Investigation into the resistance of a filament lamp
Physics A 3883

Planning

Aim

For this investigation I have been asked to find out how the current through a filament lamp varies with the potential difference across it and hence determine how the resistance of the filament and the power supplied to it vary with the potential difference across it. I will also make estimates of the temperature of the filament for different potential differences.

Key factors

Independent variables:

- **Current** (Current will be measured with a digital ammeter/multi meter)
- **Temperature** (Thermometer to measure surrounding temperature)

Dependent variable

- **Resistance**
- **Voltage** (Will be measured with a digital voltmeter)

Controlled variable

- **Filament lamp**

The range of readings that I am going to take will be from 0 volts to 10 volts this is because it will give me a good set of data to work with.

I will increase the voltage by one volt each time.

To make sure I get good accurate fair results I will repeat the process at least 3 times.

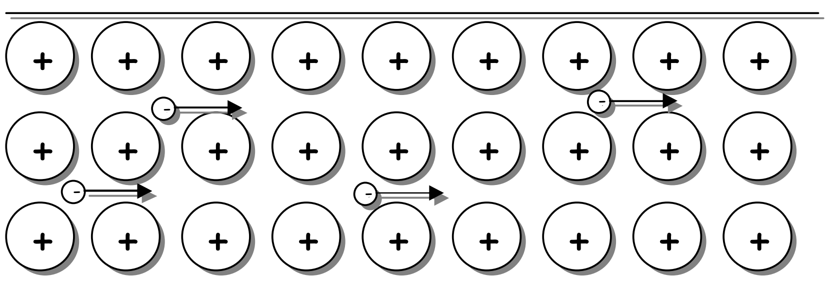
When I do repeat the process I will make sure that I leave all the equipment as it is and not replace bits or add or remove components.

To make sure that I don't have to replace any components, I will before I start the test make sure that all my equipment is working correctly and properly calibrated to the range of readings that I will take in the test. This will include testing the ammeter, voltmeter, and power supply and filament lamp.

Prediction

"I predict as the potential difference is increased the current will increase and so will the resistance and the temperature"

This is because at low temperatures the electrons in the metal of the filament lamp are flowing relatively freely (see diagram) this is because the ions are not vibrating very much so the electrons can flow easily past them without getting diverted.



But as the potential difference is increased the current also increases because there is and increased flow of electrons this causes the filament in the lamp to heat up, this is where the ions vibrate rapidly and cause the electrons to be diverted this makes the electrons lose energy due to heat and light.

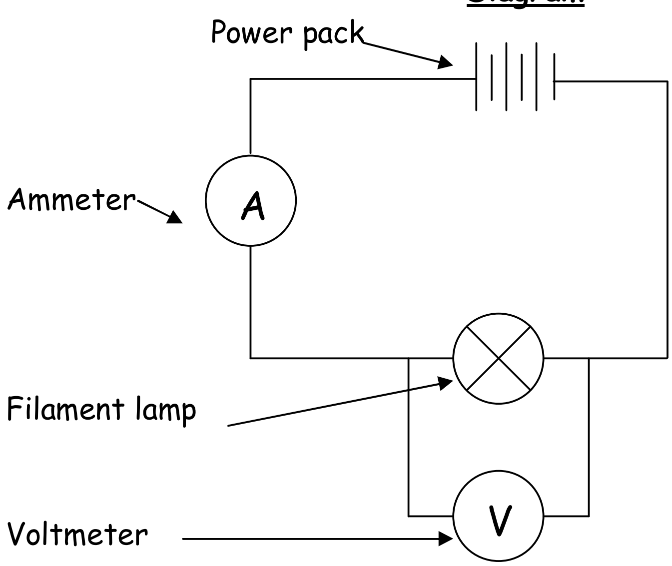
Also the filament of the lamp may be impure and have ions that obstruct the flow of the electrons causing them to take another route round the ion.

Preliminary work

For my preliminary work I carried out my planned procedure to see if there had to be any alterations made to the method. I carried out the test and I changed the analogue ammeter to a digital one because it was very had to read to get a good reading on the needle, also the analogue meter was not 100% accurate. My following results (see table) have confirmed that resistance increases when the voltage and current increase.

Voltage/ V	Current/ A	Resistance/Ω
1.00	0.97	1.03
2.00	1.28	1.56
3.00	1.52	1.97
4.00	1.74	2.30
5.00	1.95	2.56
6.00	2.15	2.79
7.00	2.32	3.02
8.00	2.49	3.21
9.00	2.63	3.42
10.0	2.79	3.58

Diagram



Method

- Set up the equipment as shown above making sure to connect up the voltmeter in parallel and the ammeter in series.
- Just before you are about to start take the surrounding temperature of the lab around the experiment area, you will use this later in an equation to find the temperature.

- Plug in the power supply and turn the voltage up until it reads 0.1 volts on the voltmeter, take the reading on the ammeter and record it and repeat until you get to 0.10v, this will give you a reading for the resistance of the filament lamp without any heat being given off.
- Repeat the above steps 2 times.
- Now do exactly the same as above but take the readings from 0.10volts to 0.50volts to see if the temperature affects the resistance at this temperature.
- Now repeat 2 times
- Now take the readings from 1.0volts to 10.0volts making sure to cool down the lamp by switching the power pack off and leaving for a minute then turning it back.
- Now repeat the whole experiment again another two times to get a good set of results.
- When you have finished take the surrounding temperature using a thermometer, it should be the same as it was at the start, if not take the middle value between the two numbers.
- When you have put all the data onto the table work out the resistance by using this formula:

$$\text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

- Make sure that you use all the significant figures then when you get the final answer round it up to 2 significant figures; this is because it is very hard to keep the experiment accurate and get good reliable results.
- Also when taking readings off a digital meter leave it for a while until the numbers stop then take your reading.

Safety

Make sure you don't touch the bulb when it is on because it will get very hot also remember not to short circuit the components as they can easily catch fire and do a lot of damage.

Results

Results table1

Potential difference/V	Current/A			Average Current/A	Resistance/Ω			Average Resistance/ Ω
	Try 1	Try 2	Try 3		Try 1	Try 2	Try 3	
0.01	0.02	0.01	0.02	**0.02**	0.50	1.00	0.50	**0.67**
0.02	0.03	0.02	0.03	**0.03**	0.67	1.00	0.67	**0.78**
0.03	0.05	0.04	0.04	**0.04**	0.60	0.75	0.75	**0.70**
0.04	0.07	0.06	0.07	**0.07**	0.57	0.67	0.57	**0.60**
0.05	0.09	0.07	0.08	**0.08**	0.56	0.71	0.63	**0.63**
0.06	0.10	0.08	0.10	**0.09**	0.60	0.75	0.60	**0.65**
0.07	0.11	0.09	0.12	**0.11**	0.64	0.78	0.58	**0.67**
0.08	0.12	0.10	0.13	**0.12**	0.67	0.80	0.62	**0.70**
0.09	0.13	0.12	0.14	**0.13**	0.69	0.75	0.64	**0.69**
0.10	0.15	0.13	0.16	**0.15**	0.67	0.77	0.63	**0.69**
0.15	0.22	0.21	0.21	**0.21**	0.68	0.71	0.71	**0.70**
0.20	0.27	0.28	0.29	**0.28**	0.74	0.71	0.69	**0.71**
0.25	0.31	0.34	0.33	**0.33**	0.89	0.86	0.76	**0.84**
0.30	0.36	0.37	0.37	**0.37**	0.83	0.81	0.81	**0.82**
0.35	0.40	0.41	0.40	**0.40**	0.95	0.95	0.88	**0.93**
0.40	0.44	0.45	0.45	**0.45**	0.98	1.00	0.89	**0.96**
0.45	0.48	0.48	0.49	**0.48**	1.00	1.00	0.92	**0.97**
0.50	0.52	0.53	0.52	**0.52**	1.04	1.02	0.96	**1.01**
1.00	0.75	0.75	0.76	**0.75**	1.33	1.33	1.32	**1.33**
2.00	1.05	1.06	1.05	**1.05**	1.90	1.89	1.90	**1.90**
3.00	1.26	1.27	1.27	**1.27**	2.38	2.36	2.36	**2.37**
4.00	1.46	1.47	1.47	**1.47**	2.74	2.72	2.72	**2.73**
5.00	1.64	1.64	1.64	**1.64**	3.05	3.05	3.05	**3.05**
6.00	1.79	1.80	1.80	**1.80**	3.35	3.33	3.33	**3.34**
7.00	1.94	1.95	1.95	**1.95**	3.61	3.59	3.59	**3.60**
8.00	2.09	2.09	2.09	**2.09**	3.83	3.83	3.83	**3.83**
9.00	2.21	2.22	2.23	**2.22**	4.07	4.05	4.04	**4.05**
10.0	2.35	2.35	2.35	**2.35**	4.26	4.26	4.26	**4.26**

INCREASING TEMPERATURE

Resistance for filament lamp at 0°C=0.68Ω

Calculated From: Average resistance of (0.01v to 0.10v)/10

I didn't use the data from 0.10 volts to 0.50 volts in any working because the heat was rising so was no good for calculating the resistance of the lamp when at 0°C

Results table 2

Potential difference/V	Temperature coefficient of resistance @ temperature	Resistance/Ω	Temperature/°C
0.00	0.00	0.68	0.00
1.00	4.41	1.33	68.90
2.00	8.27	1.90	113.68
3.00	11.45	2.37	163.50
4.00	13.89	2.73	201.66
5.00	16.06	3.05	235.88
6.00	18.09	3.34	266.32
7.00	19.79	3.60	293.88
8.00	21.34	3.83	318.26
9.00	22.84	4.05	341.58
10.00	24.26	4.26	363.84

- I have calculated the above temperature and coefficient of resistance using the formulae below in the analysis.
- Temp of surroundings at start and finish way 23°C

Results table 3

Potential difference/V	Power/W	Current/A	Resistance/Ω	Difference in resistance
0.00	0.00	0.00	0.68	------
1.00	0.75	0.75	1.33	0.65
2.00	2.10	1.05	1.90	0.57
3.00	3.81	1.27	2.37	0.47
4.00	5.88	1.47	2.73	0.36
5.00	8.20	1.64	3.05	0.32
6.00	10.8.	1.80	3.34	0.29
7.00	13.65	1.95	3.60	0.23
8.00	16.72	20.9	3.83	0.22
9.00	19.98	2.22	4.05	0.21
10.00	23.50	2.35	4.26	------

To calculate the power I used the equation: P=I*V

This data told me that as the potential difference increases so do the power but the resistance seems to be getting less resistive.

Analysis

After collection of the data I have worked out the resistance of each potential difference by using the equation: R=V/I. I have used 2 significant figures in all my calculations and on my tables because the equipment and conditions that I was doing the experiment in were not that accurate above 2 significant figures.

I have then put this information into some graphs. If I use potential difference on the x-axis and current on the y-axis then the gradient will give me resistance.

Looking at these graphs I can clearly see that there is a connection between the potential difference and the resistance because the resistance goes up in a positive curve, this shows me that the resistance is nearly constant but gets greater as you increase the potential difference.

Looking at my results I can see that as the potential difference and current are proportional to each other also the resistance is proportional and so the temperature increases as well so this can also be said to be proportional.

This is true because as the potential difference increases so does the current, this makes the resistance higher because of the increased amount of electrons crashing into ions, which are flowing in the opposite direction. The increased friction between these causes the temperature to rise, also the amount of the electrons and ions rises, this means that there are more partials to collide and more friction which means more heat being produced.

Also when the potential difference is increased the ions vibrate rapidly and obstruct the path of the electrons so they have to be diverted around the ions.

I have done some research into how to find the temperature of the filament lamp using the potential difference, current, resistance and the base temperature of the surroundings.

First you need to find the Temperature coefficient of resistance of the certain temperature you want to find, the Temperature coefficient of resistance is the unit change in resistance (per degree of temperature) when the temperature of a resistive device changes.

$$T.C.R \text{ or } a=[(R-Ro)/Ro]*[1/(T-To)]*106$$

Where: R= Resistance at target voltage
Ro=Resistance at reference temperature
T=Temperature of interest
To=Base temperature
a=Temperature coefficient of resistance

The change in resistance is proportional to the temperature change, so:

$$\Delta R/Ro=a\Delta T$$

Where: R= Resistance at target voltage
Ro=Resistance at reference temperature=0.68Ω
T=Temperature of interest
To=Base temperature=23°C (stayed constant)
a=Temperature coefficient of resistance

So:

$$(R-Ro)/Ro=a\,(T-To)$$

Rearranged:

$$T=Ro[1-a(T-To)]$$

The two equations:

1. $a=[(R-Ro)/Ro]*[1/(T-To)]*106$

2. $T=Ro[1-a(T-To)]$

Put into practice for 5 volts

1.

a=[(R-Ro)/Ro]*[1/(T-To)]*106
=[(3.05-0.68)/0.68]*[1/(0-23)]*106
=[(2.37)/0.68]*[1/(-23)]*106
=3.49*-0.04*106
a=**-16.06** @ 5volts (2 sig figs)

2.

T=Ro[1+a(T-To)]
=0.68*[1-16.06*(0-23)]
=068*(-15.06*-23)
T=**235.58°C** @ 5volts

This answer seems right because the lamp feels very hot from a distance and it must be a lot hotter in the actual filament, it is so hot because the resistance is high, this means that there is a lot of friction between the particles inside the filament.

I conclude that when a potential difference, V, exists across a filament in a lamp it is observed that negative charges flow in the conductor, from low to high electric potential, due to the electric field associated with the potential difference. A charge flow, called a current, I, is taken to be positive in the direction positive charges move in response to an electric field. In real life, many electrical circuits employ currents caused by the motions of electrons, which have negative charge; therefore, the actual direction of motion of the charged particles runs opposite to the direction of the current. A linear relationship is observed between the current through and the potential difference across a conductor. This relationship is called Ohm's Law which is the equation that we use to work out the voltage: V=I*R

Evaluation

Method

The experiment procedure that I used was suitable for the aim of the experiment but when I was collecting the data for the current under 0.10 volts was very hard to get because the difference between the current at each voltage was hard to get due to the varying voltage.

I could get more accurate results by using the equipment that I have but I could rearrange it and add more equipment that is necessary to complete the experiment and make it more reliable.

If I were to do this experiment again I would do it in a controlled environment, where the temperature of the room stayed constant. I would also use a more sensitive power supply/power pack because the low currents were hard to keep constant due to the large voltage range on the power packs. Instead of changing the power pack I could put a variable resistor called a rheostat into the circuit so I would have more control of how much current went round the circuit and through the filament of the lamp.

I could also have a fan to cool down the lamp after each voltage so that I got a fair and accurate reading rather one that had been heated partially and others that had been heated for too long. Another thing I would change is if I would be able to perform the test in a vacuum, where the surrounding would be totally controllable.

Also I would use the measured potential difference on the voltmeter as a variable rather that using it as a fixed variable because I could get even more accurate results.

Data

The main experiment went very smoothly, I got all the data that I wanted to but during the experiment where I was collecting the current for 0.01volts to 0.10 volts it was very had to collect accurate data because on the graph you can clearly see that there is a anomalous result (circled) this may have been human error or it could have been a random error like a power surge in the electric mains or a fault with the equipment. To overcome this in the future I would have a tolerance level for the current, e.g. if it wasn't 0.20±2A then I would do it again, if it kept on happening then I would try changing some of the equipment, but then I would have to start all over again because of the differences in the equipment (if any). This would also give me a good indication if the original equipment was faulty, but the new equipment may and/or be faulty so I would have to make up my mind which to use.