

APOLLO

Thermal energy transfers

HL

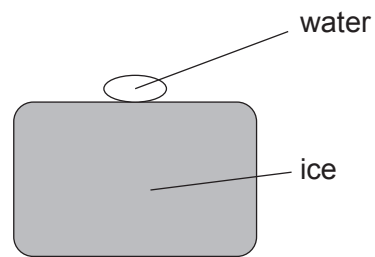
Physics

First assessment 2025

11 questions | questions

10. A block of ice of mass M is at its melting point.

A smaller mass m of water at a temperature of $T^{\circ}\text{C}$ is placed on the top surface of the ice and remains there.



The specific latent heat of fusion of ice is L and the specific heat capacity of water is c .

What mass of ice melts?

- A. $\frac{mcT}{L}$
- B. $\frac{mLT}{c}$
- C. $\frac{McT}{L}$
- D. $\frac{MLT}{c}$

9. X and Y are two spherical black-body radiators. X has a radius R and emits half the total power of Y. The absolute temperature of X is double that of Y.

What is the radius of Y?

- A. $2\sqrt{2}R$
- B. $4R$
- C. $4\sqrt{2}R$
- D. $16R$

10. A liquid is heated at a constant rate in an open container. The temperature of the liquid rises by 0.50°C per second until it boils. In a period of 10 minutes after reaching boiling point, half the mass of the liquid has vaporized.

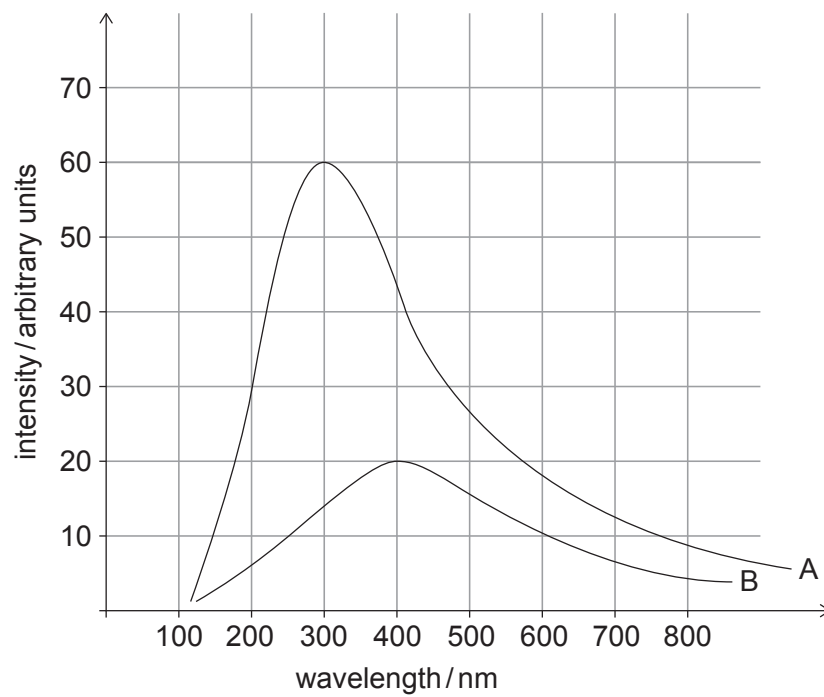
What is $\frac{\text{specific heat capacity of the liquid}}{\text{specific latent heat of vaporization of the liquid}}$?

- A. $\frac{1}{600}$
- B. $\frac{1}{300}$
- C. $\frac{1}{10}$
- D. $\frac{1}{5}$

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12. The black-body radiation curves for two objects A and B are shown.



What is $\frac{\text{temperature of A}}{\text{temperature of B}}$?

- A. $\frac{1}{3}$
- B. $\frac{3}{4}$
- C. $\frac{4}{3}$
- D. 3

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2. (a) Describe the mechanism of heat transfer by conduction.

[2]

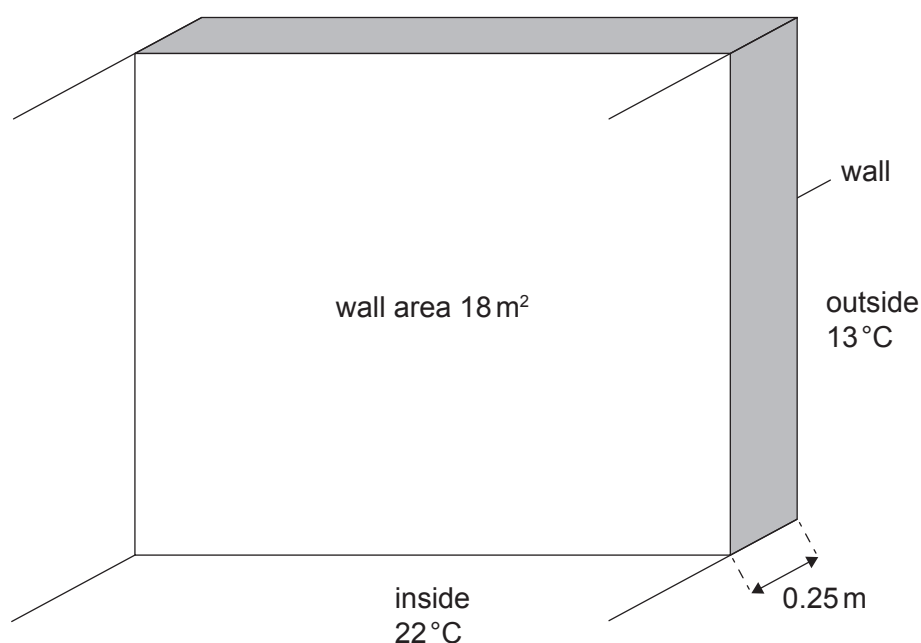
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The diagram shows a wall separating the inside of a room from the outside. The temperature of the room is kept constant by a heater.



The following data are available:

Thickness of wall = 0.25 m
 Area of wall = 18 m²
 Thermal conductivity of wall = 1.3 W m⁻¹ K⁻¹
 Constant room temperature = 22 °C
 Constant outside temperature = 13 °C

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(Question 2 continued)

- (b)
 Estimate the rate at which thermal energy leaves the room through the wall giving the answer with an appropriate unit.
 [2]

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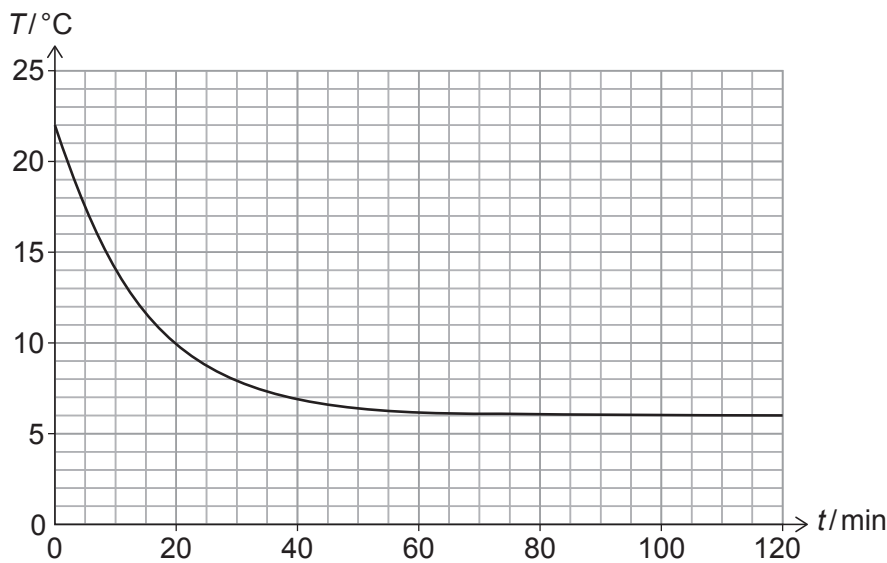
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(Question 2 continued)

- (c) At night the outside temperature falls below 13°C. The heater is turned off at time $t = 0$. The graph shows the variation with time t of the temperature T of the room.



- (i) Outline why the magnitude of the gradient of the graph decreases. [1]

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- (ii) The pressure and volume of the air in the room remain constant but the number of molecules has increased. Determine the percentage increase in the number of molecules of air in the room between $t = 0$ and $t = 120$ min. [3]

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(Question 2 continued)

- (d) Discuss how the second law of thermodynamics applies to the situation of the room cooling down.
- [2]

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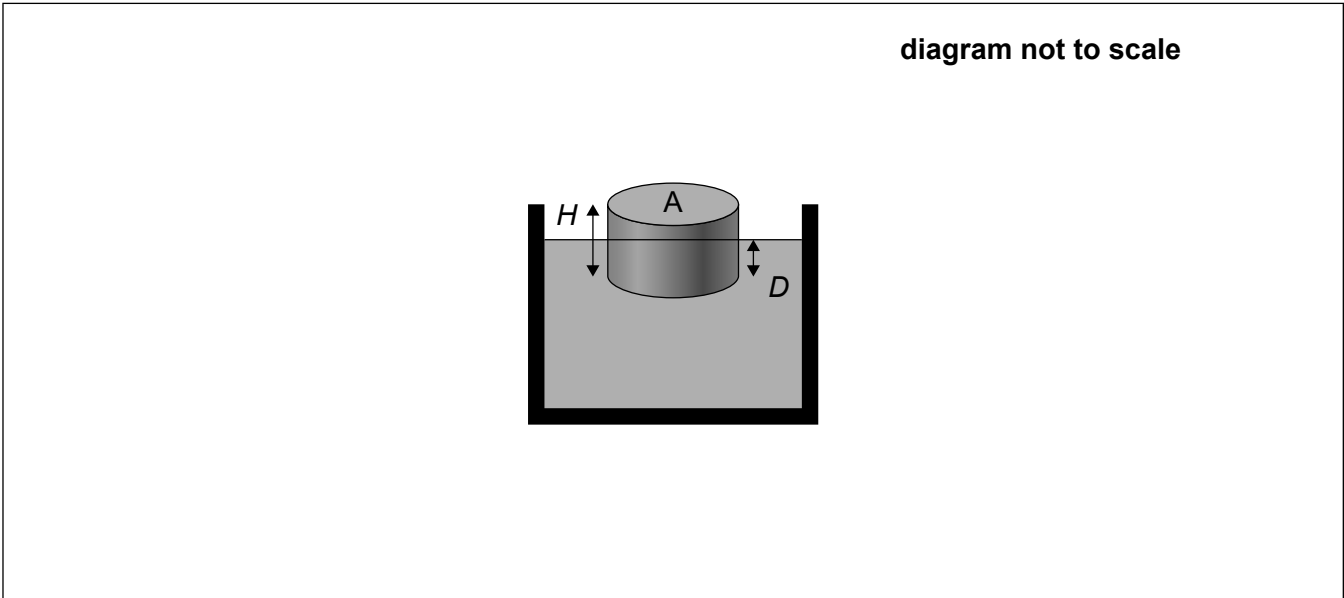


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7. A cylindrical cork of height H and cross-sectional area A is floating stationary in water. Its depth below the water surface is D .



- (a) (i) Draw and label the forces acting on the cork.

(ii) Show that

[1]

$$\frac{D}{H} = \frac{\rho_c}{\rho_w}$$

where ρ_c is the density of the cork and ρ_w is the density of water.

[2]

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(Question 7 continued)

The cork is displaced downward by a force. It is then released and it oscillates.

(b) Outline why the cork undergoes simple harmonic motion. [2]

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(Question 7 continued)

- (c)

(i)

Explain why the density of most substances in a solid state is larger than its density in a liquid state.

[2]

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Water shows an anomaly with respect to what is stated in (c)(i).

Graph 1 shows the variation with temperature of the density of water between -100°C and 100°C . **Graph 2** shows the same graph enlarged for the range 0 to 10°C .

- (ii)

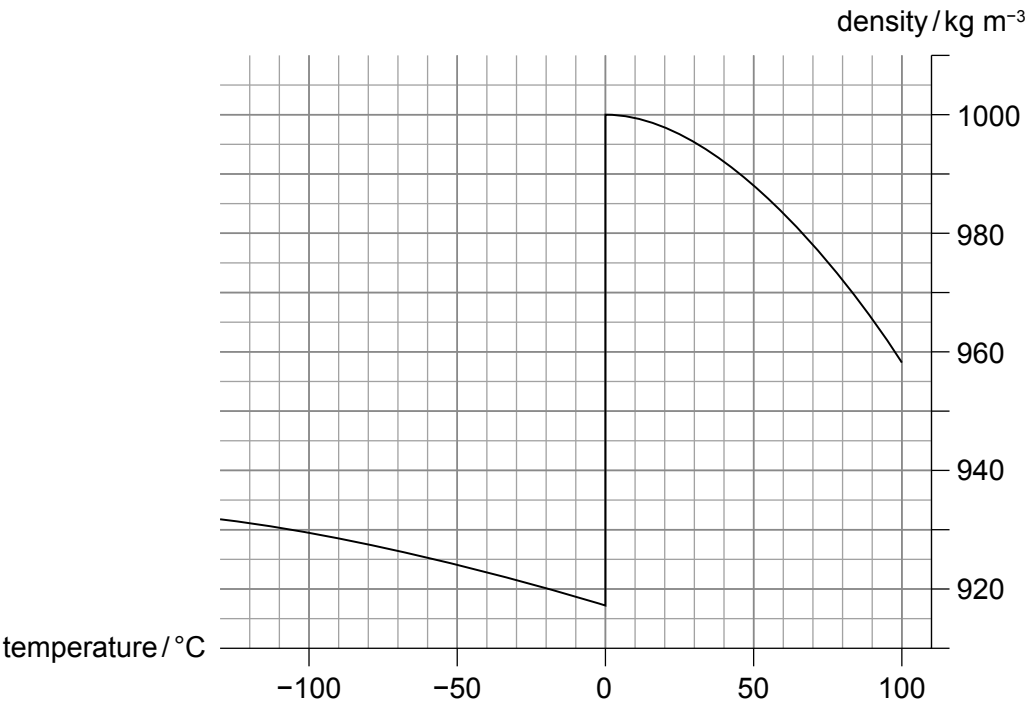
Identify the temperature at which water has its maximum density.

[1]

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Graph 1

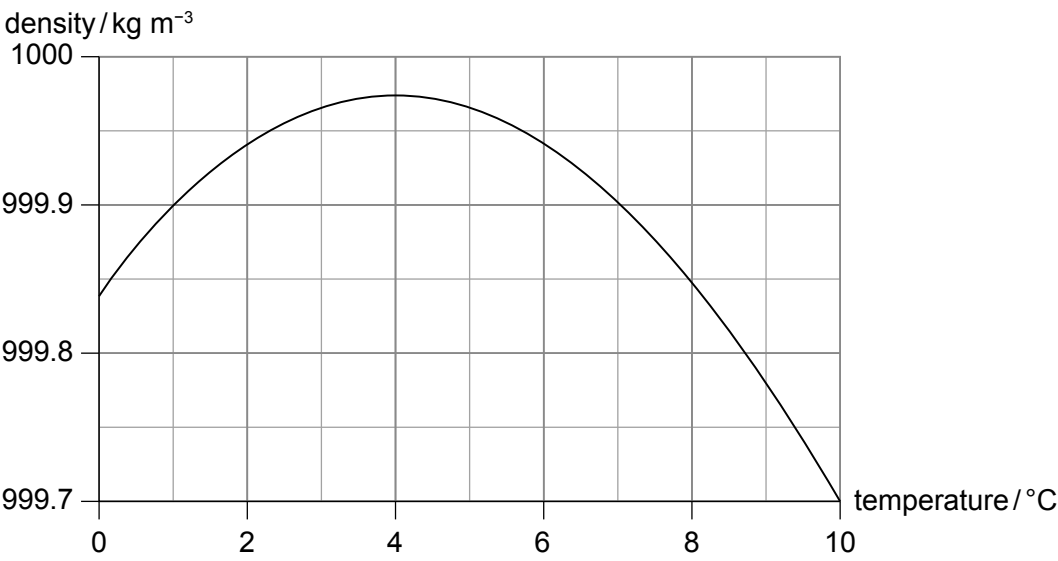


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(Question 7 continued)

Graph 2



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 will not be marked.



(Question 7 continued)

- (d) An icebreaking ship is designed to withstand a collision with an iceberg, a large partially submerged body of ice freely floating in water. The designers model the shape of the iceberg as a cylinder with an approximate cross-sectional area of 4200 m^2 and height above sea level of 32 m .

The following data are available:

$$\begin{aligned}\rho_{\text{ice}} &= 920\text{ kg m}^{-3} \\ \rho_{\text{seawater}} &= 1030\text{ kg m}^{-3}\end{aligned}$$

- (i) Show that the mass of the iceberg is about $1.2 \times 10^9\text{ kg}$. [2]

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The designers assume that the mass of the ship is about $\frac{1}{40}$ the mass of the iceberg and is moving at 12 m s^{-1} when it collides with the iceberg. They stick together after the collision.

- (ii) Calculate the speed of the ship after the collision. [2]

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(Question 7 continued)

Ice in a still lake will usually form in a single layer on the surface.

- (e) On a winter day, the surface of a lake is frozen. The temperature of the air above the lake is -6.0°C . The layer of ice frozen on the surface of the lake has a thickness of 1.9 cm.
- (i) The thermal conductivity of ice is $2.3\text{ W m}^{-1}\text{ K}^{-1}$. Calculate the rate per unit area at which thermal energy leaves the lake by conduction through the ice layer.
 [2]

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- (ii) The depth of water below the ice is 22 m and its average initial temperature is 2.0°C . Estimate the minimum thermal energy per unit area that must be removed to freeze all the water in the lake.
 [3]

The following data are available:

Specific heat capacity of water = $4.2 \times 10^3\text{ J kg}^{-1}\text{ K}^{-1}$

Latent heat of fusion of water = $3.3 \times 10^5\text{ J kg}^{-1}$

$\rho_{\text{water}} = 1000\text{ kg m}^{-3}$

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(Question 7 continued)

Layers of ice on lakes do not grow thicker than a small percentage of the lake’s depth even when the exterior temperature remains constant below the freezing point for some time.

(iii) Explain how the rate calculated in (e)(i) changes as the layer of ice grows thicker. [1]

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(iv) Discuss why the anomaly in the value of the density of water supports life in water on Earth. [2]

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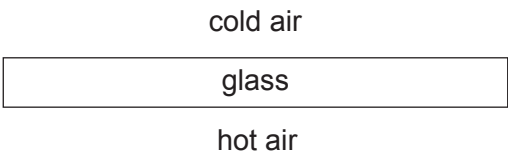


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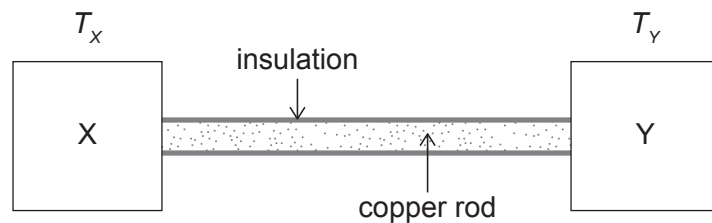
10. A layer of glass separates cold air from hot air. The temperature gradient across the glass is H , and the rate of thermal energy transfer through a unit surface area of the glass is P .



The thickness of the glass layer is doubled. What are the temperature gradient and the rate of thermal energy transfer through the glass after this change?

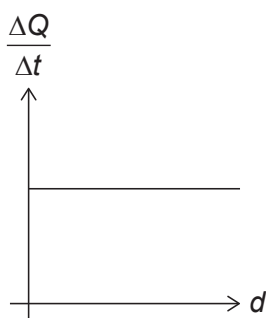
	Temperature gradient	Rate of thermal energy transfer
A.	$2H$	$2P$
B.	$2H$	$\frac{P}{2}$
C.	$\frac{H}{2}$	$2P$
D.	$\frac{H}{2}$	$\frac{P}{2}$

10. Insulated solid copper rods of different diameters and fixed length are placed in thermal contact with two objects X and Y, maintained at different temperatures T_X and T_Y respectively. The diagram shows the setup with one such rod.

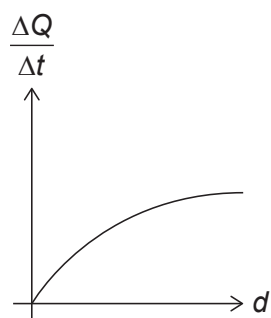


Which graph shows the variation with rod diameter d of the rate of thermal energy transfer $\frac{\Delta Q}{\Delta t}$ along the rod?

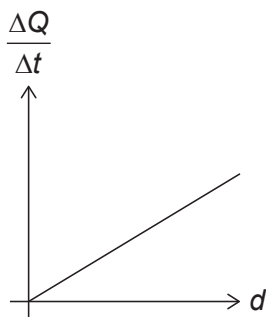
A.



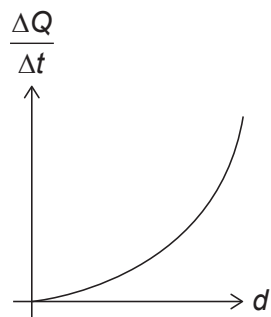
B.



C.



D.



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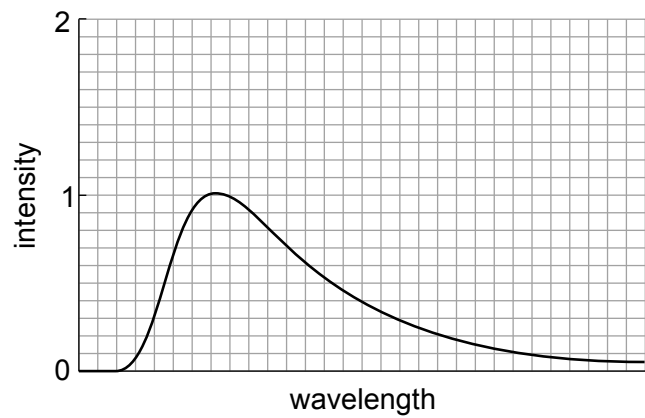
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- 11.** 80 g of a liquid are heated with a constant power output of 100 W. All the power goes into the liquid. After 60 s, the rise in temperature is 50 K.

What is the specific heat capacity of the liquid in $\text{J kg}^{-1} \text{K}^{-1}$?

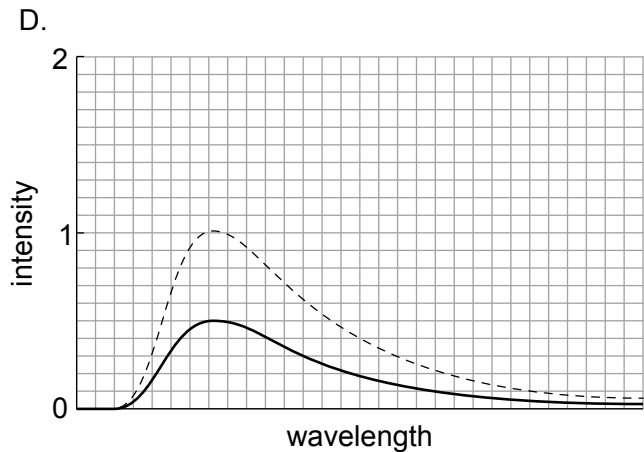
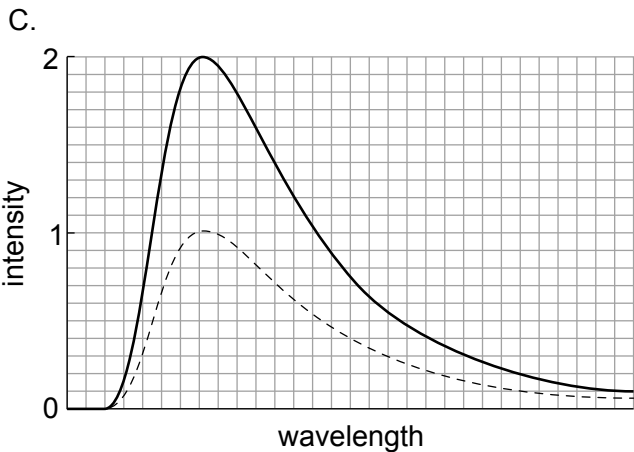
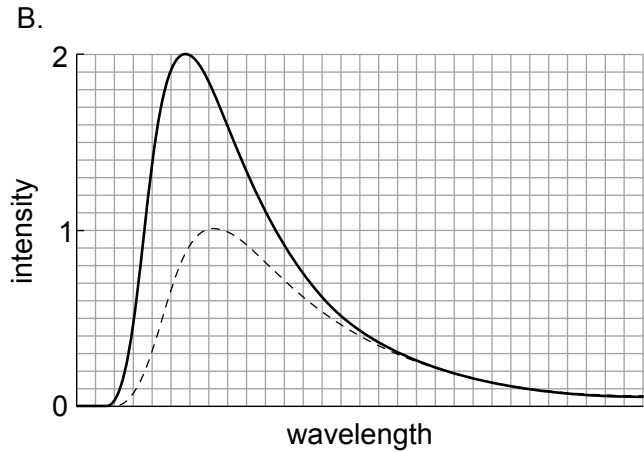
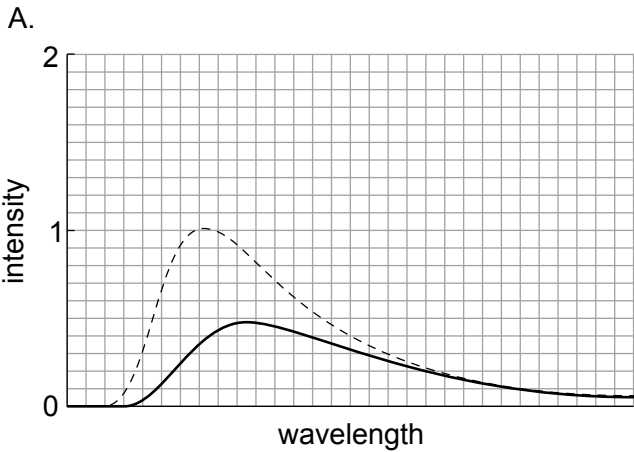
- A. 120
- B. 960
- C. 1200
- D. 1500

13. The black-body radiation curve of an object at 600 K is shown. The intensity units are arbitrary.



What is the radiation curve of the same object at 450 K?

The original curve is shown with a dashed line.



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8. Small pieces of solid paraffin with a total mass of 30 g at a temperature of 42 °C are mixed with 150 g of liquid paraffin at a temperature of 240 °C. The mixture is stirred until an equilibrium temperature is reached.

The following data for paraffin are available:

Specific heat capacity of solid paraffin = 0.7 kJ kg⁻¹ K⁻¹
 Specific heat capacity of liquid paraffin = 2.13 kJ kg⁻¹ K⁻¹
 Specific latent heat of fusion of paraffin = 220 kJ kg⁻¹
 Melting point of paraffin = 47 °C

- (a) Calculate the theoretical equilibrium temperature of the mixture. [3]

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- (b) (i) When the experiment was carried out, the equilibrium temperature of the mixture was found to be different from the theoretical value.

Suggest the reason for this difference. [2]

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- (ii) The mixture was held in a large metal container during the mixing.

Explain **one** change to the procedure that will reduce the difference in (b)(i). [1]

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