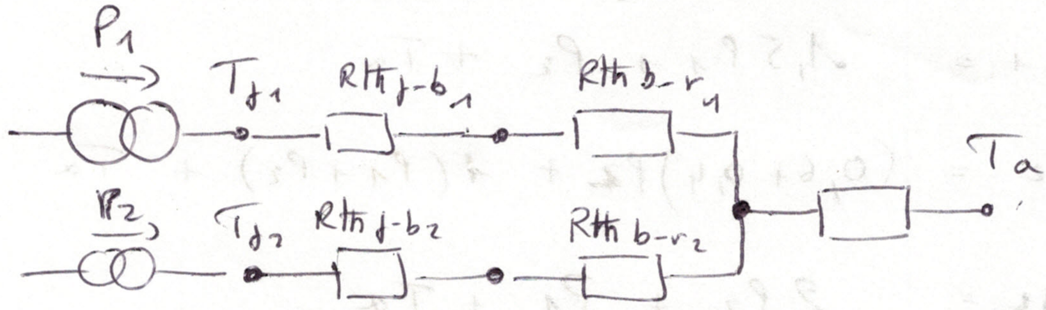
CONDUCTION

$\boxed{3.12.1}$

a)



b) $T_{j1\,max} = 140°C \qquad P_1 = 40W$

$T_{j2\,max} = 130°C \qquad P_2 = 10W$

$T_{j1} - T_r = 40\,(0{,}5 + 0{,}25) = 30°C$

$\Rightarrow T_{r\,max} = 140 - 30 = 110°C$ (1)

$T_{j2} - T_r = 10\,(0{,}8 + 0{,}4) = 12°C$

$\Rightarrow T_{r\,max} = 130 - 12 = 118°C$ (2)

Condition 1 $\Rightarrow \Delta T = T_r - T_a = 110 - 85 = 25°$

$\boxed{\Delta T = 25°C}$

c) $Rth_{r-a} = \dfrac{\Delta T}{P_1 + P_2} = \dfrac{25}{50} = 0{,}5\ K/W$

$\boxed{Rth_{r-a} = 0{,}5\ K/W}$

d) $Rth = 0{,}5\ K/W$ = <u>Valeur maximale</u>

$\boxed{3.12.2}$ $R_{th\,r-a} = 1K/W$ $T_a = 75°C$.

a/ $T_{j1} = (0{,}2 + 0{,}3)P_1 + 1(P_1 + P_2) + T_a$

$T_{j1} = 1{,}5P_1 + P_2 + T_a$

b/ $T_{j2} = (0{,}6 + 0{,}4)P_2 + 1(P_1 + P_2) + T_a$

$T_{j2} = 2P_2 + P_1 + T_a$

c/ $T_{j1\,max} = 125°C$ / $T_{j2\,max} = 145°C$

$$\begin{cases} 1{,}5P_1 + P_2 = 125 - 75 = 50 \\ P_1 + 2P_2 = 145 - 75 = 70 \end{cases}$$

$2P_1 = 30 \Rightarrow P_1 = 15W$.

$P_2 = \frac{70 - 15}{2} = 27{,}5W$.

$\boxed{P_1 = 15W \mid P_2 = 27{,}5W}$

d/ $T_r = ?$

$T_r = P_1 + P_2 \times R_{th\,r-a} + T_a = 42{,}5 + 75 = 117{,}5$

$\boxed{T_r = 117{,}5°C}$

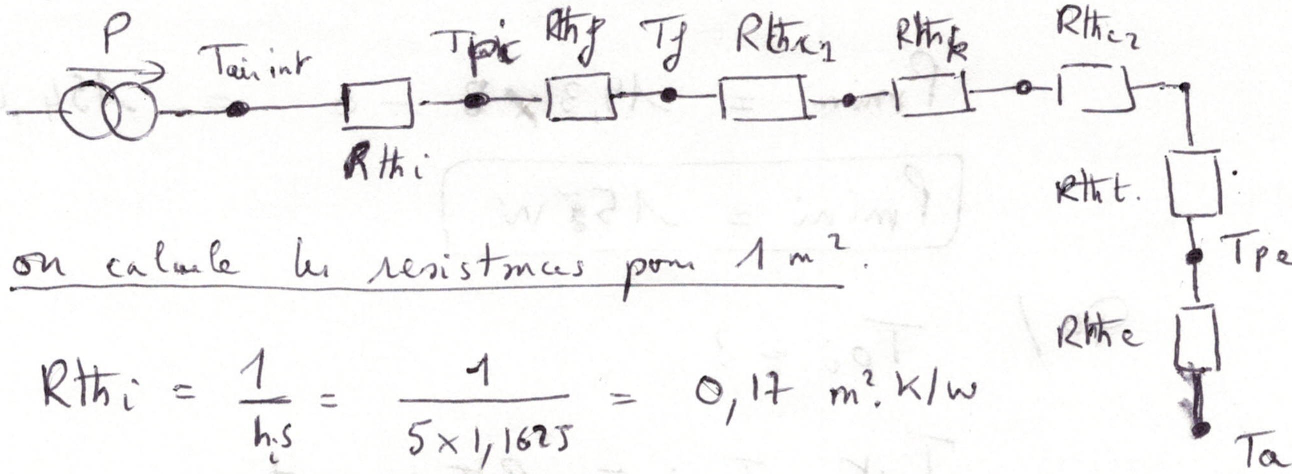
e/ $\Delta T_r = (30 + 30) \times 1 = 60°C$.

$T_{j1} - T_r = 30(0{,}2 + 0{,}3) = 15°C$.

$T_{j2} - T_r = 30(0{,}6 + 0{,}4) = 30°C$.

$$\left.\begin{aligned} T_{a1\,max} &= 125 - 15 - 60 = 50°C \\ T_{a2\,max} &= 145 - 30 - 60 = 55°C \end{aligned}\right\} \Rightarrow \boxed{T_{a\,max} = 50°C}$$

3.12.3



Q1) on calcule les resistances pour 1 m²

$$Rth_i = \frac{1}{h_i S} = \frac{1}{5 \times 1,1625} = 0,17 \ m^2.K/W$$

$$Rth_e = \frac{1}{h_e} = \frac{1}{30 \times 1,1625} = 0,0287 \ m^2.K/W$$

Absorbeur dans armoire isolée

$$* \ Rth_f = \frac{e}{\lambda S} = \frac{3 \times 10^{-4}}{180} = 1,67 \times 10^{-6} \ m^2 K/W$$

$$* \ Rth_{c1} = 0,25/1,1625 = 0,215 \ m^2 K/W$$

$$* \ Rth_k = \frac{e}{\lambda S} = \frac{0,03}{0,045} = 0,67 \ K/W$$

$$* \ Rth_{c2} = 0,25/1,1625 = 0,215 \ m^2.K/W$$

$$Rth_t = \frac{e}{\lambda S} = \frac{0,0025}{40} = 62,5 \times 10^{-6} \ m^2 K/W$$

$$\boxed{\Sigma Rth = 1,295 \ m^2.K/W}$$

Q2) $T_i - T_{ext} = \phi \times \Sigma Rth = \varphi \frac{\Sigma Rth}{S}$

$$5 - (-20) = \varphi \times 1,295$$

$$\varphi = \frac{25}{1,295} = 19,3$$

$$\boxed{\varphi = 19,3 \ W/m^2}$$

c) $P_{mini} = 19,3 \times S$ — Pertes joules mini

$P_{mini} = 19,3 \times 8 - 0 = 154,4 \text{ W}$

$\boxed{P_{mini} = 155 \text{ W}}$

Q4/ $T_{pi} = ?$

$T_{int} - T_{pi} = R_{th\,i} \times \phi$

$= 0,17 \times 19,3 = 3,28 \text{ °C}.$

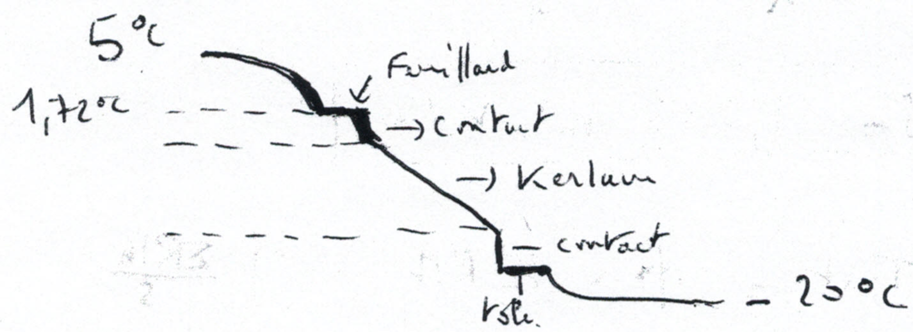
$T_{pi} = 5 - 3,28 = \boxed{1,72 \text{ °C}}$

$T_{pe} = ?$

$T_{pe} - T_{ext} = R_{th\,e} \times \phi$

$= 0,0287 \times 19,3 = 0,547 \text{ °C}$

$T_{pe} = -20 + 0,547 = \boxed{-19,45 \text{ °C}}$



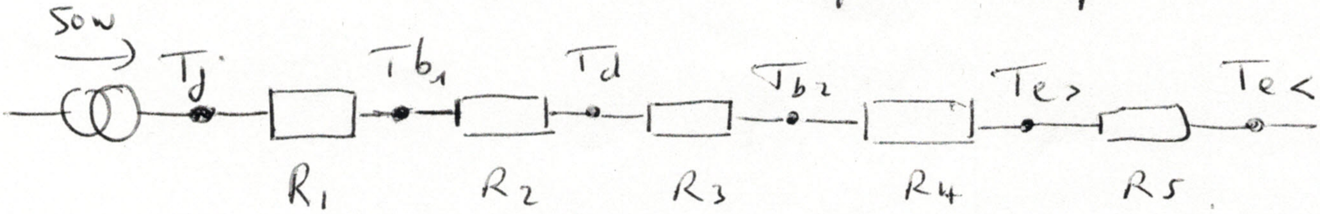
Q5/ $\Sigma R_{th} = 0,1988 \simeq 0,2 \text{ m}^2.\text{K/W}$

(à comparer avec 1,3.)

$\varphi = \frac{25}{0,2} = 125 \text{ W/}$ $\boxed{\Phi = 1000 \text{ W}}$

$\boxed{T_{pi} = 5 - 0,17 \times 125 = -16,25 \text{ °C}}$ $\boxed{T_{pe} = -16,46 \text{ °C}}$

3.12.4 Composant électronique de puissance



$$\Sigma R = \Sigma \frac{e}{\lambda S} = \frac{3\times10^{-4}}{130\times16\times10^{-6}} + \frac{5\times10^{-5}}{18\times16\times10^{-6}} + \frac{10^{-3}}{400\times16\times10^{-6}} + \frac{8\times10^{-5}}{100\times16\times10^{-6}} + \frac{16\times10^{-4}}{40\times16\times10^{-6}}$$

① $\Sigma R_{th} = 0,1442 + 0,1736 + 0,15625 + 0,05 + 2,5$

$R_{th>} = 3,024\ °K/W \Rightarrow \Delta T_> = 50\times3,024 = \underline{151°}$

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② $\Sigma R_{th} = 0,1442 + 0,1736 + \frac{10^{-3}}{400\times64\times10^{-6}} + \frac{0,05}{4} + \frac{2,5}{25} = 0,4694$

$R_{th<} \simeq 0,47\ °K/W \Rightarrow \Delta T_< = 50\times0,47 = \underline{23,5°C}$

---

③ $\Sigma R_{th} = 0,14423 + 0,1736 + \underbrace{\frac{10^{-3}}{400\times6\times4\times10^{-6}}}_{0,10417} + \underbrace{\frac{8\times10^{-5}}{100\times6\times6,16\times10^{-6}}}_{0,02164}$

$+ \underbrace{\frac{16\times10^{-4}}{40\times6,16\times9,36\times10^{-6}}}_{0,6938}$

$R_{th\,moy} = 1,1374 \Rightarrow \Delta T_{moy} = 56,9\ °C$

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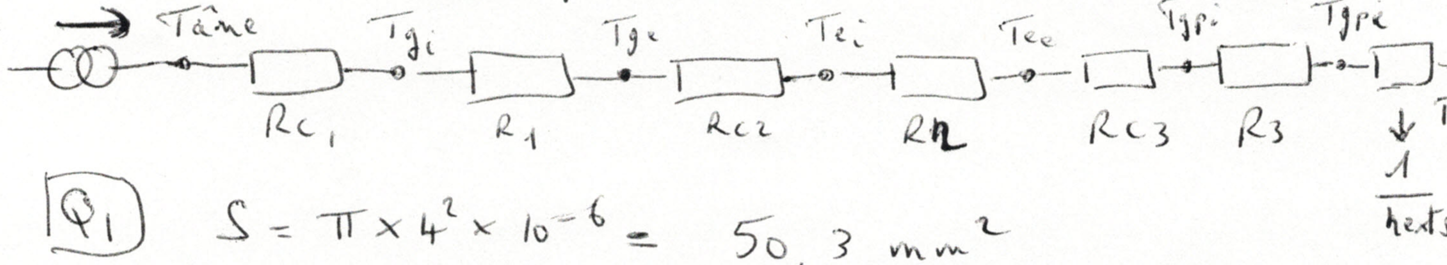
le ΔT réel sera un peu inférieur au cas 3

3.12.5 échauffement d'un câble



Q1

$$S = \pi \times 4^2 \times 10^{-6} = 50,3 \ mm^2$$

$$J = \frac{235}{50,3} = \boxed{4,675 \ A/mm^2}$$

Q2 Il manque la resistivité du cuivre à la température de l'âme.

on propose $2 \times 10^{-8} \ \Omega.m$.

Q3

$$P = \phi = RI^2 = 2 \times 10^{-8} \times \frac{1}{50,26 \times 10^{-6}} \times 235^2 = 22 \ W/m$$

$$\Sigma Rth = 3 \times 0,005 + \frac{\ln 11/8}{2\pi \times 0,4} + \frac{\ln(11,4/11)}{2\pi \times 1,5} + \frac{\ln(19,4/11,4)}{2\pi \times 0,3}$$

$$0,015 + 0,1267 + 0,0038 \quad 0,2821$$

$$\Sigma Rth = 0,4276 \ K/W$$

$$\frac{1}{h_{exts}} = \frac{1}{18 \times \pi \times 19,4 \times 10^{-3} \times 1} = 0,9115 \ K/W$$

$$T_{p\,extern} = \frac{1}{h_{exts}} \times \phi + T_{amb} = 50\,°C$$

Q4 $T_{âme} = P \times \Sigma Rth + T_{amb} = 59,5\,°C$

Q5 Il faut reprendre avec $\rho_{cuivre} = 1,95$ si pur. mais OK avec impuretés

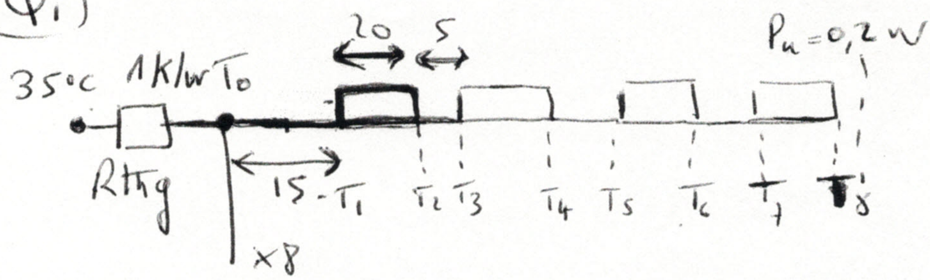
Q6

$$\left(\frac{1}{h_{exts}}\right)' = 0,9115 \times \frac{18}{11} = 1,4915 \ K/W$$

$$T_{âme} = 22 \times (0,4276 + 1,4915) + 30 = \boxed{72,2\,°C}$$

$\boxed{3.12.6}$ **Drain thermique**

(Q.1)



$$R_{drain} = \frac{l}{\lambda S} = \frac{l \times 10^{-3}}{400 \times 5 \times 10^{-6}} = 0,5\,l\,(mm) = 500\,l\,(m).$$

$$\Delta T_0 = (8 \times 4 \times 0,2) \times 1 = (P_{carte}/2) \times R_{thg} = 6,4\ °C$$

$T_0 = 41,4\ °C$ $\qquad T_1 = 0,8 \times 0,5 \times 15 + 41,4 = 47,4\ °C$

$\Delta T_{comp\ 1} = ?$

$$dT = 500\,dl \times \left(\phi_1 - 0,2 \frac{l}{20 \times 10^{-3}}\right)$$

$$\Delta T = 500 \int_0^{0,02} \phi_1 - 10\,l\,dl.$$

$$\Delta T = 500 \left[\phi_1 l - 5 l^2\right]_0^{0,02} = 500 \times \left[\phi_1 \times 0,02 - 2 \times 10^{-3}\right]$$

$$\Delta T = \left[10\phi_1 - 1\right]$$

$T_2 - T_1 = (10 \times 0,8 - 1) = 7\ °C.$ $\qquad T_2 = 54,4\ °C$

$T_3 - T_2 = 0,6 \times 2,5 = 1,5\ °C$ $\qquad T_3 = 55,9\ °C$

$T_4 - T_3 = (10\phi_2 - 1) = 10 \times 0,6 - 1 = 5\ °C$ $\qquad T_4 = 60,9\ °C$

$T_5 - T_4 = 0,4 \times 2,5 = 1,0\ °C \Rightarrow T_5 = 61,9\ °C$

$T_6 - T_5 = (10\phi_3 - 1) = 10 \times 0,4 - 1 = 3\ °C$ $\qquad T_6 = 64,9\ °C$

$T_7 - T_6 = 0,2 \times 2,5 = 0,5\ °C \Rightarrow T_7 = 65,4\ °C$

$T_8 - T_7 = (10\phi_4 - 1) = (10 \times 0,2 - 1) = 1\ °C.$ $\qquad T_8 = 66,4\ °C$

Q2

$T_8 = 67,4\,°C$

$\Delta T_{chain} = T_8 - T_0 = 66,4 - 41,4\,°C$

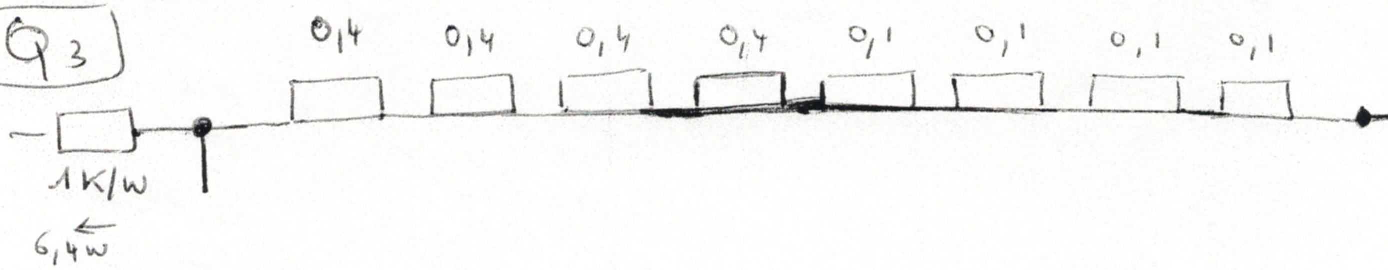
$\Delta T_{chain} = 25\,°C$

pour passer à $15\,°C$ → règle de 3 sur la surface

$\Delta T_1 \times k\, e_1 = \Delta T_2 \times k\, e_2$

$\Rightarrow e_2 = e_1 \times \dfrac{\Delta T_1}{\Delta T_2} = 1\,mm \times \dfrac{25}{15} = \boxed{1,67\,mm}$

Q3

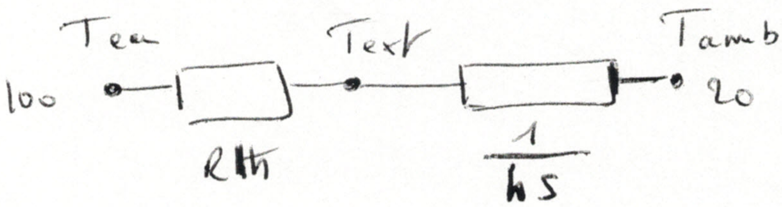


3.12.7 Radiateur à Ailettes spiralées

$\phi : 32/40$ mm $\qquad \rho_a = 7800$ kg/m³

$\lambda_{acier} = 46,5$ W/m·K

$h_{ext} = 12$ kcal/h·m²°C $= 13,95$ W/m²·K.



$\phi = 1162,5$ W.

$$\Delta T = T_{eau} - T_{air} = 100 - 20 = 80 = \phi \times Rth + \frac{1}{hS}$$

$$Rth = \frac{\ln 40/32}{2\pi \lambda L} = \frac{7,6375 \times 10^{-4}}{L} \text{ K/W}$$

$$\frac{1}{hS} = \frac{1}{13,95 \times (S_{tube} + S_{ail} \times \eta'')}$$

$S_{tube} = 0,04\pi L$

$S_{tube\ ailetée} = (0,04\pi L \times 0,9)$

$S_{ailette} = L \times 50 \times 2 \times \pi (R_{ext}^2 - 0,02^2)$.

---

① Tube Nu

$$Rth + \frac{1}{hS} = \frac{80}{1162,5} = 0,068817$$

$$\frac{7,6375}{L} + \frac{5700}{L} = 688,17$$

$$L = \frac{5707,63}{688,17} = 8,29 \text{ m.}$$

$$m_1 = \pi (0,02^2 - 0,016^2) \times L \times \rho = \boxed{29,25 \text{ kg}}$$

2) Ailettes de 6 cm hauteur

$$S_{tube} = 0{,}036\pi L = 0{,}1131\,L.$$

$$S_{ailette} = 314{,}16\,L \times (0{,}08^2 - 0{,}02^2)$$
$$= 1{,}885\,L.$$

$$\eta'' = ?$$

$$m\ell = \ell\sqrt{\frac{2h}{\lambda e}} = 0{,}06 \times \sqrt{\frac{2\times 13{,}95}{46{,}5\times 2\times 10^{-3}}}$$

$$= 0{,}06 \times 17{,}32 = 1{,}039.$$

abaque $\Rightarrow$ $\eta'' = 0{,}6.$

car $Re/Rb = 80/20 = 4$

$$S_{eff\ ailette} = 0{,}6 \times 1{,}885\,L = 1{,}131\,L.$$

$$\frac{1}{hS} = \frac{1}{13{,}95\times 1{,}2441\,L} = \frac{0{,}05762}{L}$$

$$\frac{7{,}6375}{L} + \frac{576{,}2}{L} = 688{,}17 \Rightarrow L = 0{,}848\overset{386}{}\ m.$$

$$m = \rho\left(\pi(0{,}02^2 - 0{,}016^2)\times L + \frac{1{,}885}{2}L \times 2\times 10^{-3}\right)$$

$$m_{tube} = 29{,}25 \times \frac{0{,}848}{8{,}29} = 2{,}99\text{ kg}$$

$$m_{ailettes} = \frac{1{,}885}{2} \times 2\times 7{,}8 = 12{,}47\text{ kg}$$

$$m_{total} = 2{,}99 + 12{,}47 = 15{,}46\text{ kg}$$

③ ailettes $h = 40$ mm

$$S_{tube} = 0,1131\,L$$

$$S_{ailette} = 100\pi\, L \times (0,06^2 - 0,02^2)$$
$$= 1,0053\,L$$

$$m\ell = \ell\sqrt{\frac{2h}{\lambda e}} = 0,04\sqrt{300} = 0,6928$$

Abaque $\eta'' = 0,78$ avec $Re/Rb = 60/20 = 3$

$$S_{eff\ ailette} = 0,78 \times 1,0053\,L = 0,7037\,L.$$

$$\frac{1}{hS} = \frac{1}{13,95 \times 0,81681\,L} = \frac{0,08776}{L}$$

$$\frac{7,6375}{L} + \frac{877,6}{L} = 688,17 \Rightarrow L = 1,286\text{ m}.$$

$$m = \rho\left[\pi(0,02^2 - 0,016^2)\,L + \frac{1,0053}{2}\,L \times 2\times10^{-3}\right]$$

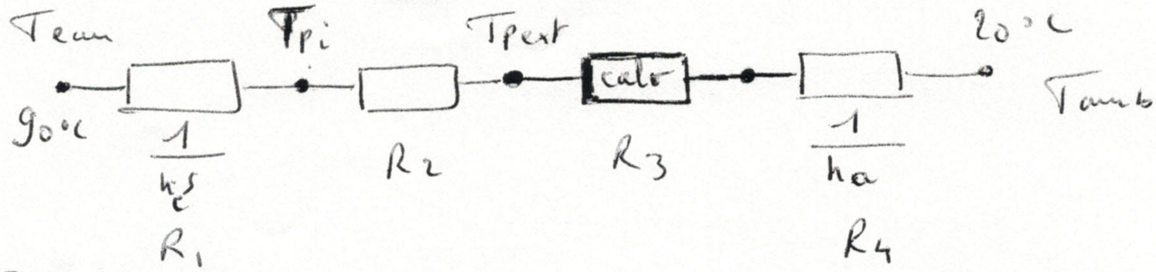
$$m_{tube} = 29,25 \times \frac{1,286}{8,29} = 4,537\text{ kg}.$$

$$m_{ailettes} = 10,08\text{ kg}$$

$$\boxed{m_{total_3} = 14,62\text{ kg}}$$

3.12.8 — Pertes thermiques tuyauterie

Q1



$$R_1 = \frac{1}{4500 \times \pi \times 0{,}032} = 2{,}21 \times 10^{-3}\ \text{°K/W.m}$$

$$R_2 = \frac{\ln D_2/D_1}{2\pi \lambda L} = \frac{\ln 38/32}{2\pi \times 40} = 0{,}684 \times 10^{-3}$$

$$R_3 = 0$$

$$R_4 = \frac{1}{10 \times \pi \times 0{,}038} = 0{,}838\ \text{°K/W.m}$$

$$\phi = 70/\Sigma R = 83{,}2$$

$$\boxed{\phi = 83\ \text{W/m}}$$

Q2

$$R_2 = \frac{3 \times 10^{-3}}{40 \times \pi \times 35 \times 10^{-3}} = 6{,}821 \times 10^{-4}$$

(Erreur de 0,3 % environ).

Q3

$$R_3 = \frac{\ln(110/38)}{2\pi \times 0{,}045 \times 1} = 3{,}7592$$

$$R_4' = \frac{1}{10 \times \pi \times 0{,}11} = 0{,}2894\ \text{K/W}$$

$$\phi = 70/\Sigma R = 70/4{,}051 = 17{,}28\ \text{W/m}$$

$$\boxed{\phi \simeq 17{,}3\ \text{W/m}}$$

Q4

$$R_3' = \frac{\ln(110/38)}{2\pi \times 0{,}5 \times 1} = 0{,}3383$$

$$\phi = 70/\Sigma R = 70/0{,}63 = 111\ \text{W}.$$

$$\boxed{\phi = 111\ \text{W}}$$

[illegible]