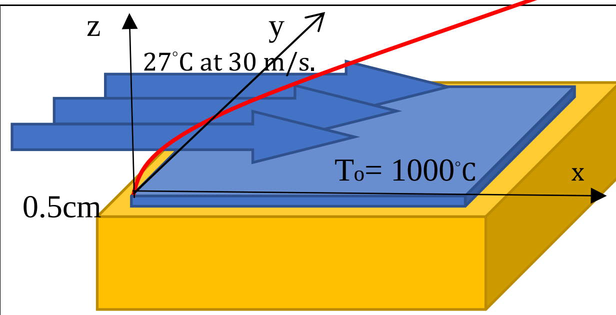
1. **A 1 m^2** slab of **mild steel** leaves a forging operation with a thickness of **0.5 cm** at **1,000°C**. It is laid flat on an insulating bed and **27°C air** is blow over the top side **at 30 m/s**. How long will it take for the hottest part **to reach 200°C**? Clearly state all your assumptions.



Assumptions:

1. Flow Geometry: Flat plate Geometry
2. Calculate reference temperature:
3. Find the Reynolds number:

T (K)	ρ (kg/m³)	c_p (J/kg·K)	μ (kg/m·s)	ν (m²/s)	k (W/m·K)	α (m²/s)	Pr
Air							
720	0.4704	1081	3.288	7.623	0.05425	10.61	0.719

4. Find local or average Convection coeffects
5. Select a Correlation Function Nu
6. Plug in and assume question

$T[oo] := 27$
$$T_{oo} := 27 \quad (1)$$

$T[s] := 1000$
$$T_s := 1000 \quad (2)$$

$T[f] := 200$
$$T_f := 200 \quad (3)$$

$v[air] := 30$
$$v_{air} := 30 \quad (4)$$

$T[ref] := evalf\left(\frac{T[s] - T[oo]}{2}\right)$

#2 reference temperature
$$T_{ref} := 486.5000000 \quad (5)$$

$\nu := 7.623 \cdot 10^{-5}$#
$$\nu := 0.00007623000000 \quad (6)$$

$l := 1$
$$l := 1 \quad (7)$$

$Reynolds := \frac{v[air] \cdot l}{\nu}$ # 3
$$Reynolds := 3.935458481\ 10^5 \quad (8)$$

 # therefore Turbulent Flow Yo!

$Pr := 0.719$
$$Pr := 0.719 \quad (9)$$

$ReynoldsCritical := 10^5$
$$ReynoldsCritical := 100000 \quad (10)$$

$A := evalf\left(0.037 \cdot ReynoldsCritical^{\frac{4}{5}} - 0.664 \cdot ReynoldsCritical^{\frac{1}{2}}\right)$
$$A := 160.0247634 \quad (11)$$

$Nui[x] := \left(0.037 \cdot Reynolds^{\frac{4}{5}} - A\right) \cdot Pr^{\frac{1}{3}}$
$$Nui_x := 848.4777704 \quad (12)$$

$k := 0.05425$
$$k := 0.05425 \quad (13)$$

$\bar{h} := \frac{Nui[x] \cdot k}{\underline{\ }1}$#4
$$h := 46.02991904 \quad (14)$$

$As := 1 \cdot 6$
$$As := 6 \quad (15)$$

$V := 1 \cdot \left(\frac{0.5}{100}\right)$
$$V := 0.005000000000 \quad (16)$$

$L[c] := 0.005$
$$L_c := 0.005 \quad (17)$$

$Bi := \frac{(\bar{h}) \cdot L[c]}{k}$
$$Bi := 4.242388852 \quad (18)$$

#Solve for t at 200 deg C

$V[air] := 0.5699$
$$V_{air} := 0.5699 \quad (19)$$

$\bar{h} := \frac{Nui[x] \cdot V[air]}{\underline{\ }1}$
$$h := 483.5474814 \quad (20)$$

$Ta := \frac{(1000 - 127)}{2}$
$$Ta := \frac{873}{2} \quad (21)$$

$Ts := \frac{(27 - 300)}{2}$
$$Ts := -\frac{273}{2} \quad (22)$$

$T[f] := \frac{(Ta + Ts)}{2}$
$$T_f := -75 \quad (23)$$

$Bi := \frac{20.9 \cdot (.005)}{50}$

 # Therfore we can use the LCM
$$Bi := 0.002090000000 \quad (24)$$

$solve\left(\frac{200 - 27}{1000 - 27} = \exp\left(-t \cdot \left(\frac{20.9}{7830(0.005) \cdot (435)}\right)\right), t\right)$
$$1407.311810 \quad (25)$$

$\boxed{\textbf{1407.311810 Seconds}}$

2. Water **at 37°C** flows **at 3 m/s** across a 6 cm diameter tube that is held **at 97°C.**

In a second configuration, **37°C** water flows at an average velocity of **3 m/s** through a **bundle of 6 cm diameter** tubes that are held at **97°C**. The bundle is staggered, with **S_T /S_L = 2.** Compare the average heat transfer coefficients for the two situations.

1. Flow Geometry
   Flow over a pip
2. Calculate reference temperature:
3. Find the Reynolds number:
4. Find local or average Convection coeffects
   3712.639193
5. Select a Correlation Function Nu
6. Plug in and assume question

$T[oo] := 37$

$$T_{oo} := 37 \quad (1)$$

$T[s] := 97$

$$T_s := 97 \quad (2)$$

$T[f] := 200$

$$T_f := 200 \quad (3)$$

$v[air] := 3$

$$v_{air} := 3 \quad (4)$$

$\mathrm{nu} := 4.308 \cdot 10^{-7}$

$$\nu := 4.308000000\ 10^{-7} \quad (5)$$

$k := 0.6605$

$$k := 0.6605 \quad (6)$$

$Pr := 2.68$

$$Pr := 2.68 \quad (7)$$

$T[f] := \frac{(T[oo] + T[s])}{2}$

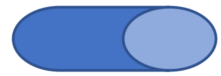
$$T_f := 67 \quad (8)$$

$d := 0.06$

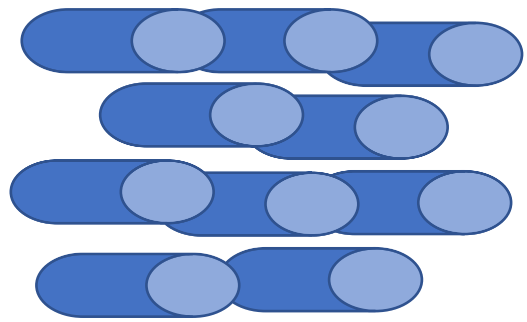
$$d := 0.06 \quad (9)$$

$Renolds := \frac{d \cdot v[air]}{\mathrm{nu}}$

$$Renolds := 4.178272980\ 10^5 \quad (10)$$



One VS bundle staggered



$Renolds < 5 \cdot 10^5$ # True, the flow is Laminar

$$4.178272980\ 10^5 < 500000 \quad (11)$$

$Nus := evalf\left(\frac{0.3 + 0.62 \cdot Renolds^{\frac{1}{2}} \cdot Pr^{\frac{1}{3}}}{\left(1 + \left(\frac{0.4}{Pr}\right)^{\frac{2}{3}}\right)^{\frac{1}{4}}} \cdot \left(1 + \left(\frac{5 \cdot 10^5}{282000}\right)^{\frac{5}{8}}\right)^{\frac{4}{5}} \right)$

$$Nus := 1065.260110 \quad (12)$$

$h := \frac{Nus \cdot k}{d}$

$$h := 11726.73838 \quad (13)$$

$\mathrm{nu} := 4.708 \cdot 10^{-7}$

$$\nu := 4.708000000\ 10^{-7} \quad (14)$$

$Renolds := \frac{d \cdot v[air]}{\mathrm{nu}}$

$$Renolds := 3.823279524\ 10^5 \quad (15)$$

$Renolds < 5 \cdot 10^5$ # True, the flow is Laminar

$$4.178272980\ 10^5 < 500000 \quad (16)$$

$NusD := Pr^{.36} \left(\frac{Pr}{1.75}\right)^{.25} \cdot 0.0321 \cdot (2)^{0.2} Renolds^{.8}$

$$NusD := 1178.126714 \quad (17)$$

$hD := \frac{NusD \cdot v[air]}{d}$

$$hD := 58906.33570 \quad (18)$$

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11726.73838 W/m^2K

58906.33570 W/m^2K

3. Copper spheres of **20 mm** diameter are quenched by being dropped into a tank of water that is maintained **at 280 K.** The spheres may be assumed to reach the terminal velocity of **2.2 m/s** on impact and to drop freely through the water. What is the approximate height of the water tank needed to cool the spheres from an initial temperature of **360 K** to a center temperature of **320 K**?

1. Flow Geometry
2. Calculate reference temperature:
3. Find the Reynolds number:
4. Find local or average Convection coeffects
5. Select a Correlation Function Nu
6. Plug in and assume question

 # Geomitry Is Sphere

$T[p] := T[oo] = 280$

$$T_p := T_{oo} = 280 \quad (1)$$

$T[p]$

$$T_{oo} = 280 \quad (2)$$

$\mathrm{nu} := 5.832 \cdot 10^{-7}$

$$\nu := 5.832000000\ 10^{-7} \quad (3)$$

$k := 0.5740$

$$k := 0.5740 \quad (4)$$

$Pr := 10.63$

$$Pr := 10.63 \quad (5)$$

$\mathrm{rho} := 999.9$

$$\rho := 999.9 \quad (6)$$

$d := 20$

$$d := 20 \quad (7)$$

$v := 2.2$

$$v := 2.2 \quad (8)$$

$ReD := \frac{d \cdot v}{\mathrm{nu}}$

$$ReD := 7.544581619\ 10^{7} \quad (9)$$

$ReD < 5 \cdot 10^{5}$ *# False Turbulent*

$$7.544581619\ 10^{7} \leq 500000 \quad (10)$$

$Nus := 2 + \left(0.4 \cdot ReD^{\frac{1}{2}} + 0.06 \cdot ReD^{\frac{2}{3}}\right) \cdot (Pr)^{0.4} \cdot \left(\frac{\mathrm{mu}}{\mathrm{mu}[s]}\right)^{\frac{1}{4}}$

$$Nus := 438.66 \quad (11)$$

$h := \frac{Nus \cdot v}{d}$

$$h := 48.25260000 \quad (12)$$

$BI := \frac{h \cdot r}{k}$

$$BI := 0.316 \quad (13)$$

$H := t(v)$

$$H := 1.43 \quad (14)$$

1.43 m