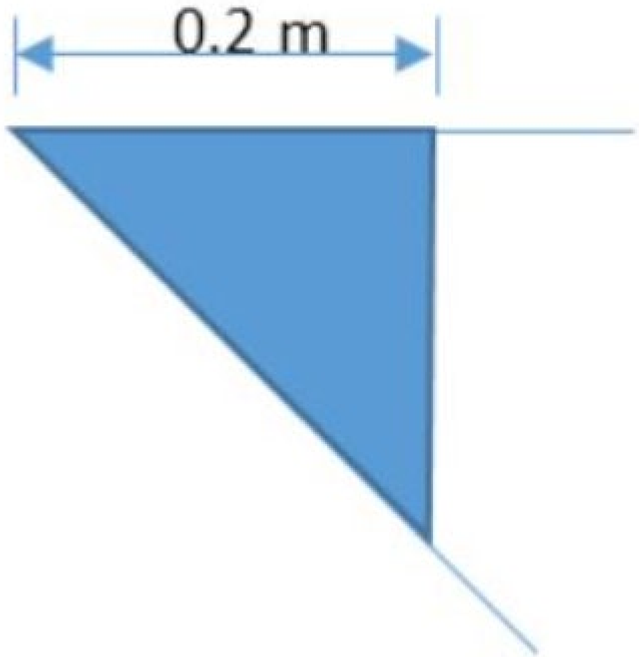
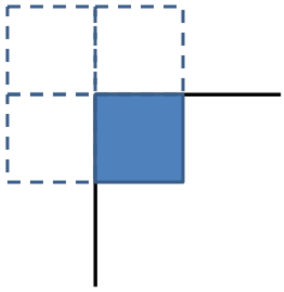
Q1

Estimate the mass entrainment rate in kg/s at z = 2.3 m using the Zukoski axisymmetric plume correlation ($\dot{m}_p = 0.071 \cdot \left(\dot{Q}_c\right)^{\frac{1}{3}}(z)^{\frac{5}{3}}$) for the fuel base located in the **corner** of a room as shown below. Note that the convective heat release rate is 104 kW for the given wedge shape fuel surface area (with a 45o angle). Round your answer to the second decimal place without any unit.



Plume in the corner and against a wall



Using Zukoski plume ($\dot{m}_p = 0.071\dot{Q}^{1/3}z^{5/3}$),

– In the corner,

$$\dot{m}_{p,corner} \approx \frac{1}{4}(0.071(4\dot{Q})^{1/3}z^{5/3})$$

$$\approx 0.028\dot{Q}^{1/3}z^{5/3}$$

– Against the wall,

$$\dot{m}_{p,wall} \approx \frac{1}{2}(0.071(2\dot{Q})^{1/3}z^{5/3})$$

$$\approx 0.045\dot{Q}^{1/3}z^{5/3}$$

$$\dot{m}_{p,\ \mathrm{corner}} \approx \frac{1}{8}\left(0.071(8\dot{Q})^{1/3}z^{5/3}\right)$$

$$= \frac{1}{8} \times 0.071 \times (8 \times 104)^{\frac{1}{3}} \times 2.3^{\frac{5}{3}} = 0.33452$$

Q2&3

Calculate the plume centerline temperature and plume centerline velocity in Kelvin at 3.5 m above the fuel base for the following condition using the Heskestad’s plume correlation. Write down your answer rounded to the nearest tens without units.

- Heptane fire in a circular pan having a 0.5 m diameter
- Heat of combustion of heptane = 44.6 [kJ/g]

- Mass burning rate per unit area for infinite diameter = 0.101 [kg/m2-s]
- Extinction coefficient multiplied by the mean beam length corrector = 1.1 [1/m]
- Convective fraction of HRR = 0.7
- Ambient temp. = 20 C

$$\dot{Q} = \dot{m}''_{\infty}\left(1 - \mathrm{e}^{-k\beta D}\right)\left(\frac{\pi}{4}D^2\right)\left(\Delta H_c\right)$$

$$= 0.101 \times \left(1 - e^{-1.1 \times 0.5}\right) \times \frac{\pi}{4} \times 0.5^2 \times 44.6 \times 10^3 = 374.178$$

$$\dot{Q}_c = \dot{m}''_{\infty}\left(1 - \mathrm{e}^{-k\beta D}\right)\left(\frac{\pi}{4}D^2\right)\left(\Delta H_c\right) \times F_c$$

$$= 374.178 \times 0.7 = 261.925$$

$$z_o = 0.083 \times \dot{Q}^{\frac{2}{5}} - 1.02 \times D$$

$$z_o = 0.083 \times 374.178^{\frac{2}{5}} - 1.02 \times 0.5 = 0.377788$$

$$T_p = T_a + 25 \times \left(\frac{\dot{Q}_c^{\frac{2}{5}}}{z - z_o}\right)^{\frac{5}{3}} = 20 + 273.15 + 25 \times \left(\frac{261.925^{\frac{2}{5}}}{3.5 - 0.38}\right)^{\frac{5}{3}} = 446.777\,[K]$$

$$u_p = 1.0 \times \left(\frac{\dot{Q}_c}{z - z_o}\right)^{\frac{1}{3}} = \left(\frac{261.925}{3.5 - 0.38}\right)^{\frac{1}{3}} = 4.37866\,[m/s]$$

Q4

Calculate the maximum possible RTI [$m^{0.5}s^{0.5}$] of a sprinkler head to satisfy the following conditions. Round your answer to the nearest ones without units.

- Sprinkler activation temperature = 57°

- Sprinkler activation time less than 1 minute.
- Sprinkler is located 3 m away from the center of a 1 m diameter kerosene pool fire on a 6 m high ceiling.
- Ambient Temp. = 25 $^\circ$C
- Kerosene's heat of combustion = 43.2 kJ/g
- Kerosene's mass burning rate per unit area for infinite diameter = 0.039 [kg/m2-s]
- Extinction coefficient multiplied by the mean beam length corrector = 3.5 [1/m]

$$t_r = \frac{RTI}{u^{0.5}} \ln\left(\frac{T_g - T_a}{T_g - T_d}\right)$$

$$RTI = \frac{t_r \cdot u^{0.5}}{\ln\left(\frac{T_g - T_a}{T_g - T_d}\right)}$$

$$For\ now,\ we\ have\ t_r = 60,\ T_a = 25,\ T_d = 57$$

$$So\ we\ should\ find\ u\ and\ T_g$$

$$In\ the\ given\ case,\ we\ have\ r = 3\ and\ H\ = 6$$

$$So,\ \frac{r}{H} = 0.5$$

$$For\ u\ and\ T_g,\ we\ have$$

$$T_g - T_\infty = \frac{5.38(\dot{Q}/r)^{2/3}}{H}\ and\ u = \frac{0.20\dot{Q}^{1/3}H^{1/2}}{r^{5/6}}$$

$$So\ we\ should\ find\ \dot{Q}$$

$$\dot{Q} = \dot{m}''_\infty(1 - \mathrm{e}^{-k\beta D})\left(\frac{\pi}{4}D^2\right)(\Delta H_c)$$

$$\dot{Q} = 0.039 \times (1 - e^{-3.5\times1}) \times \frac{\pi}{4} \times 1^2 \times 43.2 \times 10^3 = 1283.28$$

$$T_g = 25 + \frac{5.38 \times \frac{1283.28}{3}^{\frac{2}{3}}}{6} = 75.9055$$

$$u = \frac{0.2 \times 1283.28^{\frac{1}{3}} \times 6^{0.5}}{3^{\frac{5}{6}}} = 2.13114$$

$$RTI = \frac{t_r \cdot u^{0.5}}{\ln\left(\frac{T_g - T_a}{T_g - T_d}\right)} = \frac{60 \times 2.13144^{0.5}}{\ln\left(\frac{75.9055 - 25}{75.9055 - 57}\right)} = 88.4352$$