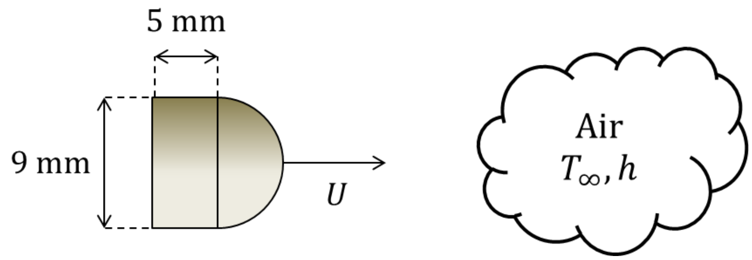
<u>Temperature Drop of a Bullet</u>

A 9 mm bullet is fired out and it is traveling through air with an average velocity of 350 m/s. The initial temperature of the bullet is 300℃ and it is cooled as it travels through air which is at 25℃ with a heat transfer coefficient $h = 1000\ W/\mathrm{m}^2.\mathrm{K}$. The bullet can be modeled by a combination of a semi-sphere and a cylinder as shown in the figure below. It is assumed that the bullet will travel around 1 km before it falls.

The properties of the bullet are $\rho = 8000\ \mathrm{kg/m^3}$, $k = 350\ \mathrm{W/m.K}$ and $c_p = 0.3\ \mathrm{kJ/kg.K}$.

Neglect radiation heat losses and compressibility effects.



a) **Is the lumped capacitance method applicable? Support your answer using appropriate calculation.**
   (Yes - Bi < 0.1)
b) **Calculate the temperature of the bullet at the moment it falls.**
   (T = 201.23 degC)
c) **Calculate the rate of heat loss from the bullet during this process.**
   (q = 231.84 W)

Convection and Numerical Method in Transient Conduction

The plate shown below consists of 3 elements (A to C) made of the ceramic. The leading and trailing edges of the plate are adiabatic as shown in the figure. Initially the plate is assumed to have a uniform temperature everywhere equal to 50°C. Suddenly the upper surface of the plate is subjected to an airflow with a velocity of $2\ \mathrm{m/s}$ and a temperature of 10°C. The temperature of nodes 1 to 3 will decrease due to heat loss by convection while temperature of nodes 4 and 5 is assumed to stay constant at 50°C. The local heat transfer coefficient between the upper surface and the flowing air is obtained from experiments and it is given in the following equation:

$$h_x = -100x^{0.2} + 2000$$

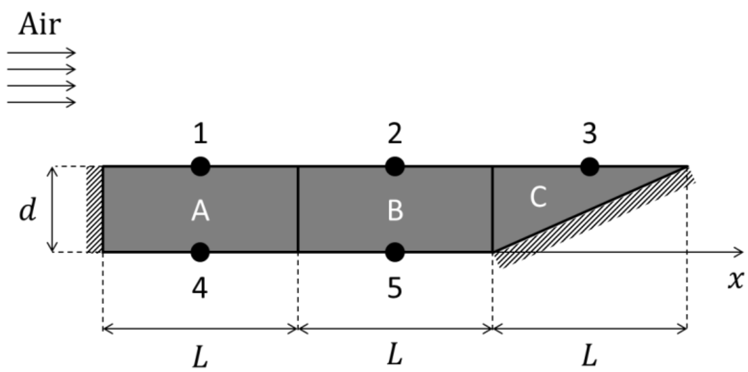
where x is in m and h in $\mathrm{W/m^2.K}$.

The plate is 1 m width into the plane of the paper and it has the following dimensions:

$$L = 5\ \text{cm and } d = 1\ \text{cm}.$$

For the ceramic $\rho = 1600\ \mathrm{kg/m^3}$, $c = 0.8\ \mathrm{kJ/kg.K}$ and $k = 3\ \mathrm{W/m.K}$.

For air $k = 0.026\ \mathrm{W/m.K}$.



a) Calculate the average heat transfer coefficient for each element A, B and C.

$\bar{h}_A = 1954\ \mathrm{W/m^2.K}$

$\bar{h}_B = 1940.62$ " "

$\bar{h}_C = 1934.1$ " "

b) Calculate the average Nusselt number.

$\overline{Nu} = 11\ 209.51$

c) Write the nodal equations for nodes 1, 2 and 3 for unsteady state conduction.

$$\Rightarrow T_1^{p+1} = \frac{\Delta t}{320}\left[97.7\,(10 - T_1^p) + 0.3\,(T_2^p - T_1^p) + 15\,(50 - T_1^p)\right] + T_1^p$$

$$T_2^{p+1} = \frac{\Delta t}{320}\left[97\,(10 - T_2^p) + 15\,(50 - T_2^p) + 0.3\,(T_1^p - T_2^p) + 0.3\,(T_3^p - T_2^p)\right] + T_2^p$$

$$T_3^{p+1} = \frac{\Delta t}{240}\left[97\,(10 - T_3^p) + 0.3\,(T_2^p - T_3^p)\right] + T_3^p$$

d) Calculate the temperature of nodes 1, 2 and 3 after 4 seconds.

18.35	18.46	11.49

e) Calculate the total amount of heat lost from the plate in 4 seconds.

$Q = 29.5$ kJ

f) Calculate the average rate of heat loss for the 4 seconds time interval.

$q = 7.37$ kW