8.2 Thermal Energy Transfer practice *[65 marks]*

1. A black body emits radiation with its greatest intensity at a wavelength of I_{max}. The surface temperature of the black body doubles without any other change occurring. What is the wavelength at which the greatest intensity of radiation is emitted? *[1 mark]*

A. I_{max}

B. $\frac{I_{max}}{2}$

C. $\frac{I_{max}}{4}$

D. $\frac{I_{max}}{16}$

Markscheme

B

2. The three statements give possible reasons why an average value should be used for the solar constant. *[1 mark]*

I. The Sun's output varies during its 11 year cycle.
II. The Earth is in elliptical orbit around the Sun.
III. The plane of the Earth's spin on its axis is tilted to the plane of its orbit about the Sun.

Which are the correct reasons for using an average value for the solar constant?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

A

3. The average surface temperature of Mars is approximately 200 K and the average surface temperature of Earth is approximately 300 K. Mars has a radius half that of Earth. Assume that both Mars and Earth act as black bodies. *[1 mark]*

What is $\frac{\text{power radiated by Mars}}{\text{power radiated by Earth}}$?

A. 20
B. 5
C. 0.2
D. 0.05

Markscheme

D

4. The solar constant is the intensity of the Sun's radiation at *[1 mark]*

A. the surface of the Earth.
B. the mean distance from the Sun of the Earth's orbit around the Sun.
C. the surface of the Sun.
D. 10km above the surface of the Earth.

Markscheme

B

5. A room is at a constant temperature of 300 K. A hotplate in the room is at a temperature of 400 K and loses energy by radiation at a rate of *P*. What is the rate of loss of energy from the hotplate when its temperature is 500 K? *[1 mark]*

A. $\frac{4^4}{5^4}P$

B. $\frac{5^4+3^4}{4^4+3^4}P$

C. $\frac{5^4}{4^4}P$

D. $\frac{5^4-3^4}{4^4-3^4}P$

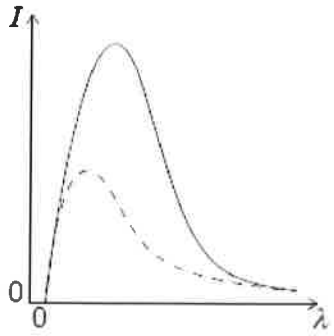
Markscheme

D

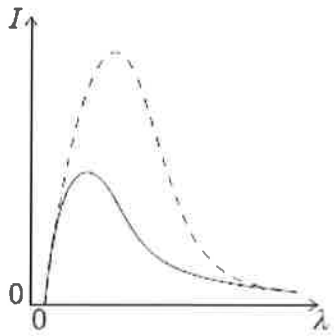
6. Planet X and planet Y both emit radiation as black bodies. Planet X has a surface temperature that is less than the surface temperature of planet Y. *[1 mark]*

What is the graph of the variation of intensity I with wavelength λ for the radiation emitted by planet Y? The graph for planet X is shown dotted.

A.



B.



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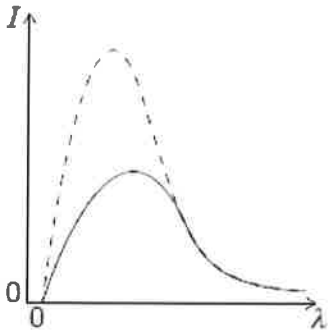

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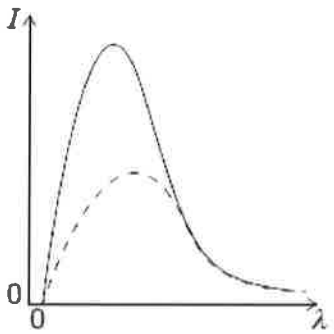


Markscheme

D

7. An object can lose energy through *[1 mark]*

I. conduction
II. convection
III. radiation

What are the principal means for losing energy for a hot rock resting on the surface of the Moon?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

B

8. The average albedo of glacier ice is 0.25. *[1 mark]*

What is $\frac{\text{power absorbed by glacier ice}}{\text{power reflected by glacier ice}}$?

A. 0.25

B. 0.33

C. 2.5

D. 3.0

Markscheme

D

9. X and Y are two spherical black-body radiators that emit the same total power. The absolute temperature of X is half that of Y. *[1 mark]*

What is $\frac{\text{radius of X}}{\text{radius of Y}}$?

A. 4

B. 8

C. 16

D. 32

Markscheme

A

10. Methane and carbon dioxide are both greenhouse gases that are believed to cause global warming. The reason for this is that these gases *[1 mark]*

A. absorb incoming radiation from the Sun.

B. transmit the incoming radiation from the Sun and radiation from the Earth.

C. reflect incoming radiation from the Sun.

D. transmit incoming radiation from the Sun and absorb outgoing radiation from the Earth.

Markscheme

D

11. A black body of surface $1.0 m^2$ emits electromagnetic radiation of peak wavelength $2.90 \times 10^{-6} m$. Which of the following statements about the body are correct? *[1 mark]*

I. The temperature of the body is 1000 K.
II. The energy radiated by the body in one second is 5.7×10^4 J.
III. The body is a perfect absorber of electromagnetic radiation.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Markscheme

D

12. Changes in the climate are leading to a reduction in ice cover on Earth. Which of the following describes, for Earth, the change in albedo and the change in the rate of energy absorption? *[1 mark]*

	Change in albedo	Change in rate of energy absorption
A.	decrease	decrease
B.	decrease	increase
C.	increase	increase
D.	increase	decrease

Markscheme

B

13. The average intensity of the solar radiation incident on a planet is 200 W m^{-2}. The albedo of the planet is 0.6. The average temperature of the planet is constant. *[1 mark]*

Which of the following is a correct statement about the intensity of radiation reflected and radiated by the planet?

	Intensity reflected by planet	Intensity radiated by planet
A.	$120\,W\,m^{-2}$	$80\,W\,m^{-2}$
B.	$120\,W\,m^{-2}$	less than $80\,W\,m^{-2}$
C.	$80\,W\,m^{-2}$	$120\,W\,m^{-2}$
D.	$80\,W\,m^{-2}$	less than $120\,W\,m^{-2}$

Markscheme

A

14. A black body has kelvin temperature *T* and surface area *A*. The total power radiated by the body is *P*. What is the new power radiated when *T* is doubled and *A* is halved? *[1 mark]*

A. 4*P*
B. 8*P*
C. 16*P*
D. 32*P*

Markscheme

B

15. The greenhouse effect can be explained by the fact that the infrared radiation emitted by the surface of Earth *[1 mark]*

A. is absorbed by the atmosphere and then re-radiated in all directions.

B. raises the temperature of the upper atmosphere.

C. is trapped by the upper atmosphere.

D. is absorbed by the atmosphere and then all of it is re-radiated back to the surface of Earth.

Markscheme

A

16. A student states that the following factors may lead to global warming *[1 mark]*

I. decreased albedo of the Earth's surface
II. increase in volcanic activity
III. deforestation.

Which of the above statements are correct?

A. I and II only
B. II and III only
C. I and III only
D. I, II and III

Markscheme

D

17. Gases in the Earth's atmosphere believed to be responsible for the greenhouse effect include *[1 mark]*

A. sulfur dioxide, nitrous oxide, water.
B. methane, carbon monoxide, ozone.
C. carbon dioxide, sulfur trioxide, carbon monoxide.
D. water, methane, nitrous oxide.

Markscheme

D

18. Which of the following geographical features has the lowest albedo? *[1 mark]*

A. Polar ice cap
B. Desert
C. Ocean
D. White cliffs

Markscheme

C

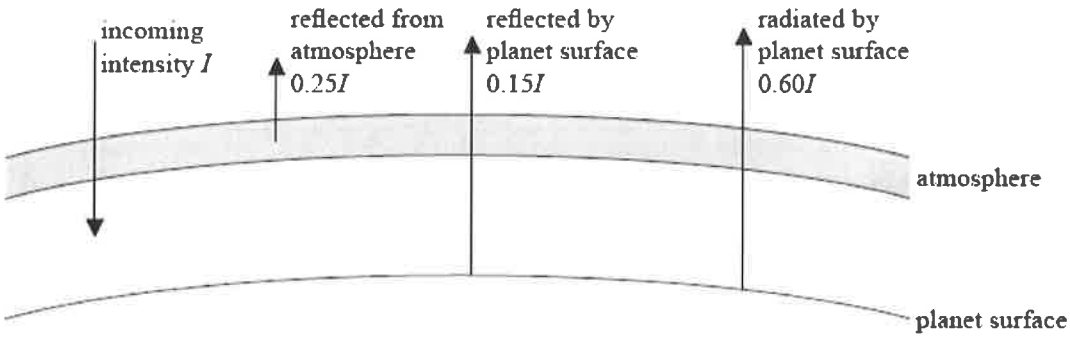
19. In which of the following places will the albedo be greatest? *[1 mark]*

A. A forest
B. A grassland
C. An ocean
D. A polar ice cap

Markscheme

D

20. The diagram shows an energy balance climate model for a planet. *[1 mark]*



The intensities of the reflected and radiated radiation are given in terms of the incident intensity I. Which of the following is the albedo of this planet?

A. 0.15
B. 0.25
C. 0.40
D. 0.60

Markscheme

C

21. The albedo for the oceans is lower than that for glaciers. This is because, compared to ice, sea water *[1 mark]*

A. has a greater density.
B. has a greater specific heat capacity.
C. has a greater coefficient of volume expansion.
D. absorbs a greater amount of radiative power.

Markscheme

D

22. Greenhouse gases *[1 mark]*

A. reflect infrared radiation but absorb ultraviolet radiation.

B. reflect ultraviolet radiation but absorb infrared radiation.

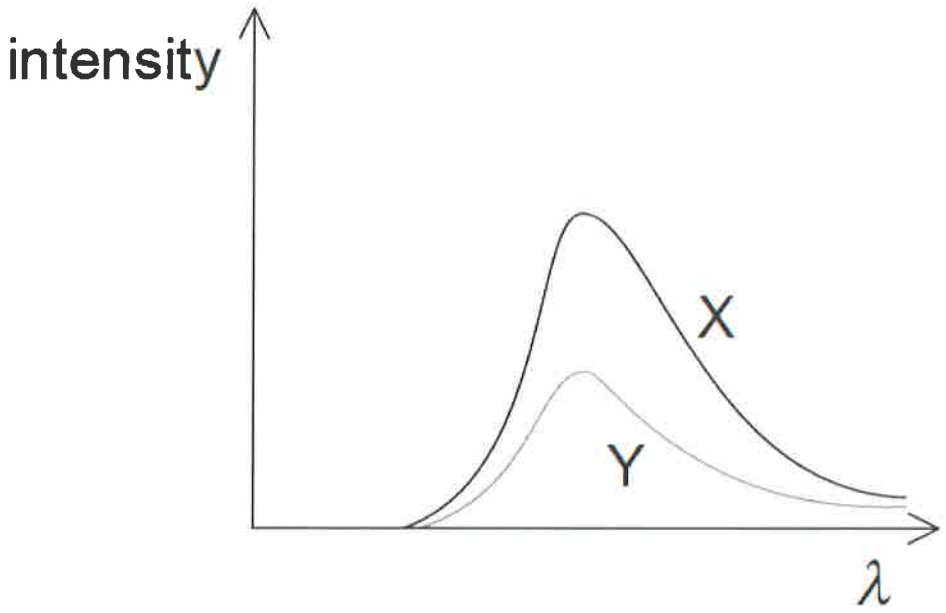
C. transmit infrared radiation but absorb ultraviolet radiation.

D. transmit ultraviolet radiation but absorb infrared radiation.

Markscheme

D

23. The graph shows the variation with wavelength of intensity of radiation emitted by two bodies X and Y. X and Y have the same surface area. *[1 mark]*



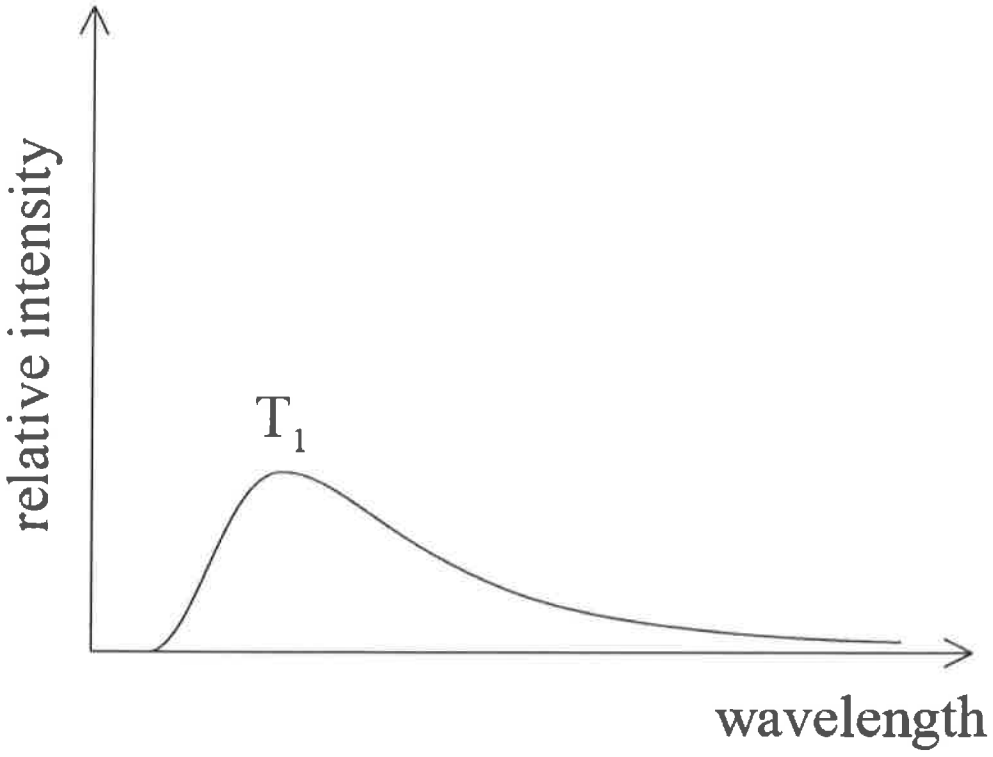
How do the temperature and the emissivity of X compare with the temperature and the emissivity of Y?

	Temperature	Emissivity
A.	different	different
B.	equal	different
C.	different	equal
D.	equal	equal

Markscheme

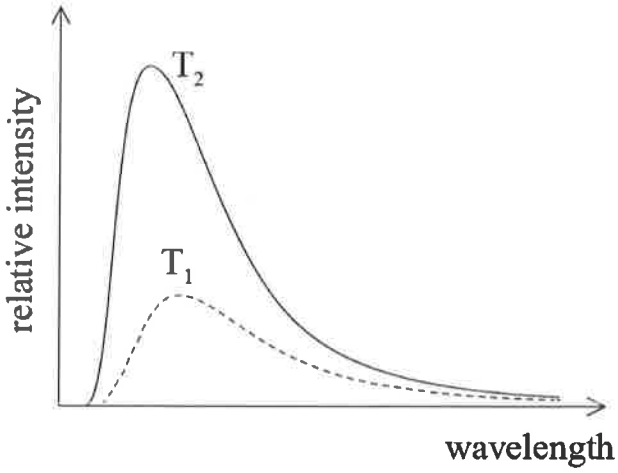
B

24. The graph shows the emission spectrum for a black body at absolute temperature T_1. *[1 mark]*



Which graph shows the emission spectrum for the same black body at an absolute temperature T_2 where $T_2 > T_1$? The original graph is shown as a dotted line.

A.



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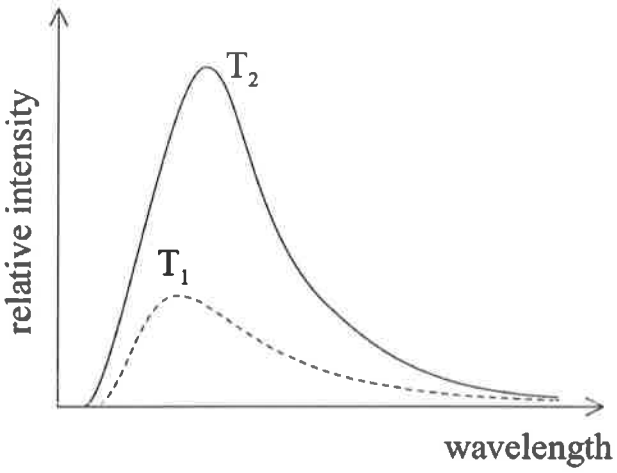
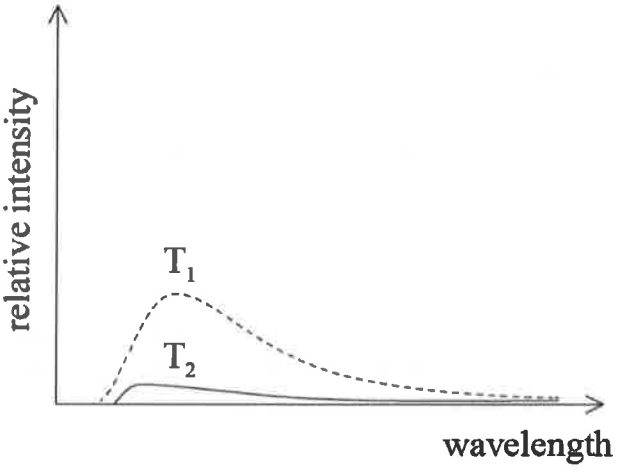
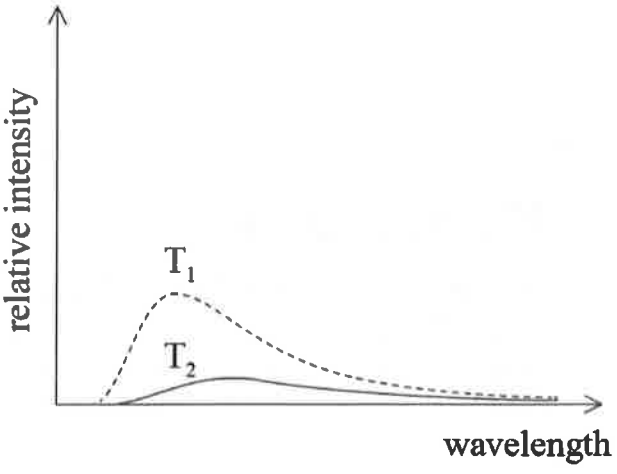


C.



D.



Markscheme

A

25a. The Sun has a radius of 7.0×10^{8}m and is a distance 1.5×10^{11} m from Earth. The surface temperature of the Sun is 5800 K. *[2 marks]*

Show that the intensity of the solar radiation incident on the upper atmosphere of the Earth is approximately 1400Wm^{-2}.

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Markscheme

$I = \frac{\sigma AT^4}{4\pi d^2}$

$= \frac{5.67\times10^{-8}\times(7.0\times10^{8})^2\times5800^4}{(1.5\times10^{11})^2}$

OR $\frac{5.67\times10^{-8}\times4\pi\times(7.0\times10^{8})^2\times5800^4}{4\pi\times(1.5\times10^{11})^2}$

I=1397 Wm^{-2}

In this question we must see 4SF to award MP3.
Allow candidate to add radius of Sun to Earth–Sun distance. Yields 1386 Wm^{-2}.

25b. The albedo of the atmosphere is 0.30. Deduce that the average intensity over the entire surface of the Earth is 245Wm^{-2}. *[2 marks]*

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Markscheme

«transmitted intensity =» 0.70 × 1400 «= 980Wm^{-2}» ┌

$\frac{\pi R^2}{4\pi R^2}\times 980\text{Wm}^{-2}$

245Wm^{-2}

25c. Estimate the average surface temperature of the Earth. *[2 marks]*

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Markscheme

$5.67 \times 10^{-8} \times T^4 = 245$

$T = 256\text{K}$

26. The average surface temperature of the Earth is actually 288 K. *[2 marks]*

Suggest how the greenhouse effect helps explain the difference between the temperature estimated in (c) and the actual temperature of the Earth.

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Markscheme

the emitted radiation is in the infrared/IR/long wavelength/low frequency region

«greenhouse» gases in the atmosphere absorb «infrared» radiation

radiated in all directions «including back down to Earth» warming the Earth

Do not allow "traps the heat".

Must see clear implication somewhere in response that gases are in the atmosphere for MP2.

Must see sense that Earth temperature is raised for MP3.

27a. This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about a mass on a spring. *[2 marks]*

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	$7.0\times10^{8}\,\text{m}$
Surface temperature of Sun	T	$5.8\times10^{3}\,\text{K}$
Distance from Sun to Earth	d	$1.5\times10^{11}\,\text{m}$
Stefan-Boltzmann constant	σ	$5.7\times10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4}$

State the Stefan-Boltzmann law for a black body.

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Markscheme

power/energy per second emitted proportional to surface area;
and proportional to fourth power of absolute temperature / temperature in K;
Accept equation with symbols defined.

27b. Deduce that the solar power incident per unit area at distance *d* from the Sun is given by [2 marks]

$$\frac{\sigma R^2 T^4}{d^2}$$

Markscheme

solar power given by $4\pi R^2 \sigma T^4$;

spreads out over sphere of surface area $4\pi d^2$;

Hence equation given.

27c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. [2 marks]

Markscheme

$\left(\frac{\sigma R^2 T^4}{d^2} =\right) \frac{5.7\times10^{-8}\times[7.0\times10^{8}]^2\times[5.8\times10^{3}]^4}{[1.5\times10^{11}]^2}$;

$=1.4\times10^{3}(\text{Wm}^{-2})$;

*Award **[2]** for a bald correct answer.*

27d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2 marks]*

Markscheme

some energy reflected;

some energy absorbed/scattered by atmosphere; depends on latitude;

depends on time of day;

depends on time of year;

depends on weather (*eg* cloud cover) at location; power output of Sun varies;

Earth-Sun distance varies;

27e. The average power absorbed per unit area at the Earth's surface is $240 Wm^{-2}$. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. *[2 marks]*