

M1. (a) (i) use of $PV/T = \text{constant}$

$$\frac{P_D V_D T_A}{P_A V_A} \checkmark$$
$$= \frac{2.5 \times 1.0 \times 300}{1.5 \times 1.0} \checkmark = 500 \text{ K}$$

2

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

$$\Delta U = 0 \checkmark$$

$$Q = W = 173 \text{ J} \checkmark$$

2

(b) (i) work out = $173 - 104 = 69 \text{ J} \checkmark$

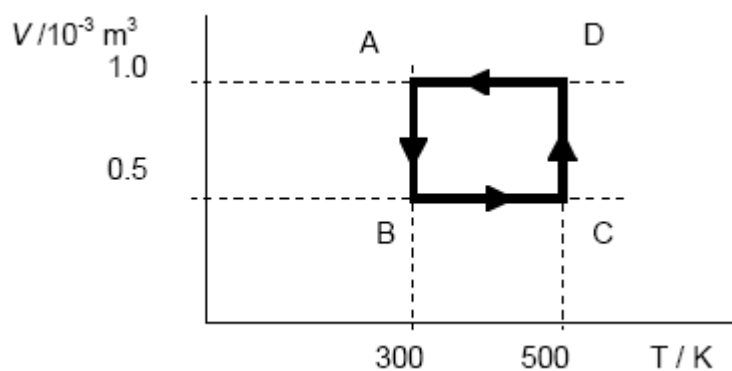
1

(ii) efficiency = $69/173 = 0.40$ or 40% \checkmark

$$\eta_{\text{max}} = (T_H - T_C)/T_H$$
$$= (500 - 300)/500$$
$$= 0.39 \text{ or } 40\% \checkmark$$

2

(c)



rectangle in correct position \checkmark

letters correct place \checkmark (arrows optional)

- (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 \times fuel flow rate)

$$= \frac{36 \times 10^6 \times 9.6}{3600} \quad \mathbf{(1)} \quad \mathbf{(1)} \quad \text{(for conversion to 3600 s) (= 96 kW)}$$

2

(b) $\eta \left(= \frac{T_H - T_C}{T_H} \right) = \frac{1400 - 360}{1400} = 0.74 \text{ or } 74\% \quad \mathbf{(1)}$

1

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

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

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

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

real mechanical P_{out} must be $< 0.74 \times 100$ 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) $p_1 V_1 = 7.8 \times 10^5 \times 1.6 \times 10^{-4} = 125$ (Pa m³)
 $p_2 V_2 = 1.9 \times 10^5 \times 6.6 \times 10^{-4} = 125$ (Pa m³) (1)
suitably correct comment (1)

2

- (b) (i) adiabatic \rightarrow no heat enters (or leaves) gas,
rapid expansion so no time for heat transfer (1)

(ii) $(p_1 V_1^\gamma = p_2 V_2^\gamma)$ gives $V_2 = \left(\frac{p_1 V_1^\gamma}{p_2} \right)^{1/\gamma}$

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

3

[5]

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

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

(allow C.E. for value of V)

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

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

(iii) $T_2 = \frac{P_2 V_2}{nR}$ or $T_2 = \frac{P_2 V_2 T_1}{P_1 V_1}$ (1)

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

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

[6]

M5. (a) (use of $pV^\gamma = \text{constant}$ 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

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

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

$T_2 = \frac{1.7 \times 10^5 \times 2.93 \times 10^{-4} \times 296}{1.01 \times 10^5 \times 4.25 \times 10^{-4}} = 343$ 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) $p_1 V_1^\gamma = p_2 V_2^\gamma$ (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 adiabatic
labelled sketch showing two correct curves

2
[10]