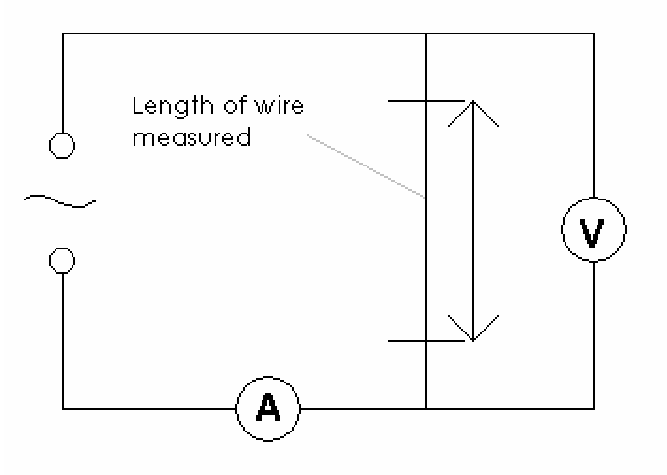
PLANNING

Title

Finding the Resistivity of a Wire

Diagram

This is the circuit diagram for the practical part of my investigation.



Partial 2b	
Complete 4c	

Apparatus

Apparatus	Use	Range	Interval
Power Pack	Supply power to the circuit	0V – 12V	--------------
Leads and Crocodile Clips	Connect components in the circuit	--------------	--------------
Ammeter	Measure current	-10A – 10A	±0.01A
Voltmeter	Measure voltage across the wire	-20V – 20V	±0.01V
Micrometer	Measure the diameter of the wire	25mm	±0.01mm
Ruler	Measure the length of the wire	0m – 1m	±0.001m
Sticky Tape	Keep wire straight	--	
Nichrome Wire	Find its resistivity	--	

Some 2d	
Comprehensive 4d	
Full specification 6d	

Variables involved (constant and changing)

- **Current** – kept constant at 0.50A by varying voltage supplied by power pack.
- **Voltage** – dependent variable measured by voltmeter.
- **Diameter of Wire** – kept constant by using the same wire for all readings.
- **Material of Wire** – kept constant by using the same wire for all readings.
- **Length of Wire** – independent variable; varied by changing contact points between wire and circuit.

Appropriate 4b	
Fixed variable 6a	

Method

First I will cut a strip of the Nichrome wire approximately 1.20 m long and measure its diameter using the micrometer six times: at three evenly spaced points on the wire, rotating the micrometer by 90° to ensure that the diameter is the same throughout the wire and roughly cylindrical.

Next I will fix the wire to the ruler. I will start by tightly fixing one end of the wire to one end of the ruler using sticky tape. Then I will ensure the wire is straight and tight before fixing it at a point approximately 0.35m down the ruler. I will repeat this at 0.65m and at the end of the metre ruler.

Subsequently, I will connect the circuit as shown in the diagram, with the wire connected between 1.00m and 0.00m. Then I will begin to take measurements. I will turn on the power; adjust the supply from the power pack so the ammeter reads 0.50A. I will note down the reading on the voltmeter and then turn off the power. I will repeat this two more times with the wire at this length, turning off the power between each reading.

Once the readings at this length are complete, I will turn off the power and alter the wire so that it is connected between 0.00m and 0.90m. I will then follow the same steps to take reading at this length. I will continue to do this until all 0.10m intervals between 1.00m and 0.10m are complete.

Detailed plan 4a	
Logical sequence 6c	

Intended readings

- **Diameter of Wire:** measured using micrometer at three separate points on the wire. At each point I will measure the diameter twice, with readings at 90° angles to each other to ensure that the wire is cylindrical.

- **Voltage across length of wire:** measured using voltmeter at 10 different lengths of wire – from 1.00m to 0.10m at 0.10m intervals, each repeated three times.

Number and range 6b	

Safety considerations

To prevent the wire from getting too hot, thus being a burn hazard, I will keep the current constant at a relatively low value of 0.50A. I will also turn off the equipment when I am not taking measurements.

2c	

Reasons for procedures

- I will limit the current to 0.50A and switch off the power pack when I am not taking a reading to prevent the wire from heating up, which will alter the wire's resistance and therefore its resistivity.
- I will measure the diameter of the wire twice, with each reading at a 90° angle to the other, to ensure that the wire is cylindrical in shape. I will then take these measurements at three evenly spaced points on the wire to ensure that slight variations of diameter are considered
- I will fasten the wire to the ruler at four points to keep it straighter, avoiding any length discrepancies.
- I will use Nichrome wire, as it produced good results in my preliminary work

8a	

Justification for design

- I will use the fixed current and the voltage readings taken to find the resistance of the wire at the different lengths, using the formula $R = \frac{V}{I}$
- I will use the diameter of the wire to find the area of the cross-section of the wire, using the formula $A = \pi r^2$
- I will plot a graph of resistance against length of wire, the gradient of which will tell me the resistivity, when it is multiplied by area, shown by the formula $\rho = \frac{AR}{l}$

8b	

Finding the Resistivity of a Wire

Safe and correct use of some apparatus 2a			
All equipment used safely and correctly 4a			
Some appropriate readings taken 2b		and recorded 2c	

Results

Having completed the practical part of the investigation, these are the tables of results. All measurements are to a measurable degree of accuracy:

	Diameter of Wire (mm, ±0.01)		
	1	**2**	**3**
Original Reading:	0.91	0.91	0.90
Reading at 90° to Original:	0.91	0.89	0.88

Length of wire used (metres, ±0.001)	Current (Amperes, ±0.01)			Voltage (Volts, ±0.01)		
	Repeat 1	**Repeat 2**	**Repeat 3**	**Repeat 1**	**Repeat 2**	**Repeat 3**
1.000	0.50	0.51	0.50	0.88	0.90	0.88
0.900	0.50	0.50	0.50	0.79	0.80	0.79
0.800	0.50	0.50	0.50	0.71	0.71	0.71
0.700	0.50	0.50	0.50	0.63	0.63	0.62
0.600	0.50	0.50	0.50	0.54	0.54	0.54
0.500	0.50	0.50	0.50	0.45	0.45	0.45
0.400	0.50	0.50	0.50	0.36	0.36	0.36
0.300	0.50	0.50	0.50	0.27	0.27	0.27
0.200	0.50	0.50	0.50	0.19	0.18	0.19
0.100	0.50	0.50	0.50	0.12	0.13	0.13

Two or more correct units 2d		Majority of reading accurate 4b	
Sufficient readings and repeats 4c		All units correct 4d	
Readings to appropriate sig figs 6a		Readings with suitable precision 6b	
Clear organised accurate presentation 6c		Mean value of repeats 8d	

Identification of significant sources of error

- The most likely significant source of error in my experiment will be the value for the area of the cross-section of the wire. This is derived from the diameter of the wire, which has a very small value (to the order of $x10^{-4}$m), so it will have a large percentage error, even though the micrometer is accurate to $\pm1x10^{-5}$m. This will then have to be squared to find the area, which will double the percentage error, causing it to be the most likely source of error.

- Other potential sources of error include the length of the wire, as it is not exactly straight and the wire being used heating up, effecting resistance, but these were identified in the plan and measures were taken against them.

Action proposed to minimise errors

During the practical part of the investigation, I took several steps to minimise errors:

- I turned off the power supply between taking readings and limited the current to 0.50A, in order to prevent the wire from heating up, which would alter the value for resistance.
- I repeated each reading three times and will find an average value for each, reducing the effect of anomalous results.
- I took six separate readings for diameter and will find an average value, to take into account discrepancies with the diameter at different points on the wire and due to the large percentage error involved with wire diameter readings.
- I fixed the wire to the ruler at four evenly separated points, in order to keep it as straight as possible to reduce errors with length measurements.

Describes action to minimise errors 8a	
Implements plan to minimise errors 8b	

Check on inconsistent readings

8c	

Title

ANALYSIS & CONCLUSIONS

Finding the Resistivity of a Wire

Data recorded 2a		Data processed and organised logically 4a	
Tabulates data 2c		Data in table with headings and units 4b	
Intends to draw graph 2d		Graph with headings an d labelled axis 4c	
Accurate plotting of points 4d			

Best fit line or curve drawn 6a	
Large triangle for gradient shown 6b	

Data taken from graph, gradient calculations
Use of calculations, equations, gradient,

I have taken an average of all the measurements taken for the diameter of the wire, which comes out as **0.90mm**, or **$9.00x10^{-4}$m** (2d.p.).

I have also taken average values for all the current and voltage readings. I then used these to find the resistance at all the lengths of wire used, using the formula $R = \frac{V}{I}$. I have put these results in a table below.

Length of wire used (metres, ±0.001)	Average Current (Amperes, ±0.01)	Average Voltage (Volts, ±0.01)	Resistance (Ohms)
1.000	0.50	0.89	1.76
0.900	0.50	0.79	1.59
0.800	0.50	0.71	1.42
0.700	0.50	0.63	1.25
0.600	0.50	0.54	1.08
0.500	0.50	0.45	0.90
0.400	0.50	0.36	0.72
0.300	0.50	0.27	0.54
0.200	0.50	0.19	0.37
0.100	0.50	0.13	0.25

Using the values found for resistance in the table above, I have drawn a graph of resistance against the lengths of wire used. The result is a linear graph which passes through the origin. Using the graph, I can find the gradient of the line of best fit, by measuring the change in resistance against the change in length:

$$\frac{\Delta R}{\Delta l} = \frac{1.76 - 0.18}{1 - 0.1} = \mathbf{1.76}$$

Use of equations and calculations 2b	
Correct readings read and recorded off graph 6c	
Gradient calculation or intercept or formula manipulation 6d	

Page 6
(Graph)

Conclusion, final answer and supporting theory and knowledge

My graph is in agreement with the properties of resistance of a wire, as it has a linear line of best fit which passes through the origin, and the resistance of a wire is directly proportional to its length.

The average value for the diameter of the wire (9.00×10^{-4}m) can be used to calculate the area of the cross-section of the wire, using the formula $A = \pi r^2$ (where r is half of the diameter), which gives an area of **6.36×10^{-7} m²** (2d.p.).

As resistivity (ρ) can be found using the formula $\rho = \frac{AR}{l}$, if I multiply the value for the gradient of the graph (1.76) by the value for the area of the cross-section of the wire ($6.36 \times 10^{-7} m^2$), this gives me a final answer for the resistivity of nichrome wire, which comes to (to 2 decimal places):

1.12×10^{-6} Ωm

This is the overall conclusion to my investigation, which was to find the resistivity of a wire.

Knowledge or theory given 8a	
Reasoned conclusion given 8b	
Final numerical answer with units and sig figs 8c	

Support or contradiction of predictions

8d	

EVALUATING

Title

Finding the Resistivity of a Wire

Possible sources of error

- **Length of wire:** I could not be sure that the wire was fully straight on the ruler, so this could have caused the measurement for length to be out by a fraction. However, my graph shows that this was fairly irrelevant, due to the reliability of the line for best fit.

- **Area of cross-section of wire:** I cannot be sure that the wire was cylindrical throughout the wire, which could have affected the resistivity value, though by taking several readings and taking an average, I should have been able to avoid this.

Possible sources of error 2a	

Most error sensitive measurements

The measurement of diameter was my most error sensitive measurement, as it had to be halved and then squared to find the area of the cross-section of the wire. For example, if the average measurement had been 0.95mm instead of 0.90mm, using the same calculations the area would have instead been $7.09 \times 10^{-7} m^2$, compared to $6.36 \times 10^{-7} m^2$.

Most error sensitive measurements 4a	

Categorising errors – systematic and random

- The only slight chance of **systematic error** would be on the ruler, due to measuring from the inside of the crocodile clips.
- **Random errors** will have occurred due to human error in the experiement, most likely in the meaurements of the length and diameter of the wire.
- The micrometer had a **zero error** of +0.01mm, but I adjusted my results for the diameter of the wire to take this into account.

Gives all systematic and random errors 6a	

Estimates of error on all measurements

I will estimate the percentage error on all my measurements by dividing the accuracy of the apparatus used by the smallest measurement taken. This is shown in the table below:

Apparatus	Accuracy	Measurement	Smallest Reading	Percentage Error
Micrometer	±0.01mm	Diameter of wire	0.88mm	**1.14%**
Ruler	±0.001m	Length of wire	0.10m	**1%**
Ammeter	±0.01A	Current	0.50A	**2%**
Voltmeter	±0.01V	Voltage	0.12V	**8.33%**

Therefore the voltmeter was the piece of apparatus with the largest potential for error, due to the small size of some of the measurements taken. However, since all the errors are under 10%, I think my investigation was accurate.

I can also illustrate the accuracy of my investigation by establishing the spread of results. Looking at my graph, there is not a great deal of spread as all but one result lie directly on the line. The only result which does not lie on the line is the result for **0.1m**, for which the average resistance was **0.25Ω**. If I work out the resistivity based on this result only, I get a value of **1.59×10^{-6} Ωm**, which gives the spread of my results to be just **4.70×10^{-7} Ωm**, which I believe is very accurate.

4b	

Comment on data discrepancy or anomalous results

There was very little discrepancy in my data. All the points on my graph lie almost exactly on the line of best fit. The only slightly anomalous result is that for the resistance at 0.1m, which lies 0.07Ω vertically away from the line. This was probably due to the higher potential for error associated with the lower readings for voltage and length.

2b	

Variation of repeats or uncertainty of data

My results are very reliable, as is shown by the lack of variation in the repeat readings. The readings for current, which I attempted to keep constant throughout, vary by only 0.01A, each set of readings for voltage varies by a maximum of 0.02V, and the readings for diameter vary by 0.03mm. This shows that my apparatus provides reliable results, as it produced very little variation between repeated readings.

2c	

Discrepancy of expected results and outcomes

According to my data sheets, the scientifically accepted value for the resistivity of nichrome is $1.1 \times 10^{-6}\Omega m$ (1d.p.). As my investigation found the resistivity of nichrome to by 1.12×10^{-6} Ωm (2d.p.), when measured to one decimal place, my result is exactly as I would have expected, so there is minimal discrepancy between the expected result and the outcome.

2d	

Comment on suitability of techniques used

I think that the technique of using a low constant current of 0.50A worked well in preventing a higher temperature, thus affecting resistance, since the resistance kept to a straight line for best fit for all measurements, not increasing towards the later results. Also, I think I managed to keep the length of wire straight enough so that was not a problem.

Comment 4c	
Criticism and improvements 6b	

Comment on reliability of conclusions

I believe that my conclusion is reliable due to the quality of the line of best fit. It is a straight line that passes through zero, which is the type of line that I expected. All the points pass very close to the line, with only one slightly anomalous result. Furthermore, the gradient of my line gave me a value of resistivity close to that which I expected.

Comment on reliability 4d	
Critical comment and value 6c	

Proposals for improvements or further work

I think there is very little I could do to improve the practical set-up for my investigation. I could possibly have used a variable resistor to be more accurate in taking voltage and current measurements, but my results were accurate enough.

To further improve the reliability of my investigation, I could look at Nichrome wire of varying diameter, to see if they had a consistent value for resistivity. To do this, I would use the same set-up for the investigation, but take measurements using about five wires of different diameters. I could use the same calculations for resistivity for each wire. To continue the investigation, I could compare Nichrome wire with other materials, such as Constantan.

6d	