Thermal Resistance and Heat Transfer in Buildings

Learning Objectives

- Understand fundamental concepts of thermal resistance and conductivity
- Apply mathematical formulas to real-world construction scenarios
- Analyze different building materials and their thermal properties
- Evaluate and select appropriate insulation solutions

Warm-Up Activity: Understanding Heat Transfer (10 minutes)

Work with a partner to explore these concepts:

Quick Experiment: Place your hand on different surfaces in the room (wood desk, metal chair, window glass)

1. Which materials feel colder? Why do you think this happens?

2. How does this relate to building materials?

Key Concepts Exercise (15 minutes)

Complete the following matching exercise and fill in the blanks:

Match the concept with its definition:

1. Thermal Resistance (R-value)	A. Measures heat flow through a material
2. Thermal Conductivity (λ)	B. Material's ability to resist heat flow
3. U-value	C. Overall heat transfer coefficient

Practical Calculations (20 minutes)

Solve these real-world problems:
Problem 1:

Calculate the R-value for a 200mm thick wall with $\lambda = 0.8$ W/mK

Problem 2:

If a wall needs to achieve $U \leq 0.24$ W/m²K, calculate the required insulation thickness using EPS ($\lambda = 0.039$ W/mK)

Material Analysis Activity (25 minutes)

Complete the following table for common building materials:

Material	λ-value (W/mK)	Typical Thickness (mm)	R-value (m²K/W)
Brick	0.72	240	
Mineral Wool	0.036	100	
Concrete	2.1	200	

Design Challenge (30 minutes)

Working in groups of 3-4, design an external wall assembly that meets Romanian standards:
Requirements:

- Must achieve $U \leq 0.24$ W/m²K
- Maximum total thickness: 400mm
- Must include structural and insulating layers
- Consider cost and local availability

Draw your wall assembly here:

[Space for wall assembly diagram]

Show your calculations:

Advanced Heat Transfer Concepts

Thermal Bridging in Building Construction

Thermal bridges are areas in building envelopes where heat flows differently (usually increased heat flow) compared to surrounding areas. Common locations include:

- Balcony connections
- Window and door frames
- Steel beams penetrating insulation
- Corner joints in walls

Impact Calculation:

For a typical thermal bridge at a concrete balcony:

- Linear thermal transmittance (ψ-value): 0.8 W/mK
- Bridge length: 5 meters
- Temperature difference: 20°C
- Heat loss = $0.8 \times 5 \times 20 = 80$ Watts

Practical Exercise: Thermal Bridge Detection

Using Thermal Imaging:

1. Analyze the provided thermal images
2. Identify potential thermal bridges
3. Propose solutions for each identified issue

Location	Issue Identified	Proposed Solution

Window Frame		
Wall Corner		

Dynamic Heat Transfer Analysis

Time-Dependent Thermal Behavior

Understanding how building materials respond to temperature changes over time is crucial for efficient design.

Important Parameters:

- **Thermal Mass:** Material's ability to store heat energy
- **Specific Heat Capacity:** Energy required to change temperature
- **Time Lag:** Delay between external and internal temperature peaks

Calculate Thermal Mass Effect

For a concrete wall (200mm thick):

- Density (ρ) = 2400 kg/m^3
- Specific heat capacity (c) = 880 J/kgK
- Area = 1 m^2
- Thermal mass = $\rho \times c \times$ volume

Case Study: Modern Office Building

Project Overview:

Analysis of a 5-story office building in Bucharest with the following characteristics:

- Total floor area: 2500 m²
- Glazing ratio: 40%
- Operating hours: 8:00 - 18:00

Thermal Performance Analysis

Building Element	U-value (W/m²K)	Area (m²)	Heat Loss (W/K)
Walls	0.24	1200	
Windows	1.4	800	

Advanced Insulation Strategies

Modern Insulation Materials

Material Type	λ-value (W/mK)	Cost (€/m²)	Advantages
Aerogel	0.013-0.014	70-100	Ultra-thin, high performance
Vacuum Insulation Panels	0.004	90-120	Highest performance
Phase Change Materials	Variable	50-80	Thermal storage

Design Challenge:

Select appropriate insulation materials for these scenarios:

1. Historic building renovation with space constraints
2. Modern passive house design
3. Industrial cold storage facility

Energy Performance Calculations

Annual Energy Consumption Analysis

Calculate the annual heating energy requirement using:

$Q = U \times A \times \Delta T \times time$

Where:

- Q = Energy consumption (kWh)
- U = Overall heat transfer coefficient (W/m^2K)
- A = Surface area (m^2)
- ΔT = Temperature difference (K)
- time = Duration (hours)

Final Assessment Project

Building Envelope Optimization

Working in teams, complete a comprehensive analysis of a building envelope design:

Required Elements:

1. Thermal resistance calculations for all assemblies
2. Thermal bridge analysis and mitigation strategies
3. Cost-benefit analysis of selected materials
4. Energy performance simulation results
5. Construction details for critical junctions

Assessment Criteria:

Criterion	Weight	Points Available
Technical Accuracy	30%	30
Innovation	25%	25
Presentation	25%	25

Documentation	20%	20

Assessment and Reflection (15 minutes)

Complete these reflection questions individually:

1. What was the most challenging concept you learned today?
2. How might you apply these thermal concepts in real-world situations?
3. What questions do you still have about thermal resistance?

Homework Assignment

Complete for next session:

1. Calculate the total R-value for your bedroom wall
2. Research one innovative insulation material and prepare a brief report
3. Complete practice problems in workbook (pages 45-47)