A-Level Physics

Engine Cycles

Mark Scheme

Time available: 44 minutes
Marks available: 34 marks

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.

6

(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

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2. 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.
2nd bullet
11. thermal efficiency = indicated power/input power

12. mechanical efficiency = brake power/indicated power

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

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3. (a) T_H = 273 + 820 = 1093 (K), T_C = 273 + 77 = 350 (K) **(1)**

efficiency = $\frac{T_H - T_C}{T_H} = \frac{1093 - 350}{1093}$ = 0.68 or 68% **(1)**

2

(b) rotational speed of output shaft = $\frac{1800}{2 \times 60}$ = 15 rev s^{-1} **(1)**

(work output each cycle = 380 J, 2 rev º 1 cycle in a 4 stroke engine)

indicated power = 15 × 190 = 5.7 kW **(1)**

2

(c) power lost (= indicated power –actual power) = 5.7 – 4.7 = 1.0 kW **(1)**
(allow C.E. for incorrect value from (b))

1

(d) energy supplied per sec (= fuel flow rate x calorific value)

$= \frac{2.1 \times 10^{-2}}{60} \times 45 \times 10^6$ = 16 kW (15.8 kW) **(1)**

1

(e) efficiency = $\frac{\text{net power output}}{\text{power input}} = \frac{4.7}{16}$ = 0.29 or 29 %

$\frac{4.7}{15.8} = 0.30$ or 30%

(allow C.E. for value from (d))

1

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4. (a) (i) work done (per kg) = area enclosed (by loop) **(1)**
suitable method of finding area (e.g. counting squares) **(1)**
correct scaling factor **(1)**
(to give answer ≈ 500 kJ)

(ii) P (= work done per kg x fuel flow rate)
= 500 (kJ) × 9.9 (kgs^1) = 5000kW **(1)**
(4950kW)

(iii) (output power = indicated power – friction power)
P_{out} = 4950 – 430 = 45(20) kW **(1)**
(use of P = 5000 gives P_{out} = 45(70)kW)
(allow C.E. for values of P in (ii))

5

(b) (i) P_{in} (= fuel flow rate × calorific value)
= 0.30 × 44 × 10^6 = 13(.2) × 10^6W **(1)**

efficiency = $\frac{4520 \times 10^3}{13.2 \times 10^6}$ = 34% **(1)**

(allow C.E. for value of P_{out} in (a) (iii) and P_{in} in (b) (i))

2

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5. (a) $P = T\omega$ **(1)**
P_{out} = 5.5kW **(1)**

2

(b) 6.2 – 5.5 = 0.7 kW **(1)**

1

(c) input power, P_{in} = fuel flow rate × calorific value **(1)**

$P_{in} = \frac{2.4 \times 10^{-2}}{60} \times 47 \times 10^6$ = 19kW **(1)**

2

(d) $\eta = \frac{P_{out}}{P_{in}} = \frac{5.5}{19}$ = 0.29 [or 29%] **(1)**

1

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