Unit 12 · Rate of Heat Flow

HARDER PRACTICE QUESTIONS

Full marks 25

Write your answers on separate paper. Show your working. $\sigma = 5.67 \times 10^{-8}$ W/(m^2 K^4). Thermal conductivity k (W/(m K)): copper 401, steel 50, cork 0.04.

1 Spot the error [3]

Find the mistake and correct it.

A black metal plate is at 127 °C. Reshma finds the energy it radiates per second from each square metre:
"$E = \sigma T^4 = 5.67 \times 10^{-8} \times 127^4 = \mathbf{14.8\ W/m^2}$."

2 Predict, then explain [4]

Write your prediction first, then explain it.

A copper rod and a steel rod of the same length and cross-section are joined end to end and lagged. The free end of the copper is kept at 100 °C, the free end of the steel at 0 °C.

i. Predict: is the junction nearer to 100 °C, nearer to 0 °C, or at 50 °C?
ii. Find the junction's temperature in the steady state.

3 Read the data [4]

Answer from the table.

In a Searle's experiment on a lagged copper bar of cross-section 4.0×10^{-4} m^2, Dipesh reads the temperature along the bar in the steady state:

Distance from the hot end (cm)	0	10	20	30
Temperature (°C)	90	75	60	45

i. Is the temperature gradient uniform? Find it.
ii. Find the rate of heat flow along the bar.
iii. Without the lagging, how would the readings change along the bar, and why?

4 Show that [3]

A wall is made of two layers of the same thickness x and area A, of conductivities k_1 and k_2. Show that it conducts heat like a single layer of thickness 2x with conductivity $k = \dfrac{2k_1k_2}{k_1 + k_2}$.

5 Estimate it [3]

Use the numbers given.

The Earth receives 1361 W on each square metre facing the Sun (the solar constant). Treat the Earth as a black body at one temperature all over. It catches sunlight on its disc, of area πR^2, but radiates from its whole surface, $4\pi R^2$.

i. Show that its temperature would be $T = \left(\dfrac{S}{4\sigma}\right)^{1/4}$.

ii. Find T in kelvin and in °C.

6 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

> Sudip wrote: “A woollen shawl makes heat to keep me warm. A metal rail feels colder than a wooden bench because the metal is at a lower temperature. And a black body only absorbs radiation; it doesn’t give any out.”

7 Think [3]

Two teapots of the same shape and size are filled with tea at the same temperature: one shiny silver, the other blackened with soot. Which keeps the tea hot longer? Would the blackened one be better for heating water on a fire? Explain both.

8 Make your own [2]

A cold-store wall of area 10 m^2 must let through no more than 100 W when the outside is 20 K warmer than the inside. Choose a thickness of cork that does this, and show that it works.