Solutions
Expt ET

table 2
time vs temperature

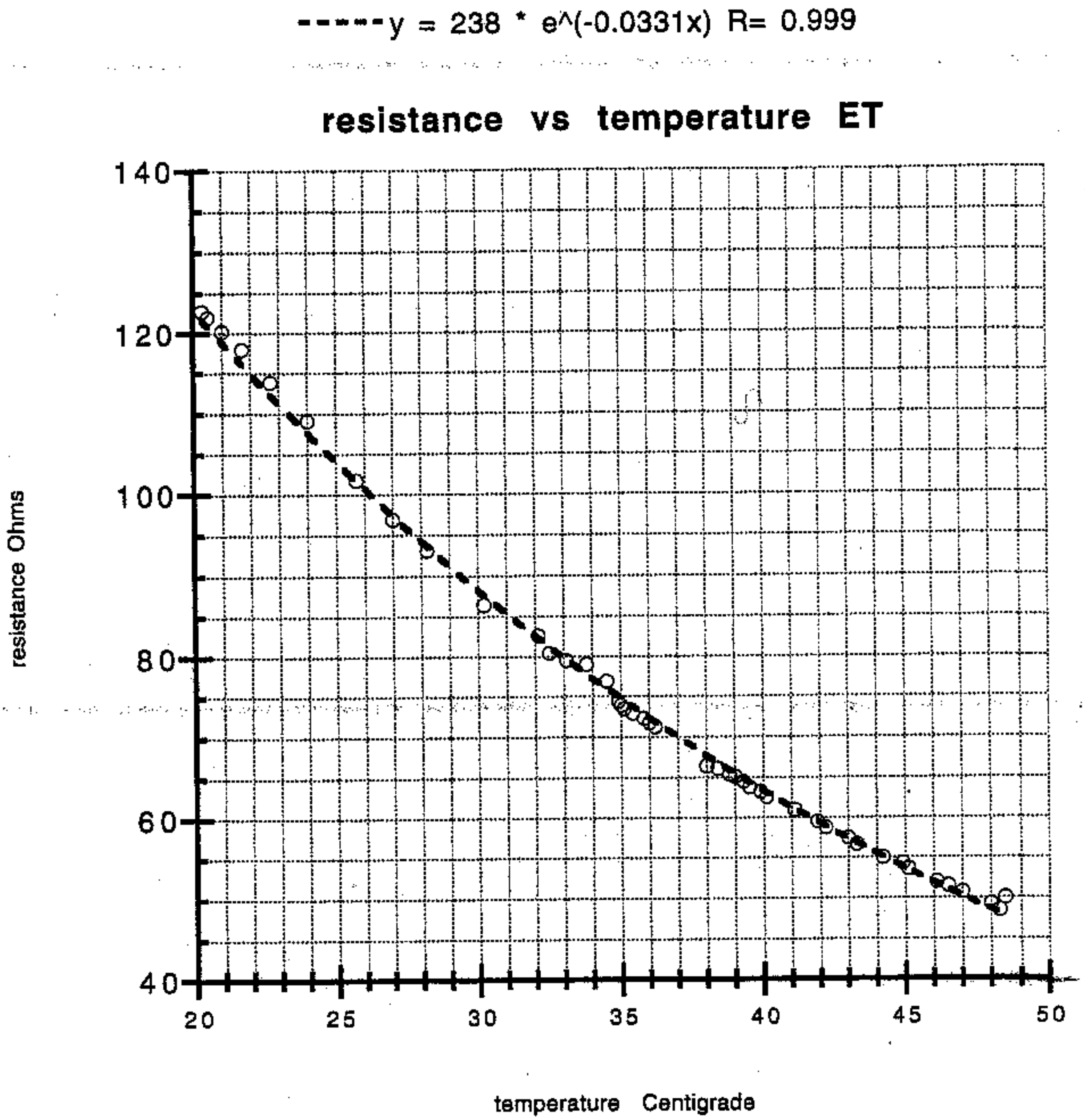
Fall 2001
8.01X

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



graph I

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

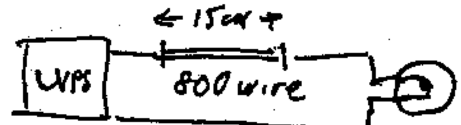
In my experiment, I used 15 cm of 800 wire with $R_{800} = .150\,\Omega$. I measured a voltage $V_{800} = .074\text{ V}$. Thus the current

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

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

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

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.

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

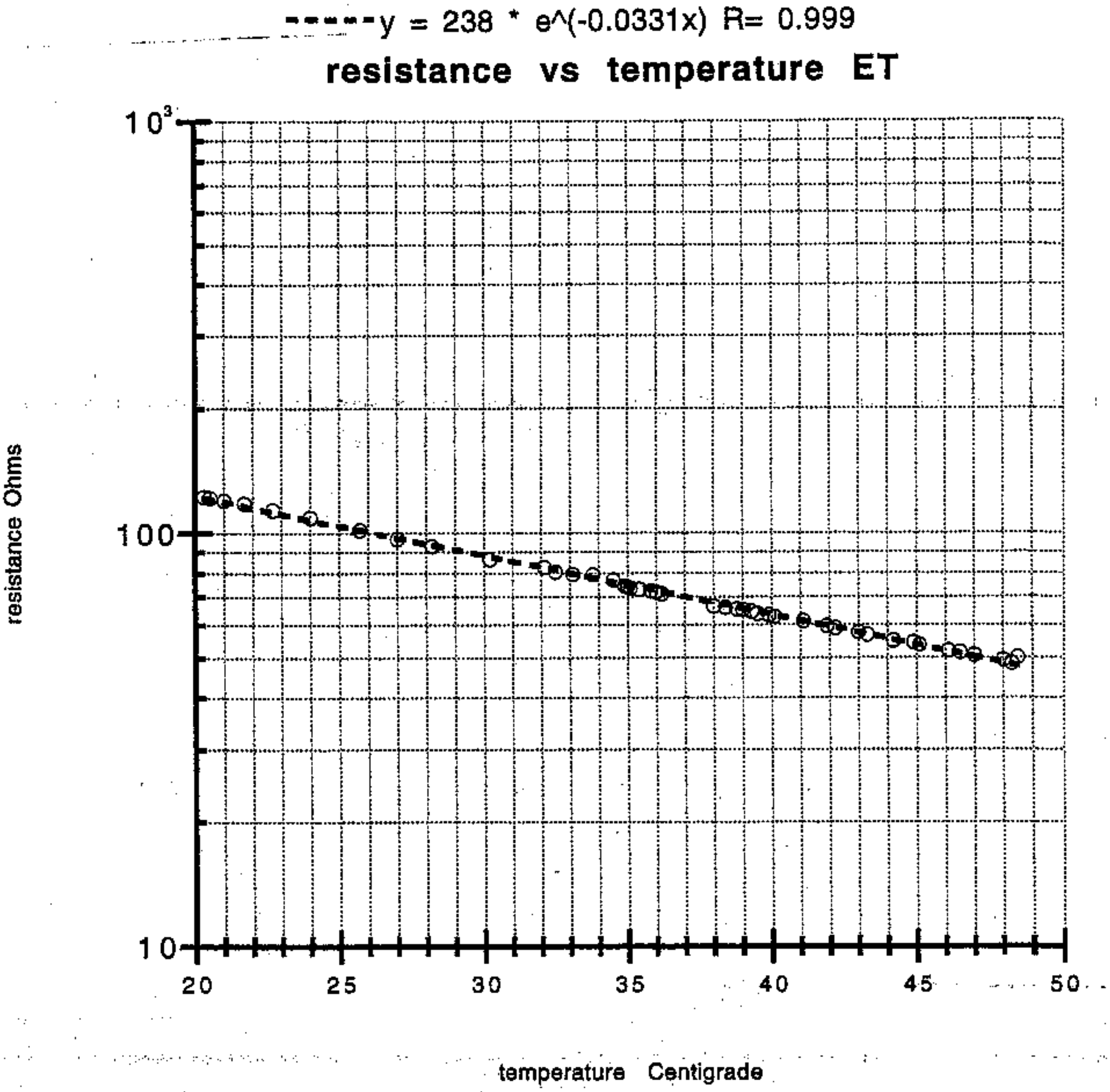
For the styrofoam cup we provide, with $r_1 = 2.0$ cm, $r_2 = 3.4$ cm, and $h = 8.2$ cm, this becomes:

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

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

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

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



graph II

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

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

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

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

$R\ \ 150\,\Omega$: $T = \dfrac{(\ln(235\,\Omega) - \ln(150\,\Omega)}{0.0331\left(\frac{1}{°C}\right)} = 13.9\ °C$

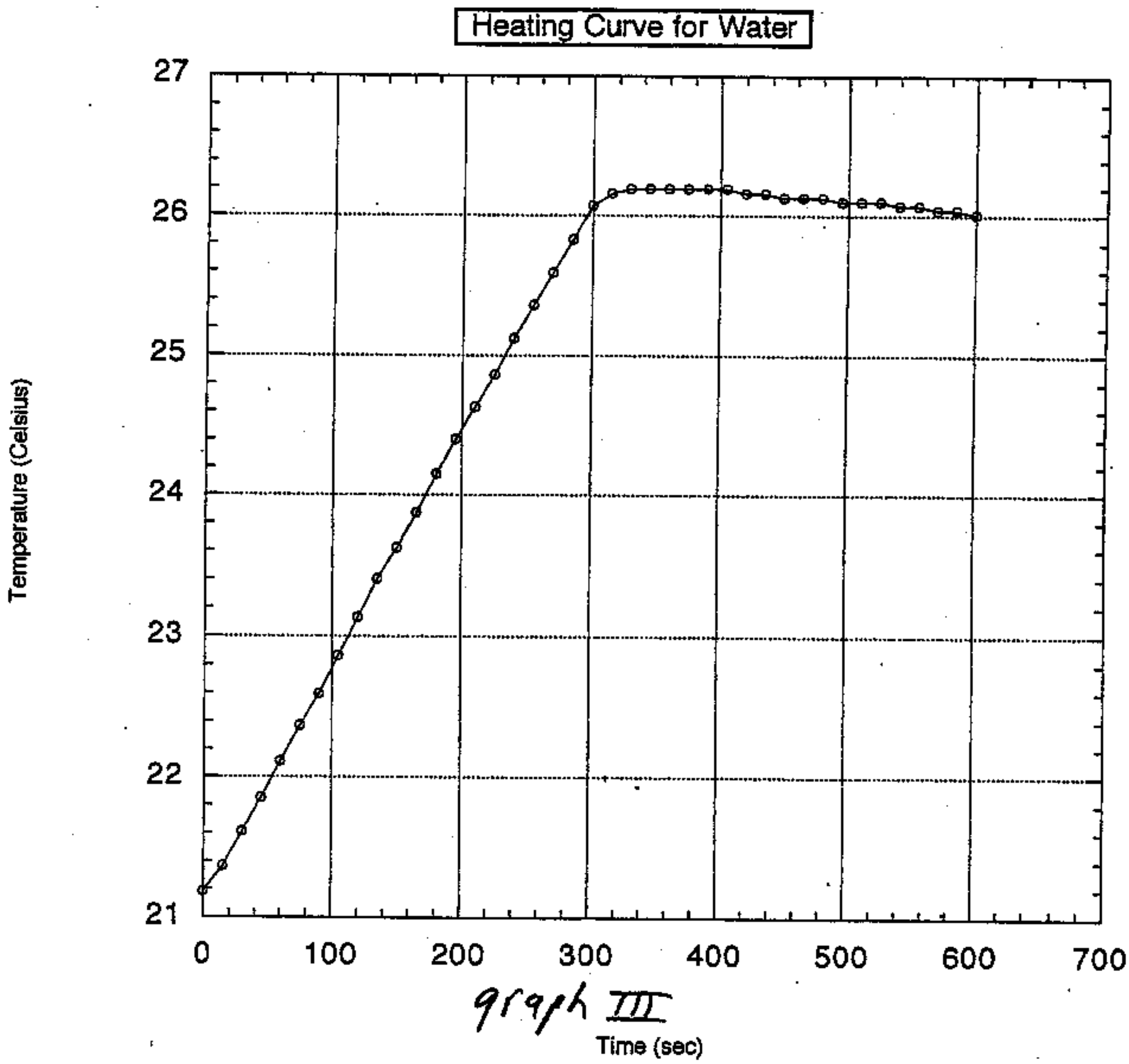
$R = 200\,\Omega$ = $T = \dfrac{(\ln(238\,\Omega) - \ln(200\,\Omega))}{0.0331\left(1/°C\right)} = 5.3\ °C$

table 1
temperature vs resistance

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
$R_0 = 238\ \Omega$
$\alpha = 0.0331\ \frac{1}{C°}$

	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 III

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

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

i) $$(C_w)_{expt} = \frac{I\,\Delta V_L}{m_w \frac{dT}{dt}}$$

$$= \frac{(4.90\,W)}{(6.61\times10^{-2}\,kg)(1.66\times10^{-2}\,\frac{K}{s})} = 4.47\times10^{3}\,\frac{J}{kg\text{-}K}$$

The accepted ~~experimental~~ value for $(C_w)_{th} = 4.186\times10^{3}\,\frac{J}{kg\text{-}K}$

My fractional error

$$f = \frac{(C_w)_{expt} - (C_w)_{th}}{(C_w)_{th}} = .068$$

d) Error Analysis

1. measuring the mass of the water
2. calibration of resistance and temp introduces an fractional error (due to error introduced in slope of ($\ln R$ vs T))

$$(f)_T = \frac{\Delta\alpha}{\alpha} = \frac{0.03}{33} \sim .03$$

3. Power is absorbed by the bulb

$$\left((C_w)m_w + m_{glass}\,c_{glass} + m_{brass}\,c_{brass}\right)\frac{\Delta T}{\Delta t} = I\,V_L$$

$$c_w = \frac{I V_L - (m_g c_g + m_b c_b)\frac{dT}{dt}}{m_w \frac{dT}{dt}}$$

Assume $m_g \simeq 6\,g$ $\quad m_b \simeq 3\,g$

$$c_g = 10^3 \frac{J}{kg\text{-}K} \qquad c_b \simeq 3\times10^2 \frac{J}{kg\text{-}K}$$

$$c_W = \frac{4.9\,W - \left(\left((6\times10^{-3}kg)\left(10^3\frac{J}{kg\text{-}K}\right) + (3\times10^{-3}kg)\left(\frac{3\times10^2}{kg\text{-}K}\right)\right)\left(1.66\times10^{-2}\frac{K}{s}\right)\right)}{(6.61\times10^{-2}kg)(1.66\times10^{-2}\frac{K}{s})}$$

$$= 4.36\times10^3 \frac{J}{kg\text{-}K} \qquad (\text{better})$$

$$f_{c_W} = \frac{4.47\times10^3\frac{J}{kg\text{-}K} - 4.36\times10^3\frac{J}{kg\text{-}K}}{4.47\times10^3\frac{J}{kg\text{-}K}} = .025$$

is the associated fractional error

the inaccuracy in the mass of the water outweighs these errors.

k. During the experiment heat is conducted in or out depending on

$$\Delta T = T_{water} - T_{room}$$

when $\Delta T < 0$, heat is conducted in

when $\Delta T > 0$, heat is conducted out.

model: $\Delta Q \sim \Delta T$.

For $\Delta T \simeq 7°$ centigrade during the cooling we calculated

$$\left(\frac{\Delta T}{\Delta t}\right)_{cooling} \sim = -6.84 \times 10^{-4} \frac{K}{s}$$

If we begin our experiment with

$$\Delta T_0 = (T_{water,0} - T_{room})$$

exactly equal to minus the final temp difference

$$\Delta T_0 = -\Delta T_f = (T_{water,f} - T_{room})$$

Then the heat conducted in during the first part of warming should exactly cancel the heat conducting out when the $T_{water} > T_{room}$.

e) see section f)