M1. (a) (i) use of PV/T = constant

$$\frac{P_D V_D T_A}{P_A V_A} \checkmark$$

$$= \frac{2.5 \times 1.0 \times 300}{1.5 \times 1.0} \checkmark = 500 \text{ K}$$

2

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

$\Delta U = 0$ ✓

$Q = W = 173$ J ✓

2

(b) (i) work out = 173 – 104 = 69 J ✓

1

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

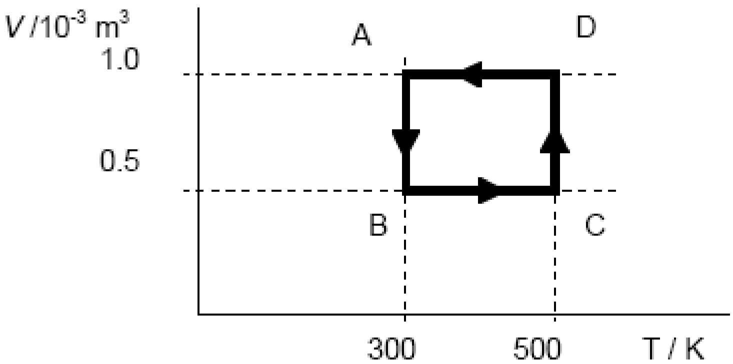
$\eta_{max} = (T_H - T_C)/T_H$

$= (500 - 300)/500$

$= 0.39$ 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]

M2. (a) P_{in}(= calorific value × fuel flow rate)

$= \dfrac{36 \times 10^6 \times 9.6}{3600}$ **(1)** □**(1)** (for conversion to 3600 s) (= 96 kW)

2

(b) $\eta \left(= \dfrac{T_H - T_C}{T_H} \right) = \dfrac{1400 - 360}{1400}$ = 0.74 or 74% **(1)**

1

(c) η claimed in (a) = $\dfrac{80(\text{kW})}{100(\text{kW})}$ = 0.80 or 80% **(1)**

[or $\dfrac{80(\text{kW})}{96(\text{kW})}$ = 0.83 or 83%]

which is > 74%, so claim 1 is unjustified **(1)**

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heat rejected from engine = $P_{in} - P_{out}$ **(1)**

real mechanical P_{out} must be < 0.74 × 100 i.e. < 74 kW **(1)**

so claim 2 is justified as $P_{in} - P_{out}$ > 20 kW **(1)**

[alternative for (c):

maximum *P*out = 71 kW (0.74 × 96) or 74 kW (0.74 × 100) **(1)**

which is < 80 kW, so claim 1 is unjustified **(1)**

heat rejected from engine is 25 kW (96 – 71) or 26 kW (100 – 74) **(1)**

actual wasted power must be > 25 kW **(1)**

claim 2 is justified as 25 kW > 20 kW **(1)**]

Max 4
QWC 1

[7]

M3. (a) $p_1V_1 = 7.8 \times 10^5 \times 1.6 \times 10^{-4} = 125$ (Pa m^3)
$p_2V_2 = 1.9 \times 10^5 \times 6.6 \times 10^{-4} = 125$ (Pa m^3) **(1)**
suitably correct comment **(1)**

2

(b) (i) adiabatic → no heat enters (or leaves) gas,
rapid expansion so no time for heat transfer **(1)**

(ii) ($p_1V_1^\gamma = p_2V_2^\gamma$) gives $V_2 = \left(\frac{p_1V_1^\gamma}{p_2}\right)^{1/\gamma}$

$= \left(\frac{1.9 \times 10^5 \times (6.6 \times 10^{-4})^{1.4}}{9.8 \times 10^4}\right)^{1/1.4}$ **(1)** = 1.1(0) × 10^{-3}m^3 **(1)**

3

[5]

M4. (i) $V = 80 \times 10^{-3} \times 1.77 \times 10^{-4}$ **(1)** ($= 1.416 \times 10^{-5}$)

$$n\left(= \frac{pV}{RT}\right) = \frac{1.03 \times 10^{5} \times 1.416 \times 10^{-5}}{8.31 \times 291} = 6.0(3) \times 10^{-4} \text{ (moles)} \textbf{ (1)}$$

(allow C.E. for value of V)

(ii) $$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} \textbf{ (1)}$$

$$= 1.03 \times 10^{5} \times \left(\frac{80}{2.0}\right)^{1.4} = 1.80 \times 10^{7} \text{ Pa} \textbf{ (1)}$$

(iii) $$T_2 = \frac{p_2V_2}{nR} \text{ or } T_2 = \frac{p_2V_2T_1}{P_1V_1} \textbf{ (1)}$$

$$T_2 = \frac{1.80 \times 10^{7} \times 2.0 \times 10^{-3} \times 1.77 \times 10^{-4}}{6.03 \times 10^{-4} \times 8.31} = 1.3 \times 10^{3} \text{ K} \textbf{ (1)} \quad (1.27 \times 10^{3} \text{ K})$$

(allow C.E. for value of p_2 or n)

[6]

M5. (a) (use of pV^{γ} = *constant* gives)
$1.01 \times 10^{5} \times (4.25 \times 10^{-4})^{1.4} = 1.70 \times 10^{5} \times V^{1.4}$ **(1)**
V calculated correctly ($= 2.93 \times 10^{-4}$)
or substitution to show equal pV^{γ} **(1)**

2

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(b) $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ **(1)**

$T_1 = 273 + 23 = 296$ (K) **(1)**

$T_2 = \frac{1.7 \times 10^5 \times 2.93 \times 10^{-4} 296}{1.01 \times 10^5 \times 4.25 \times 10^{-4}}$ =343 K (70 °C) **(1)**

3

(c) slow compression is isothermal (temperature does not increase) **(1)**
greater change in volume needed to rise to same final pressure **(1)**
(or correct pV sketches showing adiabatic and isothermal processes)
hence less **(1)** **(1)**

3

[8]

M6.(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) $p_1V_1^{\gamma} = p_2V_2^{\gamma}$ **(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) $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ **(1)**

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

5

(c) higher **(1)**
satisfactory reasoning **(1)**
possible answers:

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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]

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