Heat interactions in Thermodynamics

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Work in terms of generalized forces & displacement

- $W = p^{*}dV - \boldsymbol{\sigma}^{*}\mathbf{d(A)} - v^{*}dq - \mu H^{*}d(vM) - E^{*}d(vP)$...
- Generalized force-Intensive
- Generalized displacement-Extensive
- "Reversible transformation": Infinitesimal...While undertaking Cyclic transformation both the system & surrounding should come to the same state...All *states* should be represented in the state diagram during the transformation

$$\boldsymbol{\Delta U = Change\ in\ Internal\ Energy\ U = "Heat\ \&\ work\ exchange" = "q - W"}$$

Heat: Energy transfer due to temperature difference

- "Thermal" energy flows from regions of high to low temperature
- Heat transfer may or may not be accompanied by T change

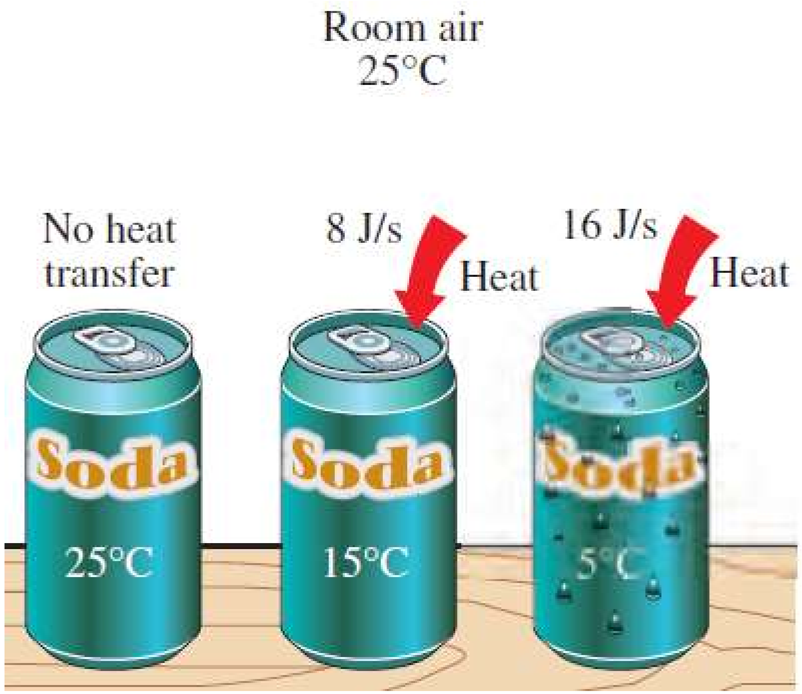


Fig: Cengel & Boles: TD

Thermal energy vs. heat

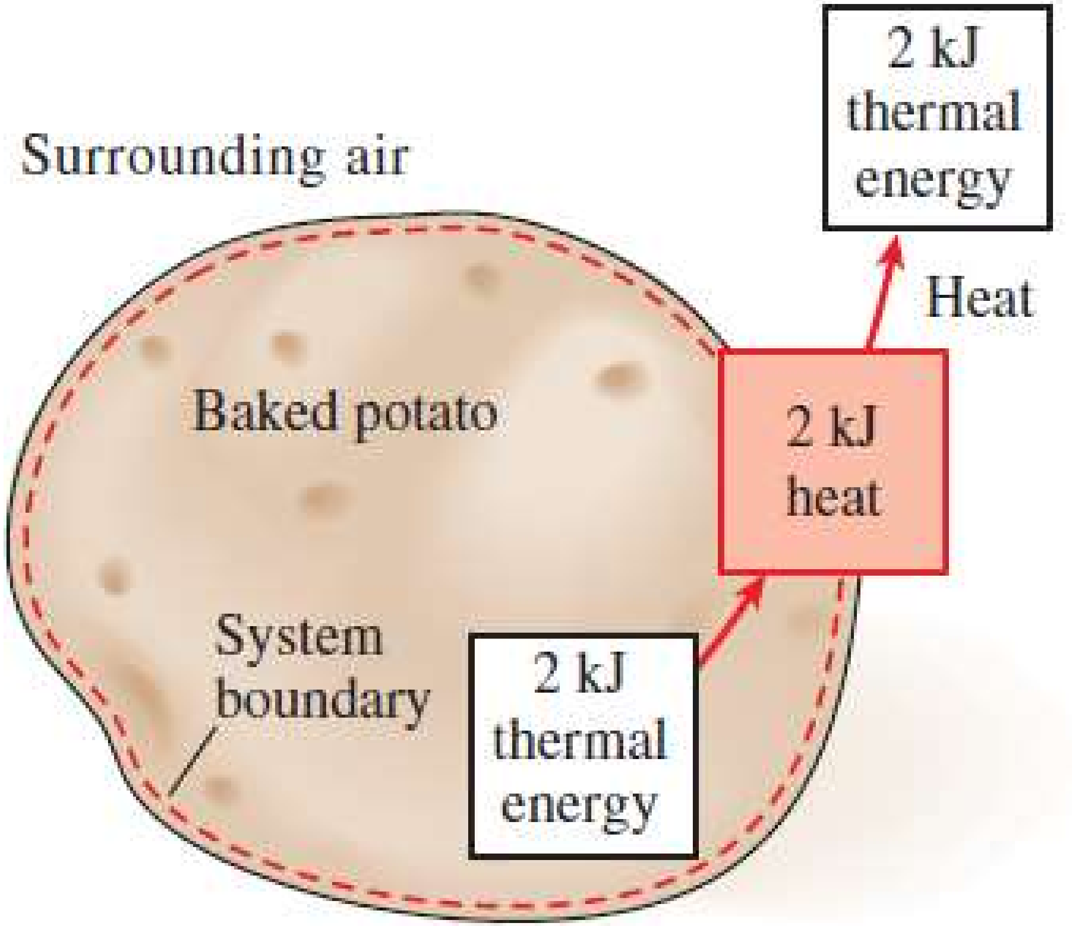


Fig: Cengel & Boles: TD

Adiabatic: A+dia+ba…Opposite of dia-thermal

- **Even without heat transfer in an adiabatic system, T of the system can be changed via work transfer**

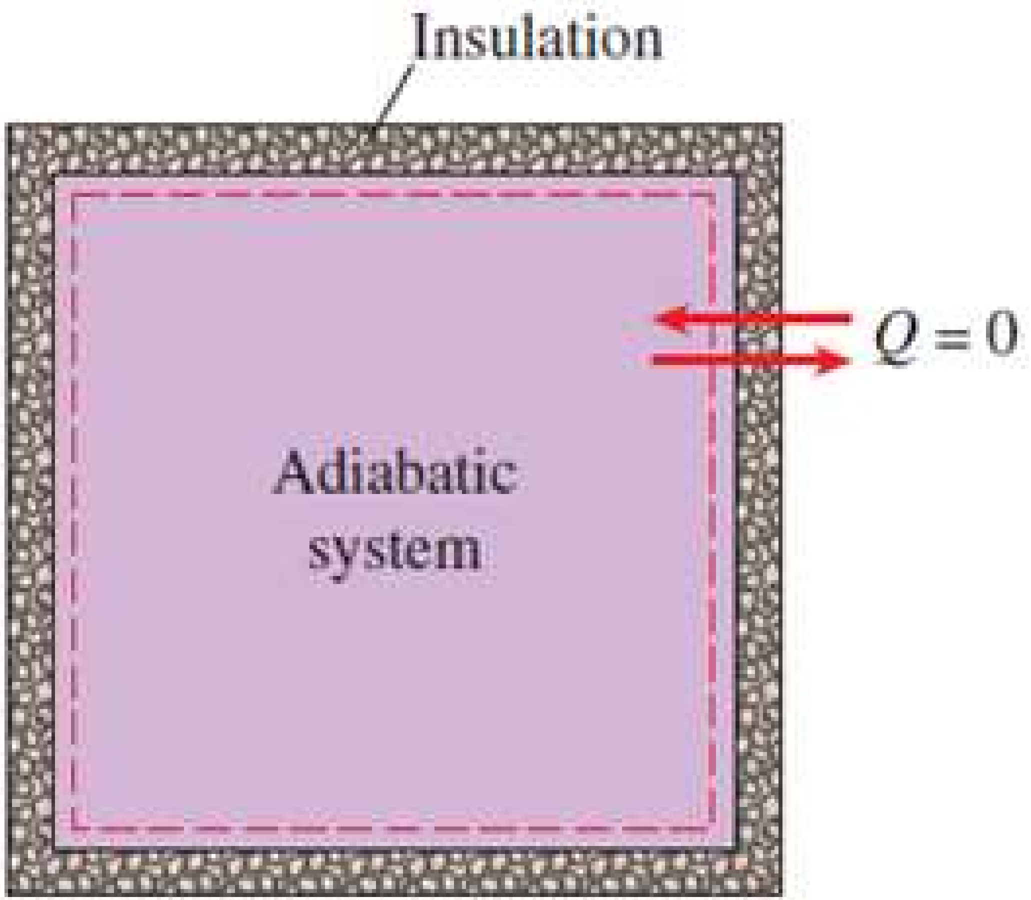
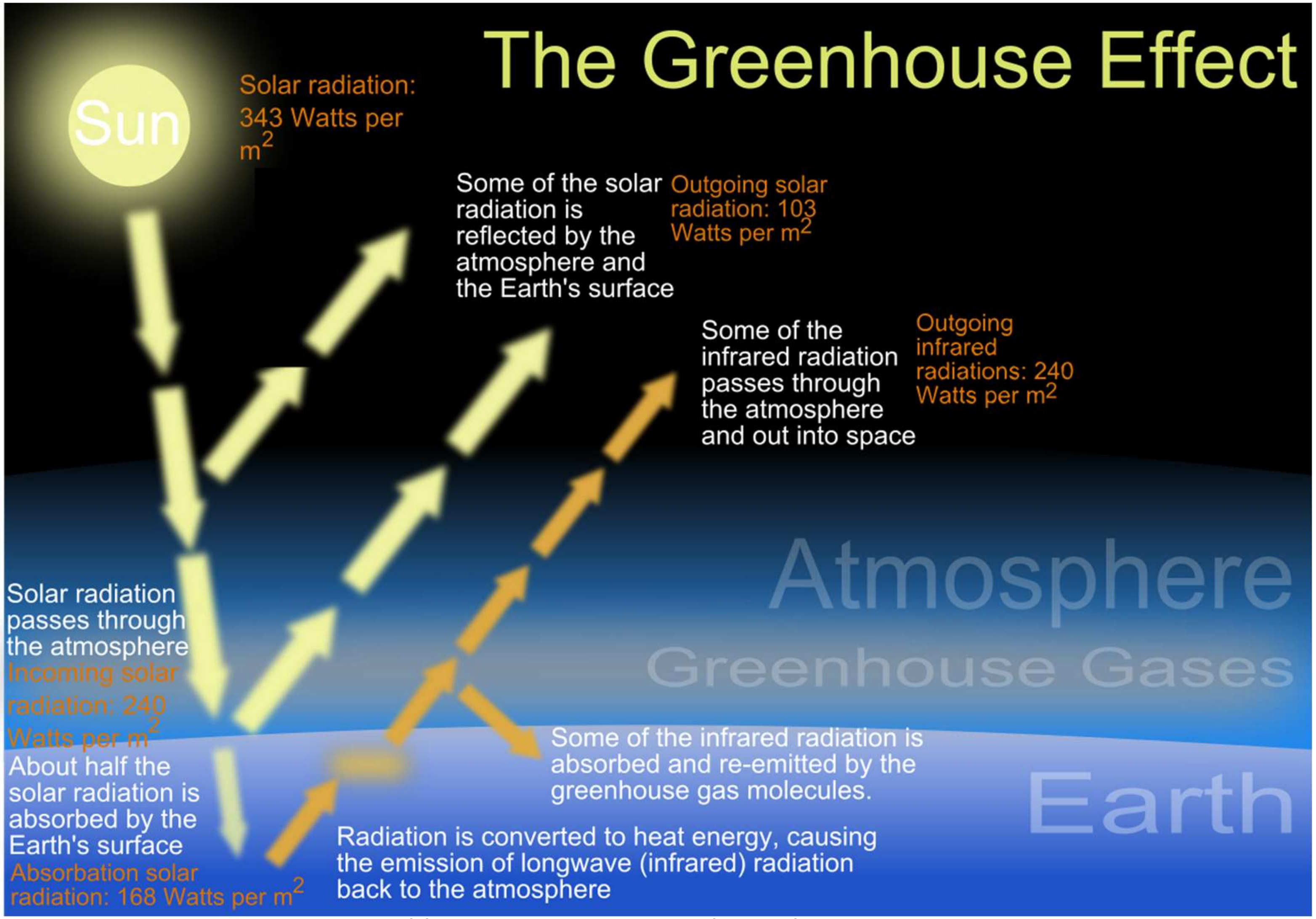


Fig: Cengel & Boles: TD

3 Modes of heat transfer

- Radiation-Does not require material medium
- Conduction-Often most important in solids
- Convection-Often most important in fluids



https://en.wikipedia.org/wiki/Heat_transfer

Conduction

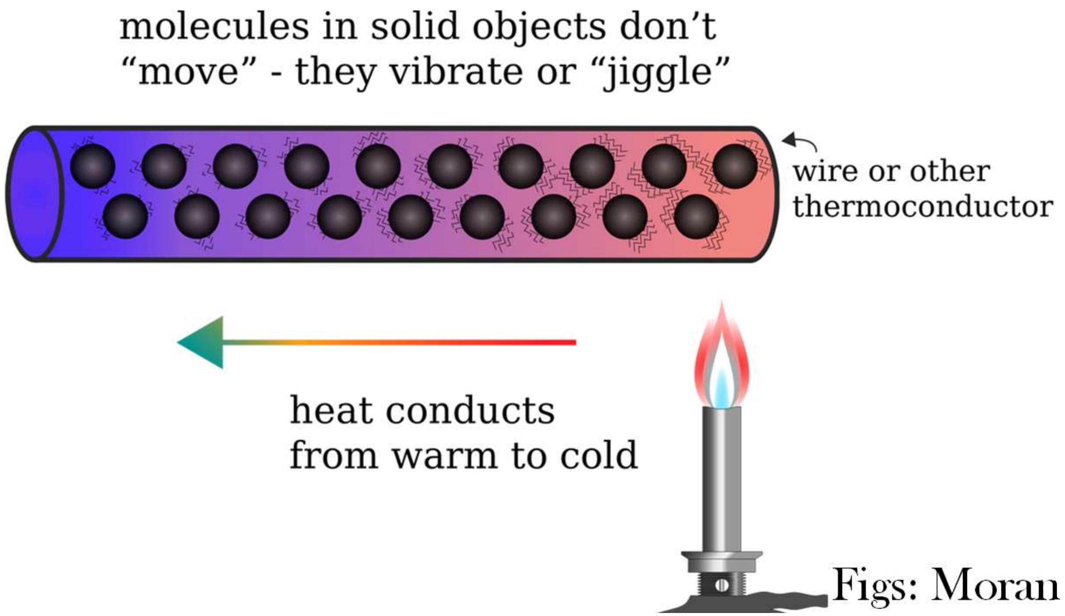
- "Vibrational thermal energy" transferred from regions of higher T (higher average vibrational energy) to lower T (lower av. vib. en.)

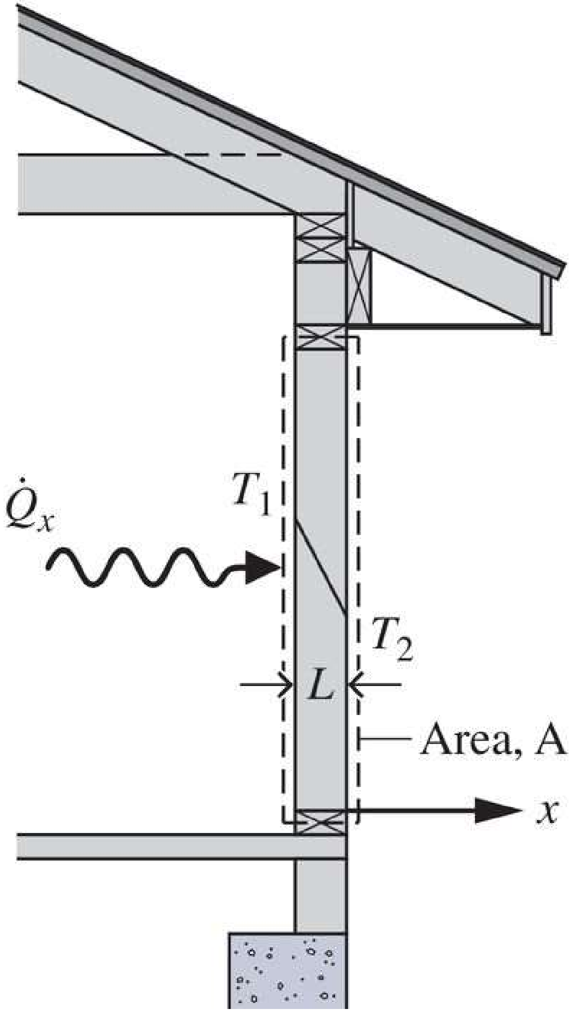
- Time rate of themal energy transfer via conduction: *Fourier's law*.

$$\frac{dT}{dx} = \frac{T_2 - T_1}{L} (< 0)$$

$$\dot{Q}_x = -\kappa A \left[\frac{T_2 - T_1}{L} \right]$$

$$\dot{Q}_x = -\kappa A \frac{dT}{dx}$$





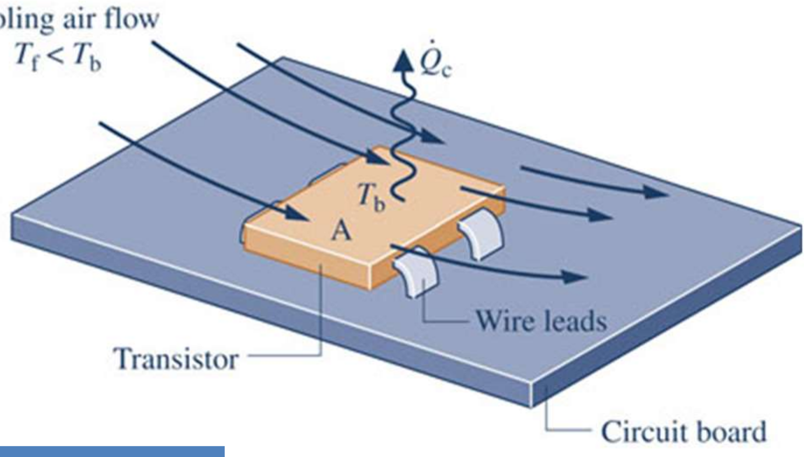
Figs: Moran & Shapiro: TD, https://www.goconqr.com/

Convection

- Combined effect of conduction at the solid interface and bulk flow at the fluid interface

- Newton's law of cooling

$$\dot{Q}_c = hA[T_b - T_f]$$

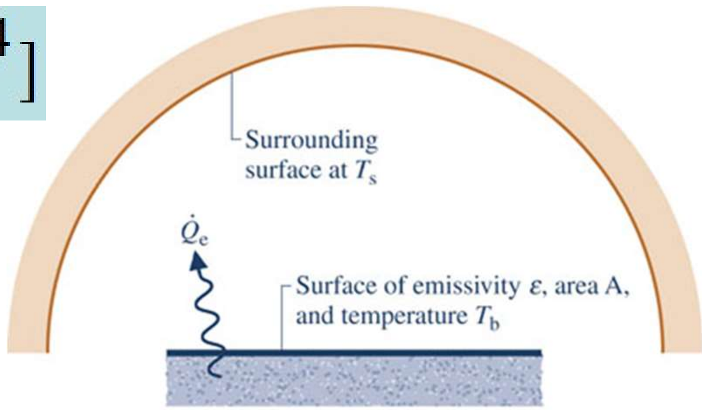


Applications	Heat Transfer Coefficient, h(W/m^2-K)
Free Convection	
Gases	2-25
Liquids	50-1000
Forced Convection	
Gases	25-250
Liquids	50-20,000

Fig & Table: Moran & Shapiro: TD

Radiation

- Black body radiation from the sun: Solar radiation
- Solar energy conversion & climate change/global warming
- Planck's distribution law…Maxwell Boltzmann distribution law
- Important role in the origins of quantum mechanics
- Most fundamental theory relies on Quantum ElectroDynamics
- Stefan-Boltzmann law: $\dot{Q}_e = \varepsilon \sigma A[T_b^4 - T_s^4]$



Figs: Moran & Shapiro: TD

Quasi-static flow of heat

- Infinitesimal heat flow under infinitesimal driving force
- Heat reservoirs-Infinite heat capacity
- System whose T is changed is contacted with different reservoirs at different T
- If the T of heat reservoir is changed slightly, heat flow can be reversed
- Quasi-Static heat transfer: Uniform TD properties of the system
- Much more important when dealing with 2^{nd} TD law