Mark schemes

1. The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (**L1**), 3 or 4 mark (**L2**) and 5 or 6 mark (**L3**) answer.

Level 3 (5–6 marks)
6 marks: both areas of the question are covered (i.e. calculations and explanations) with all efficiencies calculated correctly and at least two of points 7,8,9.
5 marks: both areas covered but with one or two minor errors in calculations or explanations.

Level 2 (3–4 marks)
4 marks: all efficiencies calculated correctly with no explanation of usefulness of efficiencies OR a good attempt at calculating efficiencies and some explanation given of usefulness of efficiencies.
3 marks: Both areas covered partially or one area covered reasonably well but not fully. E.g may only be able to calculate correctly 2 of the three required efficiencies and give no explanation of their usefulness.

Level 1 (1–2 marks)
Student is likely to make one or two calculations (e.g input power and one efficiency) at any speed, but not likely to be able to explain the usefulness of efficiency.

0 marks
The student shows inadequate understanding of the graphs. Formulae may be quoted from the Formulae Booklet or from memory, but the student is unable to apply their meaning to the question.

(a) Numerical answers:

1. Peak brake power occurs at (6200 to 6600) rev min^{-1}
2. Input power = 136 kW
3. Overall efficiency = 0.29
4. Thermal efficiency = 0.35
5. Mechanical efficiency = 0.84
6. Friction power = 7.5 kW

General points:

7. Relates thermal efficiency to how well the calorific value of fuel is converted into work/power inside the engine.
8. Relates mechanical efficiency to work/power used in overcoming friction/viscosity inside engine and work/power to operate valves, water/oil pumps etc.
9. Overall efficiency gives an idea of how well energy in fuel is converted into useful work output.

If student uses peak <u>indicated</u> power points 1 to 5 become

1. Peak power occurs at (7200 to 7600) rev min^{-1}
2. Input power = 150 kW
3. Overall efficiency = 0.26
4. Thermal efficiency = 0.32
5. Mechanical efficiency = 0.80

Do not allow marks at Level 3.

(b) Links two quantities from Figure 4 at speeds above 7000 rev min^{-1} ✓

Gives reason for not running engine at speeds above 7000 rev min^{-1} ✓

Examples of points expected for MP1:

- *brake power drops whilst input power continues to increase (as shown by fuel consumption curve)*
- *brake power drops whilst indicated power flattens off*
- *indicated power flattens off while fuel consumption increases*

Do not accept: the brake power gets less with no reference to other power(s).

MP2:

any of overall, thermal or mechanical efficiency decreases, or efficiency decreases.

friction or friction power increases at high engine speeds

breakdown of lubrication and/or greater work done against viscosity at high engine speeds.

Do not accept: damage to engine may occur -unless backed up by reason relating to friction/friction power.

Max 2

[8]

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

Automarked

1

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

<u>Claim B</u>: 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 <u>Claim B</u>:
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 × 10^{-3} × 1.00 × 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 ***14 .2*** × ***10***$^{\mathbf{5}}$ *to* ***14.8*** × ***10***$^{\mathbf{5}}$ *Pa*

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

3

[13]

3. (a) $p_1V_1^{1.4} = p_2V_2^{1.4}$

$p_2 = p_1 (V_1/V_2)^{1.4}$

$= 1.2 \times 10^6 (9.0/6.8)^{1.4}$ ✓ $= 1.8 \times 10^6$ (Pa) ✓

$$T_2 \frac{p_2V_2T_1}{p_1V_1} = \frac{1.8\times10^6\times(6.8\times10^{-5})\times290}{1.2\times10^6\times(9.0\times10^{-5})}$$ ✓

T_2 = 328 (K) ✓

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 ✓

1st mark for substituting correct values into either equation

2nd mark for answer p_2

3rd mark for substituting correct values into

$p_1V_1/T_1 = p_2V_2/T_2$ *or* $T_2 = \frac{p_2 V_2 T_1}{P_1 V_1}$

4th mark for answer T_2

ECF for p_2

With rounding answers range from 320 to 330 K

4

(b) in adiabatic compression there is no heat transfer/Q = 0 ✓

If compression is quick there is no time for heat transfer ✓

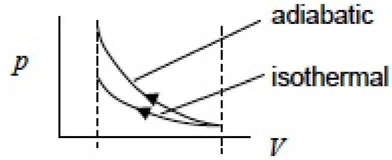
(so can be considered adiabatic)

2

(c) For isothermal compression (for same volume change) (final) pressure not as high **OR** adiabatic compression curve is steeper (on p - V diagram) than isothermal ✓ Area under a p - V curve between same volumes would be less OR addition of all $p\Delta V$ during compression will be less ✓

So less work done ✓

Give credit for these ideas shown with help of a diagram or diagrams.



Award last mark only if either or both of first two marks have been given.

3

[9]

4. The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer.

Guidance provided in section 3.10 of the ‘Mark Scheme Instructions’ document should be used to assist in marking this question.

Mark	Criteria	QoWC
6	Both bullets in question are answered. Answer includes 9 or more points taken from both lists opposite with reasons mainly matching differences. Allow for answers which state the events in both cycles, provided points alongside are covered and some reasons given for differences.	The student presents relevant information coherently, employing structure, style and SP&G to render meaning clear. The text is legible.
5	A fair attempt to answer both bullets. Answer includes 7or 8 points taken from both lists, including at least two matching reasons for differences. Answers will not be as full as for 6 marks.	
4	Comparisons are less complete but good understanding is shown of the differences between the diagrams. Answer includes 5 or 6 of the points opposite with at least one taken from each part.	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. SP&G are sufficiently accurate not to obscure meaning.
3	The student will address 4 or 5 of the points listed but reasons may not be given with confidence or reasons may not match the differences	
2	Fewer than 4 points are covered. The student is more likely to state the differences rather than explain them. The answer addresses one or	The student presents some relevant information in a simple form. The text is usually legible. SP&G allow meaning to be derived

	both bullets in the question but with limited scope. They are likely to refer to 'heat losses' or 'friction' without detail.	although errors are sometimes obstructive.
1	Some attempt is made to compare the cycles.	
0	No relevant information.	The student's presentation, SP&G seriously obstruct understanding.

The following statements are likely to be present.

First bullet: differences between cycles

- Real engine needs induction and exhaust strokes/ pumping loop
- Ideal cycle needs no pumping loop/same air used repeatedly
- Corners rounded on real cycle
- Reason: valves take finite time to open and close/combustion not instantaneous
- Heating/cooling cannot occur at constant volume in real cycle
- Reason: piston would have to stop
- In real cycle expansion & compression are not adiabatic
- Reason: heat transfer takes place to cooling medium during these strokes
- In ideal cycle air only is taken through cycle (repeatedly)/gas is ideal
- In real engine some exhaust gas/fuel vapour is present/gas is not ideal
- Max pressure is lower in real engine
- Fuel may not be completely burnt
- Ideal cycle makes no reference to any mechanism
- In real engine a mechanism is necessary e.g. for valve operation, generation of spark

Second bullet: why work output less

- Area of loop is smaller for real engine, so less work done per cycle
- Area of pumping loop has to be subtracted from main loop, reducing work done
- Friction between moving surfaces/between piston & cylinder/in bearings has to be overcome
- energy is expended in driving oil and water pumps, opening and closing valves overcoming fluid viscosity etc

Accept other reasonable answers in lieu (e.g. variation in γ during expansion and compression).

[6]

5. **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the ‘Mark Scheme Instructions’ document should be used to assist in marking this question.**

Level	**Criteria**	**QoWC**
6 marks	Both bullets in question are answered. Answer includes 8 or more points taken from both lists opposite and table below including use of data. Comes to a conclusion or advice given.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
5 marks	A fair attempt to answer both bullets. Answer includes 7 points taken from both lists opposite and table below including use of data. Answers will not be as full as for 6 marks. Comes to a conclusion or advice given.	
4	Makes some attempt to use the numerical data correctly. Answer includes any 5 or 6 of the points opposite or in table below.	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
3	Any 4 of the answer points opposite or in table below are given. May not make use of numerical data.	
2	2 or 3 answer points opposite or in table below are covered. May not make use of the numerical data.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
1	Any one pertinent statement.	
0	No sensible statements made.	The student’s presentation, spelling, punctuation and grammar seriously obstruct understanding.

Likely answer points:

First bullet

1. All heat engines must obey 2nd Law of thermodynamics

2. They must reject energy to a sink/surroundings (at low temperature)

3. Maximum efficiency determined by source and sink temperatures / formula quoted $\eta = T_H - T_C / T_H$

4. 100% efficiency would require $T_C = 0$ K and/or a small difference between T_H and T_C gives low efficiency

5. Allow: inefficiencies from nature of working cycle, friction, incomplete combustion etc.

Second bullet

6. 60 MW will cover electrical need (but not much margin for expansion)

7. Input power = 57/0.36 = 158 MW (or 167 MW at 60 MW output)

8. Max heat available for heat requirement = 101 MW (or 107 MW at 60 MW output)

9. And likely to/will be less than this

10. This is not enough for heating requirement

11. (At least) 34 MW will need to come from National Grid

12. Power station input to give 198 MW to mill = 495 MW

13. Energy <u>that would otherwise be wasted</u> is utilised.

Other answer points (other factors) for 2nd bullet are in the table below; credit sensible alternatives

National Grid		**CHP**	
advantages	**disadvantages**	**advantages**	**disadvantages**
No need to build power plant in mill - capital saving.	Cost /kWh includes cost of waste heat at power station and transmission cost.	Can provide all (average) electric power and most of heating need.	Space/land needed for installation.
High probability of uninterrupted supply.	Subject to power cuts.	Independent of any National Grid supply problems.	Maintenance and depreciation costs.
		Can sell any excess electrical power to grid.	Not all heating need can be supplied by CHP.
		Gives lower overall carbon footprint	Spikes in production may require more than 60 MW

[6]

6. (a) Attempt to determine area under graph ✓$_1$
Use of correct scaling factors to find area in J ✓$_2$
Calculates area to be between 22 J and 25 J ✓$_3$
Finds work needed to drive at least one nail into wood using $W = F \times s$ ✓$_4$
Concludes that expansion roughly matches energy to drive nail D ✓$_5$

Eg counting squares

9 large sq × 2 × 10^5 × 10 × 10^{-6} = 18 J

67 small sq × 2/25 = 5.4 J

Total 23(.4) J

Accept 11 to 12½ large sq giving 22 to 25 J

W for D = 420 × 0.050 = 21.0 J

Nail E needs much more W, others need less W. OR F = (wd by gas) ÷ length and compares with forces in Table 2.

For ✓$_5$ do not accept 'closest' answer unless answer for w.d by gas ≥ work needed to drive nail.

ECF for ✓$_5$ for their calculated area

5

(b) Isothermal process/expansion requires (relatively) long time for expansion to take place

OR

Process/expansion must occur slowly ✓$_1$

Reason: isothermal needs energy transfer (Q) for temperature/internal energy to remain constant ✓$_2$

nail fired in less than ⅓ second so expansion very fast/not enough time for energy transfer ✓$_3$
(so process cannot be isothermal)

For ✓$_2$ do not credit energy must be supplied without reference to temperature or internal energy.

For ✓$_3$ must relate time to the data in the question.

3

[8]

7. The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist marking this question.

Mark	Criteria
6	There is a response to both bullet points in the question. Student quotes or uses points A B C 11 and 12 in words or symbols **and** have 7 or more of detail points 1-10 covering all three powers.
5	There is a response to both bullet points in the question. Mark as for 6 above. Answers will not be as confident or detailed as for 6 marks, or answers may not be expressed using scientific terminology.
4	The student describes how to determine at least 2 of powers A, B, C with detail points for each. They may be able to give one of the efficiencies. They should have at least 7 of points 1 to 12. Answers show more confidence than for 3 marks.
3	Student describes how to determine at least 2 powers. They will have 5 points or more from 1 to 12 .They may miss out efficiency formulae altogether,or get them wrong.
2	Student includes 3 or 4 of points 1 to12, relating detail points 1 to 10 to the appropriate power formula.
1	Makes any 2 of points 1 to 12.
0	No relevant analysis.

Marks not awarded for simply quoting formulae from Data booklet.

Likely answer points:

<u>1st bullet</u>
Measurements/info needed and how obtained

A input power from c.v. × fuel flow rate
1. measure volume of fuel used in given time
2. by using reservoir/measuring cylinder and stopclock
3. find/look up calorific value of fuel; accept c.v. is known

B indicated power from area of indicator diagram x cycles s^{-1}
4. need cylinder pressures and corresponding volumes
5. take an indicator diagram / $p-V$ diagram
6. using sensors (data logger + computer + software)
7. determine area of indicator diagram with method
8. measure speed from tachometer <u>and</u> × ½

C brake (output) power from $P = T\omega$
9. torque on output shaft using dynamometer and engine speed using tachometer
10. multiply tachometer reading by 2π

Note: no credit for formulae simply stated as they are in formulae booklet.
<u>2nd bullet</u>
11. thermal efficiency = indicated power/input power

12. mechanical efficiency = brake power/indicated power

(Note: these formulae are not in the formulae booklet)

[6]

8. (a) Tick against answer B ✓

1

(b) COPref = $\frac{272}{343 \quad 272}$ (= 3.8 (3.83)) ✓

3.8 = $Q_C/(100 - Q_C)$ giving Q_C = 79 (W) (79.3W) ✓

P_{IN} = 79/3.8 = 21 (W) (20.7 W) ✓

OR for 2nd and 3rd marks

COPref = Q_C/W and $Q_C + W = Q_H = 100$ ✓
3.8 W + W =100
So W = 21 (W) ✓

OR for 2nd and 3rd marks
COPhp = COPref + 1 ✓
W = Q_H/4.8 = 100/4.8 = 21 (W) ✓

3

[4]

9. (a) The efficiency is 50% when the kelvin temperature of the hot source is twice the kelvin temperature of the cold sink. ✓

1

(b) Identifies $Q_H = 3 \times W$ and $Q_C = Q_H - W$ ✓

In reverse $COP_{ref} = QC / W$

Leading to $COP_{ref} = 2$ ✓

MP1 can be awarded for

$Q_H - Q_C = 0.33Q_H$ or $Q_C = 0.67Q_H$

Give credit for substituting numbers in equations eg

$W = 1$ $Q_H = 3$, $Q = 2$

OR $W = 33$ $Q_H = 100$, $Q_C = 67$

Accept working shown on a diagram

Accept working using temperatures T_H T_C with numbers substituted eg T_H = 300 (K), T_C = 200 (K)

No credit for simply quoting formulae from Formulae Booklet.

2

[3]

10. (a) Heat pump takes energy/heat from cold space/sink/reservoir/surroundings (and gives to hot space) ✓

(Electrical) energy needed by heat pump is less than (electrical) energy needed by conventional dryer by energy/heat taken from cold space ✓

OR this means more energy given to hot space/dryer per unit of electrical energy input than for a conv. dryer

Accept answers as equations:

Conv. dryer $Q_H = W_1$

In heat pump $Q_H = W_2 + Q_C$ *or WTTE* ✓

So for same Q_H, $W_2 = W_1 - Q_C$ ✓

2

(b) Converts temperatures to K (278 K, 293 K and 433 K) ✓

Calculates COP_{garage} for 278 K and 433 K = 2.8

and calculates COP_{kitchen} for 293 K and 433 K = 3.1 ✓

COP_{kitchen} is greater so lower energy input/running cost needed for the kitchen/20°C ✓

1st mark for temperatures in K

2nd mark for calculating COPs or for argument using $T_H / (T_H - T_C)$ *showing COP less for lower cold space temperature*

3rd mark for relating higher COP to lower energy input/running cost for given Q_H *or more* Q_H *per kWh.*

For 2nd mark condone temperatures not converted to K giving $COP_{kitchen} = 1.14$ $COP_{garage} = 1.03$. *Award 3rd mark as above.*

Condone 20°C space to identify kitchen

3

[5]

11. (a) $p_A V_A = p_B V_B$

$$V_B = \frac{1.0 \times 10^5 \times 9.0 \times 10^{-2}}{2.2 \times 10^5}$$ ✓ (= 4.1×10^{-2} m^3)

The mark is for attempt to use Boyle's Law with correct numbers substituted.

1

(b) Use of $\frac{V_B}{T_B} = \frac{V_C}{T_C}$ ✓

OR

Use of $\frac{p_A V_A}{T_A} = \frac{p_C V_C}{T_C}$ ✓

Leading to T_C = 425 K ✓

Allow ECF from (a)

Accept any correct application of pV/T = constant

426 K if 4.09×10^{-2} m^3 used for V_B

At least 3 sig fig answer must be seen

2

(c)

Process	Work W/J	Heat transfer Q/J
A → B	−7100	−7100
B → C	4000	*14000* ✓
C → D	10 300	10 300
D → A	*−4000* ✓	−14 000

1st mark for either italicised answer correct including sign

2nd mark for both italicised answers correct including sign

Calculations might show

*W for **D** → **A** = $p\Delta V = 1.0 \times 10^5 \times (13.0 - 9.0) \times 10^{-2}$ J = 4000 J*

2

(d) 1st Law applies/must be obeyed

OR $Q = \Delta U + W$ ✓

(for isothermal process) $\Delta U = 0$ so $Q = W$ ✓

1st mark for any reference to First Law in words or equation.

2nd mark for stating $\Delta U = 0$ (in isothermal process) and showing Q = W

2

(e) Claim is correct as

Net work = 3200 J ✓$_1$

η = 3200 / 10300 = 0.31 or 31% ✓$_2$

$\eta\text{max} = \frac{425 - 295}{425}$ = 0.31 or 31% ✓$_3$

OR

$\eta\text{max} = \frac{420 - 295}{420}$ = 0.30 or 30%

Alternative for 1st mark:

Net work = area of loop in Fig 3 = 6.5 squares × 500 J = 3250 J allow ± 250 J

If student tots up their W column in the table correctly for their values, award the 1st mark point ✓$_1$ (or if they use the area of the cycle correctly calculated)

Also award ✓$_1$ for 3200 J even if it does not agree with their table.

If they have been awarded ✓$_1$ for net work, and divide this value by 10300, give the 2nd mark point ✓$_2$

If they calculate the max theoretical efficiency correctly give ✓$_3$

Then if they have ✓$_1$, ✓$_2$ and ✓$_3$:

If there is no concluding statement award 2 marks

If the concluding statement is incorrect for their efficiencies award 2 marks

If their concluding statement is correct for their efficiencies award 3 marks

If they only get the max theoretical efficiency, award 1 mark.

If 420 K has been used allow argument that efficiencies are not (quite) the same

3

(f) Isothermal processes are impossible/difficult to achieve ✓

Because engine would have to run (very) slowly

Or perfect conducting material used ✓

OR

Economiser will not store/transfer energy effectively ✓

because it will lose heat to surroundings ✓

Or unless it has large/have large surface area

Or because it will not be perfectly insulated

Accept other sensible suggestions and corresponding reasons

Answer should relate to the real engine based on 'this cycle'. Do not allow problems common to all heat engines e.g. ignore 'friction' and simple statements relating to 'heat loss to surroundings'.

Give 1 mark if student spots that

Work/power output is very small for size of engine

1 mark if they back this up.

2

[12]

12. (a) (For 2nd law of thermodynamics to apply...)
Engine must operate between hot and cold reservoirs ✓
And must reject some energy to cold reservoir ✓
(Meaning W cannot equal Q_H)

accept hot and cold spaces / hot source and cold sink / high and low temperatures

Accept for 2nd mark:

For 100% efficiency T_C would have to be 0 K

(which is impossible)

2

(b) 175 ºC = 448 K and 30 ºC = 303 K and ✓$_1$

$\eta = \frac{T_H - T_C}{T_H}$ ✓$_1$

$= \frac{448 - 303}{448} = 0.32$ ✓$_2$

$(\eta = \frac{W}{Q_C + W}$ so $Q_C = \frac{W}{\eta} - W)$

$Q_C = \frac{2.9}{0.32} - 2.9 = 6.2$ MW ✓$_3$

6.2 MW < 6.4 MW so claim is not true ✓$_4$

Alternatives for 3rd and 4th marks:

For QC =6.4 MW, $\eta = \frac{2.9}{2.9+6.4} = 0.31$ ✓$_3$

Actual $\eta > 0.31$ so QC has to be < 6.4 MW

so claim not true ✓$_4$

1st mark for converting to K and giving thermal efficiency equation

2nd mark for calculating efficiency

3rd mark for another relevant calculation

4th mark for a comparison leading to a conclusion regarding claim. This is not an independent mark.

e.g. 4th mark: claim is not true (based on ideal engine) because 6.2 MW < 6.4 MW ✓4

OR

input power = $\frac{2.9}{0.32}$ = 9.1 MW

input power needed for company claim = 2.9 + 6.4 = 9.3 MW ✓$_3$

9.1 < 9.3 so claim not true ✓$_4$

OR accept: claim is true; for real engine η will be (considerably) less, so energy available for greenhouse heating will be/is likely to be higher than 6.4 MW

If temperatures <u>not</u> changed to K condone giving ECF for marks ✓$_3$ and ✓$_4$:

$\eta = \frac{175 - 30}{175} = 0.83$ *= 0.83*

$Q_C = \frac{2.9}{0.83} - 2.9 = 0.6$ *MW* ✓$_3$

0.6 < 6.4 so claim not true ✓$_4$

4

[6]

13. (a)

Process 1	Process 2	
constant pressure	isothermal	
constant volume	adiabatic	
constant pressure	adiabatic	
constant volume	isothermal	✓

*Tick **only** in cell indicated.*

1

(b) Attempt to apply $p_1V_1 = p_2V_2$ or pV = constant ✓
$(1.00 \times 10^{-4} + 2.80 \times 10^{-4} - V)\ 1.01 \times 10^5 =$
$1.83 \times 10^5 \times (2.80 \times 10^{-4} - V)$ ✓
Leading to $V = 1.57 \times 10^{-4}\ \text{m}^3$ ✓

1st mark for equating pV before to pV after plunger pushed in - in words or symbols or numbers

*2nd mark for correct substitution in **either** p_1V_1 **or** p_2V_2 **or** both*

3rd mark for answer

3

(c) steeper curve ✓
vertical line ✓
(as shown alongside)

Allow vertical line that does not come right down to end of isothermal compression line

2

(d) (In isothermal process) (for internal energy to remain constant) energy transfer must take place ✓
If change is slow there is enough/sufficient time (for energy transfer) ✓

Statements showing the First Law applied to an isothermal compression in symbols are not enough unless symbols are explained.

2

[8]