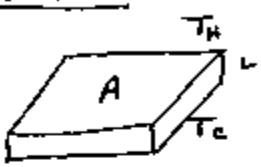
HEAT TRANSFER

Three basic mechanisms

CONDUCTION, CONVECTION, RADIATIVE TRANSFER

CONDUCTION



Rate of heat transfer

$$H = \frac{dQ}{dt} = kA\,\frac{T_H - T_C}{L}$$

k = thermal conductivity (W/m K)

Metals - "conductors" - $10 \to 10^3$

Gases $10^{-2} \to$ a few $\times 10^{-1}$

Fiberglass insulation 0.048

H_2O 0.58

Resistance to heat conduction

$$R = \frac{L}{k} \quad \text{resistance} \qquad \left(\frac{m^2\,K}{J}\right)$$

$$H = A\,\frac{T_H - T_C}{R}$$

In building R in $\frac{ft \cdot {}^\circ F \cdot h}{Btu}$

In Calif code requires

Walls R-13

Ceiling R-30 (10" k = 0.048)

Brick has a conductivity of 0.63 W/m K.
A brick house has a total surface area of 100 m² (small house). During the winter the house is maintained at 72°F (22°C) while the outside temperature is typically freezing (0°)

How much heat is conducted out of the house?

$$H = \frac{dQ}{dt} = k_T A \frac{\Delta T}{L}$$

$L = 4'' \approx 0.1\,m$

$$H = 0.63\ W/mK \cdot 100\,m^2 \cdot \frac{22\,K}{0.1\,m}$$

$$= 13860\ W = 13.86\ kW$$

What if the house were insulated to R=30 (in this case square inches)

R=30 corresponds to 10" (0.25 m) with k=0.048

$$H = 0.048\ W/m\cdot K \cdot 100\,m^2 \cdot \frac{22\,K}{0.25\,m}$$

$$H = 411\ W = 0.411\ kW$$

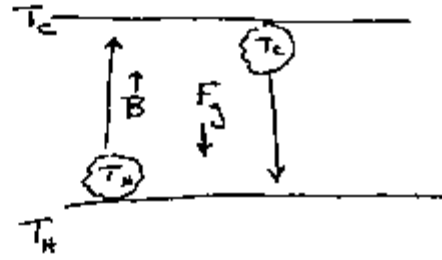
How much would the third little pig pay to heat his house

Energy costs ~ 12¢/kW·hr

1 month = 720 hr

$1200 vs $35 $58 AT 100% EFFICIENCY

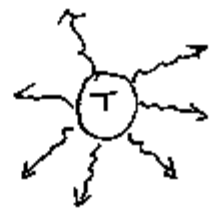
Convection



Circulating masses of fluid transfer heat from warmer to cooler regions

Q? - why do heaters near bleach rather than ceiling? Convection!

Radiation



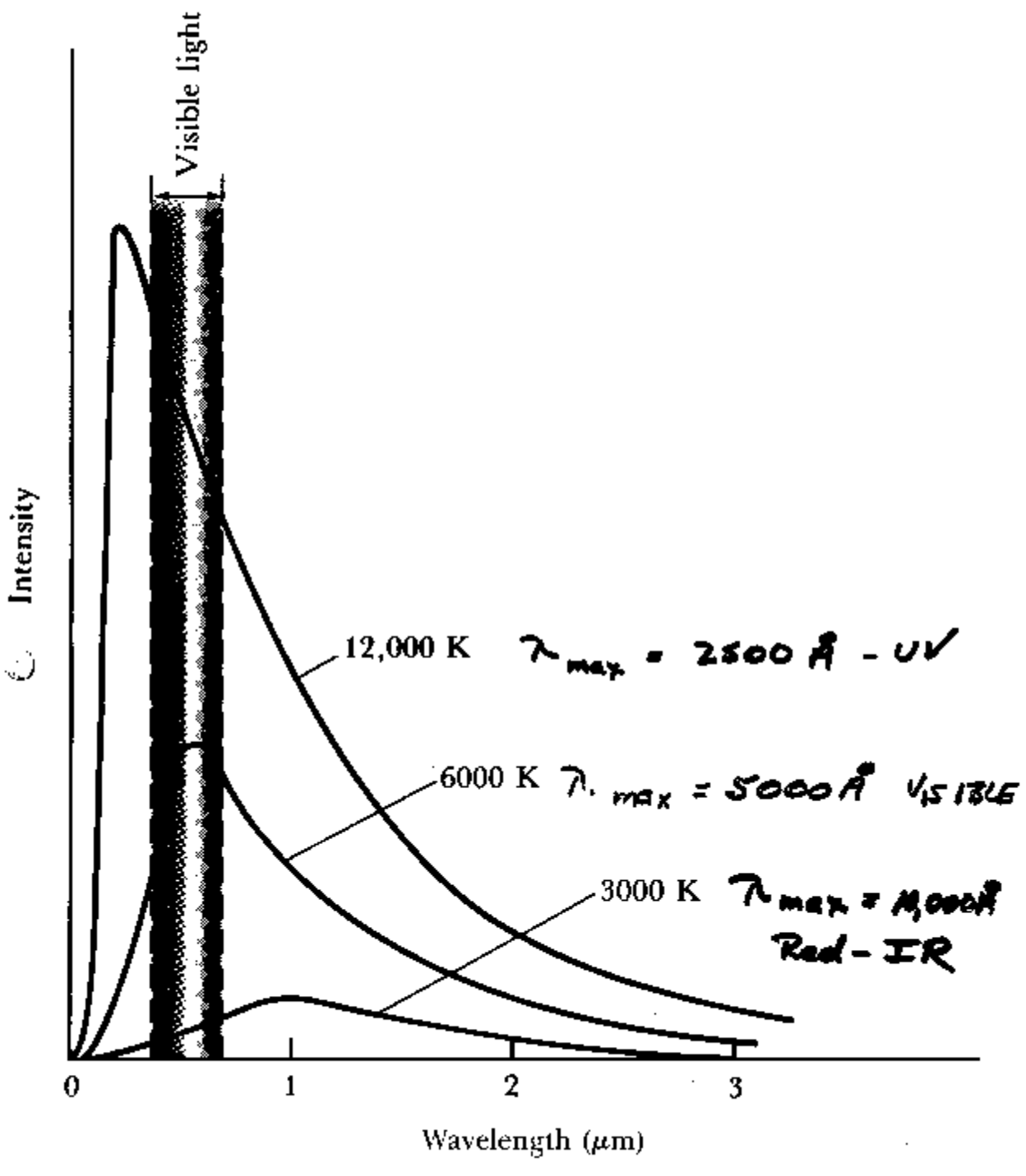
"Luminosity" (Watts) = $A \sigma T^4$

σ = Stefan Boltzmann const

=

$$\lambda_{max} = \frac{3\,mm}{T(K)}$$

e.g.	CMB	2.7K	1mm
	Human	100 K	10 μm
	Sun	6000K	500 nm


Visible light
Intensity
12,000 K
λ_{max} = 2500 Å - UV
6000 K
λ_{max} = 5000 Å VISIBLE
3000 K
λ_{max} = 10,000 Å
Red - IR
0
1
2
3
Wavelength (μm)