Access Tuition

A-Level Physics

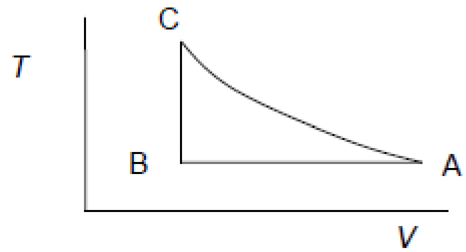
The p-V Diagram

Mark Scheme

Time available: 114 minutes
Marks available: 60 marks

Mark schemes

1. (a)



Shape ✓

Labels ✓

CA must be a curve.

2

(b) Work done (per cycle) = area of indicator diagram ✓

Appropriate method for finding area e.g. counting squares ✓

Correct scaling factor leading to area = 70 J ± 10 J ✓

1 small sq = 0.4 J.

1 large sq = 10 J.

Other methods accepted e.g. strips.

3

(c) 'Answer to part **(b)**' × 80 correctly evaluated ✓

1

(d) **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.**

L3 5-6 marks	Both parts of the question are addressed in detail with some quantification of the efficiency, either ideal, actual or both. The answer includes at least 8 answer points from the list below.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
L2 3-4 marks	The answer includes some discussion related to each part. The answer includes 5 - 7 of the answer points 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.
L1 1-2 marks	The answer addresses one part in some detail but efficiency may not be quantified. There may be consideration of up to 4 of the answer points below.	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.
0 marks	Little or no discussion of relevant content.	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

- *CA would have to be very fast to ensure no heat transfer.*
- *AB would have to be very slow to ensure constant temperature.*
- *very difficult to arrange a slow 'stroke' and a fast 'stroke' in one engine.*
- *Output speed would vary over a cycle.*
- *Difficulty in arranging for end of expansion and start of compression to occur at one point.*
- *For heating at constant volume, engine would have to stop, or combustion be very fast.*
- *Max poss efficiency is (590 - 295)/590 = 0.5 or 50%.*
- *Actual efficiency of this ideal cycle = 43/251 = 0.17.*
- *Real efficiency will be << these efficiencies and much less than engines currently available.*
- *Power output is very small for a 1 litre engine so* ***not*** *wise to go ahead*

6

[12]

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

Automarked

1

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

Claim B: 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 Claim B:
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 = $0.1 \times 10^{-3} \times 1.00 \times 10^{5}$ = 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** × **10⁵** to **14.8** × **10⁵** Pa*

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

3

[13]

3. (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 × $2 \times 10^5 \times 10 \times 10^{-6} = 18$ *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]

4. (a) ($Q = \Delta U + W$) For adiabatic $Q = 0$ ✓

1

$W = -\Delta U$ W is +ve, so internal- energy / temperature must fall✓
OR negative sign shows internal energy decrease ✓

1

Temperature related to internal energy, so T falls✓

1

(b) **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	All three aspects covered: An appreciation that because the input valve is open for longer, that the air consumption approximately doubled with reference to the relevant sections of fig 2 and fig 3. An understanding that the output power is given by the area within the diagram, with an approximate increase of 25% from fig 2 to fig 3. Furthermore, a discussion of an understanding of the link between power and torque including the assumption that the angular frequency does not change.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
5	Two of the three aspects fully covered, with some detail missing from the third.	
4	One aspect fully covered, with some detail missing from the other two. Or Two aspects fully covered, with little or no relevant information about the third.	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	All three aspects partially covered, with some detail missing from each Or One aspect fully covered, with little or no relevant	

	information about the other two.	
2	Two aspects partially covered, with little or no relevant information about the third.	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	One aspect partially covered, with little or no relevant information about the other two.	
0	Little or no relevant information about any of the three aspects.	The student's presentation, spelling punctuation and grammar seriously obstruct understanding.

The following statements are likely to be present:

Rate of consumption of air

- On fig 2 air enters from A to C, but on figure 3 from A to X
- Air consumption (hence input power) is increased because input valve open for longer
- Air consumption roughly doubled

Output torque and power

- Output power is increased because area of diagram is greater
- Output power increased but not as much as doubled
- Output power roughly increased by 25%
- Average pressure greater, so torque greater
- ω same as before so from $P = T\omega$, output power greater, comparison only valid if speed same as before

Overall efficiency

- efficiency is output power / input power
- Input power roughly doubled but output power increased only by about 25%
- Hence efficiency decreased

6

(c) Work done (per cycle) = area of indicator diagram✓

1 small sq = 0.1 J

1

Appropriate method for finding area eg counting squares✓

641 small squares

1

Correct scaling factor leading to area = 64 J ± 5 J✓

1 large sq = 2.5 J

1

P = 64 × 20 = 1280 W✓

27 large squares

Other methods accepted eg strips

1

(d) Indicated power (is developed by air in cylinder and) does not take into account frictional losses at bearings / between cylinder and piston / in opening valves✓

WTTE

Answer must give some indication of where friction acts.

Friction power alone is not enough.

1

[14]

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

1

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

$T_2 = p_2V_2T_1 / p_1V_1$ ✓

$$= \frac{4.6\times10^5 \times1.5\times10^{-4} \times310}{1.0\times10^5 \times5.0\times10^{-4}}$$

=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

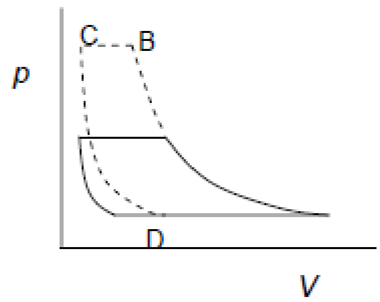
14. expansion of air in clearance volume will have negative effect on area
15. vol of air drawn in per cycle will decrease
16. increase in work per cycle gets progressively smaller as p increases

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]