

# 34.1 Thermal transport, calorimetry and expansion

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 11 marks

KEY WORDS thermal resistance • latent heat

## Objective

Combine conductive thermal resistances and distinguish heat rate from heat flux; Balance sensible and latent heat with stated isolation and heat-capacity conditions; Calculate free thermal expansion and constrained thermal stress with their limits. Original public practice; not an ETS paper.

## 1 Key knowledge and worked examples

Fourier flux is  $-\kappa dT/dx$ ; steady slab rate  $\kappa A \Delta T/L$ .  $R_{th}=L/(\kappa A)$  in K/W; add series R or parallel  $1/R$ . Rate is W; flux is W/m<sup>2</sup>.

With constant specific heat,  $Q=mc\Delta T$ . Sum all energy changes for isolated calorimetry. A phase change needs  $Q=ml$  at the transition temperature; sensible and latent energy are distinct.

Free isotropic small expansion:  $\Delta L/L \approx \alpha \Delta T$ ,  $\Delta A/A \approx 2\alpha \Delta T$ ,  $\Delta V/V \approx 3\alpha \Delta T$ . Prevented elastic expansion gives tensile-signed  $\sigma \approx -Y\alpha \Delta T$  on heating. State constraints and elastic limits.

Convection moves matter; net radiation is  $\varepsilon \sigma_{SB} A(T^4 - T_{env}^4)$  using kelvin. Lumped Newton cooling gives excess temperature decay  $\exp(-t/\tau)$ ,  $\tau = C/(hA)$ , only when internal gradients are negligible.

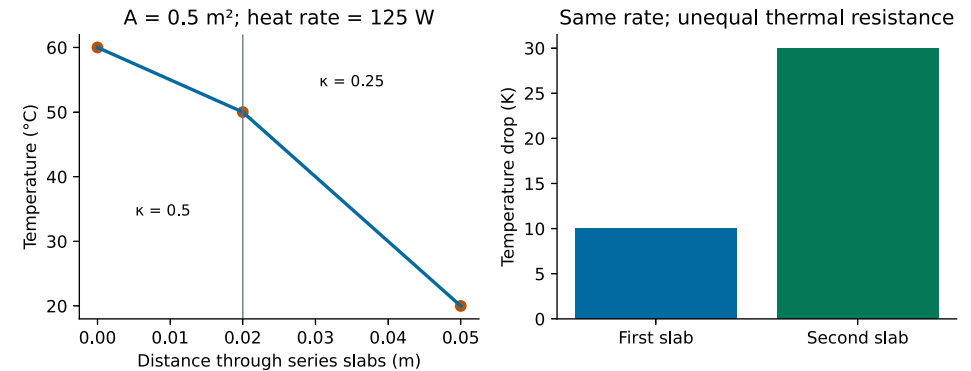
### ■ Worked method

Two slabs in series carry the same steady heat rate. Let resistances be 0.08 and 0.24 K/W. Boundary temperatures are 60 and 20 degrees Celsius.

$$\dot{Q} = \Delta T / (R_1 + R_2) = (40 \text{ K}) / (0.32 \text{ K/W}) = 125 \text{ W}.$$

$$\Delta T_1 = \dot{Q} R_1 = (125 \text{ W})(0.08 \text{ K/W}) = 10 \text{ K}.$$

The interface is 50 degrees Celsius when slab 1 touches the hot side. Heat rate has watt units; flux divides it by area.



## 2 Practice

2.1 Choose one answer. Two slabs in series without sources have thermal resistances R and 3R. The steady temperature-drop ratio is: [1]

- A 1:1
- B 3:1
- C 1:3
- D 1:9
- E Zero in both

2.2 Choose one answer. An isotropic unconstrained plate with a circular hole is warmed under small uniform expansion. Its hole radius: [1]

- A Shrinks
- B Stays fixed
- C Increases by fractional  $\alpha \Delta T$
- D Increases by fractional  $3\alpha \Delta T$
- E Must close

2.3 A body has  $C=200 \text{ J/K}$  and  $hA=10 \text{ W/K}$  under lumped Newton cooling. Its time constant is \_\_\_\_\_ s. Show your relation and units. [2]

[2]

[5]