S.I. Units

- Seven basic units
  - meter
  - kilogram
  - second
  - ampere
  - Kelvin
  - mole
  - candela
- Derived units
  - radian
  - steradian
  - Newton
  - Pascal
  - Joule
  - Watt
  - lumen
  - lux

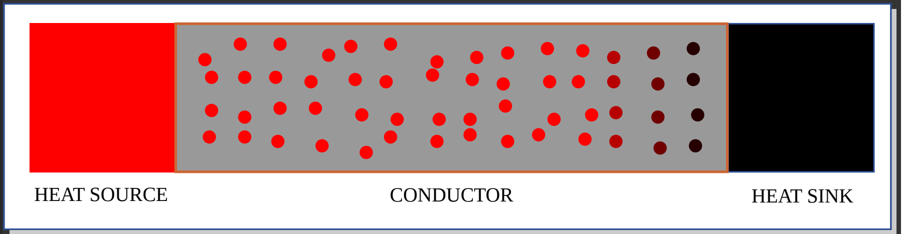
Heat transfer

Heat transfer modes due to °T difference

- Conduction
  - conductivity λ [W/(m K)]
  - U-value [W/(m²K)]
  - resistance R [m²K/W]
  - surface film:

$\alpha_{ext} \approx 23$ W/m²K i.e. $R_{se} \approx 0{,}04$ m²K/W

$\alpha_{int} \approx 8$ W/m²K i.e. $R_{si} \approx 0{,}13$ m²K/W



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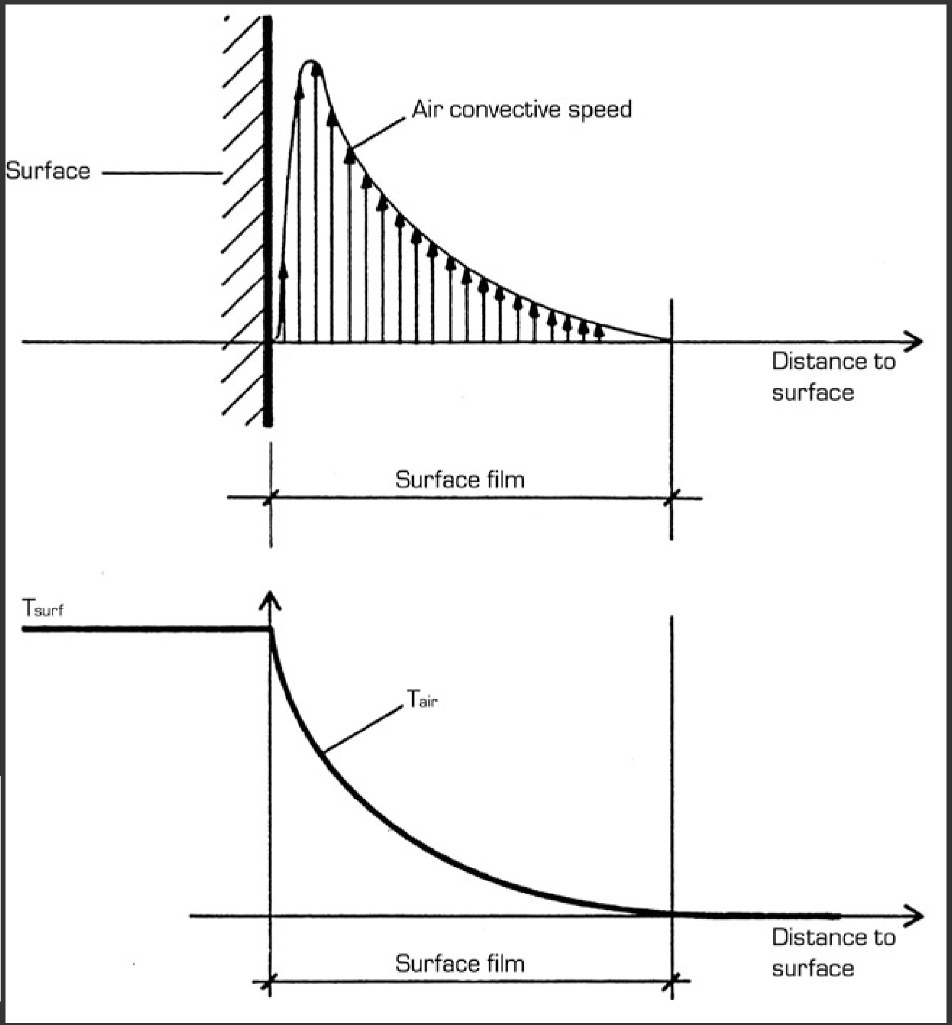
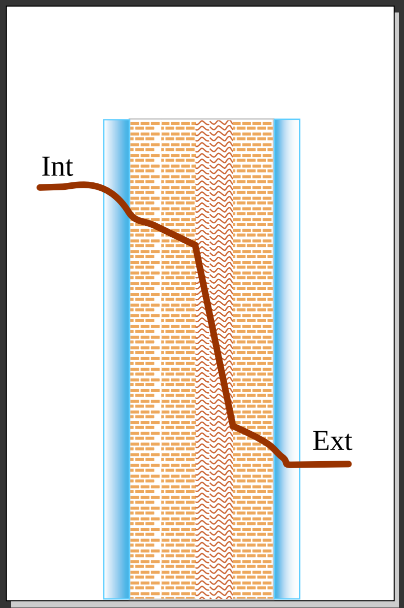
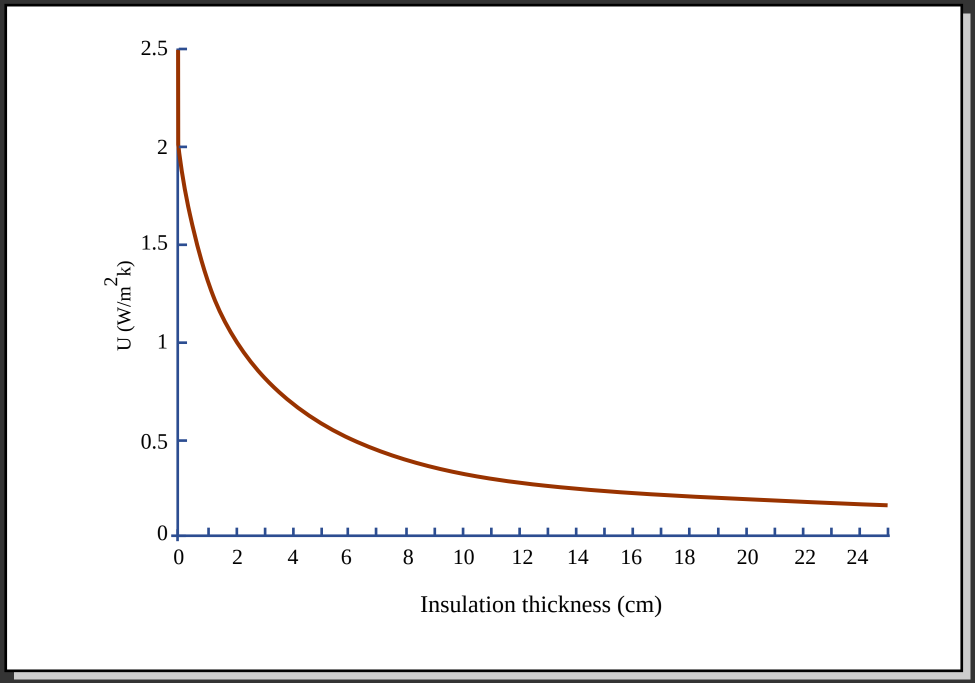


Heat transfer

Heat transfer modes due to °T difference

- Conduction and insulation laws
  - Heat flow = surface x U x ΔT i.e. = surface x (1/R_{tot}) x ΔT
  - $R_{tot} = 1/\alpha_{ext} + \Sigma R_i + 1/\alpha_{int}$ if resistance in series
  - $A_{tot} \times R_{tot}^{-1} = \Sigma (A_{el1} \times R_{el1}^{-1})$ if in parallel





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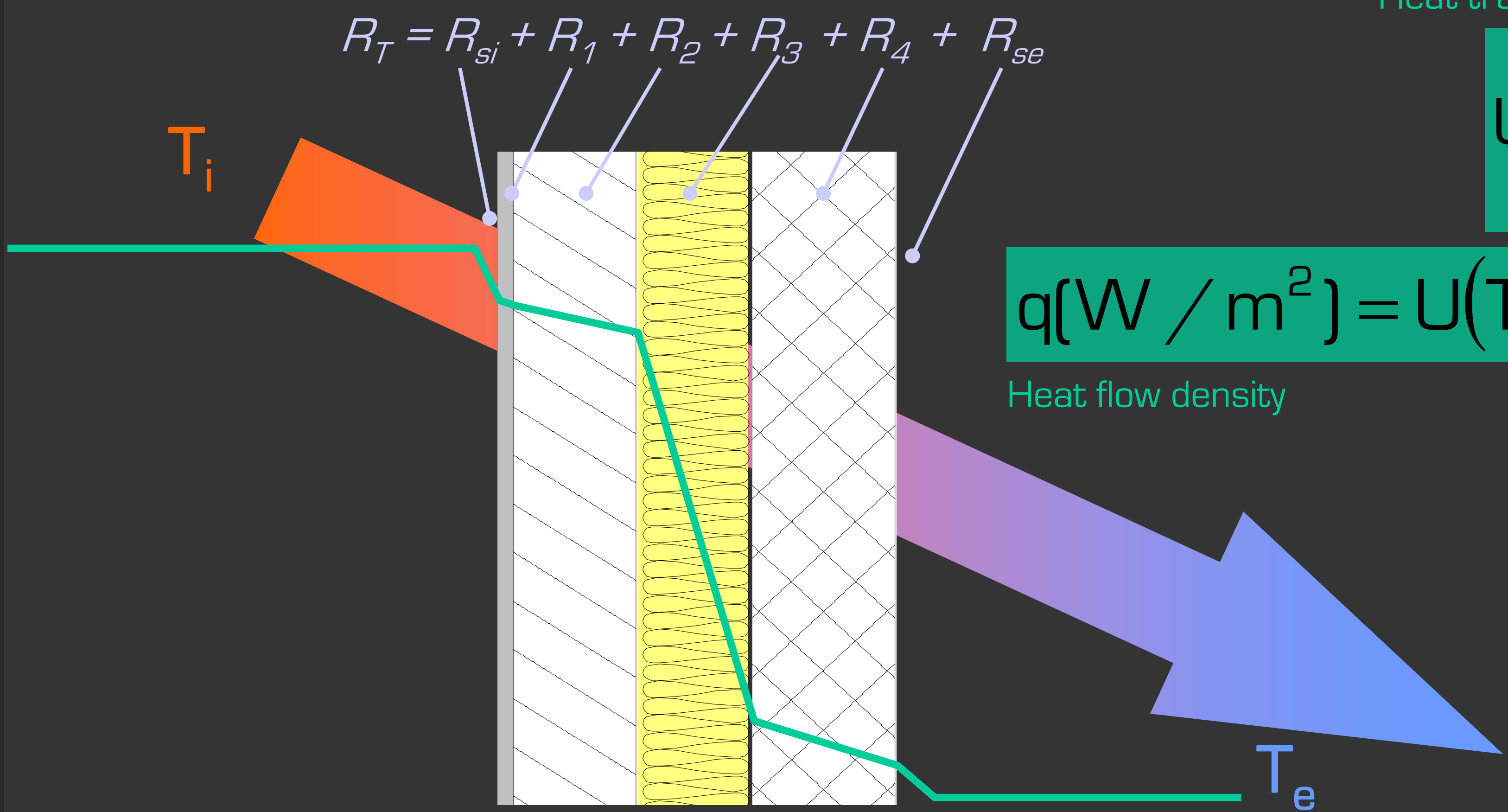
Heat transfer

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



Heat transmittance

$$U = \frac{1}{R_T}$$

$$q(W/m^2) = U(T_i - T_e)$$

Heat flow density

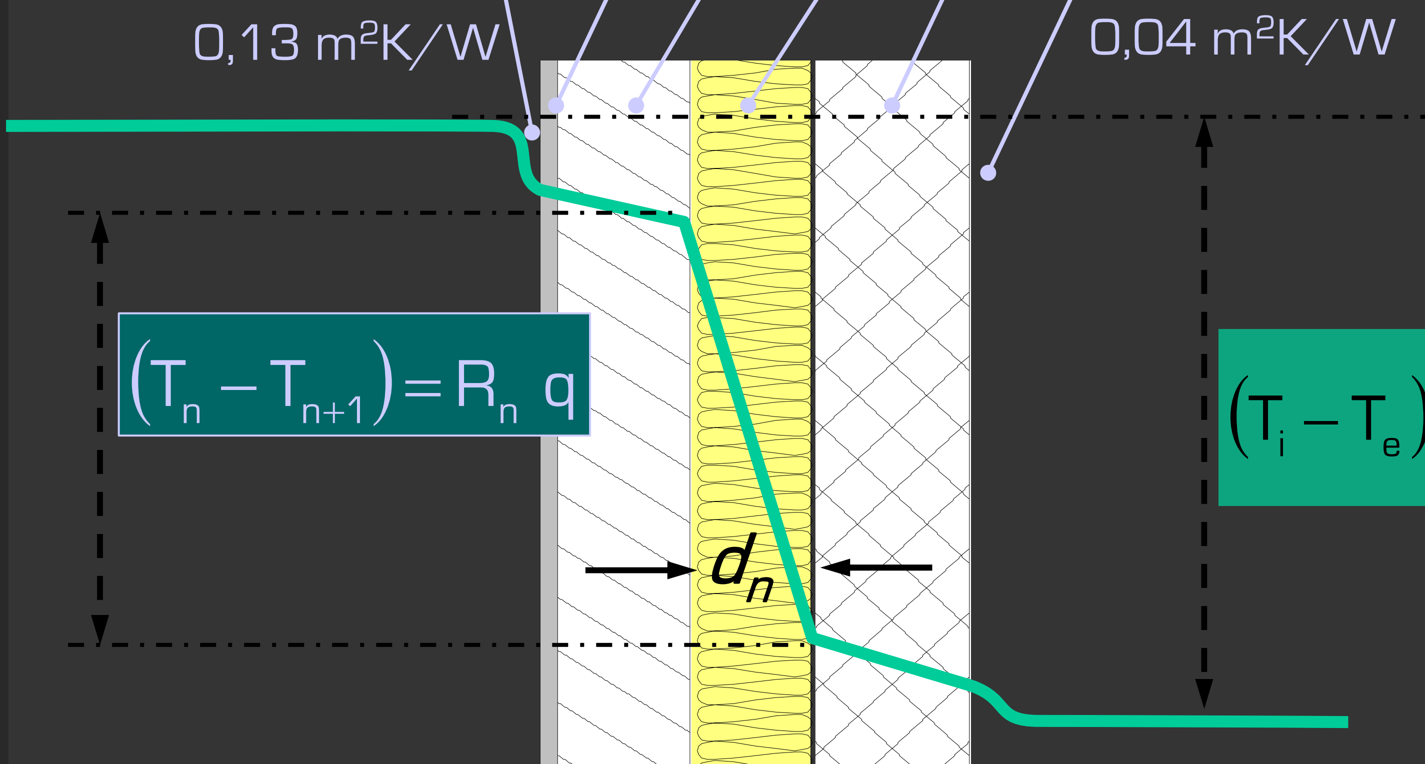
Heat transfer

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

$$R = \frac{d}{\lambda}$$

$$R_n = \frac{d_n}{\lambda_n}$$

$$R_T = R_{si} + R_1 + R_2 + R_3 + R_4 + R_{se}$$



$$\left(T_n - T_{n+1}\right) = R_n \; q$$

$$\left(T_i - T_e\right) = \frac{q}{U} = R_T \; q$$

Heat transfer

Heat transfer modes due to °T difference

- Conduction and insulation laws: resistances in series and parallel

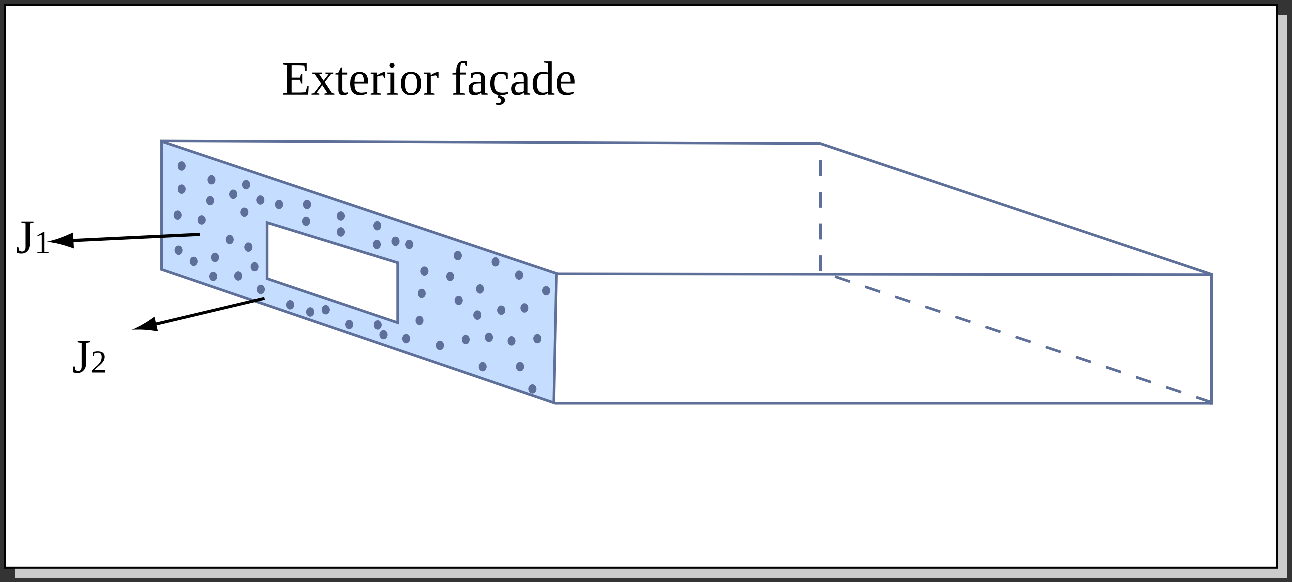


Image by MIT OCW.

60 m^3 room surrounded by other rooms at equal temperature (20°C)

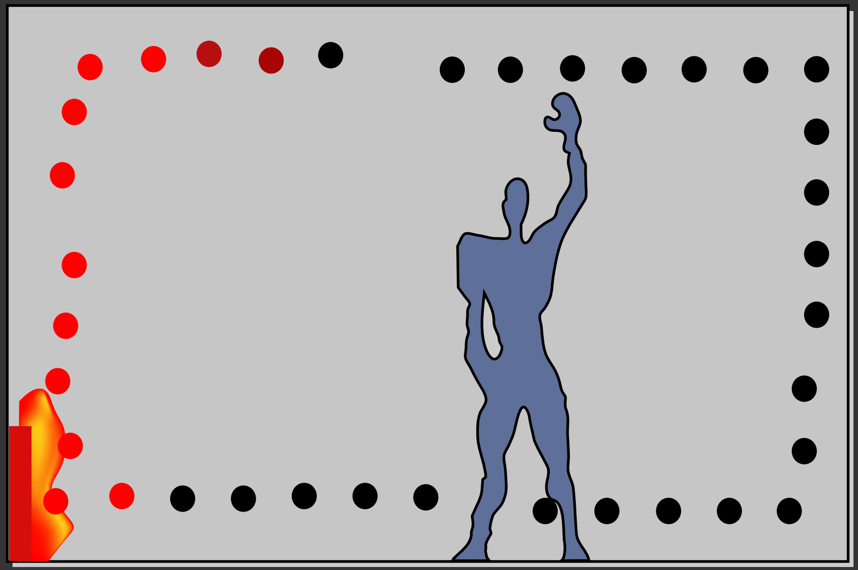
Façade in contact with exterior (0°C): surface 10 m^2 including window 3 m^2

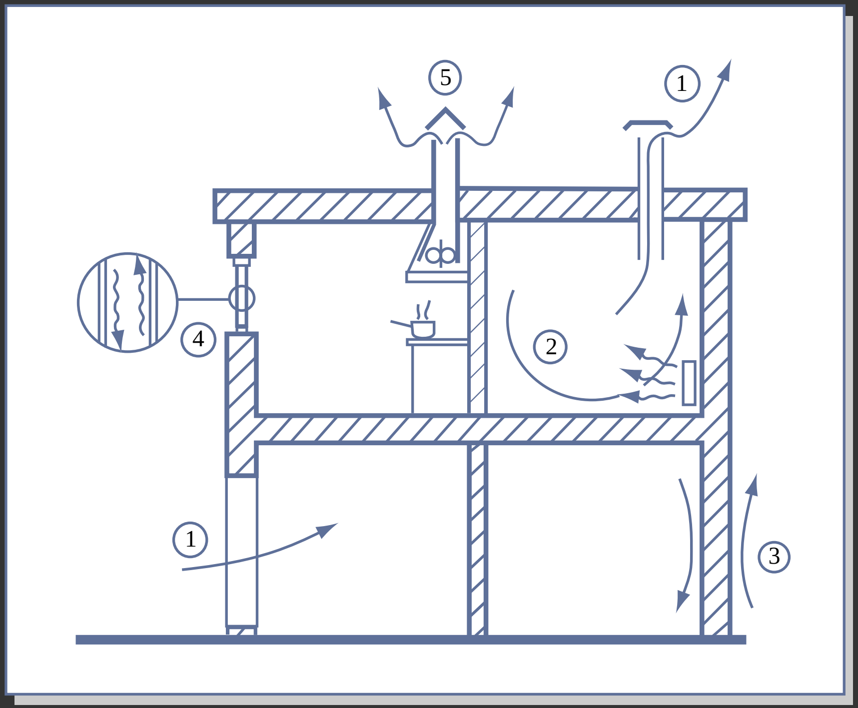
Wall = brick (37cm, $R = 0.8\ m^2K/W$) + mineral wool (4 cm, $\lambda = 0.04\ W/m^2K$) + pine paneling (20 cm, $R = 0.2\ m^2K/W$)

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

Heat transfer

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





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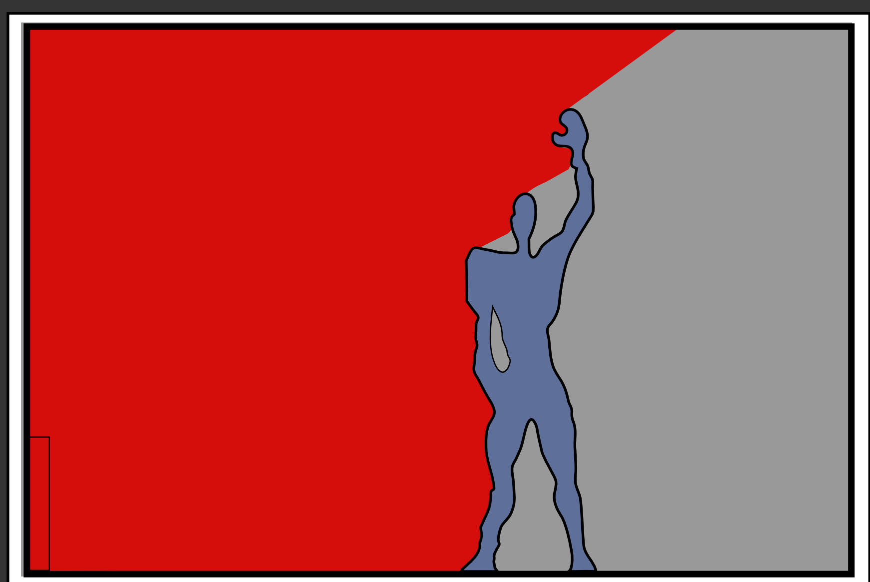
Heat transfer

- Heat transfer modes due to °T difference
  - Conduction
  - Convection
  - Radiation
    - temperature ~ wavelength (radiated power per m^2 ~ $\sigma\, T^4$)



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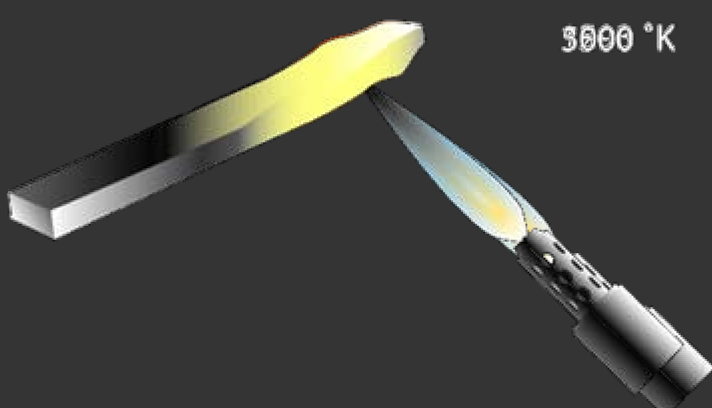
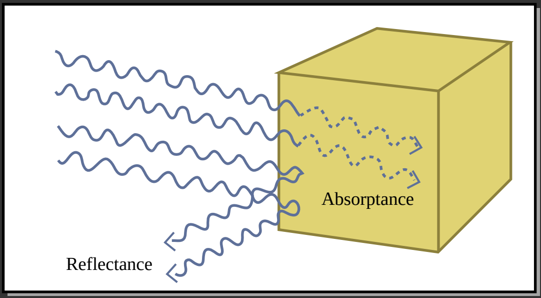
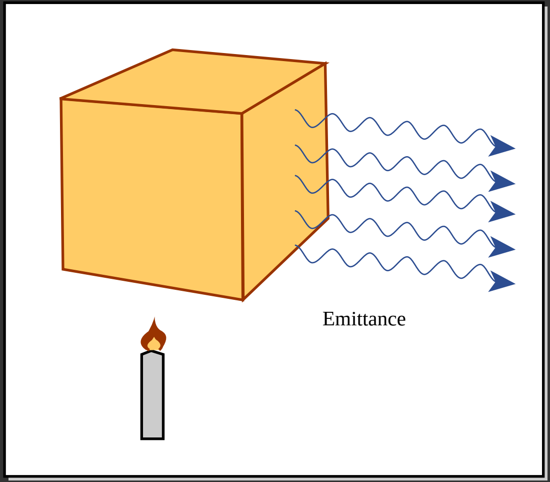


Heat transfer

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

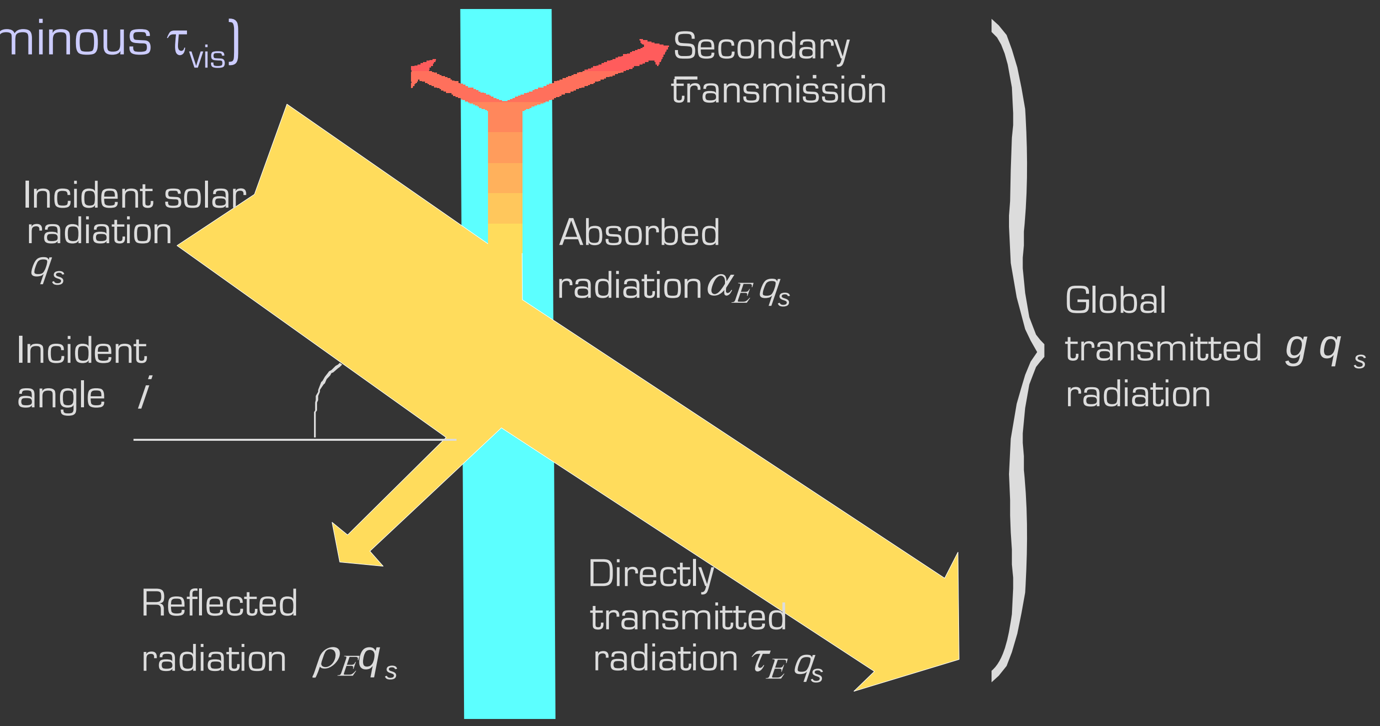


	Solar Radiation		Terrestrial Radiation	
	Absorp. Emitt.	Reflect.	Absorp. Emitt.	Reflect.
Bright aluminum	0.05	0.95	0.05	0.95
Galvanized steel	0.25	0.75	0.25	0.75
White paint	0.20	0.80	0.90	0.10
Fresh whitewash	0.12	0.88	0.90	0.10
Lt. green paint	0.40	0.60	0.90	0.10
Dk. green paint	0.70	0.30	0.90	0.10
Black paint	0.85	0.15	0.90	0.10
Concrete	0.60	0.40	0.90	0.10



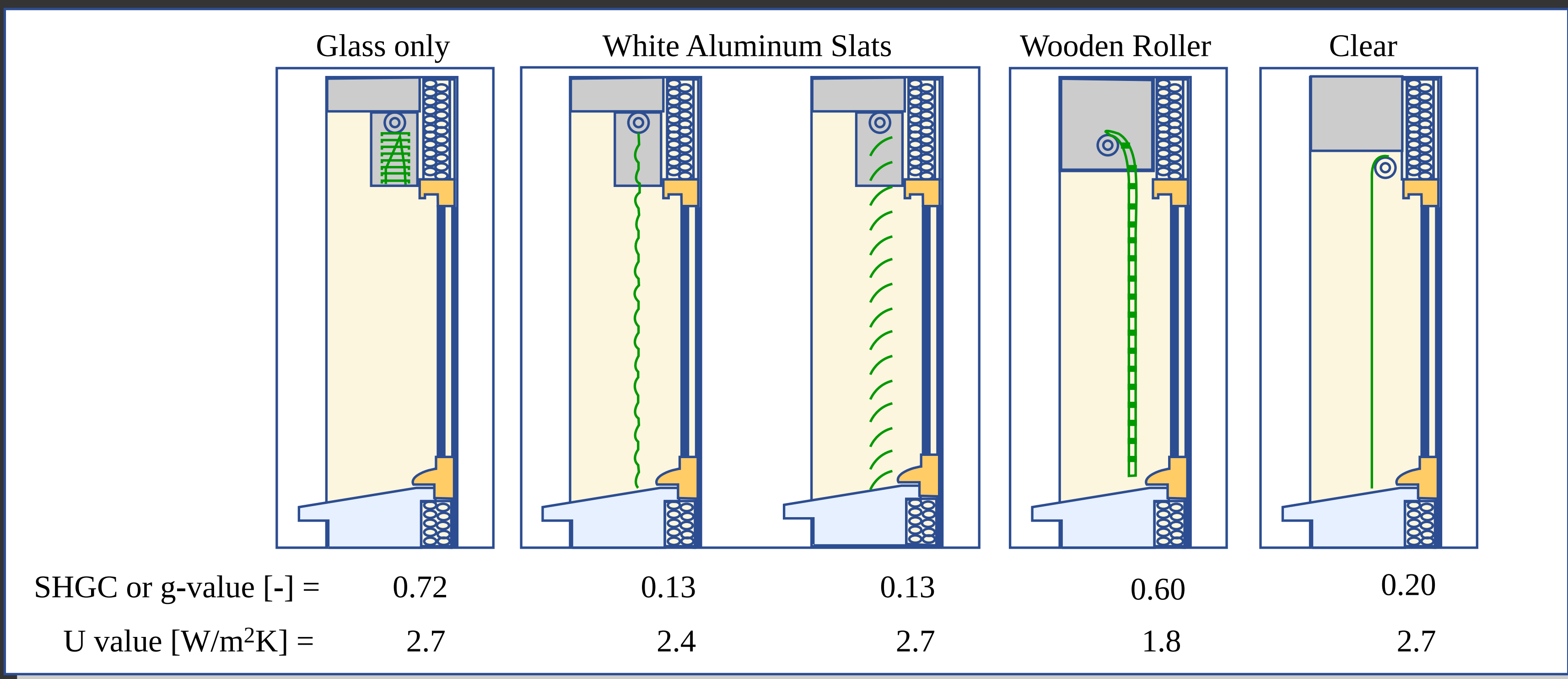
Solar radiation

- 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: $\tau_{sol\ dir} + q$ (different from luminous τ_{vis})



Solar radiation

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



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Solar radiation

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

$$G \times \alpha = h \times (T_s - T_o)$$

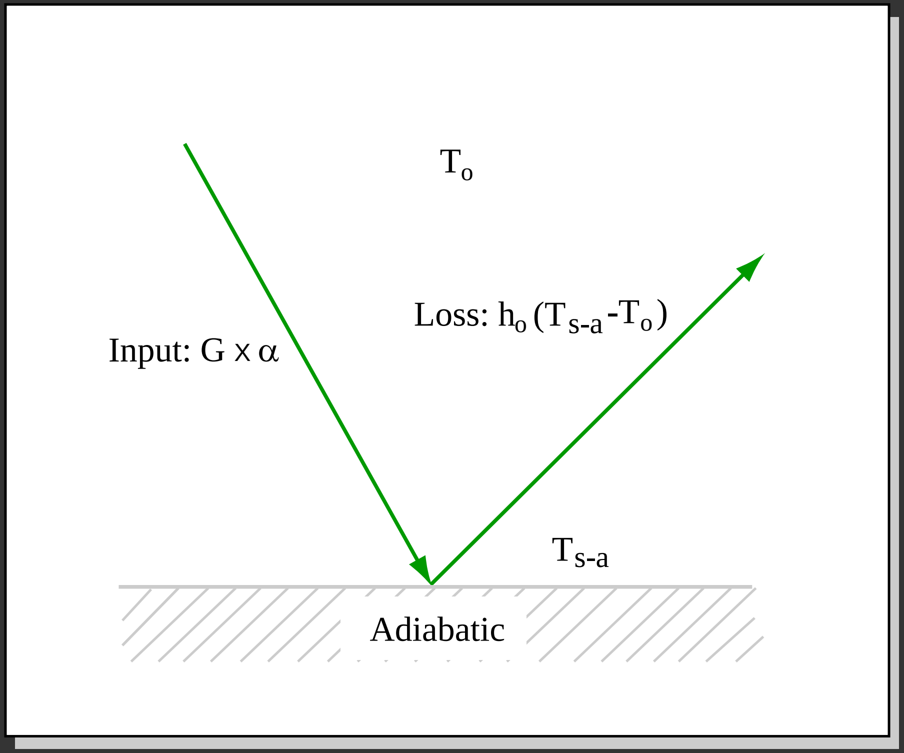

Image by MIT OCW.

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
  - Information about units: http://physics.nist.gov/cuu/Units/