IB DP PHYSICS

Theme B · The Particulate Nature of Matter

TOPICAL WORKSHEET

B.1 Thermal Energy Transfers · B.2 The Greenhouse Effect · B.3 Gas Laws
B.4 Thermodynamics (HL) · B.5 Current and Circuits

Standard and Higher Level · Syllabus 2025

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Original exam-style questions written for the IB Diploma Programme Physics course (first assessment 2025)

Section A — Multiple Choice (15 marks)

Circle the letter of the best answer to each question. Each question is worth 1 mark.

1. How much thermal energy is required to raise the temperature of 2.0 kg of water from 20°C to 80°C? (specific heat capacity of water = 4200 J kg^{-1} K^{-1}) **[1]**

A 8.4×10^{3} J

B 5.04×10^{4} J

C 5.04×10^{5} J

D 1.68×10^{6} J

2. Which mode of thermal energy transfer does NOT require a material medium and can occur through a vacuum? **[1]**

A Conduction

B Convection

C Radiation

D All three require a medium

3. A 0.50 kg block of ice at 0°C absorbs 1.67×10^{5} J and is completely converted to water at 0°C. What specific latent heat of fusion does this represent? **[1]**

A 8.35×10^{4} J kg^{-1}

B 1.67×10^{5} J kg^{-1}

C 3.34×10^{5} J kg^{-1}

D 6.68×10^{5} J kg^{-1}

4. The solar constant at Earth's orbit is approximately 1361 W m^{-2}. What power is intercepted by a solar panel of area 2.0 m^{2} held perpendicular to the Sun's rays (ignoring atmospheric losses)? **[1]**

A 680 W

B 1361 W

C 2722 W

D 5444 W

5. Which statement best describes the greenhouse effect? **[1]**

A The atmosphere absorbs and reflects all incoming visible sunlight

B Greenhouse gases selectively absorb outgoing infrared radiation and re-radiate some of it back toward the surface

C The ozone layer prevents infrared radiation from ever leaving the atmosphere

D Greenhouse gases increase Earth's albedo, reducing the energy reaching the surface

6. Earth's albedo is approximately 0.30. What fraction of the incoming solar radiation is absorbed by the Earth system (surface + atmosphere)? **[1]**

A 0.30

B 0.50

C 0.70

D 1.00

7. A fixed mass of ideal gas at pressure 2.0×10^{5} Pa and volume 3.0×10^{-3} m^{3} is compressed at constant temperature to a volume of 1.0×10^{-3} m^{3}. What is the new pressure? **[1]**

A 0.67×10^{5} Pa

B 2.0×10^{5} Pa

C 3.0×10^{5} Pa

D 6.0×10^{5} Pa

8. According to the kinetic theory of gases, the absolute temperature of an ideal gas is a direct measure of **[1]**

A the total internal energy of the gas

B the average translational kinetic energy of its molecules

C the pressure exerted by the gas on its container

D the total momentum of the gas molecules

9. A fixed mass of gas at 300 K and pressure 1.0×10^{5} Pa is heated at constant volume until its pressure doubles. What is the new temperature? **[1]**

A 150 K

B 300 K

C 450 K

D 600 K

10. A gas absorbs 500 J of thermal energy and does 200 J of work on its surroundings as it expands. What is the change in internal energy of the gas? **[1]**

A −300 J

B 200 J

C 300 J

D 700 J

11. Which statement correctly expresses the second law of thermodynamics for an isolated system? **[1]**

A Energy can never be created or destroyed

B The total entropy of an isolated system never decreases over time

C Heat always flows from a colder to a hotter body spontaneously

D The internal energy of an isolated system is always constant

12. A gas expands at a constant pressure of 1.5×10^5 Pa from a volume of 2.0×10^{-3} m^3 to 5.0×10^{-3} m^3. How much work is done BY the gas? **[1]**

A 150 J

B 300 J

C 450 J

D 750 J

13. A resistor of resistance 15 Ω carries a current of 0.40 A. What is the potential difference across it? **[1]**

A 0.027 V

B 6.0 V

C 15 V

D 37.5 V

14. Two identical resistors, first connected in series and then in parallel, are each connected across the same battery in turn. Compared with the series combination, the parallel combination has **[1]**

A a higher total resistance and draws less current from the battery

B a lower total resistance and draws more current from the battery

C the same total resistance and current in both cases

D a higher total resistance but draws more current from the battery

15. An electric heater rated at 2.0 kW operates from a 230 V mains supply. What current does it draw? **[1]**

A 0.12 A

B 4.6 A

C 8.7 A

D 460 A

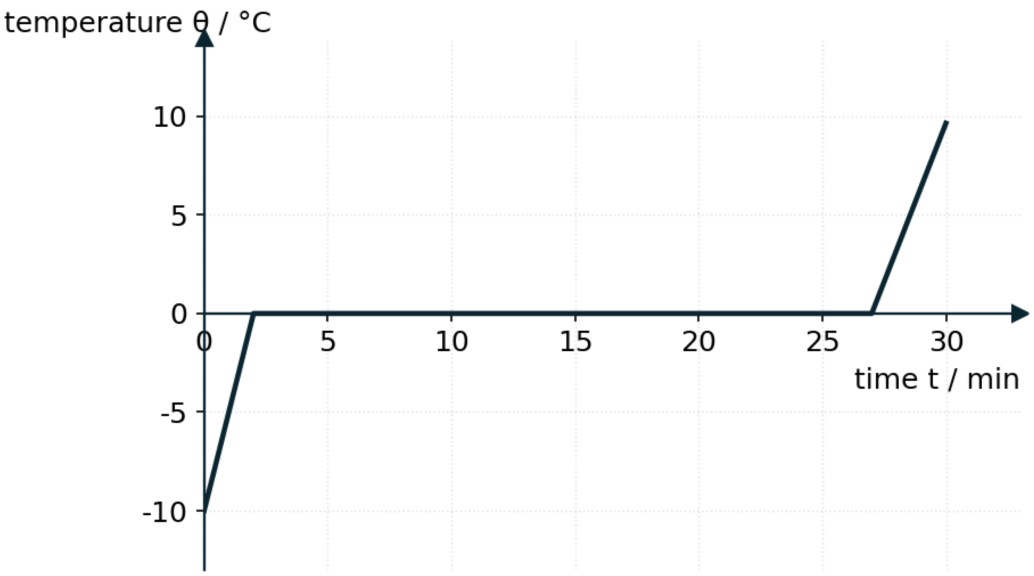
Section B — Structured Questions (68 marks)

Answer all questions in the space provided. Working must be shown for full marks.

B.1 Thermal Energy Transfers

Question 1 [7 marks]

A 0.20 kg block of ice, initially at −10°C, is heated at a constant rate by a 45 W heater. The graph shows how its temperature changes with time as it warms, melts, and the resulting water warms further.



Temperature–time graph for the heated ice/water sample (values on the axes are the given data for this question).

(a) Use the first 2.0 minutes of data (solid ice warming from −10°C to 0°C) to calculate the specific heat capacity of ice. **[2]**

(b) Use the 25-minute plateau (from t = 2.0 min to t = 27.0 min, during which the ice melts at constant temperature) to calculate the specific latent heat of fusion of the ice. **[3]**

(c) Given that the specific heat capacity of liquid water is 4200 J kg^{-1} K^{-1}, use the final 3.0 minutes of data to calculate the temperature reached at t = 30.0 min. **[2]**

Question 2 [6 marks]

A tungsten filament in an incandescent light bulb behaves approximately as a black body. It has a surface area of 8.0×10^{-5} m^2 and operates at a temperature of 2500 K. (Stefan–Boltzmann constant $\sigma = 5.67\times10^{-8}$ W m^{-2} K^{-4}; Wien's law constant $b = 2.898\times10^{-3}$ m K.)

(a) Calculate the total power radiated by the filament, assuming it radiates as an ideal black body. **[2]**

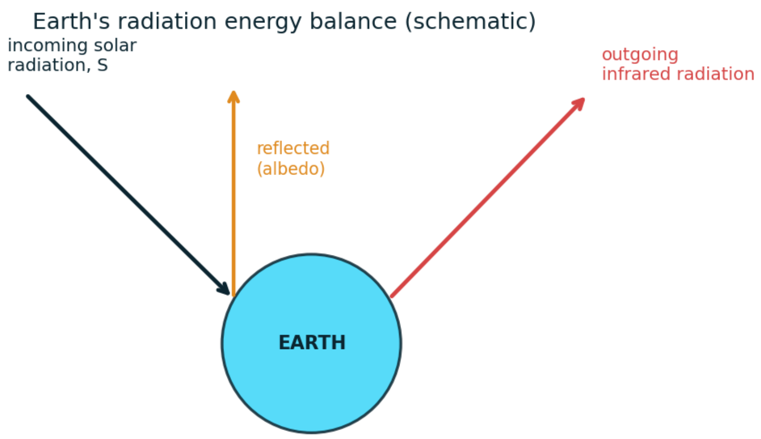
(b) Use Wien's displacement law to calculate the peak wavelength emitted by the filament. **[2]**

(c) State the region of the electromagnetic spectrum in which this peak wavelength lies, and hence explain why an incandescent bulb is an inefficient source of visible light. **[2]**

B.2 The Greenhouse Effect

Question 3 [7 marks]

The Sun delivers a solar constant of $S = 1361$ W m^{-2} at Earth's orbit. Earth has a mean radius of 6.37×10^{6} m and an average albedo of 0.30, as shown in the schematic.



Earth's radiation energy balance: incoming solar radiation is partly reflected (albedo) and partly absorbed; the planet also emits outgoing infrared radiation.

(a) Show that Earth presents a cross-sectional area of about 1.27×10^{14} m^2 to the incoming solar radiation, and hence calculate the total power intercepted, P_{in}. **[3]**

(b) Calculate the total power absorbed by the Earth system, P_{abs}, given the albedo of 0.30. **[2]**

(c) Explain, in terms of radiative equilibrium, the condition required for Earth's average surface temperature to remain stable over long timescales. **[2]**

Question 4 [6 marks]

Treating the Earth as a black body radiating uniformly from its entire surface (total surface area $4\pi r^2$), and using the absorbed power P_{abs} found in Question 3(b).

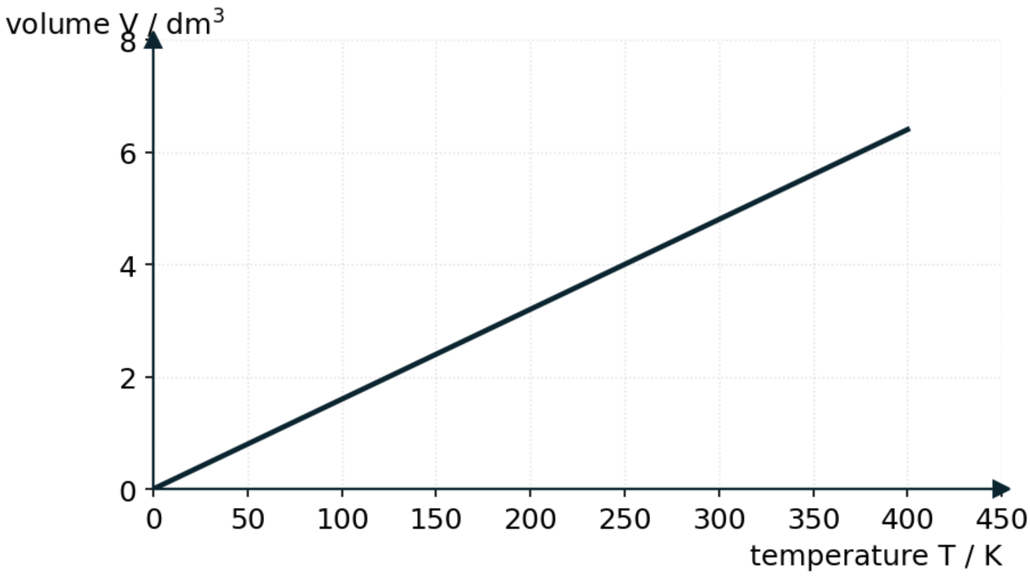
(a) Calculate the equilibrium black-body temperature of the Earth's surface, assuming all absorbed power is re-radiated as a black body over the full surface area $4\pi r^2 = 5.099\times10^{14}$ m^2. **[3]**

(b) Earth's actual average surface temperature is about 15°C. Explain, in terms of the greenhouse effect, the difference between this calculated equilibrium temperature and the actual surface temperature. **[3]**

B.3 Gas Laws

Question 5 [7 marks]

A fixed mass of an ideal gas is held at a constant pressure of 1.0×10^5 Pa in a cylinder with a frictionless piston. The graph shows how its volume varies with absolute temperature.



Volume–temperature graph for the gas at constant pressure (given data).

(a) Use the two labelled points on the graph to show that the gas obeys V/T = constant (Charles's law). **[2]**

(b) Using one of the graph points and the ideal gas equation pV = nRT (R = 8.31 J mol^{-1} K^{-1}), calculate the amount of gas present, in moles. **[3]**

(c) Calculate the number of gas molecules present (Avogadro constant N_A = 6.02×10^{23} mol^{-1}). **[2]**

Question 6 [7 marks]

A sample of oxygen gas (molar mass M = 0.032 kg mol^{-1}) is at a temperature of 300 K. (Boltzmann constant k = 1.38×10^{-23} J K^{-1}; N_A = 6.02×10^{23} mol^{-1}.)

(a) Calculate the average translational kinetic energy of a single oxygen molecule. **[2]**

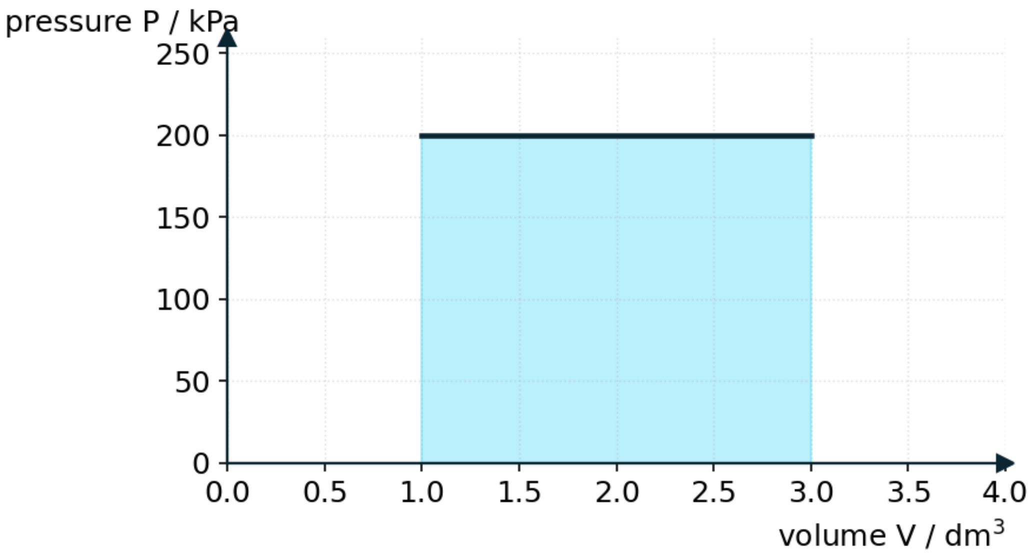
(b) Hence calculate the root-mean-square (rms) speed of the oxygen molecules. **[3]**

(c) State and explain, in terms of kinetic theory, what happens to the rms speed of the molecules if the absolute temperature is doubled. **[2]**

B.4 Thermodynamics (HL)

Question 7 [6 marks]

A fixed mass of ideal gas undergoes an isobaric (constant-pressure) expansion at $P = 2.0\times10^5$ Pa, from $V_1 = 1.0$ dm^3 to $V_2 = 3.0$ dm^3, while absorbing 800 J of thermal energy, as shown on the p−V graph.



Pressure−volume graph for the isobaric expansion; the shaded area equals the work done by the gas.

(a) Calculate the work done BY the gas during the expansion (the shaded area on the graph). **[2]**

(b) Using the first law of thermodynamics, calculate the change in internal energy of the gas. **[2]**

(c) State whether the temperature of the gas increases, decreases, or stays the same during this process, and justify your answer. **[2]**

Question 8 [8 marks]

A 25 g ice cube at 0°C (273 K) is left in a room held at a constant 20°C and completely melts, absorbing thermal energy from the room. (Specific latent heat of fusion of ice = 3.34×10^{5} J kg^{-1}.)

(a) Calculate the thermal energy absorbed by the ice as it melts. **[2]**

(b) Calculate the entropy change of the ice as it melts at a constant temperature of 273 K. **[3]**

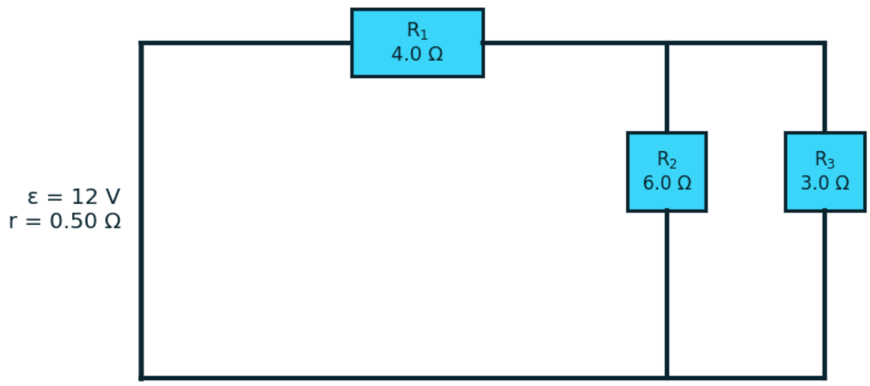
(c) As it supplies this heat, the entropy of the room decreases by 28.5 J K^{-1}. Calculate the total entropy change of the (ice + room) system, and state what this shows about whether the process obeys the second law of thermodynamics. **[3]**

B.5 Current and Circuits

Question 9 [8 marks]

In the circuit shown, a cell of emf ε = 12 V and internal resistance r = 0.50 Ω drives current through a 4.0 Ω resistor R_1 connected in series with a parallel combination of R_2 = 6.0 Ω and R_3 = 3.0 Ω.

R_1 in series with (R_2 in parallel with R_3)



R_1 in series with the parallel combination of R_2 and R_3.

(a) Calculate the combined resistance of the parallel section (R_2 and R_3). **[2]**

(b) Calculate the current drawn from the cell. **[3]**

(c) Calculate the terminal potential difference of the cell (the p.d. across the external circuit). **[3]**

Question 10 [6 marks]

A nichrome wire (resistivity $\rho = 1.10\times10^{-6}\ \Omega\ \text{m}$) has length 2.5 m and cross-sectional area $2.0\times10^{-7}\ \text{m}^2$. It is connected across a 12 V supply.

(a) Calculate the resistance of the wire. **[2]**

(b) Calculate the current in the wire. **[2]**

(c) Calculate the power dissipated as heat in the wire. **[2]**