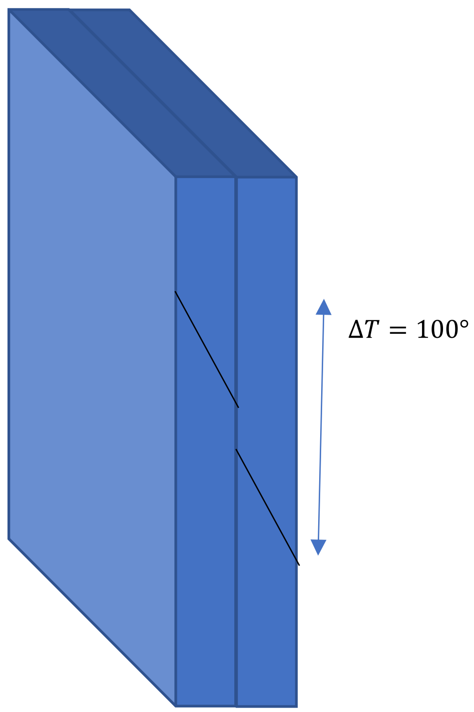
1) Two stainless steel plates 10 mm thick are subjected to a contact pressure of 1 atm under vacuum conditions for which there is an overall temperature **drop of 100°C** across the plates. What is the **heat flux through the plates**? What is the **temperature drop** across the contact plane? Hint: Use the contact conductance value in Table 2.1.

Stainless steel/stainless steel (evacuated interstices)	200 – 1,100



$$R_{t_{\text{equiv}}} = \frac{L}{kA} + \frac{1}{h_c A} + \frac{L}{kA}$$

$k := 13.8$

$$k := 13.8 \quad \textbf{(1)}$$

$h[steelEvac] := 200$

$$h_{steelEvac} := 200 \quad \textbf{(2)}$$

$L := .01$

$$L := 0.01 \quad \textbf{(3)}$$

$R[contact] := \dfrac{1}{h[steelEvac]}$

$$R_{contact} := \frac{1}{200} \quad \textbf{(4)}$$

$R[s] := \dfrac{L}{k}$

$$R_s := 0.0007246376812 \quad \textbf{(5)}$$

$R[total] := 2 \cdot R[s] + R[contact]$

$$R_{total} := 0.006449275362 \quad \textbf{(6)}$$

$DeltaT := 100$

$$DeltaT := 100 \quad \textbf{(7)}$$

$$R_{total} := 0.002242424242 \quad \textbf{(8)}$$

$q := \dfrac{DeltaT}{R[total]}$

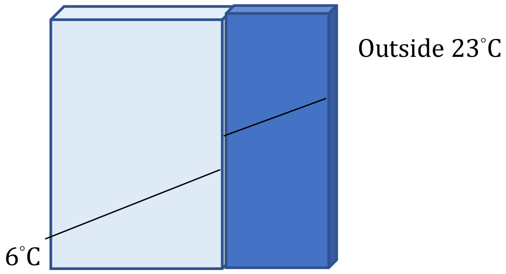
$$q := 15505.61798 \quad \textbf{(9)}$$

$solve\left(q = \dfrac{T}{R[contact]}, T\right)$

$$77.52808990 \quad \textbf{(10)}$$

2) A stainless steel (AISI 304) tube used to transport a chilled pharmaceutical has an inner **diameter of 36 mm** and a wall thickness **of 2 mm.** The pharmaceutical and ambient air are at **temperatures of 6˚C and 23˚C,** respectively, while the corresponding inner and outer convection coefficients are **400 W/m²-K** and **6 W/m²-K**, respectively.

(a) What is the heat gain per unit length [W/m]?



$h[inner] := 400$

$$h_{inner} := 400 \quad (1)$$

$h[outter] := 6$

$$h_{outter} := 6 \quad (2)$$

$r[outter] := \frac{.036}{2} + 0.002$

$$r_{outter} := 0.02000000000 \quad (3)$$

$r[inner] := \frac{.036}{2}$

$$r_{inner} := 0.01800000000 \quad (4)$$

$h[cil] := 13.8$ #back of the book

$$h_{cil} := 13.8 \quad (5)$$

$R[contact] := \frac{\left(\ln\left(\frac{r[outter]}{r[inner]}\right)\right)}{(2 \cdot \mathrm{Pi} \cdot h[cil])}$

$$R_{contact} := 0.001215119338 \quad (6)$$

$R[pharm] := evalf\left(\frac{1}{h[inner] \cdot r[inner] \cdot 2 \cdot \mathrm{Pi}}\right)$

$$R_{pharm} := 0.02210485320 \quad (7)$$

$R[steel] := evalf\left(\frac{1}{h[outter] \cdot r[outter] \cdot 2 \cdot \mathrm{Pi}}\right)$

$$R_{steel} := 1.326291192 \quad (8)$$

$R[total] := evalf(R[pharm] + R[contact] + R[steel])$

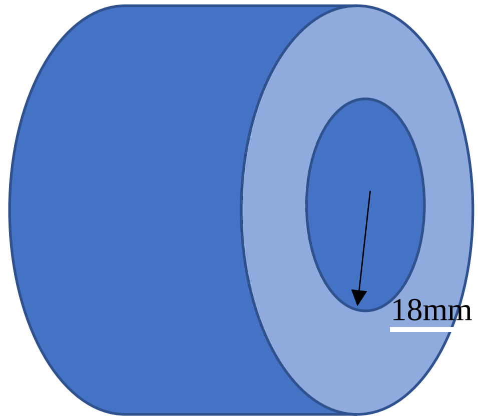
$$R_{total} := 1.349611165 \quad (9)$$

$Delta\_T := 23 - 6$

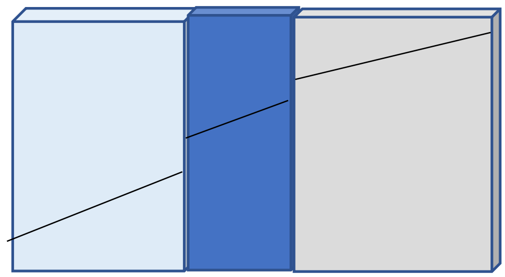
$$Delta\_T := 17 \quad (10)$$

$q[prime] := \frac{Delta\_T}{R[total]}$

$$q_{prime} := 12.59622063 \quad (11)$$



(b) What is the heat gain per unit length if a **10** mm thick layer of calcium silicate insulation (**k_{ins} = 0.05 W/m-K**) is applied to the outside of the tube?



$R[contactSC] := \frac{\left(\ln\left(\frac{\frac{0.036}{2} + 0.012}{\frac{0.036}{2} + 0.01}\right)\right)}{(2 \cdot \mathrm{Pi} \cdot 0.05)}$

$$R_{contactSC} := 0.2196111294 \quad (9)$$

$R[calcium] := \frac{1}{2 \cdot \mathrm{Pi} \cdot (0.0180 + 0.02) \cdot 6}$

$$R_{calcium} := 0.6980479960 \quad (10)$$

$R[total] := evalf(R[pharm] + R[contact] + R[steel] + R[contactSC] + R[calcium])$

$$R_{total} := 2.267270290 \quad (11)$$

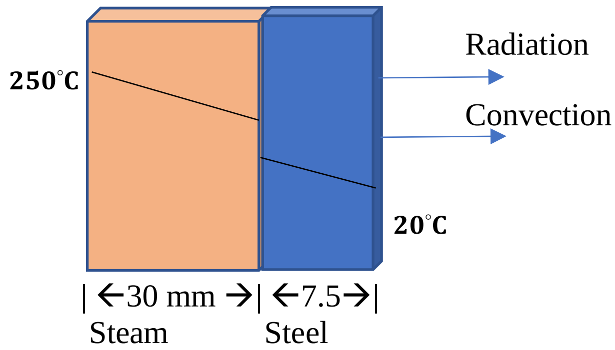
$Delta\_T := 23 - 6$

$$Delta\_T := 17 \quad (12)$$

$q[prime] := \frac{Delta\_T}{R[total]}$

$$q_{prime} := 7.498003249 \quad (13)$$

3) Steam at a temperature of **250°C flows** through a steel pipe (AISI 1010) of **60 mm inner** diameter and **75 mm outer diameter**. The **convection coefficien**t between the steam and the **inner** surface of the pipe is **500 W/m²-K,** while that between the **outer** surface of the pipe and the surroundings is **25 W/m²-K.** The pipe emissivity is 0.8, and the temperature of the air and surroundings is **20°C.** What is the heat loss per unit length of pipe?



$$\boxed{h_{\text{rad}} = 4\sigma T_m^3 \varepsilon_1} \qquad (2.31)$$

$h[inner] := 500$

$$h_{inner} := 500 \qquad \textbf{(1)}$$

$h[outter] := 25$

$$h_{outter} := 25 \qquad \textbf{(2)}$$

$r[outter] := \frac{.0750}{2}$

$$r_{outter} := 0.03750000000 \qquad \textbf{(3)}$$

$r[inner] := .030$

$$r_{inner} := 0.030 \qquad \textbf{(4)}$$

$h[cil] := 64$ *#back of the book*

$$h_{cil} := 64 \qquad \textbf{(5)}$$

$R[contactSeS] := \frac{\left(\ln\left(\frac{r[outter]}{r[inner]}\right)\right)}{(2 \cdot \text{Pi} \cdot h[cil])}$

$$R_{contactSeS} := 0.0005549124875 \qquad \textbf{(6)}$$

$R[steam] := evalf\left(\frac{1}{h[inner] \cdot r[inner] \cdot 2 \cdot \text{Pi}}\right)$

$$R_{steam} := 0.01061032954 \qquad \textbf{(7)}$$

$R[steel] := evalf\left(\frac{1}{h[outter] \cdot r[outter] \cdot 2 \cdot \text{Pi}}\right)$

$$R_{steel} := 0.1697652726 \qquad \textbf{(8)}$$

$\text{epsilon} := 0.8$

$$\epsilon := 0.8 \qquad \textbf{(9)}$$

$T := 135$ *#20+273*

$$T := 135 \qquad \textbf{(10)}$$

$\text{sigma} := 5.67 \cdot 10^{-8}$

$$\sigma := 5.670000000\ 10^{-8} \qquad \textbf{(11)}$$

$h[rad] := 4 \cdot \text{sigma} \cdot T^3 \cdot \text{epsilon}$

$$h_{rad} := 0.4464104400 \qquad \textbf{(12)}$$

$R[rad] := \frac{1}{2 \cdot \text{Pi} \cdot h[rad]}$

$$R_{rad} := 0.3565215524 \qquad \textbf{(13)}$$

$R[total] := evalf\left(R[steam] + R[contactSeS] + \left(R[steel]^{-1} + R[rad]^{-1}\right)^{-1}\right)$

$$R_{total} := 0.1261690301 \qquad \textbf{(14)}$$

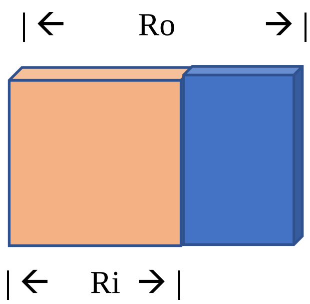
$Delta\_T := 250 - 20$

$$Delta\_T := 230 \qquad \textbf{(15)}$$

$q[prime] := \frac{Delta\_T}{R[total]}$

$$q_{prime} := 1822.951320 \qquad \textbf{(16)}$$

4) A **spherical** shell of inner and outer radii of r_i and r_o, respectively, is filled with a heat-generating material that provides for a uniform **volumetric generation rate (W/m^3) of $\dot{q}$.** The outer surface of the shell is exposed to a fluid having a temperature **T_∞** and a convection coefficient **h.** Obtain an expression for the steady-state temperature distribution **T(r)** in the shell, expressing you results in terms of **r_i, r_o, $\dot{q}$, h, T_∞,** and the thermal **conductivity k** of the shell material.



With the help for Mcklane G.

$$\frac{K}{r^2}\frac{d}{dr}\left(r^2\frac{dt}{dr}\right)=0$$

$$\frac{d}{dr}\left(r^2\frac{dt}{dr}\right)=0$$

$$\int\frac{d}{dr}\left(r^2\frac{dt}{dr}\right)=0$$

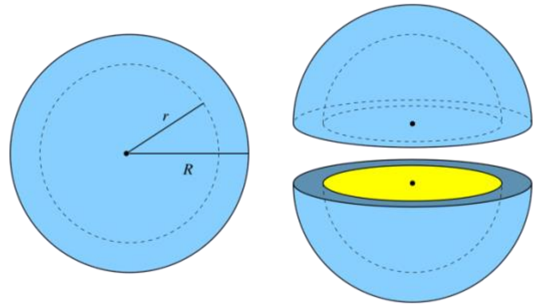
$$r^2\frac{dT}{dr}+C_1=0$$

$$\frac{dt}{dr}=-\frac{C_1}{r^2}$$

Integrate:

$$T(r)=\frac{C_1}{r}+C_2$$

https://images.app.goo.gl/BBty8fw2MHekAYDT7



1st Apply Boundary conditions for q

$$-k\frac{dT}{dr}|_{r=r_i}=q=\frac{\dot{q}V}{A}$$

$$-k\left(-\frac{c_i}{r_i}\right)=\dot{q}\frac{V}{A}$$

$$C_1=\dot{q}\,V\frac{r_i^2}{k\,A}=\dot{q}\frac{r_i^3}{Ak}$$

2nd Convective

$$-k\frac{dT}{dr}|_{r=r_o}=h(T_o-T_{oo})$$

$$-k\left(-\frac{qr^2}{3kr_o^2}\right)=h\,\left(\frac{qr^2}{3kr_o^2}+C_2-T_{oo}\right)$$

$$\frac{\dot{q}r^2}{3r_o^2}=h\,\frac{r^2}{3kr_o^2}+h\,C_2-h\,T_{oo}$$

$$\boxed{T(r)\coloneqq\frac{\dot{q}r_i^3}{3k}\left[\frac{1}{r}-\frac{1}{r_o}\right]+\frac{\dot{q}r_i^3}{3hr_o^2}+T_{oo}}$$

5. The exposed surface (**x = 0**) of a plane wall of thermal conductivity k is subjected to microwave radiation that causes volumetric heating to vary as $\dot{q}(x) = \dot{q}_o\left(1 - \frac{x}{L}\right)$ (1) where **$\dot{q}_o$ (W/m^3)** is a constant. The boundary at **x = L** is perfectly insulated, while the exposed surface is maintained at a constant temperature **T_o**. Determine the temperature distribution **T(x)** in terms of **x, L, k, $\dot{q}_o$, and T_o.** We the help of Braedin B. $$\frac{d^2T}{dx^2} + \frac{q(x)}{k} = 0$$ $$\frac{d^2T}{dx^2} + \frac{q\left(1 - \frac{x}{L}\right)}{k} = 0$$ $$\frac{dT}{dx} + \frac{q_o x}{k} - \frac{q_o x^2}{6\ k\ L} = C_1 x + C_2$$ If x =0 and T =To $$T(0) + \frac{q_0(0)^2}{2k} - \frac{q_o(0)^3}{6\ k\ L} = C_1 0 + C_2$$ $C_2 = T_0$ If x= L dt/dx = 0 $$C_1 = q_o x^2$$ $$\boxed{T(x) \coloneqq T_o + \frac{q_o L x}{2k}(1 - \frac{x}{L} + \frac{1}{3} * \frac{x^2}{L^2})}$$	

6) A long cylindrical rod of diameter **200 mm** with thermal conductivity of **0.5 W/m-K** experiences uniform volumetric heat generation of **24,000 W/m^3.** The rod is encapsulated by a circular sleeve having an outer diameter of **400 mm** and a thermal conductivity of **4 W/m-K.** The outer surface of the sleeve is exposed to a cross flow of air at **27°C** with a convection coefficient of **25 W/m^2-K.**

(a) Find the temperature at the interface between the rod and sleeve and on the outer surface.

$k[s] := 4$

$$k_s := 4 \quad (1)$$

$r[s] := 0.2$

$$r_s := 0.2 \quad (2)$$

$r[r] := 0.1$

$$r_r := 0.1 \quad (3)$$

$$R[cond] := \frac{\ln\left(\frac{r[s]}{r[r]}\right)}{2 \cdot \mathrm{Pi} \cdot k[s]}$$

$$R_{cond} := 0.02757945001 \quad (4)$$

$h := 25$

$$h := 25 \quad (5)$$

$A[outSerf] := 2 \cdot \mathrm{Pi} \cdot r[s]$

$$A_{outSerf} := 1.256637062 \quad (6)$$

$$R[convect] := \frac{1}{h \cdot A[outSerf]}$$

$$R_{convect} := 0.03183098860 \quad (7)$$

$R[pimeTot] := R[convect] + R[cond]$

$$R_{pimeTot} := 0.05941043861 \quad (8)$$

$$R_{pimeTot} := \frac{0.05941043861}{L} \quad (9)$$

$q := 24000$

$$q := 24000 \quad (10)$$

$T[infn] := 27$

$$T_{infn} := 27 \quad (11)$$

$$solve\left(q \cdot \mathrm{Pi} \cdot r[r]^2 = \frac{T[x] - T[infn]}{R[pimeTot]}, T[x]\right)$$

$$71.79441540 \quad (12)$$

(b) What is the temperature at the center of the rod?

$k[s] := 4$

$$k_s := 4 \quad (1)$$

$r[s] := 0.2$

$$r_s := 0.2 \quad (2)$$

$r[r] := 0.1$

$$r_r := 0.1 \quad (3)$$

$$R[cond] := \frac{\ln\left(\frac{r[s]}{r[r]}\right)}{2 \cdot \mathrm{Pi} \cdot k[s]}$$

$$R_{cond} := 0.02757945001 \quad (4)$$

$h := 25$

$$h := 25 \quad (5)$$

$A[outSerf] := 2 \cdot \mathrm{Pi} \cdot r[s]$

$$A_{outSerf} := 1.256637062 \quad (6)$$

$$R[convect] := \frac{1}{h \cdot A[outSerf]}$$

$$R_{convect} := 0.03183098860 \quad (7)$$

$R[pimeTot] := R[convect] + R[cond]$

$$R_{pimeTot} := 0.05941043861 \quad (8)$$

$$R_{pimeTot} := \frac{0.05941043861}{L} \quad (9)$$

$q := 24000$

$$q := 24000 \quad (10)$$

$T[infn] := 27$

$$T_{infn} := 27 \quad (11)$$

$$solve\left(q \cdot \mathrm{Pi} \cdot r[s]^2 = \frac{T[x] - T[infn]}{R[pimeTot]}, T[x]\right)$$

$$206.1776616 \quad (12)$$

7) Radioactive waste $(\mathbf{k_{rw} = 20\ W/m\text{-}K})$ is stored in a spherical, stainless steel $(\mathbf{k_{ss} = 15\ W/m\text{-}K})$ container of inner and outer radii of $\mathbf{r_i = 0.5}$ m and $\mathbf{r_o = 0.6}$ **m**, respectively. Heat is generated volumetrically within the waste at a uniform rate of $\mathbf{\dot{q} = 10^5\ W/m^3}$, and the outer surface of the container is exposed to a water flow for which $\mathbf{h = 1000\ W/m^2\text{-}K}$ and $\mathbf{T_\infty = 25^\circ C}$.

(a) Evaluate the steady-state outer surface temperature of the container, $\mathbf{T_{s,o}}$.

$$r[s] := 0.6$$

$$r_s := 0.6 \quad (1)$$

$$r[r] := 0.5$$

$$r_r := 0.5 \quad (2)$$

$$h := 1000$$

$$h := 1000 \quad (3)$$

$$R[outSerf] := \frac{1}{4 \cdot \mathrm{Pi} \cdot r[s]^2 \cdot h}$$

$$R_{outSerf} := 0.0002210485320 \quad (4)$$

$$q[dot] := 10^5$$

$$q_{dot} := 100000 \quad (5)$$

$$T[infin] := 25$$

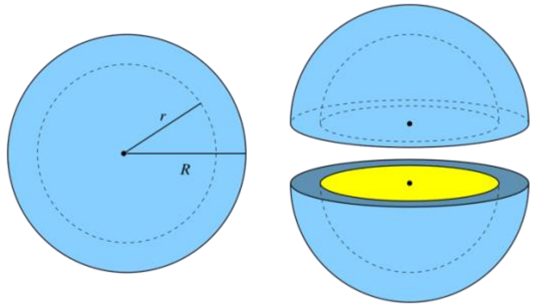
$$T_{infin} := 25 \quad (6)$$

$$solve\left(q[dot] = \frac{T[ss] - T[infin]}{R[outSerf]}, T[ss]\right)$$

$$47.10485320 \quad (7)$$

(c) Obtain an expression for the temperature distribution, $\mathbf{T(r)}$ in the radioactive waste. Evaluate the temperature at $\mathbf{r = 0}$.

https://images.app.goo.gl/BBty8fw2MHekAYDT7



(b) Evaluate the steady-state inner surface temperature of the container, $\mathbf{T_{s,i}}$.