

# Chemical Engineering RAG System

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## Question

give a numerical on conduction

## Answer

Based on the provided context, a numerical example for steady one-dimensional heat conduction in a plane wall is given in Example 2–11 from "Heat transfer a practical approach" by Yunus A. Cengel and Yunus Cengel.

**Problem Statement** (Source 7, Page 106): Consider a large plane wall of thickness  $L = 0.2$  m, thermal conductivity  $k = 1.2$  W/m · °C, and surface area  $A = 15$  m<sup>2</sup>. The two sides of the wall are maintained at constant temperatures of  $T_1 = 120^\circ\text{C}$  and  $T_2 = 50^\circ\text{C}$ , respectively. Determine: (a) The variation of temperature within the wall and the value of temperature at  $x = 0.1$  m. (b) The rate of heat conduction through the wall under steady conditions.

**Solution** (Source 7, Page 106 & Source 5, Page 109):

**Assumptions** (Source 7, Page 106-107): 1. Heat conduction is steady (temperature does not vary with time). 2. Heat conduction is one-dimensional (significant in one dimension only, negligible in others). 3. Thermal conductivity is constant. 4. There is no heat generation within the wall.

**Properties** (Source 7, Page 107): The thermal conductivity is given as  $k = 1.2$  W/m · °C.

**Analysis:**

(a) Variation of temperature within the wall:

1. Formulate the differential equation and boundary conditions: For steady one-dimensional heat conduction in a plane wall with constant thermal conductivity and no heat generation, the heat conduction equation in the  $x$ -direction (normal to the surface) is (Source 7, Page 107, Eq. 2–17):  $d^2T/dx^2 = 0$  The boundary conditions are the specified temperatures at the surfaces (Source 7, Page 107):  $T(0) = T_1 = 120^\circ\text{C}$  (at  $x = 0$ )  $T(L) = T_2 = 50^\circ\text{C}$  (at  $x = L = 0.2$  m)

2. Obtain the general solution of the differential equation: Integrating the differential equation once with respect to  $x$  yields (Source 7, Page 107):  $dT/dx = C_1$  Integrating a second time gives the general solution (Source 7, Page 107):  $T(x) = C_1x + C_2$  where  $C_1$  and  $C_2$  are arbitrary integration constants.

3. Apply boundary conditions to determine constants: \* At  $x = 0$ :  $T(0) = T_1 \rightarrow 120^\circ\text{C} = C_1(0) + C_2 \rightarrow C_2 = 120^\circ\text{C}$  \* At  $x = L$ :  $T(L) = T_2 \rightarrow 50^\circ\text{C} = C_1(0.2\text{ m}) + 120^\circ\text{C}$   $C_1(0.2\text{ m}) = 50^\circ\text{C} - 120^\circ\text{C} = -70^\circ\text{C}$   $C_1 = -70^\circ\text{C} / 0.2\text{ m} = -350^\circ\text{C/m}$

Substituting  $C_1$  and  $C_2$  back into the general solution, the specific solution for the temperature variation within the wall is (Source 5, Page 109):  $T(x) = (-350^\circ\text{C/m})x + 120^\circ\text{C}$

Temperature at  $x = 0.1$  m: Substituting  $x = 0.1$  m into the temperature relation (Source 5, Page 109):  $T(0.1\text{ m}) = (-350^\circ\text{C/m})(0.1\text{ m}) + 120^\circ\text{C} = -35^\circ\text{C} + 120^\circ\text{C} = 85^\circ\text{C}$

(b) Rate of heat conduction through the wall under steady conditions:

The rate of heat conduction anywhere in the wall is determined from Fourier's law (Source 5, Page 109):  $Q_{\text{wall}} = -kA(dT/dx)$

Since  $dT/dx = C_1 = -350 \text{ }^{\circ}\text{C/m}$  (from part a), and this is constant for steady one-dimensional conduction with constant  $k$  and no heat generation (Source 5, Page 109):  $Q_{\text{wall}} = -kA(C_1) Q_{\text{wall}} = -(1.2 \text{ W/m} \cdot \text{ }^{\circ}\text{C})(15 \text{ m}^2)(-350 \text{ }^{\circ}\text{C/m}) Q_{\text{wall}} = 6300 \text{ W}$

The rate of heat conduction through the wall is 6300 W. As noted in the discussion of Example 2-11, under steady conditions, the rate of heat conduction through a plane wall is constant (Source 5, Page 109).

## References

1. Heat transfer a practical approach (Yunus A. Cengel, Yunus Cengel) (Z-Library) (Page 131)
2. Heat transfer a practical approach (Yunus A. Cengel, Yunus Cengel) (Z-Library) (Page 291)
3. Heat transfer a practical approach (Yunus A. Cengel, Yunus Cengel) (Z-Library) (Page 314)
4. Heat transfer a practical approach (Yunus A. Cengel, Yunus Cengel) (Z-Library) (Page 81)
5. Heat transfer a practical approach (Yunus A. Cengel, Yunus Cengel) (Z-Library) (Page 109)
6. Heat transfer a practical approach (Yunus A. Cengel, Yunus Cengel) (Z-Library) (Page 42)
7. Heat transfer a practical approach (Yunus A. Cengel, Yunus Cengel) (Z-Library) (Page 106)
8. Heat transfer a practical approach (Yunus A. Cengel, Yunus Cengel) (Z-Library) (Page 141)