

CH EN 3453 – HEAT TRANSFER – FALL 2014

HOMEWORK #10

Due Friday, November 21, 2014 at 4:00 PM

Turn in to the CH EN 3453 basket at the main desk of the Chemical Engineering offices (MEB 3290)

Help session Wednesday, November 19 at 4:30 p.m. in MEB 2325

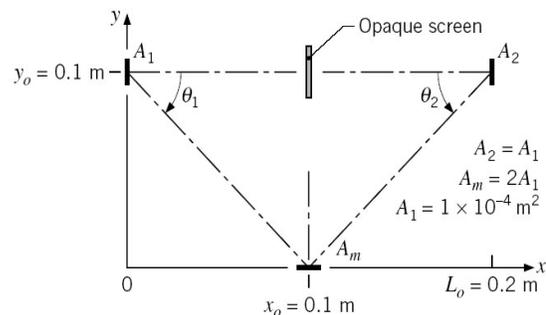
1. (20 pts) Answer each of the following short questions:

- Do all forms of matter emit radiation?
- Does the transport of thermal radiation require matter?
- What form of energy is responsible for the emission of thermal radiation? (potential, kinetic, wind, internal, chemical, or work)
- What intensive property of any given system is responsible for “driving” radiation?
- What is the equation for defining wavelength?
- What is the term describing how radiation varies with wavelength?
- In addition to the answer for part (f), what other feature complicates the nature of thermal radiation?
- What term /concept is also called ‘radiative flux’ and encompasses radiation incident from all directions?
- According to the Planck distribution, how does radiation vary with wavelength?
- Since radiative heat transfer has many terms, constants and concepts, what table in the text can you always refer to if you have a question?

2.* (10 pts) A furnace with an aperture of 20-mm diameter and emissive power of $3.72 \times 10^5 \text{ W/m}^2$ is used to calibrate a heat flux gauge having a sensitive area of $1.6 \times 10^{-5} \text{ m}^2$.

- At what distance, measured along a normal from (i.e., perpendicular to the face of) the aperture, should the gauge be positioned to receive irradiation of 1000 W/m^2 ?
- If the gauge is tilted off normal by 20° , what will be its irradiation?
- For a tilt angle of 20° , plot the gauge irradiation as a function of the separation distance for values ranging from 100 to 300 mm.

3.* (10 pts) A small radiant source A_1 emits diffusely with an intensity $I_1 = 1.2 \times 10^5 \text{ W/m}^2 \cdot \text{sr}$. The radiation detector A_2 is aligned normal to the source at a distance of $L_o = 0.2 \text{ m}$. An opaque screen is positioned midway between A_1 and A_2 to prevent radiation from the source reaching the detector. The small surface A_m is a perfectly diffuse mirror that permits radiation from the source to be reflected into the detector.



- Calculate the radiant power incident on A_m due to emission from the source A_1 , $q_{1 \rightarrow m}$ (W).
- Assuming that the radiant power, $q_{1 \rightarrow m}$, is perfectly and diffusely reflected, calculate the intensity leaving A_m , I_m ($\text{W/m}^2 \cdot \text{sr}$).
- Calculate the radiant power incident on A_2 due to the reflected radiation leaving A_m , $q_{m \rightarrow 2}$ (μW)

More problems on the other side...

4.* (10 pts) Estimate the wavelength corresponding to maximum emission from each of the following surfaces:

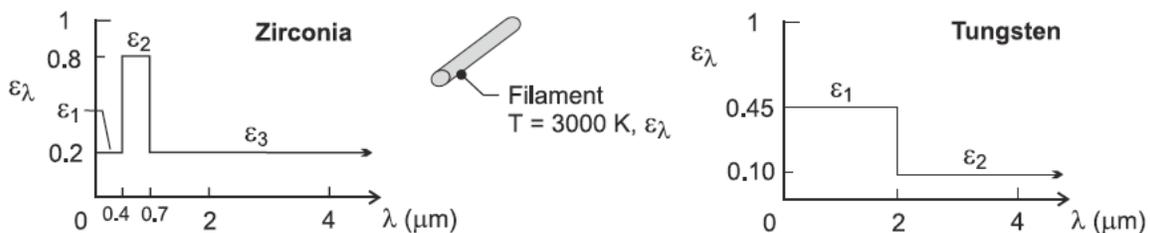
- (a) The sun
- (b) a tungsten filament at 2500 K,
- (c) a heated metal at 1500 K
- (d) human skin at 305 K
- (e) a cryogenically cooled metal surface at 60 K

5.* (10 pts) Estimate the fraction of the solar emission that is in the following spectral regions:

- (a) The ultraviolet
- (b) The visible
- (c) The infrared

Note: The ranges for the different bands of light are (μm): UV $0.01 < \lambda < 0.4$, Visible $0.4 < \lambda < 0.7$, IR $0.7 < \lambda < 100$ (See Fig 12.3)

6.* (10 pts) The spectral, hemispherical emissivities for zirconia and tungsten are shown below. Each of these metals is being considered for use as a filament in a light bulb.



- (a) What is the total, hemispherical emissivity of the zirconia filament at 3000K?
 - (b) What is the total, hemispherical emissivity of the tungsten filament at 3000K? Which type of filament, tungsten or zirconia, requires more power consumption?
 - (c) With respect to the production of visible radiation, which of the two filaments is the more efficient? Justify your answer quantitatively.
7. (15 pts) The sun is about 150 million km from Earth and is about 1.4 million km in diameter. On a clear day, solar irradiation at Earth's surface has been measured at 1140 W/m^2 . In addition to this, another 280 W/m^2 is absorbed by Earth's atmosphere. With this information, estimate the sun's effective surface temperature.
8. (15 pts) The sun's temperature is roughly 5800 K. Consult Figure 12.3 and answer the following:
- (a) What fraction of solar emission is visible?
 - (b) What fraction of solar emission lies in the ultraviolet range?
 - (c) What fraction of solar emission lies in the infrared range?
 - (d) At what wavelength is solar emissive power a maximum?