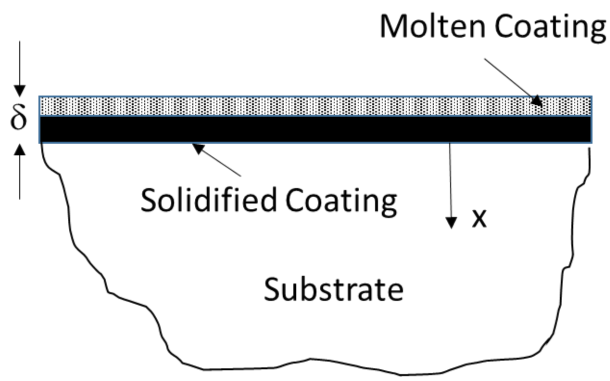
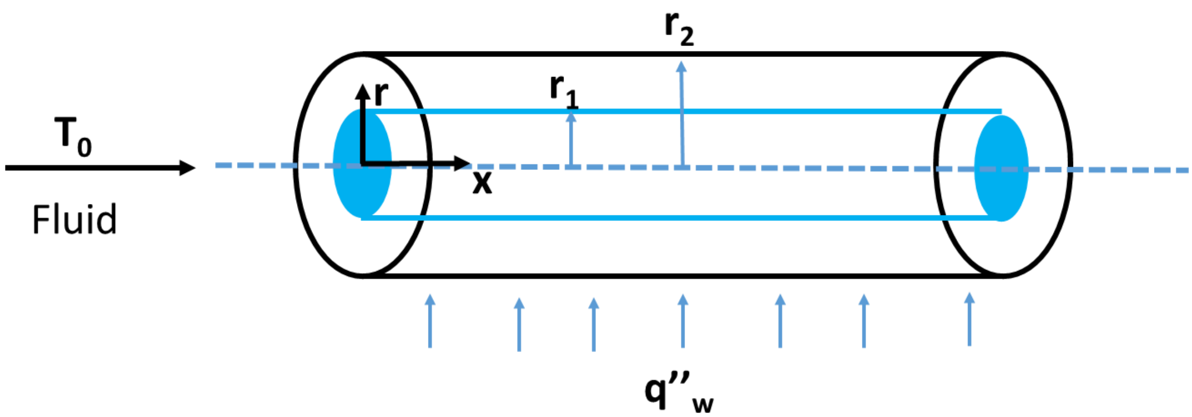
1. A thin molten coating of density ρ, latent heat of fusion h_{sf}, and thickness δ is deposited at its melting temperature, T_m, on a large solid substrate at an initially uniform temperature, $T_i < T_m$. The substrate thermal conductivity and thermal diffusivity are k_s and α_s, respectively.



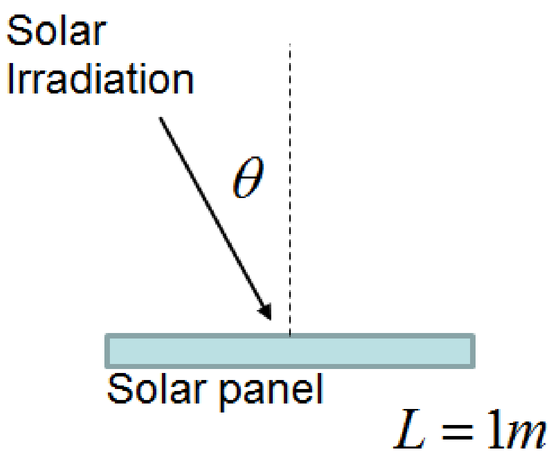
(a) 30% Sketch the one-dimensional temperature distribution, T(x), in the coating and substrate at t=0, and two subsequent times, one during the solidification, and one at the instant the solidification is complete.
(b) 70% Develop an estimate of the solidified thickness of the coating at time t, S(t), and determine when the coating will be fully solidified.

2. A long nuclear fuel rod with volumetric heat dissipation Q and radius r_1 is being cooled by annular channel whose outer radius is r_2. The inner radius of channel is same as the radius of the fuel rod r_1. The cold fluid enters channel at temperature T_0. The channel also get heat from the system outside, which can be considered as constant heat flux q_w'' at the outer surface of cannel. The laminar fluid flow in annular channel is thermally and hydraulically fully developed. Axial conduction and viscous dissipation are negligible and fluid properties can be assumed constant.

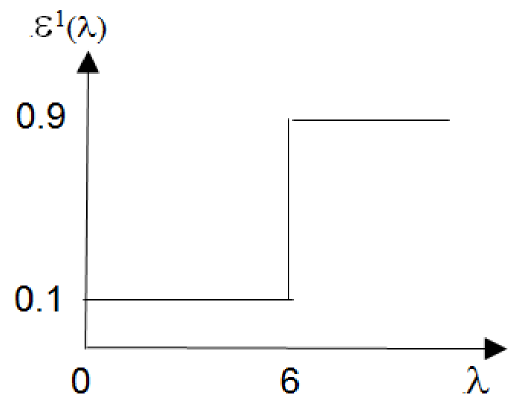


a) (20%) Write the differential equations which can be used to get expression for velocity and temperature profile in the channel.
b) (20%) Sketch the representative velocity and temperature profile in a cross-section of the channel.
c) (60%) Assume that the velocity profile can be given as $u(r) = r^2 + a.r + b$, where a and b are known constants and r is radial distance from centerline of rod. Derive an expression for temperature difference between a point inside a channel and outer surface of channel in the same cross section, i.e., $T(r,x) - T(r_2,x)$.

3.



$$\varepsilon(\lambda,\theta)=\varepsilon^{1}(\lambda)\cos(\theta)$$



Emissivity is independent of azimuthal angle.

A solar electric panel is mounted on the roof and has incident radiation from the sun at an angle of 30 degrees. The panel has directional spectral emissivity properties given above. Solar irradiation is 1388 W/m^2 and sky temperature 300K.

1. (20%) Calculate the solar absorptivity for the solar irradiation incident at angle of 30 degrees to the normal direction.
2. (20%)Calculate the emissivity and absorptivity of the panel, assuming a panel temperature of 400K.
3. (10%) Describe the energy balance if there is no wind incident on the panel.
4. (40%)Calculate the panel temperature, assume that it is thermal insulated on the back
5. (10%)Comment on the relative importance of conduction, convection and radiation heat transfer from the panel under steady-state conditions.

Supplementary information: $h = 4.5 W/m^2K$ $\sigma = 5.67x10^{-8} W/m^2K^4$

Black body table of emissive power and intensity (attached). Also note that:

$$\int_0^{\theta} \sin\theta\cos\theta d\theta = \frac{(\sin\theta)^2}{2} \qquad \int_0^{\theta} \sin\theta(\cos\theta)^2 d\theta = \frac{(\sin\theta)^3}{3}$$

TABLE 12.1 Blackbody Radiation Functions

λT ($\mu m \cdot K$)	$F_{(0 \to \lambda)}$	$I_{\lambda,b}(\lambda, T)/\sigma T^5$ $(\mu m \cdot K \cdot sr)^{-1}$	$\dfrac{I_{\lambda,b}(\lambda, T)}{I_{\lambda,b}(\lambda_{max}, T)}$
200	0.000000	0.375034×10^{-27}	0.000000
400	0.000000	0.490335×10^{-13}	0.000000
600	0.000000	0.104046×10^{-8}	0.000014
800	0.000016	0.991126×10^{-7}	0.001372
1,000	0.000321	0.118505×10^{-5}	0.016406
1,200	0.002134	0.523927×10^{-5}	0.072534
1,400	0.007790	0.134411×10^{-4}	0.186082
1,600	0.019718	0.249130	0.344904
1,800	0.039341	0.375568	0.519949
2,000	0.066728	0.493432	0.683123
2,200	0.100888	0.589649×10^{-4}	0.816329
2,400	0.140256	0.658866	0.912155
2,600	0.183120	0.701292	0.970891
2,800	0.227897	0.720239	0.997123
2,898	0.250108	0.722318×10^{-4}	1.000000
3,000	0.273232	0.720254×10^{-4}	0.997143
3,200	0.318102	0.705974	0.977373
3,400	0.361735	0.681544	0.943551
3,600	0.403607	0.650396	0.900429
3,800	0.443382	0.615225×10^{-4}	0.851737
4,000	0.480877	0.578064	0.800291

4,000	0.480877	0.578064	0.800291
4,200	0.516014	0.540394	0.748139
4,400	0.548796	0.503253	0.696720
4,600	0.579280	0.467343	0.647004
4,800	0.607559	0.433109	0.599610
5,000	0.633747	0.400813	0.554898
5,200	0.658970	0.370580×10^{-4}	0.513043
5,400	0.680360	0.342445	0.474092
5,600	0.701046	0.316376	0.438002
5,800	0.720158	0.292301	0.404671
6,000	0.737818	0.270121	0.373965
6,200	0.754140	0.249723×10^{-4}	0.345724
6,400	0.769234	0.230985	0.319783
6,600	0.783199	0.213786	0.295973
6,800	0.796129	0.198008	0.274128
7,000	0.808109	0.183534	0.254090
7,200	0.819217	0.170256×10^{-4}	0.235708
7,400	0.829527	0.158073	0.218842
7,600	0.839102	0.146891	0.203360
7,800	0.848005	0.136621	0.189143
8,000	0.856288	0.127185	0.176079
8,500	0.874608	0.106772×10^{-4}	0.147819
9,000	0.890029	0.901463×10^{-5}	0.124801
9,500	0.903085	0.765338	0.105956
10,000	0.914199	0.653279×10^{-5}	0.090442
10,500	0.923710	0.560522	0.077600
11,000	0.931890	0.483321	0.066913
11,500	0.939959	0.418725	0.057970
12,000	0.945098	0.364394×10^{-5}	0.050448
13,000	0.955139	0.279457	0.038689
14,000	0.962898	0.217641	0.030131
15,000	0.969981	0.171866×10^{-5}	0.023794
16,000	0.973814	0.137429	0.019026
18,000	0.980860	0.908240×10^{-6}	0.012574
20,000	0.985602	0.623310	0.008629
25,000	0.992215	0.276474	0.003828
30,000	0.995340	0.140469×10^{-6}	0.001945
40,000	0.997967	0.473891×10^{-7}	0.000656
50,000	0.998953	0.201605	0.000279
75,000	0.999713	0.418597×10^{-8}	0.000058
100,000	0.999905	0.135752	0.000019