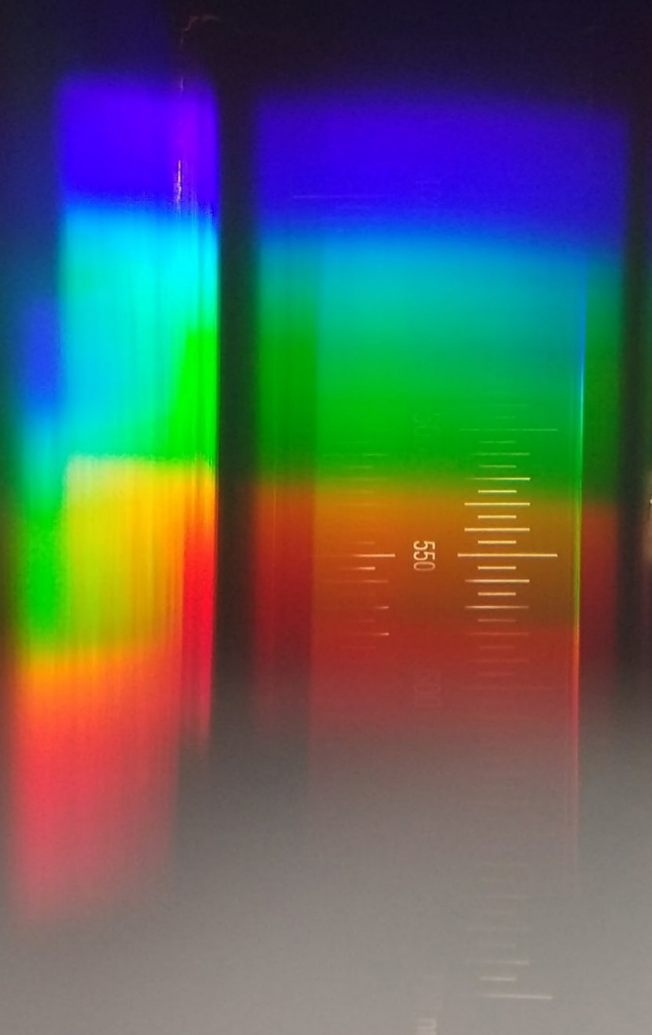


Summative Assessment Resources for Practical Science

Physics

Electromagnetic spectrum



About Project Calibrate

Project Calibrate is a research and development collaboration between University of Oxford and AQA, and aims to foster effective teaching, learning and assessment of practical science. The resource pack contains five summative assessments developed as part of the project to assess learners' understanding of and skills in GCSE practical science. The underlying framework of practical science is Brandon's matrix which highlights a variety of methods used in science. According to Brandon, there are four main categories of scientific methods (described on the next page). Four assessment tasks were designed using each category. The fifth assessment task includes all four categories and engages the learners in an evaluation of the different scientific methods.

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Project team

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Brandon’s Matrix

Brandon provides an account of diversity in scientific methods. His framework has been adapted by Project Calibrate (see Table 1) and illustrates that not all experiments rely on hypothesis testing, and that not all descriptive work is non-manipulative. Brandon represents the connections between experiments and observations in terms of a matrix (i.e. two-by-two table) in which an investigation (experiment/observation) is related to whether or not it involves manipulation, and whether or not it involves hypothesis testing or parameter measurement.

Table 1. Adaptation of Brandon’s matrix

	Experiment or observation	
	Change variable	Don’t change variable
Test hypothesis	Manipulative hypothesis testing	Non-manipulative hypothesis testing
Describe or measure	Manipulative description or parameter measurement	Non-manipulative description or parameter measurement

The importance of the matrix is that it challenges the traditional linear model of the scientific method in the science curriculum. A fairly typical depiction in school of how science is done involves the so-called ‘scientific method’, which is described as a process through which scientists produce robust evidence by applying procedures such as experimentation and observation. According to this model, scientists begin with a question they want to answer. They then design an experiment and, by carefully tracing independent and dependent variables, they produce findings that help them answer the question. However, such a step-wise and linear description of the scientific method is simplistic and hardly a realistic representation of how scientists actually do science. Rather, scientists engage in a wide array of methods some of which include hypothesis testing, and some other approaches including those where there is no manipulation of variables (Erduran & Dagher, 2014).

A contemporary example about Brandon’s matrix involves the Covid-19 pandemic (Erduran, Childs & Baird, 2020). Scientists collect data on how the virus might be influencing a patient’s breathing over a period of time. Such observation is simply based on the recording of parameters where there is no manipulation of variables in the sense of an experimental design. Sometimes the data might be subjected to hypothesis testing about correlation between incubation period and extent of lung disease, but without an experiment resulting in non-manipulative hypothesis testing. Scientists may conduct randomised control trials in which a drug could be treated as a variable in interventions that also include control groups to test the placebo effect. All of these different approaches are used in science, and there is no one single method but rather a diversity of scientific methods.

References

Brandon, R. (1994). Theory and experiment in evolutionary biology. *Synthese*, 99, 59-73.

Erduran, S., Childs, A., & Baird, J. (2020). Practical science and pandemics. <https://www.bera.ac.uk/blog/practical-science-and-pandemics>

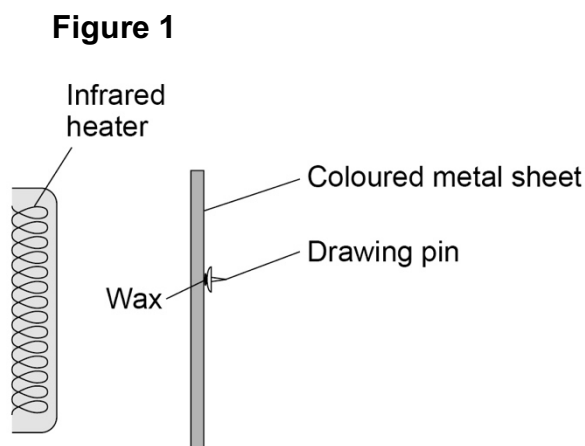
Erduran, S., & Dagher, Z. (2014). *Reconceptualising the nature of science for science education: Scientific knowledge, practices and other family categories*. Dordrecht: Springer

Physics: Electromagnetic spectrum

Question 1 [manipulative hypothesis testing]

A student investigated how the colour of a metal sheet affected the amount of infrared radiation absorbed by the sheet.

Figure 1 shows how the student set up their equipment



The drawing pin is held in place with wax.

When the wax melts, the drawing pin falls off the metal sheet.

The student measured the time it took for the wax to melt.

The student repeated the experiment with different coloured metal sheets.

1.1 Give **one** variable the student should have controlled in their investigation.

[1 mark]

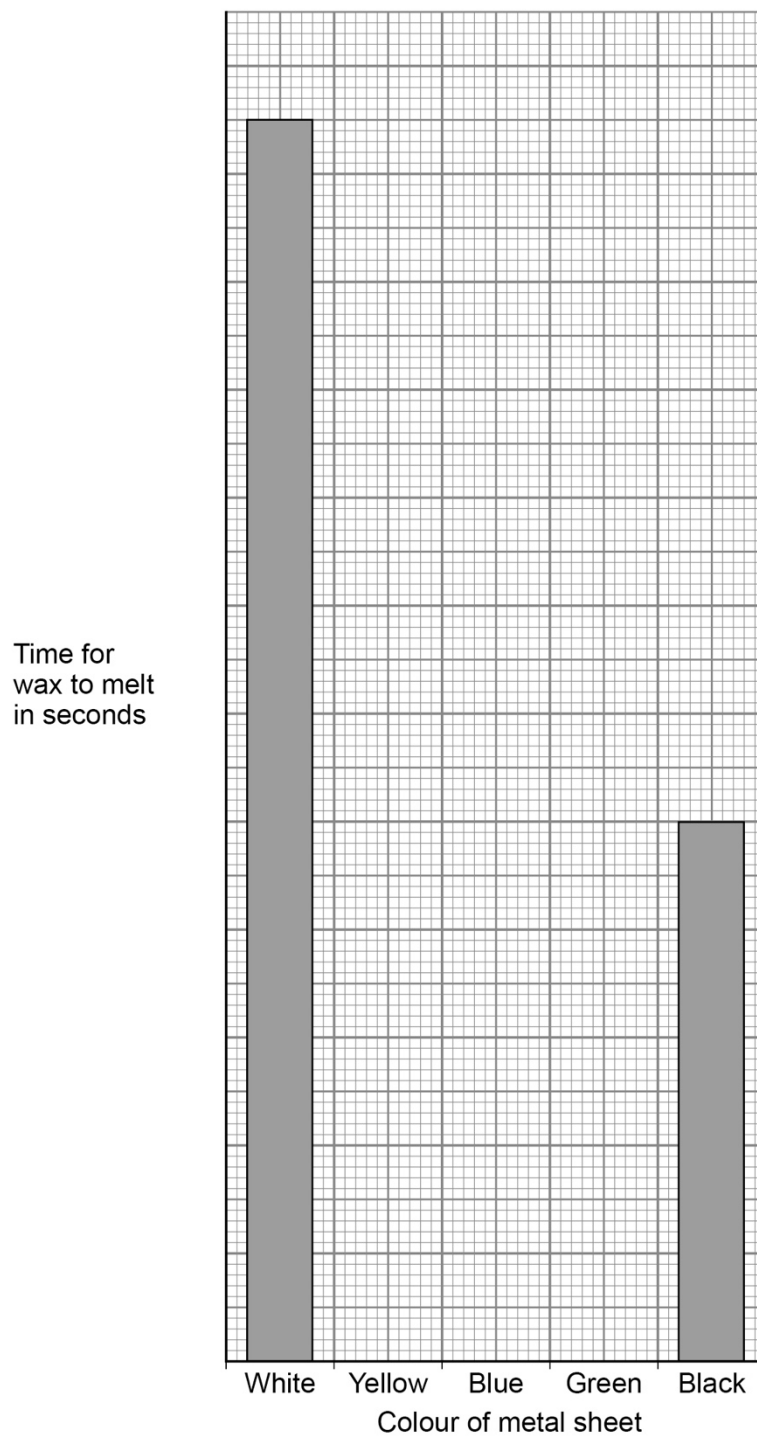
The student's results are shown in **Table 1**.

Table 1

Colour of metal sheet	Time for wax to melt in seconds
White	230
Yellow	210
Blue	150
Green	160
Black	100

Figure 2 is a bar chart of some of the student's results.

Figure 2



1.2 Complete Figure 2.

- Add a scale to the vertical axis.
- Plot the bars for the remaining data in Table 2.

[3 marks]

1.3 What can the student conclude about black surfaces and the amount of infrared radiation absorbed? Give a reason for your answer.

[2 marks]

1.4 The student's conclusion was that white surfaces reflect all the incident infrared radiation to the surroundings.

The student's conclusion was incorrect. Give **one** reason why.

[1 mark]

1.5 Albedo is a measure of how much incident radiation is reflected by a surface.

Albedo varies between 0 (perfect absorber) and 1 (perfect reflector).

Calculating the albedo of each coloured metal surface would improve the results of the investigation.

Suggest why.

[2 marks]

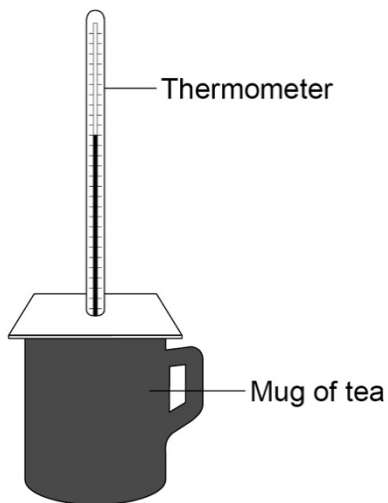
[Total= 9 marks]

Question 2 [non-manipulative parameter measurement]

A student investigated how the temperature of a mug of hot tea varied with time.

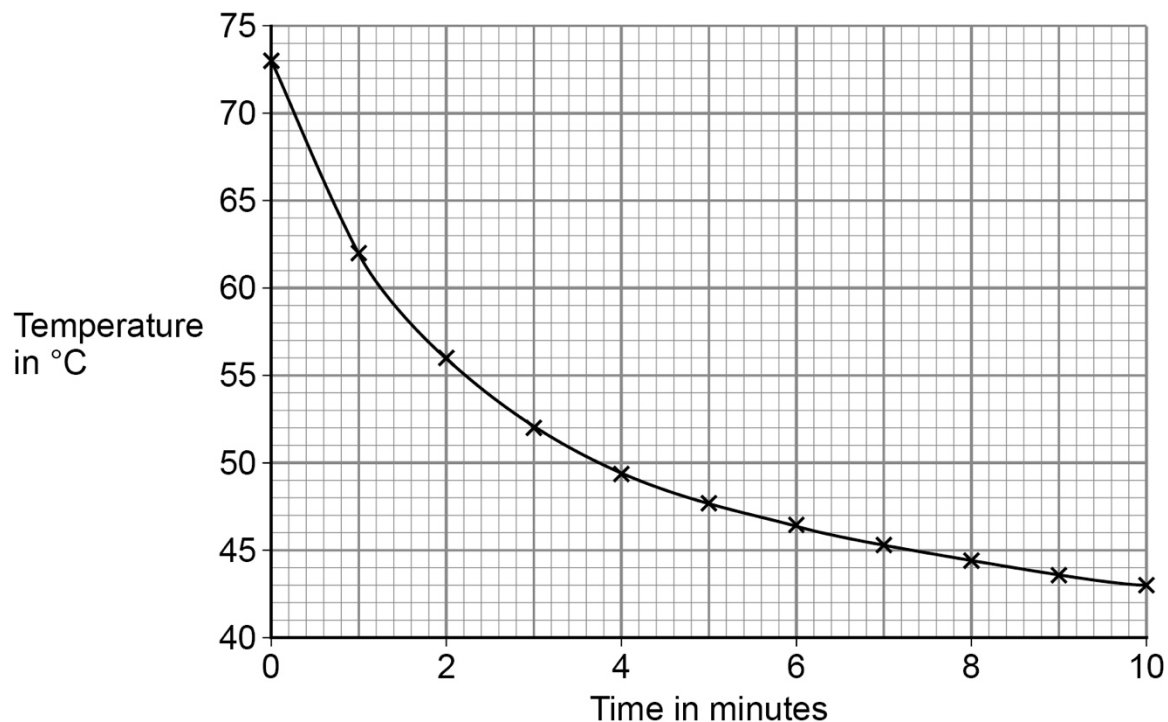
Figure 3 shows some of the equipment the student used.

Figure 3



The results of the student's investigation are shown in **Figure 4**.

Figure 4



2.1 Describe how the student should take the measurements needed to collect the data shown in **Figure 4**.

[4 marks]

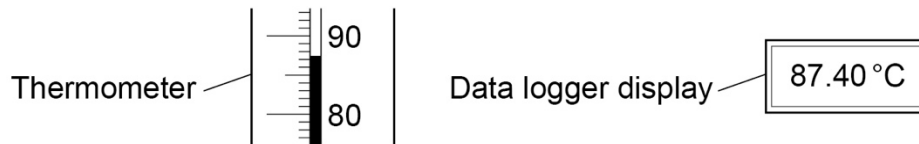
2.2 What conclusions can the student make from her investigation?

[2 marks]

2.3 Temperature can also be measured using a datalogger and temperature probe.

Figure 5 shows the display from a datalogger and a thermometer.

Figure 5



Give **one** advantage of using a datalogger and temperature probe instead of a thermometer in this investigation.

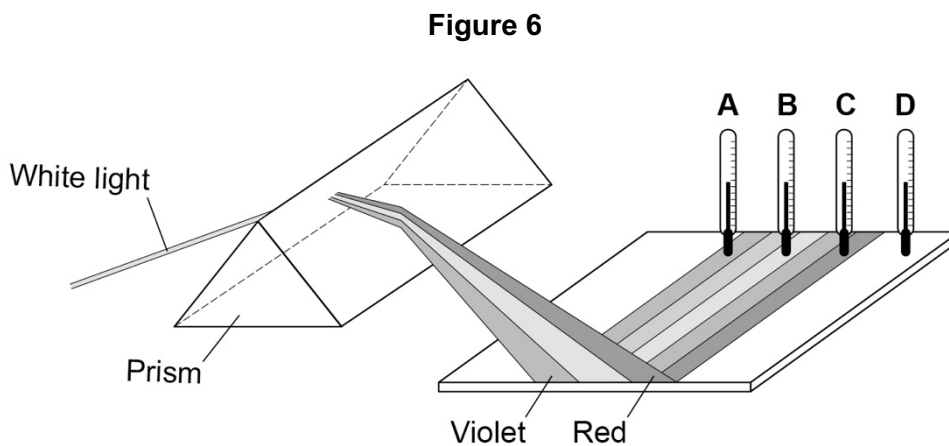
[1 mark]

[Total: 7 marks]

Question 3 [manipulative parameter measurement]

In the 18th Century a scientist called William Herschel investigated the heating effect of different colours of light.

Figure 6 shows the equipment he used.



Herschel used a prism to split white light into a spectrum of colours.

He recorded the temperature increase using thermometers placed in four positions, **A**, **B**, **C** and **D**.

His results are shown in **Table 2**.

Table 2

Position	Temperature increase after 2 minutes in °C
A	3
B	3
C	5
D	7

3.1 Suggest **one** reason Herschel would have been surprised by the result for thermometer D.

[1 mark]

3.2 Herschel concluded that there must be an invisible form of light beyond red in the visible spectrum.

Suggest why.

[1 mark]

3.3 What was Herschel's conclusion based on?

Tick **one** box.

[1 mark]

- Herschel's conclusion was based on a prediction.
- Herschel's conclusion was based on an observation.
- Herschel's conclusion was based on a hypothesis.

3.4 Modern scientists have discovered a use for a different part of the electromagnetic spectrum called terahertz radiation.

Terahertz radiation is between infrared and microwave radiation in the electromagnetic spectrum.

One use of terahertz radiation is for body scanners in airports.

Terahertz radiation allows airport security to see through people's clothes.

Suggest **one** advantage and **one** disadvantage of using terahertz radiation for this use.

[2 marks]

Advantage _____

Disadvantage _____

[Total: 5 marks]

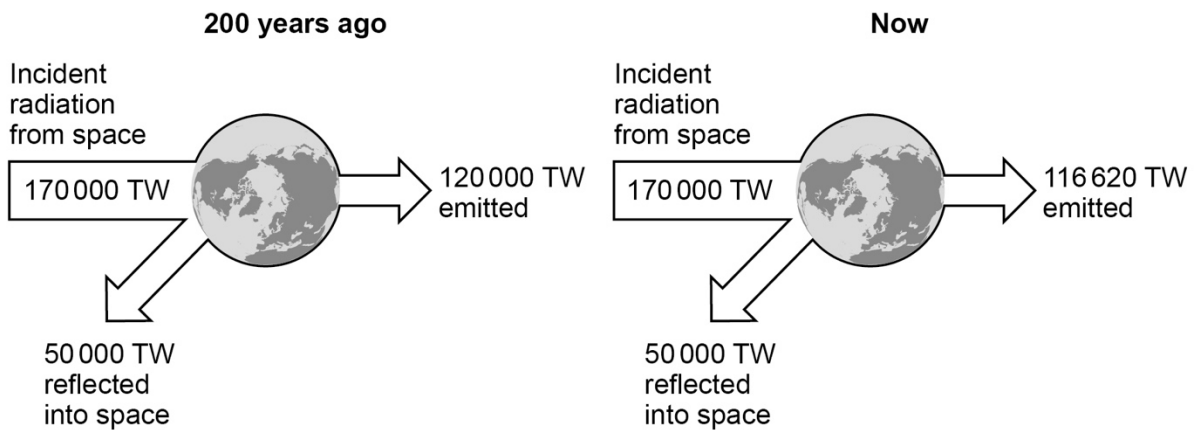
Question 4 [non-manipulative hypothesis testing]

Q4. The amount of infrared radiation absorbed by the Earth's atmosphere affects the temperature of the Earth.

Figure 7 shows how the balance between the incident radiation from space and the radiation emitted by the Earth into space has changed over the last 200 years.

1 TW = 10^{12} W

Figure 7

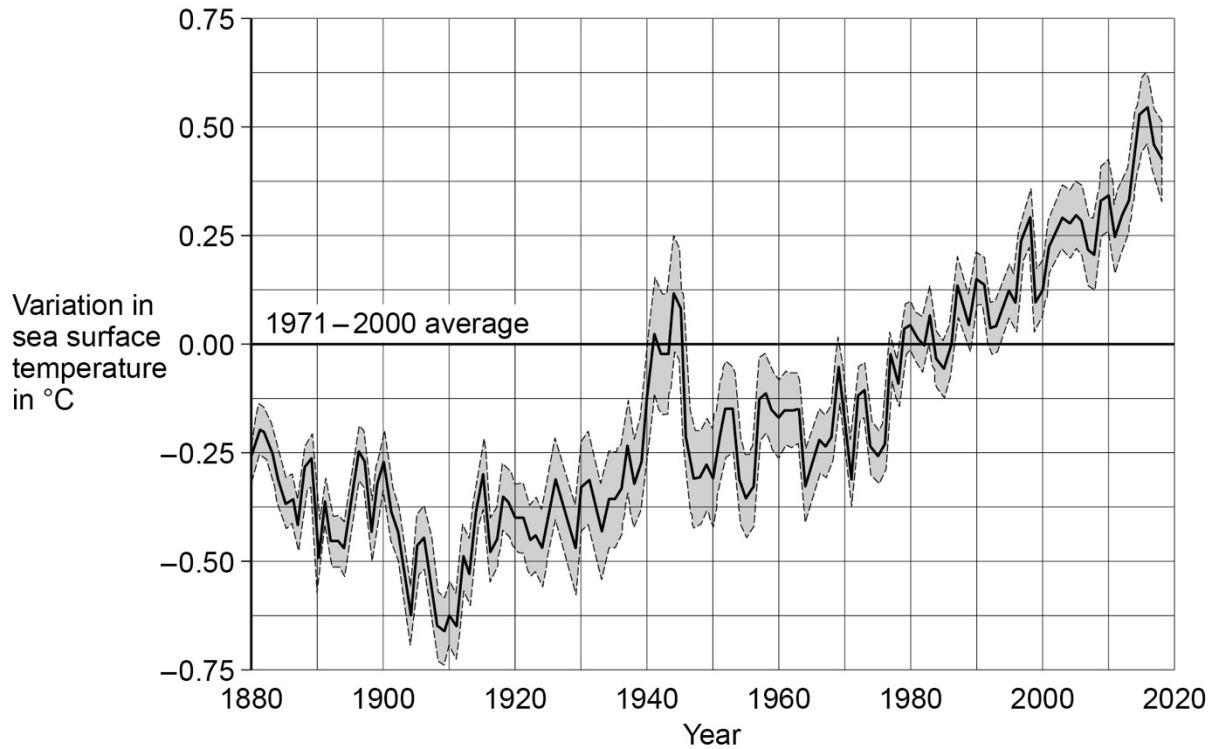


4.1 Use data from **Figure 7** to explain why the temperature of the Earth has changed over the last 200 years.

[3 marks]

Figure 8 shows how the global sea surface temperature has changed between 1880 and 2015.

Figure 8



Scientists have concluded that global sea surface temperature has increased.

The grey area shows the uncertainty in the mean measurements of the scientists.

4.2 What is meant by uncertainty?

[1 mark]

4.3 Some politicians say that the uncertainty means that the scientists are not sure of their conclusion.

Explain why these politicians are incorrect.

[2 marks]

4.4 The increase in global temperature is caused by an increase in carbon dioxide in the atmosphere.

Describe **two** ways in which humans can decrease the amount of carbon dioxide released into the atmosphere.

[2 marks]

1. _____

2. _____

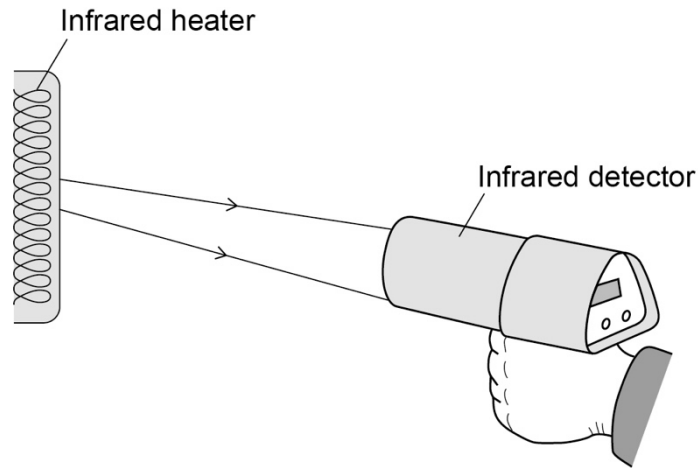
[Total: 8 marks]

Question 5 [combined task]

Two students investigated how the surface temperature of an infrared heater affected the amount of infrared radiation it emitted.

Figure 8 shows the equipment used by the two students.

Figure 8



The students varied the temperature of the infrared heater and measured the infrared radiation received by the infrared detector.

5.1 The students kept the distance between the infrared heater and the infrared detector constant during their investigations.

Tick **one** box.

[1 mark]

- Distance was a categoric variable.
- Distance was a control variable.
- Distance was the dependent variable.
- Distance was the independent variable.

Student A's hypothesis was:

"Changing the temperature of the infrared heater will affect the amount of infrared radiation received by the infrared detector."

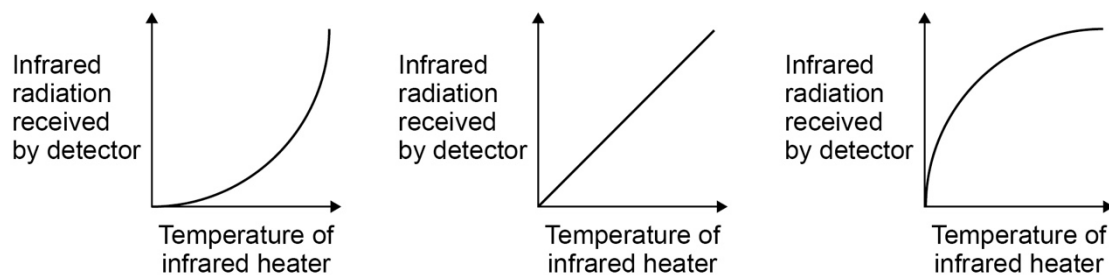
Student B's hypothesis was:

"Increasing the temperature of the infrared heater will increase the amount of infrared radiation received by the infrared detector."

5.2 Explain why Student B's hypothesis is better than Student A's hypothesis. **[2 marks]**

5.3 Student B's hypothesis would be correct if the results showed a pattern like any of the graphs shown in **Figure 10**.

Figure 10



Student C says that student B's hypothesis is not valid because each graph is different.

Is student C correct? Give reasons for your answer.

[2 marks]

- 5.4 The instruction booklet for the infrared detector states that there is an uncertainty of $\pm 5.0\%$ for the detector.

Calculate the range of possible values when the infrared detector shows a reading of 46 W/m^2 .

[2 marks]

Range = _____ to _____ W/m^2

- 5.5 A student recorded the infrared radiation detected for a small range of heater temperatures. The results are shown in **Table 3**.

Table 3

Infrared heater temperature in $^{\circ}\text{C}$	Infrared radiation detected in W/m^2	Uncertainty in infrared radiation detected in W/m^2
200	50	2.5
250	100	5.0
270	130	6.5
300	140	7.0
350	170	8.5

Measuring the infrared radiation detected for temperatures of 270°C and 300°C does not provide useful data for this investigation.

Explain why.

[2 marks]

[Total: 9 marks]

Mark scheme

Question 1

Question	Answers	Mark	Spec ref. / AO etc.
1.1	<p>any one from:</p> <ul style="list-style-type: none"> distance between infrared heater and metal sheet power output of heater amount of wax (used to hold drawing pin) thickness of metal sheet 	<p>1</p>	<p>AO2</p> <p>WS 2.2</p>
1.2	<ul style="list-style-type: none"> • correct scale on vertical axis • 3 bars plotted correctly (allow 1 mark for 1 or 2 bars plotted correctly) 	<p>1</p> <p>2</p>	<p>AO1</p> <p>MS 2c; WS 3.1</p>
1.3	<ul style="list-style-type: none"> • black surfaces absorb the most infrared radiation • because the wax melted first <p>or</p> <p>the wax took the least time to melt</p>	<p>1</p> <p>1</p>	<p>AO2</p> <p>WS 3.5, 3.6</p>
1.4	<ul style="list-style-type: none"> • if the white surface reflected all infrared, the wax would not melt <p>or</p> <p>the wax melted</p>	<p>1</p>	<p>AO3</p> <p>WS 3.5, 3.6</p>
1.5	<ul style="list-style-type: none"> • albedo is a continuous variable • allows colours to be compared accurately <p>or</p> <p>similar colours can be compared</p> <p>or</p> <p>blue and green can be compared</p> <p>or</p> <p>a line of best fit could be drawn (for the results)</p>	<p>1</p> <p>1</p>	<p>AO3</p> <p>WS2.3, 2.7</p>
Total		9	

Question 2

Question	Answers	Mark	Spec ref. / AO etc.
2.1	<p>Level 2: The method would lead to the production of a valid outcome. Key steps are identified and logically sequenced. [3-4 marks]</p> <p>Level 1: The method would not necessarily lead to a valid outcome. Some relevant steps are identified, but links are not made clear. [1-2 marks]</p> <p>No relevant content [0 marks]</p> <p>Indicative Content:</p> <ul style="list-style-type: none"> • Measure volume of tea / water using a measuring cylinder • Thermometer used to measure the temperature of the tea • Leave the thermometer in the tea for a minute before recording the temperature • Use a stopwatch to record the time • Record the temperature every minute for 10 minutes • Stir the tea using a stirring rod 	<p>3-4</p> <p>1-2</p>	<p>AO2</p> <p>WS 2.2, 2.3, 2.4</p>
2.2	<ul style="list-style-type: none"> • temperature decreases with time • the larger the difference between water temperature and surroundings the higher the rate of temperature decrease or energy transfer <p>allow for 2 marks: temperature decreases with time at a decreasing rate</p>	<p>1</p> <p>1</p>	<p>AO1</p> <p>WS 3.5, 3.6</p>
2.3	<p>higher resolution</p> <p>or</p> <p>no reaction time error</p> <p>or</p>	<p>1</p>	<p>AO3</p> <p>WS 2.3, 2.6, 3.7, 3.8</p>

	<p>data logger (and temperature probe) can simultaneously record temperature and time</p> <p>or</p> <p>datalogger and temperature probe reduce the chance of misreading the temperature</p>		
Total		7	

Question 4

Question	Answers	Mark	Spec ref. / AO etc.
4.1	<ul style="list-style-type: none"> • Earth's temperature has increased • Same incident radiation / 170 000 TW • Less (incident) radiation is emitted 	1	AO2
		1	WS 1.2
		1	
4.2	Uncertainty shows the variation in the scientists' measurements	1	AO1 WS 3.7, 4.1
	<ul style="list-style-type: none"> • temperature of the sea varies depending on location measured <p>or</p> <p>a large number of measurements has been taken</p>	1	AO2 WS 3.7, 3.8 / MS 2f
		1	
4.4	Any two from: <ul style="list-style-type: none"> • Burn less fossil fuels / named fossil fuel • Cut down fewer trees • Reduce industrial processes that release carbon dioxide 	2	AO1 WS 1.4
Total		8	

Question 5

Question	Answers	Mark	Spec ref. / AO etc.
5.1	Distance was a control variable	1	AO1 WS 2.2
5.2	<ul style="list-style-type: none"> Student A does not state how each variable varies with the other. Student B states how changing one variable will affect the other variable. 	1 1	AO2 WS 2.1, 2.2
5.3	<ul style="list-style-type: none"> Student C is incorrect because student B's hypothesis describes a possible relationship between the two variables. (Before the investigation) Student B does not know the nature of the exact / mathematical relationship between the variables. 	1 1	AO3 WS 2.1, 2.2, 3.5, 3.6
5.4	<ul style="list-style-type: none"> $46 \times 0.95 = 43.7$ (allow an answer of 44) $46 \times 1.05 = 48.3$ (allow an answer of 48) 	1 1	AO2 WS 3.7/ MS 1c
5.5	<ul style="list-style-type: none"> the values of the infrared radiation detected at 270 °C and 300 °C overlap due to the combined uncertainties in the values detected <p>or</p> <p>values of infrared radiation detected are within 10% of each other</p> <p>or</p> <p>$130 + 6.5$ is greater than $140 - 7.0$</p>	1 1	AO3 WS 3.7 / MS 1c
Total		9	

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