CH EN 3453 – Heat Transfer

Fundamentals of Convection and Radiation

Reminders

- Homework #1 due Friday at 4:00 p.m.
  - Minus 50% if not in by 4:00
  - Solutions to 2-5 are at www.chen3453.com
- Help session today
  - 4:30 p.m. in MEB 2325
    - Conflicts with that time?
  - Come with questions

Convection

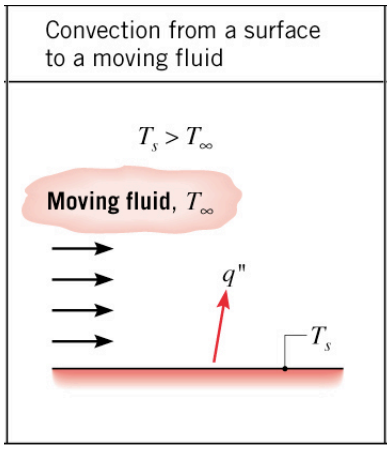
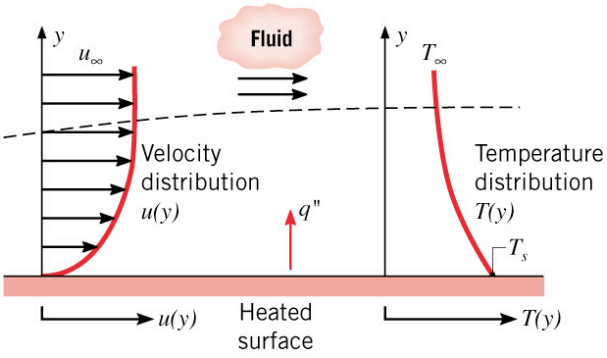


Figure 1.1(b) Convection

- Heat transfer due to the combined influence of bulk and random motion for fluid flow over a surface.
- Requires the presence of temperature variations in the material medium

Convective Heat Transfer Rate

Relation of convection to flow over a surface and development of velocity and thermal boundary layers:



Newton's law of cooling:

$$q'' = h\left(T_s - T_\infty\right) \qquad \text{Eq. 1.3a}$$

h = Convection heat transfer coefficient (W/m^2·K)

Types of Convective Heat Transfer

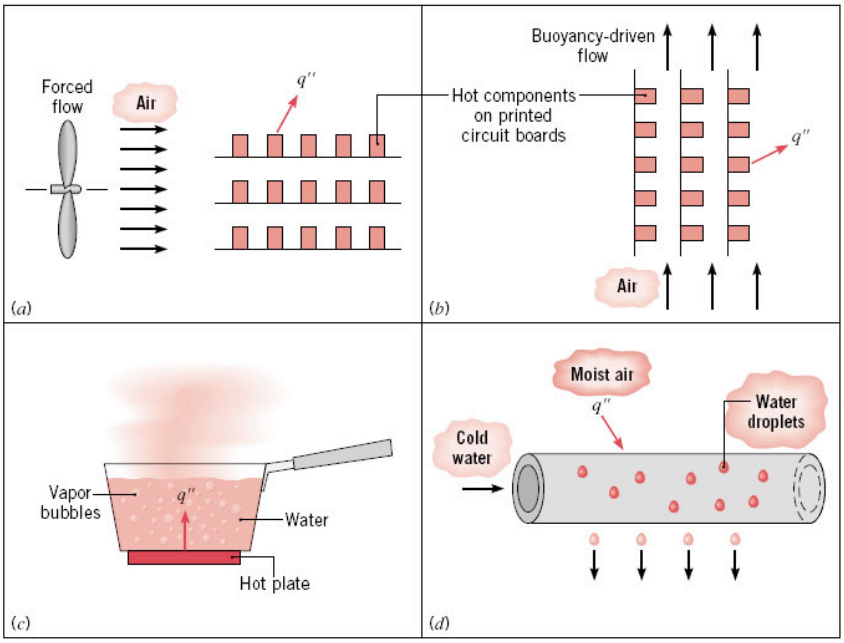
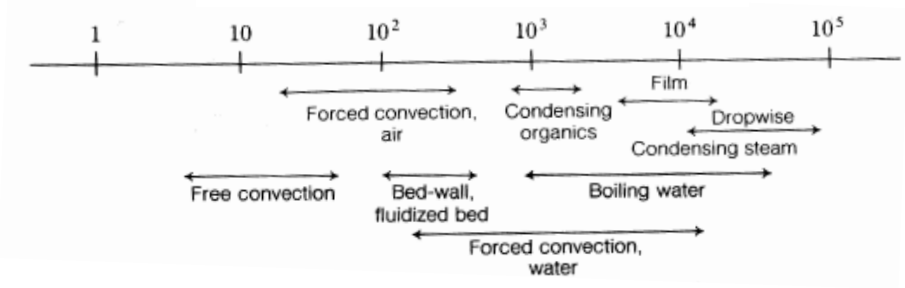


FIGURE 1.5 Convection heat transfer processes. (*a*) Forced convection. (*b*) Natural convection. (*c*) Boiling. (*d*) Condensation.

Heat Transfer Coefficient *h*

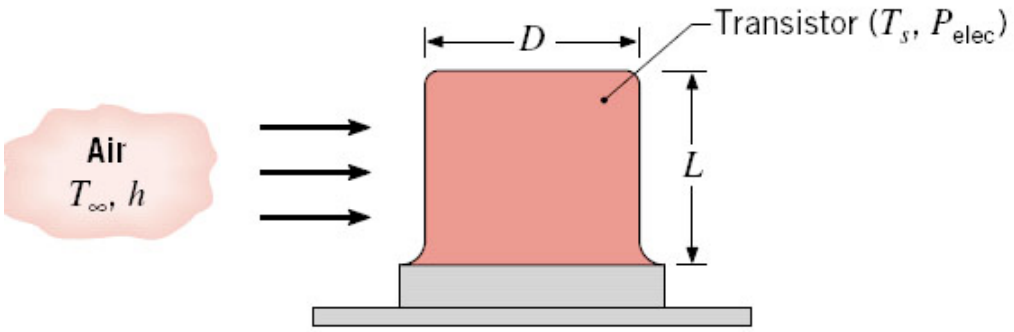
TABLE 1.1 Typical values of the convection heat transfer coefficient

Process	h ($W/m^2 \cdot K$)
Free convection	
Gases	2–25
Liquids	50–1000
Forced convection	
Gases	25–250
Liquids	100–20,000
Convection with phase change	
Boiling or condensation	2500–100,000



Example – Convection

The case of a power transistor, which is of length L = 10 mm and diameter D = 12 mm, is cooled by an air stream of temperature T_∞ = 25°C. Under conditions for which the air maintains an average convection coefficient of h = 100 W/m^2·K on the surface of the case, what is the maximum allowable power dissipation if the surface temp is not to exceed 85°C?



Radiation

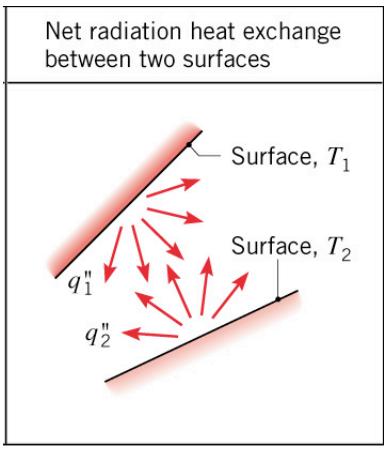


Figure 1.1(c) Radiation

- Energy that is emitted by matter due to changes in the electron configurations of its atoms or molecules and is transported as electromagnetic waves (or photons).
- Transport does not require a material medium and occurs most efficiently in a vacuum.

Radiation

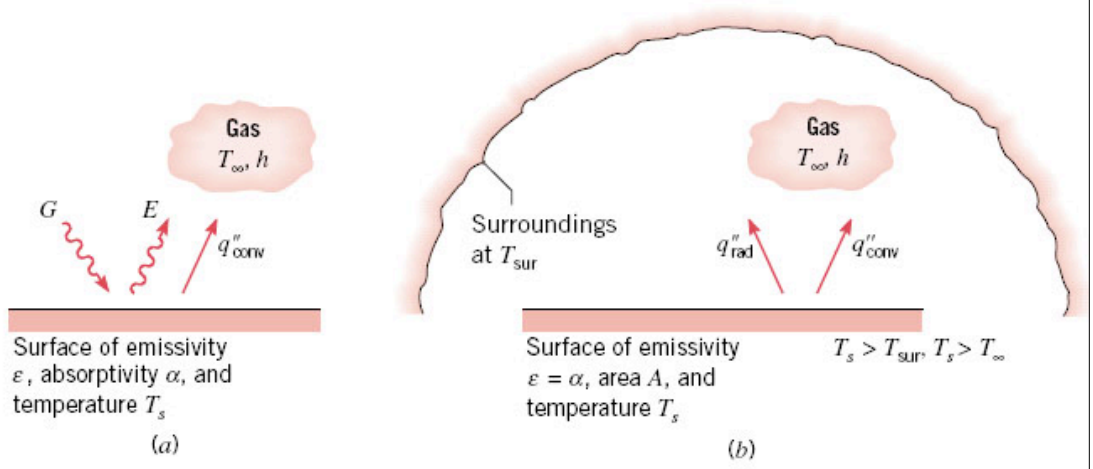
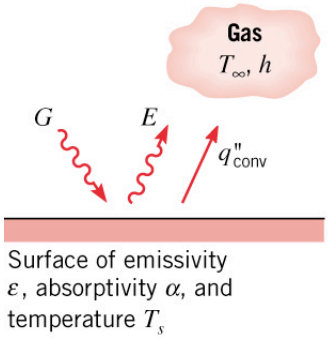


FIGURE 1.6 Radiation exchange: (*a*) at a surface and (*b*) between a surface and large surroundings.

Radiative Heat Transfer Rate

Heat transfer at a gas/surface interface involves radiation emission from the surface and may also involve the absorption of radiation incident from the surroundings (irradiation, *G*), as well as convection (if $T_s \neq T_\infty$)



Energy outflow due to emission:

$$E = \varepsilon E_b = \varepsilon \sigma T_s^4$$

E : Emissive power (W/m^2)
ε : Surface emissivity ($0 \le \varepsilon \le 1$)
E_b : Emissive power of a blackbody (the perfect emitter)
σ : Stefan-Boltzmann constant (5.67×10^{-8} W/m^2·K^4)

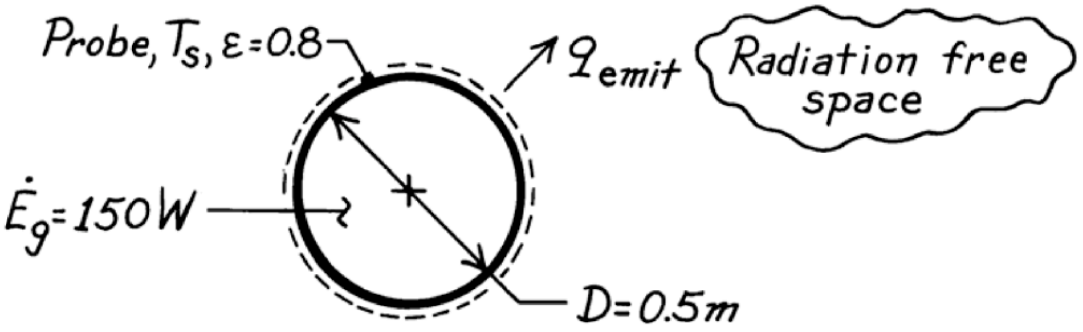
Energy absorption due to irradiation:

$$G_{abs} = \alpha G$$

G_{abs} : Absorbed incident radiation (W/m^2)
α : Surface absorptivity ($0 \le \alpha \le 1$)
G : Irradiation (W/m^2)

Example – Radiation

A spherical interplanetary probe of 0.5-m diameter contains electronics that dissipate 150 W. If the probe surface has an emissivity of 0.8 and the probe does not receive radiation from other surfaces as, for example, from the sun, what is its surface temperature?



Example – Convection + Radiation

Aluminum plate 4 mm thick mounted horizontally with bottom well insulated. Thin coating on top absorbs 80% of incident solar radiation while having an emissivity of 0.25. Density and specific heat of Al are 2700 kg/m^3 and 900 J/kg·K.

(a) If plate, initially at 25°C is suddenly exposed to air at 20°C (h = 20 W/m^2·K) and radiation of 900 W/m^2, what is the initial rate of temperature change?

(b) What will equilibrium temperature of plate be?