Problem 1

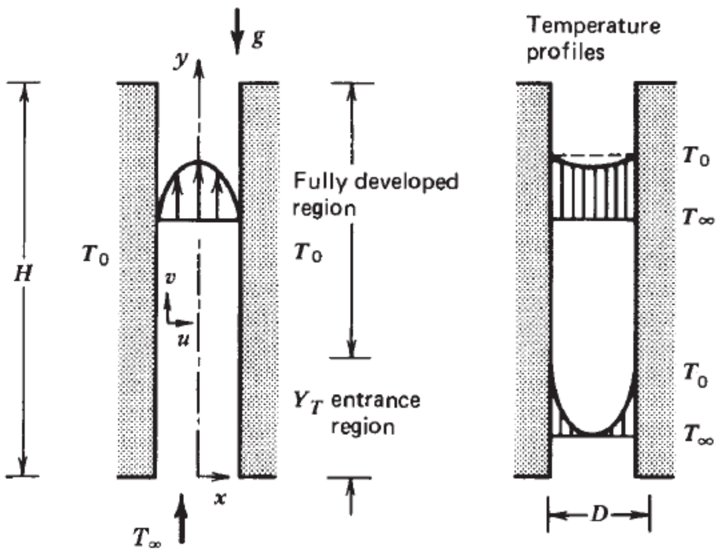
Consider a vertical wall of height H in contact with an isothermal fluid reservoir. For the purpose of scale analysis, select the square flow region of height H and horizontal thickness H. Show that if in the momentum equation you invoke a balance between friction and buoyancy, the inertia/friction ratio comes out to be of order $Gr_H = (g\beta\, \Delta T\, H^3)/\nu^2$ (note that the H × H region is not the boundary layer region; hence, the conclusion "inertia/friction $\sim Gr_H$" does not apply to the boundary layer region). Is the vertical velocity scale derived above compatible with the v scale recommended by the energy equation for the H × H region? In other words, is the invoked balance friction $\sim$ buoyancy in the H × H region realistic?

Problem 2

Using natural flows, a solar chimney has to be designed to heat the air to a uniform temperature at a constant mass flow rate. The chimney is planned to design using two parallel walls with the width of the wall significantly higher than the height of the chimney. Design the chimney by looking into the H/D. what is the condition for which the designed chimney will work and will be able to discharge fluid at a constant rate? Assume any necessary conditions with proper justification.

Hint: Find the average heat flux between the two parallel walls facing each other as depicted in the figure.

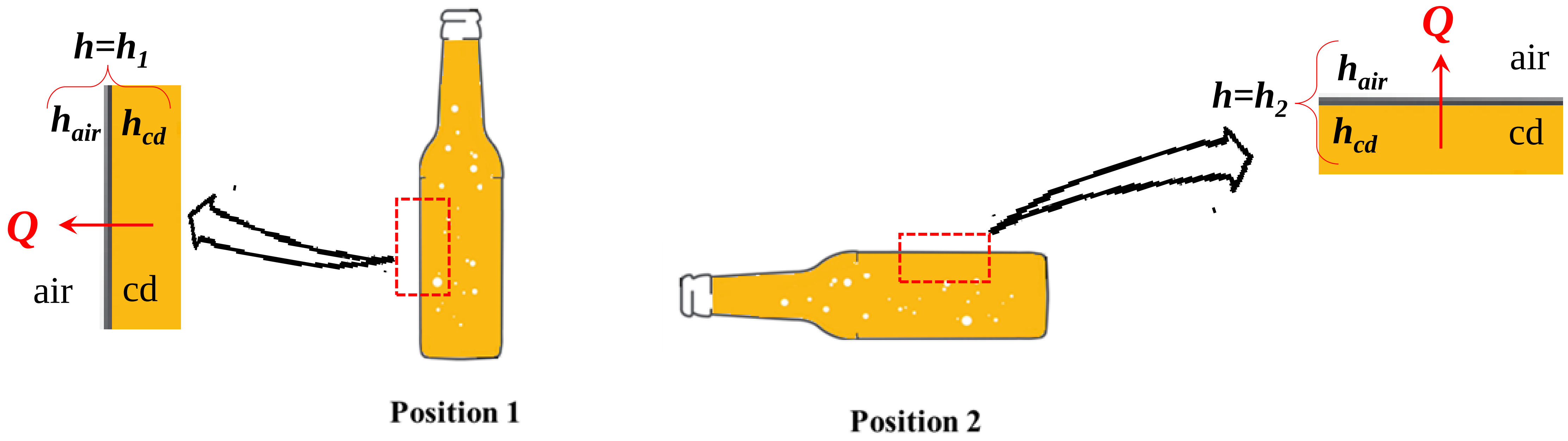
Assume the necessary conditions for an analytical solution to the problem. Validate your assumptions with the necessary condition



Problem 3

You have a bottle of cold drink at room temperature, and you would like to drink it cold as soon as possible. You place the bottle in the refrigerator; however, you have the option of positioning the bottle (1) vertically or (2) horizontally. The refrigerator cools by natural convection (it does not employ forced circulation).

(a) Which way should you position the bottle? Describe the goodness of your decision by calculating the ratio t_1/t_2, where t represents the order of magnitude of the time needed for the bottle to reach thermal equilibrium with the refrigeration chamber (base this calculation on scale analysis).



Data :

$$\left(\frac{g\beta}{\alpha\nu}\right)_{air} = 125; \quad \left(\frac{g\beta}{\alpha\nu}\right)_{cd} = 4910$$; both have same unit

k_{air}=0.025 and k_{cd}=0.58; both have same unit   Subscript *cd* stands for *cold drink*

For high *Pr* number fluids (e.g. air, water *etc.*) the *Nu* scales as

For heat transfer from vertical walls

$$Nu = \frac{Hh}{k} \sim Ra_H^{1/4}$$

Where, Ra_H is the *Rayleigh number* $Ra_H = \frac{g\beta\Delta T H^3}{\alpha\nu}$

Where *H* is the height of the wall

For heat transfer from horizontal walls

$$Nu = \frac{Lh}{k} \sim Ra_L^{1/4}$$

Where *L* is the characteristic length

Consider *H=5L* and assume $\left[(T_{cd} - T_s) = (T_s - T_{air})\right]$ Where T_s is the surface temperature of the bottle

Problem 4

The single-pane window problem consists of estimating the heat transfer rate through the vertical glass layer shown in Fig. The window separates two air reservoirs of temperatures T_h and T_c. Assuming constant properties, laminar boundary layers on both sides of the glass, and a uniform glass temperature T_w. Find the relationship between the average heat flux q'' with T_h to T_c.