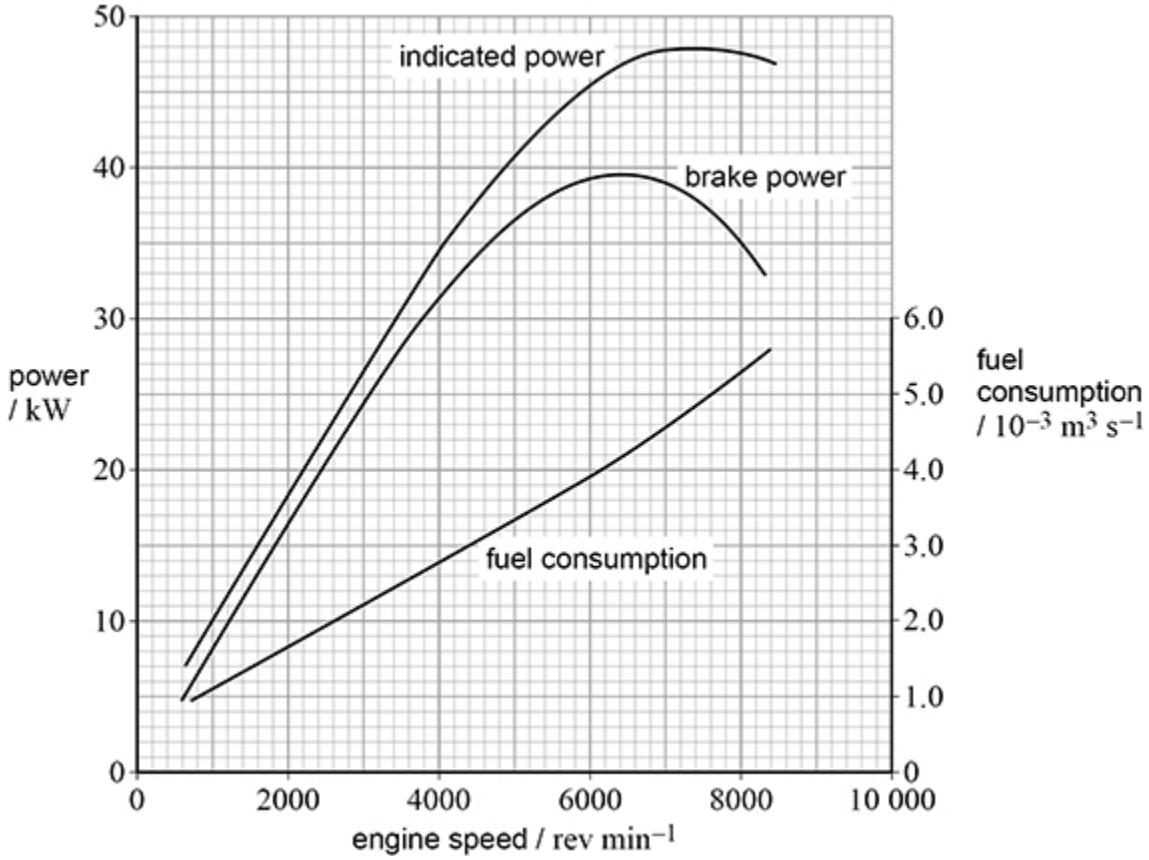
A-Level Physics

Engine Cycles

Question Paper

Time available: 44 minutes
Marks available: 34 marks

1. The figure below shows the results of a test on an internal combustion engine which uses purified biogas.



The figure above shows how the indicated power, brake (or output) power and fuel consumption of the engine vary with the engine speed. The scale on the left-hand axis is power and the scale on the right-hand axis is fuel consumption.

(a) The figure above can be used to analyse the performance of the engine.

Determine, for the speed at which the engine develops its maximum brake power:

- the overall efficiency
- the thermal efficiency
- the mechanical efficiency.

Go on to explain how knowledge of these efficiencies can be useful to an engineer.

calorific value of biogas used in the test = 32.3×10^6 J m^{-3}

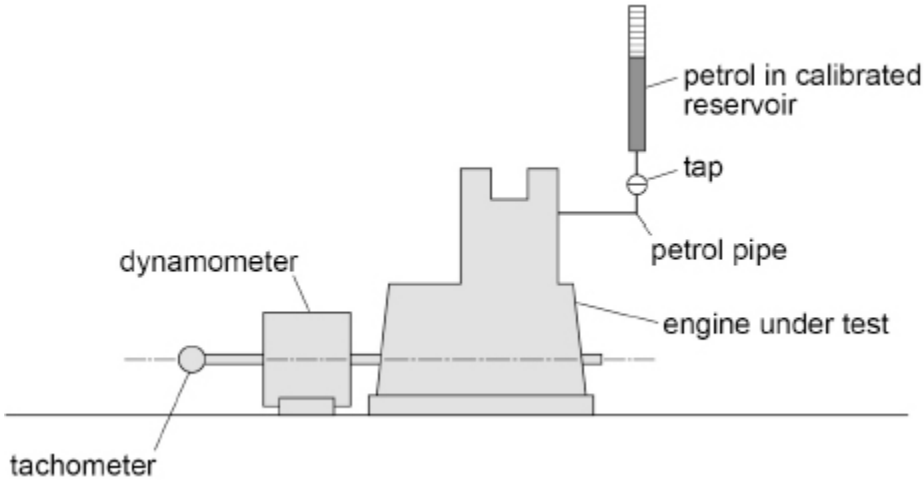
(6)

(b) Explain why it is **not** advisable to run this engine at speeds above 7000 rev min^{-1}. Refer to the figure above in your answer.

(2)

(Total 8 marks)

2. The figure shows some of the equipment used to investigate the thermal and mechanical efficiencies of a single-cylinder four-stroke petrol engine.



- Petrol is supplied to the engine from a calibrated reservoir.
- Sensors are used to measure the volume *V* and pressure *p* above the piston inside the cylinder.
- The dynamometer applies a load to the output shaft and measures the output torque of the engine.
- The tachometer measures the rotational speed of the engine in revolutions per second.

In one test the air intake valve (throttle) setting remains fixed and the load provided by the dynamometer is kept constant.

Describe how you would determine the input power, the indicated power, the brake power, the thermal efficiency and the mechanical efficiency.

In your answer you should

- describe the measurements that you would take
- show how you would use the measurements and any other necessary data.

(Total 6 marks)

3. 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.

(2)

(b) Calculate the indicated power of the engine.

(2)

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

(1)

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

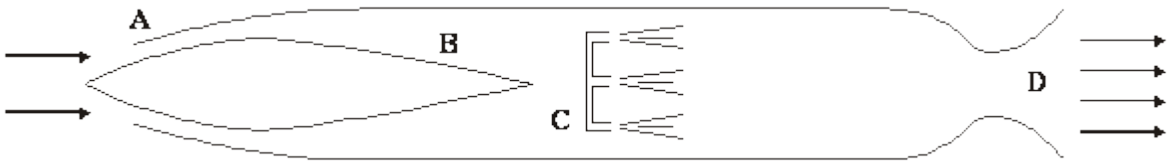
(1)

(e) Calculate the overall efficiency of the engine.

(1)

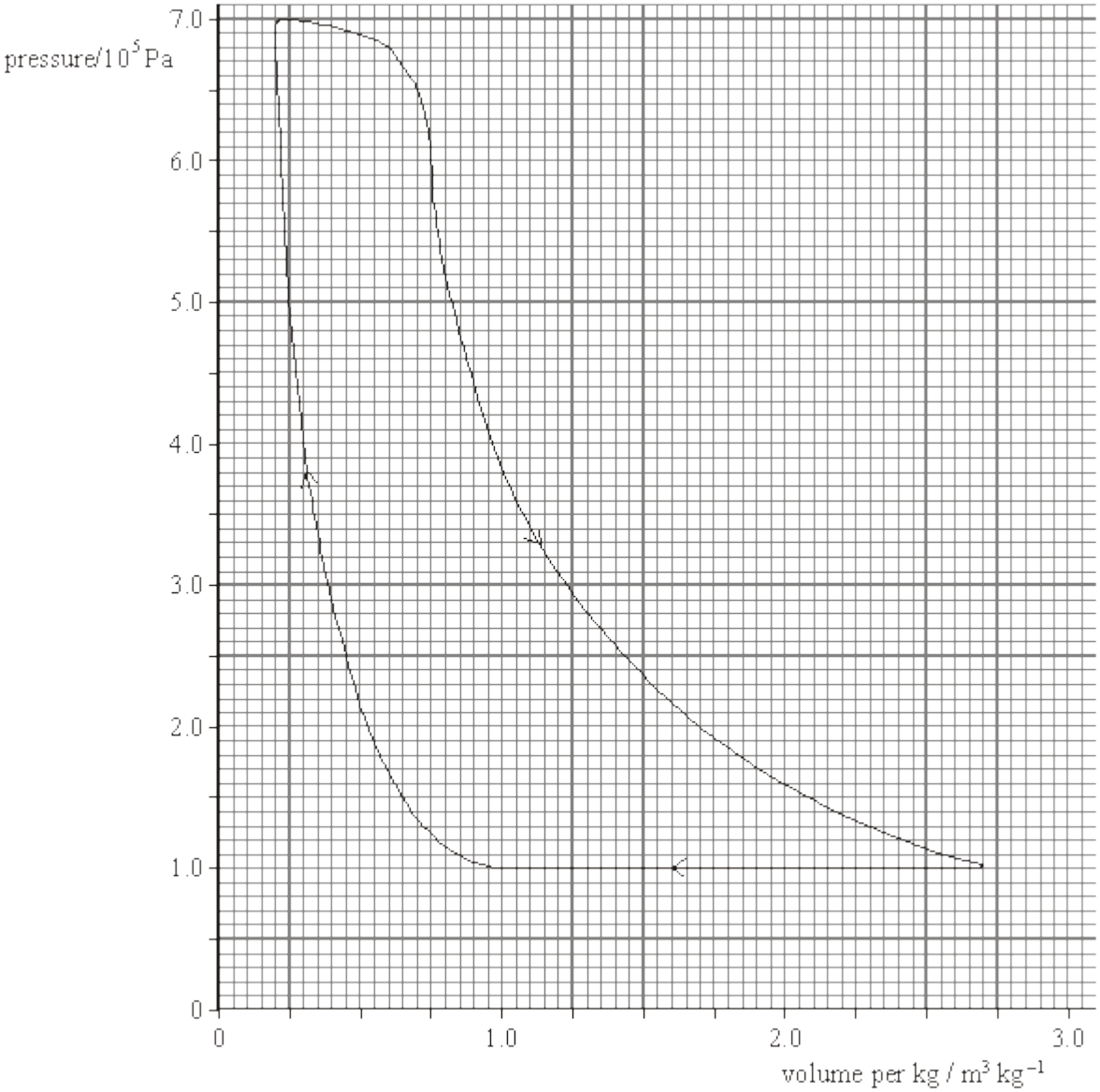
(Total 7 marks)

4. 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.

(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)

5. The following results were obtained from a test on a single-cylinder petrol engine.

torque measured at output shaft	44 N m
rotational speed of output shaft	1200 rev min^{-1}
indicated power	6.2 kW
calorific value of fuel	47 MJ kg^{-1}
flow rate of fuel	2.4×10^{-2} kg min^{-1}

(a) Calculate the output power developed by the engine at its output shaft.

(2)

(b) Estimate the power dissipated in overcoming frictional losses within the engine.

(1)

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

(2)

(d) Calculate the overall efficiency of the engine.

(1)

(Total 6 marks)