# Heat and Mass Transfer (DI05019071)

## Complete Lecture Deck

Milav Dabgar

Lecturer, GP Palanpur

July 23, 2026

# Numerical examples on Heat Exchangers (Part 1)

- Course: Heat and Mass Transfer (DI05019071)
- Unit 4: Heat exchanger
- Lecture 39: Numerical examples (LMTD Method)

# Lecture Agenda

- 1. Problem Solving Strategy
- 2. Recap of Key Formulas (Energy Balance & LMTD)
- 3. Example 1: Parallel Flow Heat Exchanger
- 4. Example 2: Counter Flow Heat Exchanger
- 5. Comparison and Discussion

# Problem Solving Strategy

- Step 1: Identify the flow arrangement (Parallel, Counter, Cross, etc.).
- Step 2: Note down given values (mass flow rates, specific heats, inlet/outlet temperatures, U).
- Step 3: Perform an overall energy balance to find any missing temperatures: Q = mh*Cph*ΔTh = mc*Cpc*ΔTc.
- Step 4: Calculate temperature differences at both ends (ΔT1, ΔT2).
- Step 5: Calculate LMTD (ΔTm).
- Step 6: Use Q = U * A * ΔTm to find the unknown (Area, U, or Q).

# Recap of Key Formulas

- Energy Balance: $Q = m_h * C_{ph} * (T_{h,in} - T_{h,out}) = m_c * C_{pc} * (T_{c,out} - T_{c,in})$
- Heat Transfer Rate: $Q = U * A * \Delta T_{lm}$
- LMTD Formula: $\Delta T_{lm} = (\Delta T1 - \Delta T2) / \ln(\Delta T1 / \Delta T2)$
- For Parallel Flow:
- - $\Delta T1 = T_{h,in} - T_{c,in}$
- - $\Delta T2 = T_{h,out} - T_{c,out}$
- For Counter Flow:
- - $\Delta T1 = T_{h,in} - T_{c,out}$
- - $\Delta T2 = T_{h,out} - T_{c,in}$

# Example 1: Problem Statement (Parallel Flow)

- Water ($Cp = 4.18$ kJ/kg.K) enters a parallel flow heat exchanger at 15°C at a rate of 0.5 kg/s.
- It is heated by hot oil ($Cp = 2.1$ kJ/kg.K) entering at 100°C at a rate of 0.8 kg/s.
- The overall heat transfer coefficient is 350 W/m$^2$.K.
- The outlet temperature of the oil is 60°C.
- Find: (a) The rate of heat transfer, (b) Outlet temperature of water, (c) The surface area of the heat exchanger.

# Example 1: Solution Step 1 & 2

- Step 1: Calculate Heat Transfer Rate (Q)
- Q = m_oil * Cp_oil * (T_oil,in - T_oil,out)
- Q = 0.8 kg/s * 2.1 kJ/kg.K * (100 - 60) K
- Q = 0.8 * 2.1 * 40 = 67.2 kW (or 67,200 W)
-
- Step 2: Find Outlet Temperature of Water (T_c,out)
- Q = m_water * Cp_water * (T_c,out - T_c,in)
- 67.2 = 0.5 * 4.18 * (T_c,out - 15)
- T_c,out - 15 = 67.2 / 2.09 = 32.15°C
- T_c,out = 47.15°C

# Example 1: Solution Step 3 & 4

- Step 3: Calculate $\Delta T1$ and $\Delta T2$ for Parallel Flow
- $\Delta T1 = T\_h,in - T\_c,in = 100 - 15 = 85°C$
- $\Delta T2 = T\_h,out - T\_c,out = 60 - 47.15 = 12.85°C$
- 
- Step 4: Calculate LMTD
- $\Delta T\_lm = (85 - 12.85) / \ln(85 / 12.85)$
- $\Delta T\_lm = 72.15 / \ln(6.615)$
- $\Delta T\_lm = 72.15 / 1.889 = 38.19°C$

# Example 1: Final Calculation

- Step 5: Calculate Surface Area (A)
- Formula: Q = U * A * $\Delta$T_lm
- Rearranging for A: A = Q / (U * $\Delta$T_lm)
- Substitute values (ensure Q is in Watts):
- A = 67,200 W / (350 W/$m^2$.K * 38.19 K)
- A = 67,200 / 13366.5
- Area (A) = 5.03 $m^2$

# Example 2: Problem Statement (Counter Flow)

- Let's use the same fluids, temperatures, and flow rates, but arrange the exchanger in Counter Flow.
- Oil: Inlet = $100^\circ$C, Outlet = $60^\circ$C. Q is still 67.2 kW.
- Water: Inlet = $15^\circ$C, Outlet = $47.15^\circ$C.
- U = 350 W/m$^2$.K
- Find: The surface area of the heat exchanger in counter-flow arrangement.
- Compare this area to the parallel flow case.

# Example 2: LMTD Calculation

- Calculate $\Delta$T1 and $\Delta$T2 for Counter Flow:
- $\Delta T1 = T\_h,in - T\_c,out$
- $\Delta T1 = 100 - 47.15 = 52.85°C$
-
- $\Delta T2 = T\_h,out - T\_c,in$
- $\Delta T2 = 60 - 15 = 45°C$
-
- Calculate LMTD:
- $\Delta T\_lm = (52.85 - 45) / \ln(52.85 / 45)$
- $\Delta T\_lm = 7.85 / \ln(1.174)$
- $\Delta T\_lm = 7.85 / 0.1608 = 48.81°C$

# Example 2: Final Area & Comparison

- Calculate Area:
- A = Q / (U * $\Delta$T_lm)
- A = 67,200 / (350 * 48.81)
- A = 67,200 / 17083.5 = 3.93 $m^2$
-
- Comparison:
- Parallel Flow Area = 5.03 $m^2$
- Counter Flow Area = 3.93 $m^2$
- Counter-flow requires ~22% less surface area for the exact same duty.

# Summary

- The LMTD method is straightforward when inlet and outlet temperatures are known or easily found via energy balance.
- Care must be taken to define $\Delta T1$ and $\Delta T2$ correctly based on the flow arrangement.
- Counter-flow configurations always yield a higher LMTD than parallel-flow for the same temperatures, resulting in a smaller required area.

# Next Lecture Preview

- Topic: Numerical Examples on Heat Exchangers (Part 2)
- Key topics:
- - What happens when we don't know the outlet temperatures?
- - Introduction to the Effectiveness-NTU method for problem-solving.
- - Solving cross-flow and shell-and-tube problems.