Access Tuition

A-Level Physics

Reversed Heat Engine

Question Paper

Time available: 44 minutes
Marks available: 32 marks

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1. **Figure 1** shows a low-voltage solid-state thermoelectric cooling element.
The element is a square of side 40 mm and is 4 mm thick.

Figure 1

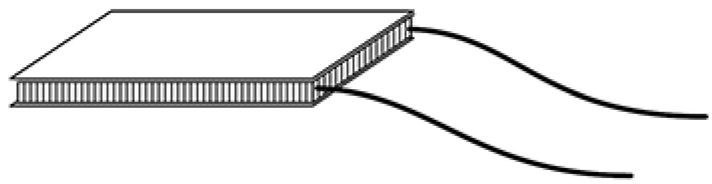
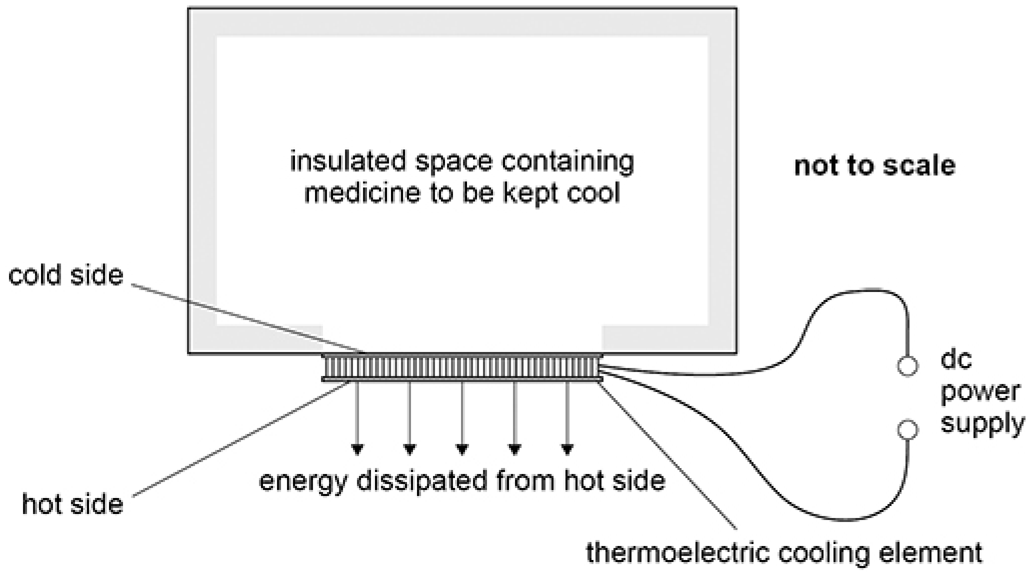


Figure 2 shows how the element is used as part of a thermoelectric refrigerator to keep small quantities of medicine at a low temperature.

Figure 2



The manufacturer's data for the element show that when the temperature of the hot side is 35 °C and the temperature of the cold side is 5 °C:

- the rate at which energy is dissipated from the hot side is 65 W
- the electrical power supplied is 28 W.

(a) It is claimed that the coefficient of performance (COP) of a thermoelectric refrigerator is much less than the COP of an ideal refrigerator.

Discuss whether the claim is valid for the thermoelectric refrigerator in this question.

(4)

(b) Suggest why a small value of the COP might be acceptable for this particular application of a thermoelectric cooling element.

(2)

(Total 6 marks)

2. (a) Which is a correct statement about an ideal heat engine?

Tick (✓) **one** box.

The efficiency is increased when the kelvin temperatures of the hot source and the cold sink are increased by equal amounts.	☐
The maximum efficiency depends on the p–V cycle.	☐
The efficiency is 50% when the kelvin temperature of the hot source is twice the kelvin temperature of the cold sink.	☐

(1)

(b) An ideal heat engine has an efficiency of 0.33
The same engine works in reverse as an ideal refrigerator between the same hot and cold spaces.

Determine the coefficient of performance COP_{ref} of the refrigerator.

COP_{ref} = ________________

(2)

(Total 3 marks)

3. (a) An ideal heat pump and an ideal refrigerator operate between the same hot and cold spaces.

Which statement relating to the coefficient of performance (COP) is correct?
Tick (✓) the correct answer.

The COP of the refrigerator must be < 1.	☐
The COP of the heat pump must be greater than the COP of the refrigerator.	☐
The COP of the heat pump will increase if the temperature of the hot space is increased.	☐
The COP of the refrigerator will decrease if the cold space temperature increases.	☐

(4)

(b) An ideal refrigerator operates between a cold space at a temperature of –1 °C and a hot space at a temperature of 70 °C.

Calculate the input power to the refrigerator if the rate of transfer of energy to the hot space is 100 W.

input power = ____________________ W

(3)

(Total 4 marks)

4. (a) Explain what is meant by the coefficient of performance of a heat pump.

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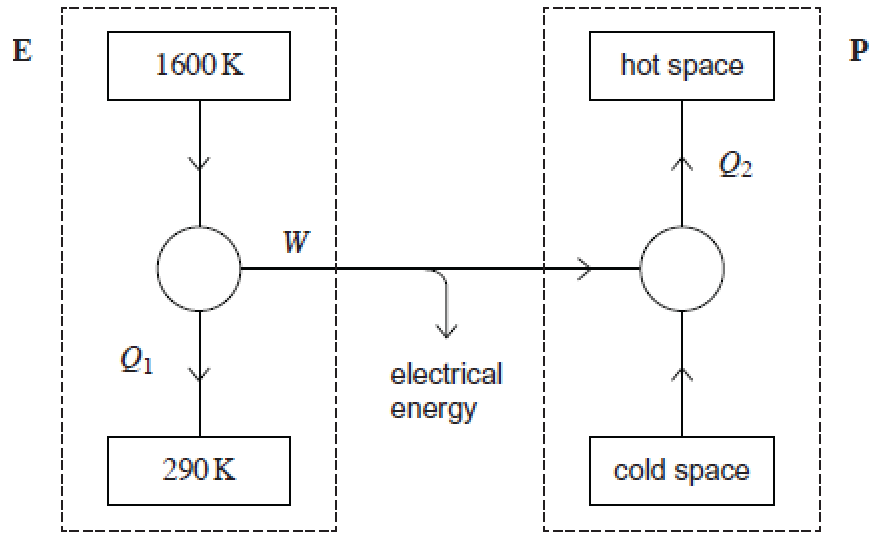
(1)

(b) The box labelled **E** in the figure below shows a diagram of a combined heat and power scheme. The scheme provides electrical energy W from an engine-driven generator and heat Q_1 for buildings situated near to the generator.

Some of the electrical energy is used to drive the heat pump shown in the box labelled **P**. Output Q_2 is also used to heat the buildings.



You may assume that the engine runs at its maximum theoretical efficiency and that the electrical generator is 100% efficient. The output power of the engine-driven generator is 80 kW.

(i) The fuel used in the engine (**E**) is propane of calorific value 49 MJ kg^{-1}. Calculate the rate of flow of propane into the engine. State an appropriate unit.

rate of flow ____________________ unit ___________

(4)

(ii) The heat pump has a coefficient of performance of 2.6.
The power supplied by the electrical generator to the heat pump (**P**) is 16 kW.
Calculate the total rate at which energy is available for heating from both the engine and heat pump.

rate at which energy is available ____________________ W

(3)

(iii) The conversion of electrical energy to heat is nearly 100% efficient. Explain why the designer has proposed installing a heat pump rather than an electrical heater to provide the additional heat Q_2.

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(2)

(Total 10 marks)

5. (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)

6. (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)