A Level AQA Physics

26 Thermodynamics and engines – answers

OXFORD Revise

Question	Answers	Extra information	Mark	AO	Spec reference
01.1	$pV = nRT$ $n = \frac{pV}{RT}$ $= \frac{5.0 \times 10^5\,\text{Pa} \times 2 \times 10^{-4}\,\text{m}^3}{8.31\,\text{J mol}^{-1}\text{K}^{-1} \times (100 + 273)}$ $= 0.032\,\text{mol}$	Substitution Answer	1 1	2	3.11.2.2
01.2	$pV = nRT$ $V = \frac{nRT}{p}$ $= \frac{0.032 \times 8.31 \times 273}{1.0 \times 10^5\,\text{Pa}}$ $= 7.3 \times 10^{-4}\,\text{m}^3$	Substitution Answer	1 1	2	3.11.2.2
01.3	**A–B**: The gas temperature and pressure decrease as the volume stays the same **C–D**: The gas temperature and pressure increase as the volume stays the same		1 1	3	3.11.2.2
01.4	**B–C**: Work done by the gas $= p\Delta V = 1.0 \times 10^5\,\text{Pa} \times (7.3 - 2) \times 10^{-4}\,\text{m}^3 = +53\,\text{J}$ **D–A**: Work done on the gas $= p\Delta V = 5.0 \times 10^5\,\text{Pa} \times (2 - 7.3) \times 10^{-4}\,\text{m}^3 = -265\,\text{J}$ Magnitude of work done D–A is 5 times work done B–C, and have opposite signs	1 mark answer, 1 mark sign 1 mark answer, 1 mark sign Comment	1 1 1	2	3.11.2.3
02.1	If T is constant, $p_A V_A = p_C V_C$ $p_C = \frac{p_A V_A}{V_C}$ $= \frac{3 \times 10^6\,\text{Pa} \times 2 \times 10^{-3}\,\text{m}^3}{4 \times 10^{-3}\,\text{m}^3}$ $= 1.5 \times 10^6\,\text{Pa}$	Explicit statement that T is constant Answer	1 1		3.11.2.2

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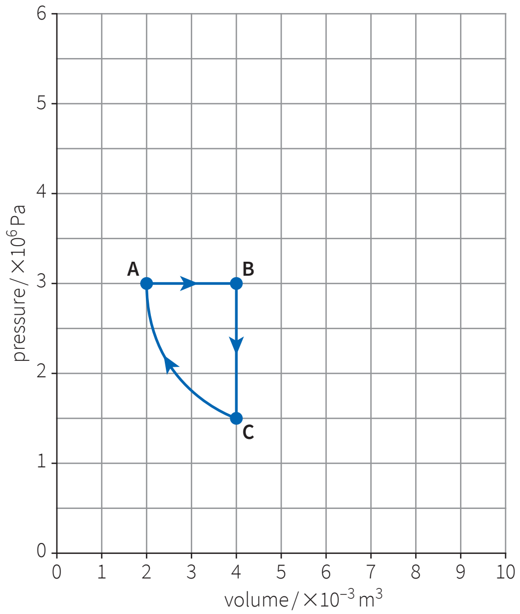
02.2		Point A correct and labelled at (2,3) Point C correct and labelled at (4, 1.5) Curved line from A to C Arrows on lines	1 1 1 1		3.11.2.3
02.3	A heat pump Correct reason – one from: Work done by the system is positive/done at a higher temperature Energy is absorbed at a higher temperature and exhausted at a lower temperature		1 1	3	3.11.2.2
02.4	Isothermal changes can involve the transfer of heat into a system to compensate for the work done by a gas, or the transfer out of a gas to compensate for the work done on it		2	3	3.11.2.2

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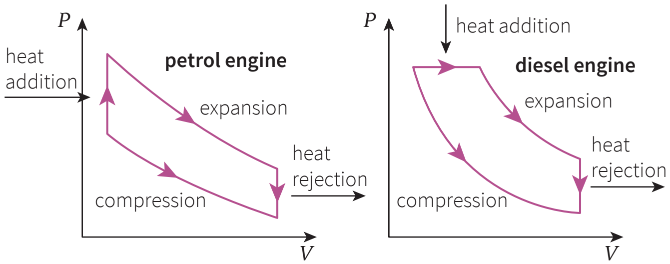
Question	Answers	Extra information	Mark	AO	Spec reference
02.5	State A: Temperature = $T_A = \frac{p_A V_A}{nR} = \frac{3\times10^6\,\text{Pa}\times2\times10^{-3}\,\text{m}^3}{3\times8.31} = 241\,\text{K}\ (240.67)$ State B: Temperature = $T_B = \frac{p_A V_B}{nR} = \frac{3\times10^6\,\text{Pa}\times4\times10^{-3}\,\text{m}^3}{3\times8.31} = 481\,\text{K}\ (481.34)$ Theoretical efficiency = $\frac{T_H - T_C}{T_H} = \frac{481-241}{481} = 50\%$	Calculations (both) Answer	1 1	3	3.11.2.5
03.1	In an adiabatic change, no heat passes in or out of the gas $Q = \Delta U + W$ (first law), and here $Q = 0$ so $\Delta U = -W$ The work done on the gas increases its temperature	 stated	1 1 1	1	3.11.2.1 3.11.2.2
03.2	$p_1 \times V_1^{\gamma} = p_2 \times V_2^{\gamma}$ $p_2 = \frac{p_1 \times V_1^{\gamma}}{V_2^{\gamma}} = \frac{1.00\times10^5\times(240\times10^{-6})^{1.4}}{(50.0\times10^{-6})^{1.4}}$ $= 8.99\times10^5\,\text{Pa}$	Substitution Answer	1 1	2	3.11.2.2
03.3	 In a petrol engine, the fuel-air mixture is ignited and the pressure increases at constant volume, shown by the vertical section of the graph where heat is added In a diesel engine, fuel is injected and the volume increases at constant pressure, shown by the horizontal section of the graph	Correct shape for both graphs Correct labels for both graphs Explanation linked to graph Explanation linked to graph	1 1 1 1	1	3.11.2.4

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<table>
<tr><th>Question</th><th>Answers</th><th>Extra information</th><th>Mark</th><th>AO</th><th>Spec reference</th></tr>
<tr>
<td>03.4</td>
<td>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
<table>
<tr><th>Mark</th><th>Criteria</th><th>QoWC</th></tr>
<tr><td>6</td><td><u>A thorough and well-communicated</u> discussion using all of the information given and answering the questions in both bullet points</td><td rowspan="2">The student presents relevant information coherently, employing structure, style, and SP&G to render meaning clear

The text is legible</td></tr>
<tr><td>5</td><td><u>An explanation that includes</u> discussion using most of the information given and answering the questions in both bullet points but may contain minor errors or omissions</td></tr>
<tr><td>4</td><td><u>The response includes a well-presented</u> discussion using some of the information given and answering the questions in both bullet points but may contain major errors or omissions</td><td rowspan="2">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</td></tr>
<tr><td>3</td><td><u>The response includes a</u> discussion of one comment from each bullet</td></tr>
<tr><td>2</td><td><u>The response</u> makes comments about one bullet point using some information</td><td>The student presents some relevant information in a simple form</td></tr>
</table>
</td>
<td>The following statements are likely to be present:
Bullet point 1 in question
(Comparison of frictional losses)
1. Frictional power = indicated power – brake power
Indicated power = work done per cycle × no. of cycles sec^{-1} × no. of cylinders
Indicated power of A:
$430 \times \frac{4250}{60} \times 4 = 121.8$ kW
Indicated power of B:
$307 \times \frac{5360}{60} \times 4 = 109.7$ kW
Frictional power A:
121.8 kW – 35 kW = 86.8 kW
Frictional power B:
109.7 kW – 27 kW = 82.7 kW
Frictional losses for Engine A are greater than those for Engine B
The statement is incorrect
Bullet point 2 in question
(Comparison of overall efficiency)
7. Overall efficiency = $\frac{\text{brake power}}{\text{input power}}$
A: Input power = $38 \times 10^{6} \times 2.8 \times 10^{-3} = 106.4$ kW
B: Input power = $42 \times 10^{6} \times 2.6 \times 10^{-3} = 109.2$ kW
Overall efficiency A:
$35 \times \frac{100}{106.4} = 33\ (32.9)\%$</td>
<td>6</td>
<td>3</td>
<td>3.11.2.4</td>
</tr>
</table>

OXFORD Revise

Question	Answers	Extra information	Mark	AO	Spec reference
	1 — Makes relevant comment — The text is usually legible. SP&G allow meaning to be derived although errors are sometimes obstructive 0 — No relevant coverage of the likely statements — The student's presentation, SP&G seriously obstruct understanding	Overall efficiency B: $27 \times \frac{100}{109.2} = 25\ (24.7)\%$ Ratio of efficiencies: $\frac{33}{25} = 1.32$ Statement is incorrect			
04.1	$P = T \times \omega$ $\omega = \frac{P}{T} = \frac{74 \times 10^6}{6.5 \times 10^6} = 11(.4)\ \text{rad s}^{-1}$ $= \frac{11(.4)\ \text{rad}}{2\pi} \times 60 = 108.7\ \text{rpm} = 110\ \text{rpm}$	Substitution Answer	1 1	2	3.11.2.4
04.2	Input power = calorific value of fuel × fuel flow rate Container ship: Input power $= 38 \times 10^6 \times \frac{3.43}{3600} = 36(.2) \times 10^3\ \text{W}$ Diesel car: Input power $= 46 \times 10^6 \times \frac{0.62}{3600} = 7900(7912)\ \text{W}$ Ratio: 4.6 (4.57)	Substitution (both) Answer (both) Comparison	1 1	2	3.11.2.4
04.3	Overall efficiency $= \frac{\text{brake power}}{\text{input power}}$ Brake power = overall efficiency × input power $= 0.35 \times 7912 = 2800\ (2769)\ \text{W}$	Substitution Answer	1 1	2	3.11.2.4

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OXFORD Revise

Question	Answers	Extra information	Mark	AO	Spec reference
04.4	$\frac{P_{cs}}{P_D} = \frac{T_{cs}}{T_D}\frac{\omega_{cs}}{\omega_D}$ $\frac{T_{cs}}{T_D} = \frac{T_{cs}}{P_D} = \frac{74 \times 10^6}{2769} = 26 \times 10^3$ The mass of the container ship is much larger than that of the diesel car, so a larger torque/force will be needed to produce an acceleration The rotational speed of the crankshaft in the car is probably larger than that in the container ship, so the ratio is smaller		1 1 1 1	3	3.11.2.4
05.1	$T_1 = 273 + 24 = 297$ K, $T_2 = 273 - 3 = 270$ K $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{270}{297} = 0.091$ Efficiency = 50% of 0.091 = 0.045	Calculation of temperatures Answer	1 1	2	3.11.2.6
05.2	$COP_{ref} = \frac{T_C}{T_H - T_c} = \frac{270}{297 - 270} = 10$ $COP_{ref} = \frac{Q_H}{W} = 10$ Q = 10% of work done by motor on refrigerator per second $= 10 \times 1.2\,kW = 12\,kJ\,s^{-1}$	Calculation Calculation Energy per second	1 1 1	2	3.11.2.6
05.3	The air inside the refrigerator is being cooled **D–A** The motor is doing work on the refrigerant **A–B** The refrigerant is condensing **B–C**		1 1 1	2	3.11.2.3
05.4	Suitable reason, e.g., Energy is transferred due to the flow of the refrigerant		1	1	3.11.2.6

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Question	Answers	Extra information	Mark	AO	Spec reference
06.1	$\text{COP}_{\text{hp}} = \frac{T_H}{T_H - T_C}$ $= \frac{293}{293 - 283} = 29.3$ $\text{COP}_{\text{ref}} = \frac{T_C}{T_H - T_C}$ $= \frac{297}{304 - 297} = 42.4$	Substitutions Answers	1 1	2	3.11.2.6
06.2	The device is working between different temperatures in each mode		1	3	3.11.2.6
06.3	energy $= mcDq$ power $= \frac{\text{mass}}{t} \times c \times \Delta q$ $\frac{\text{mass}}{t} = \frac{\text{power}}{c \times \Delta\theta}$ $= \frac{230 \times 10^3}{4200 \times (60 - 10)}$ $= 1.095\ldots \text{ kg s}^{-1}$ density $= \frac{\text{mass}}{\text{volume}}$ $\frac{\text{volume}}{t} = \frac{\frac{\text{mass}}{t}}{\text{density}}$ $\frac{1.095.. \text{ kg s}^{-1}}{1000} = 1.1 \times 10^{-3} \text{ m}^3 \text{ s}^{-1}$	Manipulation of SHC Substitution Answer in kg s^{-1} Answer in $\text{m}^3 \text{ s}^{-1}$	1 1 1 1	3	3.6.2.1
06.4	A thermistor is connected in series with a resistor and a power supply with a voltmeter/output voltage from across the resistor or thermistor As the temperature increases, the resistance of the thermistor decreases The output can be used to trigger a circuit that will cut off the heater	• potential divider description • effect of temp on output p.d. • connection to power supply of heater.	1 1 1	3	3.5.1.3

Question	Answers	Extra information	Mark	AO	Spec reference
07.1	Using the conservation of energy: Either: $\frac{1}{2}k\Delta L^2 = mgh$ $h = \frac{k\Delta L^2}{2mgh}$ Column C heading = compression^2 x-axis: ΔL^2 y-axis: h Gradient = $\frac{k}{2mg}$; k = gradient $\times$ $2mg$ or $\frac{1}{2}k\Delta L^2 = mgh$ $\Delta L = \sqrt{\frac{2mgh}{k}}$ Column C heading = $\sqrt{h}$ x-axis: $\sqrt{h}$ y-axis: ΔL Gradient = $\sqrt{\frac{2mg}{k}}$ $k = \frac{2mg}{\text{gradient}^2}$	Explicit or implied Equation of the form $y = mx$ (explicit or implied) Column heading clearly stated x and y labels (both) How to use gradient	1 1 1 1 1	3	3.4.1.8 3.4.2.1
07.2	$\frac{1}{2}k\Delta L^2 = \frac{1}{2}mv^2$ max $v_{\text{max}} = \Delta L\sqrt{\frac{k}{m}}$ Maximum possible velocity for maximum value of ΔL = 2.0 cm = 0.02 m $v_{\text{max}} = 0.02\sqrt{\frac{80}{0.05}} = 0.8\,\text{m s}^{-1}$ The mass is moving fastest at the point when the spring has reached its original length/diagram showing compressed spring and an uncompressed length	Rearranging k.e. = e.p.e Use of data from table Answer	1 1 1 1	3	3.4.1.8 3.4.2.1

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Question	Answers	Extra information	Mark	AO	Spec reference
07.3	$k = m\left(\frac{v_{max}}{\Delta L}\right)^2 = 45 \times \left(\frac{0.8}{0.08}\right)^2 = 4500\ \text{N m}^{-1}$		1	2	3.4.1.8 3.4.2.1
07.4	$Q = \Delta U + W = \Delta U + p\Delta V = 0$/adiabatic change The gas will heat up when compressed due to work done, which will heat the bike cylinder/air Less energy is available for the air to do work on the piston in expansion, so no the piston would not return to its original length		1 1 1	3	3.11.2.2
08.1	$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$ $\left(\frac{V_1}{V_2}\right)^{\gamma-1} = \frac{T_2}{T_1}$ $\left(\frac{V_1}{V_2}\right) = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}}$ $= \left(\frac{343}{293}\right)^{\frac{1}{1.4-1}}$ $= 1.48 \approx 1.5$	Substitution Answer	1 1	2	3.11.2.2
08.2	Any two from: • There is friction between the piston and the cylinder • In an ideal adiabatic change, there is no energy transfer in or out of the system, but in a real system the parts of the engine get hot • The temperature of the gas coming in is higher, and the gas is heated to a very high temperature to ensure complete combustion of the fuel		2	3	3.11.2.4
08.3	$E = \frac{V}{d}, V = E \times d = 10 \times 10^5 \times 0.8 \times 10^{-3}$ $= 800\ \text{V}$ This is low compared to the pd that is produced because the gas that is conducting is an fuel-air mixture and not just air/fuel molecules are more massive and harder to accelerate/ionise	Substitution Answer Comment	1 1 1	3	3.7.3.2

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08.4	The pd from the battery is dc and produces a constant current through a primary coil in a transformer, which produces a constant magnetic field/flux A high secondary pd in a transformer needs a large rate of change of flux Which can be produced when the current is turned on or off	Reference to constant current/ magnetic flux Rate of change of flux and pd Way to produce it	1 1 1	3	3.7.5.6

Skills box answers

Question	Answer
1	$p_2 = \frac{p_1 V_1^{\gamma}}{V_2^{\gamma}}$ $p_2 = \frac{150 \times 300^{1.4}}{600^{1.4}} = 56.8\,\text{kPa}$ $T_1 = (7 + 273)\,\text{K} = 280\,\text{K}$ $T_2 = \frac{p_2 V_2 T_1}{p_1 V_1}$ $T_2 = \frac{56.8 \times 600 \times 280}{150 \times 300} = 212\,\text{K}$
2	$p_1 V_1 = p_2 V_2$ so $p_2 = \frac{150 \times 0.06}{0.04} = 225\,\text{kPa}$
3	$p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$ $p_2 = \frac{200 \times 50^{1.67}}{5.0^{1.67}} = 9355\,\text{kPa}$