Mark schemes

Q1.

(a) MAX 4 from:

- Attempts to find area of large loop
- Subtracts area of small loop
- Shows suitable scaling factor
- Uses 4 cycles s^{-1}
- correctly calculates indicated power using their values.

592 W ✓ (cao)

eg counting small squares
157 - 9 squares = 148 squares
scaling factor of $0.10 \times 10^{-3} \times 0.1 \times 10^{5} = 1.0$ J per square
148 J × 1.0 = 148 J
If counting 'large' squares:
(6.5 - 0.5) squares $\times 0.50 \times 10^{-3} \times 0.50 \times 10^{5}$
gives 150 J
Accept approximating to triangles
cycles s^{-1} = 4 (as it is double acting at 2 rev s^{-1})
indicated power = 148 × 4 = 592 W ± 30 W

5

(b) Input power = $6.44 \times 10^{-4} \times 18.0 \times 10^{6} = 11.6 \times 10^{3}$ W ✓

Output power = $T\omega = 39.0 \times 2 \times 2\pi = 490$ W ✓

Correct answers only
Accept 1.2×10^{4} W or 12000W
Condone working not shown provided answers are correct.

2

(c) MAX 2 from:

- Power is developed for only about half of the stroke 1✓
- Maximum pressure is very much lower than in a petrol engine 2✓
- The fuel is not compressed before ignition 3✓
- Pumping loop/negative work is large compared to work output loop 4✓
- The speed of the engine is very low 5✓
- Difficulty in lubricating cylinder so friction likely to be high 6✓
- Calorific value of fuel is low 7✓

Allow for other sensible reasons

*eg efficiency from **part (b)** is only about 4%*

Do not accept simple references to 'low efficiency' or 'less efficient'

For 6✓ Do not accept 'more friction' without a reason

2

(d) Tick in 2nd box ✓

Overall efficiency is the product of mechanical efficiency and thermal efficiency.

1

[10]

Q2.

(a) All three terms stated correctly:

Q: energy transferred/supplied **to** system (by heating) ✓

ΔU: **increase** in internal energy (of system) ✓

W: work done **by** system ✓

2 terms correct for 1 mark

3 terms correct for 2 marks

Allow 'gas' in place of 'system'

For Q:
Accept 'heat energy supplied' but not 'heat supplied'.
Do not allow 'heat' in place of 'energy'
Do not accept 'heat transferred' on its own
Do not accept 'thermal energy' or 'heat energy' on its own.

For ΔU: 'of system' does not have to be seen

2

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

MP2 and MP3: reasons must be given

where

W (is provided by electrical input and) is -ve since W is done on the system ✓

$Q = 0$ because system is insulated ✓

$0 = -W + \Delta U$ and so internal energy of the room increases. ✓

MP2 and MP3: reasons must be given

3

(c) Cold sink / cold reservoir / cold space drawn and labelled with line connecting to engine with downwards arrow ✓

Accept 'low temperature' for 'cold'

Do not allow 'cold/low temperature source'

'Sink' or 'heat sink' on its own is not enough, but give the mark if T_C is written in or near implying cold temperature.

1

(d) Use of maximum theoretical efficiency = $\frac{T_H - T_C}{T_H}$ ✓

efficiency < 100 % as T_C > 0 (in practice)

OR

efficiency can only be 100 % when T_C is 0 K which is impossible ✓

Condone following argument for max 1 mark:

$\eta = (Q_H - Q_C)/Q_H$ OR $= \frac{W}{Q_H}$

so η < 1 (or < 100%) ✓

as there must be some Q_C to cold sink (in a practical case)✓

2

[8]

Q3.

(a) 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

Do not allow 'heat' in place of 'energy'

Do not accept 'heat transferred' on its own

Accept 'heat energy supplied' but not 'heat supplied'.

1

(b) Tick against top line only

-10.8 0 10.8

1

(c) Use of $p_1V_1^{1.4} = p_2V_2^{1.4}$ ✓

'use of' means by substitution or manipulation to make p_2 the subject of the equation eg $p_2 = p_1\left(\frac{V_1}{V_2}\right)^{1.4}$ seen

Accept γ for 1.4.

Giving $p_2 = 2.32 \times 10^6$ (Pa) ✓

$T_2 \left(= \frac{p_2V_2T_1}{p_1V_1}\right) = 710$(K) ✓

$$T_2 = \frac{2.32\times10^6\times(3.19\times10^{-9})\times293}{1.05\times10^5\times2.91\times10^{-8}}$$

ECF for T_2 using their p_2

3

(d) Slow change means internal energy remains (nearly) constant due to energy loss by heat transfer

OR

Slow change means (nearer to) isothermal change ✓

(Therefore)

the work done would be lower because the area under the graph would be lower

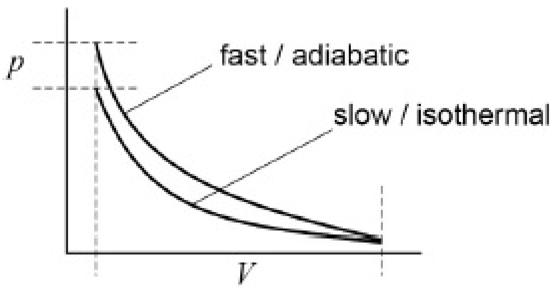
OR

the work done would be lower because the pressures are lower✓

(Therefore, cyclist is not correct)

Allow reverse argument from fast change perspective.

Accept answers where shown in a diagram:



Alternative MP2: smaller (average) p for same ΔV will give less W

Max 2

[7]

Q4.

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
6	All three areas (as outlined alongside) covered with at least two aspects covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A fair attempt to analyse all three areas. If there are several errors or missing parts then 5 marks should be awarded.
4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.
3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.
2	Only one area discussed, or makes a partial attempt at two areas.
1	One of the three areas covered without significant error.
0	No relevant analysis.

The following points are likely to be present.

First two bullets: differences at A and B

1. **Corners rounded** at B on real cycle. Reason: valves take finite time to open and close.
2. Cooling cannot occur at **constant volume** in real cycle. Reason: piston would have to stop/cooling takes finite time.
3. Heating cannot occur at **constant pressure** in real cycle. Reason: heating cannot be (precisely) controlled.
4. Max **pressure is lower** in real engine. Reason: e.g. incomplete combustion

Third bullet: region C

5. Real engine needs **induction and exhaust** strokes/ pumping loop.
6. In theoretical cycle **same air used repeatedly** (so needs no pumping loop).
7. In ideal cycle **air only** is taken through cycle (repeatedly)/gas is ideal.
8. Upper line is exhaust, lower line is induction.

Fourth bullet: why efficiency less

9. Area of loop is smaller for real engine, so less work done per cycle/indicated power.
10. Area of pumping loop has to be subtracted from main loop, reducing work done.
11. Friction between moving surfaces/between piston & cylinder/in bearings has to be overcome.
12. Energy is expended in driving oil and water pumps, opening and closing valves, overcoming fluid viscosity etc.
13. In real cycle expansion & compression are not adiabatic. Reason: heat transfer takes place to cooling medium during these strokes
14. Calorific value of fuel cannot be completely released/ Fuel may not be completely burnt.

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

[6]

Q5.

(a) 0.60 OR 60% ✓

Condone 0.6 (1 sf)

$\eta = \frac{(730-290)}{730} = 0.60$

$\eta = \frac{16.0-6.4}{16.0} = 0.60$

1

(b) Calculates P_{OUT} from engine 1 and calculates Q_C ✓

$\eta_1 = 220 \div 730 = 0.30$

$P_{OUT1} = 0.30 \times 16.0 = 4.8$ kW

$Q_C = 11.2$ kW

Uses Q_C from engine 1 as Q_H for engine 2 and calculates P_{OUT} from engine 2 ✓

$\eta_2 = 220 \div 510 = 0.43$

$P_{OUT2} = 0.43 \times 11.2 = 4.8$ kW

Allow ECF for MP2 from MP1

Compares total output power and overall efficiency of **Figure 1** and **Figure 2** engines and concludes that they are the same so student is not correct ✓

Total $P_{OUT} = 9.6$ *kW*

Overall η *for 2 stages = 9.6÷16 = 0.60*

Do not allow an ecf for MP3

Evidence can be seen on ***Figure 1*** *and* ***Figure 2*** *but answer must make clear comparisons.*

If calculations are correct, but more than 2 sf is used, then answers will be slightly greater than 9.6 kW and greater than 0.60. Do not accept a comment that the student claim is correct as this answer arises from conclusions drawn from poor sf considerations.

3

[4]

Q6.

(a) (A change in which there is) no energy/heat transfer to or from the gas/system ✓

WTTE

Condone: no heat enters or leaves the system.

1

(b) $p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$

$1.0 \times 10^5 \times V_1^{1.4} = 67 \times 10^5 \times V_2^{1.4}$ ✓

$\frac{V_1}{V_2} = 20(.2)$ ✓

First mark for correct substitution of data into

$p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$ *or* $\frac{V_1}{V_2} = \left(\frac{p_2}{p_1}\right)^{1/1.4}$

Condone POT error in MP1

Accept answer as ratio (20:1)

(calculator value = 20.15297)

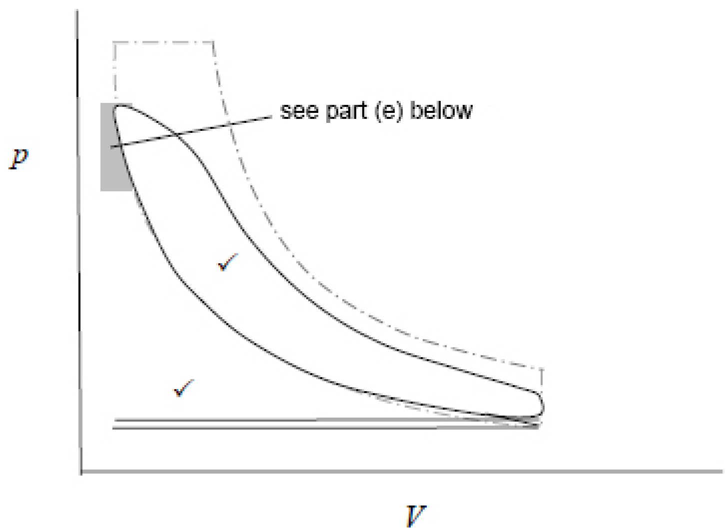
2

(c) Diesel requires a high compression ratio to give a temperature high enough to ignite fuel / for fuel to self-ignite ✓

Petrol vapour–air mixture is ignited by spark at lower pressures/temperatures ✓

2

(d)



Look for:

- *complete loop contained within/smaller than ideal loop with no sharp corners. Compression stroke may be below ideal cycle line.* ✓
- *Two close parallel lines or one single line or one narrow loop parallel to V axis at or near atmospheric pressure* ✓

2 marks for both above points provided left-hand and right-hand edges of loop and induction/exhaust loop/lines are fairly close to correct V_1 and V_2.

2

(e) **X** placed on/near curve anywhere in shaded area shown above

Near (but not at) top end of compression stroke on indicator diagram

Do not allow X on ideal cycle

1

(f) Any 2 from: ✓✓

- *Curved corners*: because valves take finite time to open and close
- *No constant volume process*: because engine would have to stop/piston constantly moving
- *Compression and expansion not adiabatic curves*: because energy is lost by heat transfer
- *Pumping loop/the cycle is open* because engine needs to draw in air and expel exhaust
- *Heating not at constant pressure*: because fuel injection and combustion cannot be exactly controlled
- *area of diagram is less* because energy is lost by heat transfer/incomplete combustion/CV of fuel not fully released
- *pressure not as high* because incomplete combustion/CV of fuel not fully released

The explanation of the difference must match the stated difference.

Do not accept answers which refer to smaller area as a result of friction in engine.

2

[10]

Q7.

(a) $Q_C = Q_H - W = 65 - 28 = 37\ W$ ✓1

COPref = 37/28 = 1.32 ✓2

COPref for ideal refrigerator = 278/(308 – 278) = 9.3 ✓3

If temperatures not changed to K, do not award marks ✓3 and ✓4

Condone consistent use of Celsius in the denominator.

Actual COP is very low compared to ideal so claim is valid ✓4

No ECF for ✓4 from incorrect values of COP, unless from arithmetic error.

4

(b) • One factor from ✓1

- Thermoelectric cooler is small/convenient/of simple construction/(highly) portable
- can run off batteries/solar panel
- has no moving parts
- requires low maintenance
- no risk of leaking fluids
- temperature is about 5 °C, not cooler
- low energy/power consumption (28W)

✓1 for advantage from bullet point list

For ✓1 accept application, eg use in hot countries, by campers, climbers, walkers etc.

For ✓2

- convenience outweighs poor COP
- any COP >1 means cooling power > power supplied
- waste of electrical energy from having low COP is acceptable

✓2 mark for relating answer to COP

2

[6]