M1.(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

If no sign take as +ve

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]

M2. (a) (i) $p_2 = p_1 (V_2/V_1)^{1.4} = 1.0 \times 10^5 (2.1/1.2)^{1.4}$ ✓

OR $1.0 \times 10^5 \times (2.1 \times 10^{-5})^{1.4} = p_2 \times ((1.2 \times 10^{-5})1.4$ ✓

$p_2 = 2.2 \times 10^5$ Pa ✓

2

(ii) $T_2 = \frac{p_2 V_2 T_1}{p_1 V_1} = \frac{2.2 \times 10^5 \times (1.2 \times 10^{-5}) \times 290}{1.0 \times 10^5 \times 2.1 \times 10^{-5}}$ ✓

OR use of $p_1V_1 = nRT_1$ to find n or nR and substitute in

$p_2V_2 = nRT_2$ to find T_2 ✓

$T_2 = 360$ K ✓ 2 sig fig ✓

3

(b) ($Q = W + \Delta U$)

$Q = 0$ (and W negative) ✓

So ΔU (= - W) = 1.4 J ✓

2

(c) (slow) compression is (nearly) isothermal / at constant temperature ✓

greater change in volume needed to rise to same final pressure ✓

(OR correct p-V sketches showing adiabatic and isothermal processes ✓)

hence less / piston pushed in further ✓

3
[10]

M3. (a) (i) *use of PV/T = constant*

$$\frac{P_D V_D T_A}{P_A V_A}$$ ✓

$$= \frac{2.5 \times 1.0 \times 300}{1.5 \times 1.0}$$ ✓ *= 500 K*

2

(ii) *Q = ΔU + W*

ΔU = 0 ✓

Q = W = 173 J ✓

2

(b) (i) *work out = 173 – 104 = 69 J* ✓

1

(ii) *efficiency = 69/173 = 0.40 or 40%* ✓

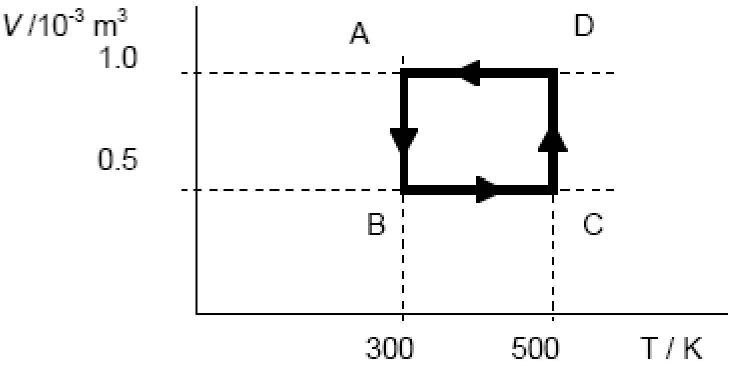
$\eta_{max} = (T_H - T_C)/T_H$

= (500 – 300)/500

= 0.39 or 40% ✓

2

(c)



rectangle in correct position ✓

letters correct place ✓ (arrows optional)

2

(d) • *isothermal process impossible unless very slow or via perfect conductor*

• *engine would have to stop for constant volume processes to take place*

• *regenerator would lose heat to surroundings (unless perfectly insulated)*

• *long time needed for heat to transfer from regenerator to working fluid*

• *regenerator would need to be very large/large surface area for heat transfer to take place quickly*

accept other sensible suggestions

***do not** accept 'heat loss to surroundings' or 'friction'*

any two ✓✓

2

[11]

M4.*(a)* ΔQ*: (heat) energy supplied to the gas **(1)***

ΔU: <u>increase</u> in internal energy of the gas **(1)**

ΔW : (mechanical) work done by the gas **(1)**

3

(b)

	ΔQ	ΔU	ΔW
constant volume		+10.0 (kJ) **(1)**	0 **(1)**
isothermal	+6.0 (kJ) **(1)**	0 **(1)**	

4

[7]