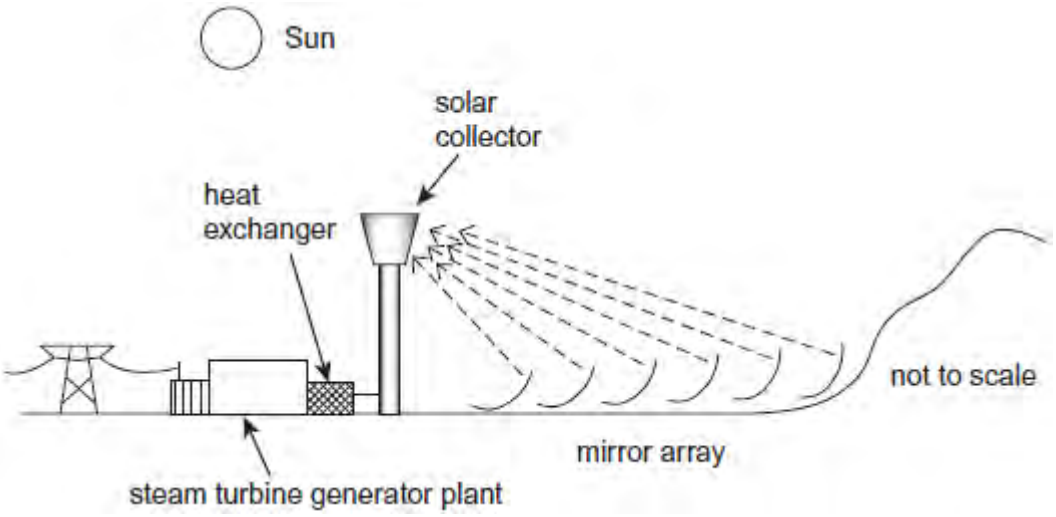
Q1. The diagram below shows the basic arrangement of a solar thermal power station. An array of mirrors tracks the Sun and reflects the Sun's rays onto a solar collector tower containing molten salt. The molten salt reaches a temperature of 540 °C. In the heat exchanger, the internal energy in the salt is transferred to water which turns to steam and drives a steam turbine generator to produce electricity. The steam turbine rejects energy to the atmosphere at 25 °C.



(a) Calculate the maximum theoretical efficiency of a heat engine operating between temperatures of 540 °C and 25 °C.

maximum efficiency = ...

(2)

(b) On one particular day the output of the power station is 48 MW. Calculate the input power to the power station assuming it can run at its maximum theoretical efficiency.

input power = ... W

(1)

(c) The actual efficiency of the steam turbine is about 38% when the molten salt is at 540 °C. State **two** reasons why the actual efficiency of the power station is much less than the maximum theoretical efficiency.

1 .....

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2 .....

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(2)
(Total 5 marks)

Q2. A company claims to be able to provide a combined heat and power plant for a market garden that requires both electrical power and space heating for greenhouses. The engine-driven generator will operate between temperatures of 1450 K and 310 K.

(a) Show that the maximum theoretical efficiency of any heat engine operating between temperatures of 1450 K and 310 K is about 80%.

(1)

(b) The company makes the following two claims about the performance of the plant:

- **Claim 1** When consuming biogas of calorific value 55.5 MJ m^{-3} at the rate of 5.00×10^{-3} m^3 s^{-1}, the electrical power output will be 210 kW.
- **Claim 2** At the same time the engine will provide heating for greenhouses at the rate of at least 55.0 kW.

Discuss the extent to which the company's claims are justified.

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(5)
(Total 6 marks)

Q3. 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)

Q4. 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)

Q5. A small geothermal power station in Iceland pumps cold water into hot rock strata far below the Earth's surface to be heated and returned at a constant temperature of 87°C. The power station uses the hot water as the heat source for a heat engine which rejects energy to the much colder sea water near the station.

(a) When the temperature of the sea water is 7°C the power output from the heat engine is 5.0 MW.

Calculate

(i) the maximum theoretical efficiency of the heat engine,

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(ii) the rate at which heat energy must be transferred from the hot water if the engine works at the maximum theoretical efficiency,

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(iii) the rate at which energy must be transferred to the sea water under these conditions.

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(4)

(b) The power station produces electrical power with an overall efficiency which is much lower than the maximum theoretical efficiency of the heat engine. Give **two** reasons for this lower efficiency.

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(2)

(c) The overall efficiency of an oil-fired power plant of similar size to the geothermal station is over four times as great. Suggest **one** reason, other than less pollution, why the geothermal source was preferred for the power station.

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(1)
(Total 7 marks)