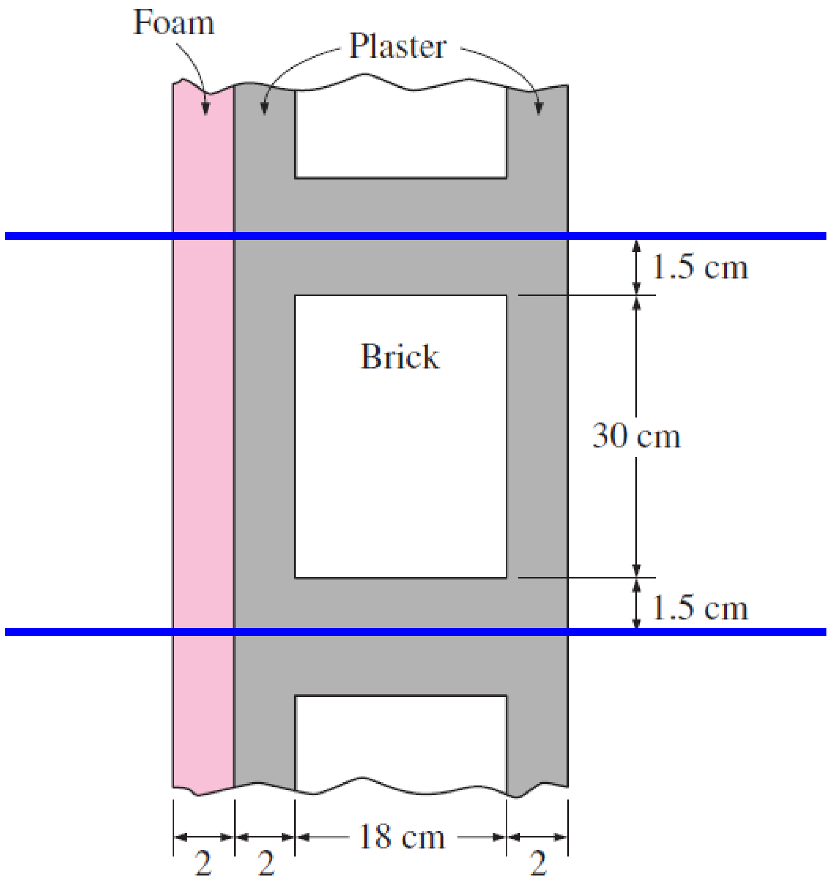
Universidade de São Paulo
Escola de Engenharia de São Carlos

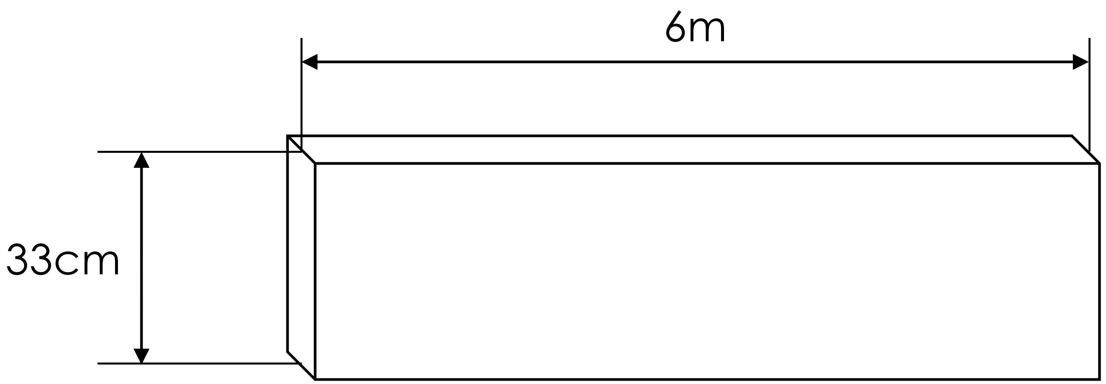
SEM0551 Fenômenos de Transporte

Transferência de Calor: Exercícios Resolvidos

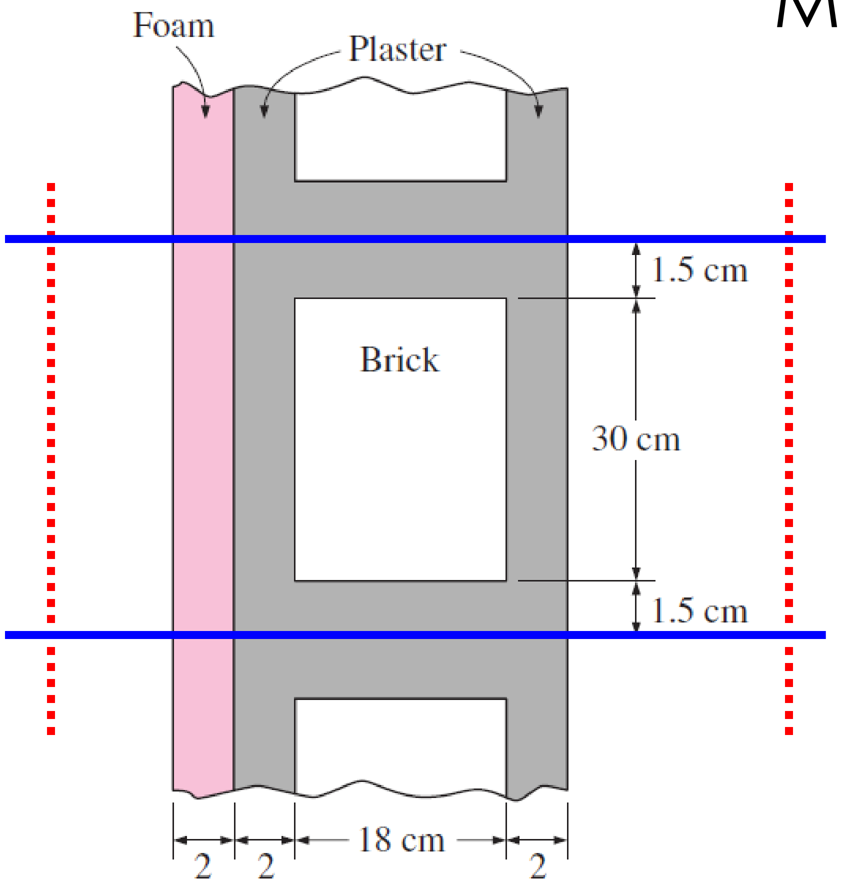
Paulo Seleghim Jr.
Universidade de São Paulo



3-52 (Çengel) A 4-m-high and 6-m-wide wall consists of a long 18-cm x 30-cm cross section of horizontal bricks (k = 0.72 W/m · °C) separated by 3-cm-thick plaster layers (k = 0.22 W/m · °C). There are also 2-cm-thick plaster layers on each side of the wall, and a 2-cm-thick rigid foam (k = 0.026 W/m · °C) on the inner side of the wall. The indoor and the outdoor temperatures are 22°C and -4°C, and the convection heat transfer coefficients on the inner and the outer sides are h1 = 10 W/m2 · °C and h2 = 20 W/m2 · °C, respectively. Assuming one-dimensional heat transfer and disregarding radiation, determine the rate of heat transfer through the wall.



Montagem do circuito térmico equivalente



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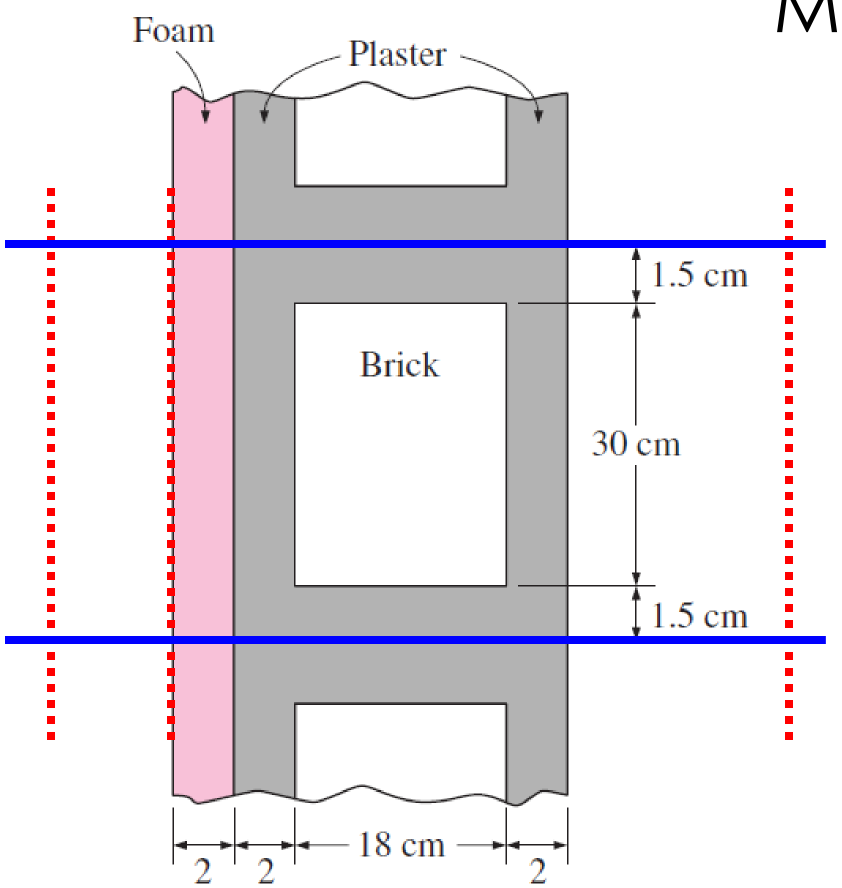

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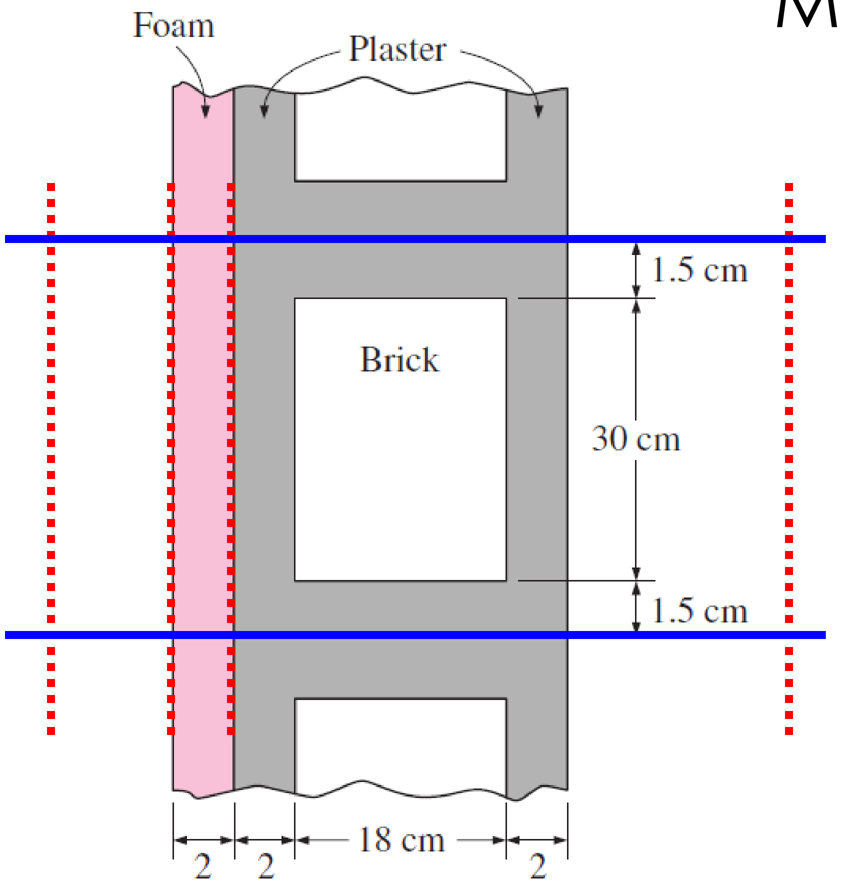

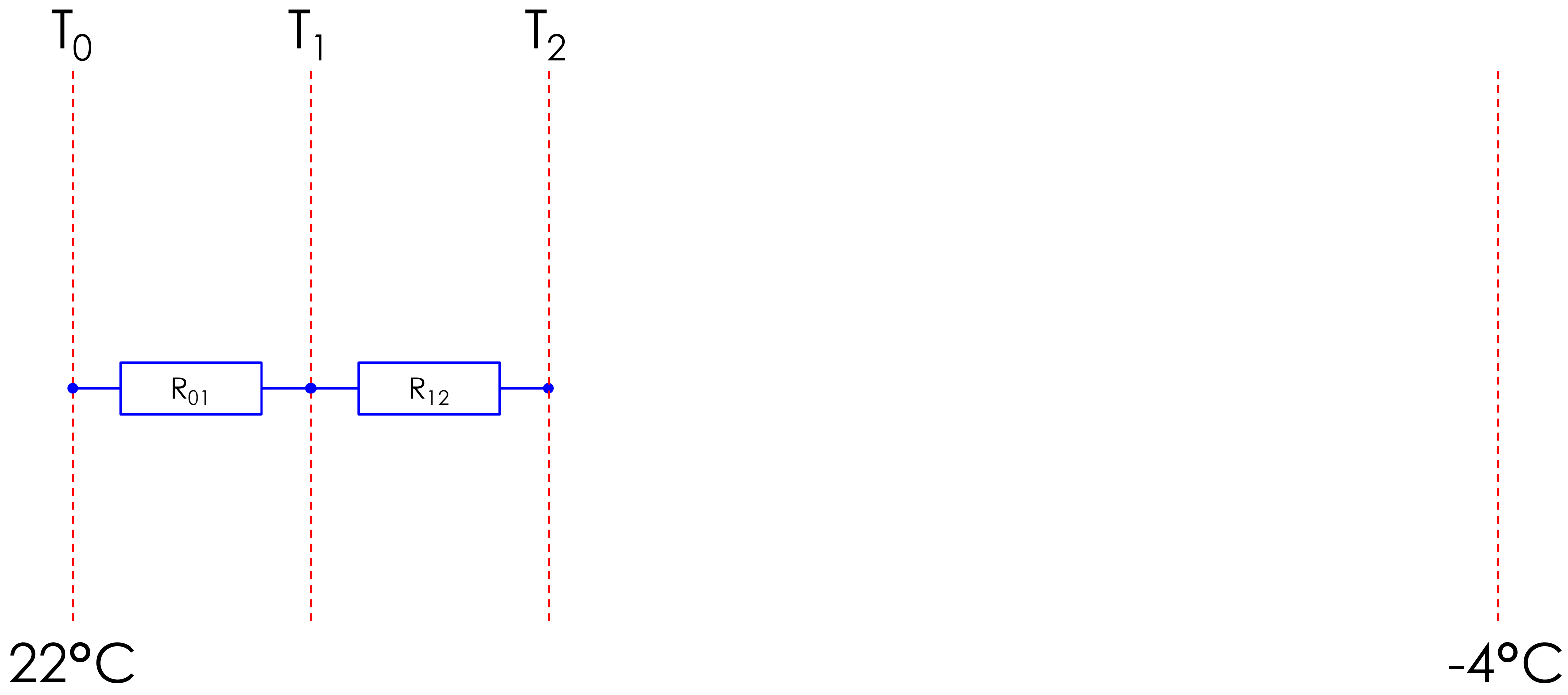

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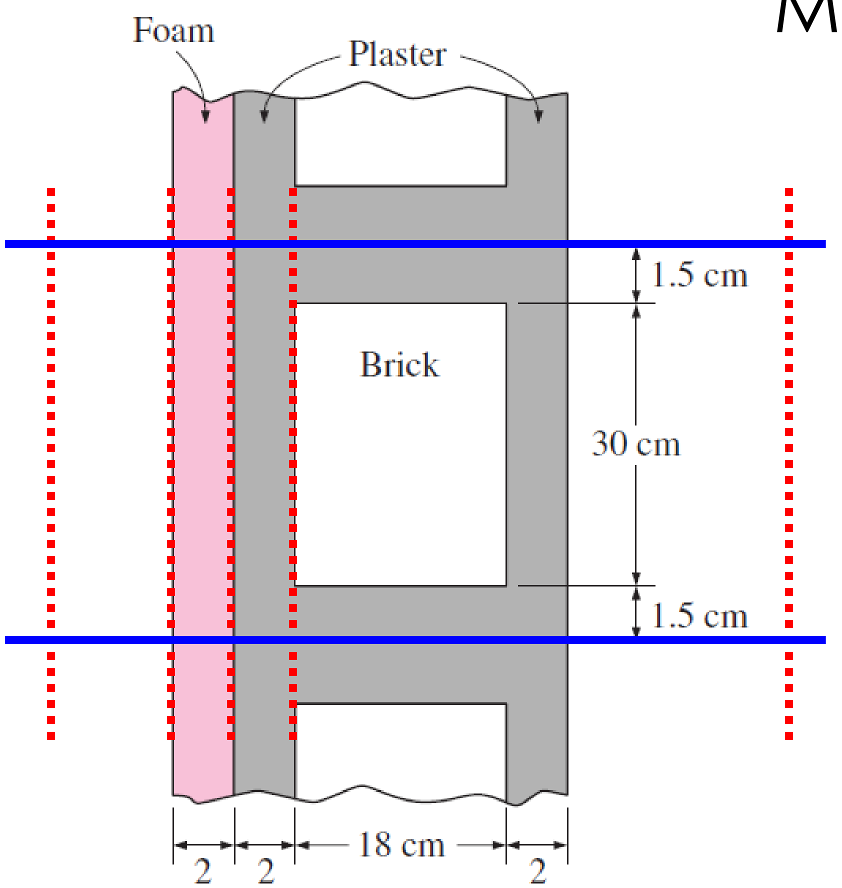

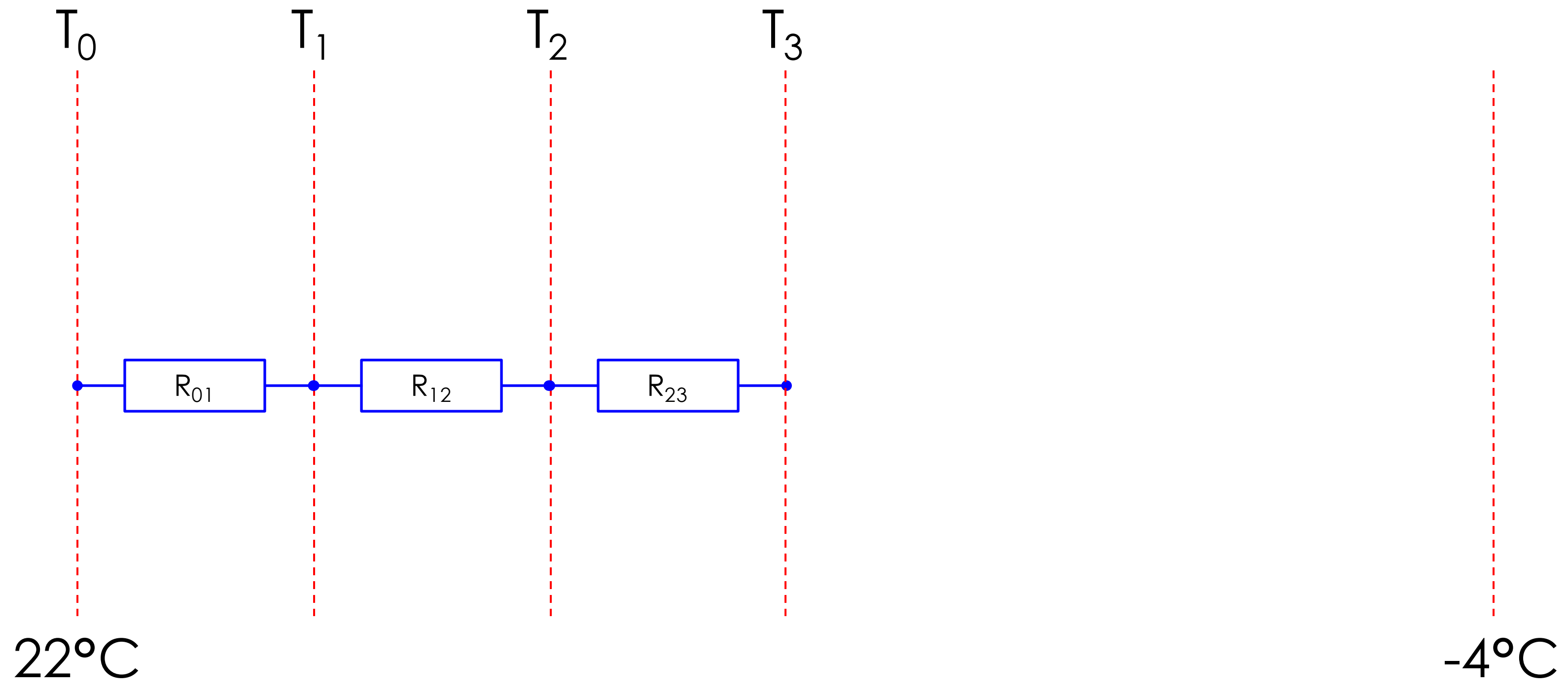

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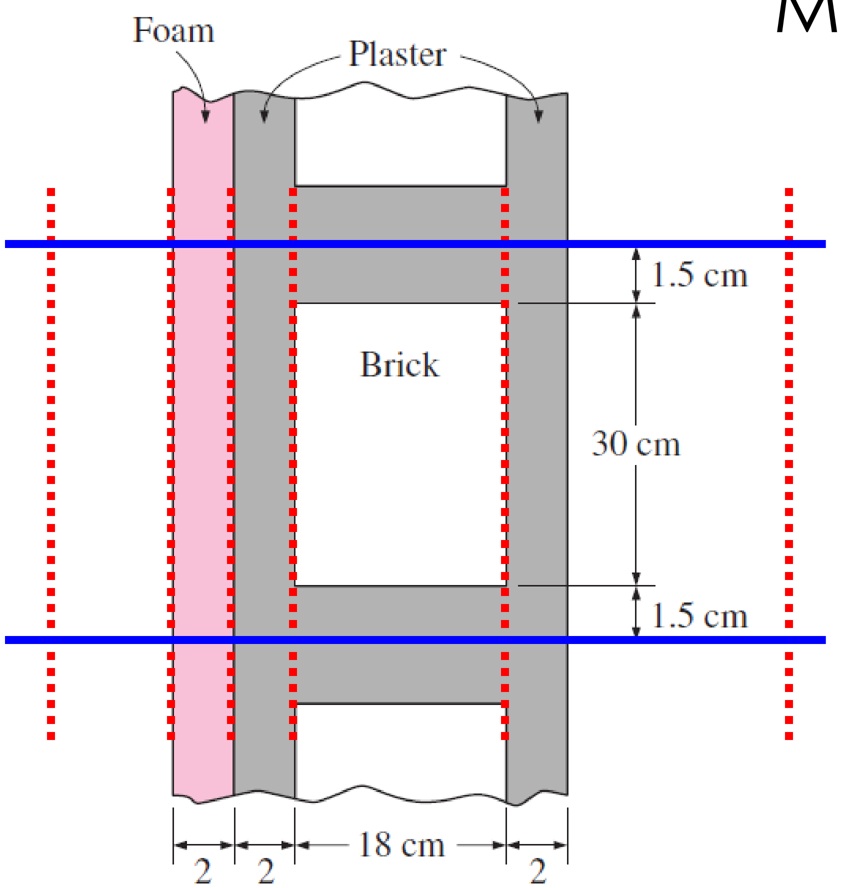

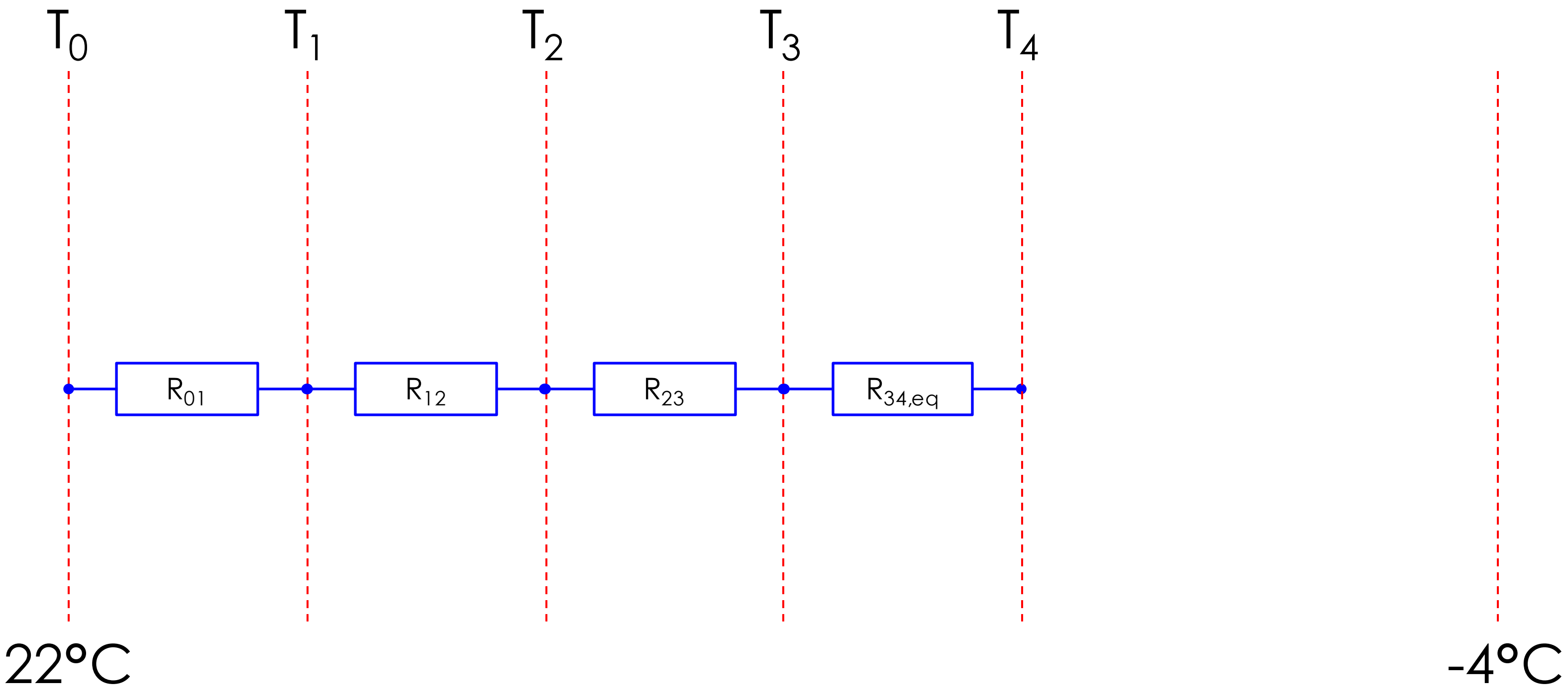

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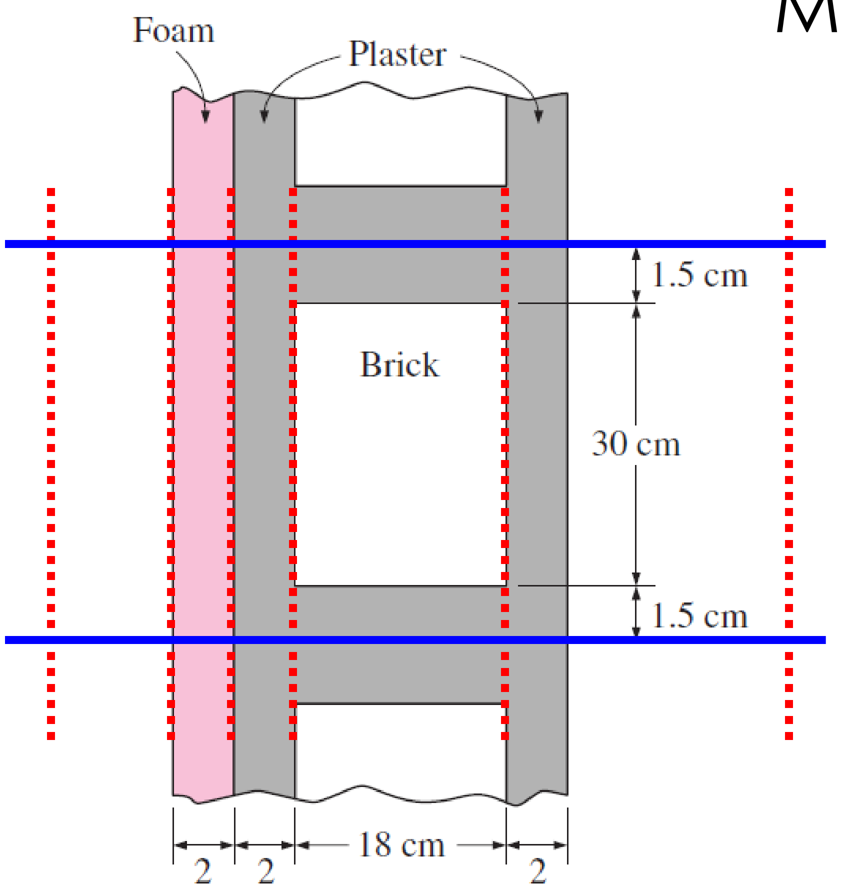

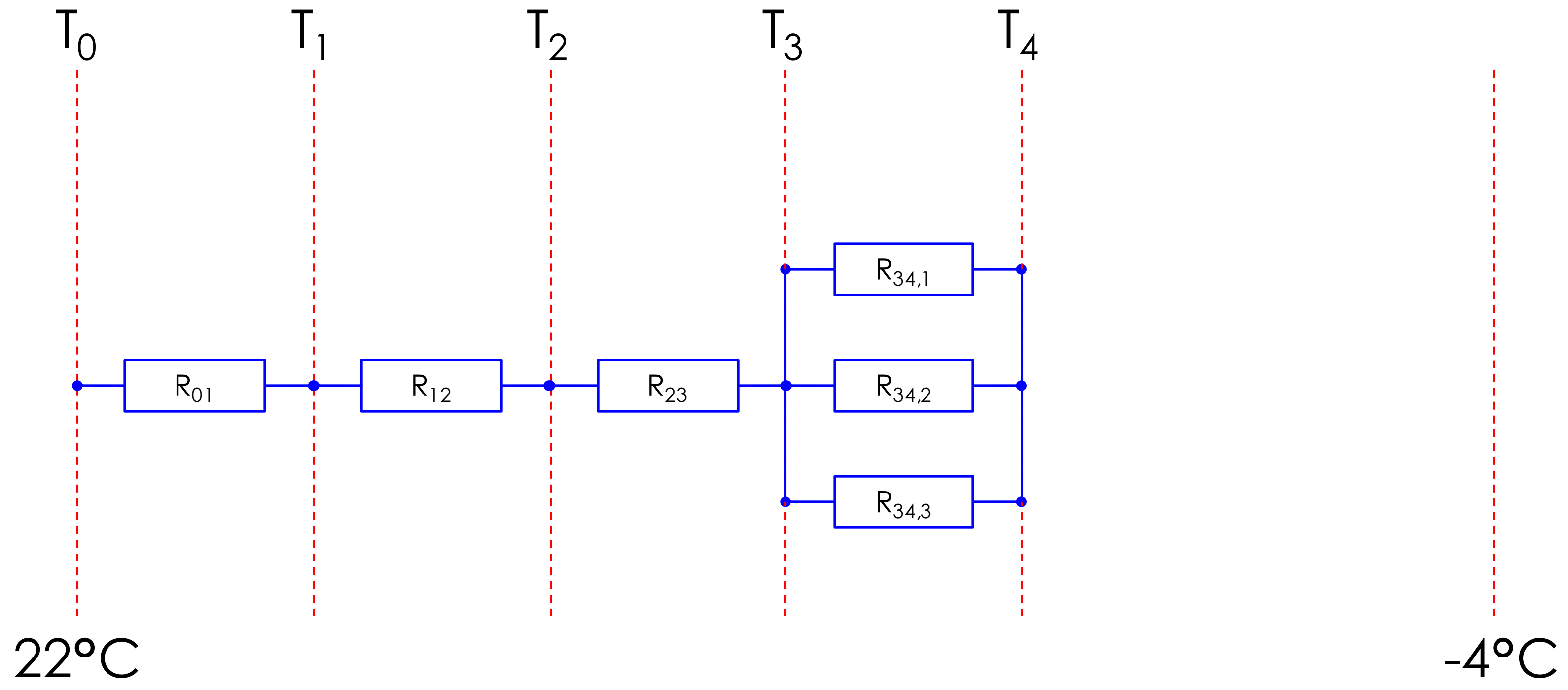

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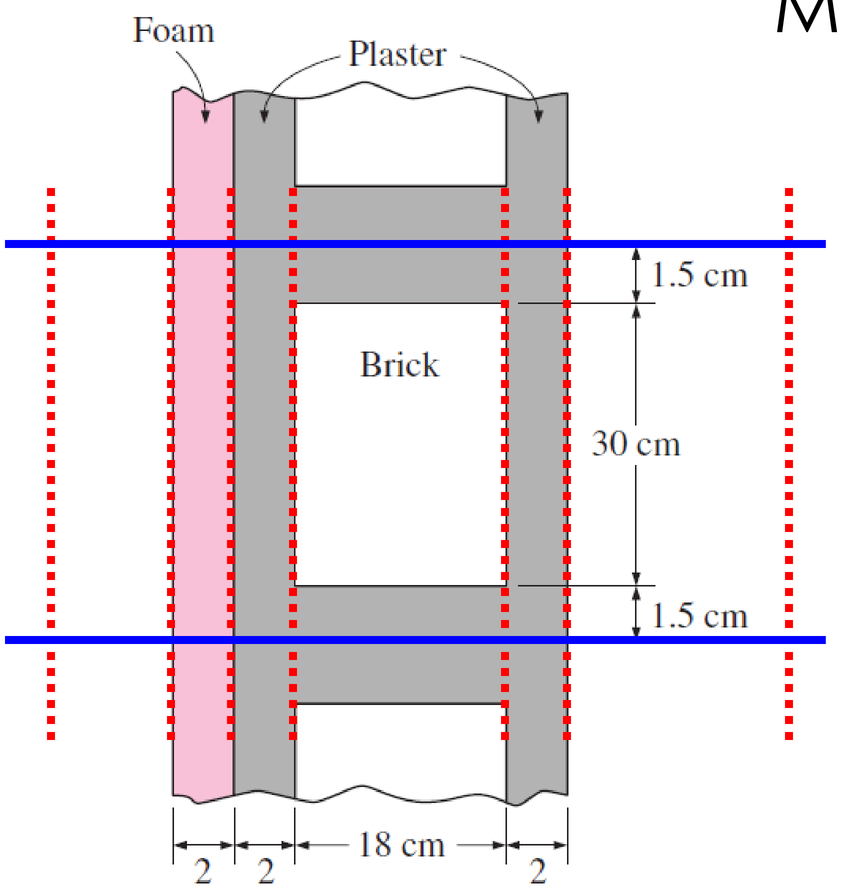

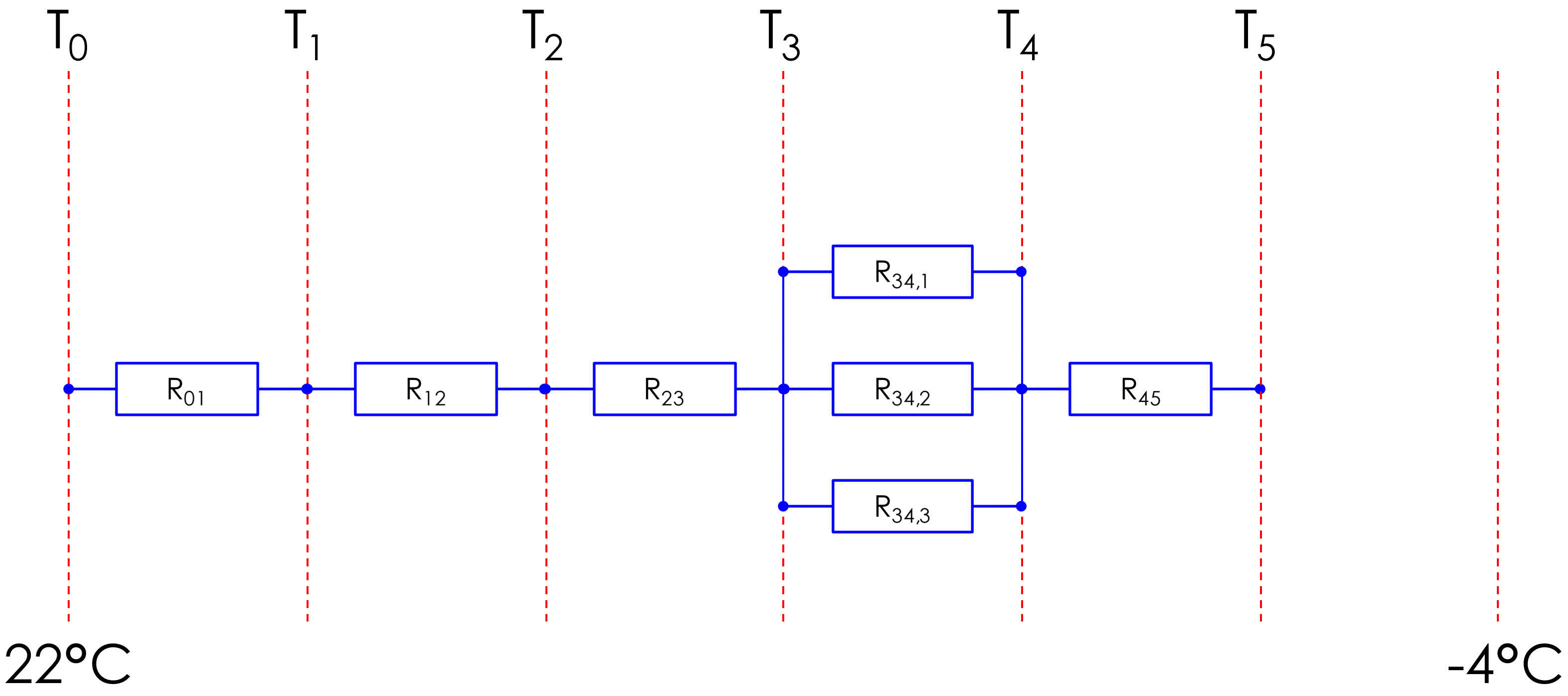

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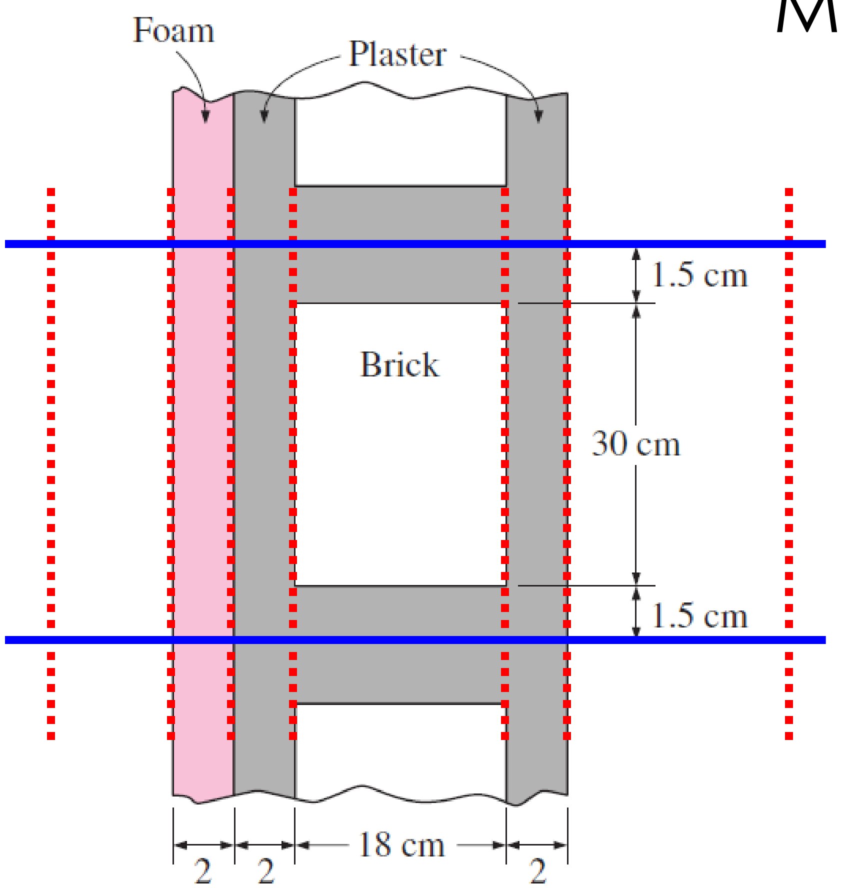

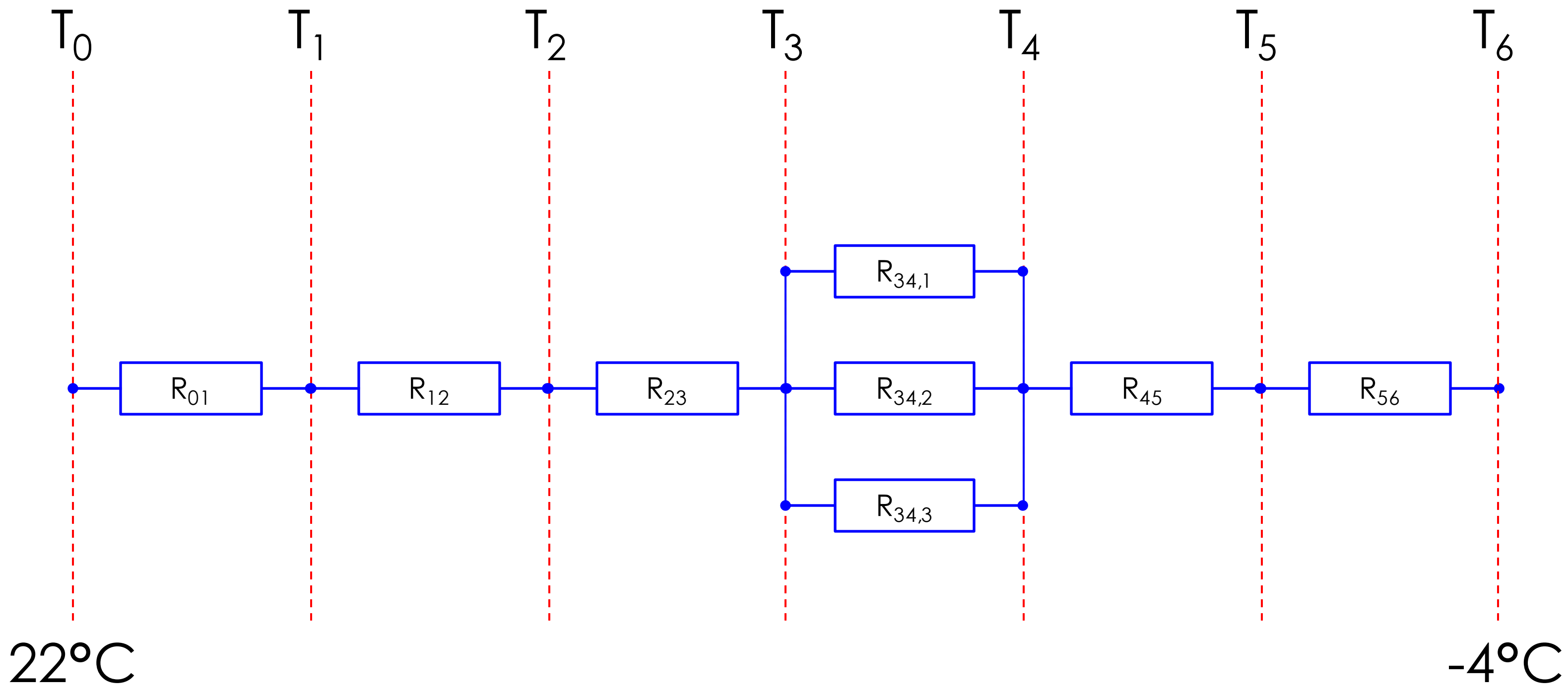

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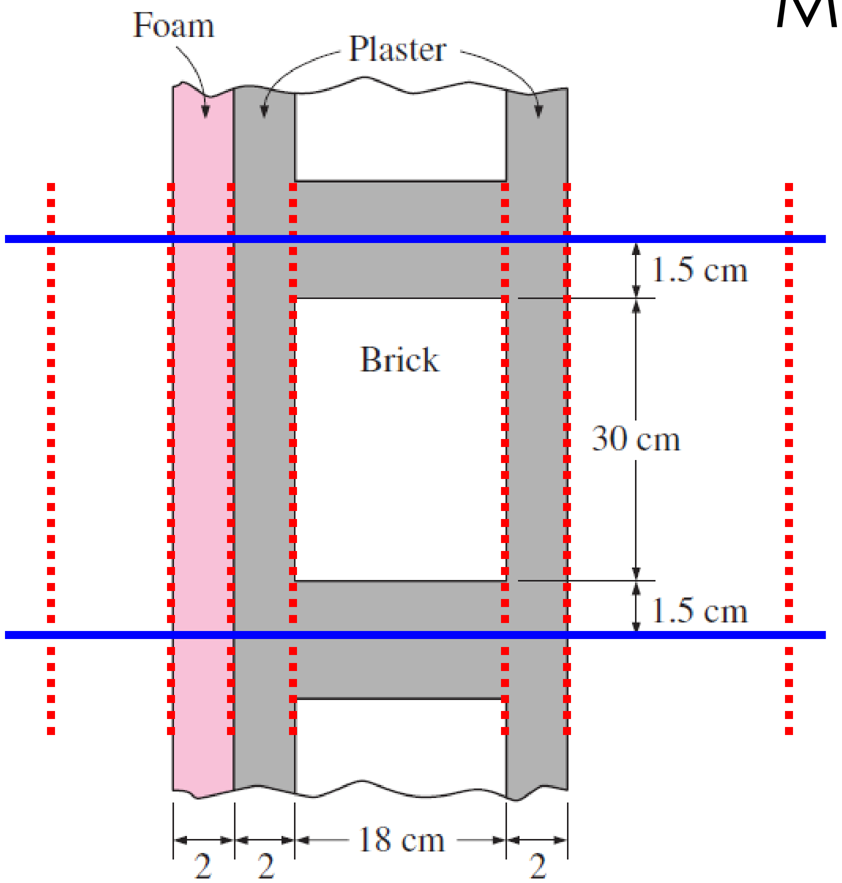
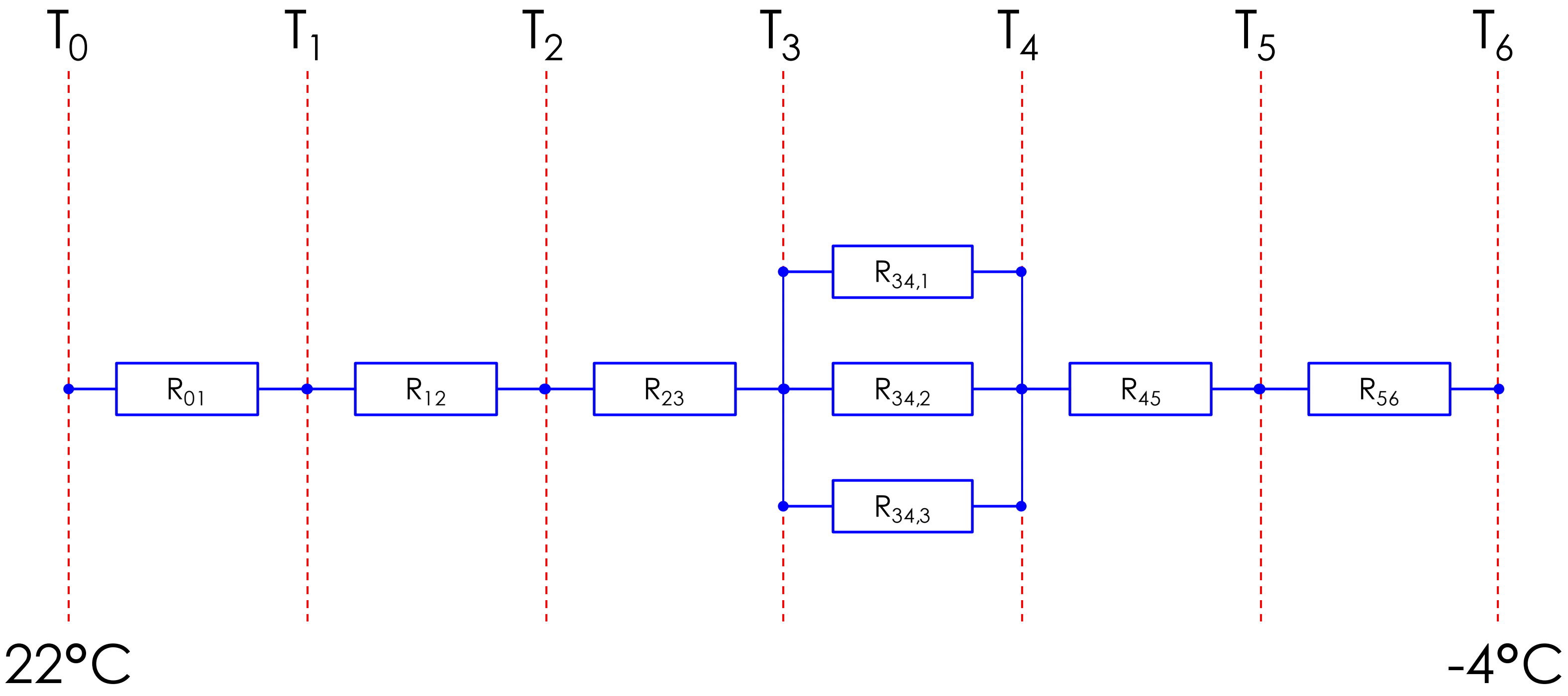
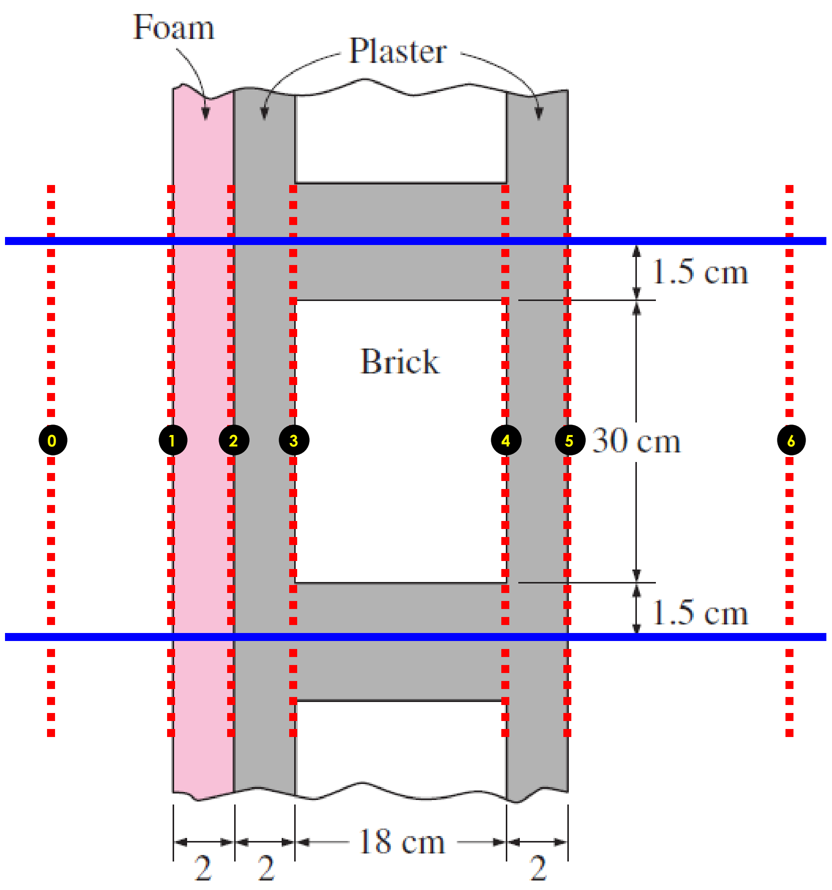




$$R_{total} = R_{01} + R_{12} + R_{23} + \left(\frac{1}{R_{34,1}} + \frac{1}{R_{34,2}} + \frac{1}{R_{34,3}} \right)^{-1} + R_{45} + R_{56}$$

$$Q = \frac{T_0 - T_6}{R_{total}} \qquad R_{conv} = \frac{1}{hA} \qquad R_{cond} = \frac{e}{kA}$$



k_{bricks} = 0.72 W/m/ °C
$k_{plaster}$ = 0.22 W/m/°C
k_{foam} = 0.026 W/m/°C
h_{innner} = 10 W/m2/°C
h_{outer} = 20 W/m2/°C

$$R_{01} = \frac{1}{h_{inner} A_{01}} = \frac{1}{10 \cdot 0.33 \cdot 6} = 5.051 \times 10^{-2} \frac{°C}{W}$$

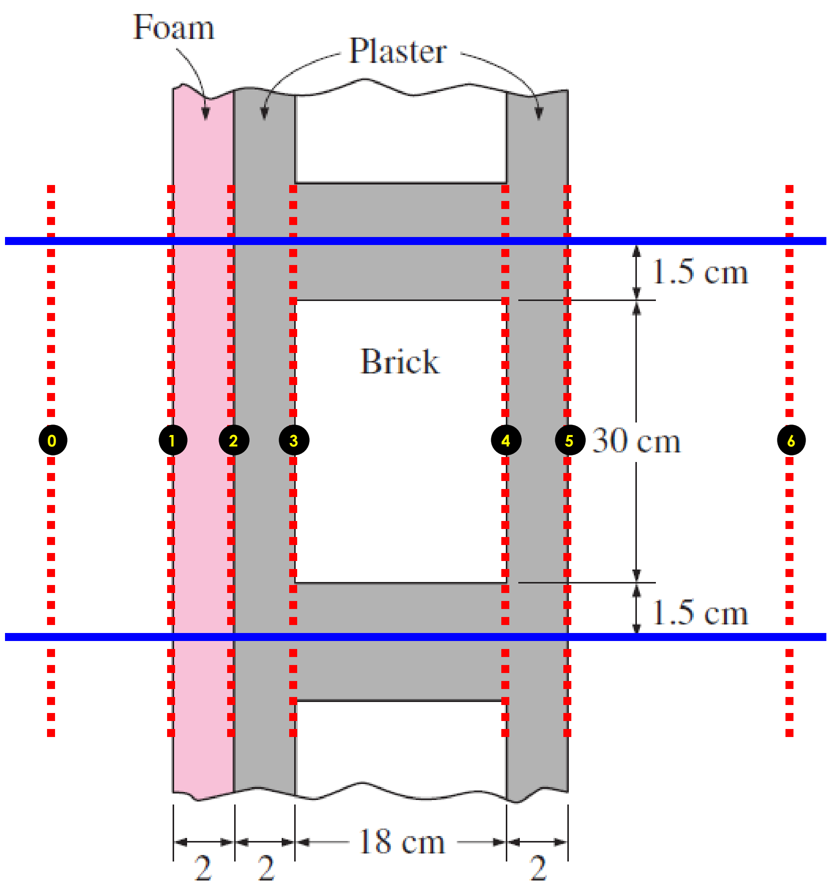
$$R_{12} = \frac{e_{12}}{k_{foam} A_{12}} = \frac{0{,}02}{0{,}026 \cdot 0.33 \cdot 6} = 3.885 \times 10^{-1} \frac{°C}{W}$$

$$R_{23} = \frac{e_{23}}{k_{plaster} A_{23}} = \frac{0{,}02}{0{,}22 \cdot 0.33 \cdot 6} = 4.591 \times 10^{-2} \frac{°C}{W} = R_{45}$$

$$R_{34,1} = \frac{e_{34}}{k_{plaster} A_{34,1}} = \frac{0{,}18}{0{,}22 \cdot 0.015 \cdot 6} = 9.091 \frac{°C}{W} = R_{34,3}$$

$$R_{34,2} = \frac{e_{34}}{k_{brick} A_{34,2}} = \frac{0{,}18}{0{,}72 \cdot 0.30 \cdot 6} = 1.389 \times 10^{-1} \frac{°C}{W}$$

$$R_{56} = \frac{1}{h_{outer} A_{56}} = \frac{1}{20 \cdot 0.33 \cdot 6} = 2.525 \times 10^{-2} \frac{°C}{W}$$



$$R_{total} = R_{01} + R_{12} + R_{23} + \left(\frac{1}{R_{34,1}} + \frac{1}{R_{34,2}} + \frac{1}{R_{34,3}} \right)^{-1} + R_{45} + R_{56}$$

$$R_{total} = 5.051 \times 10^{-2} + 3.885 \times 10^{-1} + 4.591 \times 10^{-2} + \left(\frac{2}{9.091} + \frac{1}{1.389 \times 10^{-1}} \right)^{-1} + 4.591 \times 10^{-2} + 2.525 \times 10^{-2}$$

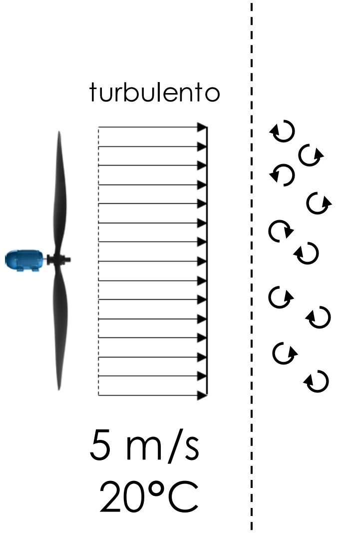
$$R_{total} = 0.691 \frac{W}{°C} \rightarrow Q_{0,33m} = \frac{22-(-4)}{0,691} = 37.63\,W$$

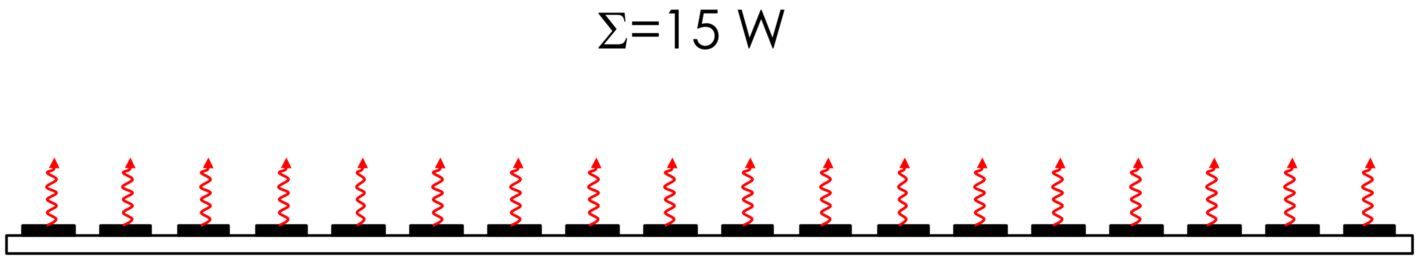
$$Q_{4m} = Q_{0,33m} \frac{4}{0,33} = 37.63 \frac{4}{0,33} = 456.1\,W$$

$$Q_{4m} = 456.1\,W = 1555.9\,BTU/h$$

k_{bricks} =	0.72 W/m/ °C
$k_{plaster}$ =	0.22 W/m/°C
k_{foam} =	0.026 W/m/°C
h_{innner} =	10 W/m2/°C
h_{outer} =	20 W/m2/°C

7–24 (Çengel) A 15-cm × 15-cm circuit board dissipating 15 W of power uniformly is cooled by air, which approaches the circuit board at 20°C with a velocity of 5 m/s. Disregarding any heat transfer from the back surface of the board, determine the surface temperature of the electronic components (a) at the leading edge and (b) at the end of the board. Assume the flow to be turbulent since the electronic components are expected to act as turbulators.





$$q_{med} = \frac{Q}{A} = h_{med} \cdot (T_{med} - T_{\infty})$$

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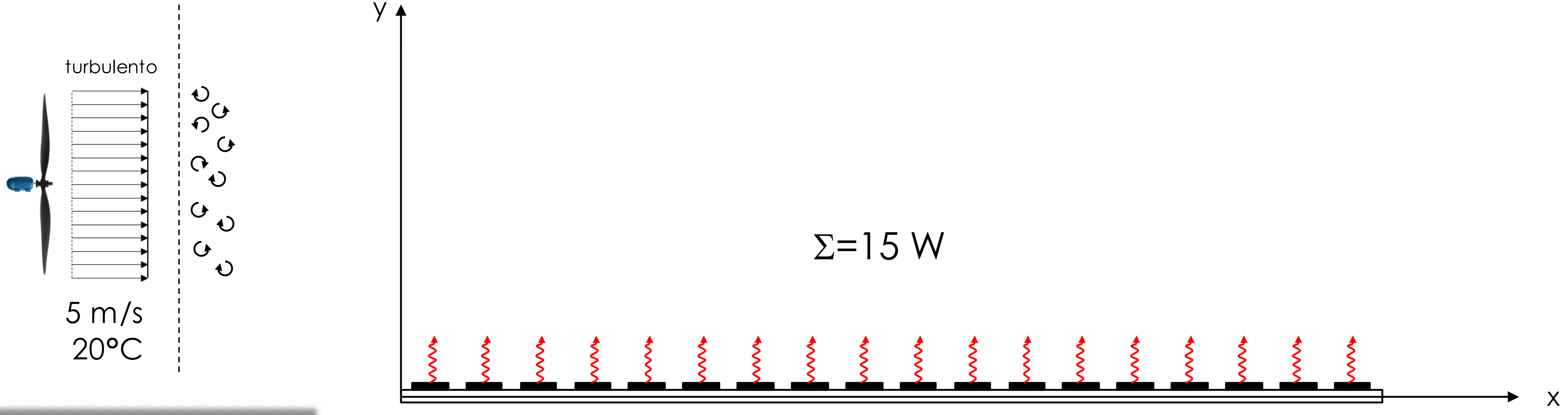

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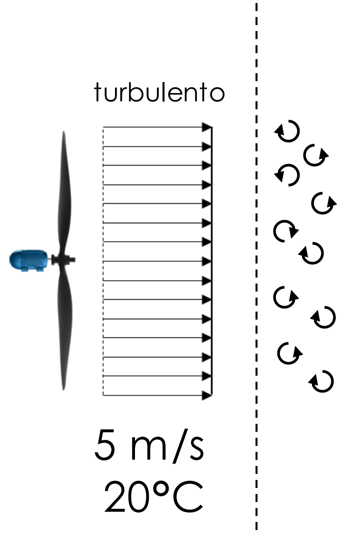

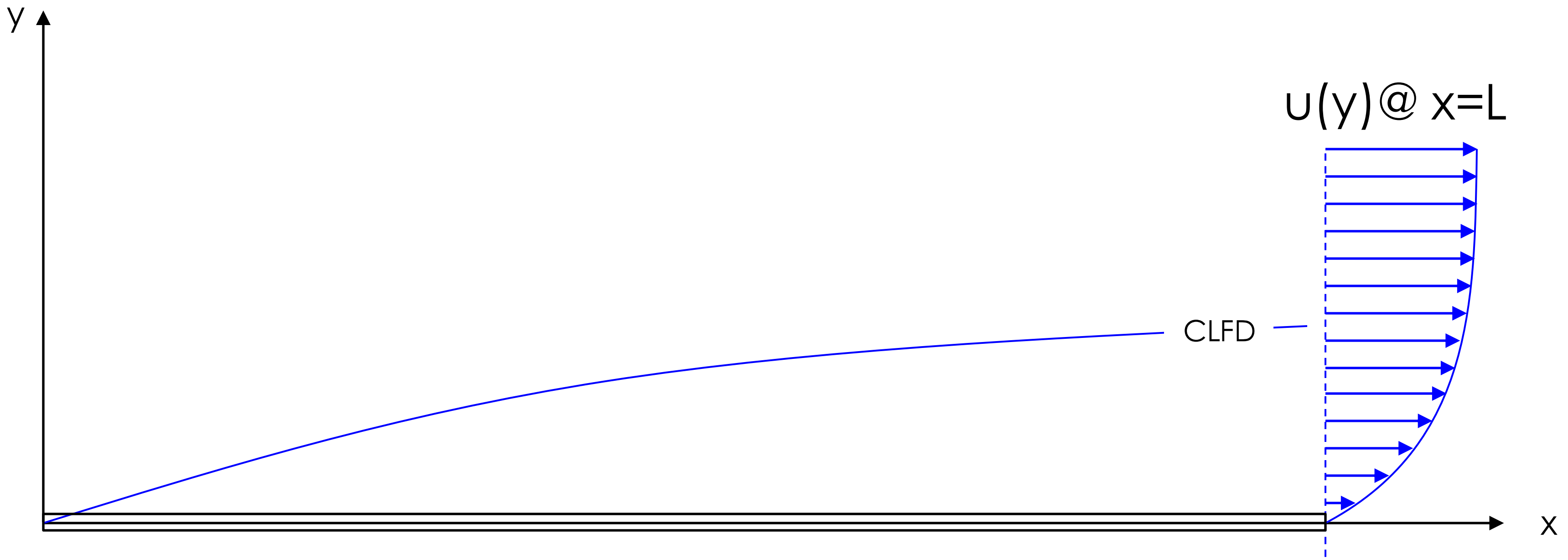

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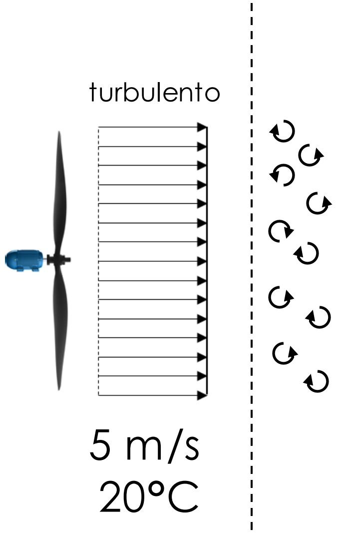

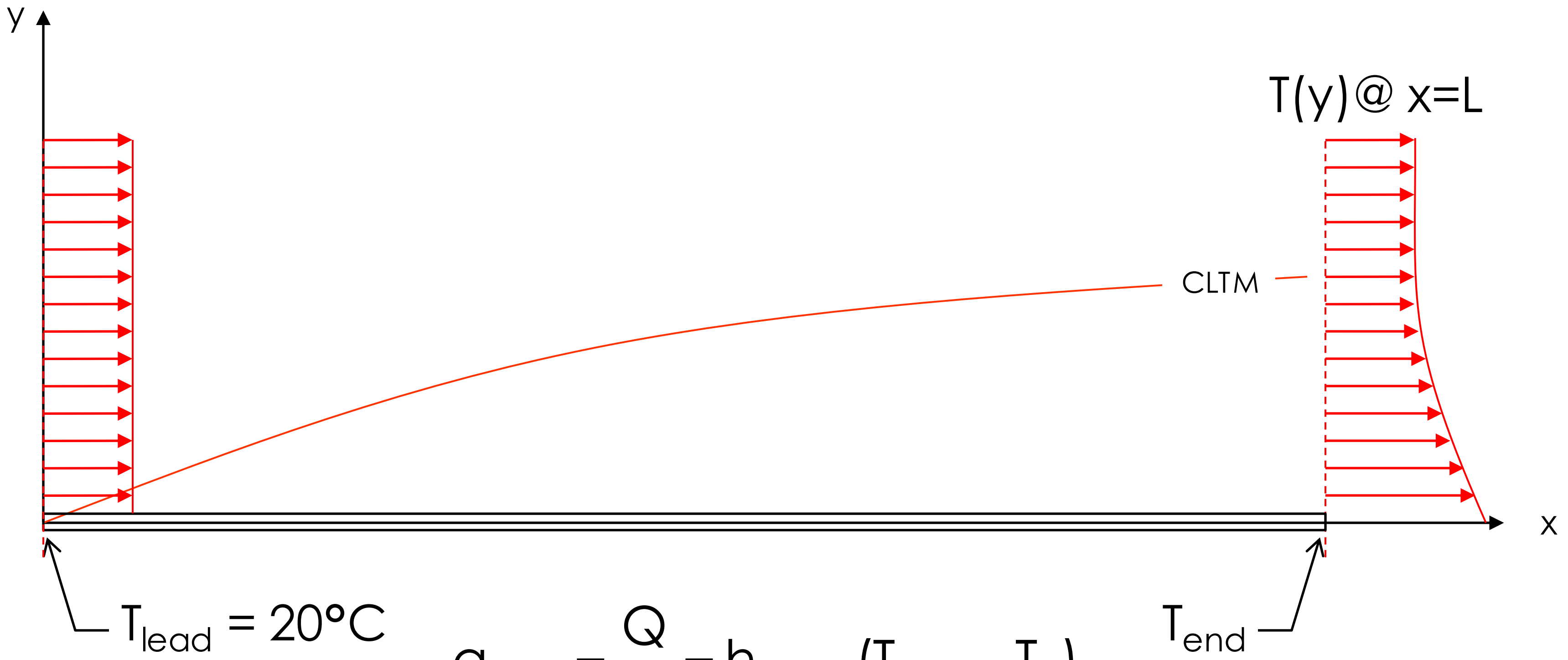

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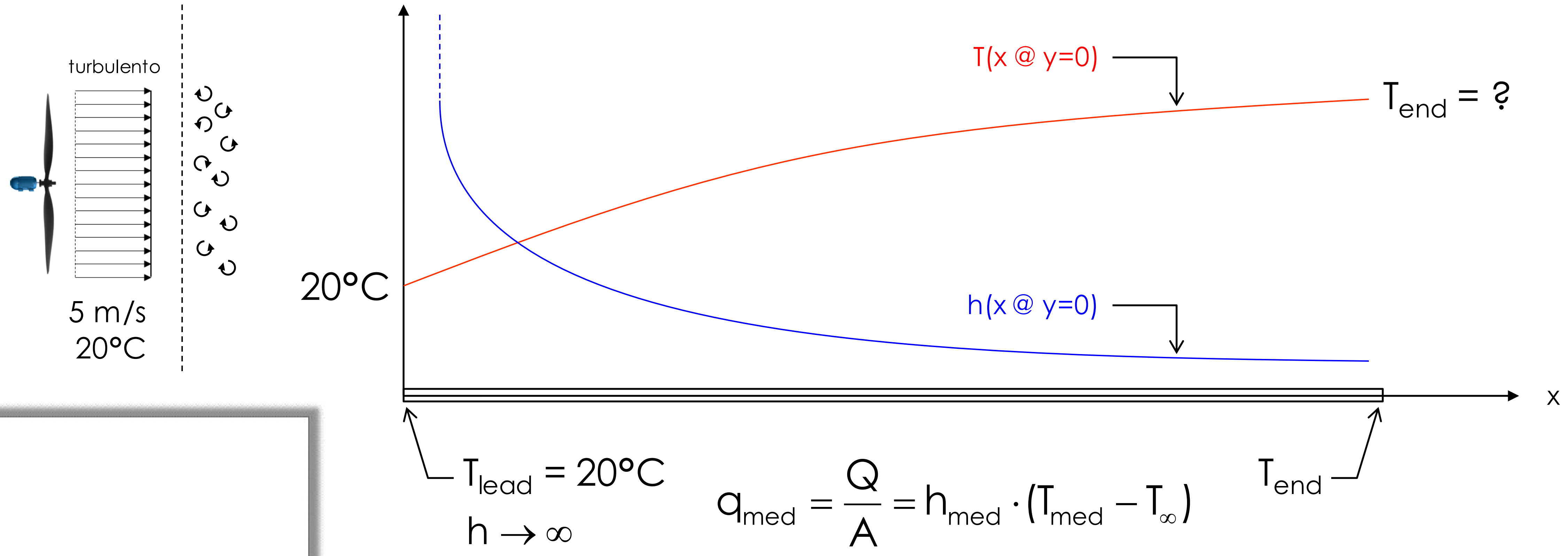


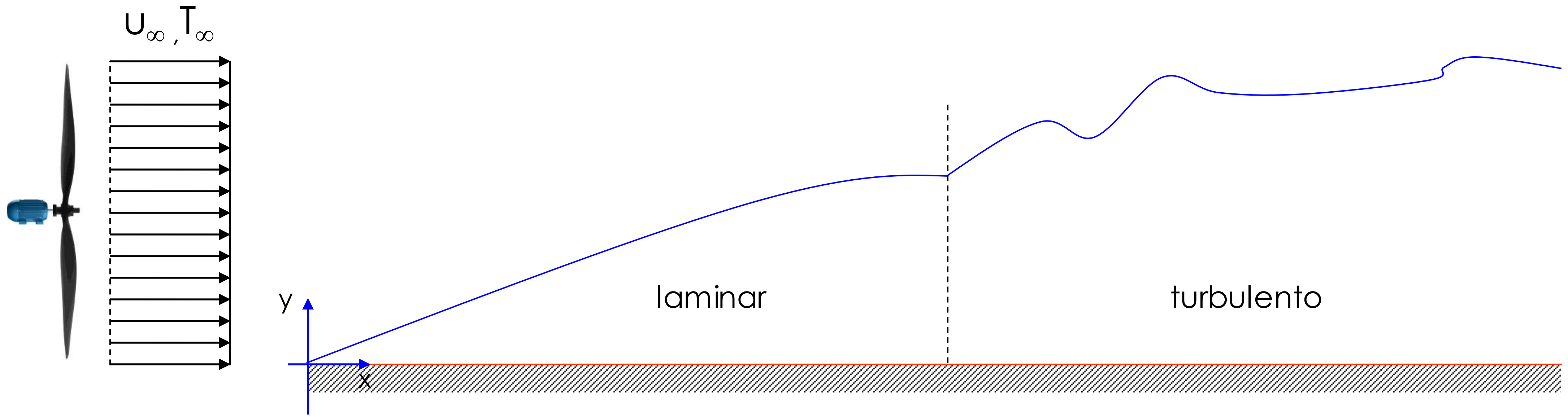
$$q_{med} = \frac{Q}{A} = h_{med} \cdot (T_{med} - T_\infty)$$

Correlações empíricas para escoamento sobre placa plana:

$$Nu = C \cdot Re^m \cdot Pr^n$$

$$Nu = C \cdot Ra^m$$

Adimensionalização das equações de escoamento sobre uma placa plana...



$$Nu \stackrel{def}{=} \frac{h_q}{k/D}$$

$$Nu_x = 0.332 \cdot Re_x^{0.5} \cdot Pr^{1/3}$$

$Pr > 0.60$

entire plate laminar ⇓ **q = cte**

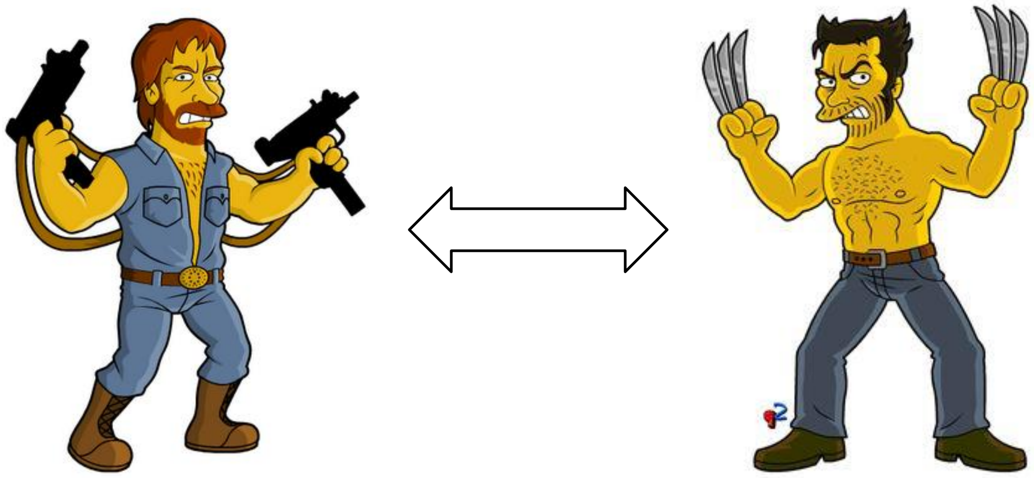
$$Nu_x = 0.453 \cdot Re_x^{0.5} \cdot Pr^{1/3}$$

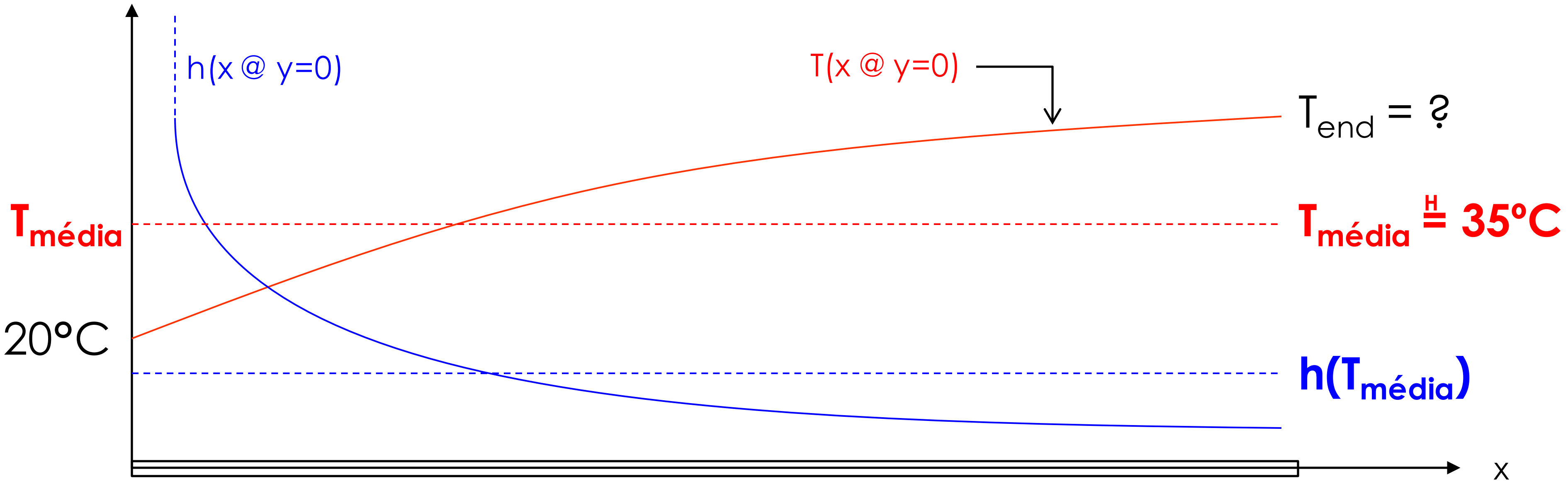
$$Nu_x = 0.0296 \cdot Re_x^{0.8} \cdot Pr^{1/3}$$

$0.6 < Pr < 60$ $\quad 5 \cdot 10^5 < Pr < 10^7$

q = cte ⇓ entire plate turbulent

$$Nu_x = 0.0308 \cdot Re_x^{0.8} \cdot Pr^{1/3}$$



Démarche:

1) chutar um valor para $T_{média}$,

2) avaliar as propriedades $\rho(T_{med})$, $\mu(T_{med})$, etc.

3) calcular Tend supondo $h(x) = h(T_{med}) = cte$

4) reavaliar T_{med}, sendo diferente iterar

REFPROP (air (dry)) - NIST Reference Fluid Properties (DLL version 9,1)

File Edit Options Substance Calculate Plot Window Help Cautions

2: air (dry): Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Cp (kJ/kg-K)	Therm. Cond. (mW/m-K)	Viscosity (μPa-s)	Prandtl	Vol. Expansivity (1/K)	Flow Exergy (kJ/kg)
1	30,000	1,0000	1,1495	429,47	3,9010	1,0065	26,618	18,689	0,70666	0,0033071	0,041728
2	32,859	1,0000	1,1387	432,35	3,9105	1,0066	26,829	18,825	0,70631	0,0032760	0,10245
3											

$$Re = \frac{\rho u L}{\mu} = \frac{1.1495 \cdot 5 \cdot 0.15}{18.689 \times 10^{-6}} = 4.6130 \times 10^{4}$$

$$Nu_L = 0.0308 \cdot Re_L^{0.8} \cdot Pr^{1/3} = 0.037 \cdot (4.6130 \times 10^{4})^{0.8} \cdot 0.70666^{1/3} = 147.732$$

$$h_L = \frac{k}{L} \cdot Nu_L = \frac{26.618 \times 10^{-3}}{0.15} \cdot 147.732 = 26.2156 \ \frac{W}{m^2 \, ^\circ C}$$

$$q = h \cdot (T_{end} - T_{\infty}) \rightarrow T_{end} = T_{\infty} + \frac{q}{h} = 20 + \frac{15/(0.15^2)}{26.2156} = 45.4302^\circ C$$

$$T_{med} = \frac{20 + 45.43}{2} = 32{,}5 \neq 30^\circ C$$

REFPROP (air (dry)) - NIST Reference Fluid Properties (DLL version 9,1)

File Edit Options Substance Calculate Plot Window Help Cautions

2: air (dry): Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Cp (kJ/kg-K)	Therm. Cond. (mW/m-K)	Viscosity (µPa-s)	Prandtl	Vol. Expansivity (1/K)	Flow Exergy (kJ/kg)
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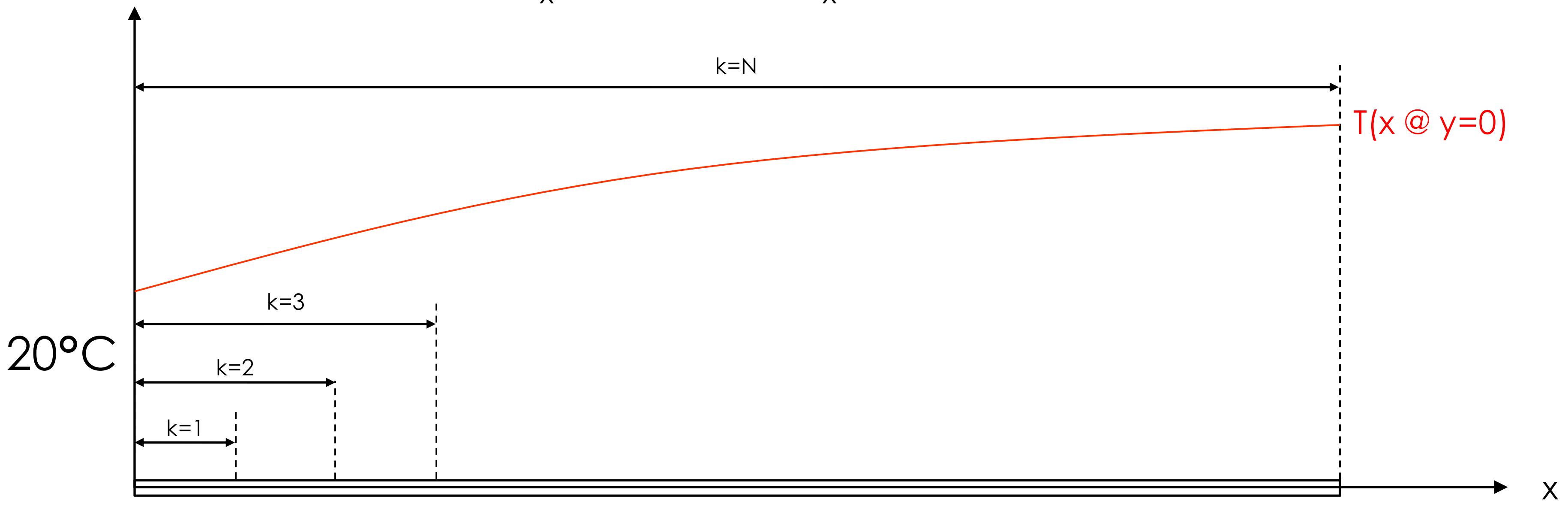
2	32,859	1,0000	1,1387	432,35	3,9105	1,0066	26,829	18,825	0,70631	0,0032760	0,10245
3											

TC5.xlsx - Excel

	A	B	C	D	E	F	G	H	I	J	K	L
1	Tmed	densid	Cp	k	visc	Pr	Re	Nu	h	Tend	Tmed	
2	30	1,1492	1,00673	26,2193	18,7312	0,71921	46014,1	148,303	25,9227	45,7175	32,8588	
3	32,8588	1,13844	1,00684	26,4274	18,8684	0,71886	45251,7	146,31	25,7772	45,8626	32,9313	
4	32,9313	1,13817	1,00684	26,4327	18,8719	0,71885	45232,6	146,26	25,7736	45,8663	32,9331	
5	32,9331	1,13816	1,00684	26,4328	18,872	0,71885	45232,1	146,258	25,7735	45,8664	32,9332	
6	32,9332	1,13816	1,00684	26,4328	18,872	0,71885	45232,1	146,258	25,7735	45,8664	32,9332	

Obs.: diferentes versões do Refprop resultando em pequenas diferenças nas propriedades...

$$Nu_x = 0.0296 \cdot Re_x^{0.8} \cdot Pr^{1/3}$$



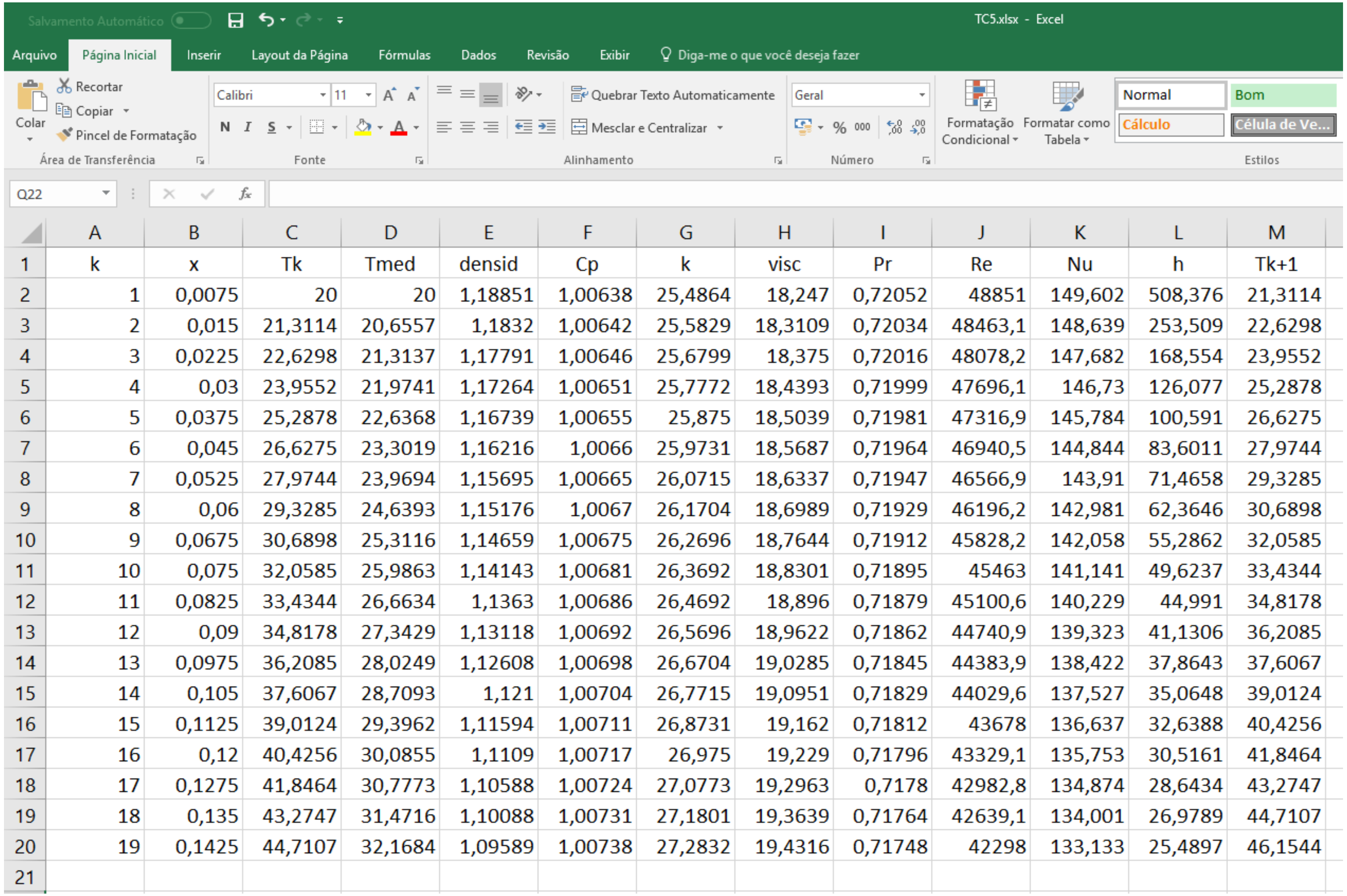
Démarche:

1) subdividir a placa e N elementos

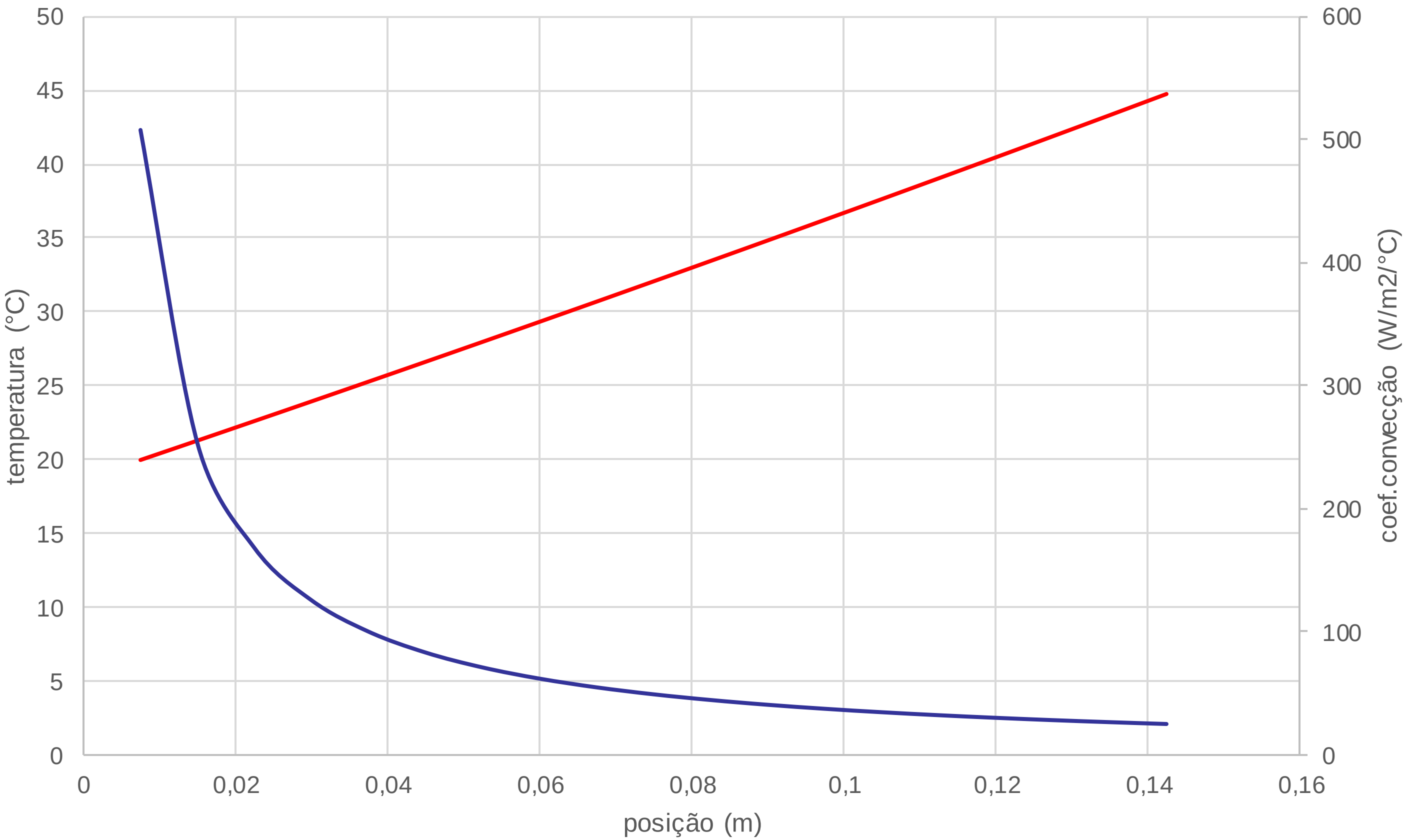
2) cada elemento dissipa $\Delta Q_k = k \cdot Q/N$

3) T_{med} média das temperaturas nodais: $T_{med,k} \overset{Hip}{=} \frac{1}{k}\sum_{j=0}^{k-1} T_j$

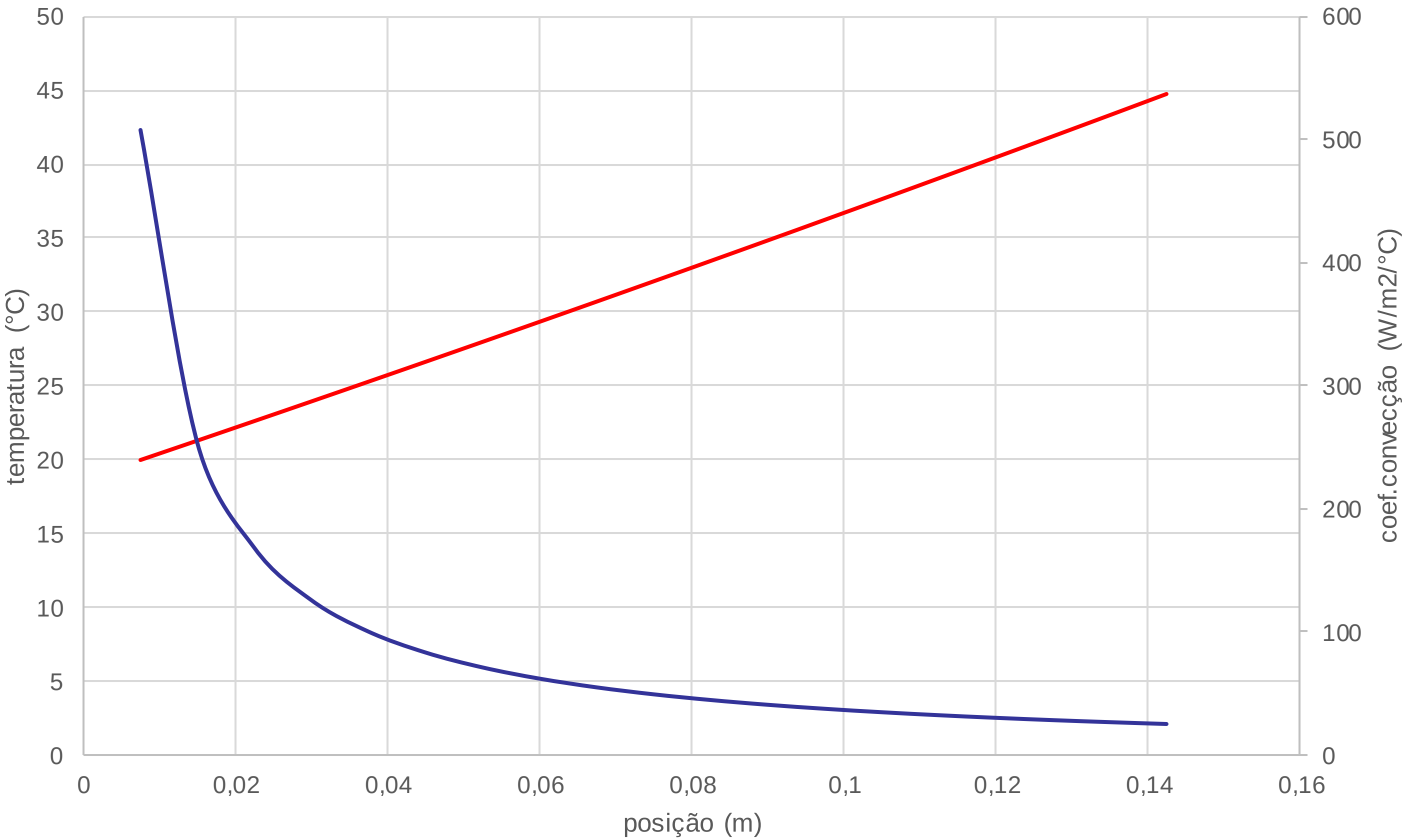
4) análogo Chuck Norris

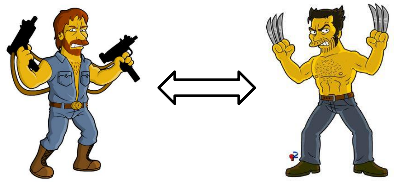


	A	B	C	D	E	F	G	H	I	J	K	L	M
1	k	x	Tk	Tmed	densid	Cp	k	visc	Pr	Re	Nu	h	Tk+1
2	1	0,0075	20	20	1,18851	1,00638	25,4864	18,247	0,72052	48851	149,602	508,376	21,3114
3	2	0,015	21,3114	20,6557	1,1832	1,00642	25,5829	18,3109	0,72034	48463,1	148,639	253,509	22,6298
4	3	0,0225	22,6298	21,3137	1,17791	1,00646	25,6799	18,375	0,72016	48078,2	147,682	168,554	23,9552
5	4	0,03	23,9552	21,9741	1,17264	1,00651	25,7772	18,4393	0,71999	47696,1	146,73	126,077	25,2878
6	5	0,0375	25,2878	22,6368	1,16739	1,00655	25,875	18,5039	0,71981	47316,9	145,784	100,591	26,6275
7	6	0,045	26,6275	23,3019	1,16216	1,0066	25,9731	18,5687	0,71964	46940,5	144,844	83,6011	27,9744
8	7	0,0525	27,9744	23,9694	1,15695	1,00665	26,0715	18,6337	0,71947	46566,9	143,91	71,4658	29,3285
9	8	0,06	29,3285	24,6393	1,15176	1,0067	26,1704	18,6989	0,71929	46196,2	142,981	62,3646	30,6898
10	9	0,0675	30,6898	25,3116	1,14659	1,00675	26,2696	18,7644	0,71912	45828,2	142,058	55,2862	32,0585
11	10	0,075	32,0585	25,9863	1,14143	1,00681	26,3692	18,8301	0,71895	45463	141,141	49,6237	33,4344
12	11	0,0825	33,4344	26,6634	1,1363	1,00686	26,4692	18,896	0,71879	45100,6	140,229	44,991	34,8178
13	12	0,09	34,8178	27,3429	1,13118	1,00692	26,5696	18,9622	0,71862	44740,9	139,323	41,1306	36,2085
14	13	0,0975	36,2085	28,0249	1,12608	1,00698	26,6704	19,0285	0,71845	44383,9	138,422	37,8643	37,6067
15	14	0,105	37,6067	28,7093	1,121	1,00704	26,7715	19,0951	0,71829	44029,6	137,527	35,0648	39,0124
16	15	0,1125	39,0124	29,3962	1,11594	1,00711	26,8731	19,162	0,71812	43678	136,637	32,6388	40,4256
17	16	0,12	40,4256	30,0855	1,1109	1,00717	26,975	19,229	0,71796	43329,1	135,753	30,5161	41,8464
18	17	0,1275	41,8464	30,7773	1,10588	1,00724	27,0773	19,2963	0,7178	42982,8	134,874	28,6434	43,2747
19	18	0,135	43,2747	31,4716	1,10088	1,00731	27,1801	19,3639	0,71764	42639,1	134,001	26,9789	44,7107
20	19	0,1425	44,7107	32,1684	1,09589	1,00738	27,2832	19,4316	0,71748	42298	133,133	25,4897	46,1544
21													



temperatura (°C)
coef.convecção (W/m2/°C)
posição (m)
0
5
10
15
20
25
30
35
40
45
50
0
100
200
300
400
500
600
0
0,02
0,04
0,06
0,08
0,1
0,12
0,14
0,16

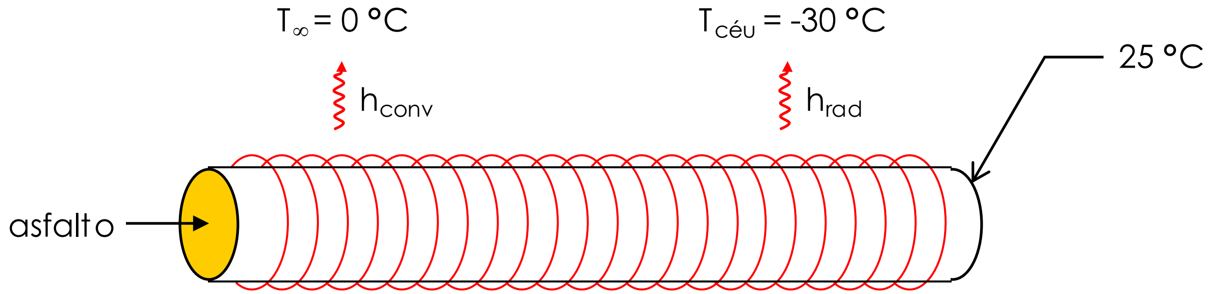




45.86°C 44.71°C

O coeficiente de convecção decai exponencialmente ao longo da placa. Deste modo. estimá-lo pelo valor da temperatura média aritmética, resulta em um valor subestimado e, consequentemente, a temperatura final é superestimada.

9–31/32 (Çengel) Thick fluids such as asphalt and waxes and the pipes in which they flow are often heated in order to reduce the viscosity of the fluids and thus to reduce the pumping costs. Consider the flow of such a fluid through a 100-m-long pipe of outer diameter 30 cm in calm ambient air at 0°C. The pipe is heated electrically, and a thermostat keeps the outer surface temperature of the pipe constant at 25°C. The emissivity of the outer surface of the pipe is ε = 0.8, and the effective sky temperature is -30°C. 1) Determine the power rating of the electric resistance heater, in kW, that needs to be used. Also, determine the cost of electricity associated with heating the pipe during a 10-h period under the above conditions if the price of electricity is $0.09/kWh.



Balanço global de energia: $W = Q_{conv} + Q_{rad}$

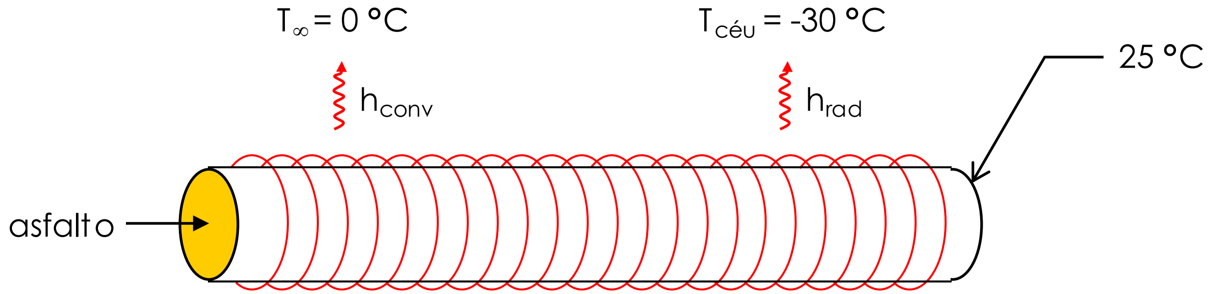
Convecção natural: $T_{med} = \dfrac{T_s + T_\infty}{2} = \dfrac{25 + 0}{2} = 12{,}5\ °C$

REFPROP (air (dry)) - NIST Reference Fluid Properties (DLL version 9,1)

File Edit Options Substance Calculate Plot Window Help Cautions

3: air (dry): Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Cp (kJ/kg-K)	Therm. Cond. (mW/m-K)	Viscosity (µPa-s)	Prandtl	Vol. Expansivity (1/K)	Flow Exergy (kJ/kg)
1	12,500	1,0000	1,2201	411,86	3,8412	1,0059	25,310	17,839	0,70898	0,0035115	0,27122
2											



$$Gr = \frac{g\beta(T_s - T_\infty)D^3}{(\mu/\rho)^2} = \frac{9.81 \cdot 0.0035115 \cdot (25-0) \cdot 0.3^3}{(17.839 \times 10^{-6}/1.2201)^2} = 1.08722 \times 10^8$$

$$Ra = Gr \cdot Pr = 1.08722 \times 10^8 \cdot 0.70898 = 7.71168 \times 10^7$$

REFPROP (air (dry)) - NIST Reference Fluid Properties (DLL version 9,1)

File Edit Options Substance Calculate Plot Window Help Cautions

3: air (dry): Specified state points

	Temperature (°C)	Pressure (bar)	Density (kg/m³)	Enthalpy (kJ/kg)	Entropy (kJ/kg-K)	Cp (kJ/kg-K)	Therm. Cond. (mW/m-K)	Viscosity (μPa-s)	Prandtl	Vol. Expansivity (1/K)	Flow Exergy (kJ/kg)
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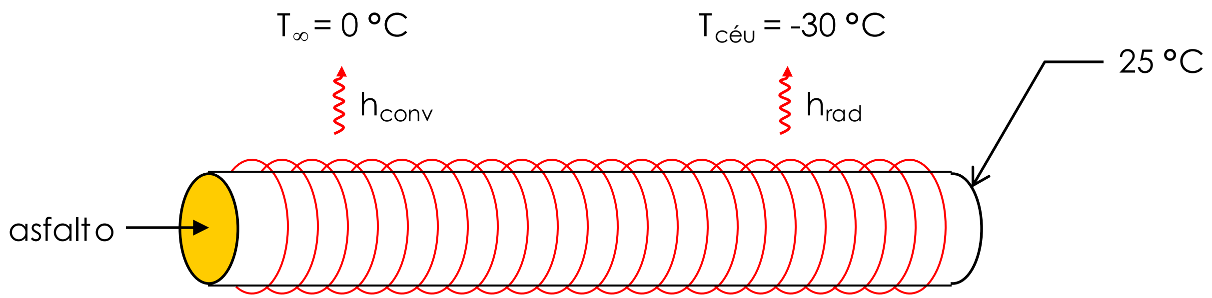
2											



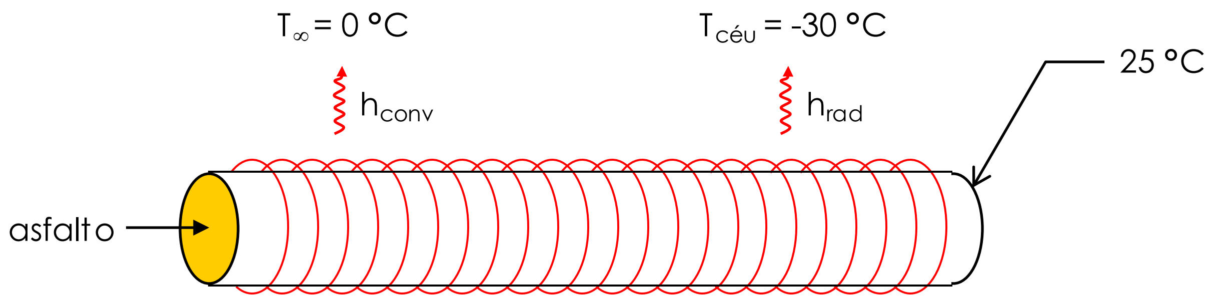
$$Gr = \frac{g\beta(T_s - T_\infty)D^3}{(\mu/\rho)^2} = \frac{9.81 \cdot 0.0035115 \cdot (25-0) \cdot 0.3^3}{(17.839 \times 10^{-6} / 1.2201)^2}$$

$$Gr = 1.08722 \times 10^8$$

$$Ra = Gr \cdot Pr = 1.08722 \times 10^8 \cdot 0.70898 = 7.71168 \times 10^7$$

$$Nu = \left\{0.6 + \frac{0.387 \cdot Ra^{1/6}}{\left[1 + (0.559/Pr)^{9/16}\right]^{8/27}}\right\}^2$$

Horiontal plate (Surface area A and perimeter p) (*a*) Upper surface of a hot plate (or lower surface of a cold plate) — Hot surface, T_s	A_s/p	10^4–10^7 10^7–10^{11}	$Nu = 0.54Ra_L^{1/4}$ $Nu = 0.15Ra_L^{1/3}$	(9-22) (9-23)
(*b*) Lower surface of a hot plate (or upper surface of a cold plate) — Hot surface, T_s		10^5–10^{11}	$Nu = 0.27Ra_L^{1/4}$	(9-24)
Vertical cylinder — L, T_s	L		A vertical cylinder can be treated as a vertical plate when $D \geq \frac{35L}{Gr_L^{1/4}}$	
Horizontal cylinder — T_s, D	D	$Ra_D \leq 10^{12}$	$Nu = \left\{0.6 + \frac{0.387Ra_D^{1/6}}{[1 + (0.559/Pr)^{9/16}]^{8/27}}\right\}^2$	(9-25)
Sphere — D	D	$Ra_D \leq 10^{11}$ $(Pr \geq 0.7)$	$Nu = 2 + \frac{0.589Ra_D^{1/4}}{[1 + (0.469/Pr)^{9/16}]^{4/9}}$	(9-26)



$$Gr = \frac{g\beta(T_s - T_\infty)D^3}{(\mu/\rho)^2} = \frac{9.81 \cdot 0.0035115 \cdot (25-0) \cdot 0.3^3}{(17.839 \times 10^{-6} / 1.2201)^2}$$

$$Gr = 1.08722 \times 10^8$$

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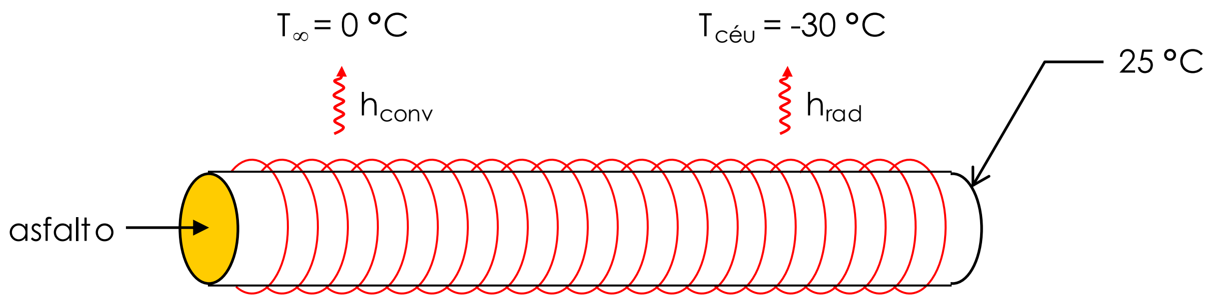
$$Nu = \left\{ 0.6 + \frac{0.387 \cdot (7.71168 \times 10^7)^{1/6}}{\left[1 + (0.559/(7.71168 \times 10^7))^{9/16}\right]^{8/27}} \right\}^2 =$$

$$Nu = 52.238$$

$$h = \frac{Nu \cdot k}{L} = \frac{52.238 \cdot 25.310 \times 10^{-3}}{0.3} = 4.407 \frac{W}{m^2 \, °C}$$

$$Q_{conv} = h \cdot \pi DL \cdot (T_s - T_\infty) = 4.407 \cdot \pi \cdot 0.3 \cdot 100 \cdot (25-0)$$

$$Q_{conv} = 10.3837 kW$$

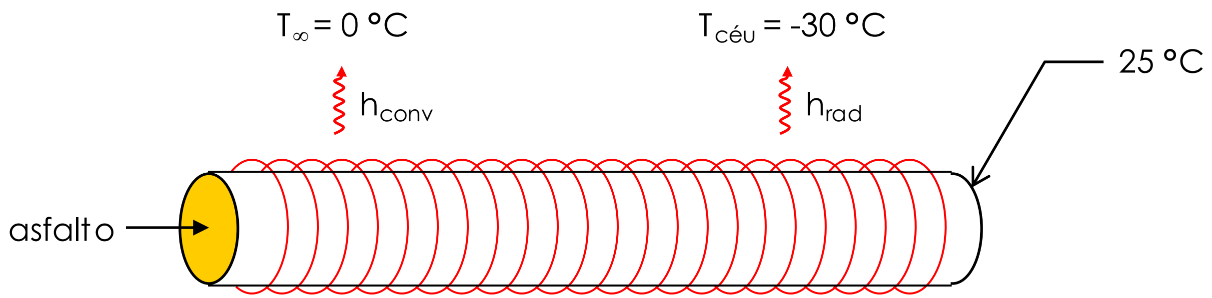


$$Q_{rad} = \varepsilon \cdot A \cdot \sigma \cdot (T_s^4 - T_{céu}^4)$$

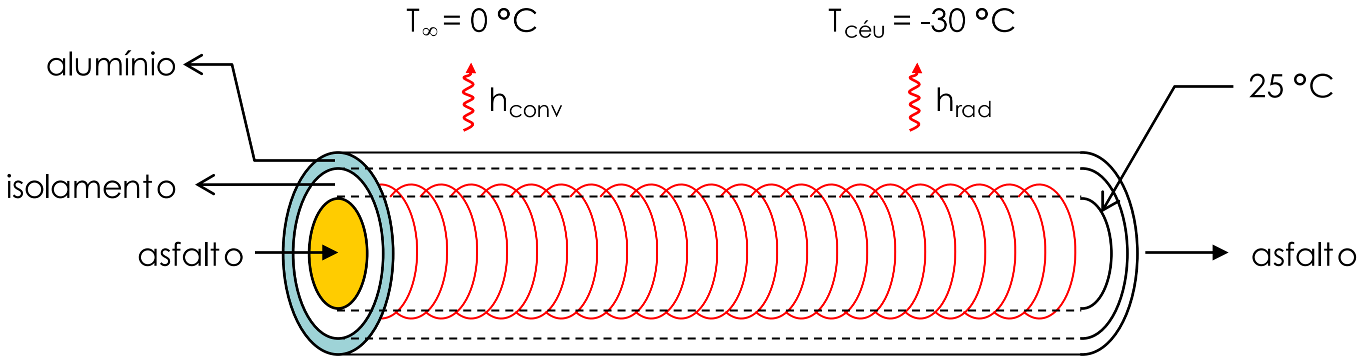
$$Q_{rad} = 0.8 \cdot \pi \cdot 0.3 \cdot 100 \cdot 5.67 \times 10^{-8} \cdot \left[(25 + 273.15)^4 - (-30 + 273.15)^4\right] = 18.838 \, kW$$

$$W = Q_{conv} + Q_{rad} = 10.384 + 18.838 = 29.222 \, kW$$

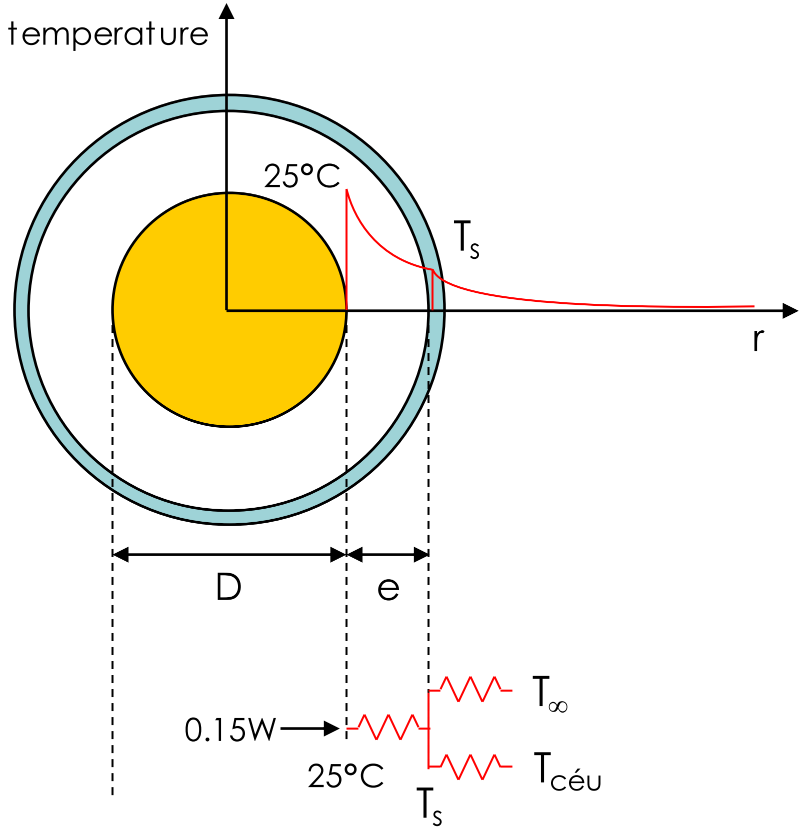
$$Custo = \int_T W \cdot dt = 29.222 \, W \cdot 10 h \cdot 0.09 \frac{\$}{kW} = 26.30 \, \$$$



9–31/32 (Çengel) Thick fluids such as asphalt and waxes and the pipes in which they flow are often heated in order to reduce the viscosity of the fluids and thus to reduce the pumping costs. Consider the flow of such a fluid through a 100-m-long pipe of outer diameter 30 cm in calm ambient air at 0°C. The pipe is heated electrically, and a thermostat keeps the outer surface temperature of the pipe constant at 25°C. The emissivity of the outer surface of the pipe is ε = 0.8, and the effective sky temperature is -30°C. 1) Determine the power rating of the electric resistance heater, in kW, that needs to be used. Also, determine the cost of electricity associated with heating the pipe during a 10-h period under the above conditions if the price of electricity is $0.09/kWh. 2) To reduce the heating cost of the pipe, it is proposed to insulate it with sufficiently thick fiberglass insulation (k = 0.035 W/m · °C) wrapped with aluminum foil (ε = 0.1) to cut down the heat losses by 85 percent. Assuming the pipe temperature to remain constant at 25°C, determine the thickness of the insulation that needs to be used. How much money will the insulation save during this 10-h period?



Equacionamento do problema:



$$\text{isolamento}: T_s \downarrow \qquad \text{alumínio}: \varepsilon \downarrow \Rightarrow \begin{cases} Q_{conv} = h \cdot \pi(D+2e)L \cdot (T_s - T_\infty) \\ Q_{rad} = \varepsilon \cdot \pi(D+2e)L \cdot \sigma \cdot (T_s^4 - T_{céu}^4) \end{cases}$$

Balanço de energia:

$$0.15 \cdot W = Q_{conv}(e) + Q_{rad}(e)$$

$$0.15 \cdot W = \frac{T_s(e) - T_\infty}{R_{conv}} + \frac{T_s(e) - T_{céu}}{R_{rad}}$$

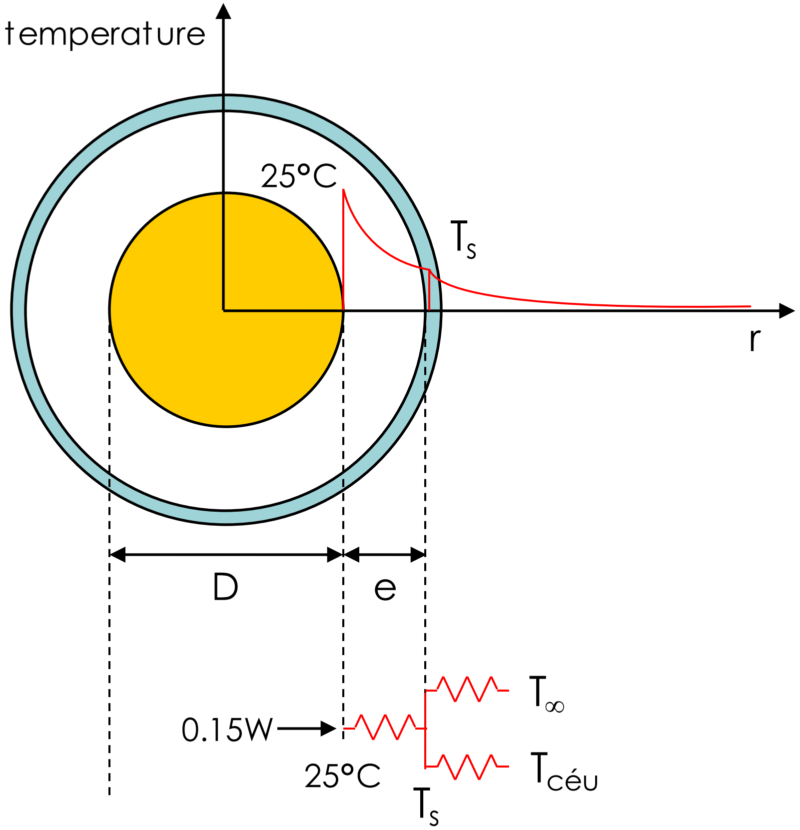
$$\Downarrow \quad T_s = T_s(e)$$

$$0.15 \cdot W = h(T_s) \cdot \pi(D+2e)L \cdot (T_s - T_\infty) + \varepsilon \cdot \pi(D+2e)L \cdot \sigma \cdot (T_s^4 - T_{céu}^4)$$

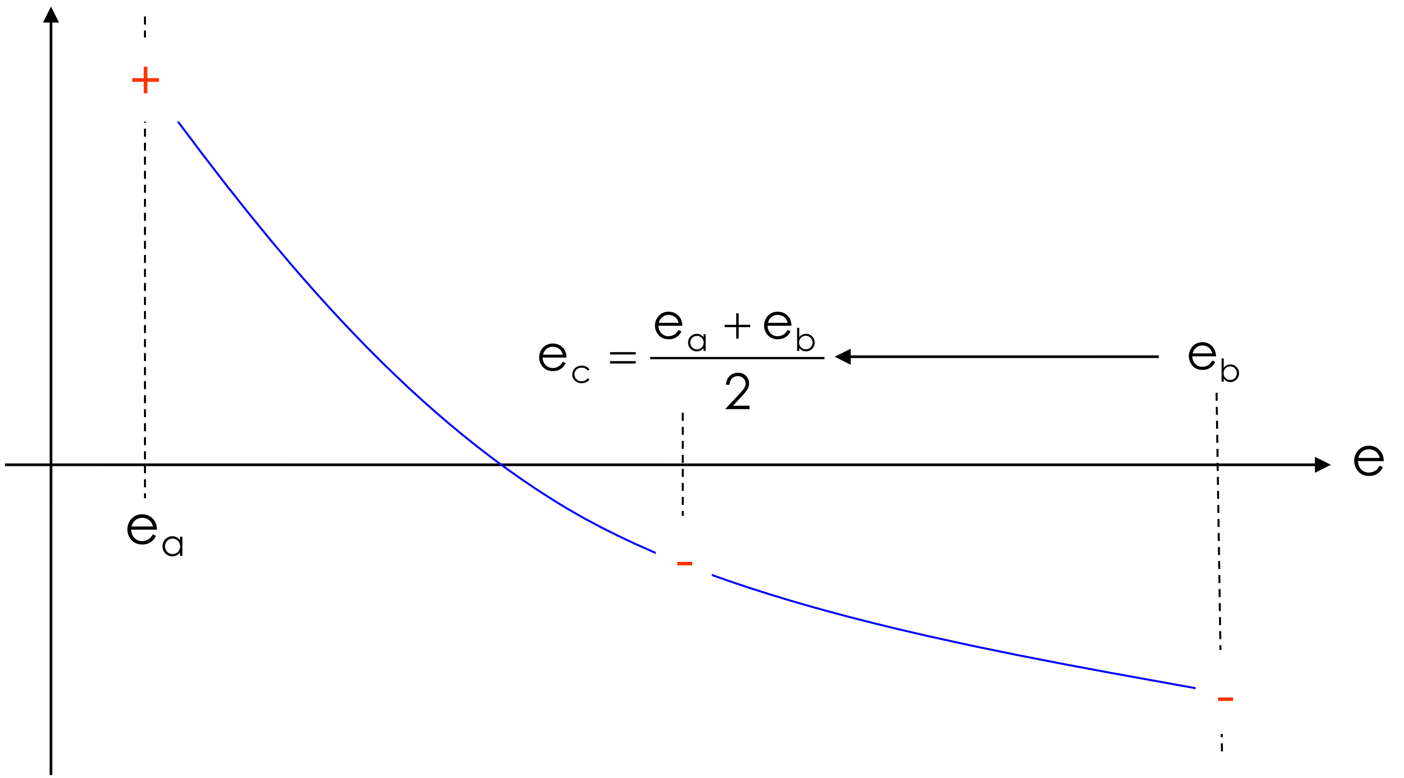
$$f(e) = h(T_s) \cdot \pi(D+2e)L \cdot (T_s - T_\infty) + \varepsilon \cdot \pi(D+2e)L \cdot \sigma \cdot (T_s^4 - T_{céu}^4) - 0.15 \cdot W$$

propriedades @ $(T_s+T_\infty)/2$

Solução pelo método de “bracketing”

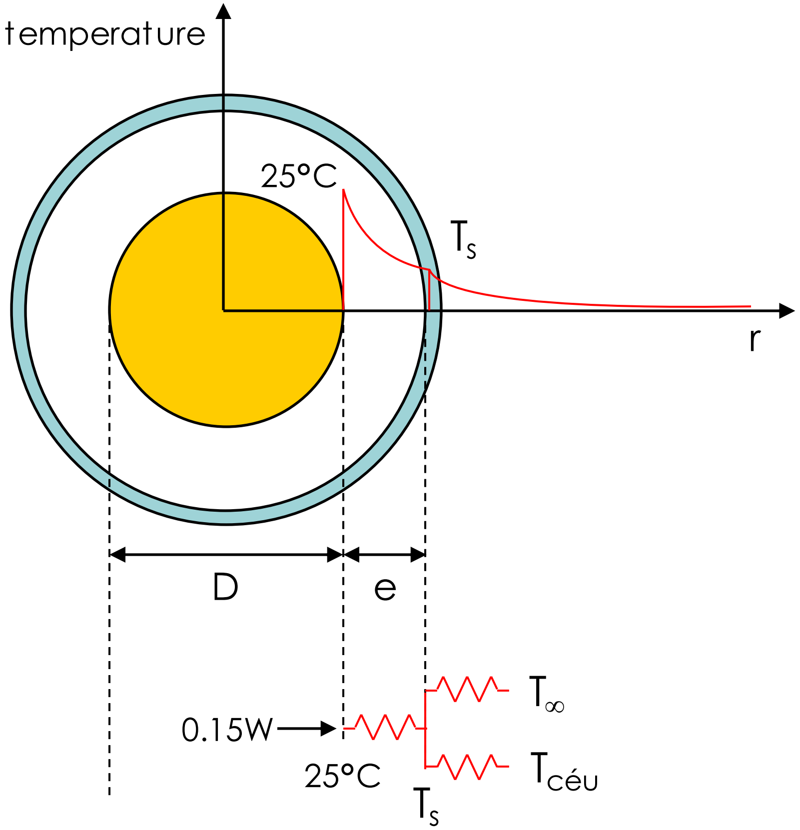


$$f(e) = h(T_s)\cdot\pi(D+2e)L\cdot(T_s - T_\infty) + \varepsilon\cdot\pi(D+2e)L\cdot\sigma\cdot(T_s^4 - T_{céu}^4) - 0.15\cdot W$$

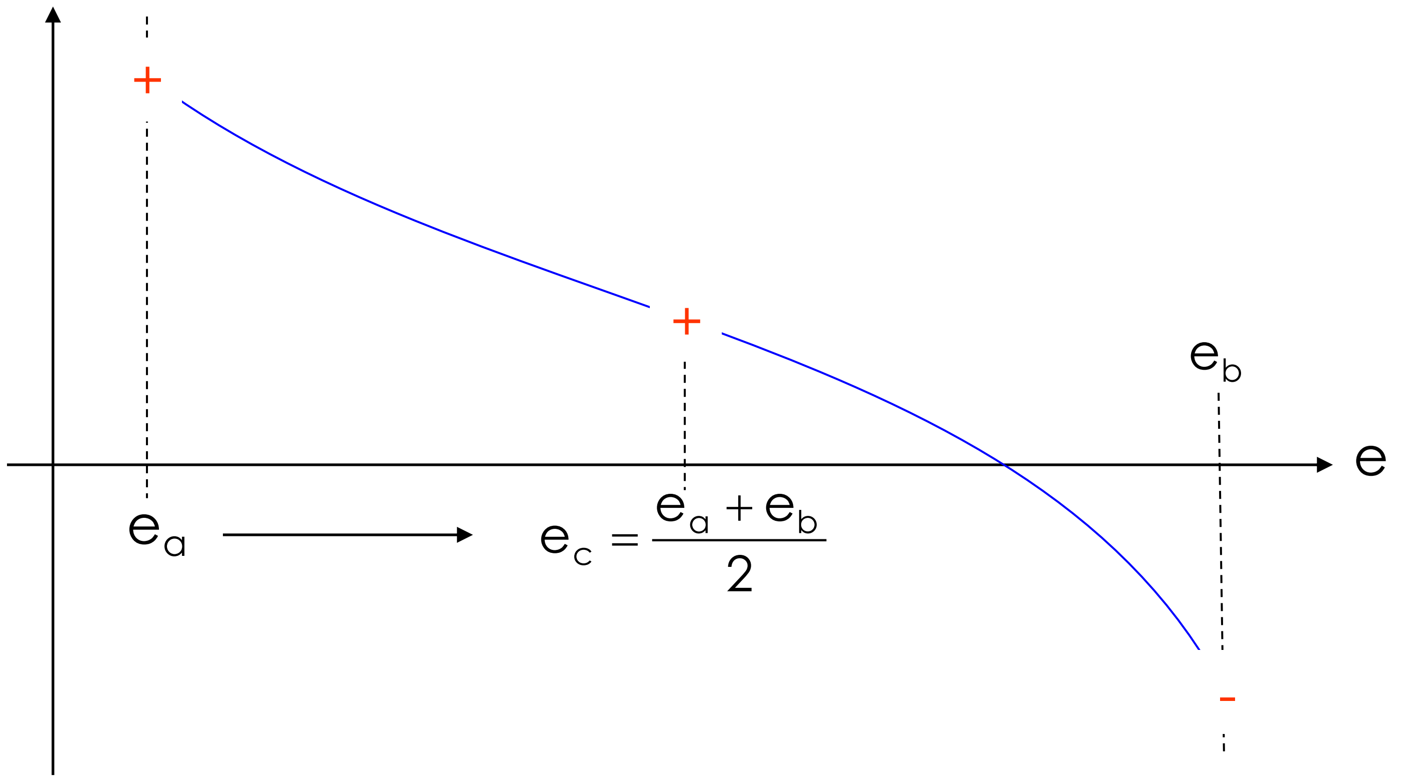


propriedades @ $(T_s+T_\infty)/2$

Solução pelo método de "bracketing"



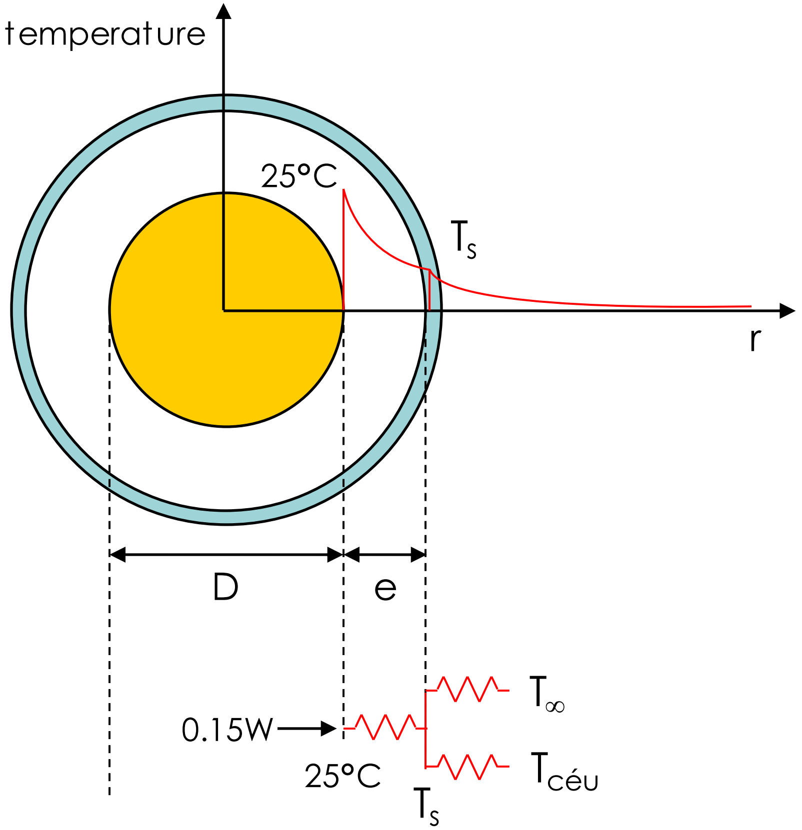
$$f(e) = h(T_s)\cdot \pi(D+2e)L\cdot(T_s - T_\infty) + \varepsilon\cdot\pi(D+2e)L\cdot\sigma\cdot(T_s^4 - T_{céu}^4) - 0.15\cdot W$$



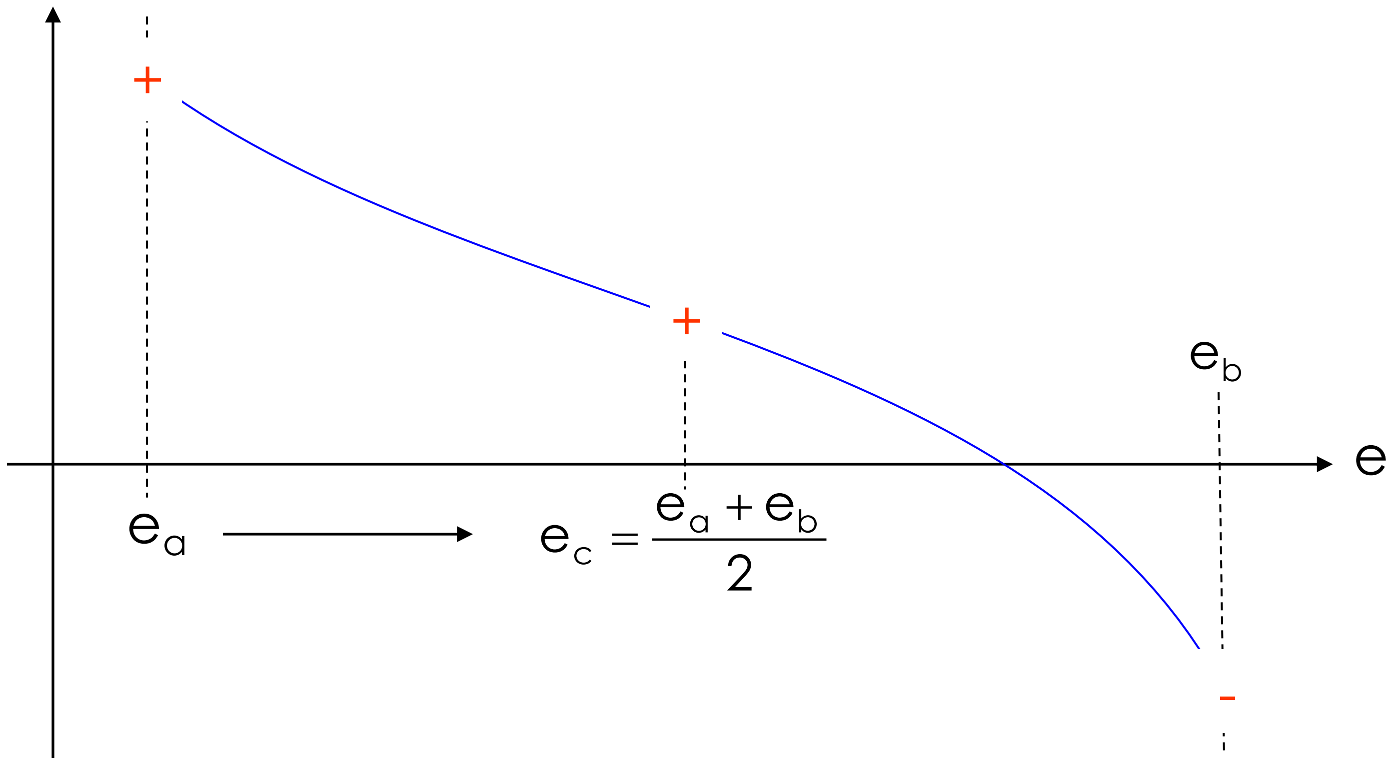
$$e_c = \frac{e_a + e_b}{2}$$

propriedades @ $(T_s+T_\infty)/2$

Solução pelo método de “bracketing”



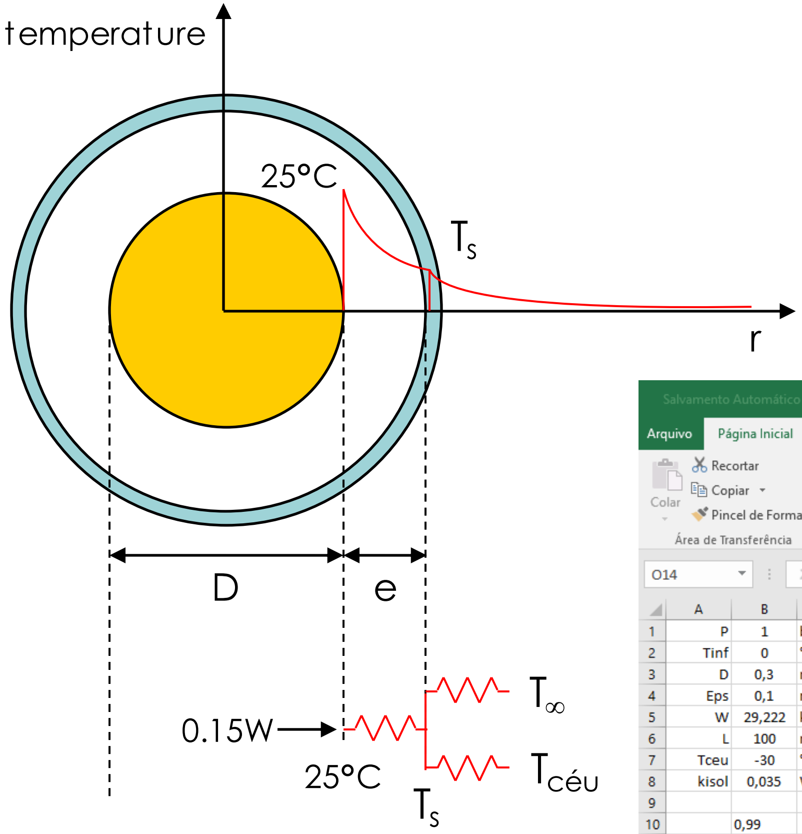
$$f(e) = h(T_s)\cdot\pi(D+2e)L\cdot(T_s - T_\infty) + \varepsilon\cdot\pi(D+2e)L\cdot\sigma\cdot(T_s^4 - T_{céu}^4) - 0.15\cdot W$$



$$e_a \leftarrow \begin{cases} e_a \text{ if } e_a\cdot e_c < 0 \\ e_c \text{ if } e_a\cdot e_c > 0 \end{cases} \qquad e_b \leftarrow \begin{cases} e_b \text{ if } e_b\cdot e_c < 0 \\ e_c \text{ if } e_b\cdot e_c > 0 \end{cases}$$

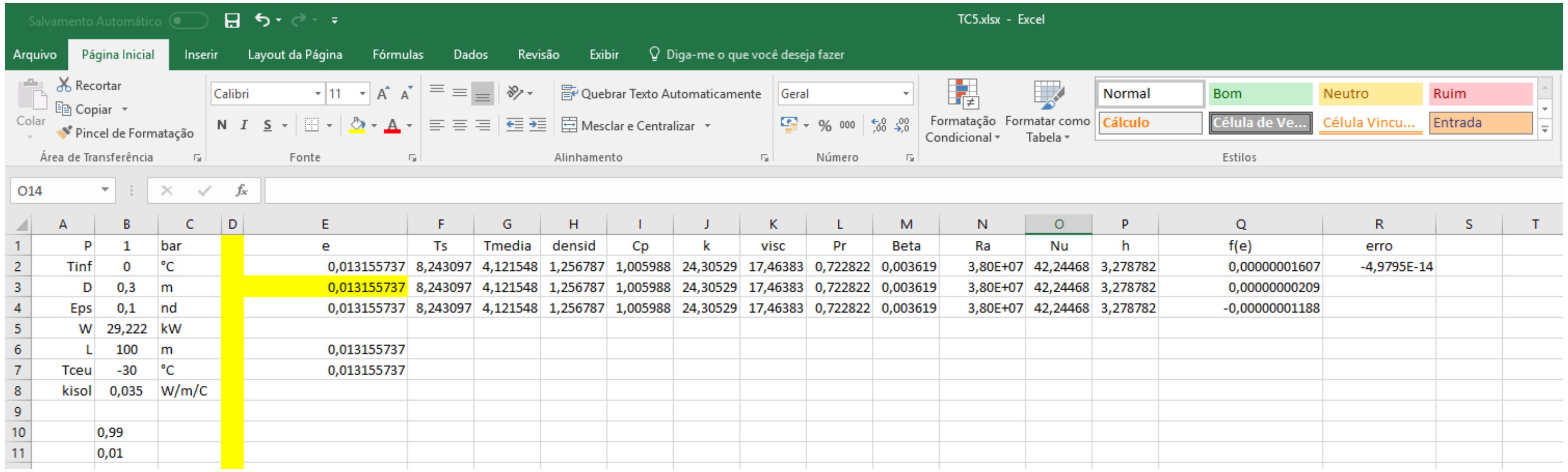
propriedades @ $(T_s+T_\infty)/2$

Solução pelo método de "bracketing"



$$f(e) = h(T_s)\cdot\pi(D+2e)L\cdot(T_s - T_\infty) + \varepsilon\cdot\pi(D+2e)L\cdot\sigma\cdot(T_s^4 - T_{céu}^4) - 0.15\cdot W$$

e=0,013 m



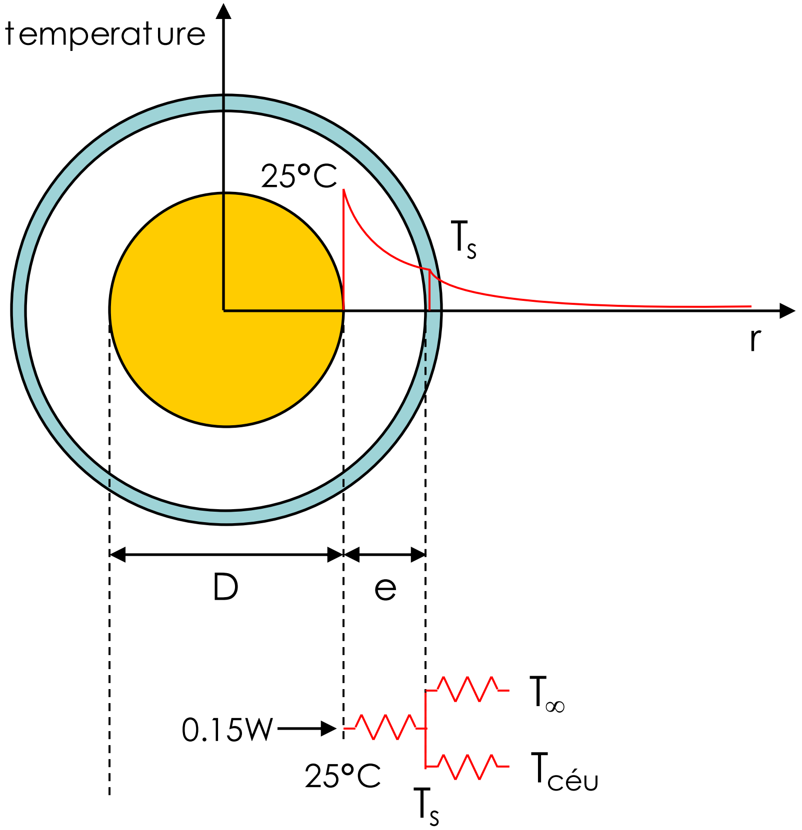
TC5.xlsx - Excel

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	P	1	bar		e	Ts	Tmedia	densid	Cp	k	visc	Pr	Beta	Ra	Nu	h	f(e)	erro
2	Tinf	0	°C		0,013155737	8,243097	4,121548	1,256787	1,005988	24,30529	17,46383	0,722822	0,003619	3,80E+07	42,24468	3,278782	0,0000001607	-4,9795E-14
3	D	0,3	m		0,013155737	8,243097	4,121548	1,256787	1,005988	24,30529	17,46383	0,722822	0,003619	3,80E+07	42,24468	3,278782	0,0000000209	
4	Eps	0,1	nd		0,013155737	8,243097	4,121548	1,256787	1,005988	24,30529	17,46383	0,722822	0,003619	3,80E+07	42,24468	3,278782	-0,0000001188	
5	W	29,222	kW															
6	L	100	m		0,013155737													
7	Tceu	-30	°C		0,013155737													
8	kisol	0,035	W/m/C															
9																		
10		0,99																
11		0,01																

propriedades @ $(T_s+T_\infty)/2$

$$e_a \leftarrow \begin{cases} e_a \text{ if } e_a\cdot e_c < 0 \\ e_c \text{ if } e_a\cdot e_c > 0 \end{cases} \qquad e_b \leftarrow \begin{cases} e_b \text{ if } e_b\cdot e_c < 0 \\ e_c \text{ if } e_b\cdot e_c > 0 \end{cases}$$

Solução por iteração funcional:



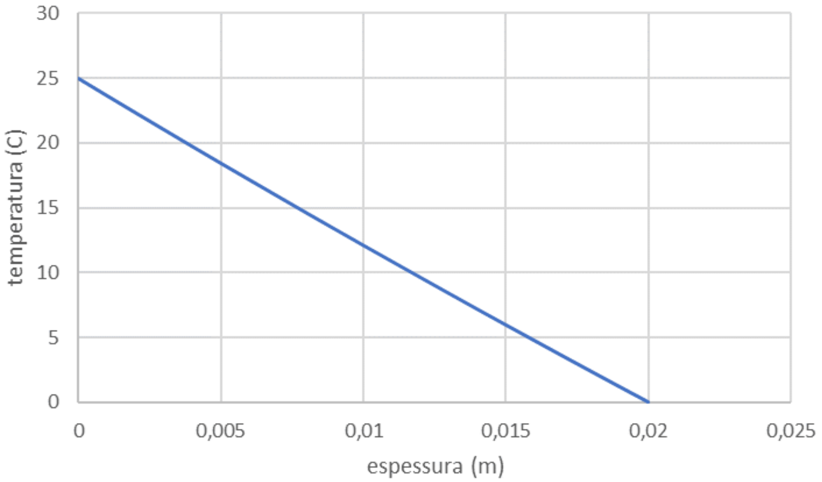
isolamento : $T_s \downarrow$

alumínio : $\varepsilon \downarrow$

$$\Rightarrow \begin{cases} Q_{conv} = h \cdot \pi(D+2e)L \cdot (T_s - T_\infty) \\ Q_{rad} = \varepsilon \cdot \pi(D+2e)L \cdot \sigma \cdot (T_s^4 - T_{céu}^4) \end{cases}$$

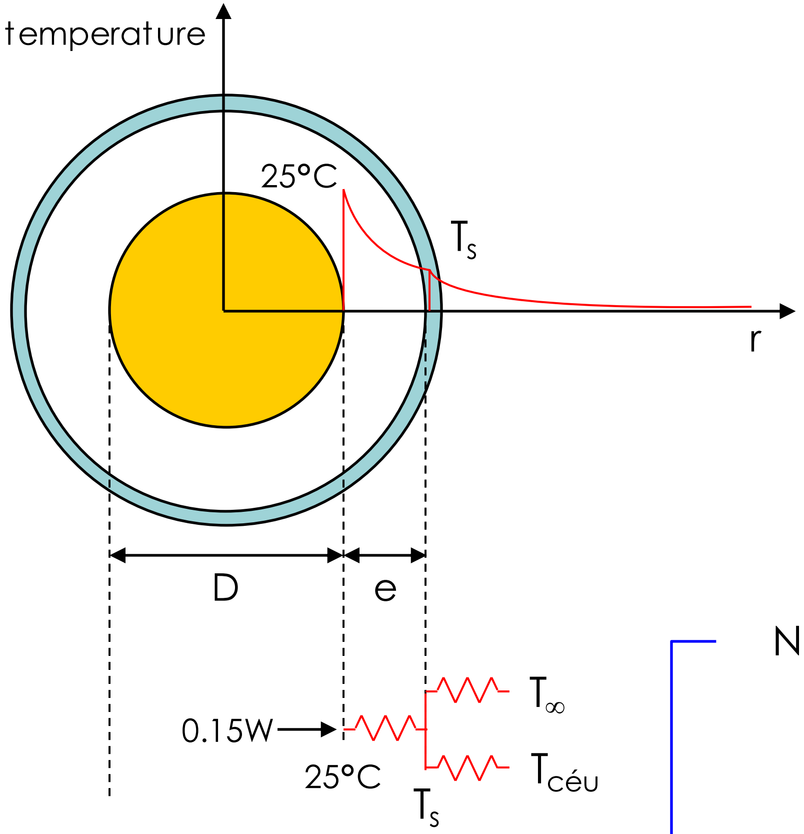
$$0.15 \cdot W = \frac{25 - T_s}{R_{isol}} = \frac{25 - T_s}{\frac{1}{2\pi L k_{isol}} \ln(r_{ext}/r_{int})}$$

$$T_s = 25 - \frac{1}{2\pi L k_{isol}} \ln\left(\frac{D/2 + e}{D/2}\right) \cdot 0.15 \cdot W$$



$$R_k = \frac{\ln(r_{k+1}/r_k)}{2\pi L k_k}$$

Solução por iteração funcional:



$$\text{Resolver}: \; Q_{conv}(e) + Q_{rad}(e) = 0.15 \cdot W$$

$$h(T_s) \cdot \pi (D+2e) L \cdot (T_s - T_\infty) + \varepsilon \cdot \pi (D+2e) L \cdot \sigma \cdot (T_s^4 - T_{céu}^4) = 0.15 \cdot W$$

$$e_k \;\rightarrow\; 25 - \frac{1}{2\pi L k_{isol}} \ln\left(\frac{D/2+e}{D/2}\right) \cdot 0.15 \cdot W = T_s$$

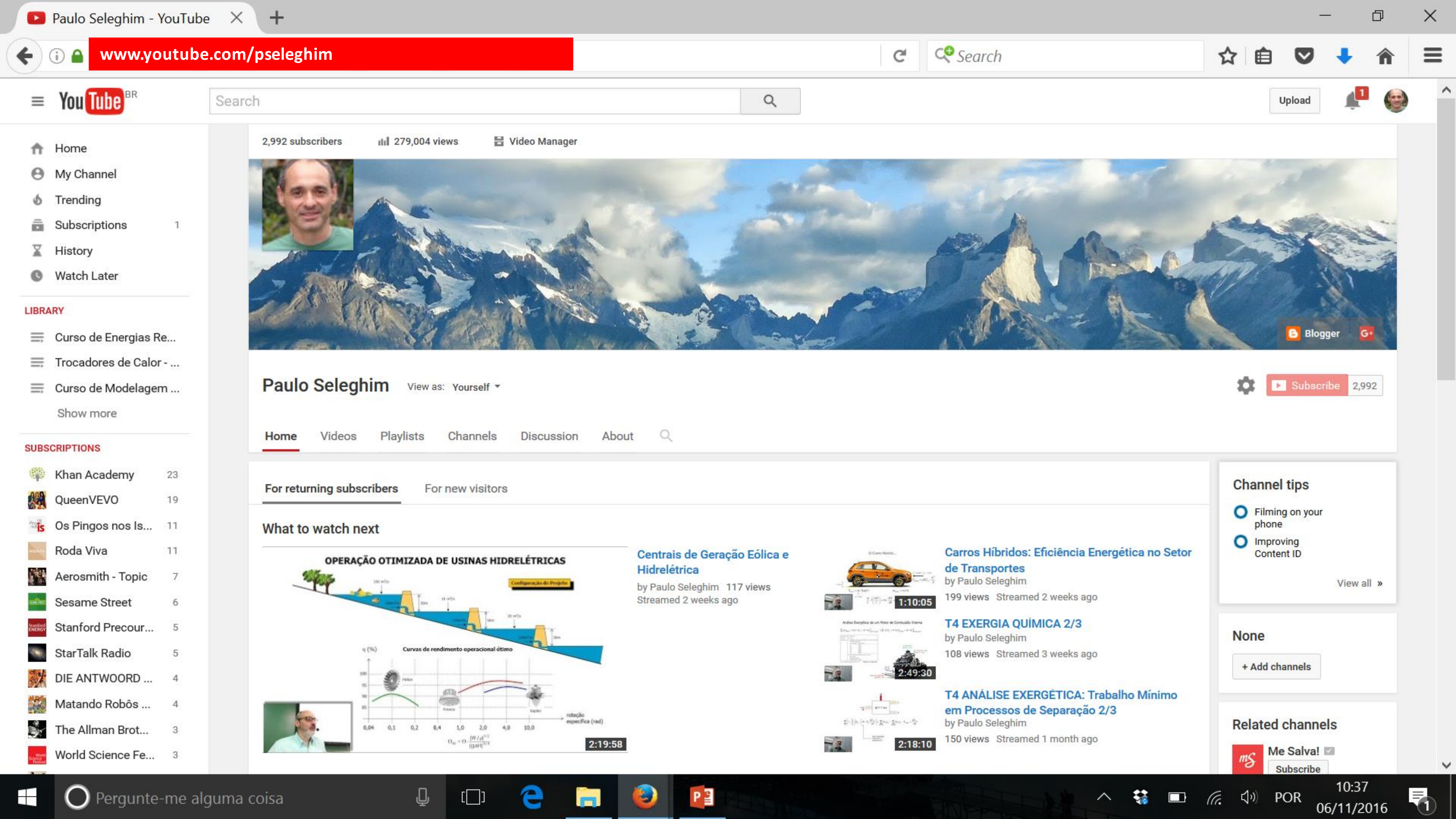
$$Ra = \frac{g\beta (T_s - T_\infty)(D+2e)^3}{(\mu/\rho)^2} \cdot Pr$$

$$\leftarrow \; Nu = \left\{ 0.6 + \frac{0.387 \cdot Ra^{1/6}}{\left[1 + (0.559/Pr)^{9/16}\right]^{8/27}} \right\}^2$$

$$h = \frac{k}{D+e} \cdot Nu \;\rightarrow\; \frac{1}{2}\left[\frac{0.15 \cdot W}{h(T_s) \cdot \pi L \cdot (T_s - T_\infty) + \varepsilon \cdot \pi L \cdot \sigma \cdot (T_s^4 - T_{céu}^4)} - D\right] = e_{k+1}$$

DIVERGENTE !!!

propriedades @ $(T_s+T_\infty)/2$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Stanford Precour... 5
StarTalk Radio 5
DIE ANTWOORD ... 4
Matando Robôs ... 4
The Allman Brot... 3
World Science Fe... 3
2,992 subscribers
279,004 views
Video Manager
Blogger
Paulo Seleghim
View as: Yourself
Subscribe 2,992
Home
Videos
Playlists
Channels
Discussion
About
For returning subscribers
For new visitors
What to watch next
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