S.I. Units

- Seven basic units
  - meter
  - kilogram
  - second
  - ampere
  - Kelvin
  - mole
  - candela

- Derived units
  - radian
  - steradian
  - Newton
  - Pascal
  - Joule
  - Watt
  - lumen
  - lux
Heat transfer modes due to °T difference

- **Conduction**
  - conductivity $\lambda$ [W/(m K)]
  - U-value [W/(m$^2$K) ]
  - resistance $R$ [m$^2$K/W ]
  - surface film:
    - $\alpha_{ext} \approx 23$ W/m$^2$K i.e. $R_{se} \approx 0.04$ m$^2$K/W
    - $\alpha_{int} \approx 8$ W/m$^2$K i.e. $R_{si} \approx 0.13$ m$^2$K/W
Heat transfer modes due to °T difference

Conduction and insulation laws

- Heat flow = surface x U x ΔT i.e. = surface x (1/R<sub>tot</sub>) x ΔT
- R<sub>tot</sub> = 1/α<sub>ext</sub> + Σ R<sub>i</sub> + 1/α<sub>int</sub> if resistance in series
- A<sub>tot</sub> x R<sub>tot</sub><sup>-1</sup> = Σ (A<sub>e1</sub> x R<sub>e1</sub><sup>-1</sup>)
  if in parallel

Images by MIT OCW.
Heat transfer

- Heat transfer modes due to °T difference
  - Conduction and insulation laws: resistances in series

\[ R_T = R_{si} + R_1 + R_2 + R_3 + R_4 + R_{se} \]

\[ q \left( \frac{W}{m^2} \right) = U \left( T_i - T_e \right) \]

Heat transmittance

\[ U = \frac{1}{R_T} \]

Heat flow density
Heat transfer modes due to °T difference

- Conduction and insulation laws: resistances in series

\[ R_T = R_{si} + R_1 + R_2 + R_3 + R_4 + R_{se} \]

\[ R = \frac{d}{\lambda} \]

\[ R_n = \frac{d_n}{\lambda_n} \]

\[ (T_n - T_{n+1}) = R_n \ q \]

\[ (T_i - T_e) = \frac{q}{U} = R_T \ q \]

\[ 0,13 \ m^2K/W \]

\[ 0,04 \ m^2K/W \]
Heat transfer

Heat transfer modes due to °T difference

- Conduction and insulation laws: resistances in series and parallel

60 m³ room surrounded by other rooms at equal temperature (20°C)

Façade in contact with exterior (0°C): surface 10 m² including window 3 m²

Wall = brick (37 cm, R = 0.8 m²K/W) + mineral wool (4 cm, λ = 0.04 W/m²K) +
  pine paneling (20 cm, R = 0.2 m²K/W)

$U_{\text{window}} = 2 \text{ W/m}^2\text{K}$
Heat transfer

- Heat transfer modes due to °T difference
  - Conduction
  - Convection
    - Convection coefficient $h_c$ [W/(m²K)]
Heat transfer modes due to °T difference

- Conduction
- Convection
- Radiation
  - temperature \sim \text{wavelength} \text{[radiated power per m}^2 \sim \sigma T^4\text{]}

Image by MIT OCW.
Heat transfer

- Heat transfer modes due to °T difference
  - Conduction
  - Convection
  - Radiation
    - temperature ~ wavelength

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright aluminum</td>
<td>0.05</td>
<td>0.95</td>
<td>0.05</td>
<td>0.95</td>
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<tr>
<td>Galvanized steel</td>
<td>0.25</td>
<td>0.75</td>
<td>0.25</td>
<td>0.75</td>
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<tr>
<td>White paint</td>
<td>0.20</td>
<td>0.80</td>
<td>0.90</td>
<td>0.10</td>
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<tr>
<td>Fresh whitewash</td>
<td>0.12</td>
<td>0.88</td>
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<td>Lt. green paint</td>
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<td>Dk. green paint</td>
<td>0.70</td>
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<td>Black paint</td>
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<tr>
<td>Concrete</td>
<td>0.60</td>
<td>0.40</td>
<td>0.90</td>
<td>0.10</td>
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</tbody>
</table>

Images by MIT OCW.
Solar radiation

- Heat transfer modes due to °T difference for windows
  - Same law for heat loss (U value), impact \( \propto \Delta T \) (+ air infiltration)
- Additional heat gain component: solar gains
  - SHGC or g-value (-) through transparent materials: \( \tau_{\text{sol dir}} + q \)
    (different from luminous \( \tau_{\text{vis}} \))
Solar radiation

- Additional heat gain component: solar gains
  - SHGC or g-value (-) through transparent materials

<table>
<thead>
<tr>
<th>Material</th>
<th>SHGC or g-value [-]</th>
<th>U value [W/m²K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass only</td>
<td>0.72</td>
<td>2.7</td>
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<tr>
<td>White Aluminum Slats</td>
<td>0.13</td>
<td>2.4</td>
</tr>
<tr>
<td>Wooden Roller</td>
<td>0.13</td>
<td>2.7</td>
</tr>
<tr>
<td>Clear</td>
<td>0.60</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.7</td>
</tr>
</tbody>
</table>

Image by MIT OCW.
Solar radiation

- Additional heat gain component: solar gains
  - SHGC or g-value (-) through transparent materials
  - Sol-air temperature concept for opaque materials

\[ G \times \alpha = h \times (T_s - T_o) \]
Heat Flow

- **Reading assignment from Textbook:**
  - “Introduction to Architectural Science” by Szokolay: § 1.1.1 - 1.1.2 + § 1.4.1

- **Additional readings relevant to lecture topics:**
  - "How Buildings Work" by Allen: pp. 47 – 51 in Chap 8
  - "Heating Cooling Lighting" by Lechner: Chap 3