8.2 Thermal Energy Transfer

Question Paper

Course	DP IB Physics
Section	8. Energy Production
Topic	8.2 Thermal Energy Transfer
Difficulty	Medium

Time allowed: 80

Score: /60

Percentage: /100

Question 1a

Thermal radiation is emitted by all bodies with an absolute temperature. It is often modelled using an idealised 'black body'.

(a)
Explain how the temperature of a black body can be estimated based on the frequency of radiation emitted from it.

[2 marks]

Question 1b

The spectrum of radiation emitted by a sample of glacier ice is examined. The ice is at a temperature of −55 °C.

(b)
Calculate the peak wavelength of radiation emitted by the ice.

[2 marks]

Question 1c

The average albedo of clean snow is 0.9. The average albedo of the glacier ice is 0.25.

(c)
For the glacier:

(i)
Determine the ratio of radiation scattered from the snow compared to the glacier ice

[2]

(ii)
Outline an assumption made in part (i) and give a reason why this assumption may not be correct.

[2]

[4 marks]

Question 1d

The average intensity of radiation incident on the glacier is 4.7 kW h m^{-2} during the summer and 0.23 kW h m^{-2} during the winter, but these values are expected to rise as the climate changes.

When the snow melts and exposes the glacier ice beneath the surface albedo falls. This process is being accelerated. Explain how this acceleration affects global warming.

[3 marks]

Question 2a

An industrial kiln is used for 'firing' ceramic and pottery items at very high temperatures.

The kiln emits electromagnetic radiation of peak wavelength, $\lambda_{max} = 3.50 \times 10^{-6}$ m.

(a)
Determine the temperature, in degrees Celsius, of the kiln. You can treat the kiln as an ideal black body.

[2 marks]

Question 2b

The kiln has a surface area of 160 m^2.

(b)
Calculate the energy radiated per second.

[3 marks]

Question 2c

The large kiln is compared to a smaller model with a surface area of 120 m^2 and a lower operating temperature of 710 K. The smaller kiln is made from the same materials and can also be treated as an ideal black body.

(c)
Determine the ratio of power radiated for the large kiln to the small kiln.

[2 marks]

Question 2d

The working areas and people around kilns need to be protected from the high levels of heat energy emitted.

(d)
With reference to the mechanisms by which heat energy is transferred, outline how protection from heat energy could be achieved.

[3 marks]

Question 3a

(a)
The intensity of radiation from a source radiating energy at a rate of *P* follows an inverse square law with the distance, *r*, from the source.

(i)
Derive an expression for intensity of this radiation at distance, *r*, from the source.

(ii)
Outline an assumption made in part (i).

[3 marks]

Question 3b

A planned Mars Rover will be powered using several solar panels each with dimensions of 2800 × 5900 mm. The equipment is tested on Earth at a point where the albedo of Earth's atmosphere is 0.310.

The radiant power of the Sun is 3.90×10^{26} W and the average radius of Earth's orbit around the Sun is 1.50×10^{11} m.

(b)
Determine the power, in kW, incident on a single solar heating panel being tested on Earth.

Assume that the Sun is at its highest point and the light from the Sun is normally incident on the panel.

[4 marks]

Question 3c

An astronomer uses the following data for a simple climatic model of Mars without an atmosphere:

Orbital radius between Mars and the Sun = 2.3×10^{11} m
Absorbed solar radiation = 493 W m^{-2}

(c)
Determine the average albedo for Mars that is to be used in the modelling.

[2 marks]

Question 3d

(d) Determine the ratio $\frac{P_M}{P_E}$

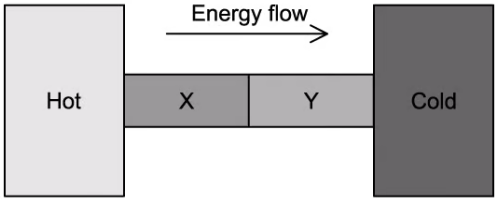
Where P_M is the power of solar radiation incident on the solar panel on Mars and P_E is the power of solar radiation incident on the solar panel on Earth.

[2]

[2 marks]

Question 4a

A regular cylinder is made up from two materials, X and Y. The cylinder's dimensions are uniform throughout X and Y. The cylinder is placed in contact with a hot and cold source such that energy is conducted between them.



(a)
State and explain whether the following values are equal for the cylinder:

(i)
The energy flow rates through X and Y

[2]

(ii)
The temperature difference across X and the temperature difference across Y.

[2]

[4 marks]

Question 4b

The following data are available for two metallic elements.

Silver	Gold
Density = 10.49 g cm^{-3}	Density = 19.3 g cm^{-3}
Relative atomic mass = 107.8682	Relative atomic mass = 196.9665

(b)
Using the data, and by determining a suitable equation, determine whether silver or gold is a better conductor of electricity.

Assume that each metal atom contributes one free electron.

[4 marks]

Question 4c

It is very common at the coast for beaches to experience onshore winds during the day and offshore winds at night.

(c)
Outline why this might be the case.

[4 marks]

Question 4d

A satellite orbiting Earth has a malfunction, with some of its external components overheating.

(d)
Discuss the ways in which the component can and cannot cool down while the satellite remains in orbit.

[3 marks]

Question 5a

Scientists modelling climate change are considering the effects of a range of actions on a global scale.

One possible model theorises an Earth with no atmosphere.

(a)
Explain why scientists use models which ignore some of the conditions of the situation they are studying. Include the benefits and limitations of this method.

[3 marks]

Question 5b

Energy flow diagrams can be used to represent energy transfers, making them clearer to understand.

(b)
Using the data available, draw a diagram showing the energy flows for a 'no-atmosphere' Earth.

Data available:
Incident solar radiation = 350 W m^{-2}
Absorbed solar radiation = 250 W m^{-2}

[3 marks]

Question 5c

The average solar radiation reaching the surface can be found using the following equation:

$$\text{Average intensity at the surface, } I = \frac{(1-\alpha)S}{4}$$

Where α is albedo and S is the solar constant.

(c)
Write an energy balance equation to show that the power received by the Earth is equal to the power radiated by the Earth.

Make clear any assumptions you make.

[3 marks]

Question 5d

(d)
The average intensity of radiation reaching the surface is 238 W m^{-2}.

(i)
Use the equation determined in part (c) to calculate the surface temperature of the Earth.

[2]

(ii)
Comment on the validity of your answer.

[2]

[4 marks]