Flat plate in a wind tunnel

Consider a flat plate positioned inside a wind tunnel, and air at 1 bar and 20 °C is flowing with a free stream velocity of 50 m/s.

What is the minimum length of the plate necessary for the Reynolds number to reach $2.5 \cdot 10^7$?

If the critical Reynolds number is $5 \cdot 10^5$, what type of flow regime would the airflow experience in the boundary layer at 0.25 m from the leading edge?

Institute of Heat and Mass Transfer | RWTH AACHEN UNIVERSITY

UNIVERSITY OF TWENTE.

Different fluids

Consider a fluid flowing with a free stream velocity of 5 m/s over a flat plate, where the critical Reynolds number is $5 \cdot 10^5$. Determine the distance from the leading edge at which the transition from laminar to turbulent flow occurs for air, water, methanol , fuel oil and mercury, with P = 1 bar and T = 20 °C

Laminar ideal gas

Consider a laminar ideal gas flow over a flat plate, where the local Nusselt number can be expressed as:

$$\mathrm{Nu_x} = 0.347\mathrm{Re_x^{1/3}}\mathrm{Pr}^{1/2}$$

Using the expression for the local Nusselt number, show that it can be rewritten in terms of local convection heat transfer coefficient as

$$\alpha_x = C[V/(xT)]^m$$

where C and m are constants.

Cold winter day

During a cold winter day, wind at 40 km/h is blowing parallel to a 4-m-high and 8-m-long wall of a house. If the air outside is at 5 °C and the surface temperature of the wall is 15 °C, determine the rate of heat loss from that wall by convection.

Moving train

The top surface of the passenger car of a train moving at a velocity of 80 km/h is 3 m wide and 10 m long. The top surface is absorbing solar radiation at a rate of 250 W/m^2, and the temperature of the ambient air is 20 °C. Assuming the roof of the car to be perfectly insulated and the radiation heat exchange with the surroundings to be small relative to convection, determine the equilibrium temperature of the top surface of the car.

Cooling a transformer

A transformer that is 15 cm long, 6.5 cm wide and 7 cm high is to be cooled by attaching a 15 cm x 6.5-cm-wide polished aluminum heat sink (emissivity = 0.05) to its top surface. The heat sink has ten fins, which are 5 mm high, 2 mm thick and 15 cm long. A fan blows air at 20°C parallel to the passages between the fins. The heat sink is to dissipate 15 W of heat and the base temperature of the heat sink is not to exceed 60 °C. Assuming the fins and the base plate to be nearly isothermal and the radiation heat transfer to be negligible, determine the minimum free-stream velocity the fan needs to supply to avoid overheating. Assume the flow is laminar over the entire finned surface of the transfromer.

Cylindrical rod

A heated, long cylindrical rod is placed in a cross flow of air at 20°C and 1 bar with velocity of 10 m/s. the rod has a diameter of 5 mm and its surface has an emissivity of 0.95. If the surrounding temperature is 20 °C and the heat flux dissipated from the rod is 16000 W/m^2, determine the surface temperature of the rod. Evaluate the air properties at 80 °C.

Hot stainless ball

A stainless steel ball ($\rho = 8055$ kg/m^3, $c_p = 480$ J/kgK) of diameter D = 10 cm is removed from the oven at a uniform temperature of 250 °C. The ball is then subjected to the flow of air at 1 bar pressure and 20 °C with a velocity of 8 m/s. The surface temperature of the ball eventually drops to 150 °C. Determine the average convection heat transfer coefficient during this cooling process and estimate how long this process has taken.

Hint: Use $\eta_\infty = 1.872 \cdot 10^{-5}$ kg/m $\cdot$ s and $\eta_\mathrm{w} = 2.934 \cdot 10^{-5}$ kg/m $\cdot$ s

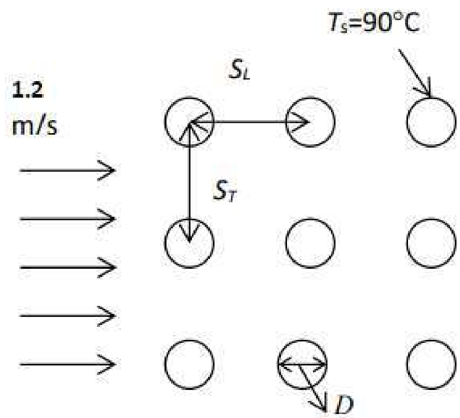
Cooled lamp

Consider a 15-cm-diameter 50-W lightbulb cooled by a fan that blows air at 20 °C to the bulb at a velocity of 3 m/s. The surrounding surfaces are also at 20 °C. Assuming 10 percent of the energy passes through the glass bulb as light with negligible absorption and the rest of the energy is absorbed and dissipated by the bulb itself, determine the equilibrium temperature of the glass bulb.

Hint: Use $\eta_\infty = 1.872 \cdot 10^{-5}$ kg/m · s and $\eta_\mathrm{w} = 2.181 \cdot 10^{-5}$ kg/m · s

Water heater

Water at 15 °C is to be heated to 65 °C by passing it over a bundle of 4-m-long, 1-cm-diameter resistance heater rods maintained at 90 °C. Water approaches the heater rod bundle in normal direction at a velocity of 1.2 m/s. The rods are arranged in-line with transverse and longitudinal pitches of $t_\mathrm{t} = 3$ cm and $t_\mathrm{l} = 4$ cm. Determine the number of tube rows N_L in the flow direction needed to achieve the indicated temperature rise



Transverse flow

Air flows transversely across a beam of length L, with a square cross-sectional area, as shown. Provide all the necessary equations to calculate the heat transfer coefficient α, under the assumption that $10^4 \leq \mathrm{Re} \leq 10^5$. Define all unknowns as a function of the given variables.

Given parameters:

- Beam geometrical dimensions: a, L
- Material properties of the air: $\eta, \rho, \mathrm{Pr}, \lambda$
- Velocity of the crossflow: u_∞