Homework 7

Homework due Apr 16, 2021 23:14 CDT Past due

Due Date

Friday, 4/16 at 11:59 PM ET *(4/17 at 03:59 UTC)*

Directions:

1. Answer each of the homework problems listed below.
2. Click the **Click here to open Gradescope button** below to access Gradescope.
3. Follow the prompts to submit your PDF to the assignment **HW 7**.

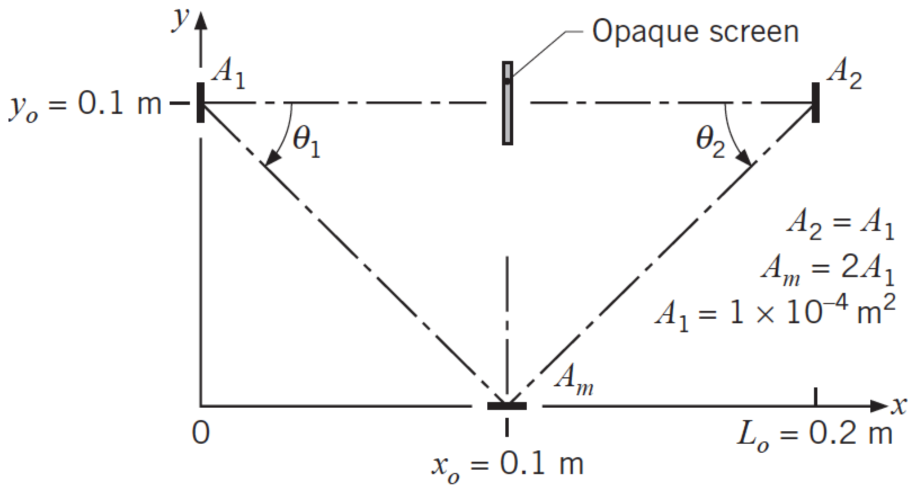
   Refer to the *Submitting Assignments With Gradescope* section of this course if you need a reminder of how to submit your assignment in Gradescope.

Homework Information and Guidelines:

1. Each student must turn in their own homework assignment and complete their own calculations, coding, etc. independently.
   - However, we encourage you to use most available resources including other textbooks, information from similar courses online, discussions with class and lab mates, office hours, etc. with the exception of using old solutions to the exact problems to complete the assignment.
   - Cite all your sources including discussions with colleagues and online websites. For example, if you and a friend compare answers or work together on a problem indicate this at the end of the problem. As an example, you might have a list like this at the end of each problem: "Resources used: [1] Fourier, J.B.J., *La Theorie Analytique de la Chaleur*, F. Didot, 1822. [2] Discussion with Joseph Fourier. [3] Wikipedia: Heat Flux, https://en.wikipedia.org/wiki/Heat_flux."
   - If we find papers with identical answers and approaches that do not indicate collaboration in the resource list, this is a violation of the academic honesty policy. Similarly, if your solutions match resources available online, this is a violation of the academic honesty policy.
2. Homework will be collected via Gradescope and is due at 11:59 PM ET. A grace period of 15 minutes is allowed in case of issues during the upload. Beyond that no late homework is accepted.
3. You may submit handwritten solutions or type up your solutions. We encourage you to use computer programs of your choice to solve problems, and some problems will require computational solutions. Recall "sketch" indicates you can draw something by hand, while "plot" indicates you should quantitatively calculate the curves and will likely use a computer program to create the graph. If "sketching" a curve, make sure trends, boundary conditions, etc. are clear.

Problem 1

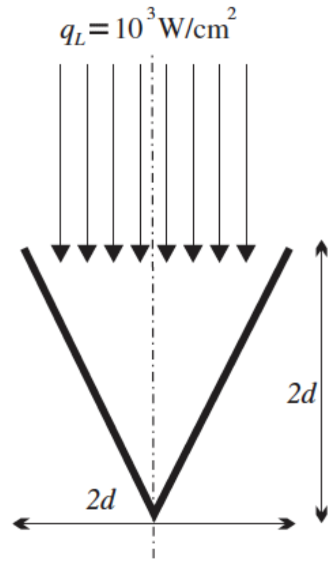
- (a) As shown in the figure below, a small vertical black surface A_1 = 1 cm^2 has a temperature of T_1 = 3,000 K. The radiation detector A_2 = 1 cm^2 is aligned normal to the source at a distance of L_0 = 0.2 m. An opaque vertical screen is positioned midway between A_1 and A_2 to prevent radiation from the source reaching the detector. The small horizontal surface A_m = 2 cm^2 is a diffuse mirror that permits radiation emitted from the source to be reflected into the detector. The reflectivity of mirror has a spectral dependence, where $\rho = 0.5$ for $\lambda \leq 1\ \mu m$ and $\rho = 1$ for $\lambda > 1 \mu m$. Calculate the radiant power q (W) incident on A_2 due to emission from the source A_1.



- (b) As shown in the figure, a conical cavity is irradiated by a uniform CO_2 laser (wavelength = 10.6 μm) along its axial direction. The height of the cavity is $2d$ and the diameter of the base is $2d$ as well. The cavity has a coating with a spectral, directional emissivity

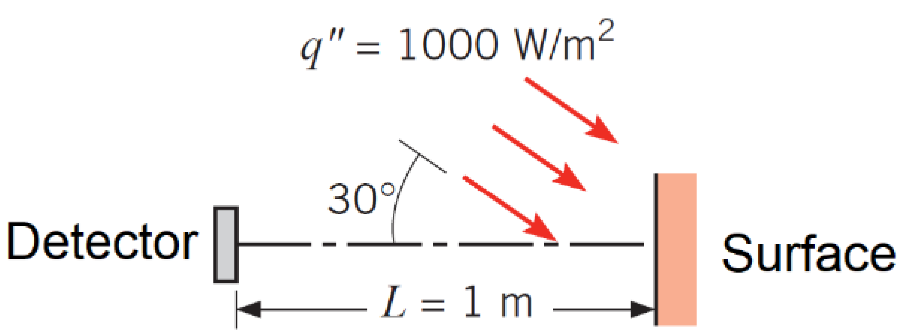
$$\varepsilon'_{\lambda}(\lambda, \theta) = \begin{cases} 0.15cos\theta, & \lambda < 6\mu m \\ 0.8cos^2\theta, & \lambda \geq 6\mu m \end{cases}.$$

Determine the absorptivity the cavity surface for this direct laser irradiation (without considering the reflected laser lights).



Problem 2

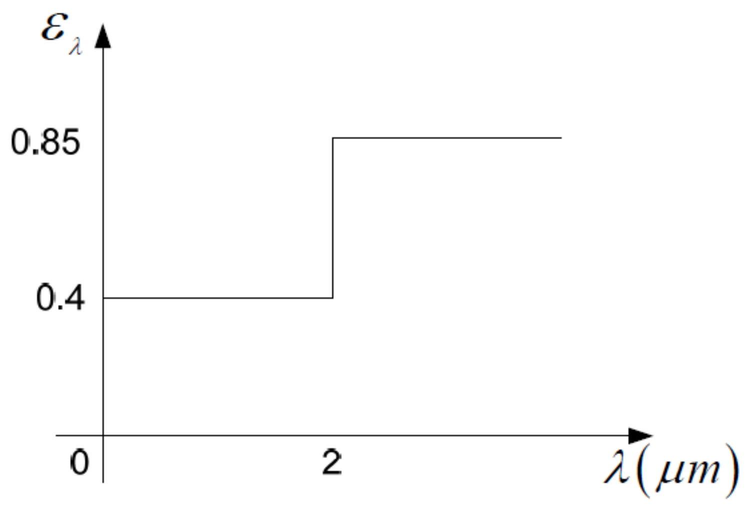
As shown in the figure, a small and flat surface of 1 cm^2 is kept at a uniform temperature of 1,000 K. Its surface is diffuse and opaque and has spectral emissivities of ε_λ=0.2 for $0 \leq \lambda \leq 1\mu m$ and ε_λ=0.8 for $\lambda \geq 1\mu m$. Direct sunlight, with a radiant flux of 1,000 W/m^2, is incident on the surface at an angle of 30° relative to the surface normal. The sun is known to have a surface temperature of 5,800 K. A detector is positioned at 1 m away from the plate surface along the normal to the area. And the aperture of the detector is 0.1 cm^2.



- a) Calculate the total radiosity of the plate surface.
- b) Calculate the total radiant power from the plate to the detector.

Problem 3

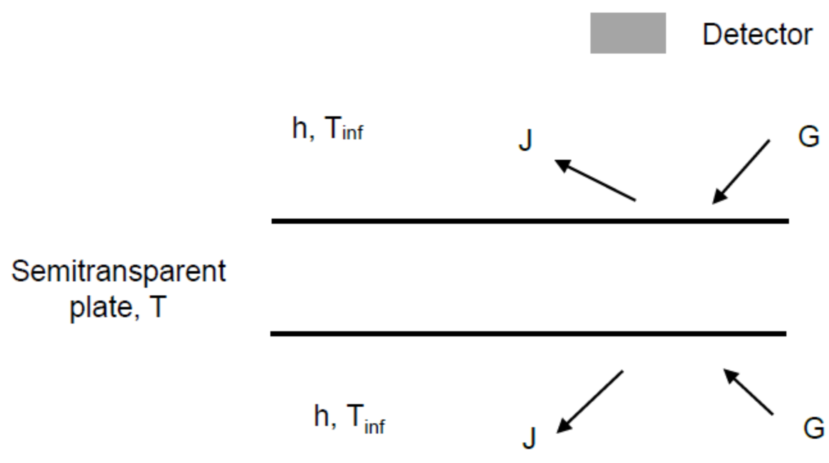
A thin, opaque plastic coating is applied to a long cylindrical metal rod of 15 mm diameter. The coating is treated by placing the rod horizontally in a large isothermal furnace whose walls are maintained at 1000 K. The furnace contains quiescent air 1 atm and 1000 K. The rod is inserted into the furnace at a temperature of 300 K. As shown in the figure, the spectral emissivity of the coating has spectral dependence where ε_λ=0.4 for $0 \le \lambda \le 2$ μm and ε_λ=0.85 for $\lambda \ge 2$ μm. Calculate the initial rate of heat transfer (W/m) for the rod and determine whether it is entering or leaving the rod.



Problem 4

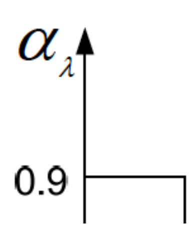
A horizontal semitransparent plate is uniformly irradiated from above and below, while air at T_{inf} = 300 K flows over the top and bottom surfaces, providing a uniform h = 40 W/m^{2}K. The total, hemispherical absorptivity of the plate to the irradiation is 0.40. Under steady state condition measurement made with a radiation detector above the top surface measures a radiosity (which includes transmission, reflection and emission) of J = 5000 W/ m2, while the plate is maintained at uniform temperature of T = 350 K.

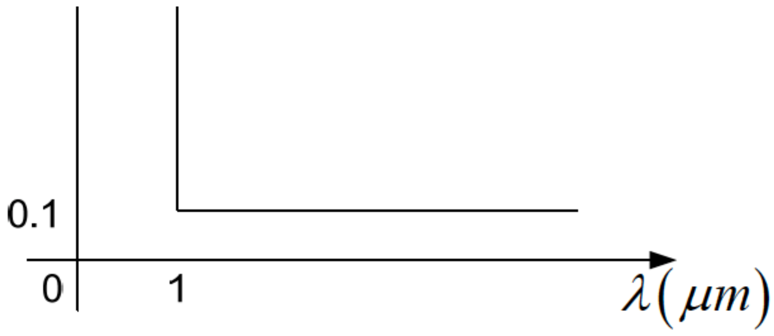
- a) Determine the irradiation G.
- b) Determine the total hemispherical emissivity of the plate. Is the plate gray for the prescribed condition?



Problem 5

A flat surface maintained at 290 K is perpendicular to the sun's rays so that the irradiation is 1353 W/m^2. The spectral absorptivity characteristics for the surface are shown below, where the spectral emissivity ε_λ=0.9 for $0 \le \lambda \le 1$μm and ε_λ=0.1 for $\lambda \ge 1$μm. Assume that the sun is a blackbody at 5800 K, that the diameters of the sun and earth are 1.39×10^9 m and 1.27×10^7 m, respectively, and that the distance between the sun and earth is 1.5×10^{11} m.





- a) Sketch the curves representing spectral irradiation and spectral black surface emissive power for the surface. Label the maximum value (W/m^2-μm) for each curve and the wavelength (μm) at which it occurs.
- b) What is the maximum value (W/m^2-μm) of spectral emissive power for the surface?
- c) Calculate total absorptivity for the surface.
- d) Calculate total emissivity for the surface.
- e) Determine the net heat flux (W/m2) for the surface and whether it is entering or leaving the surface.

Gradescope (External resource) (100.0 points possible)

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Piazza

Post your questions/comments about Homework 7 to the *HW7* discussion forum in Piazza below (optional).

Piazza (External resource)

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