MCL 7347 Intermediate Heat Transfer
Major (May 08, 2018)

Duration: 2-hour **Marks: 30**

Instructions: Questions 1 and 2 are compulsory. Answer any **ONE** from 3 and 4.

Q. 1. (a) What is Kolmogorov length scale in turbulence? **(3)**

(b) The common mechanisms by which a nanoparticle might develop slip with respect to the base fluid are (i) Inertia, (ii) Brownian diffusion, (iii) Thermophoresis, (iv) Diffusiophoresis, (v) Magnus effect, (vi) fluid drainage and (vii) gravity. Out of these, which ones are most significant in presence of turbulence and which ones are significant in absence of turbulence. **(3)**

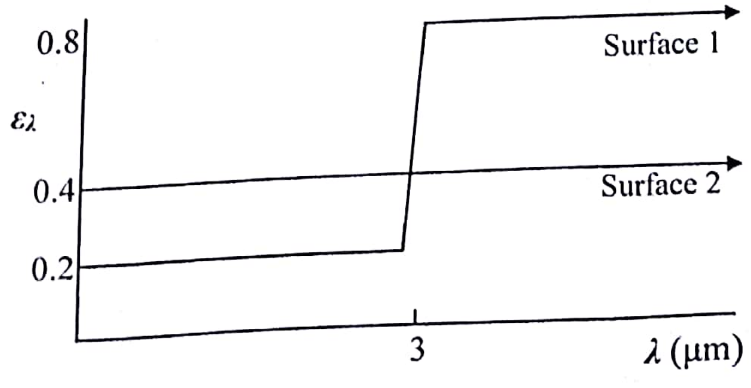
(c) The form of equation which is to be solved for heat transfer in biological systems is known as Bio-heat equation which in its simplest 1-D form is given as: $\frac{d^2T}{dx^2}+\frac{\dot{q}_m+\dot{q}_p}{k}=0$ where $\dot{q}_m$ and $\dot{q}_p$ are the metabolic and perfusion heat source terms. What these source terms account for? **(3)**

(d) The radiative transfer equation in a participating media looks like:

$$\frac{dI_\lambda(\kappa_\lambda)}{d\kappa_\lambda}=\underbrace{-I_\lambda(\kappa_\lambda)}_{\text{term 1}}+\underbrace{(1-\Omega_\lambda)I_{b\lambda}}_{\text{term 2}}+\underbrace{\frac{\Omega_\lambda}{4\pi}\int I_\lambda(\kappa_\lambda,\omega_i)\Phi(\lambda,\omega,\omega_i)\,d\omega_i}_{\text{term 3}}$$

where I_λ is the intensity, $\Phi(\lambda,\omega,\omega_i)$ is the scattering phase function, κ_λ is the optical thickness and Ω_λ is the albedo for scattering. What does the three terms account for? **(3)**

Q. 2. Consider two infinite vertical parallel plates at temperatures $T_1=1000K$ and $T_2=2000K$ respectively. The hemispherical spectral emissivity distribution for both
The space between the two plates is evacuated. The hemispherical spectral emissivity distribution for both ... Compute the net radiation heat transfer from surface 1. **(12)**
the surfaces are given in the figure.



Q. 3. Consider the natural convection in a room with one wall of height H exposed to the cold ambient. The difference between the room-air temperature and the side cold-wall temperature is ΔT_a. If the room circulation is to be simulated in a small laboratory apparatus filled with water, how tall should the water cavity of the apparatus be? In the laboratory water experiment, the temperature difference between the water body and the inner surface of the cooled wall is ΔT_w. Find the expression using symbolic values of the thermophysical properties like β, α, ν etc. with subscripts "a" and "w" to represent properties of air and water respectively. Also note that air and water both have Prandtl numbers of order 1 or greater. **(6)**

Q. 4. Derive the Reynolds Average from of energy equation for turbulent flows. **(6)**

Blackbody Radiation Functions

λT ($\mu m \cdot K$)	$F_{(0 \to \lambda)}$	$I_{b,\lambda}(\lambda,T)/\sigma T^5$ $(\mu m \cdot K \cdot sr)^{-1}$	$\dfrac{I_{b,\lambda}(\lambda,T)}{I_{b,\lambda}(\lambda_{max},T)}$
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
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
4,200	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