Radiatve Heat Transfer

Questions

Module 1

1. **Assume that the filament of a tungsten filament lamp is a gray surface at 3000 K. Find the fraction of radiation emitted by the tungsten filament lamp in the visible region(0.4 to 0.7 micron).**
2. **Show that there are two temperatures in which the fraction of blackbody radiation in the visible region is equal to 25%. Show graphically why there are two solutions**
3. **Show that 98% of the blackbody radiation lies between the wavelengths λ_{min} =1448/T and λ_{max} = 23,220/T. Hence show that the wavelength of photons emitted by the sun and the earth are completely different.**
4. **Show that the maximum of $E_{\lambda b}$(hemispherical spectral emissive power of a blackbody per unit wavelength) occurs at a different wavelength than the maximum of $E_{\nu b}$ (hemispherical spectral emissive power of a blackbody per unit frequency). Explain why this difference occurs.**
5. **Can a surface be a diffuse emitter and a specular reflector?**
6. **Consider the absorption and emission of radiation by a metal at a temperature T_s on which blackbody radiation at temperature T_i is incident. The hemispherical spectral emissivity of metal depends both on the surface temperature and wavelength. Explain why the total hemispherical emissivity of the metal depends only on the surface temperature T_s while the total absorptivity of the metal depends upon both T_s and T_i .**
7. **If you want the roof of a house to be cool during summer what kind of selective coating will you use on the roof and why?**
8. **If you want the roof of a house to be warm during winter what kind of selective coating will you use on the roof and why?**
9. **According to the law of conservation of energy, the sum of directional spectral absorptivity and directional spectral reflectivity is equal to 1 for an opaque surface. Which kind of**

reflectivity should we use in this equation (directional-hemispherical or hemispherical-directional)?

10. If the spectral emissivity of a material varies as $\{ 1/(\lambda T_s)\}$ show that the total emissivity is independent of temperature

Module2

1. **What are the conditions under which the concept of geometric configuration factor can be used?**
2. **Consider infinitely long cylinder 1 inside another infinitely long cylinder 2. Find $F_{2\text{-}2}$ using a) energy conservation and reciprocity or b) Hottel's crossed-string method**
3. **Consider sphere 1 inside another sphere 2. Find F2-2 using energy conservation and reciprocity. Can you use Hottel's crossed-string method ?**
4. **The configuration between disc 1 with radius R_1 and another disc 2 with radius R_2 located a distance L below disc 1 is known. Find the configuration factor between two rings distance L apart in terms of the configuration between two discs.**
5. **A cylinder is surrounded symmetrically by 12 other cylinders with same radius. If all the cylinders are touching each other, show that the geometric configuration factor between the inner and outer cylinder is equal to {1/12}. If six outer cylinders are removed show that the configuration factor between inner and outer cylinder will be greater than {1/12}.**
6. **Consider radiation heat transfer between two concentric cylinders. Find the reduction heat transfer between the two cylinders if a thin concentric cylindrical radiation shield is introduced between the two cylinders. Assume all surfaces are gray and have same emissivity.**
7. **A thermocouple (assumed to be a sphere) is placed at the centre of an infinitely long circular duct (surface temperature T_d) to measure the temperature of the gas(T_g)**

flowing in the duct. Assume that the convective heat transfer between the gas and cylinder is h. Estimate the error in the measurement of temperature of the gas on account of radiation heat transfer between the thermocouple and the duct. Assume all surface are gray and the emissivities of the thermocouple and the duct are ε_t and ε_d respectively.

8. **Consider a hollow sphere of surface area A with an opening with area A_o . Assume that the surface of the sphere is isothermal and gray with an emissivity ε. Find the effective emissivity of the radiation leaving the opening.**
9. **Consider the radiation heat transfer between 2 infinite concentric metallic cylinders at temperature T_1 and T_2. Assume that the emissivity of the metallic surface can be assumed to vary as $\varepsilon_\lambda = B\{T/\lambda\}^{0.5}$. Find the radiation heat transfer between the cylinders. Show that the radiation heat transfer between the two surfaces(for fixed T_1) increases as T_2 decreases but reaches a maximum and then approaches zero as T_2 approached zero degrees Kelvin. Explain why this result is different from the general expectation that heat transfer between two surfaces should increase as the temperature difference between the two surfaces increases.**
10. **A flat metallic shield is placed between two infinite parallel black plates at temperatures T_1 and T_2. Find the temperature of the shield. Assume that the spectral emissivity of the shield varies as $\varepsilon_\lambda = B\{T/\lambda\}^{0.5}$.**

Module 3

1. **Assume that the directional spectral absorptivity of a layer of carbon dioxide at 830 K is unity in 4 absorption bands. Assume that these bands are between 1.8 and 2.2**

microns, 2.6 and 2.8 microns, 4.0 and 4.6 microns and 9 and 19 microns respectively. Calculate the directional total emissivity of the gas at 830 K . Explain why it is low.

2. Using the data from the previous problem, calculate the directional total solar absorptivity of the carbon dioxide layer assuming that the sun is a blackbody at 5780 K. Explain why the solar absorptivity is much lower than the gas emissivity
3. Consider a container containing pure carbon dioxide at 1 bar, 300 K. Nitrogen gas is added to the container till the pressure increase to 10 bar. Will the emissivity of the mixture at 10 bar be same as that of pure carbon dioxide at 1 bar? Assume that Nitrogen does not emit or absorb any radiation.
4. For the 4.3 micron band of carbon dioxide, find the total pressure at which the Doppler half-width of the line becomes comparable to the Lorentz half width.
5. Show that the mean free path of a photon (in a non-scattering medium) is equal to { $1/a_\lambda$) where a_λ is the spectral absorption coefficient of the gas.
6. Using Kirchoff's law, show that the directional spectral emissivity of a thin layer of gas with thickness ds is equal to $a_\lambda\, ds$
7. A layer of gray gas has reflectivity ρ and transmissivity τ. Find the fraction of the incident radiation absrobed by this gas layer(due to multiple reflections) in terms of ρ and τ using ray tracing method
8. Find the efficiency of a power plant furnace using Hottel's well-stirred model. Include the effect of the ash deposit on the water walls of the power plant furnace and convective heat transfer to the walls

Module 4

1. **Radiation emitted by the earth's surface is 390 W/m^2 while the radiation emitted by earth and the atmosphere to space is around 240 W/m^2. What is the greenhouse effect? Which gases in the earth's atmosphere contributes to the greenhouse effect?**
2. **Why is the greenhouse effect in Venus much stronger that on the earth while that in Mars is much weaker than that on earth?**
3. **Find the change in surface temperature of the earth for a) 1% change in albedo of the earth-atmosphere system, b) 1% change in emissivity of the atmosphere , c)1% change solar constant and d) 1% change in solar absorptivity of the atmosphere**
4. **Consider radiative equilibrium in a plane parallel atmosphere using the Eddington's approximation. When will the exponential kernel approximation give an answer identical to the Eddington's approximation ?**
5. **Consider the earth's atmosphere in radiative equilibrium. If the atmosphere is gray and the optical thickness in the infrared in 1, show that the radiation slip at the ground will be around 24 K?**
6. **Consider a gray gas between two parallel gray plates whose emissivity is 0.1. If the optical thickness of the gray gas is one, what is error in the calculation of radiative flux between the plates if we neglect the effect of the gas?**
7. **Consider Carbon dioxide gas at a temperature of 1000 K. If the Rosseland mean absorption coefficient of the gas is 10 m^{-1}, show that the radiative conductivity of the gas is thousand times larger than the thermal conductivity of the gas**