Indian Institute of Technology, Kharagpur

Date of Exam.: 27 Nov 2018 (AN)
End Sem Exam
Sub No. ME60017
No. of Students: 21

Time: 3Hrs. Full Marks 60
1st Yr Mtech+ 5th Yr Dual Degree
Sub Name: **Conduction and Radiation**
of the dept. of: **Mech Engg**

Answer all questions. The marks are given on the left margin in the box. Symbols have their usual meanings. Clearly indicate the coordinate system used in your analysis. Make suitable assumptions wherever necessary. Please state your assumptions clearly

[12] 1. Consider one-dimensional transient heat conduction in a solid slab of thickness L. The initial temperature distribution in the slab is

$$T(x,0) = T_{\text{init}}(x) = T_1 + \frac{T_2 - T_1}{L}x,$$

at time $t = 0$. Here, T_1 and T_2 are constants and $T_1 \neq T_2$. The faces, $x = 0$ and $x = L$, of the slab are suddenly insulated at time $t = 0$. Both the surfaces, $x = 0$ and $x = L$, of the slab are kept insulated for times $t > 0$. There is no volumetric generation of heat inside the solid. An engineer thinks that the temperature field, $T(x, t)$, will approach the steady state distribution, $T_{ss}(x) = T_{\text{final}}$, as $t \to \infty$, where T_{final} is a constant. Do you agree with the engineer? if you agree, obtain and expression for the constant steady state temperature, T_{final}, in terms of T_1 and T_2. If you do not agree, give reasons to explain why the engineer is wrong. Justify your answer by obtaining a solution of the unsteady heat conduction equation satisfying appropriate initial and boundary conditions, using the method of separation of variables.

[12] 2. A collimated light beam of q_0=10W/cm^2 originating form a blackbody source at 1250K is aimed *at a small target* A_1=1cm^2 as shown. The target is coated with a diffusely reflecting material, *whose emittance is*

$$\epsilon'_\lambda = \begin{cases} 0.9 & \lambda < 4\mu m \\ 0.2 & \lambda > 4\mu m \end{cases}$$

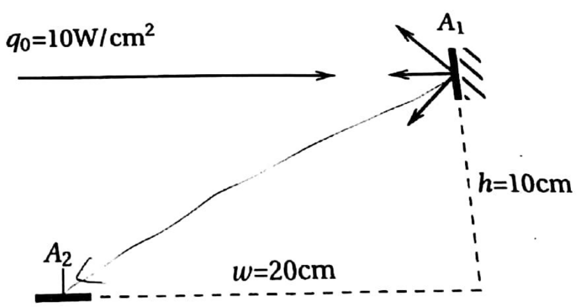
Light reflected from A_1 travels on to a detector A_2=1cm^2, coated with the same material as A_1.

(a) What is the fraction of total power of the light beam having $\lambda < 4\mu m$?

(b) What is the total reflectivity of the target A_1 in the direction $1 \to 2$?

(c) What is the approximate value of view factor F_{12} between surfaces A_1 and A_2

(d) How much of the collimated energy of q_0 is absorbed by detector A_2. Express is W/cm^2



[12] 3. Two very large parallel isothermal plates of emissivity $\epsilon = 0.3$ and $\epsilon = 0.8$ exchange heat by radiation. Find the percentage reduction in radiation heat transfer when a polished aluminum plate of emissivity $\epsilon = 0.05$ is placed between them. Show the radiation network diagram. Assume diffuse gray surfaces.

[12] 4. A long greenhouse has the cross-section of an equilateral triangle as shown. The side exposed to the sun consists of a thin sheet of glass (A_1) and it is assumed to be perfectly transparent to

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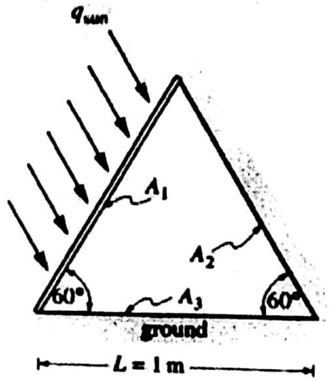
solar radiation. The glass is totally opaque to radiation emitted inside the greenhouse and has reflectivity ρ_1=0.1. The other side wall (A_2) is opaque with emittance ϵ_2=0.2, while the floor (A_3) has ϵ_3=0.8. All surfaces reflect diffusely. For simplicity, you may assume surfaces A_1 and A_2 to be perfectly insulated, while the floor loses heat to the ground according to

$$q_{3,\text{conduction}} = U\,(T_3 - T_\infty)$$

where T_∞=280K is the temperature of the ground, and U=19.5W/m^{2}K is an overall heat transfer coefficient. The sun shines onto the greenhouse with strength q_{sun}=1000 W/m^2 in a direction parallel to surface A_2.

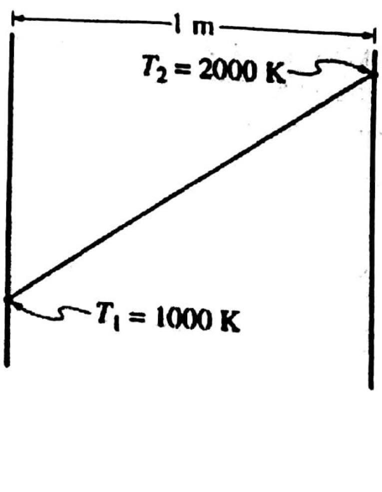


(a) Find the irradiation of solar energy in W/m^2 on to the surface A_3.

(b) Draw the radiation network diagram.

(c) Determine the temperatures of all three surfaces.

[12] 5. A 1m thick slab of an absorbing–emitting gas has an approximately linear temperature distribution as shown in the sketch. On both sides the medium is bounded by vacuum with non-reflecting boundaries.



(a) What in the expression for radiation intensity $I(\tau_s)$ at an optical distance τ_s.

(b) If the medium has a constant and argy absorption coeflicient of κ=1m^{-1} what is the intensity (as a function of direction) leaving the hot side of the slab?

(c) Give an expression for the radiative heat flux leaving the hot side.

The fractional blackbody emissive power

$n\lambda T$ [μm K]	η/nT [cm^{-1}/K]	$E_{b\lambda}/n^3T^5$ [W/m^2 μm K^5]	$E_{b\eta}/nT^3$ [W/m^{2}cm^{-1}K^3]	$f(n\lambda T)$
3000	3.3333	1.28245×10^{-11}	1.15420×10^{-8}	0.27322
3100	3.2258	1.27242	1.22280	0.29576
3200	3.1250	1.25702	1.28719	0.31809
3300	3.0303	1.23711	1.34722	0.34009
3400	2.9412	1.21352	1.40283	0.36172
3500	2.8571	1.18695	1.45402	0.38290
3600	2.7778	1.15806	1.50084	0.40359
3700	2.7027	1.12739	1.54340	0.42375
3800	2.6316	1.09544	1.58181	0.44336
3900	2.5641	1.06261	1.61623	0.46240
4000	2.5000	1.02927	1.64683	0.48085
4100	2.4390	0.99571	1.67380	0.49872
4200	2.3810	0.96220	1.69731	0.51599
4300	2.3256	0.92892	1.71758	0.53267
4400	2.2727	0.89607	1.73478	0.54877
4500	2.2222	0.86376	1.74912	0.56429
4600	2.1739	0.83212	1.76078	0.57925
4700	2.1277	0.80124	1.76994	0.59366
4800	2.0833	0.77117	1.77678	0.60753
4900	2.0408	0.74197	1.78146	0.62088
5000	2.0000	0.71366	1.78416	0.63372
5100	1.9608	0.68628	1.78502	0.64606
5200	1.9231	0.65983	1.78419	0.65794
5300	1.8868	0.63432	1.78181	0.66935
5400	1.8519	0.60974	1.77800	0.68033
5500	1.8182	0.58608	1.77288	0.69087
5600	1.7857	0.56332	1.76658	0.70101
5700	1.7544	0.54146	1.75919	0.71076
5800	1.7241	0.52046	1.75081	0.72012
5900	1.6949	0.50030	1.74154	0.72913
6000	1.6667	0.48096	1.73147	0.73778
6100	1.6393	0.46242	1.72066	0.74610
6200	1.6129	0.44464	1.70921	0.75410
6300	1.5873	0.42760	1.69716	0.76180
6400	1.5625	0.41128	1.68460	0.76920
6500	1.5385	0.39564	1.67157	0.77631
6600	1.5152	0.38066	1.65814	0.78316
6700	1.4925	0.36631	1.64435	0.78975
6800	1.4706	0.35256	1.63024	0.79609
6900	1.4493	0.33940	1.61587	0.80219