Name	Date started	Target end date

GCE A LEVEL — THERMAL PHYSICS QUESTION PACK

Legacy PH4 · New spec Unit 3 Topic 4 · A2 unit, 25% of A-level

REVISE

.wales

PHYSICS — UNIT 3 · THERMAL PHYSICS

3.4 Thermal physics — heat capacity, the first law and p–V cycles

Specific heat capacity by method-of-mixtures and immersion heater, the first law ΔU = Q – W applied step-by-step around a cycle, and heat-engine efficiency from p–V loops.

NEW 2015 SPEC · UNIT 3 TOPIC 4

Estimated time for entire question pack: ~2h 19m

Derived from the legacy PH4 paper's pace of 120 marks in 1h 45m.

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC PH4 papers (2008 modular spec) that maps onto new-spec Unit 3 Topic 4 (3.4).

Questions are ordered chronologically within each section.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.

For Examiner's use only

Q	Source	Max	Mark
1	PH4 Jun 13 Q2	11	
2	PH4 Jun 16 Q4	11	
3	PH4 Jun 10 Q3	14	
4	PH4 Jun 12 Q1	12	
5	PH4 Jan 10 Q4	13	
6	PH4 Jun 15 Q3	11	
7	PH4 Jan 14 Q4	14	
8	PH4 Jan 13 Q7	13	
	Total	**99**	

Thermal Physics — what the new spec asks

WJEC GCE A Level Physics (from 2015) · Unit 3: Oscillations & Nuclei · Topic 3.4.

Heat & temperature A

- Temperature ~ mean KE of particles; thermal equilibrium = no net heat flow.
- Convert $T/\mathrm{K} = \theta/^\circ\mathrm{C} + 273.15$.

Specific heat capacity A

- $Q = mc\Delta\theta$ with c in J $\mathrm{kg}^{-1}\,\mathrm{K}^{-1}$.
- Determine c by method-of-mixtures or by an immersion-heater calorimetry.

Internal energy & first law B

- U = sum of kinetic and potential energies of all particles.
- First law: $\Delta U = Q - W$ (legacy convention — W is work done by gas).
- $\Delta U = 0$ around any closed cycle; ΔU depends only on initial and final states.

p-V cycles & engines C

- Work done by gas in a quasi-static process = area under p-V curve.
- Isobaric $W = p\Delta V$; isochoric $W = 0$; isothermal $W = nRT \ln(V_2/V_1)$.
- Closed cycle efficiency $\eta = W_{net} / Q_{in}$; W_{net} = enclosed area.

Thermal Physics in one page

Quick-reference notes — revisit before each section.

Thermal equilibrium

Two bodies at the same T have no net heat flow.

$T/K = \theta/°C + 273.15$.

Specific heat capacity

c in $J\ kg^{-1}\ K^{-1}$.

Method-of-mixtures: heat lost = heat gained (isolated system).

Immersion heater: $c = VIt\ /\ (m\Delta\theta)$.

Latent heat

$Q = mL$: no T change.

L_{fus} for melting; L_{vap} for boiling.

Internal energy

U = KE + PE of all particles.

Monatomic ideal gas: U = &frac32; nRT — T only.

Around a closed cycle $\Delta U = 0$.

First law

Legacy WJEC convention: W = work done BY the gas.

$Q > 0$ if heat flows into the gas.

Modern texts may write $\Delta U = Q + W$ — same physics.

p–V work

Quasi-static expansion: $W = \int p\ dV$.

Isobaric: $W = p\Delta V$.

Isochoric: $W = 0$.

Isothermal (ideal): $W = nRT\ \ln(V_2/V_1)$, $\Delta U = 0$, $Q = W$.

Adiabatic

No heat exchange ⇒ $\Delta U = -W$.

Fast compression heats the gas; fast expansion cools it.

Cycles & engines

Closed cycle: W_{net} = enclosed area on a p–V loop.

Efficiency $\eta = W_{net}\ /\ Q_{in}$.

Strategy

1. Tabulate Q, W, ΔU for each leg.
2. Check ΔU totals to 0 around the loop.
3. Sum W to get the net work.

Section index

Use this index to jump straight to the section you need.

2. A container made of insulating material contains $1.7 \times 10^{-3}\ m^3$ of water. The water is heated by a 3 kW electric immersion heater. A student records the water temperature at 0.5 minute intervals.

Time / min	Temperature of water / °C
0.5	32.5
1.0	45.0
1.5	57.5
2.0	70.5
2.5	83.0
3.0	95.5

(a) The density of water is $1.0 \times 10^3\ kg\ m^{-3}$. Calculate the mass of the water. [1]

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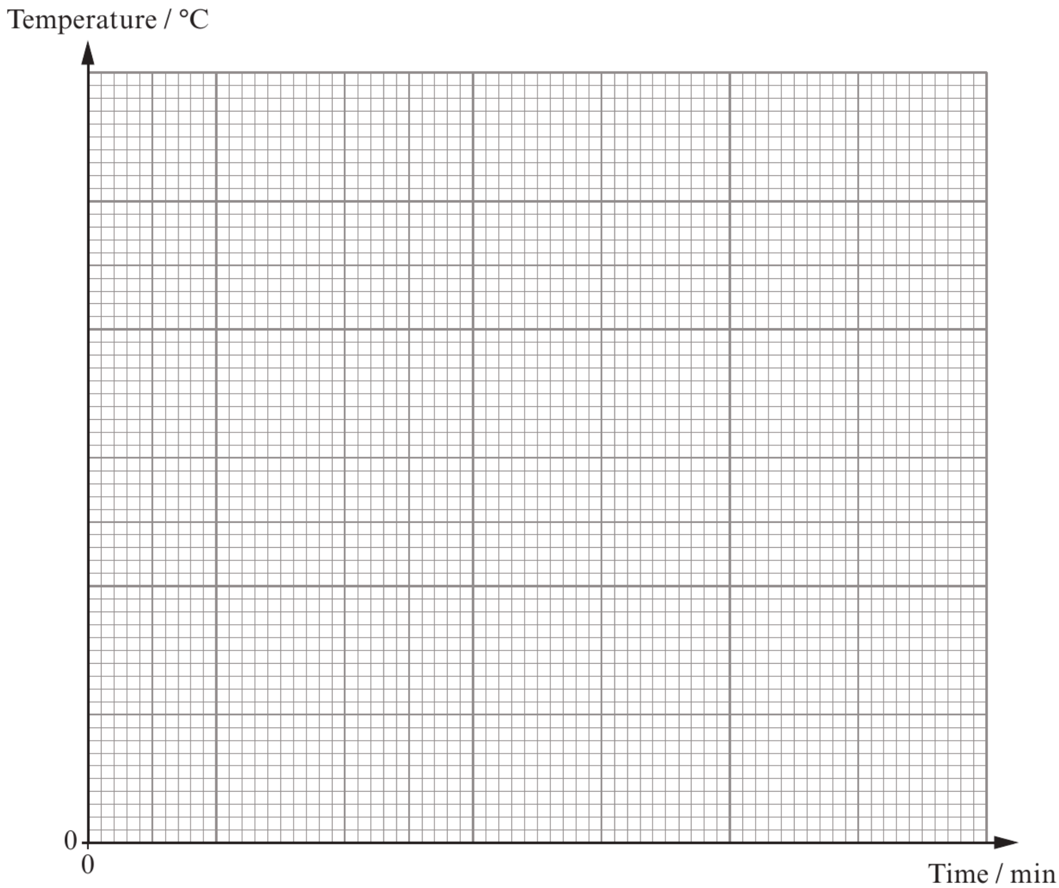
(b) Plot a graph of the water temperature against time in minutes. [2]



Examiner only

(c) Estimate the original temperature of the water. .... [1]

(d) If the heating continues, how long after the start of heating will the water boil? [1]

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(e) The power of the heater is 3 kW. Determine a value for the specific heat capacity of the water in the insulating container. [3]

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(f) The student repeats the experiment but uses a container that is not such a good insulator. Readings are obtained at the same time intervals as before. State what happens to the:

(i) values of temperature;

(ii) gradient of the graph;

(iii) value obtained for the specific heat capacity.

Calculations are not required. [3]

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4. A metal saucepan of mass 0.9 kg contains 1.6 kg of water at a temperature of 92 °C. The water and saucepan are in thermal equilibrium, and the saucepan-water system is **isolated from its surroundings**.

(a) Explain what is meant by thermal equilibrium. [2]

(b) Vegetables of mass 1.1 kg and temperature 17 °C are placed in the water, and the system is left to reach thermal equilibrium once again. Describe in terms of heat flows how thermal equilibrium is reached between the saucepan, water and vegetables. *(Calculations are not required.)* [3]

(c) Calculate the final temperature of the saucepan, water and vegetables given the specific heat capacities below. [4]

	Specific heat capacity / $J\,kg^{-1}\,°C^{-1}$
Water	4 200
Saucepan	500
Vegetables	3 500

Examiner only

(d) Explain what will happen to the final temperature if the system is not completely isolated from the surroundings. [2]

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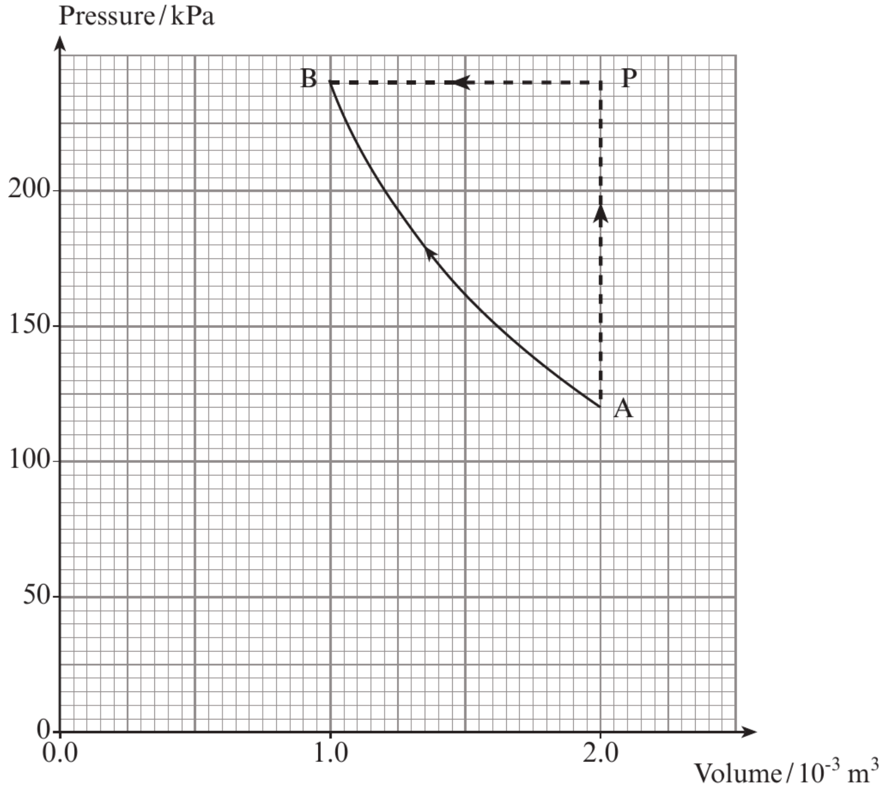
SECTION B

First law of thermodynamics

Questions 3 – 4 · 26 marks

3. A gas is contained in a metal cylinder with a leak-proof piston at one end

The pressure and volume of the gas during an experiment are shown on the graph below.



(a) The first law of thermodynamics may be written.

$$\Delta U = Q - W$$

By referring to the gas in the cylinder, explain the meaning of

(i) ΔU .... [1]

(ii) Q .... [1]

(iii) W .... [1]

Examiner only

(b) If the cylinder contains 0.1 mol of gas and the initial conditions are given by point A on the graph, show that the initial temperature of the gas is approximately 290 K.

....

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....

.... [3]

(c) The gas is compressed along the curved path AB at a constant temperature of 290 K. Show that the total work done along this path is approximately 170 J.

....

....

.... [2]

(d) In an alternative process for changing the state, the gas follows path APB.

(i) Explain why no work is done on or by the gas along the path AP.

....

....

.... [2]

(ii) Estimate the total work done along path PB, **indicating clearly** whether the work is done on or by the gas.

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.... [2]

(e) Use the first law of thermodynamics to explain why the heat flowing out of the gas system along path APB is different from the heat flowing out along path AB. A calculation is not required.

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.... [2]

1. *(a)* The first law of thermodynamics may be written $\Delta U = Q - W$.

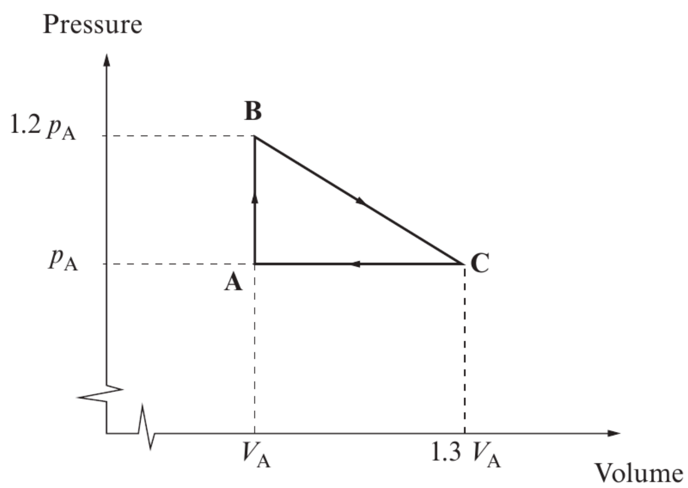
Explain carefully the terms

(i) ΔU .... [1]

(ii) Q .... [1]

(iii) W .... [1]

(b) A sealed container with a leak-proof piston at one end contains 0.40 mole of an ideal gas. The gas is taken around a cycle (**ABCA**).
The pressure and volume of the gas are shown on the graph where $p_A = 1.01 \times 10^5$ Pa and $V_A = 1.00 \times 10^{-2}$ m^3.



Calculate the temperature at point **C**. [2]

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(c) Determine the work done (if any) along the following paths, indicating clearly if it is done **on** or **by** the gas. [4]

(i) **CA**

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(ii) **AB**

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(iii) **BC**

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(d) Determine the total heat transferred if the gas is taken around the cycle **three** times, stating clearly whether it flows in or out of the gas. [3]

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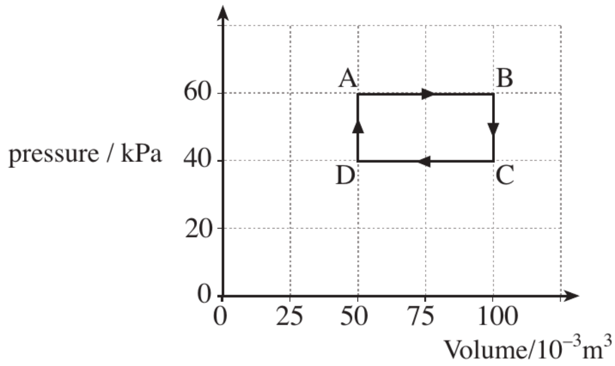
SECTION C

p–V cycles & internal energy

Questions 5 – 8 · 51 marks

4. A gas undergoes a thermodynamic cycle, ABCDA, as shown in the *p*-*V* diagram.



(a) The first law of thermodynamics can be written in the form $\Delta U = Q - W$

Sate the meaning of **each** term. [2]

ΔU ....

Q ....

W ....

(b) (i) Calculate the work done by the gas during process AB. [2]

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(ii) The temperatures at point A and B are 278 K and 556 K respectively and the amount of gas is 1·3 moles. The internal energy of the gas is given by the equation $U = \frac{3}{2}nRT$.

Calculate the **change** in internal energy of the gas during the process AB. [2]

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(c) (i) How much work is done during process BC? [1]

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(ii) Describe and explain the heat flow during the process BC (no calculations are required). [2]

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(d) (i) Explain why the change in internal energy over the closed cycle ABCDA is zero. [1]

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(ii) Calculate the net heat supplied to the gas over the cycle ABCDA. [3]

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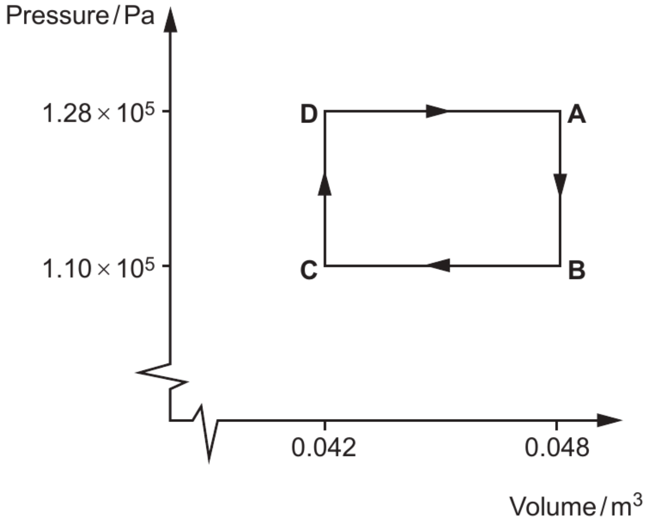
3. A heat engine has a cylinder with a leak-proof moveable piston which contains 2.00 mol of ideal monatomic gas. The gas is taken around the 4-stage cycle **A**→**B**→**C**→**D**→**A** as shown in the diagram.



(a) Complete the table indicating the temperature and internal energy of the gas in state **C**. [2]

State	Temperature T/K	Internal energy U/J
A	369.7	9 217
B	317.7	7 920
C		
D	323.5	8 065

Space for calculations.

Examiner only

(b) Determine the work done (W) **by** the gas for each of the following: [4]

(i) **A→B**;

(ii) **B→C**;

(iii) **C→D**;

(iv) **D→A**;

(v) **A→B→C→D→A** (net work done by the gas during the whole cycle).

(c) Determine the stages of the cycle in which heat is **absorbed by** (supplied to) the gas. Show that the total heat absorbed in these stages is approximately 3000 J. *(Hint: Use the first law of thermodynamics for each stage.)* [3]

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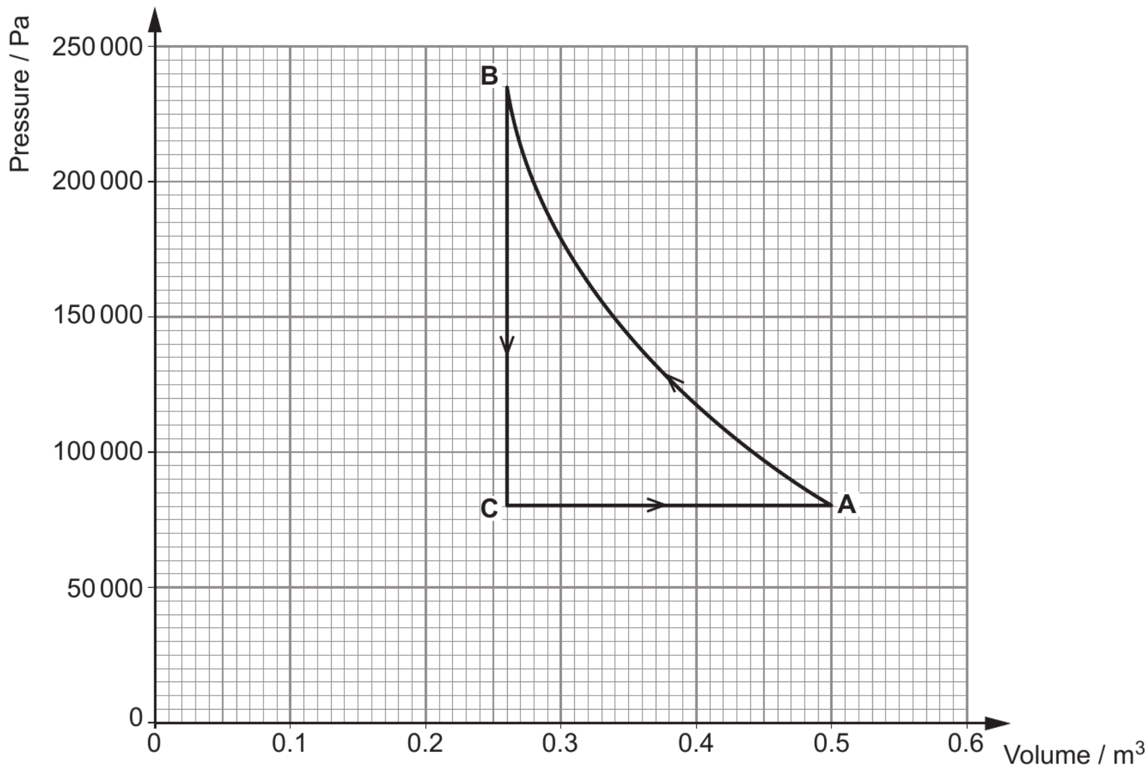
(d) A heat engine absorbs heat and does work. The efficiency of a heat engine is given by:

$$\text{efficiency} = \left(\frac{\textbf{net}\text{ work done }\textbf{by}\text{ the engine}}{\text{heat }\textbf{absorbed}\text{ by the engine}}\right) \times 100\%$$

Calculate the efficiency of the gas heat engine. [2]

4. An ideal monatomic gas is taken through the closed cycle ABCA as shown.



(a) There are 15.6 mol of gas. Show that the temperatures of points **A**, **B** and **C** are 309 K, 471 K and 160 K respectively. [3]

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(b) Calculate the **change** in internal energy for the three processes. [3]

(i) **AB** ....

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(ii) **BC** ....

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(iii) **CA** ....

....

Examiner only

(c) Calculate the work done by the gas for each of the three processes.

(i) **AB** (one mark is available for the accuracy of your estimate) [3]

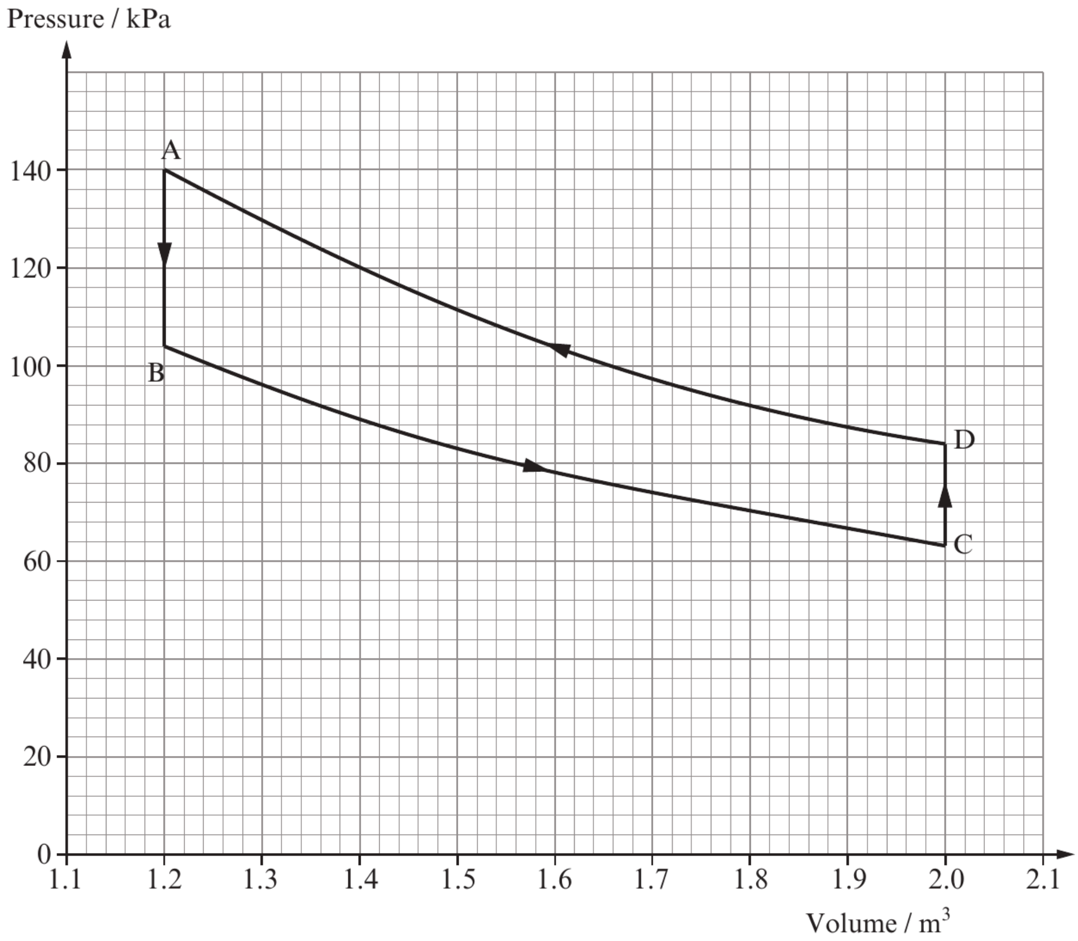
(ii) **BC** [1]

(iii) **CA** [1]

(d) (i) Calculate the heat supplied to the gas for process **AB**. [2]

(ii) Process **AB** is in fact a very rapid compression. Explain why the answer to *(d)*(i) should be a low value. [1]

7. An ideal monatomic gas undergoes the cycle ABCDA shown below.



BC and DA are isotherms (the temperature along each of BC and DA is constant) and there are **49.3 mol** of ideal gas.

(a) By considering one point on BC and one on DA, show that the temperature of BC is approximately 300 K and that of DA is approximately 400 K. [2]

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(b) (i) Calculate the internal energy of the gas for BC, [1]

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....

(ii) and DA. [1]

(c) Explain why the work is zero for both AB and CD. [1]

(d) Explain why the change in internal energy is zero for both BC and DA. [1]

(e) (i) Show that the work done by the gas for DA is approximately –90 kJ. [2]

(ii) Estimate the work done for BC. [1]

(f) For **each** of the processes AB, BC, CD, DA and the whole cycle ABCDA, write the values of W (the work done by the gas), ΔU (the **change** in internal energy of the gas) and Q (the heat supplied to the gas). [4]

	Process				
	AB	BC	CD	DA	ABCDA
W	0		0	–90 kJ	
ΔU		0		0	
Q				–90 kJ	

THERE ARE NO MORE QUESTIONS IN THE EXAMINATION.

END OF QUESTION PACK

8 questions · 99 marks · ~2h 19m
Source: WJEC PH4 (2008 modular spec)
Curated for WJEC Physics 2015 spec A2 Unit 3 — Topic 4 (3.4)