M1.(a) **E** to **X** circled

1

(b) (i) $p_1V_1 / T_1 = p_2V_2 / T_2$

$T_2 = p_2V_2T_1 / p_1V_1$ ✓

$$= \frac{4.6\times10^5 \times 1.5\times10^{-4} \times 310}{1.0\times10^5 \times 5.0\times10^{-4}}$$

=430 K ✓

Also: work out n or nR in $p_1V_1 = nRT_1$

Substitute in $p_2V_2 = nRT_2$

Accept use of 4.5×10^5 Pa for p_2

Giving $T_2 = 420$ K

$nR = 0.161$

$n = 1.94 \times 10^{-2}$

2

(ii) Work per cycle = area enclosed by loop ✓

Suitable method for calculating area used correctly e.g. counting squares ✓

E.g. 355 small sq × $0.2 \times 10^5 \times 0.1 \times 10^{-4}$

OR

14 × 1 cm squares × $1.0 \times 10^5 \times 0.5 \times 10^{-4}$

Correct scaling factor used leading to 70J ± 5 J ✓

If no. of squares incorrectly counted but correct scaling factor used for their squares give CE for final answer

3

(iii) P = 70 × 420 / 60 = 500 W ✓

CE from ii

1

(iv) Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response.

0 marks

The information conveyed by the answer is sketchy, and neither relevant nor coherent.
The candidate shows inadequate understanding of the operation of the compressor and how its performance will change.

Level 1 (1−2 marks)
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary.
*The candidate has some appreciation of how the performance will change, but is only likely to cover **up to three** of the points listed below, and probably without reasons.*

Level 2 (3−4 marks)
The information conveyed in the answer may be less well organized and not fully coherent. There is less use of specialist vocabulary or specialist vocabulary may be used or spelled incorrectly. The form and style of writing is less appropriate.
The candidate is able to make some correct predictions concerning how the diagram, work done, power and temperature (but not all) will change, but reasoning will be less confident.
Answers will include 4 to 6 of the points listed below.

Level 3 (5−6 marks)
The information conveyed by the answer is clearly organized, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.
A good attempt is made at how the compressor will operate at higher pressures. Statements are made relating to the diagram, work or power, temperature and flywheel, backed up by some sound reasoning.
Answers at this level will include more than 6 of the points listed below.

examples of the points made in the response

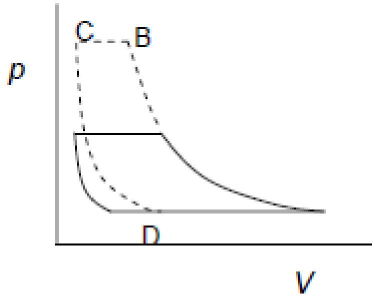
1. area of loop increases as p increases
2. BC at higher pressure / point B moves up and to left
3. p higher in $W = p\Delta V$ for BC / higher p more work to force air into tank
4. (so) work done per cycle increases
5. input power increases (if speed constant)
6. temperature will increase
7. reason: because B gets further from graph origin / $p_2V_2$gets larger / int energy increases because little time for heat transfer
8. higher p means more applied crankshaft torque (between dead centres)
9. so jerkier motion
10. flywheel needed to smooth motion of crankshaft
11. flywheel acts as energy store
12. speeding up / gaining energy - then slowing down / losing energy when torque needed is high / takes piston over dead centres
13. application of $T = I\alpha$: fluctuations in ω small if I large
14. expansion of air in clearance volume will have negative effect on area
15. vol of air drawn in per cycle will decrease
16. increase in work per cycle gets progressively smaller as p increases

check to see if Fig 3 drawn on

Bullet points 1, 14 and 15 can be supported by diagram

Expect to see: BC to be at higher pressure and loop to get narrower

Candidates are unlikely to show the effect of clearance volume (CD)



Point 6: accept correct use of pV/T constant

14,15,16 unlikely but give credit in lieu of other points

6

[13]

M2.(a) (i) Appreciates pV should be constant for isothermal change (by working or statement) $W = p\Delta V$ is TO

Allow only products seen where are approximately 150 for 1 mark
Penalise J as unit here

M1

Demonstrates pV = constant using 2 points (on the line) set equal to each other or conclusion made or **shows** that for V doubling that p halves (worth 2 marks)
need to see values for p and V

Products should equal 150 to 2 sf
Accept statement that products are slightly different so not quite isothermal

A1

Demonstrates pV = constant using 3 points (on the line) with conclusion
Need to see values for p and V

Products should equal 150 to 2 sf
Accept statement that products are slightly different so not quite isothermal

A1

3

(ii) Adiabatic therefore no heat transfer **or**
Adiabatic therefore $Q = 0$

B1

Work is done by gas therefore W is negative **or**
Work is done by gas therefore energy is removed from the system

B1

ΔU is negative therefore internal energy of gas decreases **or** energy is removed from the system therefore internal energy of gas decreases or work done by the gas so internal energy decreases

Allow

$-\Delta U = -W$ *or* $\Delta U = -W$

B1

3

(iii) Uses pV / T = *constant or uses* $pV=nRT$ *or uses* $pV=NkT$
e.g. makes T subject or substitutes into an equation with p_A and V_A or p_C and V_C (condone use of n = 1) or their $\frac{(pV)_A}{(pV)_C}$

V_a *read off range*
= 2.5 to 2.6 (× 10^{-4})
p_A *= 600 × 10^3*
V_C *read off range*
= 8.5 to 8.6 (× 10^{-4})
p_C *= 140 × 10^3*

C1

Correct substitution of coordinates (inside range) into $\frac{(pV)_A}{(pV)_C}$
With consistent use of powers of 10

$(pV)_A$ range is 150 to 156 and $(pV)_C$ range is 119 to 120.4

C1

1.2(5) Allow range from 1.2 to 1.3

Accept decimal fraction : 1

A1 **3**

(b) Energy per large square = 10(J) **or** <u>states</u> that work done is equal to area under curve (between A and B)
or energy per small square = 0.4(J)
or square counting seen on correct area

Must be clear that area represents energy either by subject of formula or use of units on 10 or 0.4

Alternative:
W = area of a trapezium (with working)
or *W =* $P_{mean} \times \Delta V$ ***or***
W = 450 × 10^3 *× 2.5 ×* 10^{-4}
or *W = area of a rectangle + area of a triangle (with working)*

B1

Number of large squares = 10.5 to 11.5 seen <u>and</u> (W) =
number of squares × area of one square (using numbers)
Range = 105 to 115 (J)
Or

Number of small squares = 263 to 287 seen <u>and</u> (W) =
number of squares × area of one square (using numbers)
Range = 105 to 115 (J)

States that actual work done would be lower because of curvature of line

B1 **2**

(c) (Total energy removed per s =) 4560 (J)
or number of cycles per s = 40
or (Mass per second =) 114 ÷ 68400 in rearranged form
or their energy ÷ (c ΔT) **or** their energy ÷ 68400

C1

0.067 (kg) seen Allow 0.066 (kg) here
or allow V / t = 1.67 × 10^{-3} ÷ 1100
or ($\frac{V}{t}$) = $\frac{E}{\rho c\,\Delta\theta}$ and correct **substitution** seen

Condone E = 114 (J) **or** temperature = 291(K)

C1

$= 0.061 \times 10^{-3}$ or 6.06×10^{-5} (m^3)

A1

3

[14]

M3.(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]