Access Tuition

A-Level Physics

First Law of Thermodynamics

Mark Scheme

Time available: 65 minutes
Marks available: 46 marks

Mark schemes

1. (a) Energy is supplied to the air by heating only in process 2 → 3 ✓

Automarked

1

(b) Claim A: Each square represents 10 J ✓
Area of loop 4 → 5 → 1 → 4 = 9 squares
Giving increase in work done = 90 J ✓

Claim B: area enclosed by loop 1 → 2 → 3 → 4 → 1 = 55 sq /550 J ✓
(Each square represents 10 J)
Increase in efficiency = 9 sq/55 sq or 90 J/550 J = 16% ✓
So claim A not met, claim B efficiency better than claimed ✓

OR Claim B:
Area enclosed by loop 1 → 2 → 3 → 4 → 1 = 55 sq /550 J ✓
Divides 550 J and 640 J by any same value for (heat) input energy
And calculates increase in efficiency ✓
Draws correct conclusion for A and B for answers ✓

W done per square = $0.1 \times 10^{-3} \times 1.00 \times 10^{5} = 10$ J

Allow 8 to 11 squares giving 80J to 110 J

Accept answers where area 4 → 5 → 1 → 4 is approximated to a triangle giving 112(.5) J

Allow 50 to 60 squares giving 500 to 600 J

ECF from above areas if out of tolerance

Allow last mark only if statements re claims agree with answers

***Example** 550/1000 = 0.55 or 55%; 640/1000 =.64 or 64%*

Increase in efficiency = 9%

Values for input energy must > 640 J

5

(c) Q: energy supplied/transferred/input (to system/gas by heating/heat transfer) ✓

OR energy transferred/lost/output (from system/gas by cooling heat transfer) if Q negative

ΔU: increase/change in internal energy ✓

OR decrease if negative

Do not allow 'heat' in place of 'energy'

'Heat transferred' on its own is not enough

Accept heat energy supplied but not heat supplied

2

(d) $W = p\Delta V = 1.0 \times 10^5 \times (3.00 - 1.50) \times 10^{-3}$ J (= 150 J) ✓

(Use of $Q = \Delta U + W$)

gives $Q = -150 + (-374) = (-)\ 524$ J ✓

Check that sign convention is consistent for 2nd mark

Allow if − sign not seen on answer line

2

(e) Attempt to use $pV = nRT$ ✓

Recognises max temperature is at point **3** in the cycle ✓

Substitution of p, V and n in $T = \frac{pV}{nR}$ for point 3

Giving $T = 1310$ K ✓

2nd mark can be implied from values of p and V used in the equation

p from $\mathbf{14.2 \times 10^5}$ *to* $\mathbf{14.8 \times 10^5}$ *Pa*

V from $\mathbf{0.42 \times 10^{-3}}$ *to* $\mathbf{0.48 \times 10^{-3}}$ *m*^{3}

3

[13]

2. (a) (i) Clear statement that for isothermal pV =constant or $p_1V_1 = p_2V_2$ ✓

Applies this to any 2 points on the curve AB ✓

e.g. $1.0 \times 10^5 \times 1.2 \times 10^{-3} = 4.8 \times 10^5 \times 0.25 \times 10^{-3}$

120 = 120

*Allow pV = c applied to intermediate points **estimated** from graph*

e.g. $V = 0.39 \times 10^{-3}$, $p = 3 \times 10^5$

2

(ii) $W = p\ \Delta v$

$= 4.8 \times 10^5 \times (0.39 - 0.25) \times 10^{-3}$

= 67 J ✓

1

(b)

	Q / J	W / J	ΔU / J	
process A → B	−188	−188	0	✓
process B → C	+235	(+)67	(+)168	✓
process C → A	0	+168	−168	✓
whole cycle	+47	+47	0	✓

Any horiz line correct up to max 3

Give CE in B → C if ans to ii used for W

<u>If no sign take as +ve</u>

max 3

(c) $\eta_{overall}$ = 47 / 235 = 0.20 or 20% ✓

1

(d) Isothermal process would require engine to run very slowly / be made of material of high heat conductivity ✓
Adiabatic process has to occur very rapidly / require perfectly insulating container / has no heat transfer ✓
Very difficult to meet both requirements in the same device ✓
Very difficult to arrange for heating to stop exactly in the right place (C) so that at end of expansion the curve meets the isothermal at A ✓

Do not credit bald statement to effect
adiabatic / isothermal process not possible - must give reason
Ignore mention of valves opening / closing, rounded corners,
friction, induction / exhaust strokes

wtte

max 2

[9]

3. (a) (i) ΔQ (heat) **added** (to gas) **(1)**
ΔU **increase** in internal energy (of gas) **(1)**
ΔW work done **by** gas **(1)**

(ii) temperature is constant (in isothermal expansion) **(1)**
absolute temperature depends upon internal energy **(1)**
hence ΔU =0 **(1)**

max 5

(b) (i) isothermal line C shown correctly **(1)**
constant volume line D shown correctly **(1)**

(ii)

process	ΔQ / J	ΔU / J	ΔW / J
A	**–83**	0	–83
B	+200	+200	**0**
C	**+139**	0	+139
D	**–200**	**–200**	0
whole cycle	**+56**	**0**	**+56**

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(iii) max possible efficiency $\left(= \frac{T_H - T_C}{T_H}\right) = \frac{500 - 300}{500}$ = 0.4 (or 40%) **(1)**

actual efficiency of ideal cycle = $\frac{\text{work input per cycle}}{\text{heat input at high temperature}} = \frac{56}{139}$

(= 0.4 or 40%) **(1)**

[14]

4. (a) $\Delta Q = 0$ **(1)**
as heat has no time to transfer **(1)**
$\Delta U = \Delta W$ **(1)**
U related to T **(1)**

max 3

(b) (i) $p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$ **(1)**

$p_2 = 100 \times 10^3 \times \left(\frac{1}{1.7}\right)^{1.4}$ **(1)**

$p_2 = 4.8 \times 10^4$ Pa **(1)**

(ii) $\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$ **(1)**

T_2 = 253 [or 255] K **(1)**

5

(c) higher **(1)**
satisfactory reasoning **(1)**
possible answers:
heat transfer so temperature fall is less
final temperature is higher than adiabatic so greater pressure
falling isothermal curve is less steep than adiabiatic
labelled sketch showing two correct curves

2

[10]