Support material permitted: attached collection of formulas.

Write on each and every page:
Code and name of the course
Name and student number
Department and date

1.

Discuss and compare the following concepts, physical meaning and practical applications:
a) Biot number and Nusselt number. List and analyze the appropriate formulas.
b) Hydrodynamic and thermal entry lengths, fully developed flow. In which region is the convection heat transfer coefficient *h* larger?

2.

a) A wall consists of two layers, with thicknesses respectively l_1=10cm and $l_2 = 15cm$, while the thermal conductivities k_1 and k_2 are unknown.
The two sides of the wall are at temperatures $T_L = 50°C$ and $T_R = 20°C$. Calculate the thermal conductivities k_1 and k_2, knowing that the heat flux is measured to be $q'' = 216\, W/m^2$.

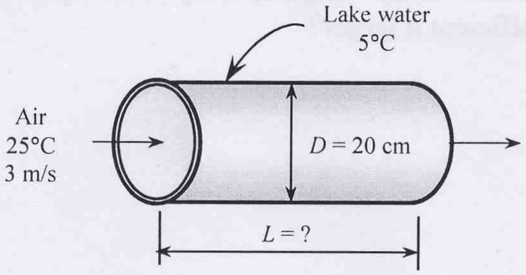
b) A 1-meter-long cylindric pipe, with internal diameter D_1=30cm, thickness 5cm and k=2.5 W/mK transports hot water, with temperature $T_1 = 85°C$ and $h_1 = 12W/m^2K$. We want to cover this pipe with two insulators.
The ambient temperature is $T_\infty = 5°C$ with $h_\infty = 25\, W/m^2K$.
Two materials A and B are chosen for the covering, with thermal conductivities $k_A = 0.52\, k_B$, and the same thickness 3cm.

Examine the two design options: pipe->A->B or pipe->B->A, calculate the thermal resistance and determine which one is the better choice.

3.

In an industrial facility built right next to a lake, there is need of a steady air flow at temperature 15°C entering a certain machine room. A circular duct of diameter D=20 cm is thus installed under the surface of the lake, whose waters have an average temperature of 5°C. The pipe takes air from another building at 25°C, and air enters the duct with velocity 3 m/s.

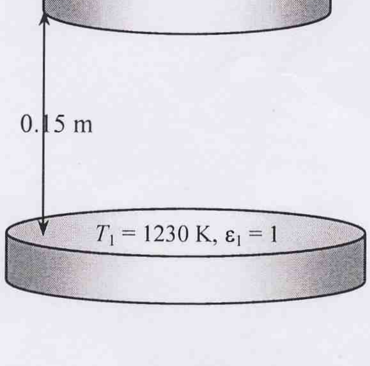
a) You are asked by the company to determine where to install this pipe. Do this by computing the portion L of the pipe which is exposed to heat transfer with the water, to obtain the outlet temperature Tout=15°C.
Assume the surface of the duct to be at the lake temperature.



b) How can you calculate the pumping power $\dot{W}_p \propto \Delta P$ required to overcome the pressure drop ΔP in the duct? Remember that $N = J/m$, and use dimensional analysis to find the unknown proportionality constant in the formula for $\dot{W}_p$ given above. If you can calculate the pumping power explicitly, assume a smooth pipe.

4.

Discuss the following concepts:
a) Blackbody radiation, Stefan-Boltzmann law and the view factor.
b) Some 20m x 30m water container contains water at temperature $T = 30°\text{C}$. Assume that the sky above is at $T_{sky} = 17°\text{C}$ and compute the radiation heat rate. Remember that the emissivity of water is $\epsilon = 0.95$.
c) Two parallel disks with diameters $D_2 = 20cm$ and $D_1 = 30cm$ are located on top of each other and separated by $L = 0.15m$. The respective temperatures are $T_2 = 600K$ and $T_1 = 1230K$. Treating both the disks as blackbodies, determine the rate of radiation heat transfer between these.



5.

Choose one of the following problems (specifying the time step necessary for your calculation).

a) A 4 cm large plate at an initial temperature of T=80°C is suddenly immersed into a cold environment with T=0°C through convection.
Use the unsteady and explicit scheme for a three-node grid to determine the transient response of the temperatures of the plate for one time step assuming that $\alpha = \frac{k}{\rho C_p} = 10 \times 10^{-6}\, m^2/s$, $h = 80\, W/m^2K$.

b) A 4 cm wooden plate at initial 30% moisture content is suddenly placed into a 15% environment. Assume the surface moisture content of the plate to be the same as that of the environment. Use the unsteady and explicit scheme for a three-node to determine the transient response of the moisture contents of the plate for one time step, assuming that the moisture diffusion coefficient D is $0.1 \times 10^{-5}\, cm^2\,/s$ at 0%, $1.6 \times 10^{-5}\, cm^2\,/s$ at 20% and $9.5 \times 10^{-5}\, cm^2\,/s$ at 30%. D is linear between these points, given the moisture diffusion equation as

$$\frac{\partial W}{\partial t} = \frac{\partial}{\partial x}\left(D\frac{\partial W}{\partial x}\right)$$

where
W is the moisture content (kg/kg or %)
D_v is the diffusion coefficient (cm^2/s)

(In the figure below, points 1 and 3 are external, while point 2 is internal).