GCE Physics Salters Horners

Exemplar Coursework
GCE Advanced Subsidiary – Unit 3

Short Experiments

Contents

Introduction

Experimental skills

It is recommended that candidates do at least three practical assignments and the marks for the best two are submitted. Each practical is assessed under all four skill area headings and the maximum mark that can be achieved on each practical is 22. The best two total marks for practical assignment are then added to the mark awarded for the visit report and submitted as the final mark for unit PSA3.

Suitable practical activities would normally be found within topics studied during units PSA 1 and 2. However, there is a requirement that the activity should allow candidates to demonstrate clearly experimental skills beyond those required for GCSE.

The practical activity must allow all four experimental skills to be demonstrated.

The activities must be carried out by candidates working individually.

The practical reports can be either hand written or word processed. It is expected that the planning section of the report will be written in the future tense before any practical activity takes place. Skill B (Implementing) is teacher assessed on the basis of direct observation of the candidate at work in the laboratory. This mark should be recorded, with a brief supporting comment, on the front sheet of the candidate's report.

The following examples demonstrate a range of practical activities carried out with different levels of success. They have been word processed for clarity but practical reports can be hand written.

A Planning — 6 marks

2 marks

There is some attempt at planning. Apparatus selected is largely appropriate, with some regard to safety.

4 marks

There is a coherent plan for the experiment, with attention paid to safety. There is some attention to accuracy and sensitivity in the selection of apparatus.

6 marks

There is a clear plan of action. Work is planned in order to make good use of the time and facilities available. Apparatus selected is appropriate to the experiment. There is thought and ingenuity in the design of the experiment, with due attention to sensitivity and accuracy. Apparatus is devised or modified to suit the experiment.

B Implementing — 4 marks

2 marks

Apparatus is set up and used correctly, with attention paid to safety. Previously learned techniques and procedures are carried out correctly. Work is generally well organised.

4 marks

Apparatus is used with confidence, care and skill. Techniques are applied correctly, and extended or modified where appropriate. Work is methodical and well organised.

C Observing and recording 4 marks

2 marks

Measurements and observations are recorded methodically. Measurements are recorded with appropriate units. A reasonable number and range of observations and measurements are carried out. Some turning points or anomalous results (if present) are noted.

4 marks

Measurements and observations are repeated as appropriate. Numerical results are recorded to an appropriate degree of precision. Any turning points or anomalous results are noted and investigated. If problems arise in the making of measurements or observations, procedures are adapted.

D Interpreting and evaluating 8 marks

2 marks

Data are processed using routine methods, including a graph where appropriate. There is an attempt to apply physics principles. A conclusion is stated.

4 marks

Conclusions are stated and are supported by the experimental results. The limitations of the experimental results, and conclusions based upon them, are recognised and discussed qualitatively.

6 marks

Data are processed thoughtfully, using appropriate methods that reveal trends and patterns. Results are interpreted using physics principles and concepts. Relevant physics principles are applied correctly throughout. The limitations of experimental results, and conclusions based upon them, are recognised and there is some attempt to discuss them quantitatively.

8 marks

There is a thorough quantitative discussion of the limitations of the experimental results and the conclusions based upon them. Any limitations of the experimental procedure are commented upon, and sensible modifications suggested.

Experiment into how the resistivity of a material varies as a function of stress

Introduction:

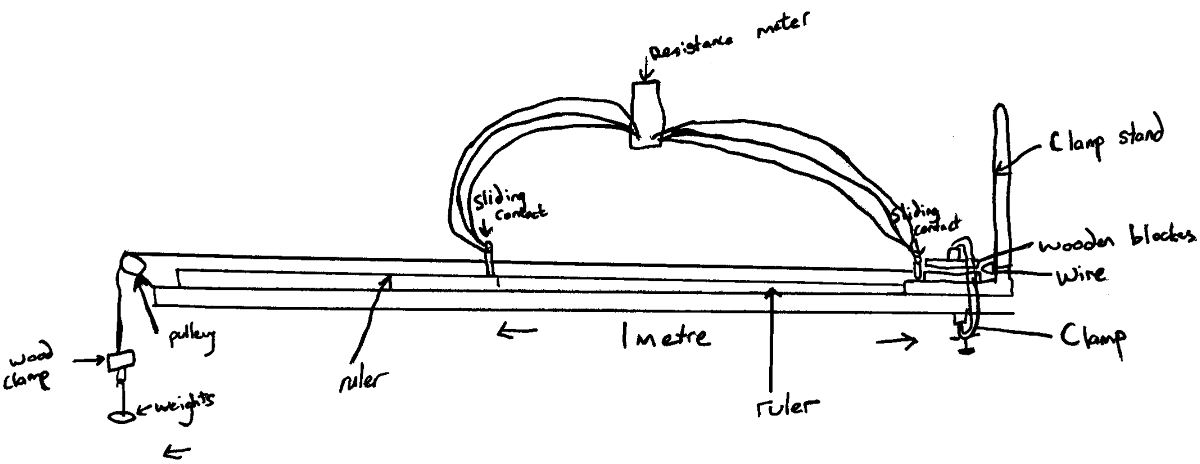
The aim of this experiment is to investigate how the resistivities of two materials vary with the stress placed upon the materials. The materials available for testing are nichrome and steel wires, and I am expecting the resistivities of both materials to change when a stress is applied to them, although I am not sure exactly how the resistivity will change.

The candidate could still suggest a possible hypothesis based on their background physics knowledge.

Apparatus required:

Length of nichrome wire
Length of steel wire
Resistance meter
Pulley 'Sliding contacts' - with a hole through which the wire can pass - used to form a connection to the wire
Clamps and clamp stand
Flat pieces of wood
Wooden clamp to hold end of wire
Weights with weight holders
Wire cutters
Ruler
Wires
Masking tape
Jiffy bags
Safety glasses

Method:



1) Firstly, I will set up the apparatus as shown above. I will clamp the wire between wood at both ends to ensure that it could not slip out. I will be careful to use the wire cutters when cutting the wire, and also to not allow the wire to get tangled up as even a small nick in the wire could alter its breaking stress. I must also be careful when tightening the wire contacts for the same reason. I will try to use masking tape on the wire to mark the exact spot on the wire which I was measuring. I will ensure that I wear safety glasses for the duration of the experiment.

2) Set up the apparatus with just the weight of the wooden clamp and metal ring holding the nichrome wire taught. Measure the resistance of the selected length of wire (using the resistance meter set to its most sensitive setting), add weights onto the end of the wire, 1 Newton at a time. Each time note the extension and resistance.

3) Continue this exercise until the wire breaks.

4) Perform the same exercise for the steel wire.

5) Repeat the same procedure again for both wires to help me in my analysis if I find any seemingly anomalous readings.

The candidate has not introduced the physics principles ie stress = force / cross sectional area. The candidate has not linked resisitivity (in the title) with the resistance meter in the diagram. It is a reasonable plan but it omits to explain how the cross sectional area is going to be determined. In fact this becomes more apparent as the experiment proceeds – the candidate has clearly not thought this out and it therefore scores a low mark. If the candidate had suggested the use of a micrometer to determine diameter then this would be a sensible approach and could be appropriately credited. This was also a missed opportunity to discuss accuracy of measuring instruments.
Skill A: 2 marks

Results:

Nichrome

Force / N	Extension mm	Resistance
0.37	0	37.8
1.39	0	37.9
2.41	0	37.9
3.43	0	37.9
4.45	0	37.9
5.47	0	37.9
6.49	0	37.9
7.50	0	37.9
8.52	0	37.9
9.54	0	37.9
10.6	0	38.0
11.6	0	38.0
12.6	1	38.1
13.6	1	38.1
14.6	1.5	38.2
15.7	7	38.6
16.7	15	39.2
17.7	23	39.8
18.7	31	40.4
19.7	41	41.2
20.8	55	42.1
21.8	68	43
22.8	80	43.9
23.8	94	44.9

N.B. – I noted that the nichrome began to deform plastically at between 16-18 N

Steel

Force / N	Extension mm	Resistance
0.37	0	140.9
0.88	1	141.3
0.98	1	141.5
1.08	1	141.7
1.18	1	141.8
1.29	2	141.9
1.39	2	142.1
1.49	2	142.4
1.59	3	142.4
1.69	3	142.5
1.80	5	142.7
1.90	5	142.9
2.00	6	142.9
2.10	7	143.4
2.20	8	143.8
2.31	9	144.6
2.41	16	147
2.51	19	147.1
2.61	20	147.8
2.71	23	148.2
2.82	24	149.3
2.92	28	150.1
3.02	30	152.3
3.12	38	153.5
3.22	46	155.9
3.33	53	158.2
3.43	63	161.5
3.53	69	164.1
3.63	80	166.4
3.73	88	168
3.83	100	171.8
3.94	120	178.1
4.04	130	183

N.B. - did not notice the steel deforming plastically at any point

Note: the candidate has omitted the units for resistance, and at first sight the data appears to be to an inconsistent number of significant figures however some spreadsheets ignore 0 at the end of a number therefore this will not be penalised as it is clear the candidate does appreciate the idea.

Analysis:
The purpose of this experiment is to investigate how resistivity varies with stress.

To begin with, we must calculate the resistivity of the material when each force was applied. To begin with, the formula:

$$R = \rho \frac{l}{A}$$

can be used. By re-arranging this, we get:

$$\text{resistivity} = \frac{RA}{l}$$

Thus, to calculate the resistivity, we must know the resistance (measured), the length (measured) and the cross-sectional area (unknown). This cross-sectional area can be calculated from the radius of the wire. If we assume that the volume of the wire stays constant, then:

$$r_1^2 l_1 = r_2^2 l_2$$

Hence, the formula for the new radius is:

$$r_2 = \frac{\sqrt{r_1^2 l_1}}{l_2}$$

The candidate should consider these principles in the planning.

To calculate the stress, we need to know the force (measured) and the cross-sectional area as calculated above.

For the resistances, I have taken away the contact resistance from each value. I believe that this will make the result more accurate. I found the contact resistance placing the probes touching the wire and as close to each other as possible The values that I obtained for this contact resistance were 0.5Ω for nichrome and 1.5Ω for steel.

Well recognised.

When all this information is entered into a spreadsheet program, the following tables can be produced.

Results:

Nichrome

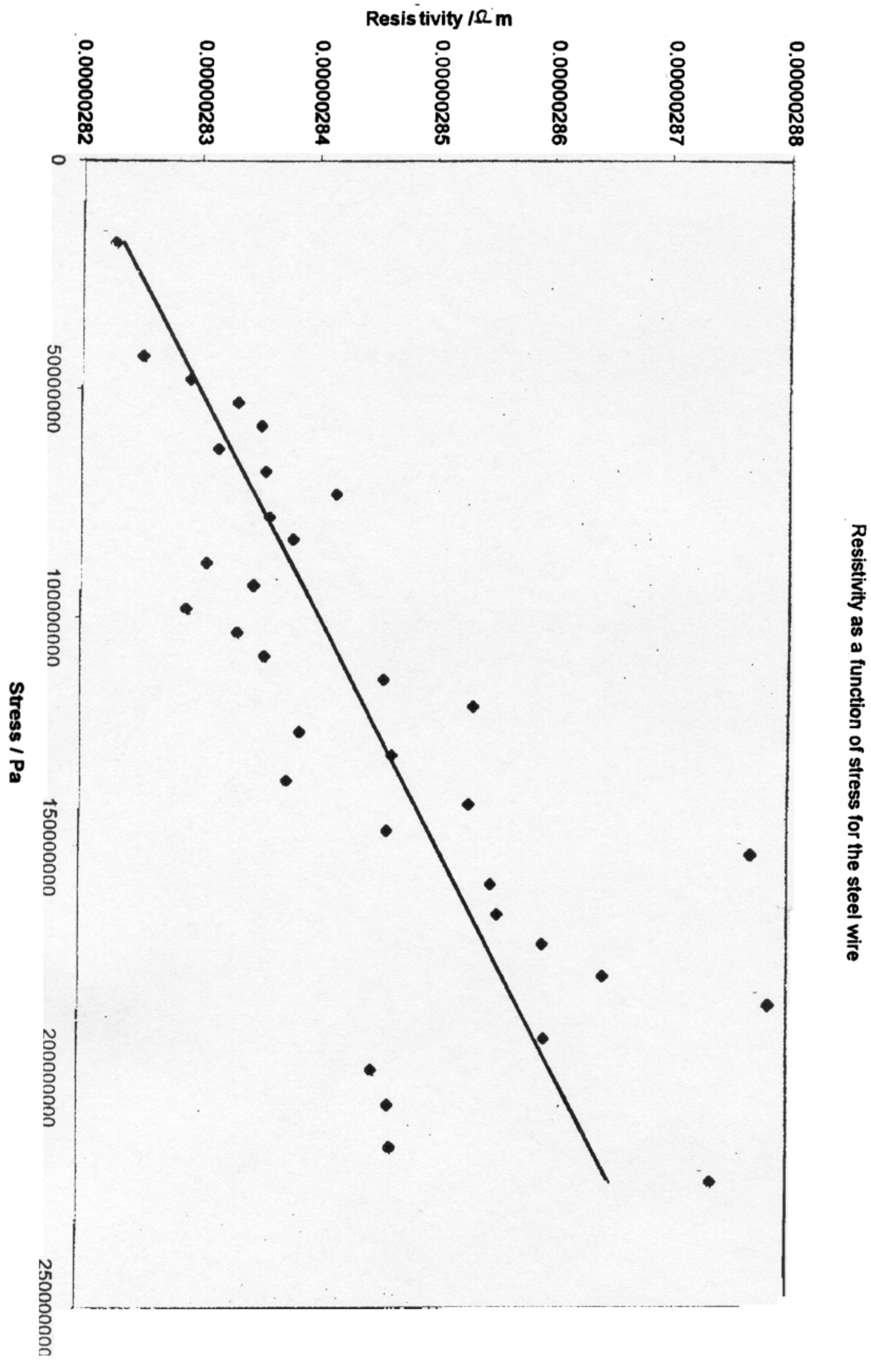
Stress / Pa	Resistivity / Ωm
3191916	4.23E-06
12009365	4.24E-06
20826813	4.24E-06
29644261	4.24E-06
38461710	4.24E-06
47279158	4.24E-06
56096607	4.24E-06
64914055	4.24E-06
73731503	4.24E-06
82548952	4.24E-06
91366400	4.25E-06
IE+08	4.25E-06
1.09E+08	4.26E-06
1. 18E+08	4.26E-06
1.27E+08	4.26E-06
1.36E+08	4.26E-06
1.46E+08	4,26E-06
1.57E+08	4.26E-06
1.67E+08	4.26E-06
1.78E+08	4.26E-06
1.89E+08	4.24E-06
2.01E+08	4.23E-06
2.13E+08	4.22E-06
2.25E+08	4.2IE-06

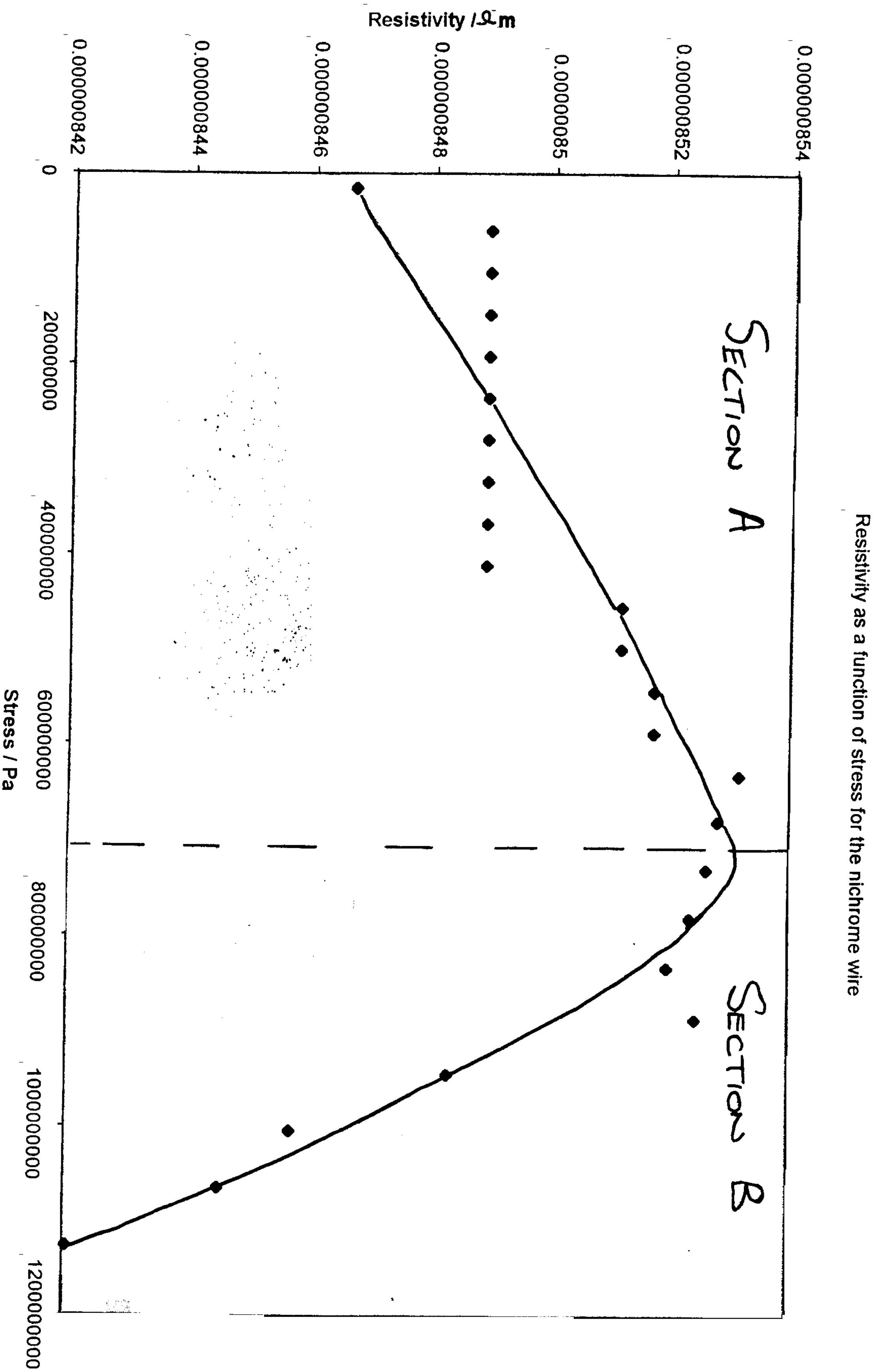
Steel

Stress / Pa	Resistivity / Ωm
18004403	2.82E-06
42915235	2.83E-06
47893801	2.83E-06
52872366	2.83E-06
57850932	2.84E-06
62892264	2.83E-06
67875803	2.84E-06
72859342	2.84E-06
77920569	2.84E-06
82909082	2.84E-06
88072864	2.83E-06
93071324	2.83E-06
98167366	2.83E-06
1.03E+08	2.83E-06
1.08E+08	2.84E-06
1. ME+08	2.85E-06
1. 19E+08	2.8SE-06
1.25E+08	2.84E-06
1.3E+08	2.85E-06
1.35E+08	2.84E-06
1.41E+08	2.85E-06
1.46E+08	2.85E-06
1.52E+08	2.88E-06
1.58E+08	2.86E-06
1.64E+08	2.86E-06
1.71E+08	2.86E-06
1.7SE+08	2.86E-06
1.84E+08	2.88E-06
1.91E+08	2.86E-06
1.98E+08	2.85E-06
2.06E+08	2.85E-06
2.15E+08	2.85E-06
2.23E+08	2.87E-06

These tables should be placed alongside the original tables of results. The stresses are presented to an inconsistent and excessive number of significant figures.

When resistivity is plotted against stress for both the wires, the graphs on the following two pages are produced.


Resistivity as a function of stress for the steel wire
Resistivity /Ω m
0.00000282
0.00000283
0.00000284
0.00000285
0.00000286
0.00000287
0.00000288
Stress / Pa
0
5000000
10000000
15000000
20000000
25000000



Resistivity as a function of stress for the nichrome wire
Resistivity /Ωm
0.000000854
0.000000852
0.00000085
0.000000848
0.000000846
0.000000844
0.000000842
0
20000000
40000000
60000000
80000000
100000000
120000000
Stress / Pa
SECTION A
SECTION B

Firstly, if we look at the graph for steel, we can see an obvious, positive linear correlation between stress and resistivity.

My hypothesis for this behaviour is as follows. Resistivity is a property of the material (at a constant temperature with no stress) and so is linked to the number of available charge carriers (in the case of a metal, electrons) per unit volume. As the stress - i.e. the force exerted upon the cross-sectional area - is increased, the number of free charge carriers is not being increased, but the volume is. Hence, the number of free charge carriers per unit volume is decreasing and so the resistivity will increase. This would apply as long as the metal deformed elastically - as the steel wire did.

A line of best fit is not appropriate in these circumstances. Comments on the scatter of points would be reasonable. The candidate appears to be confusing the concept of resistance with resistivity. The values of resistivity only vary on the third significant figure ie by a very small amount. The candidate should be considering the limitations of the experiment. The variation in resistivity might be due to experimental limitation; the resistivity probably doesn't vary with stress. This would be a perfectly sensible approach and would attract considerable credit for skill D. As it is the candidate has mis-interpreted these results.

We can now look at the more complicated graph of stress plotted against resistivity for the nichrome wire. I believe that this graph can be split into two sections, marked A and B on the graph.

In section A, the wire is deforming elastically. This means that it is undergoing changes as described for steel above, and the net result should be, and is, the same i.e. a positive linear correlation between stress and resistivity. It should be noted that the line of nine points, starting with the second, that appears anomalous is actually due to the resistance meter not being accurate enough. Although it may appear otherwise, I am sure that the points would slope along the line of best fit drawn, if the resistance meter had measured to an extra decimal place.

Section B, however, is completely different. Here the wire is deforming plastically, and it can be seen that this drastically affects the resistivity/stress relationship. Instead of being positively correlated, they are now negatively correlated and resistivity falls quickly (although still linearly) with increasing stress. I believe that this is because when the material is deforming plastically, it is being permanently changed. At the atomic level, it is being tom apart, and I believe that this is the cause of the fall in resistivity. I believe that the tearing apart of the material at the atomic level causes an increase in the number of free charge carriers per unit volume. This would explain the sharp drop in resistivity that I have found on my graph.

However, there were several limitations to this experiment. Firstly, I believe that the resistance meters with which we were provided were not accurate enough for the experiment and that we should have used meters capable of measuring to a tenth of an ohm. This would have removed the apparent anomalies in the graph of stress against resistivity for the nichrome wire.

Also, when the nichrome was deforming plastically, I had to choose a moment to measure the resistance and extension since both were changing constantly. The readings obviously varied with the exact moment at which I chose to measure them, and although I tried to keep the time between adding the weights and measuring constant for all readings, I had to do this using my own judgement, and so it was obviously not completely accurate.

Another problem is the radius of the wire. In order to calculate both the stress and the resistivity, I had to know the radius of the wire. Since it was not practical to measure the radius of the wire after each measurement accurately enough, I chose to measure it at the beginning and then assume the volume of the wire stayed constant to calculate it when the wire had extended. These calculations gave me a value of 0.18mm for the nichrome wire at the end of the experiment. However, when I measured it, I discovered it had a diameter of 0.17mm. Thus I believe that the volume of the wire had actually increased slightly during the experiment, and so my initial assumption that it would not change is incorrect.

There are some interesting modifications required to obtain results which the candidate has understood and implemented and therefore deserves credit.

Despite these limitations in the experiment, I believe that I have paid due attention to sensitivity and accuracy. I made several adjustments to my technique (e.g. using three wires in parallel to lower resistance) in order to increase accuracy and 1 believe that since the resistance meter was the limiting factor in terms of accuracy, I have done all that I can on this front. I also feel that my results are accurate enough for me to base my conclusions on them. I did repeat both the steel and nichrome results, but since all the results were almost exactly the same, I chose to use the first set of results.

If I were doing this experiment again, there are several modifications I would make. Firstly, I would use a more accurate resistance meter. Also, I would use a thicker wire since this would reduce the percentage error in all readings and would also have a greater breaking stress, thus enabling me to obtain more readings. I would also try to measure the diameter of the wire at each turn although this would require a significant amount of time as well as a way of stopping the wire from deforming plastically whilst the measuring was being done.

Commentary

This is a very appropriate experiment and has given the candidate considerable opportunity to demonstrate practical skills.

A: Planning

The candidate has only partially planned this experiment in advance. Apparatus is largely correct. There is no explanation of how the cross sectional area will be determined which is a key part of this experiment. The plan should explain any simple related principles.

Skill A: 2 marks

B: Implementing

Work was well organised and thorough. The apparatus was used sensibly and accurately. Procedures needed some interesting modifications.

Skill B: 4 marks

C: Observing and recording

The candidate has omitted units in one column of the table. A good range of results have been taken. Significant figures are consistent as far as measured quantities are concerned. Tabulation could have been made simpler by combining tables of results. Repeats do not appear to have been taken – and this has not been justified.

Skill C: 2 marks

D: Interpreting and evaluating

Graphs have been produced to aid the interpretation of results. Some useful physics principles have been applied and a conclusion is stated. However the relationship is not linear and this should be commented on.   (2 marks)
The candidate has missed the real argument. The limitations of this experiment can explain why the resistivity has varied. There was considerable potential for discussion. 4 marks cannot be achieved, a mark of 3 was awarded because the candidate needed to modify a number of procedures and justified these at length and has discussed further possibilities.

Skill D: 3 marks.

Final marks awarded

Planning	2 (6)
Implementing	4 (4)
Observing and recording	2 (4)
Interpreting and evaluating	3 (8)
Total	**11 (22)**

Bungee jumping

Set up and test a model bungee jump, using a piece of elastic. For a given piece of rubber cord, your task is to predict a launch height that would give the jumper an 'interesting' ride i.e. stopping a very short distance from the ground without actually hitting it.

In the sport of bungee jumping, a participant ties one end of a stout elastic rope round his middle and the other end to a fixed member of some bridge or high buildings. The jumper then throws himself off and performs a set of damped vertical oscillations. Success is achieved if the jumper just does not hit the water or earth below on his first descent.

When an object, or a person, is attached to a bungee cord and dropped the desired result is that this object is brought to rest at some predetermined location. (Usually this is before the object reaches the ground!) Physics is used in bungee jump, which relies on elastic materials.

I have drawn a chart to make a clear plan of the experiment. The bungee jump is a mechanics problem that is so complex that the best way to understand it is to model it. I am going to use a mathematical model.

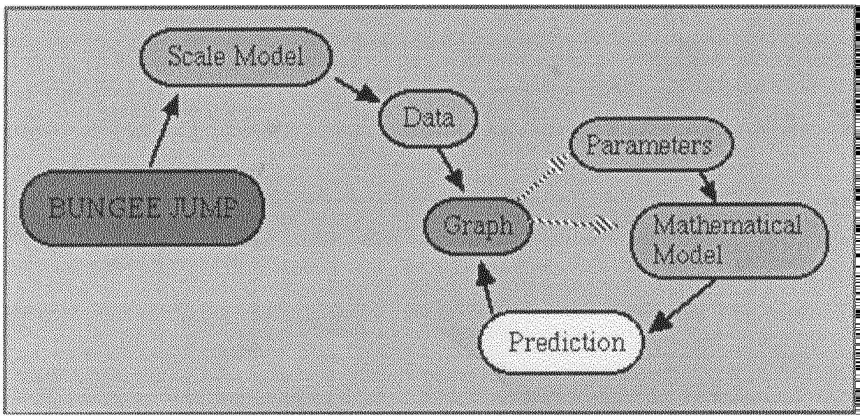


Figure 1
Structure of Work

The parameters are values that apply to a particular jump, such as the mass of the jumper and the stiffness of the elastic. My variable is to change the parameters (mass) of the model.

The art of modelling is to make good simplifying assumptions. To investigate the bungee jump, we need to simplify it. But we always have to be careful that our assumptions don't invalidate our results.

Ignore one dimension: The real jump takes place in two dimensions: the up-and-down motion is one and the back-and-forth motion is the other. It will be much easier to understand if we can focus on the up-and-down dimension and ignore the other.

Ignore air friction: Air rushing by will slow down the bungee jumper a bit. This is called air friction. But perhaps air friction will be so small compared to the other forces that we can ignore it.

One approach to solving many problems of the motion is to use forces. The forces on a bungee jumper are shown in below.

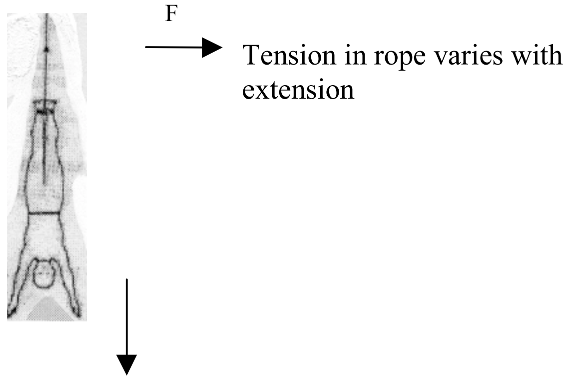


Figure 2: The forces on a bungee jumper

Because the tension in the rope varies with extension, the force on the jumper is not constant, which makes it more difficult to apply the equations of motion.

Another approach is to use energy conservation. When an object is tossed off a high place the gravitational potential energy is converted to kinetic energy. As a result the object is usually moving quickly when it encounters the ground. In this case, some amount of energy is absorbed and stored in the spring (bungee cord). Under ideal circumstances enough energy is stored in the spring so that the object has no kinetic energy (stopped) when it reaches the ground. The energy conservation tells us that the gravitational energy lost must be equal to the elastic energy gained by the cord.

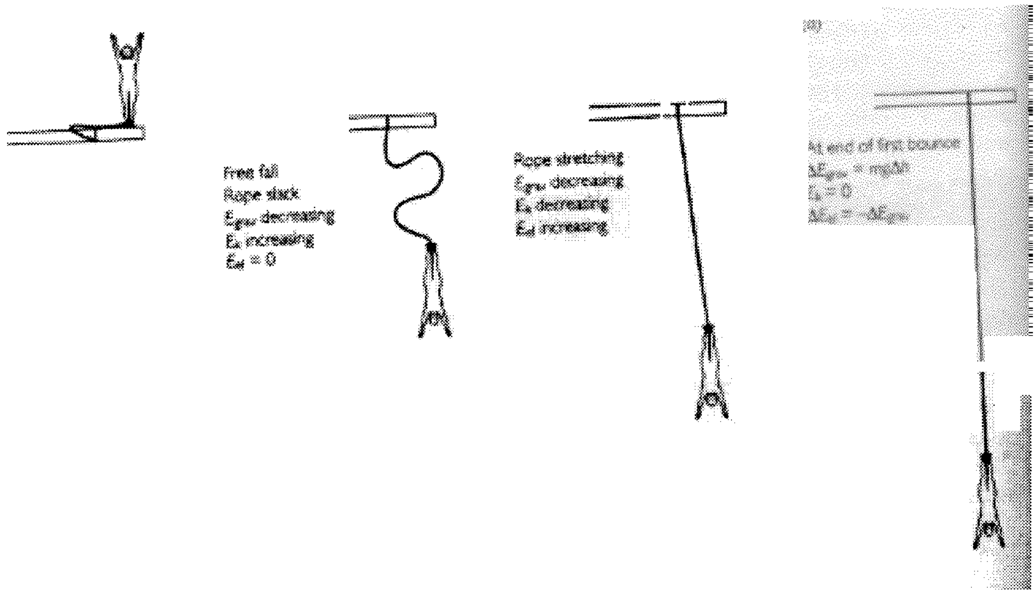


Figure 3: Energy in a bungee jump

To accomplish this task, I was given a Lego man, rubber cord, and masses. For these given pieces of equipment my task is to predict a launch height. In order to find the correct height, I am going to draw a force-extension graph to find the elastic energy stored at different extensions of the cord.

Firstly I am going to make a model of bungee jump using Lego man as a bungee jumper. I have securely attached about 1/4 meter of elastic to a mass. I have a used small mass for safety purpose. Too large a mass could break the cord and cause a hazard to feet. In order to observe the drop, I have simulated a bungee jump by holding the elastic in clamp and dropping the masses.
The experiment will involve increasing masses on a known length of rubber cord and measuring the corresponding extensions with a rule. To enhance the accuracy of our data set, the data will be repeated. A stopwatch will be used to give an equal time for the each extension to come to rest before they are measured.
I then hope to consider a graph of energy stored in the cord with extension and compare it with the loss in potential energy.

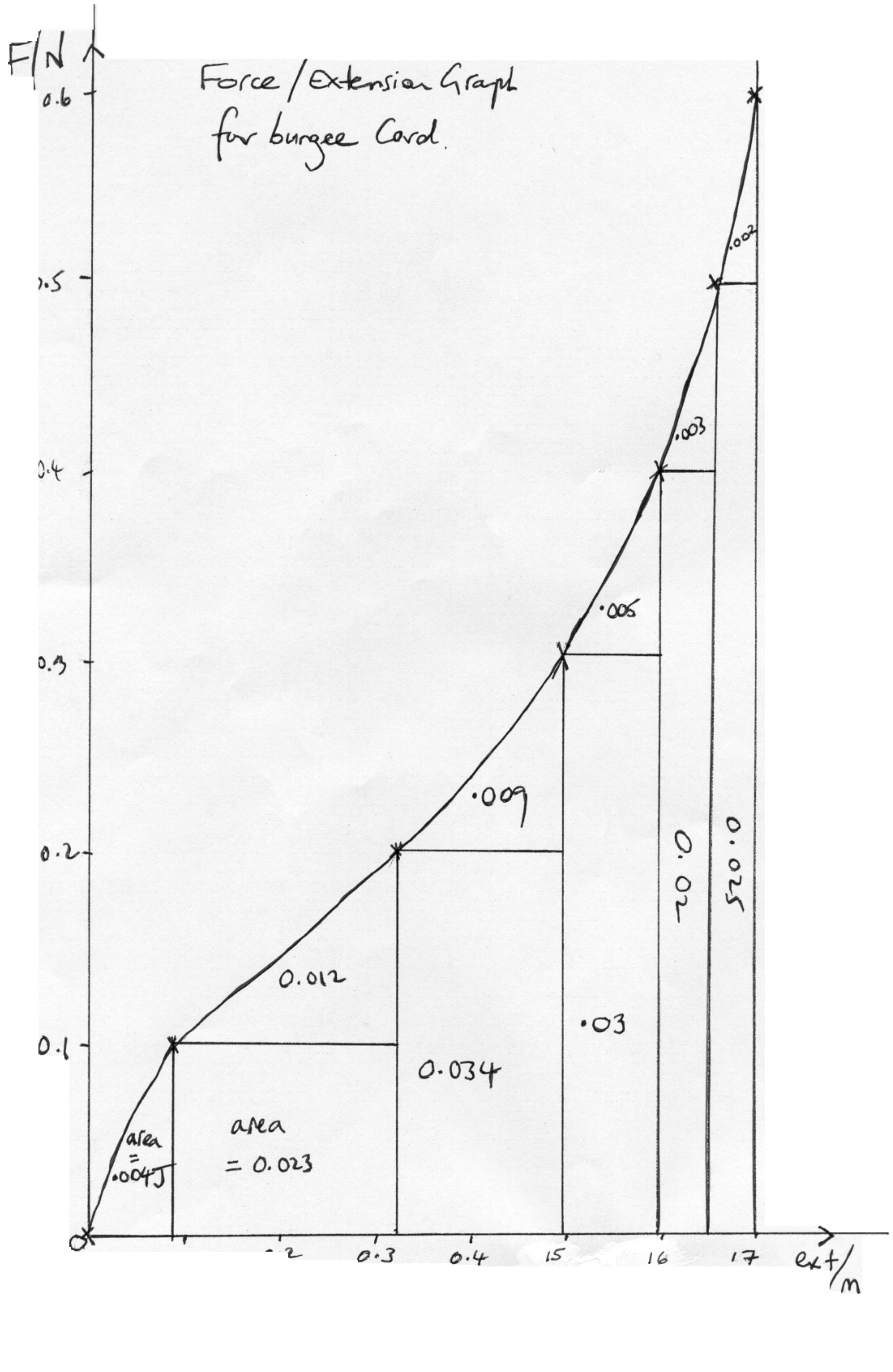
There is a plan and it has been explained quite well. The candidate does not clearly set out how the extension is going to be measured as accurately as possible given the circumstances. Neither does the candidate quite fully explain how these graphs are going to be used. The requirement for a stop watch is not explained at all. *Skill A: 3 marks*

The results were recorded in the table below.

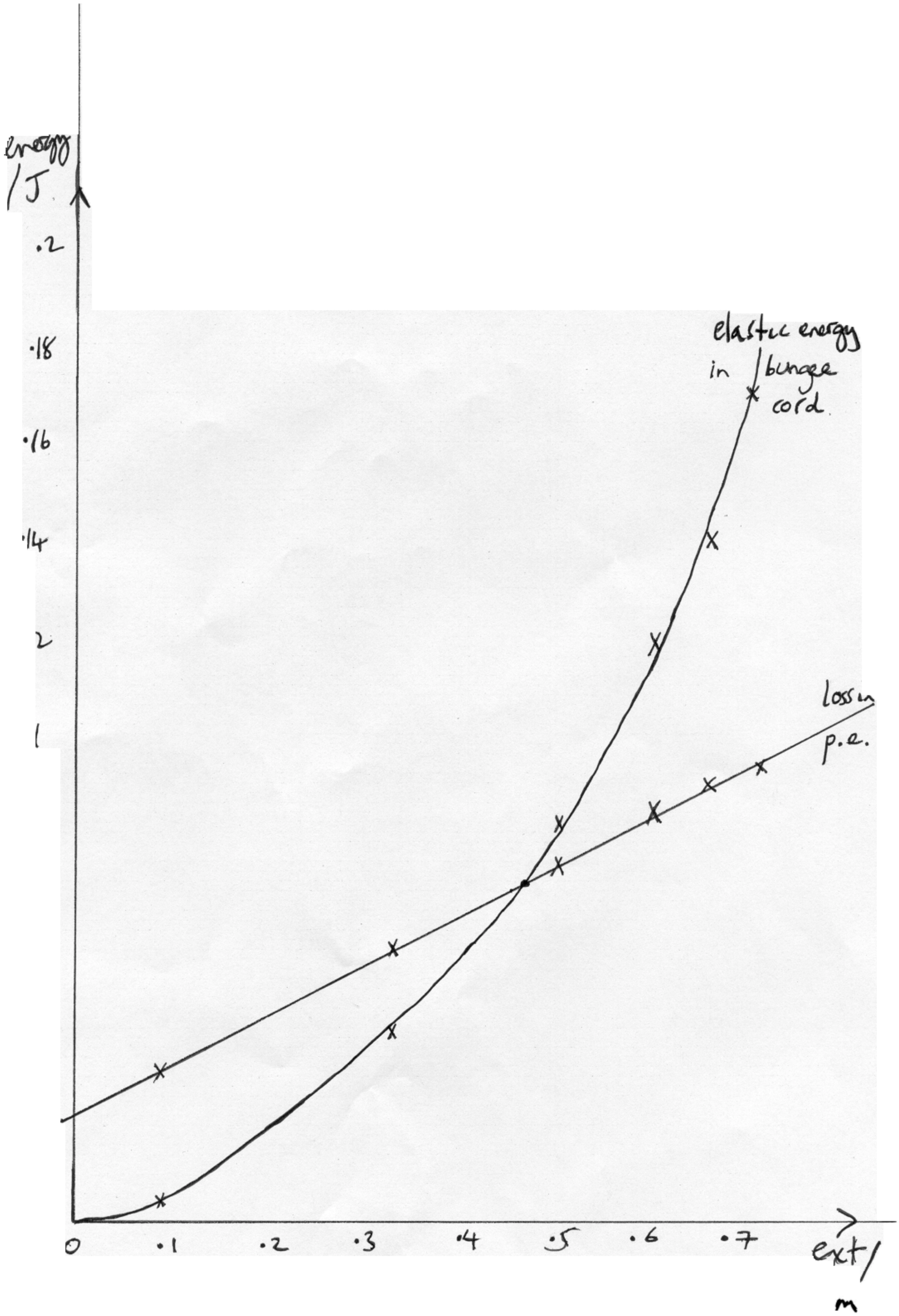
The original length of the rubber cord was 0.25 m. The gravity of the earth is taken 10kg/m/s^2

Force (N)	**Extension(m)**	**Extension (m)**	**Average(m)**
0.1	0.08	0.09	0.085
0.2	0.31	0.34	0.35
0.3	0.48	0.52	0.495
0.4	0.58	0.65	0.595
0.5	0.63	0.67	0.65
0.6	0.68	0.70	0.69

Standard force/extension table is given. A good range of results with units and repeats is presented. One could argue that the significant figures of the averages should be consistent with data. The candidate should have taken an extra data reading between 0.1 and 0.2 N as the extension does increase significantly here. Skill C could achieve 3 marks.



F/N
Force / Extension Graph
for bungee Cord.
0.6
0.5
0.4
0.3
0.2
0.1
ext/m
0.3
0.4
15
16
17
.002
.003
.005
.009
0.012
0.034
.03
0.02
0.025
area = .004J
area = 0.023


energy /J
·2
·18
·16
·14
2
1
elastic energy in bungee cord
loss in p.e.
0
·1
·2
·3
·4
·5
·6
·7
ext/ m

The area under the curve gives the energy stored within the bungee cord. Finding the area under the curve is a calculus problem but I shall take a more direct approach. I have begun by determining the energy represented by little rectangles and triangles on the plot. The area under the curve is made up of many of these little shapes. By calculating the area I have figured total energy stored to be 0.14 J at 0.65 m extension.
I have worked out elastic potential energy from the force-extension graph**.**

This calculation of area/energy stored is taken as part of interpretation/use of a graph ie as part of skill D.

ELASTIC ENERGY (J)	EXTENSION (M)
0.004	0.085
0.039	0.325
0.082	0.495
0.117	0.595
0.140	0.65
0.168	0.69

After stretching the cord through an extension x, the gravitational energy lost by the jumper is $\Delta Eg = mg\ (l+x)$

The candidate has omitted to state the mass of the bungee Lego man. In the light of the previous comments, skill C is awarded 2 marks.

Using this equation will give the gravitational energy lost by the jumper.

Gravitational potential energy (J)	*Extension (m)*
0.0335	0.085
0.0575	0.325
0.0745	0.495
0.0845	0.595
0.0900	0.65
0.0940	0.69

I have drawn the graph based on the results in the table. A graph of elastic potential energy stored against extension was found from the area under a force extension graph. I have also drawn a graph of the gravitational energy lost on the same axes as elastic energy against extension. In theory where the graph of elastic energy and gravitational energy against extension on the same axes, the point where the lines meet should shows the extension at which the jumper comes to rest because this is where the gravitational energy lost has been totally stored by the cord and the kinetic energy of the jumper will be zero.

Interpretation/Conclusions

According to my graph this intersection is when the extension (x) is 0.455 m ie if the bungee jumper jumps from a height of 0.25 m + 0.455 m = 0.705 m from the ground she will come to halt just as she touches the ground. This assumes the jumper had no initial kinetic energy.

Sources of Error: the main error is due to the accuracy of measuring the extensions. These were thought to be best done to the nearest cm as the position of the bungee person was rather difficult to pinpoint. For a typical extension such as 50 cm this will give a 2% error.

The masses were assumed to be accurately marked – this might lead to at least a 2% error in the energies stored.

The use of triangles when the line was curved will also lead to small errors – however the line was curved outward in some places and inwards in others – probably cancelling out for the total stored energy.

Relevant physics principles are applied throughout. Graph axes are scaled appropriately. Correct use of units is demonstrated and a smooth curve has been drawn. *The limitations are recognised and there is some attempt to discuss these quantitatively.* *Skill D: 6 marks* *The limitations might have been discussed in more depth to qualify for 7 or 8 marks but some valid points for possible modifications are made below.*

There are several modifications I might pursue:

Test the model by repeating the experiment under different conditions, i.e. different temperature and initial length.

Examine the effect of friction. Does the model correctly account for air and other kinds of friction? Friction always reduces energy. Without it, the bungee jumper would return to the same height it started. The bungee cord has internal friction. When a stretched cord has been released, it warms and this can result in energy loss. One way is to try to change one kind of friction without changing anything else. Air friction can be increased by making the bungee go faster or making it larger. The bungee friction can be reduced by substituting a spring.

Improve the experiment with computer interface electronics. The force and length measurement were not accurate and might be a source of error. Updating that part of the experiment with photo gates and software that uses computer as an instrument could give more accuracy.

This "use of electronic light gates" is often suggested as a modification. Candidates are expected to state exactly what they intend to do with these light gates or a computer etc. The first two points are valid.

Look at the two-dimensional motion of the bungee by using a video camera. My experiment was one-dimensional, looking just at the up-and-down motion of the jumper. What about the horizontal motion? Will the jumper crash into the building before reaching ground? Analyzing a video record is the best way to do this.

Commentary

A: Planning

The candidate has attempted to consider the physics principles and apply them to the stated problem. The candidate appears to have concentrated more on explaining the use of principles and rather less on the experimental methods. The candidate should draw a diagram showing arrangement of apparatus (rule etc.).

Skill A: 3 marks

B: Implementing

Work was well organised and thorough. The apparatus was used sensibly and accurately.

Skill B: 4 marks

C: Observing and recording

The candidate has made some simple errors:

- omitting a measurement (the mass of the Lego man)
- not adding an extra data point as the extension increases significantly between the first and second value.

Average values should be presented to consistent figures with the measured data.

Skill C: 2 marks

D: Interpreting and evaluating

Data is processed thoughtfully. A sensibly scaled graph of force against extension has been drawn. The candidate has numerically integrated this curve and plotted the resulting graph. The candidate understands the physics principles and has applied them. This would be a minimum of 4 marks.
The limitations are discussed quantitatively and the candidate has reached a sound conclusion based on these results. (6 marks)
Some of the modifications are valid but they are not particularly explained in any depth.

Skill D: 7 marks

Final marks awarded

Planning	3 (6)
Implementing	4 (4)
Observing and recording	2 (4)
Interpreting and evaluating	7 (8)
Total	**16 (22)**