11.6.1 Fonctionnement cyclique d'une résistance de charge

$S = 10\,m^2$ $V = 0{,}01\,m^3$ $\rho = 6000\,kg/m^3$

$C_p = 500\,J/kg.K.$

si $U = 100\,V$

$\Delta T = 400°C$

$\tau = 100\,s.$

Q1 a) $\tau = R_{th}\,C_{th} \Rightarrow R_{th} = \dfrac{\tau}{C_{th}}$

$C_{th} = m\,C_p = \rho V c_p = 6000 \times 0{,}01 \times 500$

$C_{th} = 30\,000\ J/K.$

$R_{th} = \dfrac{100}{30000} = \dfrac{1}{300}\ K/W$

$hS = \dfrac{1}{R_{th}} \Rightarrow h = \dfrac{1}{R_{th}.S} = \dfrac{300}{10} = 30\ W/m^2.K$

$$\boxed{h = 30\ W/m^2.K}$$

b) on en déduit ϕ

$\phi = hS\Delta T = 30 \times 10 \times 400 = 120\,000\ W$

$$\boxed{\phi = 120\ kW = P\ \text{électrique}}$$

$\phi_{rayonné} = \sigma \varepsilon S R (T_r^4 - T_a^4)$

$\phi_{ray} = R \times 5{,}67 \times 10 \times 0{,}05 \times (7{,}23^4 - 3{,}23^4)$

$= R \times 7438\ W \quad (R < 1).$

$7438\ W = 6{,}2\,\%$ de $120\ kW.$

$\boxed{Q_2}$

$$\phi = P = \frac{U^2}{R} \Rightarrow R = \frac{U^2}{\phi}$$

$$R = \frac{100^2}{120\,000} = \frac{1}{12}\ \Omega.$$

$$\boxed{R = 1/12\ \Omega = 0{,}083\ \Omega}$$

$\boxed{Q_3}$

$$\begin{cases} T_t = T_a + (T_{final} - T_a)\, e^{-\frac{t}{\tau}} \\ T_t = 100\,°C \end{cases}$$

$$\Rightarrow 100 = 50 + 400\, e^{-\frac{t}{\tau}}$$

$$\Rightarrow e^{-\frac{t}{\tau}} = \frac{50}{400} = \frac{5}{40} = \frac{1}{8}$$

$$\Rightarrow \frac{-t}{\tau} = \ln\left(\frac{1}{8}\right) \Rightarrow t = \tau \ln(8)$$

$$t = 100 \times \ln(8) = 208\ s$$

$\boxed{Q_4}$

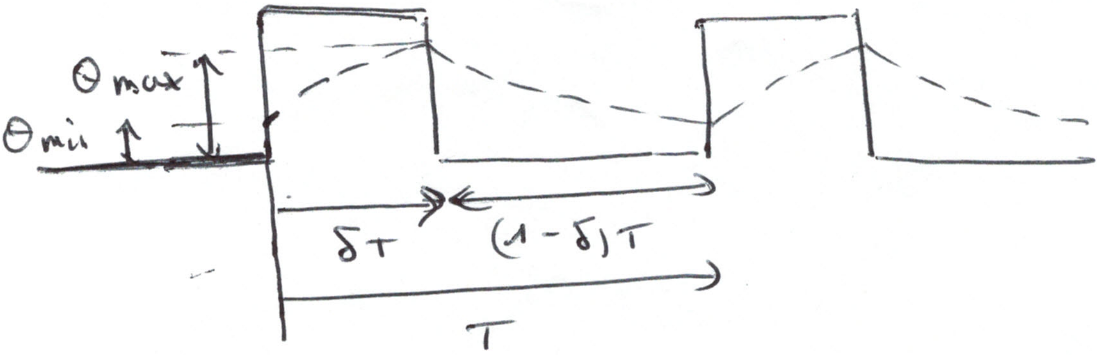
en continu

$$\begin{cases} \phi = \frac{U^2}{R} = h S \Delta T \Rightarrow U = \sqrt{R h S \Delta T} \\ \Delta T = 600\,°C \end{cases}$$

$$U = \sqrt{\frac{1}{12} \times 30 \times 10 \times 600} = \sqrt{25 \times 600} = 5\sqrt{600}$$

$$\boxed{U = 5 \times \sqrt{600} = 122{,}5\ V}$$

en regime haché.



$\boxed{P\,17\text{-}8}$

Pendant δT (chauffage)

$$\begin{cases} \Theta = \Theta_{min}\, e^{-\frac{t}{\tau}} + R_{th}\,\Phi\left(1 - e^{-\frac{t}{\tau}}\right) \\ R_{th}\,\Phi = \frac{1}{300} \times \frac{U^2}{R} = \frac{12}{300} U^2 = 0{,}04\, U^2 \\ \Theta_{(t)} = \Theta_{min}\left(e^{-\frac{t}{100}}\right) + 0{,}04 U^2 \left(1 - e^{-\frac{t}{100}}\right) \\ \Theta_{max} = \Theta_{min}\left(e^{-\frac{\delta T}{100}}\right) + 0{,}04\, U^2 \left(1 - e^{-\frac{\delta T}{100}}\right) \quad (1) \end{cases}$$

Pendant (1-δ)T (Refroidissement).

$$\begin{cases} \Theta_{(t)} = \Theta_{max}\, e^{-\frac{t}{100}} \\ \Theta_{min} = \Theta_{max}\, e^{-\frac{(1-\delta)T}{100}} \quad (2) \end{cases}$$

(1) et (2) $\Rightarrow$

$$\Theta_{max} = \Theta_{max}\, e^{-\frac{\delta T}{100}} e^{-\frac{(1-\delta)T}{100}} + 0{,}04\, U^2 \left(1 - e^{-\frac{\delta T}{100}}\right)$$

$$\Theta_{max}\left(1 - e^{-\frac{T}{100}}\right) = 0{,}04\, U^2 \left(1 - e^{-\frac{\delta T}{100}}\right)$$

$$\begin{cases} U^2 = 25\,\theta_{max}\,\dfrac{\left(1-e^{-\frac{T}{100}}\right)}{\left(1-e^{-\frac{\delta T}{100}}\right)} \\[2ex] \theta_{max} = 650 - T_a \end{cases}$$

$$\Rightarrow \boxed{U_{max} = 5\sqrt{(650-T_a)\,\frac{1-e^{-\frac{T}{100}}}{1-e^{-\frac{\delta T}{100}}}}}$$

Q5 <u>Sans ventilation pendant toff.</u>

$$\begin{cases} \theta_{max} = \theta_{min}\, e^{-\frac{\delta T}{100}} + 0{,}04\,U^2\left(1-e^{-\frac{\delta T}{100}}\right) \\[2ex] \theta_{min} = \theta_{max}\, e^{-\frac{(1-\delta)T}{500}} \longleftarrow \text{car } h/5 \Rightarrow 5\,R_{th}. \end{cases}$$

$$\theta_{max} = \theta_{max}\, e^{-\frac{\delta T}{100}}\, e^{-\frac{(1-\delta)T}{500}} + 0{,}04\,U^2\left(1-e^{-\frac{\delta T}{100}}\right)$$

$$\theta_{max}\left(1-e^{-\frac{(T+4\delta T)}{500}}\right) = 0{,}04\,U^2\left(1-e^{-\frac{\delta T}{100}}\right)$$

$$\boxed{U_{max} = 5\sqrt{(650-T_a)\,\frac{1-e^{-\frac{(1+4\delta)T}{500}}}{1-e^{-\frac{\delta T}{100}}}}}$$

Q6 $U = 207\,V$ / $P = 514\,400\,W$ | $U = 149{,}5\,V$ / $P = 268\,300\,W$

11.6.2 Résistance thermique transitoire du Thyr[illegible]

Q1 La résistance thermique stationnaire

se lit courbe 1 pour $t = \infty$

on lit $R_{th} = 0{,}00225$ K/W

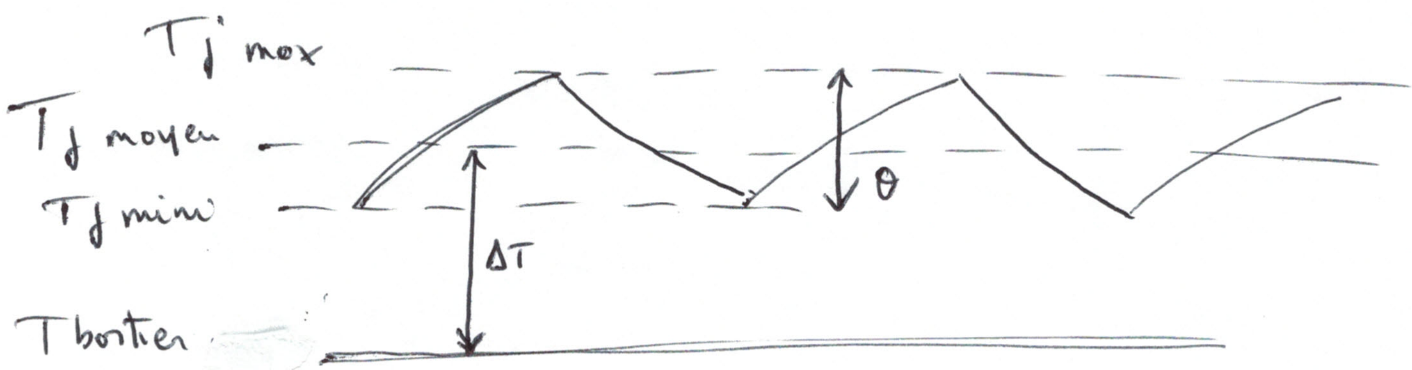
La doc p 197 donne $R_{th\,max} = 0{,}023$ K/W

Q2 Pour 1200 A et $\Delta = 180°$ $(\delta = 0{,}5)$

Courbe 3, on lit $P_{max\ moyen} = 2400$ W

Courbe 2 $T_{boitier\ max} = 60\ °C$

donc $\Delta T_{jonction-boitier} = 125 - 60 = 65\ °C$



$$\Delta T = P_{moy} \times R_{th\,stat} = 0{,}023 \times 2400 = 55{,}2\ °C$$

$$\theta = Z_{th}\,\hat{P} = Z_{th} \times 2 P_{moy} = 4800\, Z_{th}$$

$$\Delta T + \frac{\theta}{2} = T_{j\,max} - T_{boitier} = 125 - 60 = 65$$

$$\frac{\theta}{2} = 65 - 55{,}2 \Rightarrow \theta = 2 \times 9{,}8 = 19{,}6\ °C$$

$$\Rightarrow Z_{th} = \frac{19{,}6}{4800} = 0{,}004\ \text{K/W}$$

Courbe 1 $Z_{th} = 0{,}004$ pour 10 ms = 1/2 période du 50 Hz.

Q3 $Z_{th} = 0{,}0077 \Rightarrow \theta = 37\ °C$ $\theta/2 = 18{,}5\ °C$

$T_{boitier} = 125 - 55{,}2 - 18{,}5 = 51{,}3\ °C$