EXAM III

HEAT TRANSFER

June 26, 2015

I. Explain the following terms: (18%)

(1) Black body

(2) E_b

(3) Kirchhoff's law

(4) Diffuse-gray surface

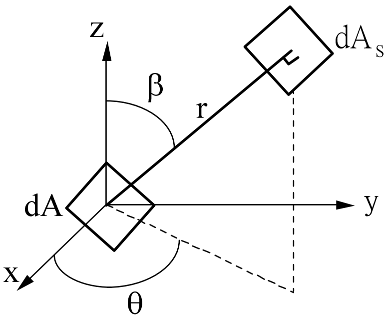
(5) Radiosity

(6) Beer's Law

II. 簡答題: (33%)

1. In what conditions $E_b = J$ for a non-transparent body?

2. In the following figure, use the emitted intensity I_b to express the radiation energy emitted from dA to dA_s? dA and dA_s are black bodies, dA is on the x-y plane and dA_s is perpendicular to the direction of r.



3. For a gray-diffuse and non-transmitted surface, i.e., $\rho + \alpha = 1$, the expression of J in a surface (shown in the figure above) can be written as $J = \varepsilon E_b + (1 - \varepsilon)G$. For a transparent material (assume gray-diffuse and reflectivity equal zero), write down the expression of J. Hint: $\alpha + \tau = 1$.

4. What kind of materials are good for radiation shields?

5. A non-transparent shield is put between two surfaces. The radiation from the first surface cannot be transmitted through the shield and neither can the radiation from the second surface. If the temperature of the first surface is higher than that of the second one, the second surface can still receive a net radiation energy. Why?

6. 在烈日之下，為何在樹下比在遮雨棚下更涼爽？ (If the sun is strong, it is cooler under a tree than under a rain shelter. Why?)

7. In deriving the radiation shape factor, why is the emitted intensity used instead of the emissive power?

8. In the heat-transfer analysis of thermal radiation, the assumption of black body is not used generally. Why not?

9. In what condition is F_{ii} not equal to zero?

10. Explain the effect of green house.

11. 以熱輻射觀點，簡述為何有些影像擷取儀器可以看穿衣服？ (From the view point of thermal radiation, how can some image-capture devices see through the clothing?)

III. (a) Determine the view factor F_{12} and F_{21} for Fig. III-(a); (b) Prove that $F_{12} = (A_1 + A_2 - A_3)/(2A_1)$ for Fig. III-(b). (12%)

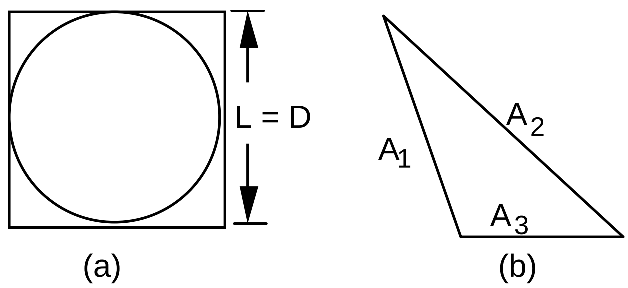


Fig. III (a) Sphere of diameter D inside a cubical box of length L = D; (b) Infinitely long enclosure formed by three plane areas.

Hint: Some view factor may be obtained by inspection.

IV. Two very large parallel plates are maintained at uniform temperatures $T_1 = 800$ K and $T_2 = 500$ K and have emissivities $\varepsilon_1 = 0.2$ and $\varepsilon_2 = 0.7$, respectively, as shown in Fig. III-(a). $\sigma = 5.669 \times 10^{-8} \mathrm{W/m^2K^4}$.

(1) Determine the net rate of radiation heat transfer between the two surfaces per unit surface area of the plates (Fig. IV-(a)). (6%)

(2) A thin aluminum sheet with an emissivity of 0.1 on both sides is placed between these two plates, as shown in Fig. IV-(b). Determine the net rate of radiation heat transfer between the two surfaces per unit surface area of the plates (Fig. IV-(b)) and compare the result to that without the shield. (6%)

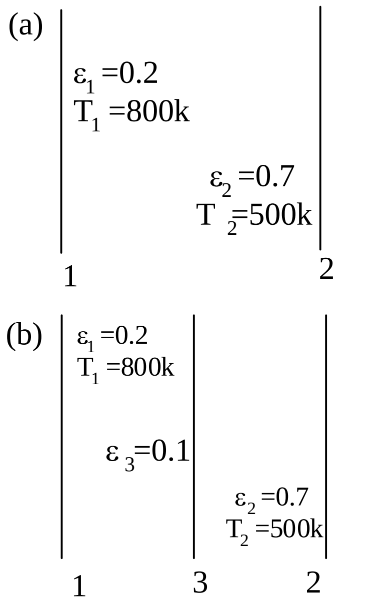


Fig. IV

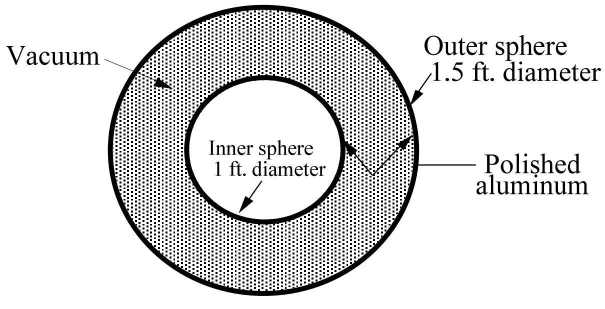
V. Prove that $A_1F_{12} = A_2F_{21}$. (6%)

VI. Liquefied oxygen (boiling temperature, 297°F) is to be stored in a spherical container of 1 ft diameter. The system is insulated by an evacuated space between the inner sphere and a surrounding 1.5-ft-ID concentric sphere as shown in the following figure. Both spheres are made of polished aluminum ($\varepsilon = 0.03$), and the temperature of the outer sphere is 30°F. Estimate the rate of heat flow by radiation to the oxygen in the container. (8%)

Hint: 1. The absolute temperature is

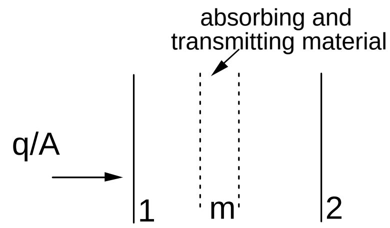
T_{abs} (R) = 460 + T (°F)

2. $\sigma = 0.1714 \times 10^{-8}$ Btu/hr ft^2 R^4



VII. Two perfectly black parallel planes 1.2 by 1.2 m are separated by a distance of 1.2 m. One plane is maintained at 800 K and the other at 500 K. What is net heat transfer between the planes? Stefan-Botltzmann constant, $\sigma = 5.669 \times 10^{-8} W/m^2K^4$, F_{12} = 0.2. (6%)

VIII. An absorbing and transmitting medium ($\rho_m = 0, \alpha_m + \tau_m = 1 = \varepsilon_m + \tau_m$) is put between two non-black surfaces ($\tau = 0, \alpha + \rho = 1 = \varepsilon + \rho$), which is shown in the following figure



(a) Derive the expression of the net radiation exchange by transmission between surface 1 and 2. (6%)

(b) Derive the expression of the net radiation energy exchange between surface 1 and m. (6%)

IX. A laser irradiates a silicon thin film, shown in the following figure. The temperature of the film is function of x and time. Prove that the heat diffusion equation of the film can be expressed as

$$\rho C_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(k \frac{\partial T}{\partial x}\right) + I_0 \kappa e^{-\kappa x}$$

where I_0 is the laser intensity at x = 0 and κ is the absorption coefficient. Hint: Beer's law can be used to prove this equation. (10%)