather on protecting all parts of ecosystems for future generations, and with sustainability more concerned about meeting our current and future economic needs.

**Question 26**

A fundamental challenge to the sustainability of future human populations is

- A. economic growth.
- B. food and water security.
- C. an increasing rate of species extinction.
- D. increasing the amount of all fossil fuel energy sources.

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**Question 27**

When conducting any experiment, Environmental Science students manage a range of variables.

Controlled variables are variables that

- A. the students measure accurately over time to record any changes or variations.
- B. if not measured and recorded by the students, could cause the hypothesis to be falsely supported or refuted.
- C. the students keep under control and that they vary and adjust according to the particular experimental method.
- D. could change, but that the students intentionally keep constant to more clearly isolate the relationship between the independent variable and the dependent variable.

**Question 28**

Students were required to conduct fieldwork that recorded the numbers of small mammals in an area of forest. To collect this data, the students considered replacing baited cage traps with fixed infra-red cameras.

A major bioethical reason for making such a change is

- A. trying to reduce errors in the data to make the population numbers more accurate.
- B. trying to reduce any disturbance or harm to individual mammals within the forest.
- C. wanting to make improvements to the safety and health of the students when they are working in the field.
- D. making it easier for students as they can leave cameras in the field for a number of days rather than having to check the traps and rebait them each day.

**Question 29**

When preparing a management plan for an environmental project, methods should be developed to reduce the occurrence of negative outcomes.

This focus could be described as

- A. a risk assessment.
- B. impact minimisation.
- C. a regulatory framework.
- D. following the precautionary principle.

**Question 30**

An important method of evaluating the effectiveness of management strategies when monitoring a completed environmental science project is to

- A. analyse and compare historical data with current data, and continue with a focused monitoring program.
- B. describe all aspects of the current ecosystem conditions after the environmental science project is finished.
- C. make sure that most of the management strategies set out in the guidelines for the project have been implemented correctly.
- D. continue to collect data that assesses both the harmful and beneficial impacts on the biosphere in the region around the environmental project.

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**SECTION B****Instructions for Section B**

Answer **all** questions in the spaces provided.

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

**Question 1** (12 marks)

The biodiversity of an urban creek is under threat from erosion and the spread of exotic weeds. A community group made up of volunteers was formed in 1990. The group runs monthly weed clearing and revegetation sessions. The group used quadrat sampling to monitor the plant species diversity of a few sites along the creek bank. The volunteers then calculated Simpson's Index of species diversity (D) to compare the biodiversity of the site before and after habitat restoration efforts.

The index (D) can be calculated using the following formula.

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

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

Calculations using 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.

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- a. Calculate Simpson's Index of species diversity ( $D$ ) for the site after habitat restoration in the blank spaces in the table below. The index value before habitat restoration has already been calculated. 3 marks

Species	Before habitat restoration				After habitat restoration		
	$n_i$	$n_i - 1$	$n_i (n_i - 1)$		$n_i$	$n_i - 1$	$n_i (n_i - 1)$
common tussock grass	10	9	90		24		
gold dust wattle	5	4	20		8		
milky beauty-head	7	6	42		15		
feather spear grass	19	18	342		24		
river red gum	4	3	12		4		
hemp bush	0	0	0		4		
manna gum	0	0	0		5		
river bottlebrush	1	0	0		2		
twiggy daisy bush	3	2	6		9		
various exotic weed species	55	54	2970		15		
N =	104		$\sum[n_i (n_i - 1)]$ = 3482	N =			$\sum[n_i (n_i - 1)]$ =
$N(N - 1) =$	10 712			$N(N - 1) =$			
		D =	$1 - \frac{3482}{10\,712}$			D =	
		D =	0.675			D =	

- b. Evaluate whether the habitat restoration efforts have been successful. Use data to support your answer. 3 marks

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c. One of the volunteers suggested excluding the exotic weed species from the calculation of Simpson’s Index.

Give **two** reasons why the weed species may have been included in the calculation of Simpson’s Index.

2 marks

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d. Explain **one** management strategy, other than habitat restoration, that the volunteers could use to improve the ecological health of the creek site.

2 marks

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e. Outline **one** advantage of quadrat sampling as a method of measuring species diversity.

2 marks

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**SECTION B – continued  
TURN OVER**

**Question 2** (9 marks)

An Australian native possum species is threatened with extinction. This species is classified as ‘extinct in the wild’, with a population of only 50 individuals remaining in a local wildlife sanctuary. The possums’ previous habitat was a rainforest ecosystem that is currently classified as a ‘biodiversity hotspot’. Wildlife officers are concerned that the genetic diversity of the captive possum population is low.

- a. Justify why the possum species is classified as ‘extinct in the wild’. 2 marks

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- b. Describe **one** possible threat to biodiversity that could have led to the ‘extinct in the wild’ classification. 2 marks

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- c. Outline **one** strategy for maintaining the genetic diversity of the possum population in captivity. 2 marks

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- d. Identify **one** factor related to the rainforest ecosystem that may have contributed to its classification as a ‘biodiversity hotspot’. 1 mark

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- e. Conservationists have suggested that the remaining possum population be reintroduced to a nearby grasslands ecosystem, where natural predators of the possum are not present.

Is this strategy likely to be successful? Give **two** reasons to explain your answer.

2 marks

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**SECTION B – continued**  
**TURN OVER**

**Question 3** (12 marks)

A large bayside city, located at the mouth of a river, has ongoing water shortage issues, especially during periods of drought. Water from the river, further up the catchment area, is already being used by agricultural producers. Furthermore, the population of the city is expected to grow by 25 000 over the next 10 years. The city has one main water supply dam built on the river system and an investigation has identified a suitable site for a second dam. Environmentalists have increasing concerns about the impact of reduced water flows on an already struggling river ecosystem and argue that a second dam would flood a large area of woodland. An alternative proposal to a second dam is to construct a desalination plant, which will take seawater from the bay and convert it into freshwater for use by the city’s residents. This will be a costly project to build and will require a large ongoing input of electrical energy. Two tunnels would need to be constructed under the seabed: one tunnel to take seawater into the desalination plant and an outflow tunnel to return saline concentrate (the very highly concentrated saltwater left after the freshwater is extracted) back into the marine environment.

- a. Describe and compare how the two proposals – the second dam and the desalination plant – could be assessed as meeting the sustainability principles of efficiency of resource use and conservation of biodiversity and ecological integrity. In your answer, clearly define each of these two principles. 6 marks

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- b. The group proposing the desalination plant option argues that this development will provide a plentiful supply of drinking water for the current population as well as allow for some growth in the population of the city. The group claims that this meets the sustainability principle of intergenerational equity, which a second dam would not be able to meet.

Justify this claim, making clear the meaning of the term 'intergenerational equity'.

2 marks

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- c. If the desalination plant were to become operational, explain why monitoring the marine environment around the saline concentrate tunnel outflow point would be required.

2 marks

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- d. Various stakeholder groups will need to be involved in the decision-making process.

Give **one** example of a non-government organisation that could be involved in the decision-making process and describe how it could be involved.

2 marks

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**Question 4 (9 marks)**

A small, country, farming town has been struggling to meet its electrical energy needs with outdated infrastructure. Electricity from the national grid cannot always meet peak demand.

The town is surrounded by canola crops, a source of canola oil, and the remnant plant materials are used for stock feed. The canola oil and remnant plant materials can also be used to make renewable biodiesel, which can be used in any diesel engine without having to modify the engine to meet other regulatory requirements.

It is believed that the town has excess supply of this canola resource, enough to justify building a renewable biodiesel production plant. The renewable biodiesel would be used by the town to run renewable biodiesel generators to meet its electrical energy needs.

- a. When combusted, renewable biodiesel produces carbon dioxide, water and other wastes; however, renewable biodiesel makes a much lower contribution to global warming in the long term when compared to diesel produced from fossil fuels.

Justify this statement in terms of the carbon cycle and the possible contribution to global warming of both energy sources (biodiesel and diesel from fossil fuels).

3 marks

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- b. The generator is 25% efficient and creates 12 units of electrical energy.

How many units of energy from renewable biodiesel are needed to power the generator?

1 mark

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- c. Why would the renewable biodiesel production plant meet the town’s peak demand for electrical energy? Include an explanation of the term ‘peak demand’ in your answer.

3 marks

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- d. Identify and describe **one** environmental reason for locating the renewable biodiesel production plant close to the town.

2 marks

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**SECTION B – continued**  
**TURN OVER**

**Question 5** (9 marks)

Near a small, exposed, coastal city in Victoria, a major power company is in the process of decommissioning one of its larger coal-fired power stations and installing a 700 MW battery storage facility.

As part of this plan, the company is required to go through a remediation process and it aims to restore the old open-cut mine to create a large lake surrounded by parkland replicating endemic habitats. The remediation plans also include an area set aside for housing.

The site of the power station will become the battery storage facility.

- a. With no coal-fired power station, name **two** sources of renewable energy that could be built to obtain electricity. 2 marks

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- b. The plan to close the power station and remediate the site is partly focused on the ethical principle of ‘biocentrism’.  
State the meaning of ‘biocentrism’ and explain how it applies to the plan. 3 marks

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- c. Identify and describe **one** disadvantage of replacing a coal-fired power station with renewable energy sources that use battery storage systems. 2 marks

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- d. Explain **one** reason, related to infrastructure, for using the coal-fired power station site for the battery storage facility.

2 marks

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**SECTION B – continued**  
**TURN OVER**

**Question 6** (11 marks)

Sally, a cattle farmer, understands the important role that the natural greenhouse effect plays in climate regulation. She ensures that her staff have an understanding of both the natural greenhouse effect and the enhanced greenhouse effect. As part of future planning, Sally and her staff regularly consider how the farm can reduce its greenhouse gas emissions.

- a. Outline the natural greenhouse effect, including the types of incoming radiation, radiation interactions in the atmosphere and at Earth's surface, and the impact that these interactions have on Earth. You may include a labelled diagram. 5 marks

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- b. State the major cause of the natural greenhouse effect and the enhanced greenhouse effect. 2 marks

Natural greenhouse effect \_\_\_\_\_  
\_\_\_\_\_

Enhanced greenhouse effect \_\_\_\_\_  
\_\_\_\_\_

- c. List the two major greenhouse gases that Sally’s farm would be emitting, which contribute to the enhanced greenhouse effect, and state the source of each. 2 marks

Greenhouse gas 1 \_\_\_\_\_

Source \_\_\_\_\_

Greenhouse gas 2 \_\_\_\_\_

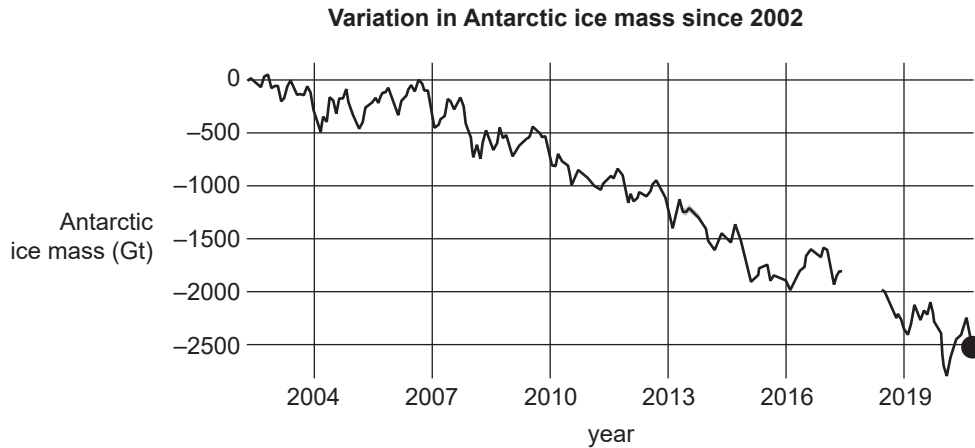
Source \_\_\_\_\_

- d. Sally decided to use carbon sequestration to offset the farm’s greenhouse gas emissions.  
Define ‘carbon sequestration’ and suggest **one** way in which this process could be carried out on the farm. 2 marks

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\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Question 7** (8 marks)

The graph below uses satellite data to show the changes in the mass of Antarctic ice from the year 2002 to the year 2020. The gap in the data around 2017 represents a space in time between satellite missions.



Source: adapted from National Aeronautics and Space Administration (NASA), 'Global Climate Change: Vital Signs of the Planet', <<https://climate.nasa.gov/vital-signs/ice-sheets/>>

- a. Describe the trend shown in the graph above and give **one** reason to explain this trend. 3 marks

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- b. Changes in the amount of global ice and snow coverage can be used to monitor the rate of climate change.

Describe **one** other global measurement that can be used to indicate the rate of climate change. 2 marks

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- c. Explain what is meant by the term 'albedo effect' and describe what will happen to this effect as a result of melting Antarctic ice.

3 marks

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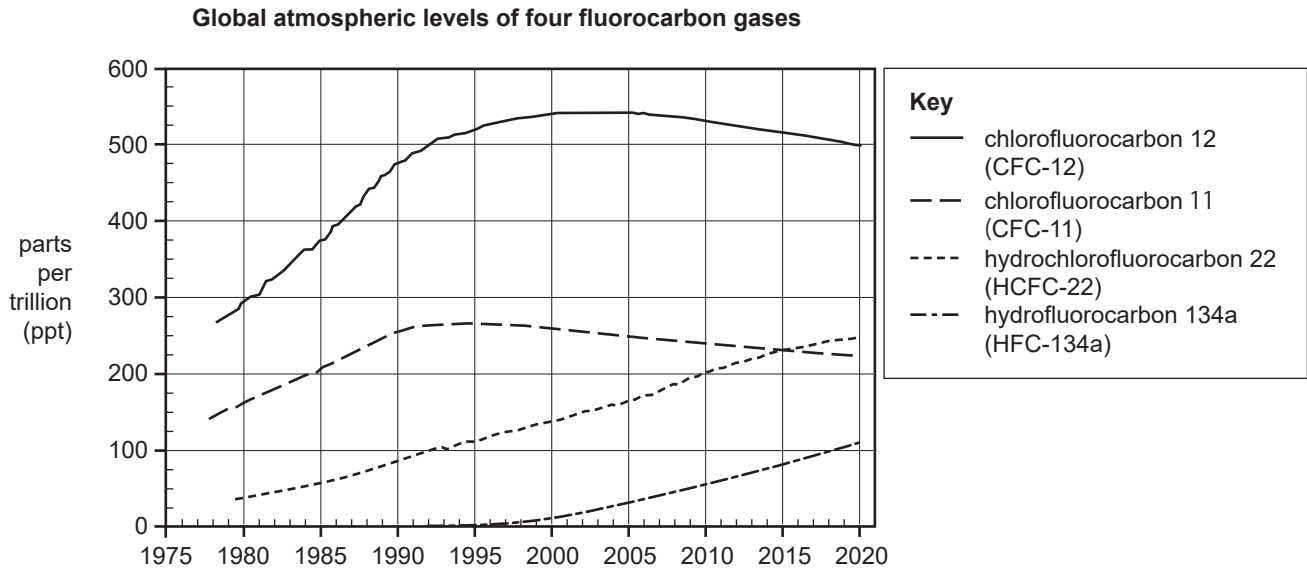
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**SECTION B – continued**  
**TURN OVER**

**Question 8** (6 marks)



- a. The unit of measurement for the four fluorocarbon gases shown in the graph above is parts per trillion (ppt). The unit of measurement for atmospheric levels of carbon dioxide is usually parts per million (ppm).

Explain why carbon dioxide has a different unit of measurement from the four fluorocarbon gases. 2 marks

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- b. What were the atmospheric levels of these four gases prior to 1900? Why? Justify your answer. 2 marks

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- c. These four fluorocarbon gases have a relatively low atmospheric concentration (less than 600 ppt).

Explain why they are still of concern in terms of their impact on global warming.

2 marks

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**SECTION B – continued**  
**TURN OVER**

**Question 9** (14 marks)

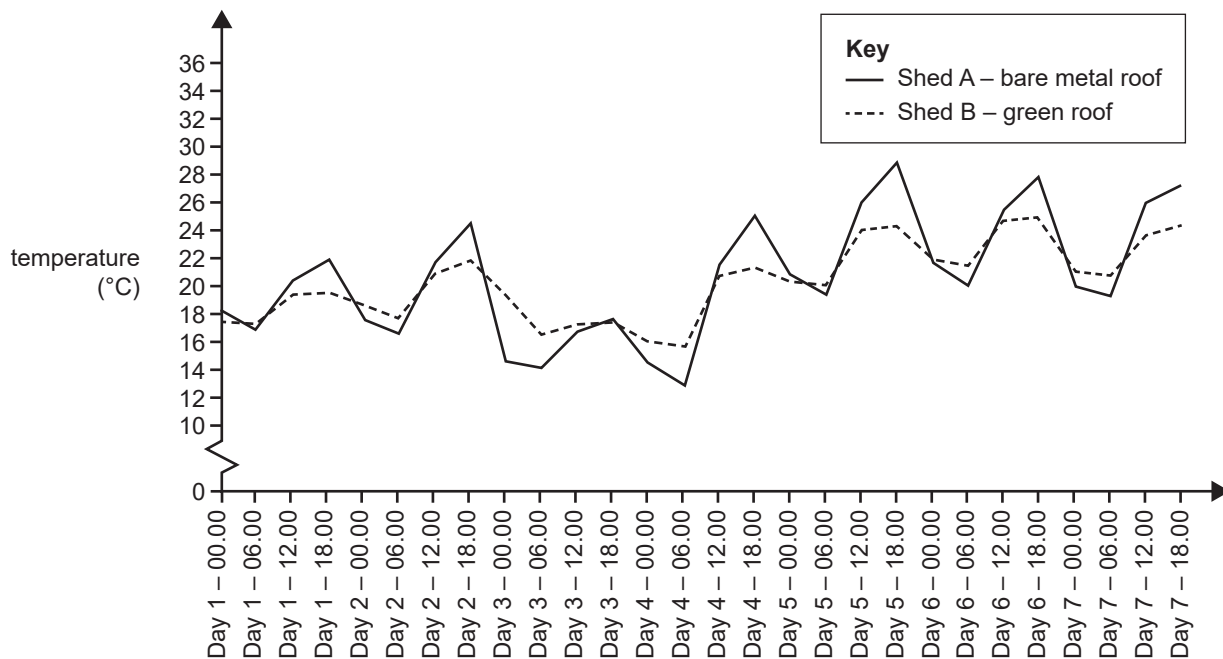
A class of students designs an investigation to measure the effects of a green roof on the temperature inside a building. A green roof is a roof on a building that is covered by low-growing plants in soil, on top of a root barrier and waterproof layer. The students are divided into two groups and develop two different hypotheses:

- Group 1 hypothesis – If the bare metal roof of a shed is covered by plants and soil (that is, a green roof), then the average temperature inside the shed will be lower.
- Group 2 hypothesis – If an insulating substance, such as a green roof (with suitable soil and plant material), is put on a bare shed roof, it will lower the temperature inside the shed during the day and allow much more heat to be retained overnight.

The students construct two identical small, metal garden sheds, Shed A and Shed B, on a flat area in the corner of the schoolyard. The students hang the same type of data loggers 250 mm below the ceiling in the centre of each shed to record the inside temperature every 30 minutes. The metal roof of Shed A is left bare. The students cover the metal roof of Shed B with special plastic trays containing 100 mm of soil planted with low-growing plants. The trays also have a water storage system that gathers rainwater to water the plants.

The class collected the inside temperature data for one week and produced the results as a graph, shown below.

**Temperature inside Shed A and Shed B over time**



Source: adapted from SJ Wilkinson and R Castiglia Feitosa, 'Retrofitting housing with lightweight green roof technology in Sydney, Australia, and Rio de Janeiro, Brazil', *Sustainability*, 7(1), 2015, pp. 1090 and 1091, <<https://doi.org/10.3390/su7011081>>; licensed CC-BY 4.0 <<https://creativecommons.org/licenses/by/4.0/>>

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a. What is the dependent variable in this investigation? 1 mark

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b. Before the investigation began, the students made sure the data loggers recording temperature were checked and calibrated correctly in the laboratory.

Explain whether this was done to improve scientific accuracy or precision and make clear the difference in meaning between the two terms.

4 marks

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c. Explain **one** environmental factor that could have caused the temperatures recorded in both sheds on Day 3.

2 marks

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**d.** Evaluate which of the two hypotheses is better supported by the data. 3 marks

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**e.** Describe **one** beneficial impact on the local hydrosphere of using green roof systems on a large scale in urban environments. 2 marks

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**f.** How do the results of this investigation illustrate the potential benefits for energy consumption of using green roof systems on a large scale in urban environments? 2 marks

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