Heat Transfer Operations- CHE 2253

End- semester Examination (June-2022)

Type: DES

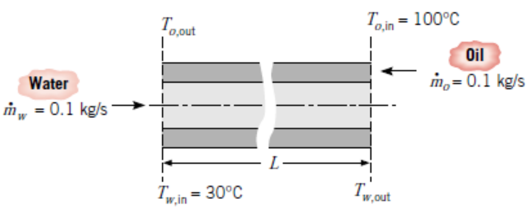
Q1. Define solar Constant. Describe in brief absorption, reflection, and transmission in real surfaces with a help of a neat diagram. (2)

Q2. Air at 25°C flows over a 10-mm-diameter sphere with a velocity of 25 m/s, while the surface of the sphere is maintained at 75°C.

PROPERTIES: *Table A.4*, Air (T_∞ = 298 K, 1 atm): $\mu = 184 \times 10^{-7}$ N·s/m^2; $\nu = 15.71 \times 10^{-6}$ m^2/s, k = 0.0261 W/m·K, Pr = 0.71; (T_s = 348 K): $\mu = 208 \times 10^{-7}$ N·s/m^2; (T_f = 323 K): $\nu = 18.2 \times 10^{-6}$ m^2/s, ρ = 1.085 kg/m^3.

What is the rate of heat transfer from the sphere? (3)

Q3. A concentric tube heat exchanger for cooling lubricating oil is comprised of a thin-walled inner tube of 25-mm diameter carrying water and an outer tube of 45-mm diameter carrying the oil. The exchanger operates in counterflow with an overall heat transfer coefficient of 60 W/m^2. K and the tabulated average properties.



Properties	Water	Oil
ρ (kg/m^3)	1000	800
c_p (J/kg · K)	4200	1900
ν (m^2/s)	7×10^{-7}	1×10^{-5}
k (W/m · K)	0.64	0.134
Pr	4.7	140

(a) If the outlet temperature of the oil is 60°C, determine the total heat transfer and the outlet temperature of the water. (b) Determine the length required for the heat exchanger. Use both LMTD and NTU method to solve the problem. (5)

Q4. Velocity and temperature profiles for laminar flow in a tube of radius r_o=10 mm have the form with units of m/s and K, respectively.

$$u(r) = 0.1[1 - (r/r_o)^2]$$
$$T(r) = 344.8 + 75.0(r/r_o)^2 - 18.8(r/r_o)^4$$

Determine the corresponding value of the mean temperature, *Tm*, at this axial position. (4)

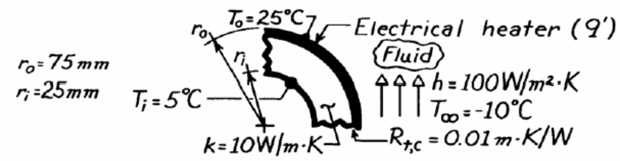
Q5. Steel balls 12 mm in diameter are annealed by heating to 1150 K and then slowly cooling to 400 K in an air environment for which T_∞= 325 K and h= 20 W/m^2.K. Assuming the properties of the steel to be k= 40 W/m.K, ρ=7800 kg/m^3, and c= 600 J/kg. K, estimate the time required for the cooling process. (3)

Q6. With the help of a neat diagram explain various types of condensation. (3)

Q7. Derive the heat diffusion equation for spherical coordinates. (4)

Q8. Define spectral directional reflectivity. The free convection heat transfer coefficient on a thin hot vertical plate suspended in still air can be determined from observations of the change in plate temperature with time as it cools. Assuming the plate is isothermal and radiation exchange with its surroundings is negligible, evaluate the convection coefficient at the instant of time when the plate temperature is 225°C and the change in plate temperature with time (dT/dt) is -0.022 K/s. The ambient air temperature is 25°C and the plate measures 0.3X0.3 m with a mass of 3.75 kg and a specific heat of 2770 J/kg. K. (3)

Q9. A thin electrical heater is wrapped around the outer surface of a long cylindrical tube whose inner surface is maintained at a temperature of 5°C. The tube wall has inner and outer radii of 25 and 75 mm, respectively, and thermal conductivity of 10 W/m. K. The thermal contact resistance between the heater and the outer surface of the tube is $R_{t,c}$=0.01 m.K/W. The outer surface of the heater is exposed to a fluid with *temperature* -10°C and a convection coefficient of h= 100 W/m^2. K.



Determine the heater power per unit length of tube required to maintain the heater at T_o= 25°C.

(3)

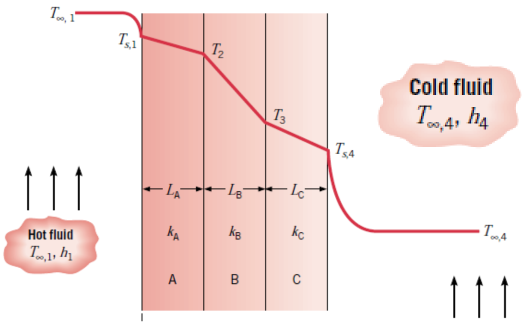
Q10. Copper tubes 25 mm in diameter and 0.75 m long are used to boil saturated water at 1 atm. If the tubes are operated at 75% of the critical heat flux, how many tubes are needed to provide a vapor production rate of 750 kg/h? $C_{s,f}$ = 0.0128 and n=1.

PROPERTIES: *Table A-6*, Saturated water (100°C): $\rho_\ell = 957.9$ kg/m^3, $c_{p,\ell} = 4217$ J/kg·K, $\mu_\ell = 279 \times 10^{-6}$ N·s/m^2, $Pr_\ell = 1.76$, $h_{fg} = 2257$ kJ/kg, $\sigma = 58.9 \times 10^{-3}$ N/m, $\rho_v = 0.5955$ kg/m^3.

What is the corresponding tube surface temperature? (3)

Q11. Consider a large isothermal enclosure that is maintained at a uniform temperature of 2000 K. Calculate the emissive power of the radiation that emerges from a small aperture on the enclosure surface. What is the wavelength λ_1 below which 10% of the emission is concentrated? What is the wavelength λ_2 above which 10% of the emission is concentrated? Determine the maximum spectral emissive power and the wavelength at which this emission occurs. (5)

Q12. For the given composite system,



Draw the thermal circuit and write the expression for heat transfer rate in a one-dimensional flow. (2)

Q13. A cartridge electrical heater is shaped like a cylinder of length *L*= 200 mm and outer diameter *D*= 20 mm. Under normal operating conditions the heater dissipates 2 kW while submerged in a water flow that is at 20°C and provides a convection heat transfer coefficient of *h*=5000 W/m^2. K. Neglecting heat transfer from the ends of the heater, determine its surface temperature T_S. If the water flow is inadvertently terminated while the heater continues to operate, the heater surface is exposed to air that is also at 20°C but for which *h*= 50 W/m^2. K. What is the corresponding surface temperature? What are the consequences of such an event? (3)

Q14. A plane wall of thickness 2*L*= 40 mm and thermal conductivity *k*= 5 W/m.K experiences uniform volumetric heat generation, while convection heat transfer occurs at both of its surfaces (*x*= - *L*,+ *L*), each of which is exposed to a fluid of temperature *T*= 20°C. Under steady-state conditions, the temperature distribution in the wall is of the form $T(x)= a+ bx+ cx^2$, where *a*= 82.0°C, *b*= -210°C/m, *c*=- 2X 10^4 °C/m^2, and *x* is in meters. The origin of the *x*-coordinate is at the midplane of the wall. (a) What is the volumetric rate of heat generation in the wall? (b) Determine the surface heat fluxes, at +L and -L. How are these fluxes related to the heat generation rate? (c) What are the convection coefficients for the surfaces at x=-L and x=+L when T(-L)= 78.2^{0}C and T (+L)= 69.8^{0}C? (d) Obtain an expression for the heat flux distribution. (4)

Q15. Calculate thermal diffusivity of pure aluminum at 300K with ρ=2702 kg/m^3 *Cp*=903 J/kg K *k*= 237 W/m K. Define Conduction,Convection and Radiation. (3)