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QUESTION WORKBOOK

Heat engines and heat pumps

Engineering physics · Year 13

AQA 3.11.2.4, 3.11.2.5, 3.11.2.6

17 questions · 51 marks

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SECTION A · Warm-up

A1 State the energy transfers that take place in one cycle of a heat engine, and write an equation for the work done per cycle. [2]

A2 Explain why no heat engine can be 100% efficient, even if all friction could be removed. [2]

A3 Write the equation for the maximum theoretical efficiency of a heat engine, and state the temperature scale that must be used in it. [2]

A4 Define the coefficient of performance of a refrigerator and of a heat pump. [2]

A5 State how the net work done per cycle by an engine is found from its loop on a p-V diagram, and state the direction in which an engine traverses the loop. [2]

A6 State how the input power of an engine is calculated from its fuel. [1]

SECTION B · Standard

B1 In each cycle an engine absorbs 1500 J of heat from its source and rejects 1050 J to its sink. Calculate the work done per cycle and the efficiency of the engine. [3]

B2 An engine takes in heat from a source at 520 °C and rejects heat to a sink at 30 °C. Calculate its maximum theoretical efficiency. [3]

B3 A four-cylinder engine runs at 30 cycles per second and the p-V loop for each cylinder encloses an area of 260 J. Calculate the indicated power of the engine. [3]

B4 The crankshaft of an engine delivers a torque of 145 N m at 3600 revolutions per minute. Calculate the brake power. [3]

B5 An engine burns fuel of calorific value 43 MJ kg^{-1} at a rate of 3.5×10^{-3} kg s^{-1} and delivers a brake power of 52 kW. Calculate the input power and the overall efficiency. [3]

B6 In each cycle a refrigerator extracts 250 J of heat from its cold compartment using 100 J of work. Calculate its coefficient of performance and the heat rejected into the kitchen per cycle. [3]

B7 A heat pump with a coefficient of performance of 3.6 delivers heat to a house at 7.2 kW. Calculate the electrical power it consumes and the rate at which it extracts heat from the outside air. [3]

SECTION C · Stretch

C1 A six-cylinder engine burns fuel of calorific value 45 MJ kg^{-1} at 4.0×10^{-3} kg s^{-1}. Each cylinder's p-V loop encloses 480 J and the engine completes 25 cycles per second. The output shaft turns at 2900 revolutions per minute and delivers a torque of 210 N m. Calculate the input power, the indicated power, the brake power, the friction power and the overall efficiency. [6]

C2 In each cycle an engine absorbs 2400 J of heat from a source at 900 K and rejects 1560 J to a sink at 320 K, completing 20 cycles per second. Calculate the work per cycle, the output power, the actual efficiency and the maximum theoretical efficiency, and comment on the comparison. [5]

C3 A householder can heat a room either with a 3.0 kW electric heater or with a heat pump of coefficient of performance 4.0 drawing the same 3.0 kW of electrical power. Calculate the heating power delivered by each, and explain why the heat pump does not break conservation of energy. [4]

C4 A refrigerator has a coefficient of performance of 2.4 and its compressor draws 90 W of electrical power. Calculate the rate at which heat is removed from the cold compartment and the rate at which heat is delivered to the kitchen, and explain why running the refrigerator with its door left open warms the kitchen rather than cooling it. [4]