Ref. No. Ex/PE/PC/B/T/223/2022

B.E. POWER ENGINEERING SECOND YEAR SECOND SEMESTER - 2022

SUBJECT: HEAT TRANSFER

Time: Three Hours

(Full Marks 100)

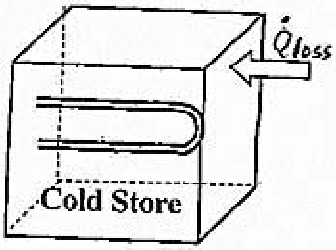
Assume the following properties of air and water unless otherwise specified:

AIR: $\rho = 1.16$ kg m^{-3}, $\nu = 1.86\times10^{-5}$ m^2 s^{-1}, $C_p = 1.014$ kJ kg^{-1} K^{-1}, $Pr=0.7$

WATER: $\rho = 1000$ kg m^{-3}, $\nu = 1.0\times10^{-6}$ m^2 s^{-1}, $C_p = 4.186$ kJ kg^{-1} K^{-1}, $Pr=7.0$

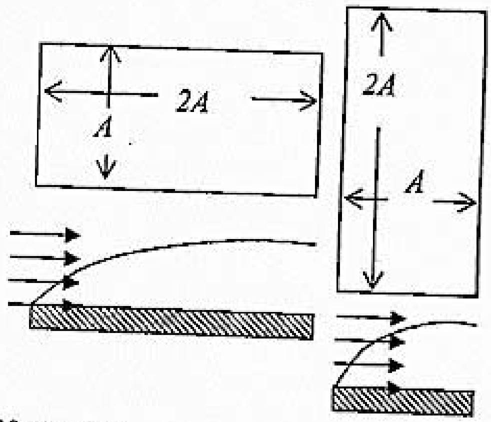
Part I (10 marks)

1. A 5 cm outer diameter refrigerant pipe, having surface temperature of −23 °C, is running through a cold store that is steadily maintained at 7° C. The inner walls of the cold store, which is acting as an infinite enclosure with respect to the refrigerant pipe, is also at 7 °C. The emissivity of the outer wall of the pipe is 0.9, while the convective heat transfer coefficient between the pipe and its surrounding is 10 W/m.K. If 5.14 kW of heat is leaking into the cold storage steadily on a summer day, find the length of refrigerant tube needed to maintain the cold storage at steady condition. 10



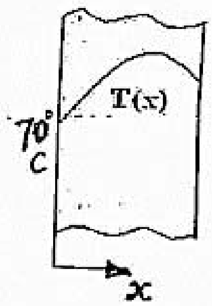
OR

Local heat transfer coefficient for forced flow over a flat plate of dimension A×2A, in a particular heat transfer problem, follows the relationship $h(x) = ax^{-0.1}$. Find the ratio of heat transfer rates when the flow takes place along the shorter side and along the longer side (see the figure on the right) 10



Part II (Answer Q 2 and 3, total 30 marks)

2. The temperature distribution across a 100 cm thick copper plate is given by $T(x) = 70 + 30x - 20x^2$ where T is in K and x is in meters. Thermal conductivity of the material is 400 W/m K. (i) Calculate the heat flux at the left and the right walls. (ii) Find the location of maximum temperature. (iii) Do you think there is any volumetric heat generation taking place inside the plate? If so, calculate the magnitude of the volumetric heat generation. 20



OR

Starting from the governing differential equation of steady-state one-dimensional heat conduction through a spherical shell, deduce the expression of thermal resistance offered by a spherical shell of inner radius a, outer radius b and thermal conductivity k. 20

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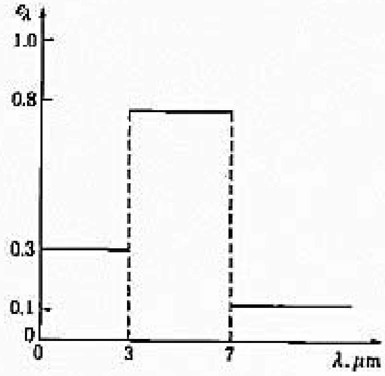
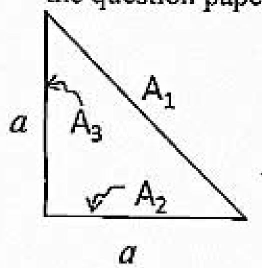
3. The temperature of the filament of an incandescent lightbulb is 2000 K. Assuming that the filament has a spectral emissivity function as shown in the figure on the right, determine the fraction of energy radiated by the filament below 7 μm wavelength. Use the spectral blackbody radiation function table provided at the end of the question paper. **10**



OR



The figure on the right shows an infinitely long right-angle triangular prism. Find the view factors F_{12}, F_{13}, F_{21}, F_{31} F_{23} and F_{32} **10**

Part III (Answer Q 4 and 5; 20×2 = 40 Marks)

4. Atmospheric air at 27°C flows with a free stream velocity of 0.3 m/s over a 1 m diameter spherical oil sludge tank equipped with an electric heater inside. The heater power is so adjusted that the outer wall of the tank is maintained steadily nearly at 77°C. Determine the power required by the heater. Assume the correlation $Nu_D = 2+ (0.4\ Re^{1/2} + 0.06\ Re^{2/3})/\ Pr^{0.4}$ to hold for forced convection over a sphere. Neglect radiative heat loss and the effect of natural convection. **20**

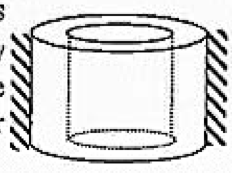
OR

A perfect grey, 50 cm× 50 cm square plate of having $\varepsilon = 0.8$ is heated electrically from below to a temperature of 327 °C, while its upper surface at is exposed to stagnant air at 27 °C? The entire assembly is kept inside an enclosure which is also at the same temperature. Find the heater power needed to maintain the plate temperature. Nusselt number correlation for the pertinent configuration is Nu=0.54 $Ra^{1/4}$ for Ra<10^7 and Nu=0.15 $Ra^{1/3}$ for Ra>10^7. **20**

5. Air at 15° C flows at a velocity of 2 m/s over a 500 mm long electronic chip panel that dissipates 420 W/m^2 of heat. If the safe operating limit of the panel is 105°C, find if the forcing of air is sufficient to ensure safe operation of the panel. Assume air to be of the following properties: ρ= 1 kg/m^3, ν= 2×10^{-5} m^2/s, C_p = 1.0 kJ/kgK, Pr=0.7. Also, find the average heat transfer coefficient for the panel surface, and the mean surface temperature of the panel. The expression of local Nu_x= 0.418 $Re_x^{1/2} Pr^{1/3}$ holds good. **20**

OR

A 0.1 m long cylinder of inner radius 50 mm and outer radius 100 mm has uniform heat generation given by $q''' = 2\times10^4$ W/m^3. Inside the hollow cylinder ice is kept. What is the rate of melting of ice? k = 4 W/mK for the cylinder material. The outer surface is insulated. Latent heat of fusion for ice is 336 kJ/kg. Also find the outer wall temperature. **20**



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Part IV (20 Marks)

6. A hot surface at 100 °C is to be cooled by attaching an array of 10 cm-long, 2mm-diameter metal pin fins (k = 200 W/m K) to it, with a center-to-center distance of 1 cm. The temperature of the surrounding medium is 30 °C, and the heat transfer coefficient on the surfaces is 200 W/m² K. Determine the rate of heat transfer from the surface for a 1-m × 1-m section of the plate. Also determine the overall effectiveness of the finned surface. **20**

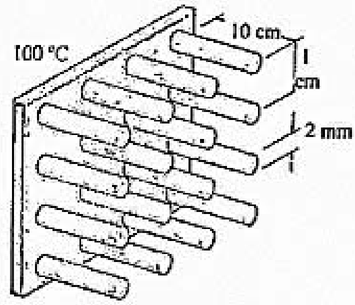

Fig 6A

OR

Engine oil (C_p=2100 J/kg.K) is to be heated from 20°C to 60°C by steam in a counterflow heat exchanger. The oil is passed through a 2 cm diameter copper pipe at 0.3 kg/s rate, while dry saturated steam at 130° C (h_{fg} = 2174 kJ/kg.K) is condensed as it passes through the annular space between the outer and the inner tubes, and comes out as saturated water. The outside walls of the outer tubes are insulated such that there is no heat loss. If the overall heat transfer coefficient (based on the inner tube) is 650 W/m².K, determine the rate of heat transfer and the length of tube required to achieve this. Also calculate the effectiveness of the heat exchanger Neglect the thickness of the inner tube, and assume steady state. **20**

ADDITIONAL INFORMATION

Blackbody Radiation Function f_λ

λT (μm.K)	f_λ	λT (μm.K)	f_λ
200	0	1600	0.019718
400	0	1800	0.039341
600	0	2000	0.066728
800	0.000016	2200	0.100888
1000	0.000321	2400	0.140256
1200	0.002134	2600	0.18312
1400	0.00779	2800	0.227897