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Physics Coursework

An Investigation Into The Factors Affecting The Temperature Rise of Water Heated Electronically

Plan

In this experiment I am trying to find out, how different factors affect the temperature rise when heated electronically.

Variables

In this experiment the key variables I am considering are:

- Time (t)(s)
- Power (IV)(W)
- Mass of water (M) (g)
- Change of temperature (Δt) (^{o}C)

The variables that are fixed must remain the same in order to attain an accurate conclusion, if they were not it would make the experiment void. Any 2 variables can be varied but the other 2 must be held fixed. I have a choice in what factors will be fixed or varied either:

1. Power and time are fixed, whilst mass and change it temperature remain varied. E.g. I would put a fixed power for a fixed time and see how the change in temperature relates experimentally to the mass of the water.
2. Mass and time are fixed, whilst power and change in temperature vary. E.g. I would see how the power input and change in temperature relate to each other.
3. Power and mass are fixed, whilst time and change in temperature vary. E.g. I would have a fixed power input and mass, in order to see how both factors relate to one another.

Preliminary experiment

In my preliminary experiment, I have chosen to investigate two different factors; these are keeping the mass and time fixed, and keeping the power and mass fixed. In the preliminary experiment I am aiming to find out the most suitable independent factors to use in the actual experiment. As well as this I am trying to find out the most suitable volumes of water to use, so the experiment does not take too long or too slow to make an accurate evaluation.

Apparatus

- Beaker
- A polystyrene cup
- Water
- A heater
- A thermometer
- A power supply

- An ammeter
- A voltmeter
- Electronic weighing scales
- Stopwatch
- Wires

Method

In the first experiment I used time and power as the independent variables while keeping change in temperature as the dependant variable. So in this way I am keeping the mass and power fixed while changing the time. Firstly I created the circuit using the connecting wires, power pack, voltmeter, and ammeter.

After connecting the circuit, I filled the polystyrene cup with 68 grams of water, and then I put the cup into the beaker and put the heater into the water. Then I took the starting temperature of the water, and placed the thermometer and placed it in the water. I then switched on the power at 3 volts though I decided this was taking too long; so I turned the power to 5 volts, which was more suitable. After every 30 seconds the temperature was recorded.

A Diagram showing the set up of the Apparatus

The second preliminary experiment was conducted in the same way, though here the power was the variable, and the change in temperature was named as the dependant variable. I fixed the mass of the water at 20 grams and the time for 4 minutes; I felt this was appropriate as if I used 1 volt of power it would take a long time for a large amount of water to be heated.

Results

First experiment

Time (s)	Temperature (C)	Change in Temperature (C)
00	20	0
30	23	3
60	24	4
90	26	6

120	26	6
150	27	7
180	27.5	7.5

Second Experiment

Power (IV)	Temperature (°C)	Change in Temperature (°C)	Volts (V)	Current (Amps)
0.8	23	1	1	0.8
2.6	26	4	2	1.3
5.7	27.5	5.5	3	1.9

Conclusion

After looking at the result I can see that the first experiment the longer I left the heater i n the water, the hotter the water became. In the second experiment I saw that using more power there was a larger change in temperature.

So after looking at my preliminary results I have decided that the independent factors that I will investigate in this experiment will be time and power, so therefore I will fix the mass of the water and the power. In the real experiment I will record every result to three significant figures and record the time every 30 seconds. As well as this I will record each piece of data reliably as I will be measuring the exact mass of water using electronic scales and make sure my circuit is working before I start the experiment. To make sure the experiment is safe I will be sure to let the heater cool before attempting to touch it.

Experimental Prediction

In the experiments I predict that when the mass and temperature are fixed and the power and change in temperature are varied, they should be proportional to each other producing a straight lined graph. And if the power and mass are fixed, and time and change in temperature vary; the variables should be proportional to each other producing a straight lined graph. I have made these predictions from using my previous knowledge of heating. I know that:

Energy Supplied = Mass x Specific Heat Capacity of Water x Temperature Rise

This can also be explained as:

Amps x Volts x Time = Mass x Specific Heat Capacity x Temperature Rise

Since I know that - Power x Time = Energy. And that Amps x Volts = Power

So when:

V = Volts

I = Amps

t = Time in seconds (s)

M = Mass in grams (g)

S = specific heat capacity in degrees Celsius (^oC)

Δt = temperature rise in degrees Celsius (^oC)

$IVt = mS\Delta t$

Since I am varying both the power and the time, I will first show you how I made a prediction with power and then with time. Given that I am using power I will rearrange the formula so the subject is IV.

$IV = \frac{mS\Delta t}{t}$

Knowing that the temperature, time and mass of the water are fixed, I can remove them from the formula; as they will remain constant throughout the experiment, in this way they will not affect the result:

$IV = \underline{\Delta t}$

This shows that temperature rise and power are proportional to each other, so as one rises the other should rise equally. Though this basic theory does not take into account heat loss to air or energy absorbed by the cup. Using the same formula, I predict that as the time increases the temperature rise will also increase proportionally, meaning that as the temperature rise doubles the time doubles.

Apparatus

- Beaker
- A polystyrene cup
- Water
- A heater
- A thermometer
- A power supply
- An ammeter
- A voltmeter
- Wires
- Electronic weighing scales
- Stopwatch

Actual Method

The method, in which the experiment will be carried out, will be exactly as in the preliminary. In the first experiment where the time and change in temperature vary, I will measure out 68g of water in the polystyrene cup this will be then put inside a beaker to try and keep the heat in. Then I will make sure the circuit is correctly connected, and immerse the heater into the water. At this point, I will put the thermometer into the water, switching on the power pack and begin timing the experiment. After 30 second I will record the temperature and after 10 minutes I will end the experiment.

In the second experiment I will measure out 20g of water and carry out the experiment in the same way. To make sure I have a fair test I will use new water of the same starting temperature after every attempt

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Obtaining Evidence

First Experiment: Keeping power and time fixed

Starting Water Temperature = 20.0C

Time (s)	Temperature Of Water (°C)	Change in Temperature (°C)	Time (s)	Temperature (°C)	Change in Temperature (°C)	Time (s)	Temperature (°C)	Change in Temperature (°C)
0	20	0	300	32	12	600	43.5	23.5
0	20	0	300	31	11	600	43	23
0	20	0	300	32	12	600	43.5	23.5
30	21	1	330	33	13			
30	23	3	330	32	12			
30	22	2	330	33	13			
60	24	4	360	34	14			
60	23	3	360	34	14			
60	23	3	360	33.5	13.5			
90	25	5	390	35	15			
90	24.5	4.5	390	34.5	14.5			
90	24	4	390	34.5	14.5			
120	25	5	420	36.5	16.5			
120	24.5	4.5	420	35.5	15.5			
120	25	5	420	35	15			
150	25.5	5.5	450	37	17			
150	26	6	450	37	17			
150	26	6	450	36.5	16.5			
180	27	7	480	39	19			
180	27	7	480	38.5	18.5			
180	26.5	6.5	480	38	18			
210	28	8	510	40	20			
210	28	8	510	40	20			
210	27.5	7.5	510	39.5	19.5			
240	29.5	9.5	540	41.5	21.5			
240	29	9	540	41	21			
240	29	9	540	41	21			
270	30.5	10.5	570	43	23			
270	30.5	10.5	570	42.5	22.5			
270	31	11	570	42	22			

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Average

Time (s)	Average Change in Temperature (^0C)	Time (s)	Average Change in Temperature (^0C)
0	0	330	12.6
30	2	360	13.8
60	3.3	390	14.7
90	4.5	420	15.7
120	4.8	450	16.8
150	5.8	480	18.5
180	6.8	510	19.8
210	7.8	540	21.2
240	9.2	570	22.5
270	10.7	600	23.3
300	11.6		

Experiment 2: Keeping the mass and time fixed

Power (IV)	Temperature (^oC)	Change in Temperature (^oC)	Volts (V)	Current (Amps)
0.8	23.5	1.5	1	0.8
0.8	23	1	1	0.8
0.8	24.5	2.5	1	0.8
2.6	25.5	3.5	2	1.3
2.6	25	3	2	1.3
2.6	26	4	2	1.3
5.7	28	6	3	1.9
5.7	27.5	5.5	3	1.9
5.7	28	6	3	1.9
10	32.5	10.5	4	2.5
10	31.5	9.5	4	2.5
10	32	10	4	2.5
15	36	14	5	3
15	35	13	5	3
15	37	15	5	3

Average

Power (IV)	Average Change in Temperature (^oC)
0.8	1.7
2.6	3.5
5.7	5.8
10	10.0
15	14.0

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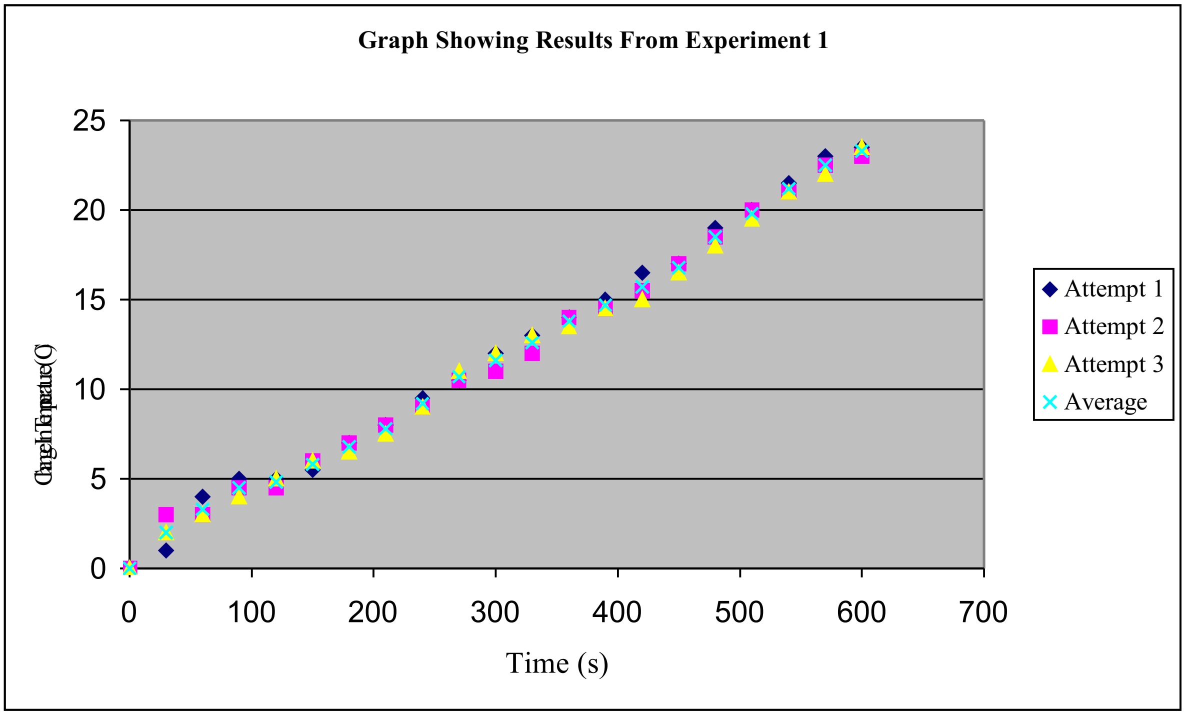

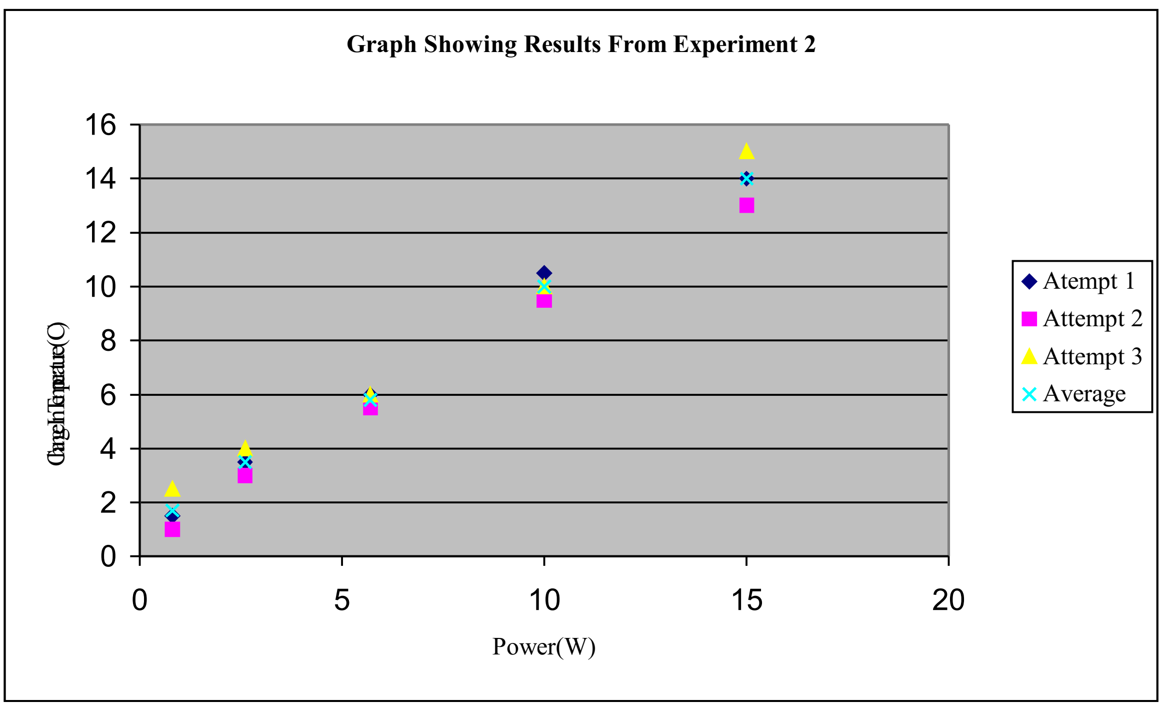

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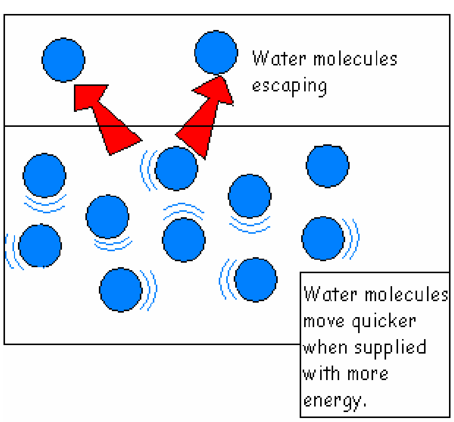
Analysis

The graphs I have drawn are in the format of a line graph. Both graphs show that the temperature rise is proportional to the power (IV) and time (t). The line of best fit seems to be close to nearly all the results. After looking at this, I have found that all results congregated generally near to each other, suggesting the results were very accurate. In the 1st experiment showing change in temperature against the time, the results seemed very accurate, but there were a few results at the beginning not following the line of best fit; and in the 2nd experiment showing power against the change in temperature I seem to have most the results scattered along the line of best fit. Which shows that these results were also very accurate. Though there are some results that do not completely fit in with the line of best fit, but are not far in enough from the line of the best fit to be called anomalies. These may have been caused by the heater not being totally submersed in the water or that the water may have been inaccurately measured, causing more water to be in the cup. For example in the graph showing time against the change in temperature, the result are seem to be accurate and close to the line of best fit, but the few results off the line of best fit may have been caused by there being too much or too little water inside the polystyrene cup. As if there was more water in t he polystyrene cup, it would take longer to heat up, as there are more molecules to heat; while if there is less water than there should be in the polystyrene cup it would heat up quicker as there are less water molecules to heat up.

Both graphs show a clear positive correlation; in the 1st experiment we see that as the time increases, the change in temperature increases proportionally. It increases proportionally as the line of best fit goes straight through the origin, forming a straight line. This agre es with my prediction as in my prediction I stated that as the time doubled the rise in temperature would also double. The pattern in the 2nd graph show that as the power increase, the change in temperature increases, since it goes near to the origin and forms a straight line. In my prediction I said that as the power increase the rise in temperature would increase. This seems correct from my results though my quantative result, which stated that as the power doubled the rise in temperature would also doubl e, has been proven to be incorrect. Though looking at the graph it does not fully agree with my prediction as the line of best fit is not exactly directly proportional. The reason for this is that the line does not go through the origin but close to it. So in this way the graph has a linear relationship. There are many reasons why this did not agree with my prediction, the main is that the results were not totally correct since some of the heat energy is lost to the air, or absorbed by the polystyrene cup. But since nearly all my results seem to be close to the line of best fit in both graphs, it shows that the results were not affected by these factors in any great way



The results I have obtained can be further proven by science. The rise in temperature caused by a rise in power is because the energy goes to the water molecules, which makes them move faster. Some molecules will move faster than others, some may even overcome the forces of attraction from the other molecules and evaporate.

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Evaluation

In order to improve the accuracy of my experiment there are a number of things I am able to do, in order to prevent anomalous results being obtained. A lot of heat from the experiment is lost in two main ways:

1. Heat loss through convection currents in the air, causing some water that has been evaporated and heat to escape. In order to stop this I think the container should be sealed, so that no air could escape, therefore improving the accuracy of the experiment. Though this may prove to be a problem as the pressure would build up inside the container, and it would be very difficult to measure the temperature rise. But I believe that if we leave a small hole to fit the thermometer through it would solve the problem; as in this way small amounts of heat and evaporated water will escape if any. Especially if we are only heating the water to around 50^0C.
2. As well as this, the container used in the actual experiment was made of polystyrene; even though this is an insulator, it is not a very good one and heat is lost through radiation. A way in which to combat this is by using a better insulator such as a plastic cup. Though the idea of losing heat through radiation is unlikely especially if we are not heating the water to above 50^0C.

Another way in which to improve this experiment is by conducting it more times so therefore I would get a more accurate average. Though looking at my graphs, my results were quite accurate. The other equipment such as the thermometer and time were very accurate (the thermometer to ½ of a degree and the stopwatch to $1/10^{th}$ of a second). In this way the results would not really vary in accuracy and provided a fair test. All in all I believe the results to be reliable, since in repeating three times I hopefully cut down on errors, and in using the same equipment each time I made sure the test was fair. As well as this to see if the relationship between time and change in temperature varies as I carry on the experiment for a longer period of time; I will continue the experiment to around 80°C. I will also extend the 2^{nd} experiment by seeing if the relationship between power and the change in temperature carries on as I raise the power to above 15 W. I could also see how a change in the mass of water affects the temperature rise. For example if I used a high water mass it would take longer as there are more water molecules to heat than a small water mass.

Looking at the graphs, the 1^{st} experiment shows very accurate results while the results in the 2^{nd} experiment are more varied. Though during this experiment I found there to be no anomalies. There are many reason for this inconsistency in the 2^{nd} experiment, the main reason I feel is that the amount of water used was slightly higher than it should have been, and this small error has affected the results. Other reasons for these results could be caused by heat loss to the air, heat lost by the cup, stirring the water, and impurities in the water. Even though there are many reasons for results to be inaccurate, I believe that the results I have gained are quite reliable and accurate enough to support my conclusion, since there are no obvious anomalies. To extend this experiment I could test the effect of varying the mass of the water, whilst heating it. As well as this I could conduct the same experiment varying the time, on distilled water and tap water. In this way I will be able to find out how impurities in the water affect the results by comparing it to an experiment using normal tap water. This would provide an interesting experiment that would further improve the accuracy of my conclusion.