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Thermal Radiation

So far in ME 320, we've dealt with the following:

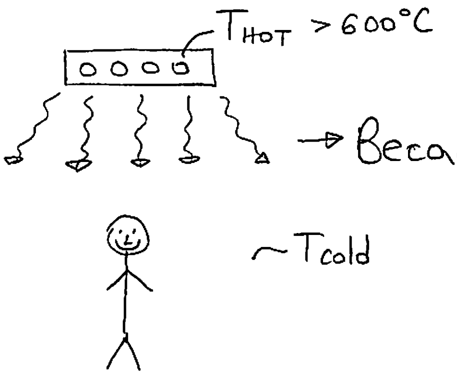
Conduction }
Convection } Heat transfer by a temperature gradient in a medium.

Radiation } - no medium required (can propagate in vacuum)
- a form of energy emitted by all matter at a finite temperature.

Applications & Examples:

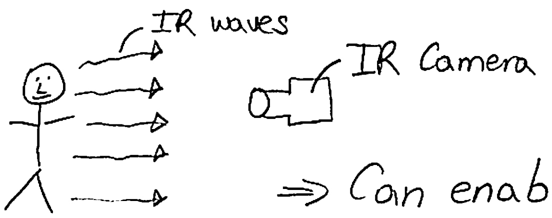
1) Global Energy Balance → Earth recieves it's energy from the sun.

2) HVAC → Heating, Ventilation & Air Conditioning
↳ Radiative heaters (bar or patio heaters)



→ Because ratiation is not affected by fluid motion, you feel comfortabl

3) Infrared Detection



⇒ Can enable night-vision.

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Theory:

① Electromagnetic Theory (Maxwell) ⇒ Light is a wave

$$\boxed{c = \lambda \nu = \frac{3.0\times10^{8}\ \text{m/s}}{n}}$$

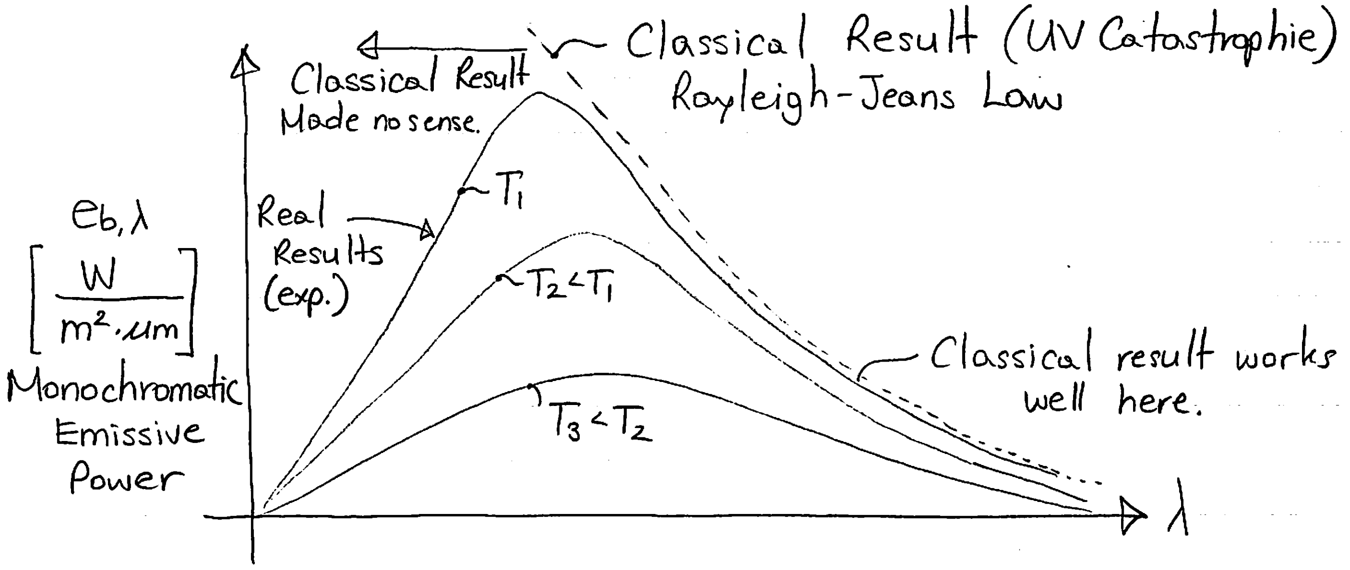
$c \equiv$ speed of light
$n \equiv$ medium index of refra
$\nu = \frac{c}{\lambda} \equiv$ frequency of ligh
$\lambda \equiv$ wavelength of light

② Quantum Theory (Planck) ⇒ Light is a particle (photon)

$$\boxed{e = \frac{hc}{\lambda} = h\nu}$$

$e \equiv$ energy of a photon [J]
$c \equiv$ speed of light in a medium
$\lambda \equiv$ wavelength of light
$h \equiv 6.6256\times10^{-34}\ \text{J}\cdot\text{s}$ (Planck's const.)

These two theories came to a head in early 1900's. Classical theory didn't make sense:



To solve this problem, Planck assumed light was made of particles, and applied kinetic theory. This was the basis for quantum theory.

By treating light as particles & using statistical thermody. he derrived:

$$e_{b,\lambda} = \frac{2\pi h c^2 \lambda^{-5}}{e^{\frac{hc}{k_B \lambda T}} - 1} = \frac{C_1 \lambda^{-5}}{e^{C_2/\lambda T} - 1}$$

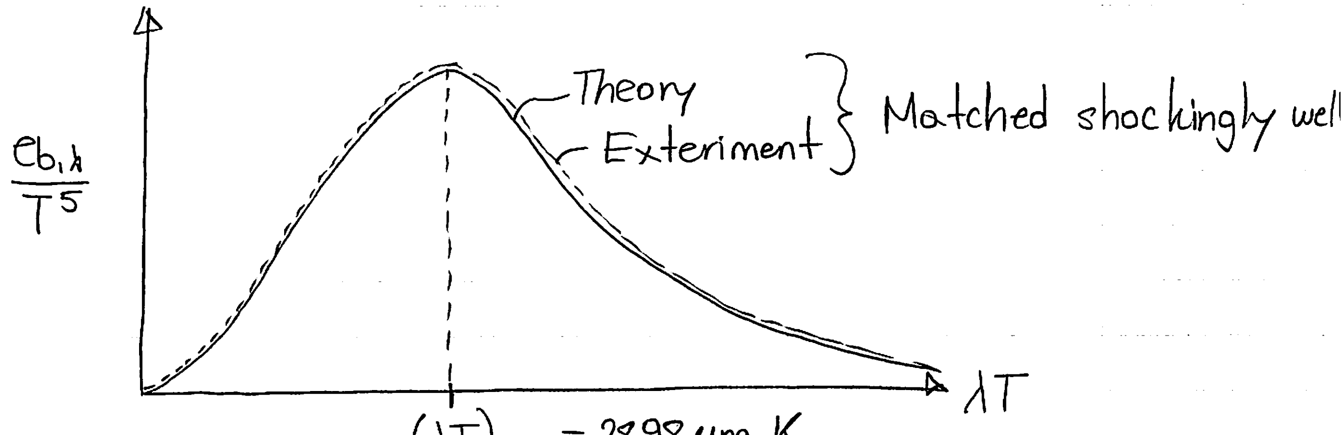
Dividing both sides by T^5:

$$\boxed{\frac{e_{b,\lambda}}{T^5} = \frac{C_1 (\lambda T)^{-5}}{e^{C_2/\lambda T} - 1}}$$,

$k_B \equiv$ Boltzman constant

$C_1 = 2\pi h c^2 = 3.742 \times 10^8 \frac{W \mu m^4}{m^2}$

$C_2 = \frac{hc}{k_B} = 1.4389 \times 10^4 \mu m \cdot K$



$$\underbrace{(\lambda T)_{max} = 2898 \mu m \cdot K}_{\text{Wien's Displacement Law}}$$

Visible wavelenght range: $0.4 < \lambda < 0.7 \mu m$ (blue to red)
Thermal radiation: $0.1 - 100 \mu m$

So as energy increases, ($T\uparrow$), the peak emissive wavelength is shifted to lower wavelengths (visible)

Example: Hot IRON Bar ⇒ goes from no color → red → orange → yellow → white