# 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?

**Properties of air:**

| **T** $°C$ | $\rho$ $kg/m^3$ | $c$ kJ/kgK | $\lambda$ $10^{-3}$ W/mK | $\nu$ $10^{-6}$ $m^2/s$ | $a$ $10^{-6}$ $m^2/s$ | **Pr** - |
|---|---|---|---|---|---|---|
| 0 | 1.275 | 1.006 | 24.18 | 13.52 | 18.83 | 0.7179 |
| 20 | 1.188 | 1.007 | 25.69 | 15.35 | 21.47 | 0.7148 |
| 40 | 1.112 | 1.007 | 27.16 | 17.26 | 24.24 | 0.7122 |
| 80 | 0.9859 | 1.01 | 30.01 | 21.35 | 30.14 | 0.7083 |
| 100 | 0.9329 | 1.012 | 31.39 | 23.51 | 33.26 | 0.707 |

# 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.

**Properties of air:**

| **T** °$C$ | $\rho$ $kg/m^3$ | $c$ kJ/kgK | $\lambda$ $10^{-3}$ W/mK | $\nu$ $10^{-6}$ $m^2/s$ | $a$ $10^{-6}$ $m^2/s$ | **Pr** - |
|---|---|---|---|---|---|---|
| 0 | 1.275 | 1.006 | 24.18 | 13.52 | 18.83 | 0.7179 |
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| 40 | 1.112 | 1.007 | 27.16 | 17.26 | 24.24 | 0.7122 |
| 80 | 0.9859 | 1.01 | 30.01 | 21.35 | 30.14 | 0.7083 |
| 100 | 0.9329 | 1.012 | 31.39 | 23.51 | 33.26 | 0.707 |

# 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.

**Properties of air:**

| **T** °$C$ | $\rho$ $kg/m^3$ | $c$ kJ/kgK | $\lambda$ $10^{-3}$ W/mK | $\nu$ $10^{-6}$ $m^2/s$ | $a$ $10^{-6}$ $m^2/s$ | **Pr** - |
|---|---|---|---|---|---|---|
| 0 | 1.275 | 1.006 | 24.18 | 13.52 | 18.83 | 0.7179 |
| 20 | 1.188 | 1.007 | 25.69 | 15.35 | 21.47 | 0.7148 |
| 40 | 1.112 | 1.007 | 27.16 | 17.26 | 24.24 | 0.7122 |
| 80 | 0.9859 | 1.01 | 30.01 | 21.35 | 30.14 | 0.7083 |
| 100 | 0.9329 | 1.012 | 31.39 | 23.51 | 33.26 | 0.707 |

# 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 · s and $\eta_\text{w} = 2.934 \cdot 10^{-5}$ kg/m · s and for the air:

| **T**<br>°$C$ | $\rho$<br>$kg/m^3$ | $c$<br>kJ/kgK | $\lambda$<br>$10^{-3}$ W/mK | $\nu$<br>$10^{-6}$ $m^2/s$ | $a$<br>$10^{-6}$ $m^2/s$ | **Pr**<br>- |
|---|---|---|---|---|---|---|
| 0 | 1.275 | 1.006 | 24.18 | 13.52 | 18.83 | 0.7179 |
| 20 | 1.188 | 1.007 | 25.69 | 15.35 | 21.47 | 0.7148 |
| 40 | 1.112 | 1.007 | 27.16 | 17.26 | 24.24 | 0.7122 |
| 80 | 0.9859 | 1.01 | 30.01 | 21.35 | 30.14 | 0.7083 |
| 100 | 0.9329 | 1.012 | 31.39 | 23.51 | 33.26 | 0.707 |

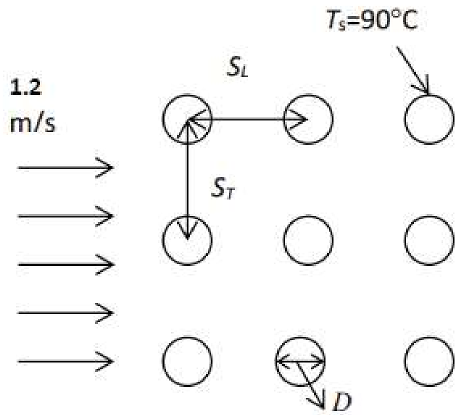
# Cooled lamp

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.

| **T** $°C$ | $\rho$ $kg/m^3$ | $c$ kJ/kgK | $\lambda$ $10^{-3}$ W/mK | $\nu$ $10^{-6}$ $m^2/s$ | $a$ $10^{-6}$ $m^2/s$ | **Pr** - |
|---|---|---|---|---|---|---|
| 0 | 1.275 | 1.006 | 24.18 | 13.52 | 18.83 | 0.7179 |
| 20 | 1.188 | 1.007 | 25.69 | 15.35 | 21.47 | 0.7148 |
| 40 | 1.112 | 1.007 | 27.16 | 17.26 | 24.24 | 0.7122 |
| 80 | 0.9859 | 1.01 | 30.01 | 21.35 | 30.14 | 0.7083 |
| 100 | 0.9329 | 1.012 | 31.39 | 23.51 | 33.26 | 0.707 |

# 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 $t_t = 3$ cm and $t_l = 4$ cm. Determine the number of tube rows $N_L$ in the flow direction needed to achieve the indicated temperature rise




**Properties of water:**

| **T** $°C$ | $\rho$ $kg/m^3$ | $c$ kJ/kgK | $\lambda$ W/mK | $\nu$ $10^{-6}$ $m^2/s$ | $a$ $10^{-6}$ $m^2/s$ | **Pr** - |
|---|---|---|---|---|---|---|
| 0 | 0.9998 | 4.218 | 0.561 | 1.793 | 0.133 | 13.48 |
| 20 | 0.9982 | 4.181 | 0.598 | 1.004 | 0.1434 | 7.001 |
| 40 | 0.9922 | 4.177 | 0.631 | 0.658 | 0.1521 | 4.3280 |
| 60 | 0.9832 | 4.184 | 0.654 | 0.475 | 0.1591 | 2.983 |
| 80 | 0.9586 | 4.197 | 0.67 | 0.365 | 0.1643 | 2.221 |