F2002

Problem Expt ET

table 1
temperature vs resistance

8.01X

Here is my data table for the calibration of the thermistor.

Graph 1 is a resistance vs temperature plot. I fit an exponential curve

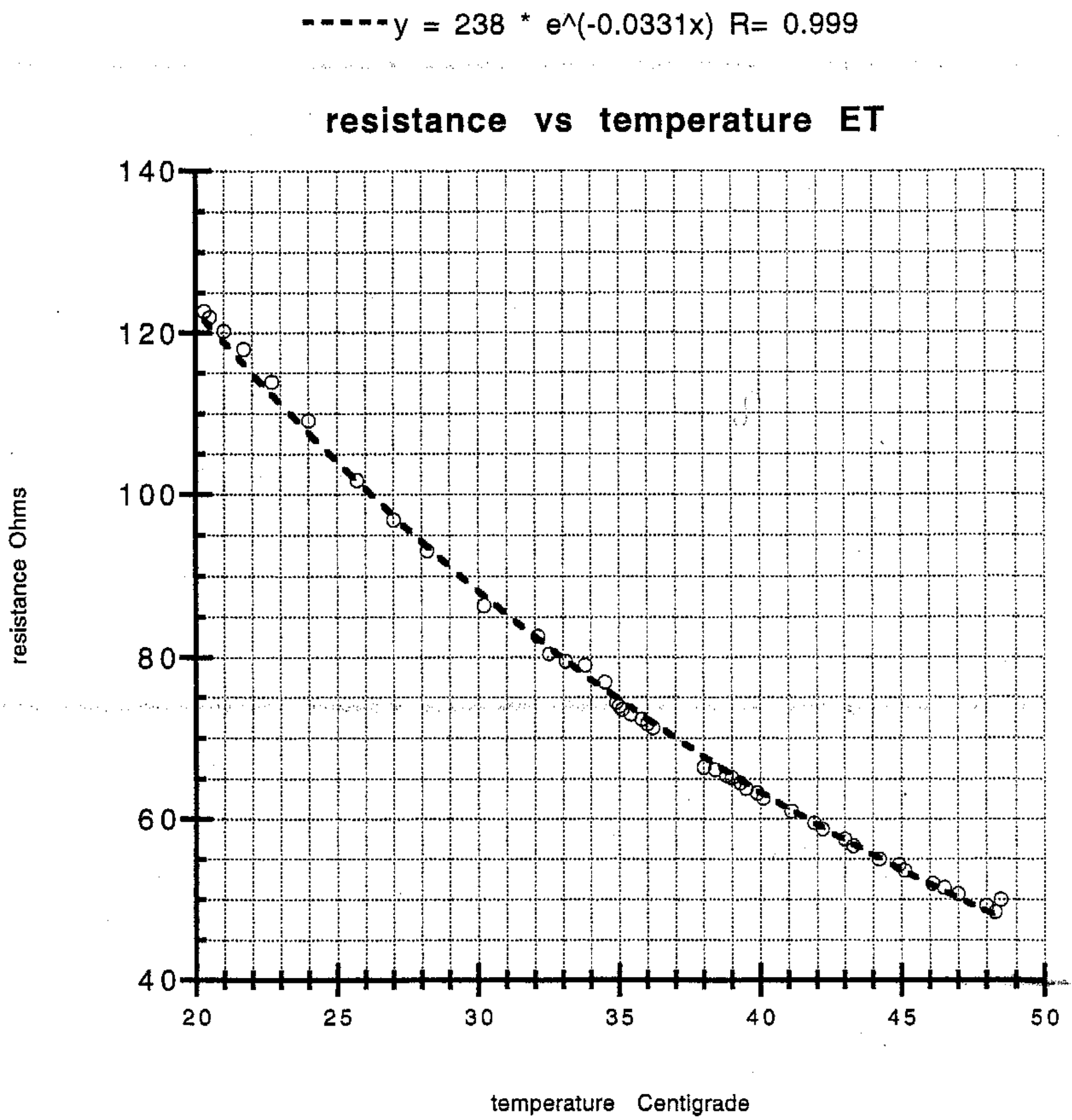
$R(T) = R_0 e^{-\alpha T}$

with best-fit parameters

$R_0 = 238\ \Omega$

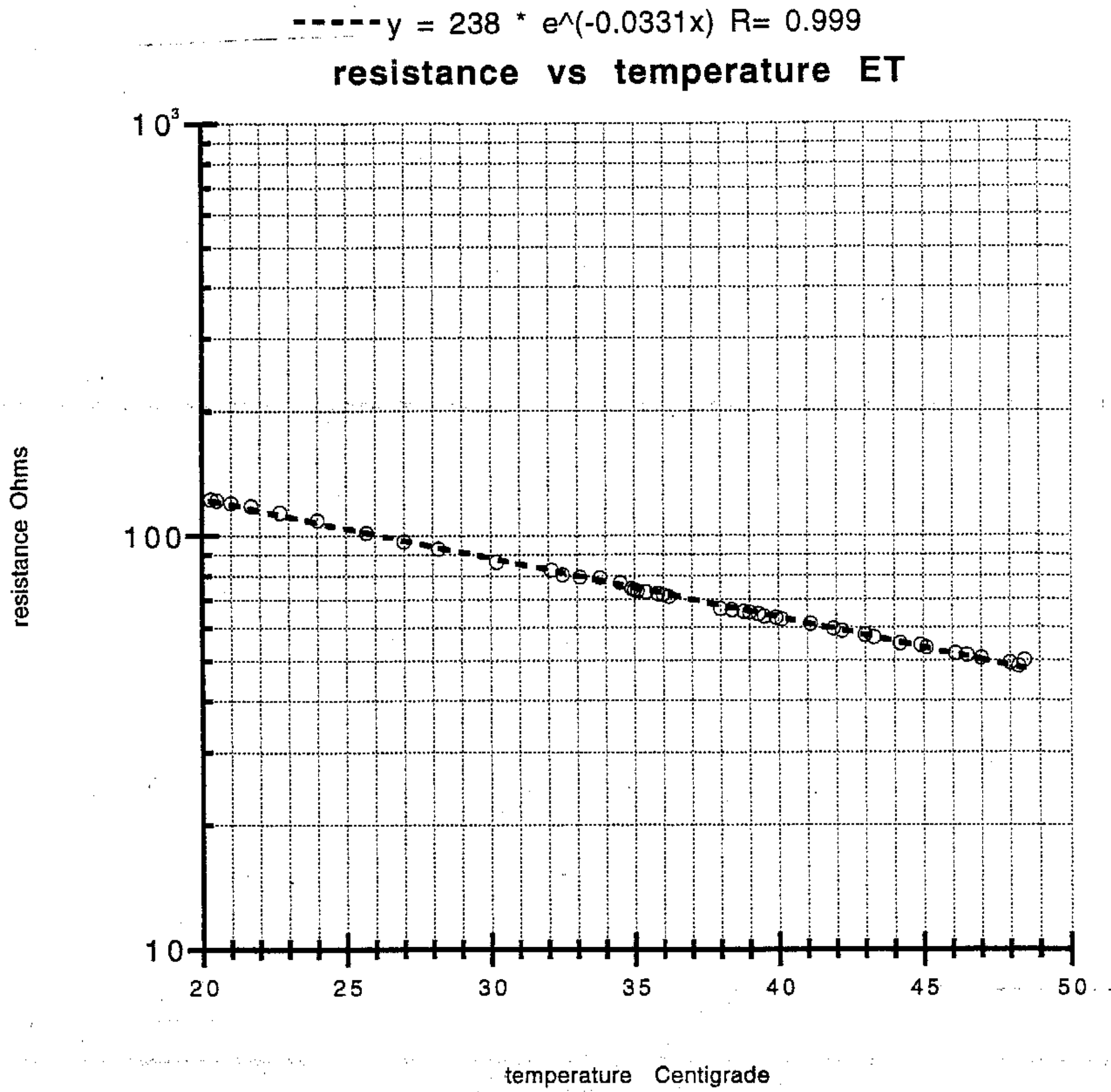
$\alpha = 0.0331\ \frac{1}{C^\circ}$

	temperature °C	resistance Ohm
0	20.3	122.7
1	20.5	122.0
2	21.0	120.2
3	21.7	118.0
4	22.7	113.9
5	24.0	109.1
6	25.7	101.8
7	27.0	96.90
8	28.2	93.10
9	30.2	86.40
10	32.1	82.60
11	32.5	80.40
12	33.1	79.50
13	33.8	79.00
14	34.5	76.90
15	34.9	74.40
16	35.0	73.90
17	35.1	73.50
18	35.4	72.90
19	35.8	72.30
20	36.0	71.70
21	36.2	71.20
22	38.0	66.40
23	38.4	66.10
24	38.8	65.40
25	39.0	65.10
26	39.3	64.50
27	39.5	63.80
28	39.9	63.20
29	40.1	62.60
30	41.1	61.00
31	41.9	59.50
32	42.2	58.70
33	43.0	57.50
34	43.3	56.60
35	44.2	55.00
36	44.9	54.30
37	45.1	53.60
38	46.1	52.00
39	46.5	51.50
40	47.0	50.70
41	48.5	50.00
42	48.0	49.30
43	48.3	48.50



graph I

I also plotted ln R vs T, a semi-ln graph, (graph II). The best-fit line is shown on the graph.



graph II

Using the expression $T = (\ln R_0 - \ln R)/\alpha$

$R = 10\,\Omega$: $T = \dfrac{(\ln(238\,\Omega) - \ln(10\,\Omega))}{0.0331\,\left(\frac{1}{°C}\right)} = 95.8\ °C$

$R = 50\,\Omega$: $T = \dfrac{(\ln(238\,\Omega) - \ln(50\,\Omega))}{0.0331\left(\frac{1}{°C}\right)} = 47.1\ °C$

$R = 100\,\Omega$: $T = \dfrac{(\ln(238\,\Omega) - \ln(100\,\Omega))}{0.0331\,\left(\frac{1}{°C}\right)} = 26.2\ °C$

$R\ 150\,\Omega$: $T = \dfrac{(\ln(238\,\Omega) - \ln(150\,\Omega))}{0.0331\,\left(\frac{1}{°C}\right)} = 13.9\,°C$

$R = 200\,\Omega$ = $T = \dfrac{(\ln(238\,\Omega) - \ln(200\,\Omega))}{0.0331\,(1/°C)} = 5.3\ °C$

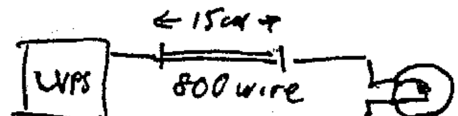
In my experiment, I used 15 cm of 800 wire with $R_{800} = .150\,\Omega$. I measured a voltage $V_{800} = .074\,V$. Thus the current

$$I = \frac{.074\,V}{.150\,\Omega} = .493\ A$$

The power delivered to the bulb when I set my LVPS to 10 volts is

$$P_{bulb} = I\,V_{bulb} = (.493\ A)(10\,V - .074\,V) = 4.90\ \text{Watts}$$

note



$V_{LVPS} = V_{800} + V_{bulb}$

I used 15 cm as the distance between clip leads from my LVPS and 8W lamp.

I used the relation (3) to calculate the volume of water in the cup.

$$V = \pi r_1^2 d + \pi r_1 \left(\frac{r_2 - r_1}{h}\right) d^2 + \frac{\pi\left(\frac{r_2 - r_1}{h}\right)^2}{3} d^3 \qquad (3)$$

For the styrofoam cup we provide, with $r_1 = 2.0$ cm, $r_2 = 3.4$ cm, and $h = 8.2$ cm, this becomes:

$$V(\text{cm}^3) = 12.6\ d + 1.07\ d^2 + 0.03\ d^3 \qquad (4)$$

I measured $d = 3.85$ cm so this implies that I had 66.1 gms of H_2O in my cup.

$$m_{H_2O} = 66.1 \times 10^{-3}\ kg$$

The temperature vs time data is shown in table 2 for the heating and then cooling of the water

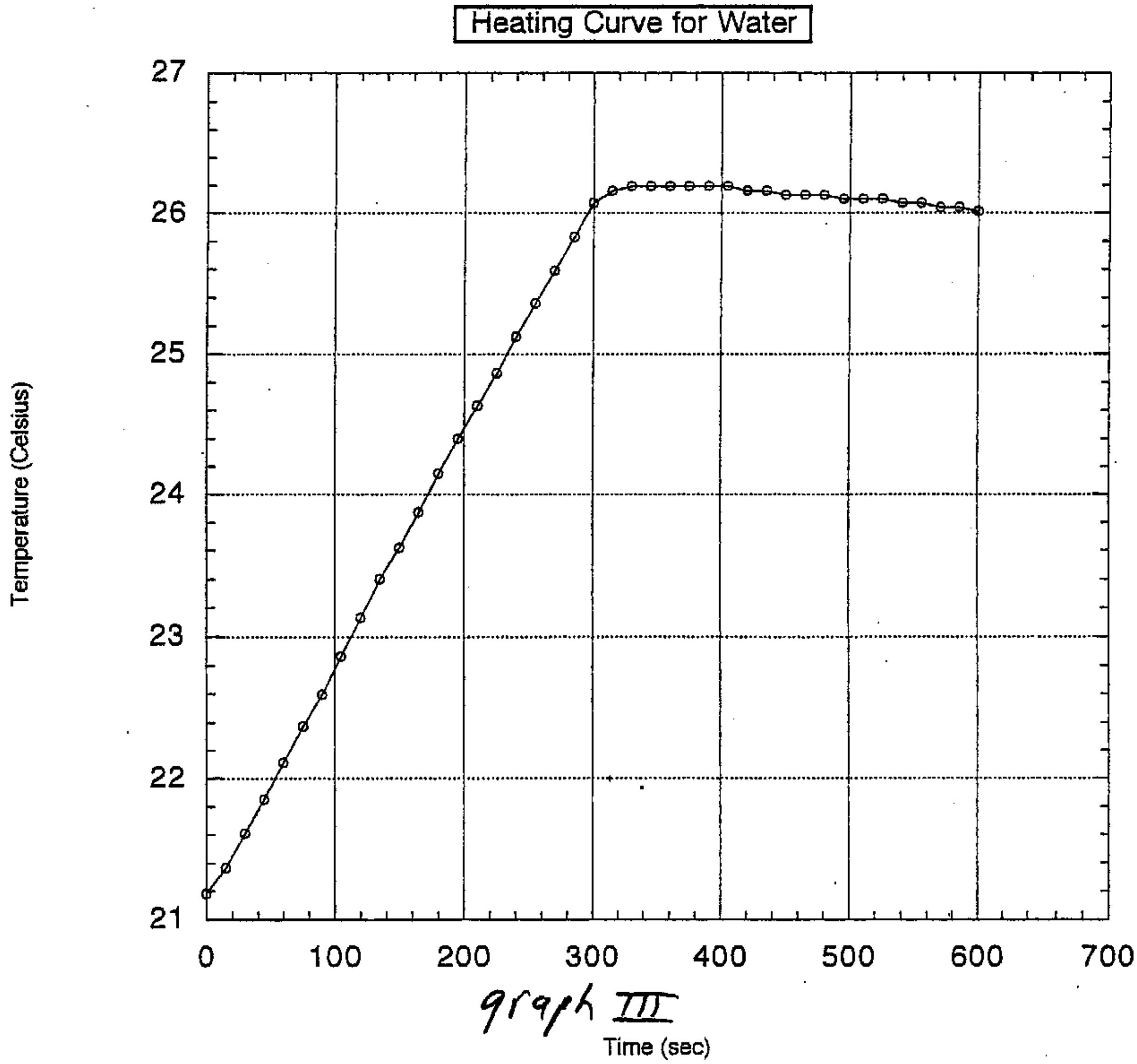
table 2
time vs temperature

Data table II for measurements of heating of water when 8W light bulb was placed in water as a function of time.

I already converted to temperature using

$$T = \frac{\ln(R_0) - \ln(R)}{\alpha}$$

	Time (sec)	Temperature (Celsius)
0	0.0	21.18
1	15.	21.36
2	30.	21.61
3	45.	21.85
4	60.	22.11
5	75.	22.37
6	90.	22.59
7	105	22.86
8	120	23.13
9	135	23.40
10	150	23.62
11	165	23.87
12	180	24.15
13	195	24.40
14	210	24.63
15	225	24.86
16	240	25.12
17	255	25.36
18	270	25.59
19	285	25.83
20	300	26.07
21	315	26.16
22	330	26.19
23	345	26.19
24	360	26.19
25	375	26.19
26	390	26.19
27	405	26.19
28	420	26.16
29	435.	26.16
30	450.	26.13
31	465.	26.13
32	480.	26.13
33	495.	26.10
34	510.	26.10
35	525.	26.10
36	540.	26.07
37	555.	26.07
38	570.	26.04
39	585.	26.04
40	600.	26.01



My data is plotted in graph III. The slope of the straight line for the heating phase

$$\text{slope}_1 = \left(\frac{dT}{dt}\right)_{\text{heating}} = 1.66 \times 10^{-2} \ \frac{K}{s}$$

the slope for the cooling phase

$$(\text{slope})_2 = \left(\frac{dT}{dt}\right)_{\text{cooling}} = -6.84 \times 10^{-4} \ \frac{K}{s}$$

Now

$$P_{in} \rightarrow \boxed{\begin{array}{c} P_{absorbed} \\ \text{water} \end{array}} \rightarrow P_{out}$$

power in $\qquad\qquad\qquad\qquad$ cooling

(power into system) = (Power absorbed)

$$P_{in} + P_{out} = P_{absorbed}$$

$$P_{in} = V I_{bulb} = 4.90 \text{ watts}$$

$$P_{absorbed} = m_{H_2O}\, c_{H_2O} \left(\frac{dT}{dt}\right)_{heating}$$

$$P_{out} = m_{H_2O}\, c_{H_2O} \left(\frac{dT}{dt}\right)_{cooling}$$

this last expression is only an approximation for the radiative power lost. It is a small contribution.

$$m_{H_2O}\, c_{H_2O} \left(\frac{dT}{dt}\right)_{heating} = V I_{bulb} + m_{H_2O}\, c_{H_2O} \left(\frac{dT}{dt}\right)_{cooling}$$

$$m_{H_2O}\, c_{H_2O} \left(\left(\frac{dT}{dt}\right)_{heating} - \left(\frac{dT}{dt}\right)_{cooling} \right) = V I_{bulb}$$

$$c_{H_2O} = \frac{V I_{bulb}}{m_{H_2O}\left(\left(\frac{dT}{dt}\right)_{heating} - \left(\frac{dT}{dt}\right)_{cooling} \right)} = \frac{4.90 \text{ W}}{(66.1 \times 10^{-3} \text{ kg})\left(1.66 \times 10^{-2} \frac{K}{s} - (-6.84 \times 10^{-4} \frac{K}{s}\right.}$$

$$c_{H_2O} = 4.35 \times 10^{3} \frac{J}{kg - K}$$

the experimental value for $C_{H_2O} = 4.186 \times 10^3 \frac{J}{kg-K}$.

error $f = \frac{C_{H_2O} - (C_{H_2O})_{exp}}{C_{H_2O}} = \frac{4.35 \times 10^3 - 4.186 \times 10^3}{4.186 \times 10^3} = .038$

Error Analysis

1. A main source of error is determining the radiative power loss. I assumed that the power loss at ~ 26 °C was the same throughout the heating range 21°-26°C. the straight line slopes of both quantities are pretty good.

2. measuring the mass of the water is a large source of error.

3. The calibration of resistance and temperature introduces a small error

$\alpha = 0.0331 \pm .001$ Slope of $\ln R$ vs T

error $= \frac{\Delta \alpha}{\alpha} = \frac{1}{33} \sim .03$ 4%

4. if we consider the Power absorbed by the bulb we get

$$(P_{ab})_{bulb} + (P_{ab})_{H_2O} = \left(m_{H_2O} C_{H_2O} + m_{glass} C_{glass} + m_{brass} C_{brass}\right)\left(\frac{dT}{dt}\right)_{abs}$$

Then $\quad P_{in} + P_{out} = (P_{as})_{total}$

$$I V_b + m_{H_2O} c_{H_2O} \left(\frac{dT}{dt}\right)_{cooling} = \left(m_{H_2O} c_{H_2O} + m_g c_g + m_b c_b\right)\left(\frac{dT}{dt}\right)_{ab}$$

$$c_{H_2O} = \frac{I V_b - \left(m_g c_g + m_b c_g\right)\left(\frac{dT}{dt}\right)_{ab}}{m_{H_2O}\left(\left(\frac{dT}{dt}\right)_{ab} - \left(\frac{dT}{dt}\right)_{cool}\right)}$$

$$= \frac{4.9\,W - \left(\left(6\times10^{-3}\,kg\right)\left(\frac{1000\,J}{kg-K}\right) + \left(3\times10^{-3}\,kg\right)\frac{300\,J}{kg-K}\right)(6.84}{\left(66.1\times10^{-3}\,kg\right)\left(1.66\times10^{-2}\,\frac{K}{s} - \left(-6.84\times10^{-4}\,\frac{K}{s}\right)\right)}$$

Where I assumed $m_{glass} \simeq 6g$, $m_{brass} \simeq 3g$

$c_{H_2O} = 4.28\times10^{3}\,\frac{J}{kg-K}$ this accounts for $\Delta C \simeq .07\times10^{3}\,\frac{J}{kg-K}$ a small effect outweighed by the error in the water estimate.