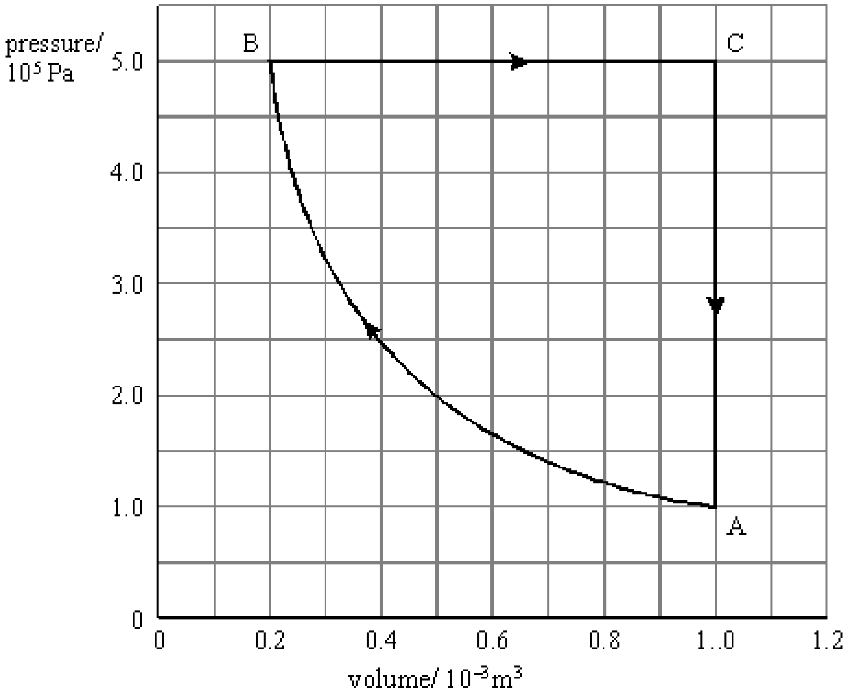
Q1. The *p V* diagram shows a cycle in which a fixed mass of an ideal gas is taken through the following processes: A → B isothermal compression, B → C expansion at constant pressure, C → A reduction in pressure at constant volume.



(a) Show that the compression in process A → B is isothermal.

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(2)

(b) In which **two** of the three processes must heat be removed from the gas?

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(1)

(c) Calculate the work done by the gas during process B → C.

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(2)

(d) The cycle shown in the diagram involves 6.9×10^{-2} mol of gas.

(i) At which point in the cycle is the temperature of the gas greatest?

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(ii) Calculate the temperature of the gas at this point.

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(4)
(Total 9 marks)

Q2. Test-bed measurements made on a single-cylinder 4-stroke petrol engine produced the following data:

mean temperature of gases in cylinder during combustion stroke	820 °C
mean temperature of exhaust gases	77 °C
area enclosed by indicator diagram loop	380 J
rotational speed of output shaft	1800 rev min^{-1}
power developed by engine at output shaft	4.7 kW
calorific value of fuel	45 MJ kg^{-1}
flow rate of fuel	2.1×10^{-2} kg min^{-1}

(a) Estimate the maximum theoretical efficiency of this engine.

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(2)

(b) Calculate the indicated power of the engine.

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(2)

(c) Calculate the power dissipated in overcoming the frictional losses in the engine.

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(1)

(d) Calculate the rate at which energy is supplied to the engine.

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(1)

(e) Calculate the overall efficiency of the engine.

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(1)
(Total 7 marks)

Q3. A single cylinder steam engine has an idealised indicator diagram as shown in **Figure 1**.
Between **A** and **B** the cylinder is connected directly to a source of high pressure steam.
Between **C** and **D** the cylinder is connected to the atmosphere.

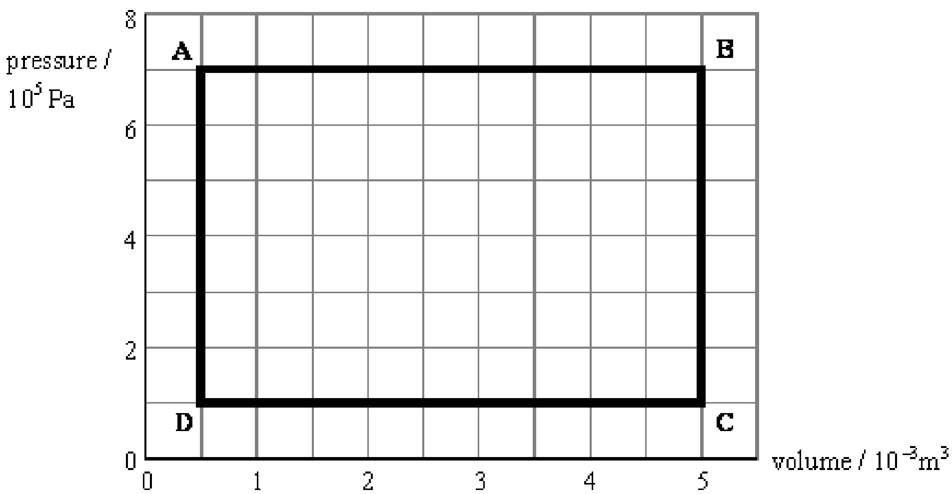

Figure 1

(a) Calculate the indicated power output of the engine when it is working at a rate such that one cycle takes 0.20 s.

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(2)

(b) In a modified version of the engine, the steam input is cut off when the piston is part way along its stroke. The new indicator diagram is shown in **Figure 2**.

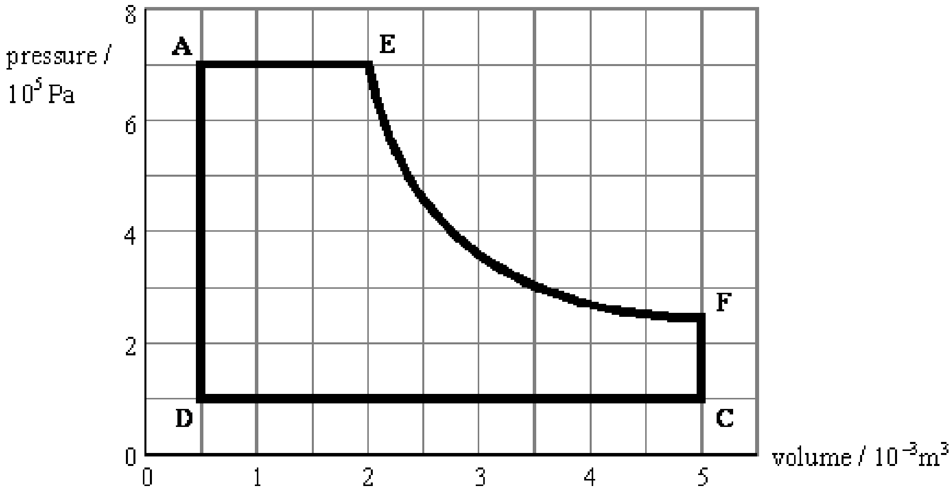

Figure 2

Use **Figures 1** and **2** to compare the performance of an engine based on the modified cycle with that of the original engine when both engines are making the same number of cycles per second. In your comparison you should consider the steam supplied to the engines, their power outputs and their efficiencies.

You may be awarded marks for the quality of written communication in your answer.

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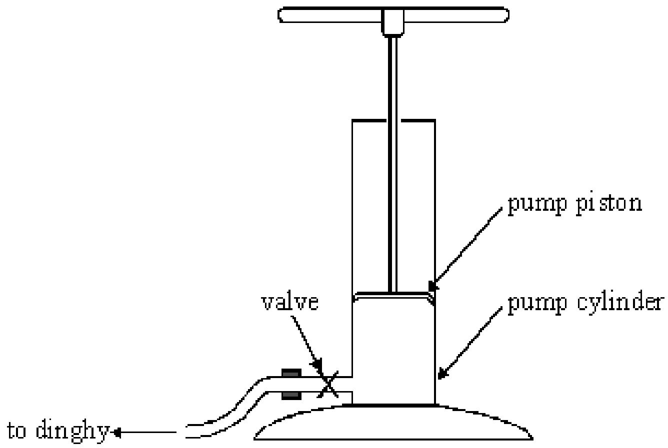
(4)
(Total 6 marks)

Q4. The diagram below shows a pump used to inflate a rubber dinghy. When the piston is pushed down, the pressure of air in the cylinder increases until it reaches the pressure of the air in the dinghy. At this pressure the valve opens and air flows at almost constant pressure into the dinghy.



(a) The pump is operated quickly so the compression of the air in the cylinder before the valve opens can be considered adiabatic.

At the start of a pump stroke, the pump cylinder contains 4.25×10^{-4} m^3 of air at a pressure of 1.01×10^5 Pa and a temperature of 23 °C. The pressure of air in the dinghy is 1.70×10^5 Pa.

Show that, when the valve is about to open, the volume of air in the pump is 2.93×10^{-4} m^3.

γ for air = 1.4

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(2)

(b) Calculate the temperature of the air in the pump when the valve is about to open.

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(3)

(c) State, explaining your reasons, whether the volume of air in the cylinder at the point when the valve opens would be less than, equal to or greater than 2.93×10^{-4} m^3 if the compression of the air had been carried out very slowly. You may find it helpful to sketch a *pV* diagram of the compression.

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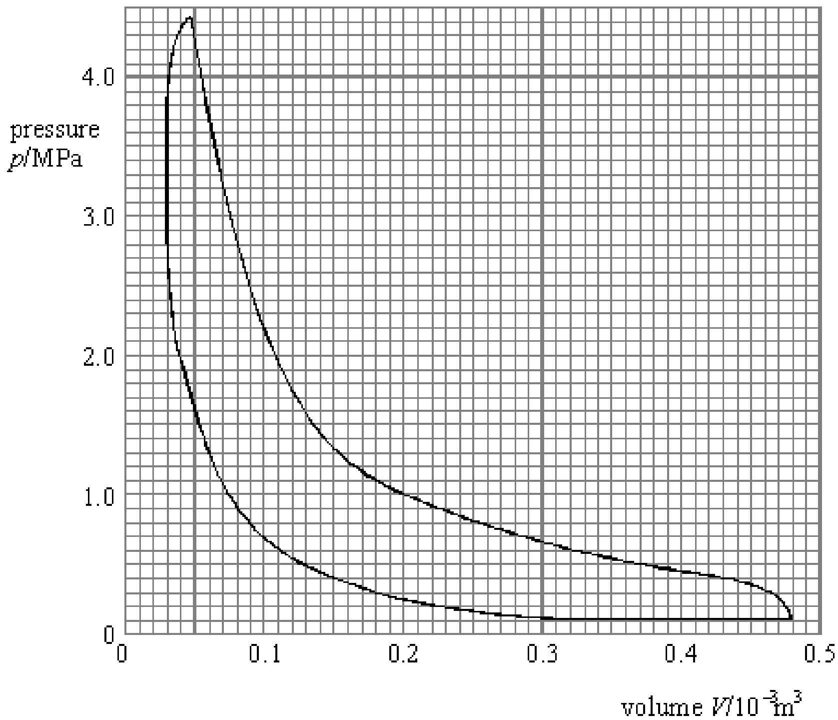
(3)
(Total 8 marks)

Q5. The indicator diagram below is for a single-cylinder, four-stroke internal combustion engine. The measurements were made during a test in which a constant load was applied to the engine output shaft, which was rotating at a steady 2400 rev min^{-1}. During the test, fuel with a calorific value of 42.9 MJ kg^{-1} was supplied at a rate of 4.45×10^{-4} kg s^{-1}.



(a) Calculate the input power to the engine.

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(1)

(b) (i) Show that the indicated work output per cycle is about 350 J.

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(ii) Calculate the indicated output power of the engine.

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(5)

(c) The actual output power of the engine was measured as 6.3 kW.

(i) Explain why this value is not the same as the indicated output power of the engine.

You may be awarded marks for the quality of written communication in your answer.

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(ii) Calculate the overall efficiency of the engine under the conditions of the test.

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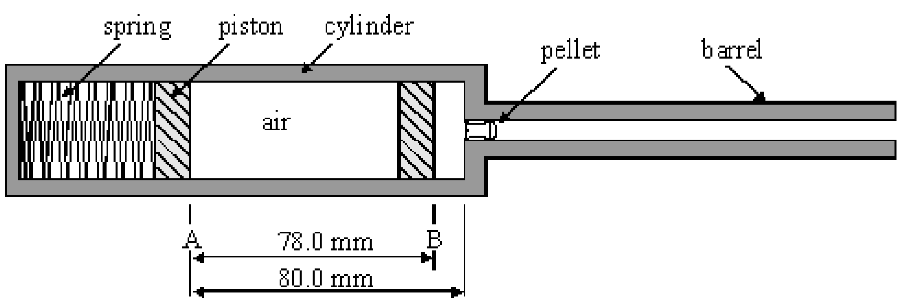
(3)
(Total 9 marks)

Q6. The diagram shows the mechanism of an air gun. The energy needed to propel the pellet is stored in a spring which is held in compression by a trigger. Pulling the trigger releases the spring, which pushes the piston rapidly along the cylinder from A to B. This compresses the air behind the pellet, exerting a force on it and causing it to accelerate along the barrel.



When the piston is at A, the air in the cylinder is at a pressure of 103 kPa and a temperature of 291 K. After the spring is released, the pellet remains in place until the piston reaches B.

(a) (i) The internal cross-sectional area of the cylinder is 1.77×10^{-4} m^2. Calculate the quantity of air, in moles, contained in the cylinder.

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(ii) Estimate the pressure of the air in the cylinder when the piston has just reached B.

γ for air = 1.4

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(iii) Estimate the temperature of the air in the cylinder when the piston has just reached B.

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(Total 6 marks)

Q7. (a) The first law of thermodynamics can be represented by $\Delta Q = \Delta U + \Delta W$.

State and explain, with reference to the equation, **two** ways in which the internal energy of a gas can be decreased.

You may be awarded marks for the quality of written communication in your answer.

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(3)

(b) A volume of 20 m^3 of exhaust gas from a diesel engine leaves the exhaust pipe at a pressure of 1.0×10^5 Pa. The gas is cooled by the surrounding atmosphere, which is also at a pressure of 1.0×10^5 Pa, and, as a result, the exhaust gas contracts to half its volume.

(i) Calculate the work done by the atmosphere on the gas during this contraction.

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(ii) 4.9 MJ of heat is transferred to the atmosphere during cooling. Using the first law of thermodynamics, calculate the change in internal energy of the gas.

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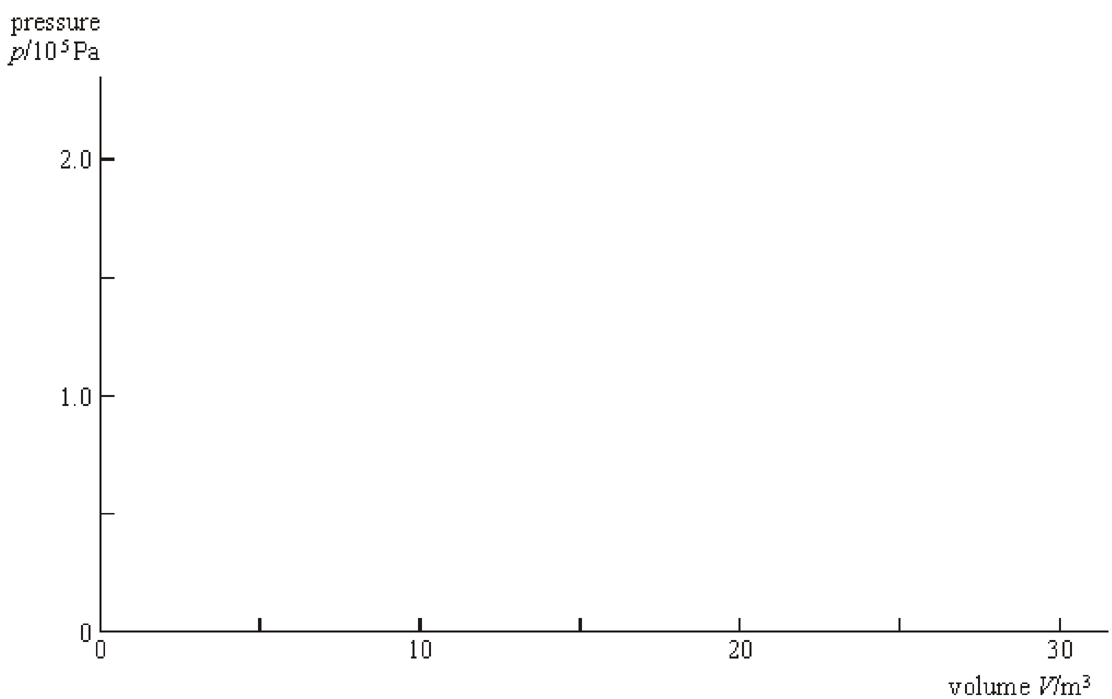
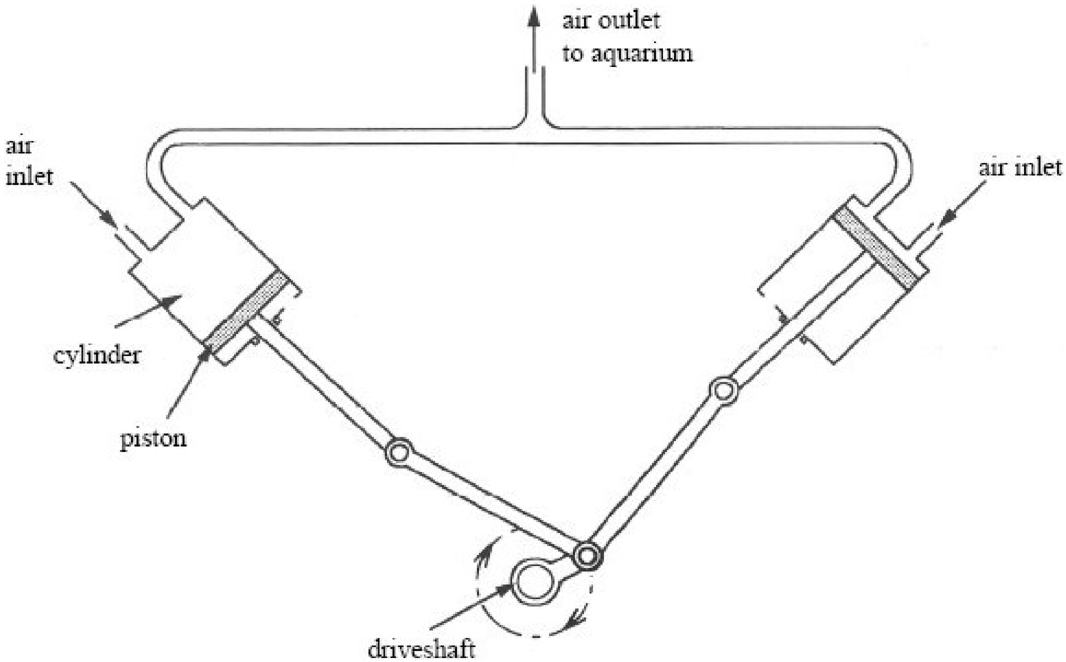
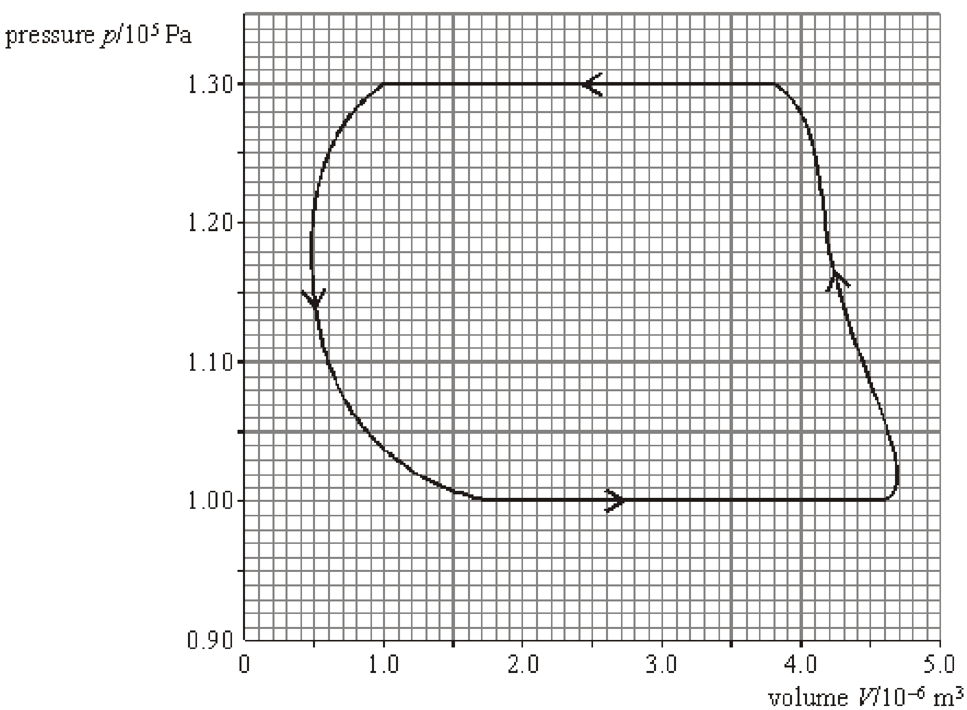
(iii) Use the axes below to represent this process as a *p*-*V* diagram, showing the direction of the process.



(5)
(Total 8 marks)

Q8. A small, two-cylinder pump shown in the diagram is used for aerating water in an aquarium. The two cylinders are identical and each has a piston driven by a rotating driveshaft so that both cylinders pump air to the aquarium during one rotation of the driveshaft. The inlet and outlet valves controlling the airflow are not shown.





Air at a pressure of 1.00×10^5 Pa is drawn into the cylinders, is compressed and exhausted to an underwater outlet in the aquarium, where it is released as a stream of bubbles. The graph shows the *p*-*V* diagram for one cycle of one cylinder.

(a) Use the graph to determine the outlet pressure of the air from the pump.

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(1)

(b) Estimate

(i) the net work done on the air in one cylinder during one revolution of the driveshaft,

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(ii) the power input to the pump if the driveshaft rotates at 360 rev min^{-1}.

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(6)

(c) Give **one** reason why the motor driving the pump would need to have a greater power than your answer to part (b)(ii).

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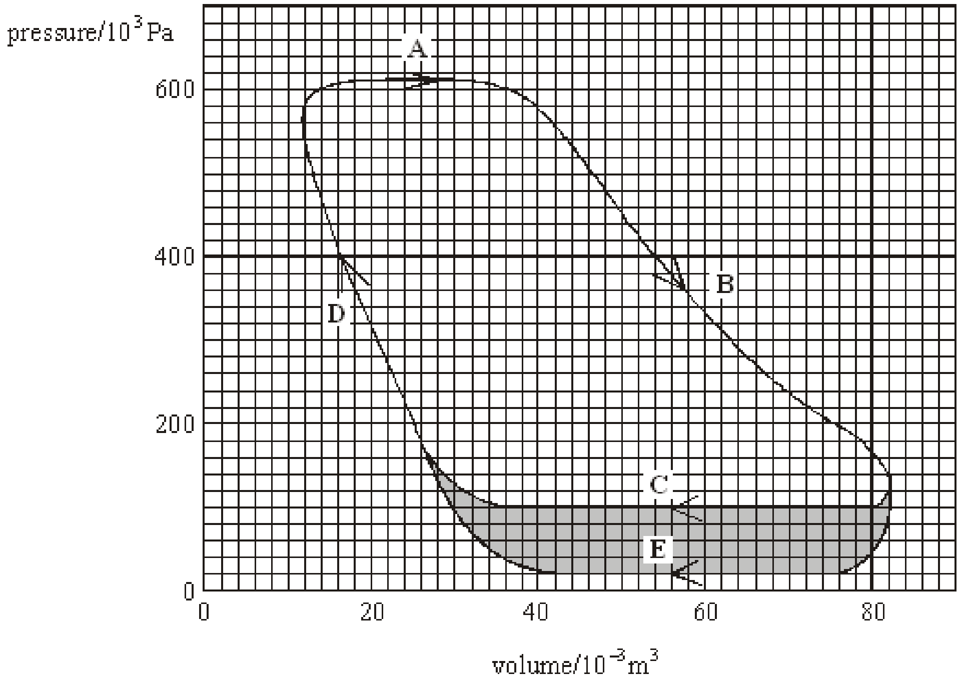
(1)
(Total 8 marks)

Q9. The line **ABCD** in the graph below is the indicator diagram for a single cylinder steam engine in which the exhaust steam is released directly into the atmosphere.



(a) (i) Calculate the work done by the engine during the cycle **ABCD**.

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(ii) Calculate the indicated output power of the engine when running at 3 cycles per second.

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(iii) To achieve this output power, fuel of calorific value 34 MJ kg^{-1} must be burnt at a rate of 2.4×10^{-2} kg s^{-1}. Calculate the thermal efficiency of the engine.

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(5)

(b) The line **ABED** in the graph is the indicator diagram for the same engine after a modification has been made so that the exhaust steam is passed into a condenser, where it is converted to water. The hot water formed is returned to the boiler for reheating.

Without further calculation, compare the performance of the modified engine with that of the original engine when both engines are making the same number of cycles per second. In your comparison you should consider the fuel consumption of the engines, the mass of steam supplied to them, their power outputs and efficiencies.

You may be awarded marks for the quality of written communication in your answer.

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(3)
(Total 8 marks)

Q10. An inventor has designed a gas engine for a small combined heat and power plant which will operate between temperatures of 1400 K and 360 K. The inventor makes two claims about the performance of the engine:

claim 1 When the engine consumes gas of calorific value 36 MJ kg^{-1} at a rate of 9.6 kg h^{-1}, it will deliver a useful mechanical output power of 80 kW.

claim 2 At the same time, the engine will also provide energy at the rate of at least 20 kW for heating purposes.

(a) Show that the input power to the engine is approximately 100 kW.

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(2)

(b) Calculate the maximum possible efficiency of any heat engine which operates between temperatures of 1400 K and 360 K.

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(1)

(c) Using the result of your calculation in part (b) and any other necessary calculations, explain whether either or both of the inventor's claims are justified. You may be awarded marks for the quality of written communication in your answer.

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(4)
(Total 7 marks)

Q11. A spray can contains liquid paint with compressed gas in the space above it, as shown in **Figure 1**. Pressing down the cap opens a valve which allows the gas to expand, forcing paint through the nozzle. The cap is pressed until all the paint is expelled, leaving the can filled with gas at a pressure which is still greater than atmospheric.

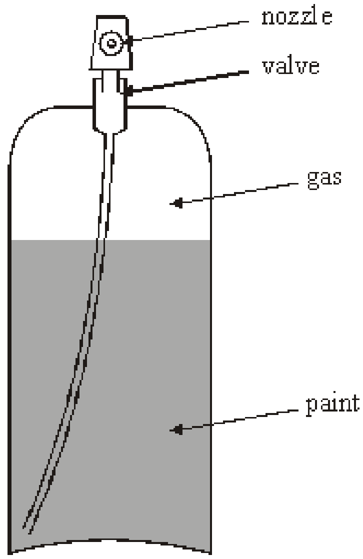

Figure 1

(a) The can has an internal volume of $6.6 \times 10^{-4} m^3$ and initially contains $5.0 \times 10^{-4} m^3$ of paint. The gas in the can is at an initial pressure of 7.8×10^5 Pa. The pressure of the gas left in the can when all the paint has just been expelled is 1.9×10^5 Pa. Show that the expansion of the gas was an approximately isothermal process.

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(2)

(b) The cap is now pressed again to open the valve and is held down to allow the gas to expand rapidly into the air around the can. The atmospheric pressure is 9.8×10^4 Pa and the temperature of the gas at the start of the expansion is 22 °C.

(i) Explain why this expansion can be considered to be approximately adiabatic.

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(ii) Calculate the total volume that the gas would occupy if it were collected at atmospheric pressure immediately after the expansion.

γ for the gas = 1.4

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(3)
(Total 5 marks)

Q12. In the pneumatic tool shown in **Figure 1**, preheated air enters the cylinder via the inlet valve at a pressure of 2.0×10^6 Pa and a temperature of 77 °C. The pressure and temperature remain constant while the inlet valve is open, and the piston is forced down the cylinder. When the volume of air contained in the cylinder between the inlet valve and the piston is 3.5×10^{-4} m^3 the inlet valve closes and the air expands to a final volume of 6.2×10^{-4} m^3. **Figure 2** shows the *p*-*V* diagram for this stroke of the piston. Details of the return stroke are not needed in this question.

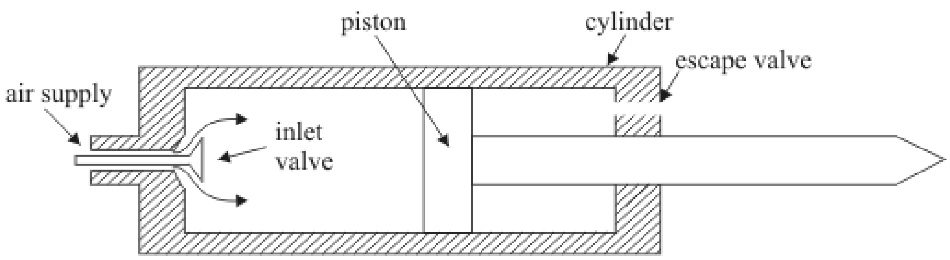

Figure 1

(a) Using the values of pressure and volume from **Figure 2**, show that the expansion of the air between points **B** and **C** is approximately adiabatic.

γ for air = 1.4

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(1)

(b) Calculate the amount of air in the cylinder, in moles, when the inlet valve closes.

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(2)

(c) Calculate the temperature of the air at the end of the outward stroke, corresponding to the point marked **C** in **Figure 2**.

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(1)

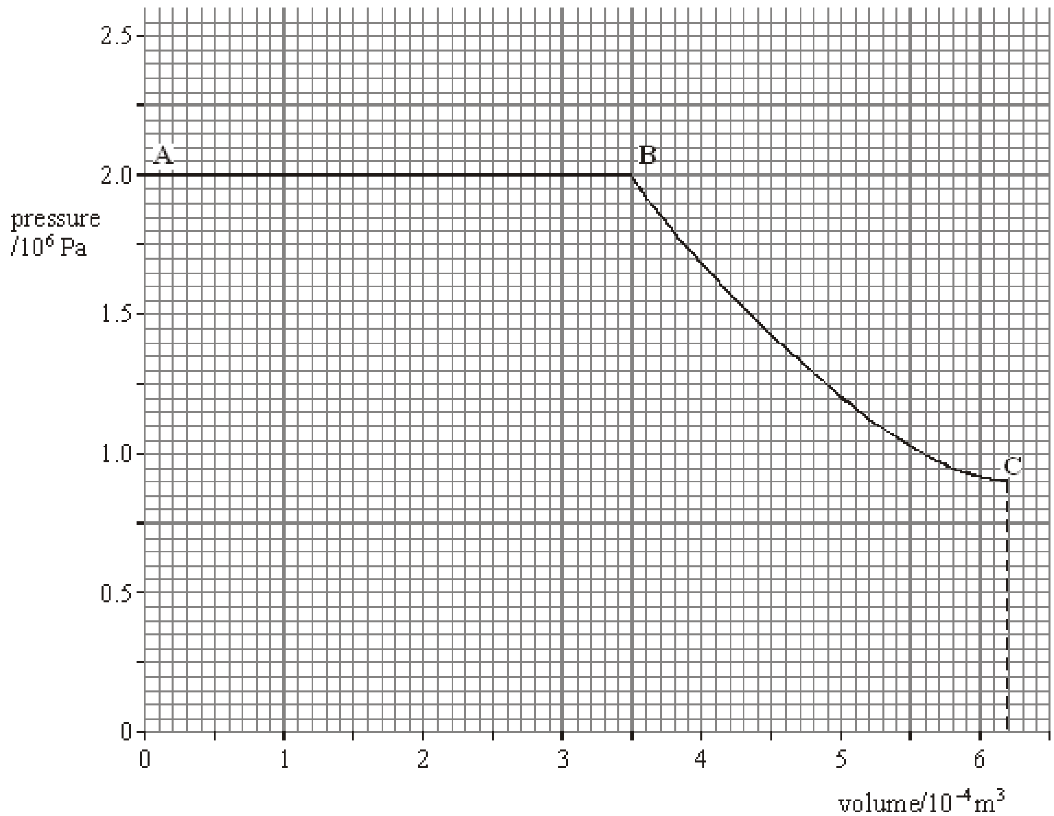

Figure 2

(d) Calculate the total work done by the air during the outward stroke of the piston, between points **A** and **C** in **Figure 2**.

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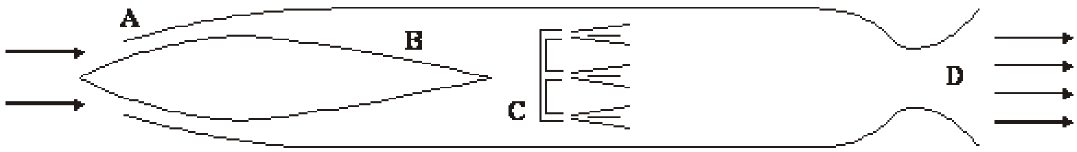
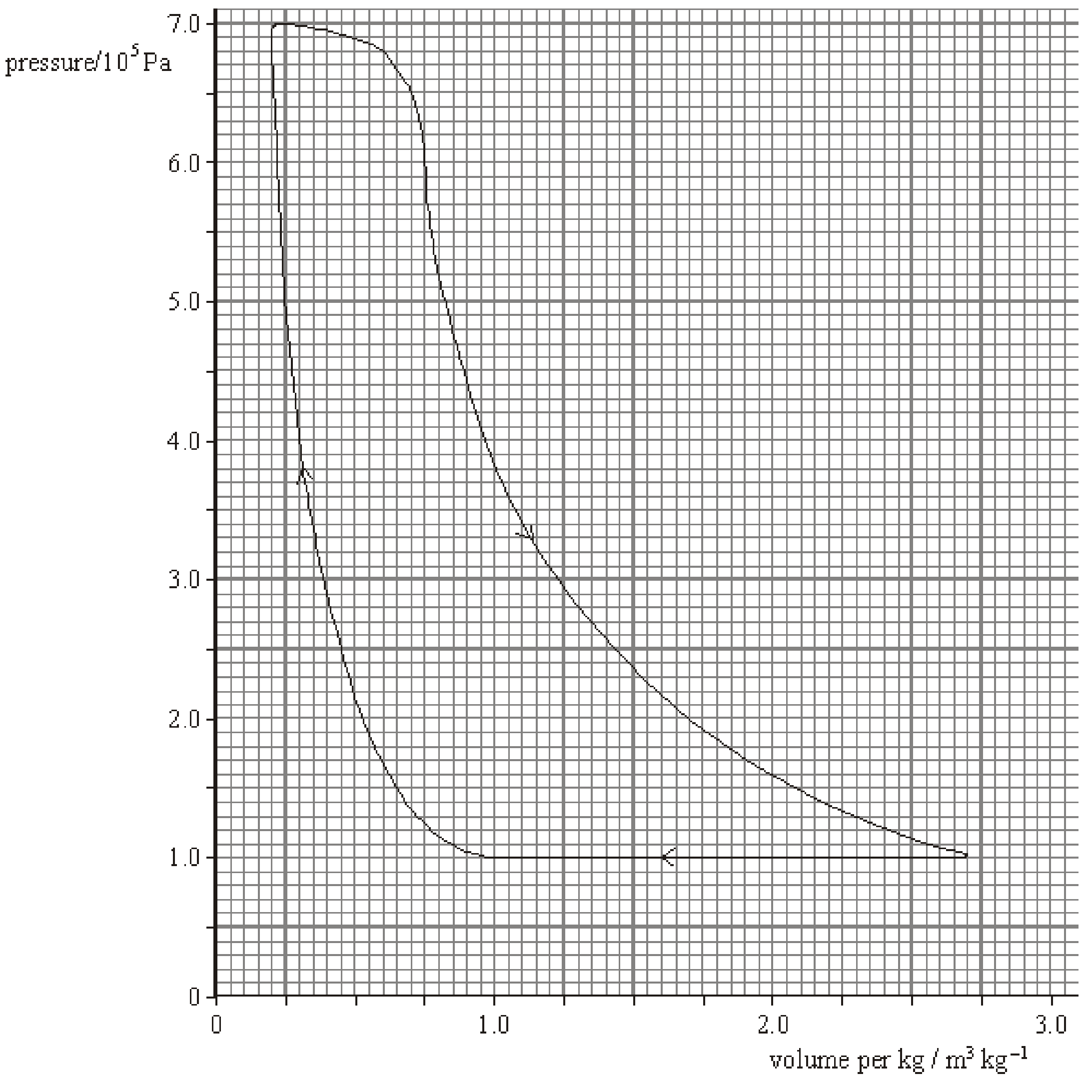
(2)
(Total 6 marks)

Q13. The ram jet engine was used as a cheap and efficient propulsion unit for high speed guided missiles. The figure below shows a section through this engine.



When moving at high speed, air enters the nose at **A** and its pressure increases up to region **B**. At **C**, fuel is injected directly into the air stream where it is ignited, and the burning gases are exhausted at high speed through the nozzle at **D**. This provides the thrust.

The graph shows the pressure-volume diagram for 1.0 kg of air passing through the engine. Note that the volume axis has units of $m^3 kg^{-1}$ i.e. the volume for every kg of air that passes through the engine.



(a) (i) Use the graph to show that the work done for every kg of air that passes through the engine is about 500 kJ.

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(ii) The mass flow rate of the air through the engine is 9.9 kg s^{-1}. Determine the work done in one second in the engine. This is the equivalent of the indicated power of the engine.

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(iii) Because of the high speed of the air in the engine, there is significant frictional heating amounting to a power loss of 430 kW. Determine the power output of the engine (available for thrust).

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(5)

(b) The engine consumes fuel at the rate of 0.30 kg per second. The calorific value of the fuel is 44 MJ kg^{-1}. Calculate

(i) the input power to the engine,

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....

(ii) the overall efficiency of the engine.

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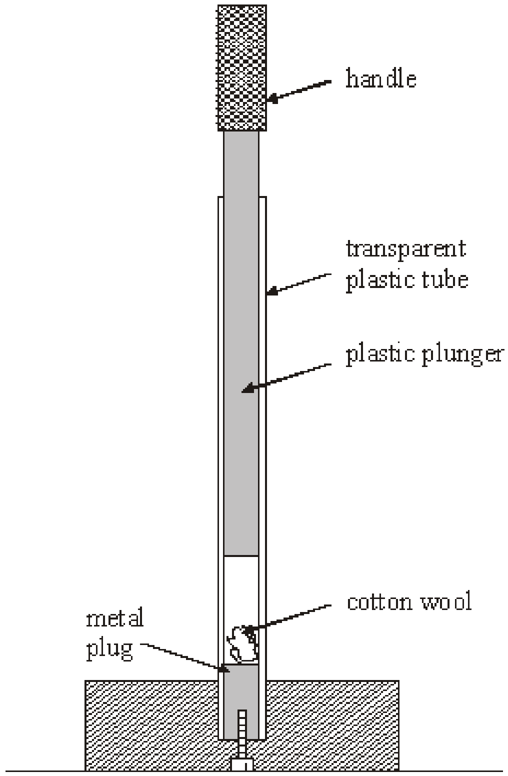
(2)
(Total 7 marks)

Q14. The figure below shows a device for demonstrating an effect of adiabatic compression. A small pad of dry cotton wool is placed on the metal plug at the lower end of a long transparent plastic tube. The plunger is pushed quickly down the tube compressing the air in the tube. When the plunger nears the bottom the cotton wool is seen to ignite in a small tongue of flame.



(a) With the plunger at the top of the tube the air inside the tube has a volume of 1.2×10^{-5} m^3 and is at atmospheric pressure of 1.0×10^5 Pa.
When the plunger has been pushed down the tube to its lowest point, the volume of air in the tube is 3.1×10^{-7} m^3. Assuming the compression of the air to be adiabatic, show that the pressure of air in the tube is 1.7×10^7 Pa.

γ for air = 1.4

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(2)

(b) The temperature of the air before the compression is 290 K.

Calculate

(i) the number of moles of air in the tube,

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....

(ii) the temperature of the air at the end of the compression.

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(4)

(c) Use the first law of thermodynamics to explain why the cotton wool will not ignite if the plunger is pushed down the tube very slowly.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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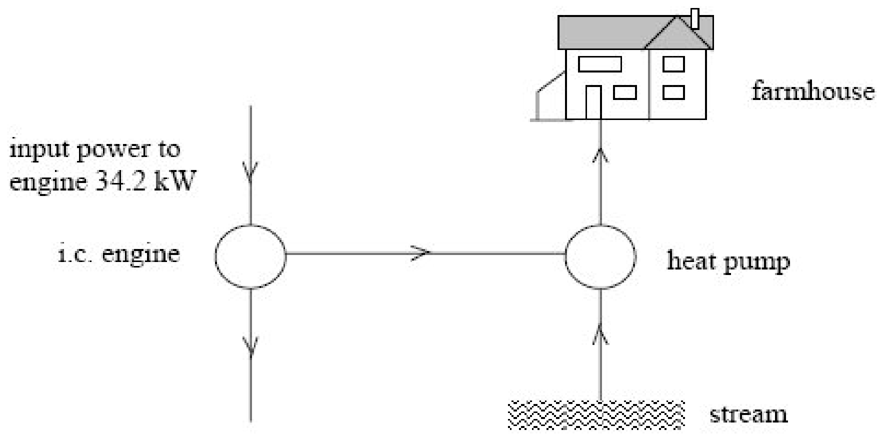
(3)
(Total 9 marks)

Q15. Two systems are proposed for heating a remote farmhouse. In the first system bottled gas heats water in a boiler and the hot water is circulated through radiators. The maximum power input to the boiler is 34.2 kW and the maximum boiler output is 28.0 kW.

In the second system the same fuel as in the system described above is burned at the same maximum rate in an internal combustion engine of overall efficiency 36%. The engine drives a heat pump of coefficient of performance 2.5 which extracts energy from a nearby stream. The system is shown schematically below.



(a) Determine the maximum

(i) power output of the internal combustion engine,

Power output = ...

(ii) rate at which the heat pump supplies energy to the farmhouse

Rate of supply of energy = ...

(iii) rate at which the heat pump extracts energy from the stream.

Rate of extraction of energy = ...

(3)

(b) State which system is cheaper to run, giving **two** reasons for your answer.

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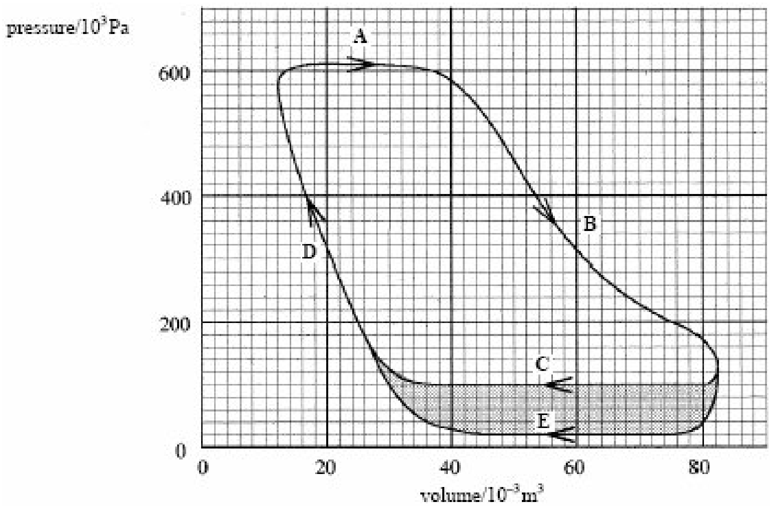
(3)
(Total 6 marks)

Q16. The line **ABCD** in the graph below is the indicator diagram for a single cylinder steam engine in which the exhaust steam is released directly into the atmosphere.



(a) (i) Calculate the work done by the engine during the cycle **ABCD**.

Work done = ...

(ii) Calculate the indicated output power of the engine when running at 3 cycles per second.

Indicated output power = ...

(iii) To achieve this output power, fuel of calorific value 34 MJ kg^{-1} must be burnt at a rate of 2.4×10^{-2} kg s^{-1}. Calculate the thermal efficiency of the engine.

Thermal efficiency = ...

(6)

(b) The line **ABED** in the graph is the indicator diagram for the same engine after a modification has been made so that the exhaust steam is passed into a condenser, where it is converted to water. The hot water formed is returned to the boiler for reheating.

Without further calculation, compare the performance of the modified engine with that of the original engine when both engines are making the same number of cycles per second. In your comparison you should consider the fuel consumption of the engines, the mass of steam supplied to them, their power outputs and efficiencies.

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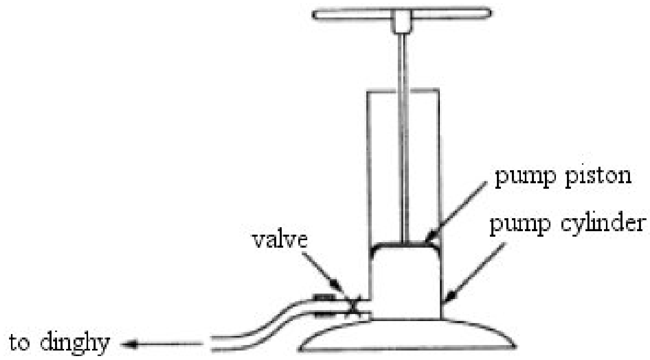
(3)
(Total 9 marks)

Q17. The diagram below shows a pump used to inflate a rubber dinghy. When the piston is pushed down, the pressure of air in the cylinder increases until it reaches the pressure of the air in the dinghy.
At this pressure the valve opens and air flows at almost constant pressure into the dinghy.



(a) The pump is operated quickly so the compression of the air in the cylinder before the valve opens can be considered adiabatic.
At the start of a pump stroke, the pump cylinder contains 4.25×10^{-4} m^3 of air at a pressure of 1.01×10^5 Pa and a temperature of 23ºC. The pressure of air in the dinghy is 1.70×10^5 Pa.

Show that, when the valve is about to open, the volume of air in the pump is 2.93×10^{-4} m^3.

γ for air = 1.4

(2)

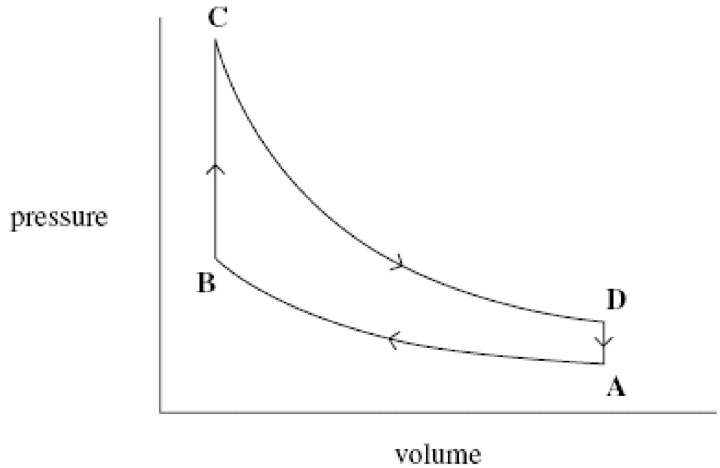
(b) Calculate the temperature of the air in the pump when the valve is about to open.

Temperature = ...

(4)
(Total 6 marks)

Q18. (a) **Figure 3** shows the indicator diagram for a theoretical or ideal four-stroke petrol engine (Otto) cycle.

Figure 1



Use **Figure 1** to describe the process that occurs during each of the parts **A** to **B**, **B** to **C**, **C** to **D** and **D** to **A** of the cycle. Describe whether heating or cooling is taking place, the type of process and whether work is being done on or by the air.

The quality of your written answer will be assessed in this question.

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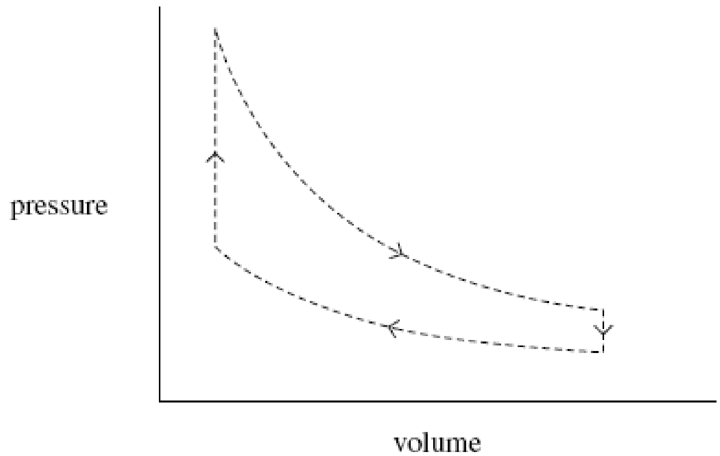
(6)

(b) Show, on **Figure 2**, how the indicator diagram might be expected to appear if measurements of pressure and volume were made on a real four-stroke petrol engine of the same volume under operating conditions. The ideal cycle is shown in dashed lines as a guide.

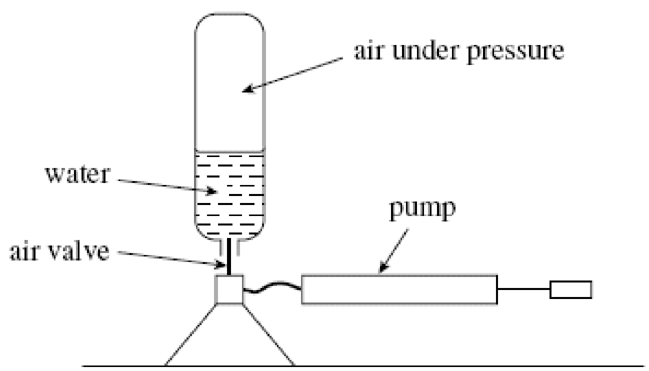
Figure 2



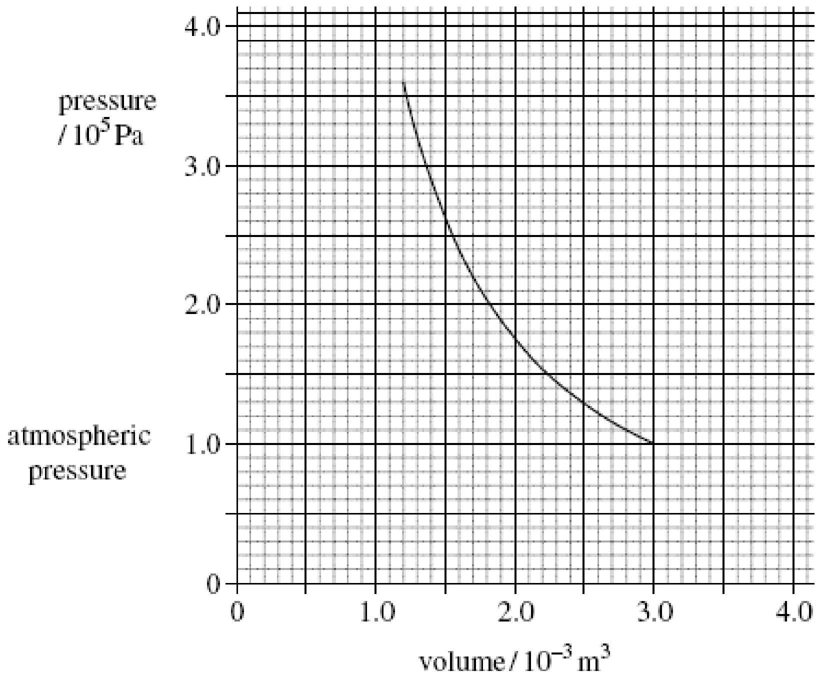
(2)
(Total 8 marks)

Q19. The figure below shows a model rocket for demonstrating the principle of rocket propulsion. Air is pumped into an upside-down plastic bottle that has been partly filled with water.

When the pressure reaches 3.6×10^5 Pa, (i.e. 2.6×10^5 Pa above atmospheric pressure) the air valve is forced out by the water pressure and the air in the bottle expands. The expanding air forces the water out of the neck of the bottle at high speed; this provides the thrust that lifts the bottle high into the air.



The graph shows the variation of pressure with volume for the air initially in the bottle as it expands from 3.6×10^5 Pa to atmospheric pressure, assuming the expansion is adiabatic.



(a) Use the graph to estimate the work done by the air as it expands from a pressure of 3.6×10^5 Pa to atmospheric pressure.

answer = ... J

(3)

(b) With reference to the graph above, state and explain whether the rocket would have reached the same height if the air had expanded isothermally.

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(3)
(Total 6 marks)

Q20. (a) The coefficient of performance of a refrigerator is given by

$$COP_{ref} = \frac{Q_{out}}{Q_{in} - Q_{out}}$$

With reference to a refrigerator, explain the terms Q_{in} and Q_{out}.

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(2)

(b) A refrigerator is designed to make ice at –10 °C from water initially at room temperature. The energy needed to make 1.0 kg of ice at –10 °C from water initially at room temperature is 420 kJ. The refrigerator has a coefficient of performance of 4.5.

(i) Calculate the power input to the refrigerator if it is required to make 5.5 kg of ice every hour.

answer = ... W

(2)

(ii) Calculate the rate at which energy is delivered to the surroundings of the refrigerator.

answer = ... W

(1)
(Total 5 marks)

Q21. A heat pump is used for heating a small workshop. The heat pump extracts energy from a patch of ground outside the workshop. The coefficient of performance of the heat pump is 3.2 and the average electrical power input is 780 W.

(a) (i) Calculate the rate at which energy is delivered to the workshop.

answer = ... W

(1)

(ii) Calculate the rate at which energy is extracted from the ground.

answer = ... W

(1)

(b) A student claims: "A heat pump delivers more energy than is supplied to it". Discuss this statement and explain why a heat pump does not contradict the law of conservation of energy or the second law of thermodynamics.

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(3)
(Total 5 marks)

Q22. In an ideal 'hot air' engine, a fixed mass of air is continuously taken through the following four processes:

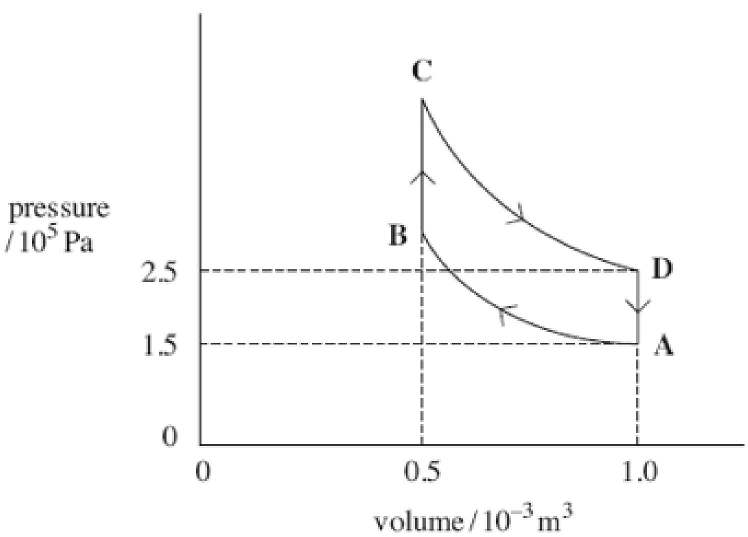
A → B isothermal compression at a temperature of 300 K. The work done on the air is 104 J.

B → C heating at constant volume.

C → D isothermal expansion. The work done by the expanding air is 173 J.

D → A cooling at constant volume.

The cycle is shown in the figure below.



(a) (i) Show that the temperature of the air at point D is 500 K.

(2)

(ii) Apply the first law of thermodynamics to calculate the energy supplied by heat transfer in process C → D.

answer = ... J

(2)

(b) The engine contains a device called a regenerator which stores **all** the energy rejected by cooling in process D → A and gives up **all** this energy to the air again in process B → C. This means that energy must be supplied to the air by heat transfer from an external source **only** in process C → D.

(i) Calculate the net work done during the cycle.

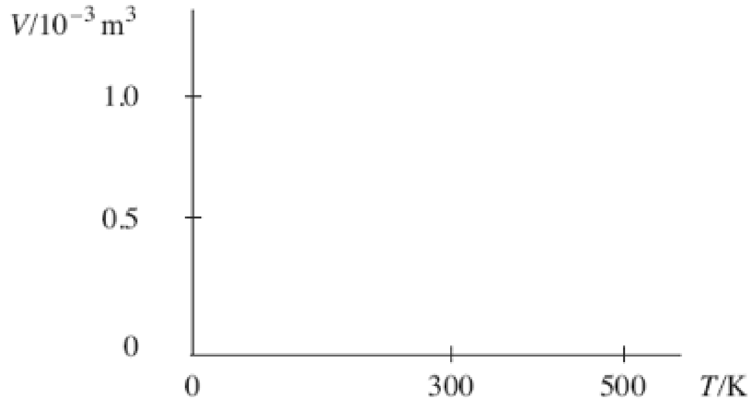
answer = ... J

(1)

(ii) Show that the efficiency of the cycle is the same as the maximum possible efficiency of any heat engine operating between the same highest and lowest temperatures in the cycle.

(2)

(c) On the axes below, sketch the cycle on a graph of volume *V* against temperature *T*. Label the points A, B, C and D.



(2)

(d) Several inventors have tried to build an engine that works on this cycle. Give **two** reasons why they have been unsuccessful.

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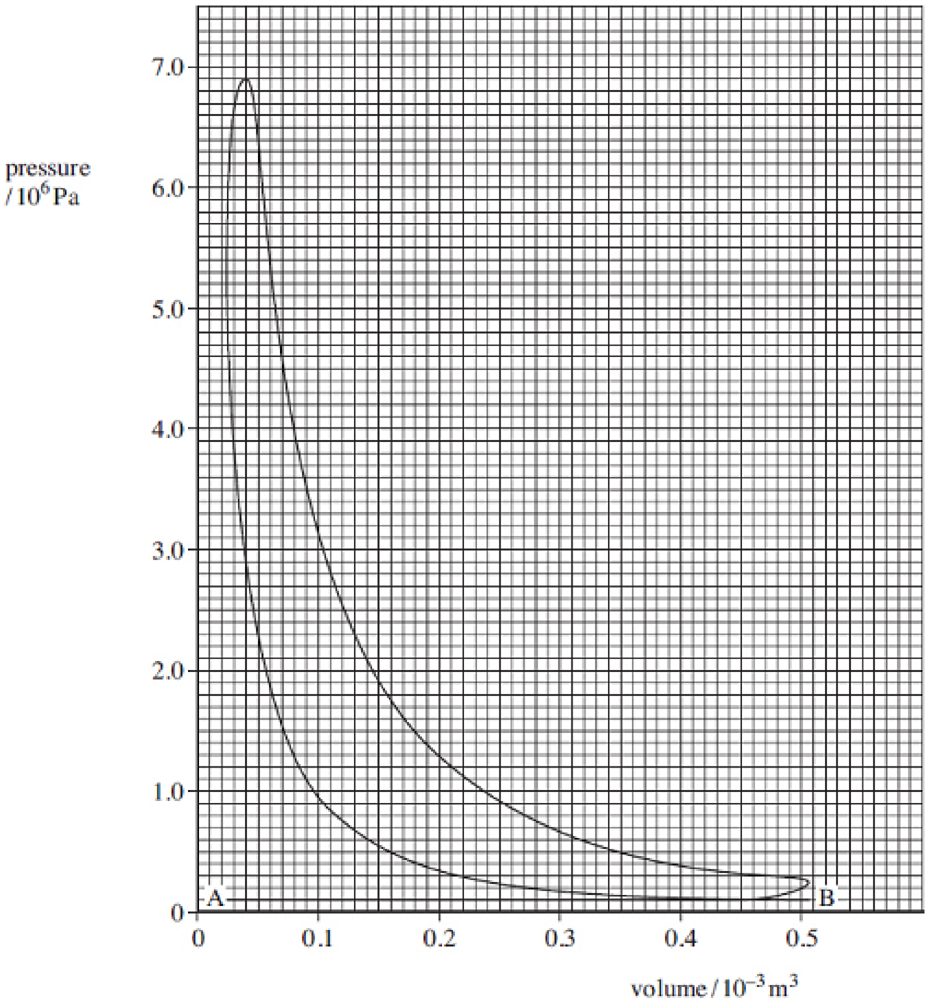
(2)
(Total 11 marks)

Q23. A four-stroke diesel engine with four cylinders is running at constant speed on a test bed. An indicator diagram for **one cylinder** is shown in the figure below and other test data are given below:

measured output power of engine (brake power)	= 55.0 kW
fuel used in 100 seconds	= 0.376 litre
calorific value of fuel	= 38.6 MJ litre^{-1}
engine speed	= 4100 rev min^{-1}



(a) (i) Determine the indicated power of the engine, assuming all cylinders give the same power.

answer = ... kW

(4)

(ii) Calculate the overall efficiency of the engine.

answer = ...

(3)

(b) Account for the difference between the indicated power and brake power.

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(1)

(c) What is represented by the line AB on the figure above?

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(1)
(Total 9 marks)

Q24. **Figure 1** shows a model steam engine used in a school to demonstrate energy transfers. The steam engine drives a dynamo which requires a constant torque.
By means of valves, high pressure steam is applied to one side of the piston on the outward stroke (as shown) and to the other side of the piston on the inward stroke. The motion of the piston is converted to rotary motion by a connecting rod and crank. A flywheel (not shown) is fitted to the crankshaft.

Figure 1

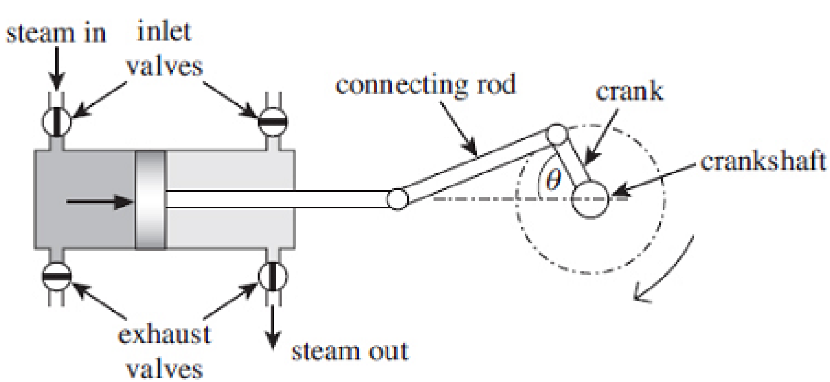
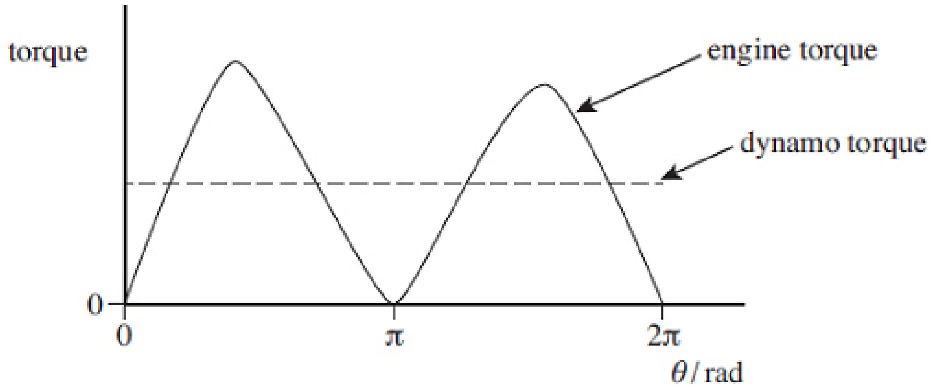


Figure 2 shows how the torque on the crankshaft due to the engine varies with the crankshaft angle θ for one rotation of the crankshaft. The broken line shows the constant dynamo torque required from the output.

Figure 2



(a) State and explain how you could use **Figure 2** to determine the work done by the engine in one revolution of the crankshaft.

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(1)

(b) The dynamo has a low moment of inertia.

- Explain why the engine torque varies over a cycle.
- Explain why, in terms of kinetic energy or angular momentum, it is necessary to fit a flywheel to the crankshaft of the engine.
- Discuss how the motion of the crankshaft is influenced by the value of the moment of inertia of the flywheel.

The quality of your written communication will be assessed in your answer.

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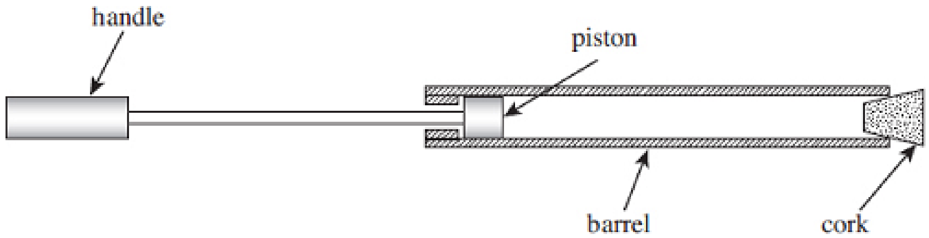
(6)
(Total 7 marks)

Q25. The figure below shows a child's 'pop' gun in which a piston is pushed quickly along the barrel, compressing the air in the barrel. When the pressure is high enough, the cork is expelled at high speed from the end of the barrel.



The figure above shows the gun before it is 'fired'. The air in the barrel is at a pressure of 1.0×10^5 Pa, a temperature of 290 K and the volume is 2.1×10^{-5} m^3.

(a) (i) The volume of air in the barrel at the instant the cork is expelled is 1.2×10^{-5} m^3. Calculate the pressure of the air in the barrel at the instant the cork is expelled. Assume that the air is compressed adiabatically.

adiabatic index, γ, for air = 1.4

answer = ... Pa

(2)

(ii) Calculate the maximum temperature reached by the air in the gun. Give your answer to an appropriate number of significant figures.

answer = ... K

(3)

(b) The work needed to compress the air adiabatically from 2.1×10^{-5} m^3 to 1.2×10^{-5} m^3 is 1.4 J. Use the first law of thermodynamics to determine the change in internal energy of the air during the compression. Explain how you arrived at your answer.

answer = ... J

(2)

(c) Explain, giving your reasons, whether the volume of air in the barrel at the point when the cork leaves the gun would be less than, equal to, or greater than 1.2×10^{-5} m^3 if the handle of the gun had been pushed in slowly. Assume there is no leakage of air past the cork or piston. You may find it helpful to sketch a *p* - *V* diagram of the compression.

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(3)
(Total 10 marks)

Q26. (a) Explain what is meant by a reversed heat engine.

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(2)

(b) Explain why the coefficient of performance of a reversed heat engine when operating as a heat pump is always greater than the coefficient of performance of the same reversed heat engine when operating as a refrigerator.

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(2)
(Total 4 marks)

Q27. (a) Explain why the compression stroke of a diesel engine is considered to be an adiabatic change.

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(2)

(b) **Figure 1** shows the cylinder of a diesel engine. The pressure of the air at the start of the compression stroke is 1.0×10^5 Pa and the volume above the piston is 4.5×10^{-4} m^3.

Figure 1

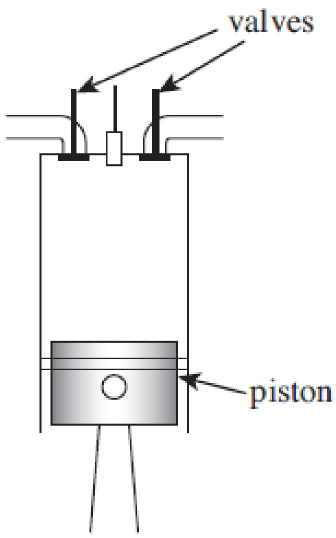

Figure 2

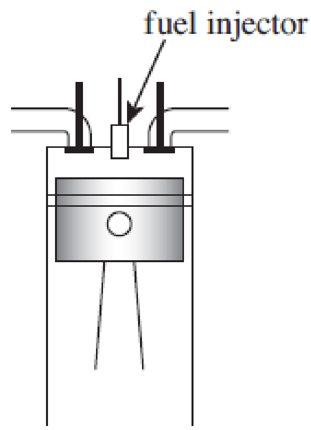

Figure 2 shows the same cylinder at the instant just before the fuel is injected. The pressure above the piston is now 6.2×10^6 Pa. The compression is adiabatic with no leakage of air past the piston or valves.

adiabatic index γ for air = 1.4

(i) Calculate the volume above the piston at the instant just before the fuel is injected. Give your answer to an appropriate number of significant figures.

volume .... m^3

(3)

(ii) The temperature of the air in the cylinder at the start of the compression stroke is 297 K. Calculate the temperature of the air at the instant just before the fuel is injected.

temperature .... K

(2)

(iii) Explain why, in a diesel engine, the fuel starts to be injected into the cylinder slightly before the piston reaches its highest point in the cylinder.

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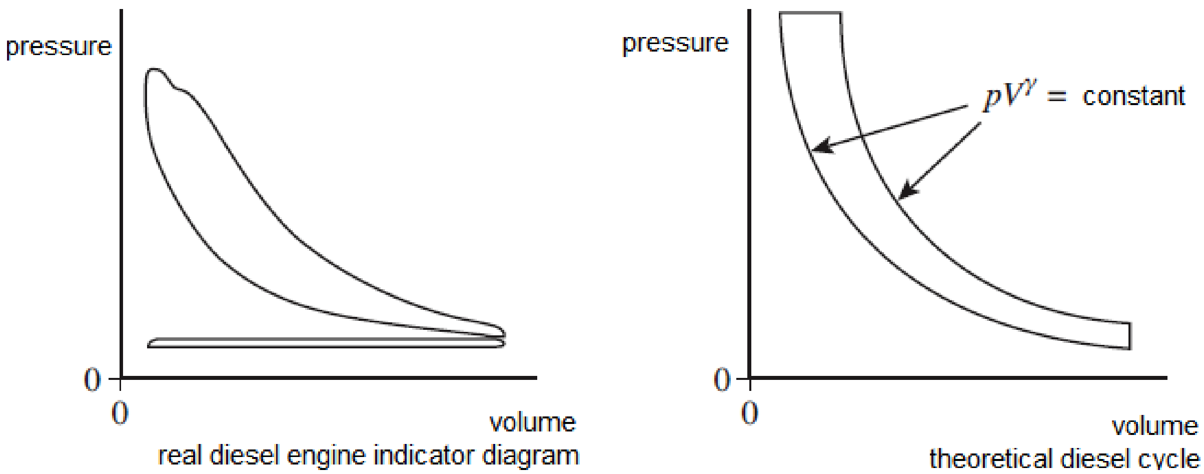
(1)

(c) **Figure 3** shows the indicator (*p* – *V*) diagram for a real diesel engine compared to the *p* – *V* diagram for a theoretical diesel cycle of the same maximum and minimum volumes and fuel injection cut-off.

Figure 3



Compare the real engine cycle with the theoretical cycle. In your account you should:

- discuss the important differences between the cycles
- explain why the overall efficiency of the real engine is less than that predicted by an analysis of the theoretical cycle.

The quality of your written communication will be assessed in your answer.

(6)
(Total 14 marks)