Václav Mašlka CZE 4

EXPERIMENT 2 1/8

$P = 10\,W$ heating duration 3600 s (during whole measurement)

$d t = 100\,s$

all values for all measurements between 2500 and 3600 s

$L_1 = 3$ cm	$L_2 = 9$ cm	$L_3 = 15$ cm	$L_4 = 21$ cm	$L_5 = 27$ cm
T_1 (C)	T_2 (C)	T_3 (C)	T_4 (C)	T_5 (C)
from 125,0 to 125,4	121,5 – 121,9	118,2 – 118,6	116,6 – 117,0	115,6 – 116,0
$\doteq 125{,}2\,°C$	$\doteq 121{,}7\,°C$	$\doteq 118{,}4\,°C$	$\doteq 116{,}8\,°C$	$\doteq 115{,}8\,°C$
$= 398{,}3\,K$	$= 394{,}8\,K$	$= 391{,}5\,K$	$= 389{,}9\,K$	$= 388{,}9\,K$

⇒ the values are constant for about 18 minutes

⇒ the temperature do not change ⇒ the specific heat c do not effect this part of measurement

the energy cannot disapear

$$W = S \cdot \alpha \left(T - T_0\right) + S \cdot \beta \sigma \left(T^4 - T_0^4\right)$$

The best will be make a graph, aproximate the ~~...~~ curve and calculate the integral, but I do not have time for it so I will use simple aproximation and I will ~~assume~~ divide the rod into 5 pieces with „constant" temperature.

Václav Maštera CZE 4

EXPERIMENT 2 2/8

One piece lost energy

$$E_i = S_p \cdot \alpha (T_i - T_0) + S_p \cdot \beta \cdot \sigma (T_i^4 - T_0^4)$$

$$W = \sum_{i=1}^{5} E_i = S_p \cdot \alpha \cdot \sum_{i=1}^{5} (T_i - T_0) + S_p \cdot \beta \cdot \sigma \sum_{i=1}^{5} (T_i^4 - T_0^4)$$

lenght $L = 30$ cm radius $r = 1$ cm

area of a part of the cylinder

$$S_p \approx 2\pi r \cdot \frac{L}{5} \qquad S_p \approx 2\pi \cdot 1 \cdot \frac{30}{5} \doteq 37{,}68 \text{ cm}^2$$

$$\doteq 37{,}7 \cdot 10^{-4} \text{ m}^2$$

heater make in one second work $W = 10$ J

$$\sum_{i=1}^{5} (T_i - T_0) = T_1 + T_2 + T_3 + T_4 + T_5 - 5T_0 = 597{,}9 - 5 \cdot 26{,}9 = 463{,}4$$

$$\sum_{i=1}^{5} (T_i^4 - T_0^4) = T_1^4 + T_2^4 + T_3^4 + T_4^4 + T_5^4 - 5T_0^4 \doteq 7{,}844 \cdot 10^{10}$$

$$10 = 37{,}7 \cdot 10^{-4} \cdot 463{,}4 \cdot \alpha + 37{,}7 \cdot 10^{-4} \cdot 7{,}844 \cdot 10^{10} \cdot 5{,}67 \cdot 10^{-8} \cdot \beta$$

$$\text{I} \quad 10 = 1{,}747\alpha + 16{,}767\beta$$

There will be similar measurement with heating power 100 W

Václav Maštera CZE 4

EXPERIMENT 2 3/8

$P = 100W$ heating duration 3600 s (during whole experiment)

$dt = 100$ s

all values for all measurement between 1100 s – 3600 s

$L_1 = 3cm$	$L_2 = 9cm$	$L_3 = 15cm$	$L_4 = 21cm$	$L_5 = 27cm$
T_1 (C)	T_2 (C)	T_3 (C)	T_4 (C)	T_5 (C)
480,7 – 481,1	446,5 – 447,0	421,1 – 421,5	404,9 – 405,3	396,0 – 396,4
≐ 480,8°C	≐ 446,8°C	≐ 421,3°C	≐ 405,1°C	≐ 396,2°C
≐ 753,9K	= 719,9K	= 694,4K	= 678,2K	= 669,3K

Everything same as before.

$$W = \sum_{i=1}^{5} E_i = S_p \cdot \alpha \sum_{i=1}^{5} (T_i - T_0) + S_p \cdot \beta \sigma \sum_{i=1}^{5} (T_i^4 - T_0^4)$$

heater make in one second work $W = 100J$

$$\sum_{i=1}^{5} (T_i - T_0) = 2015,7$$

$$\sum_{i=1}^{5} (T_i^4 - T_0^4) \doteq 1,196 \times 10^{12}$$

$$100 = 37,7 \cdot 10^{-4} \cdot 2015,7 \cdot \alpha + 37,7 \cdot 10^{-4} \cdot 1,196 \cdot 10^{12} \cdot 5,67 \times 10^{-8} \cdot \beta$$

$$\underline{\underline{\text{II } 100 = 7,600 \cdot \alpha + 255,6\,\beta}}$$

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EXPERIMENT 2 4/8

Two equations with two variables

I. $\Rightarrow$ $$\alpha = \frac{10 - 16{,}77\beta}{1{,}747}$$

II $\Rightarrow$ $$100 = 7{,}600 \frac{10 - 16{,}77\beta}{1{,}747} + 255{,}6\beta$$

$$100 = 43{,}50 - 72{,}95 + 255{,}6\beta$$

$$56{,}50 = 182{,}65\beta$$

$$\underline{\underline{\beta}} \doteq 0{,}3093 \doteq \underline{\underline{0{,}309}} \quad \text{(dimensionless)}$$

$$\underline{\underline{\alpha}} = \frac{10 - 16{,}77 \cdot 0{,}3093}{1{,}747} \doteq 2{,}755 \doteq \underline{\underline{2{,}76}} \ \frac{W}{m^2K}$$

THE SPECIFIC HEAT c $\left[\frac{J}{kg\,K}\right]$

I will keep it simple so I will asume that

if the temperature is under 35°C* that the cylinder

does not lost the heat. $\underbrace{(\text{i.e.} = 308{,}1\,K)}_{T_{LOST}}$

* and the time is short like under 20 s

Becouse:

Let's whole cylinder had top temperature 35°C.

How many ~~he~~ heat ~~an~~ will the cylinder lost during $t_{LOST} = 20\,s$

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EXPERIMENT 2 5/8

$$E_{LOST} = S \cdot t_{LOST} \cdot \alpha (T_{LOST} - T_0) + S \cdot t_{LOST} \cdot \beta \cdot \sigma \cdot (T_{LOST}^4 - T_0^4)$$

$S \approx 2\pi r \cdot l$ $\quad S = 2\pi \cdot 1 \cdot 30 = 188,4\,cm^2 \doteq 0,02\,m^2$

$$E_{LOST} = 0,02 \cdot 20 \cdot 2,76 \cdot 8,1 + 0,02 \cdot 20 \cdot 0,31 \cdot 5,67 \times 10^{-8} \cdot 9,1 \cdot 10^{8}$$

$E_{LOST} \doteq 15\,J$

If the power of the heater is 10 W $\Rightarrow \frac{E}{W} = \frac{15}{10 \cdot 20} = 0,075$

$\Rightarrow 7,5\%$

Back to the specific heat

I will divide the cylinder into 5 spaces like before.

$m_p = \frac{0,46}{5} = 0,092\,kg$ mass of the part

And I will asume that the whole piece has constant temperature. like before

t (s)	$L_1 = 3$ cm	$L_2 = 9$ cm	$L_3 = 15$ cm	$L_4 = 21$ cm	$L_5 = 27$ cm
	T_1 (C)	T_2 (C)	T_3 (C)	T_4 (C)	T_5 (C)
5	30,1	28,0	27,1	26,9	26,9
10	32,2	29,5	27,9	27,2	26,9
15	33,9	30,8	28,8	27,7	27,2
20	35,3	32,0	29,8	28,4	27,8

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EXPERIMENT 2 6/8

$t_1 = 5\,s$ $t_2 = 10\,s$ $t_3 = 15\,s$ $t_4 = ~~x~~\,20\,s$

power of heater $p = 10\,W$ $T_0 = 26{,}9\,°C$

(heater is on during whole time)

$$p \cdot t_{\cancel{4}} = m_p \cdot c \left[(T_1 - T_0) + (T_2 - T_0) + (T_3 - T_0) + (T_4 - T_0) + (T_5 - T_0) \right]$$

$$p\,t = m_p \cdot c \left[T_1 + T_2 + T_3 + T_4 + T_5 - 5T_0 \right]$$

$$c = \frac{p\,t}{m_p \left(T_1 + T_2 + T_3 + T_4 + T_5 - 5T_0 \right)}$$

$$c_1 = \frac{10 \cdot 5}{0{,}092 \left(30{,}1 + 28{,}0 + 27{,}1 + 26{,}9 + 26{,}9 - 5 \cdot 26{,}9 \right)} \doteq 120{,}7 \frac{J}{kgK}$$

$c_2 \doteq 118{,}1 \frac{J}{kgK}$ The values are similar.

$c_3 = 117{,}3 \frac{J}{kgK}$ c_4 .. has biggest mistake

$c_4 = 115{,}6 \frac{J}{kgK}$ ~~x~~ c .. the average from c_1, c_2, c_3

$$\underline{\underline{c \doteq 119 \frac{J}{kgK}}}$$

THERMAL CONDUCTIVITY $[\lambda] = \frac{W}{mK} = \frac{J}{mK \cdot s}$

~~I will assume as before that the cylinder do not lost heat.~~
~~(is similar situation like before)~~

I find balanced situation for heater power 1W.
Because of the small heater power I can <u>not</u> assume that the cylinder do not lost the heat.

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EXPERIMENT 2 7/8

heat flux

[illegible] $\Phi = \frac{P}{S_c}$

$\Phi \approx \lambda \frac{\Delta T}{\Delta w} \implies$

$\frac{P}{S_c} = \lambda \frac{\Delta T}{\Delta w}$

* on next site

~~heater power 10 W~~

$\lambda = \frac{P \cdot \Delta w}{S_c \cdot \Delta T}$

$t(s)$	$L_1 = 2\,cm$	$L_2 = 3\,cm$	$L_3 = 4\,cm$	$L_4 = 5\,cm$	$L_5 = 6\,cm$
	$T_1(C)$	$T_2(C)$	$T_3(C)$	$T_4(C)$	$T_5(C)$
5	38,6	38,5	29,7	28,2	28,6
10	38,8	37,6	31,7	31,2	30,4
15	39,5	39,3			

~~$P = RI$~~ $P = 1\,W$ $\Delta w = 7\,cm = 0{,}07\,m$

$\Delta T = 38{,}5 - 38{,}1 = 0{,}4\,K$

$S_c = \pi r^2$ $r = 1\,cm$ $S_c \doteq 3{,}14\,cm^2 = 3{,}14 \cdot 10^{-4}\,m^2$

~~$\lambda = \frac{1 \cdot 0{,}07}{0{,}4 \cdot 3{,}14 \cdot 10^{-4}} \doteq 560$~~

How many of power is lost because of that the cylinder lost heat

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EXPERIMENT 2 8/8

$\square$ $\frac{\Delta T}{\Delta W}$ are also quite small numbers so the linear aprox. of curve is better.

$\ast$ heater power 1 W (during whole time)

during 2400 - 3600 s

$L_1 = 3$ cm

$T_1 \doteq 38{,}5\,°C$

$L_2 = 10$ cm

$T_2 \doteq 38{,}1\,°C$

Why so small power?

I wanted not to solve the lost of heat but the losts were too big. So I can ... the temperature at least realy nice aproximate as constant function, because it do not change a lot. $\square$

$$S_L = 2\pi \cdot 1 \cdot 10 \doteq 62{,}8\ \text{cm}^2 = 62{,}8 \cdot 10^{-4}\ \text{m}^2$$

$T_L \doteq 38{,}8\,°C$ – the temperature of whole part – (aprox) $= 311{,}9$ K

$$P_L = S \cdot \alpha (T_L - T_0) + S \cdot \beta \cdot \sigma \left(T_L^4 - T_0^4\right)$$

$$P_L = 62{,}8 \cdot 10^{-4} \cdot 2{,}76 \cdot (38{,}8 - 29{,}6) + (311{,}9^4 - 300^4) \cdot 62{,}8 \cdot 10^{-4} \cdot 0{,}31 \cdot 5{,}67 \cdot 10^{-8}$$

$$P_L \doteq 0{,}31\ \text{W}$$

$$\lambda = \frac{(1 - P_L)\,\Delta W}{S_C \cdot \Delta T} \qquad \lambda = \frac{(1 - 0{,}31) \cdot 0{,}07}{0{,}4 \cdot 3{,}14 \cdot 10^{-4}} \doteq 385\ \frac{\text{W}}{\text{mK}}$$

From my results I can gues the metal because λ is right ... (but I think it's that possible value) $\Rightarrow$ metal is Cu