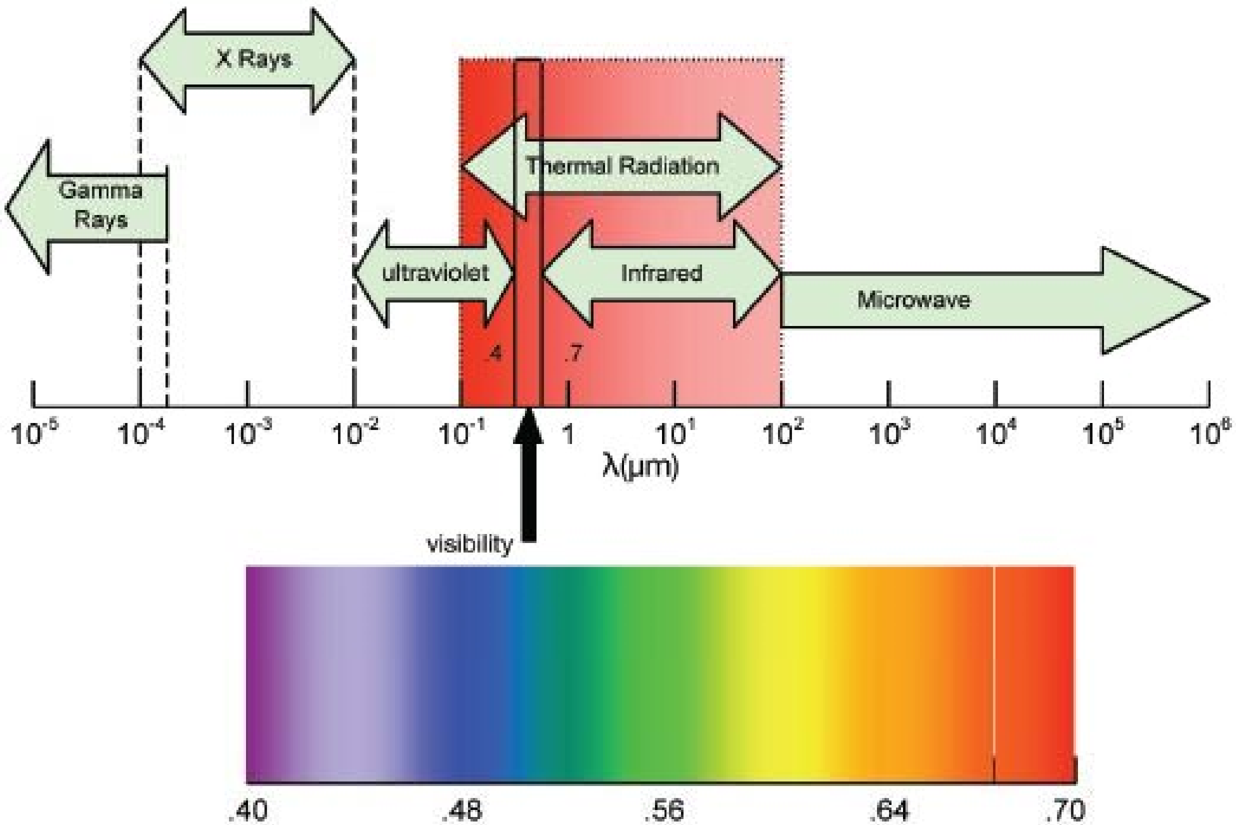
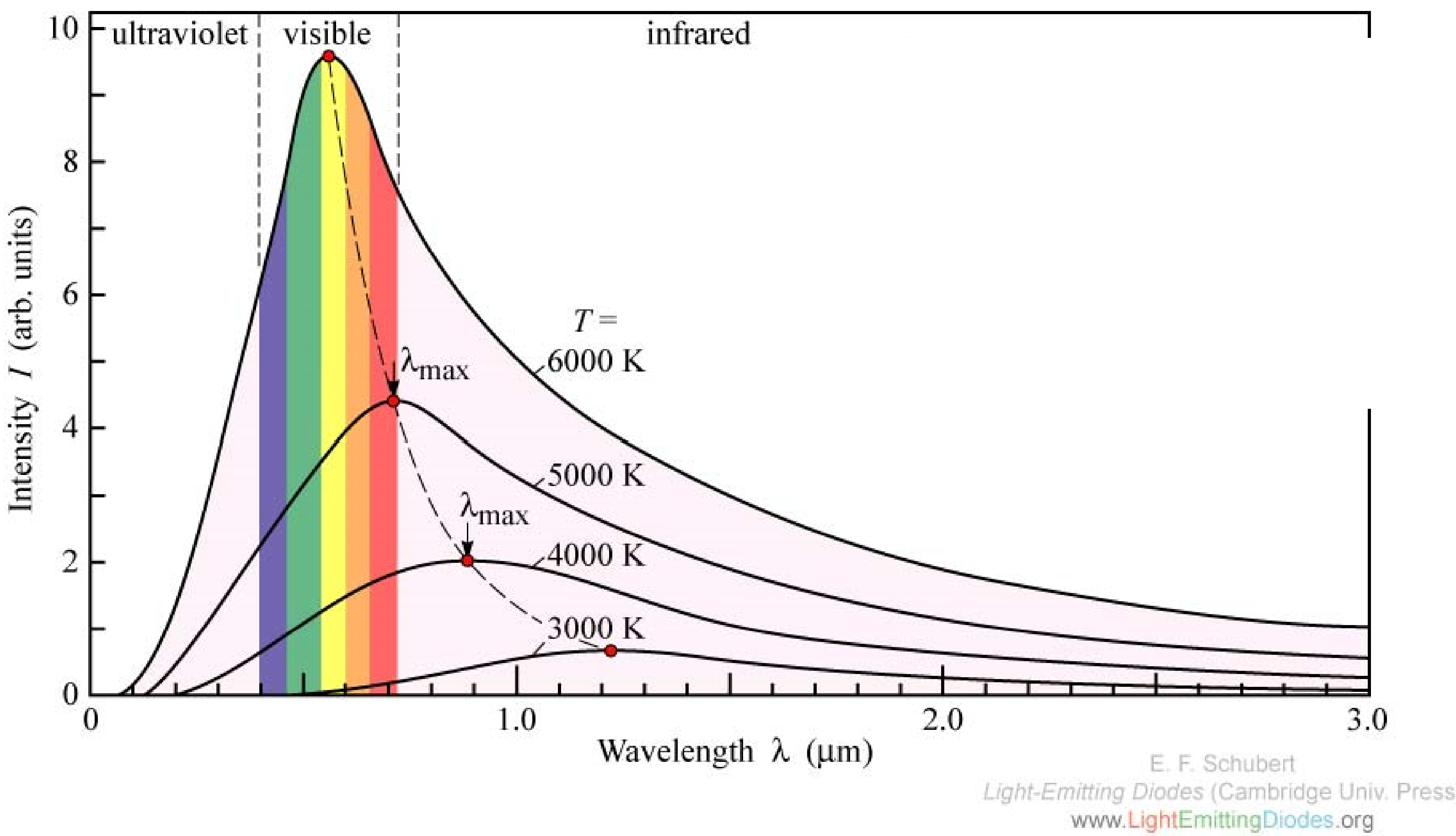
Thermal Radiation

- Thermal radiation is a heat transfer mode by electromagnetic waves. (0.1-100 μm)
- All bodies emit thermal radiation by virtue of their temperature.
- No medium required.

Electromagnetic Spectrum



Spectral Intensity Distribution



Thermal Radiation

- Stefan-Boltzmann Law

  Maximum possible power, E_b, emitted from a black body at temperature T

$$E_b = \sigma T^4$$

E_b: Emissive power, black body (W/m^2)
T: Absolute temperature (K)
σ: Stefan-Boltzmann constant
5.6697×10^{-8} W/m^2-K^4

Such an ideal emitter is called a ‘black body’.

- Black body: Surface is an ideal emitter and absorber. It emits and absorbs energy over all wavelength and directions.

Thermal Radiation

- Emissivity

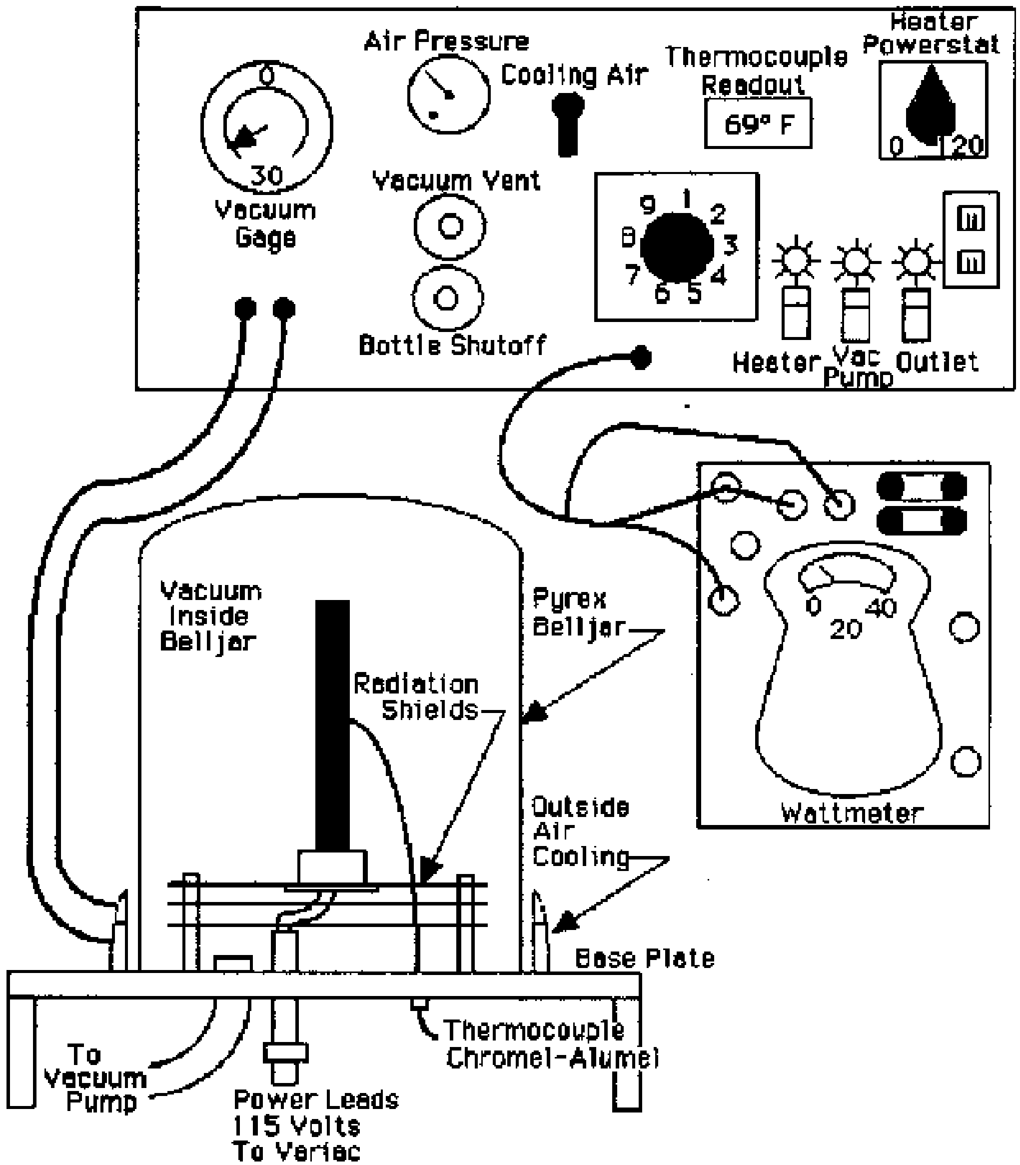
  The ratio of the actual power emitted by a real surface divided by the emissive power of a black body at the same temperature

$$\varepsilon = \frac{E}{E_b} = \frac{E}{\sigma T^4}$$

Heat flux emitted by a real surface:

$$E = \varepsilon \sigma T^4$$

Experiment Apparatus



Net Radiative Heat Transfer

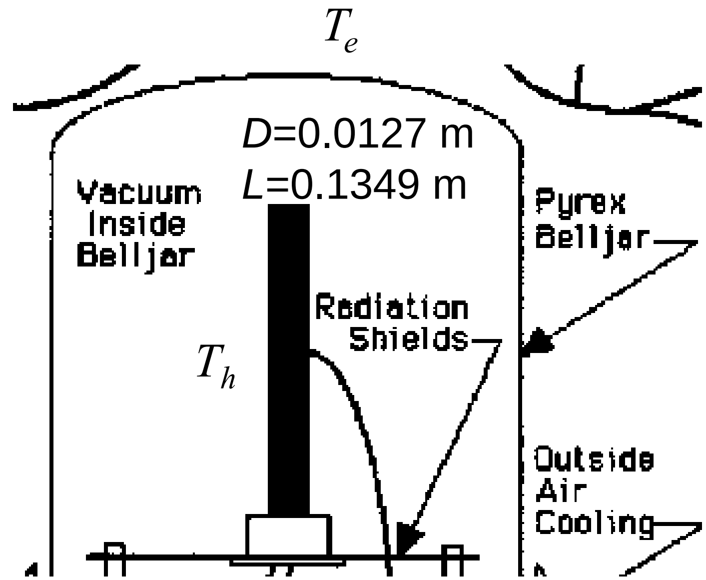
- For steady state with perfect vacuum

$$\dot{q} = A\varepsilon\sigma\left(T_h^{\,4} - T_e^{\,4}\right)$$

$$\dot{q} = \dot{W}_e$$

Solve for ε

$$\varepsilon = \frac{\dot{W}_e}{A\sigma\left(T_h^{\,4} - T_e^{\,4}\right)}$$



Net Radiative Heat Transfer

- If not a perfect vacuum

$$\dot{q} = A\varepsilon\sigma\left(T_h^{\,4} - T_e^{\,4}\right) + hA\left(T_h - T_e\right)$$

$$\dot{q} = \dot{W}_e$$

Solve for ε

$$\varepsilon = \frac{\dot{W}_e - hA(T_h - T_e)}{A\sigma\left(T_h^{\,4} - T_e^{\,4}\right)}$$

Natural Convection Heat Transfer Coefficient

$$h = 1.42\left(\frac{\Delta T}{L}\right)^{0.25} P^{0.5} \qquad for\ 10^4 < Gr_L \Pr < 10^9$$

$$h = 1.31(\Delta T)^{1/3} P^{2/3} \qquad for\ 10^9 < Gr_L \Pr < 10^{13}$$

Where Grashof's number is

$$Gr_L = \frac{g\beta\,\Delta T L^3}{\upsilon^2}$$

Properties are evaluated at

$$T_{avg} = \frac{T_h + T_e}{2}$$

Experiment

- Calculate the emissivity using Eq. 3 assuming perfect vacuum condition. Plot ε versus T_h
- Calculate the emissivity using Eq. 4 assuming imperfect vacuum condition. Plot ε versus T_h on the same plot as above.