Department of Material Science and Engineering
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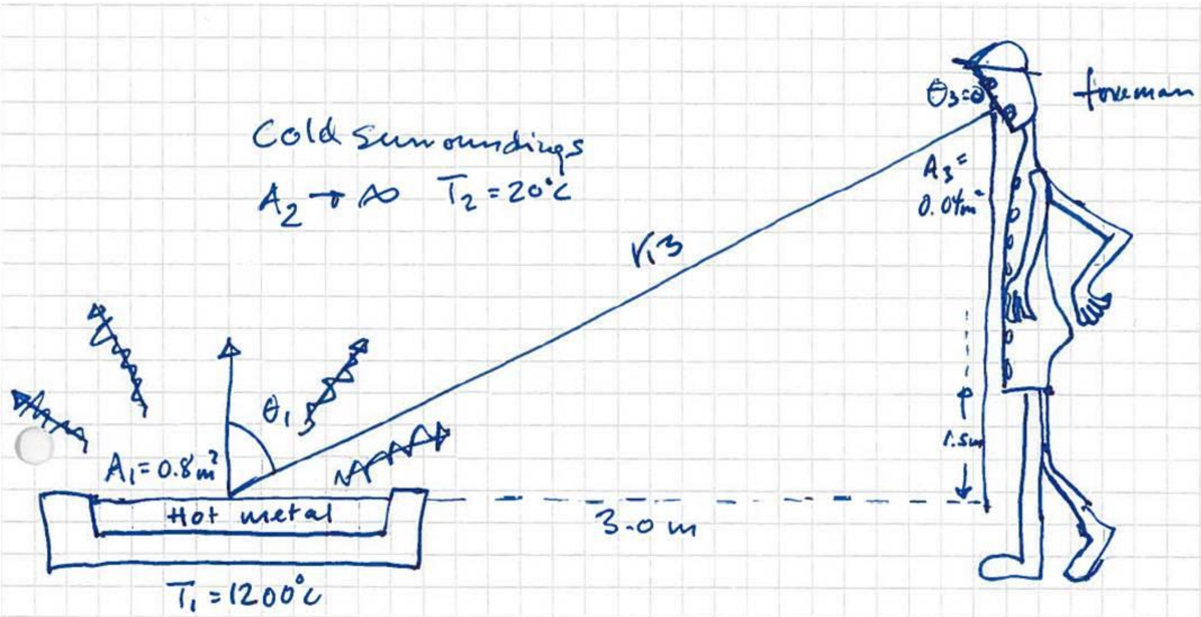
Exercise 12: TMT4208

Hand out: 19.04.2021
Seminar: 23.04.2021
Hand in: 30.04.2021

Task 1 Hot Foreman

The foreman to the right is inspecting liquid metal as shown, and his face has reached its steady state temperature even if it hurts. The face acts as an adiabatic surface with



area A_3=0.04 m^2 and convective heat transfer to the surroundings is neglected. The metal surface has an area A_1= 0.8 m^2, uniform temperature T_1 = 1200°C and emissivity ε_1 = 0.5. The width of A_1 is considered small relative to the distance r_{13}. Other measurements are given on the sketch above.

a) Compute the distance between the metal and the face, r_{13}, determine the angle θ_1 (θ_3 = 0°) and use the equation:

$$F_{31} = \frac{1}{A_3} \int_{A_1} \left(\int_{A_3} \frac{\cos\theta_3 \cos\theta_1}{\pi\, r_{31}^2} dA_3 \right) dA_1$$

to show that $F_{31} \cong 0.01$

Determine the view factors F_{33}, F_{32}, F_{13} and F_{12} based on the assumption that the foreman's face can be assumed to be a flat disc and calculate the relevant *geometric* and *surface* resistances R_{ij} and R_i – .

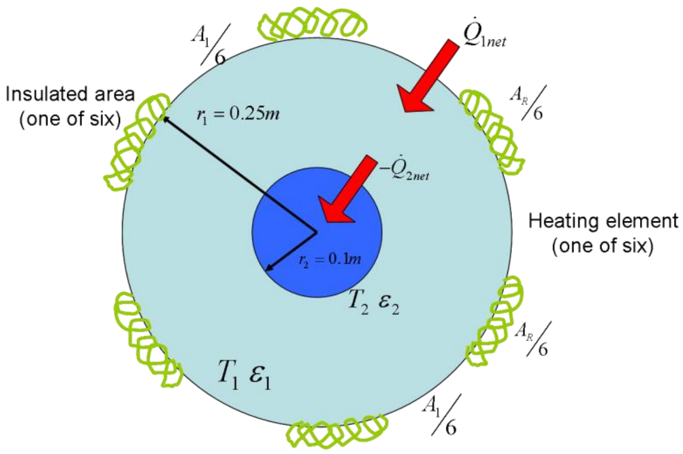
b) Show that $\dot{Q}_{1\,net}$ is approximately 100 kW in this case.

c) Estimate the temperature on the face of the foreman.

Stefan-Boltzmann's constant $\sigma=5.67\cdot10^{-8}$ [W/m²K⁴].

Task 2 Infra-Red heating furnace

A long (L=2.0m) cylindrical heating furnace with radius r_2=0.25m has six rectangular infra-red heating elements of identical size and shape equally distributed on the periphery of the furnace wall which is equipped with insulation of high quality between the elements as indicated on the figure to the right showing a cross section of the furnace. The total heating area A_1 is accordingly equal to the total insulated area A_R. In the center of the furnace we find a cylindrical object with length equal to that of the furnace and this has a radius r_2=0.1m. End effects can be disregarded.



Bearing in mind that also the insulated area will receive and emit radiation, but assuming that these entities are equal ($\dot{Q}_{1\to R} = \dot{Q}_{R\to 1}$), no net heat flow will occur through this area.

Temperature and emissivity of heating elements: T_1 = 927°C; ε_1 = 0.8

Temperature and emissivity of cylindrical object A_2: T_2 = 27°C; ε_2 = 0.3

a) What type of surface is the insulated area?
b) Use simple geometrical considerations to determine the view factors F_{21}, F_{22} and F_{2R} as well as F_{12}, F_{R2}, F_{11} and F_{1R}; the last two can be assumed equal.
c) Using the expressions in the electric analogy circuit given below compute the net radiation heat flow ($\dot{Q}_{1net}$) from the heating elements A_1 and the net radiation heat flow ($-\dot{Q}_{2net}$) to the object A_2.
d) How large part of the net radiation heat flow ($-\dot{Q}_{2net}$) to the object A_2 is transferred via the isolated area A_R? What is the temperature T_R of the isolated area A_R?