Physics 2007

Sample assessment instrument and student responses

Extended experimental investigation

December 2009

Queensland Government
Queensland Studies Authority
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Purposes of assessment[1]

The purposes of assessment are to:

- promote, assist and improve student learning
- inform programs of teaching and learning
- provide information for those people — students, parents, teachers — who need to know about the progress and achievements of individual students to help them achieve to the best of their abilities
- provide information for the issuing of certificates of achievement
- provide information to those people who need to know how well groups of students are achieving (school authorities, the State Minister for Education and Training and the Arts, the Federal Minister for Education).

It is common practice to label assessment as being formative, diagnostic or summative, according to the major purpose of the assessment.

The major purpose of formative assessment is to help students attain higher levels of performance. The major purpose of diagnostic assessment is to determine the nature of students' learning, and then provide the appropriate feedback or intervention. The major purpose of summative assessment is to indicate the achievement status or standards achieved by students at a particular point in their schooling. It is geared towards reporting and certification.

Syllabus requirements

Teachers should ensure that assessment instruments are consistent with the requirements, techniques and conditions of the Physics syllabus and the implementation year 2007.

Assessment instruments[2]

High-quality assessment instruments[3]:

- have construct validity (the instruments actually assess what they were designed to assess)
- have face validity (they appear to assess what you believe they are intended to assess)
- give students clear and definite instructions
- are written in language suited to the reading capabilities of the students for whom the instruments are intended
- are clearly presented through appropriate choice of layout, cues, visual design, format and choice of words
- are used under clear, definite and specified conditions that are appropriate for all the students whose achievements are being assessed
- have clear criteria for making judgments about achievements (these criteria are shared with students before they are assessed)
- are used under conditions that allow optimal participation for all
- are inclusive of students' diverse backgrounds
- allow students to demonstrate the breadth and depth of their achievements
- only involve the reproduction of gender, socioeconomic, ethnic or other cultural factors if careful consideration has determined that such reproduction is necessary.

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[1] QSA 2008, *P–12 Assessment Policy*, p. 2.

[2] Assessment instruments are the actual tools used by schools and the QSA to gather information about student achievement, for example, recorded observation of a game of volleyball, write-up of a field trip to the local water catchment and storage area, a test of number facts, the Senior External Examination in Chinese, the 2006 QCS Test, the 2008 Year 4 English comparable assessment task.

[3] QSA 2008, *P–12 Assessment Policy*, pp. 2–3.

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About this assessment instrument

The purpose of this document is to inform assessment practices of teachers in schools. For this reason, the assessment instrument is not presented in a way that would allow its immediate application in a school context. In particular, the assessment technique is presented in isolation from other information relevant to the implementation of the assessment.

This document does not contain timelines, the process of performing the extended experimental investigation, information about how and why to keep a journal, the research plan, the draft report checklist, Material Safety Data Sheets, the equipment request form and the risk assessment form. All of these would be necessary to present to and discuss with students before performing the extended experimental investigation.

Bibliographies have not been included with student responses.

No evidence from the student’s journal has been provided.

The given headings in the instrument-specific criteria and standards are the areas in the report where the standards are most likely to be demonstrated. The wording of the standards was not instrument-specific as the given task was an open-ended.

For further information about those aspects of the assessment not explained in this document, please refer to the assessment section of the syllabus.

This sample provides opportunities for students to demonstrate:

- establishing and developing an investigative process
- conducting and managing the investigation
- analysis of data and discussion
- evaluation and concluding
- communication within a report format.

This sample assessment instrument is intended to be a guide to help teachers plan and develop assessment instruments for individual school settings.

Assessment instrument

The student work presented in this sample is in response to an assessment task which is a type of assessment instrument involving students applying and using relevant knowledge and skills to create a response to a problem or issue.

THE TASK

The task you are being asked to complete is to undertake experimental research on a physics concept related to or extending on from the physics topics studied. You will need to discuss your proposal with your teacher. A research plan, an equipment requisition form and a risk assessment form MUST be submitted before commencing work. (Forms to be used for this are attached)

YOUR REPORT - should be structured as shown below. It is to be written in passive voice, past tense.

Title page – subject, assessment task type, title, your name, date, teacher's name.

Abstract

A paragraph, that if read by itself, summarises the project in the least possible words (usually 50 – 200). It should include the aim, principles/techniques employed and a very brief statement of your results and conclusions.

Introduction:

Research Question and Aim you have posed and the Hypothesis to be tested.

The Research Question should obviously be in the form of a question, eg "What factors influence the flight of an arrow? How is the corrosion of a shipwreck influenced by …?

The Aim should be in the form of an explicit statement relating to your variables, eg: "To investigate the effect of (manipulated variable) on (dependent variable) when (controlled variables) are kept constant.

Hypothesis and Justification of hypothesis. The Hypothesis is your predicted outcome of the investigation. It should be in the form: "The relationship between (manipulated variable) and the (dependent variable) is … (appropriate mathematical proportionality stated)".

You will need to justify your hypothesis by referring to relevant scientific (physics) principles from your library research. You will need to reference your sources.

Theory review: This will be used to tell a story that generates interest in the reader for the field of your research and link to the practical investigation to follow. It will draw on your library research and will be referenced.

- Orientation of the reader to the overall design, and the reasons for performing particular steps in the method.

Planning and Preliminary trials:

- Introduction: What values you chose to try for your manipulated variable/s (eg masses of 0.1 kg to 0.8 kg)
- Method: What you did. Diagrams, photos as necessary.
- Results: Presented in appropriate form (tables, graph etc).
- Discussion: Could measurable results be obtained? Could you collect sufficient data?
- You are not expected to make a conclusion about the relationships between variables as outlined
- in the Research Question, Aim and Hypothesis. This is a discussion about the experimental design.

- Conclusion: How the original plan is to be modified in light of the pilot study.

Method.

A description of what was done in the final practical tasks; this includes how raw data is to be treated ie. what formulae are applied. You should do this in the traditional form (a replicable, stepwise description in passive voice, past tense. This applies to all other parts of the report such as discussion and conclusion as well). ‘Replicable’ means that someone else could repeat the experiment by following your method.

Results.

The collected results should be displayed in forms that are appropriate to your data; eg tables, graphs, photos. Calculations such as averages, substitution into equations, gradients, intercepts - and so on - may be shown as necessary. You should show examples of calculations (eg rate of change, solutions concentrations etc) but not all calculations need be shown. All tables, graphs pictures etc should be numbered and given a comprehensive title.

Analysis, Discussion and Interpretation of Data.

You will need to show evidence of critical thinking in interpreting your data in relation to your hypothesis and theory presented in your introduction. This is an opportunity to identify any trends or patterns in your data, examine any mathematical relationships in your data, to critically discuss various aspects of the experiment, such as: what generalisations can be made to support or refute your hypothesis, how the results relate to the theory, the limitations of the result, the method used and possible improvements, which measured quantities limited the accuracy of the result, further related investigations that this experiment could lead to (and why). (NB. Discussions must relate the experimental issues to physics theory.)

Conclusion.

You should state very briefly the essential conclusion or conclusions you have drawn from the experiment. It should satisfy the statement set out in the Aim at the beginning and must clearly address the stated hypothesis. Be sure to include any conditions that apply to your result (eg ‘at constant temperature’). It is important not to overstate what you can rightly claim as a result of the experiment. Statements like ‘the results supported…’ are more justifiable than ‘the results proved…’. You should not introduce any new material in this section.

Bibliography. Guidelines for a bibliography and referencing can be found on the school web page.

Instrument-specific criteria and standards

Schools draw instrument-specific criteria and standards from the syllabus dimensions and exit standards. Schools will make judgments about the match of qualities of student responses with the standards descriptors that are specific to the particular assessment instrument. While all syllabus exit descriptors might not be assessed in a single assessment instrument, across the course of study, opportunities to demonstrate all the syllabus dimensions and standards descriptors must be provided.

The assessment instrument presented in this document provides opportunities for the demonstration of the following criteria:

- establishing, conducting and managing the investigation
- analysis of data and discussion
- evaluation and conclusion
- communication.

This document provides information about how the qualities of student work match the relevant instrument-specific criteria and standards at standards A and C. The standard A and C descriptors are presented below. The complete set of instrument-specific criteria and standards is on page 40.

Establishing, Conducting and managing the investigation		
IP1	Formulation of justified significant questions/hypotheses which inform effective and efficient design, refinement and management of investigations	Formulation of questions and hypotheses to select and manage investigations
IP2	Assessment of risk, safe selection and adaptation of equipment, and appropriate application of technology to gather, record and process valid data	Assessment of risk, safe selection of equipment, and appropriate application of technology to gather and record data
Analysis of data and discussion		
IP3	Systematic analysis of primary and secondary data to identify relationships between patterns, trends, errors and anomalies.	Analysis of primary and secondary data to identify obvious patterns, trends, errors and anomalies.
KCU1	Reproduction and interpretation of complex and challenging concepts, theories and principles	Reproduction of concepts, theories and principles
KCU2	Comparison and explanation of complex concepts, processes and phenomena	Explanation of simple processes and phenomena
KCU3	Linking and application of algorithms, concepts, principles, theories and schema to find solutions in complex and challenging situations.	Application of algorithms, principles, theories and schema to find solutions in simple situations.
Evaluation and conclusion		
EC1	Analyses and evaluates complex scientific interrelationships	Describes scientific interrelationships
EC2	Explore scenarios linked to the research focus, suggesting possible outcomes, and generates justified conclusions/recommendations	Describes scenarios linked to the research focus, suggesting possible outcomes with statements about conclusions and recommendations
Communication		
EC3	Discriminating selection, use and presentation of scientific data and ideas to make meaning accessible to intended audiences through innovative use of range of formats.	Selection, use and presentation of scientific data and ideas to make meaning accessible in range of formats.

Sample student response: Standard A

Standard descriptors	Student response A
	Abstract
	The aim of this experiment was to determine the relationship between cross-sectional area of a conductive surface on the average acceleration at which the magnet descends and to investigate the effect of the changing temperature of the magnet on the average velocity that the magnet descends.
	The experiment was conducted by timing the descent of a magnet down aluminium wedges of different cross-sectional areas, and with the magnet at different temperatures, with the slope at a constant angle, and friction kept constant. It was found that the relationship between cross-sectional area and the average acceleration was $a = \frac{210.05}{A \times 10^{-6}} + 0.399$, which partially supported the hypothesis, and the relationship between the temperature of the magnet and the average acceleration was found to be a=0.009T+0.639, which supported the hypothesis.
	Introduction
Formulates a justified significant researchable question and hypothesis	Research Question: In the situation of a magnet descending down an inclined plane composed of a conductive surface that cannot be magnetized, how will the average acceleration of the descending magnet be affected by the cross-sectional area of the conductive surface it descends down and the temperature of the magnet as it descends?
	Aim: To investigate the relationship between cross-sectional area of the conductive surface on the average acceleration at which the magnet descends and the relationship between the temperature of the magnet on the average velocity that the magnet descends.
	Hypotheses:
	As the cross-sectional area of the conductive material increases; the average velocity at which the magnet descends will decrease in a linear relationship, with acceleration down the plane due to gravity and the force of friction as constants.
	As the temperature of the magnet increases; the average velocity at which the magnet descends will be directly proportional to the square of the temperature of the magnet, with acceleration due to gravity, and friction as constants.
	Justification of Hypothesis:
	Cross-sectional Area:
	The downhill force acting on the magnet is given by
	$F = mg\sin\theta$
	Where F is the force, m is the mass of the magnet, g is acceleration due to gravity and sin0 is the angle of the slope. (Western Washington University, no date)
	And the friction acting on the magnet is given by
	$F = \mu mg\cos\theta$
	(physicsclassroom.com, 2009)
	The movement of the magnet down the slope creates a magnetic field that varies in

Sample student response: Standard A

Linking of algorithms, concepts, principles, theories and schema to find solutions in a complex and challenging situation

strength with time in relation to the aluminium. This results in an electromotive force, creating a potential difference in the material according to Faraday's law of induction:

$$EMF = Bv\ell \sin\theta$$

B is the strength of the magnetic field, v is the relative motion of the conductor and theta is the angle that the conductor cuts the magnetic field. (Nave R, no date)

According to Ohm's Law:

$$EMF = IR$$

EMF is the potential difference generated by the magnet's movement, I is the induced current and R is the resistance in the aluminium.

The resistance of a conductor is given be the equation:

$R = \frac{L\rho}{A}$ where R is the resistance, L is the length , p is the resistivity of the material and A is the cross-sectional area (Nave R, no date).

Therefore, the magnitude of the current in the aluminium is

$$I = \frac{Bv\ell \sin\theta A}{L\rho}$$

According to Lenz's Law, this magnetic field will act on the magnet to cause a force up the slope, as it much opposed the change that created it (ie. the downhill motion of the magnet). (Nave R, no date)

Magnetic fields can exert forces on current carrying conductors according to the law $F = BIL\sin\theta$, where B is the magnetic field of the magnet, I is the current and sin0 is the angle the current cuts the field. As the current-carrying wire does not move, the magnet experiences a reaction force of equal magnitude in the opposite direction. (Calvert J, __).

Therefore, the force that slows the motion of the magnet is given by the equation:

$$F = B\frac{Bv\ell \sin\theta A}{L\rho}\ell \sin\theta$$

.

Newton's second law of motion is that F=ma

Therefore, the acceleration of the magnet down the slope is given by:

$$a = \frac{mg\sin\theta - B\frac{Bv\ell \sin\theta A}{L\rho}\ell \sin\theta - \mu mg\cos\theta}{m}$$

If all but A is kept constant:

$$a = -kA + K$$

Therefore, $a \propto -A$

That is why it is hypothesised that the average acceleration of the magnet down the slope should be negatively directly proportional to the cross-sectional area, with acceleration due to gravity, and friction as constants.

Sample student response: Standard A

Presents ideas and data with discrimination to make meaning accessible to the intended audience

Temperature:

Magnets have a temperature dependency co-efficient (Tco-eff) depending on the material the magnet is made of. For example, the strength of a NdFeB magnet drops by about 12% per degree centigrade rise (magnetman.com, no date) (Ninggang Magnets, no date), up to its maximum operating temperature.

Given this, $B = {}^{-}T_{co-eff} \times T \times B$, where B is the maximum field strength the magnet can produce.

$$a = \frac{mg\sin\theta - {}^{-}T_{co-eff}TB\dfrac{{}^{-}T_{co-eff}TBv\ell\sin\theta A}{L\rho}\ell\sin\theta - \mu mg\cos\theta}{m}$$

If all but T is kept constant:

$$a = K + T^2$$

Therefore, $a \propto T^2$

The composition of the magnet used in this experiment was not known, however, all magnets experience a decrease in magnetic field strength with temperature rises.

That is why it is hypothesised that the average acceleration of the magnet down the slope should be directly proportional to the square of the temperature of the magnet, with acceleration due to gravity, and friction as constants.

Theory Review:

The expected slowing of the magnet as it descends aluminium wedges of different thicknesses and the expected decrease of slowing with the magnet at different temperatures is predicted by the physics concepts of magnetism, magnetic induction and Lenz's law.

Magnetism is an effect created by moving charged particles. In an atom, each atom orbiting around the nucleus creates a magnetic field.

Material removed due to copyright restrictions.

Diagram of the magnetic field created by the movement of electrons around an atom.

In many atoms, depending on the positioning of electrons in shells, the net effect of all the electrons means that there is no overall magnetic field on the atom.

Sample student response: Standard A

Additionally, even in materials made up of atoms with net magnetic fields, on overall magnetic field for the whole material does not exist as an overall magnetic effect is cancelled out as the fields do not align (Brown K, 2009)

Material removed due to copyright restrictions.

The diagram showed an alignment of magnetic domains.

Most substances, like aluminium in this experiment, are classed as diamagnetic. The external magnetic field causes the electrons to orbit around the atom in a specific way, and according to Lenz law, this must be in such a way as to oppose the applied magnetic field, so the substance is slightly repelled by the magnet. (Brown K, 2009)

Comparison and explanation of complex concepts, processes and phenomena

Some substances are paramagnetic. The electrons within each atom of the substance have net magnetic fields, so when exposed to an external magnetic field, the individual atoms fields tend to line up with the applied field, causing an overall attraction. However there is still a diamagnetic effect.(Brown K, 2009)

Other substances, like the magnet in this experiment, are ferromagnetic. This means that in most situations, they have an overall net magnetic dipole field. The magnetic domains of individual atoms line up, and additionally, there is an alignment of the intrinsic spin axes of the individual electrons in each atom, and across the whole material. (Brown K, 2009)

The strength of the magnetic field created by a ferromagnetic substance decreases with temperature. The spin axes of the electrons are believed to align when there is a specific distance between each electron in the shells of each atom. As the temperature rises, electrons move within the atoms, meaning the spins will no longer align, and additionally, the random motion of atoms effects the alignment of magnetic domains and intrinsic spin axes across the entire material (Brown K, 2009). Each ferromagnetic substance has a curie temperature, above which magnetic domains no longer align, and the substance loses its overall magnetic field and will now only act as a paramagnetic substance. (UCLA physics, no date).

When there is a relative motion between a charged particle and a magnetic field, the particle will experience a force perpendicular to both the direction of the field and the motion of the particle, known as the lorentz force (Nave R, no date). Due to this effect, when there is relative motion between an electrically conductive material and a magnetic field, the free electrons will all experience a force in a particular direction, creating a potential difference, and current will then flow when the motion changes. This is known as Faraday's law, and the size of the potential difference created is proportional to the strength of the field, the speed of the relative motion between the field and particle, and the angle that the motion of the particle cuts the field. This then causes current to flow in the conductor, and they flow in circular

Sample student response: Standard A

	patterns, as particles under the influence of a lorentz force more in circles. (NDT Resource Centre, no date) Electric currents also create a magnetic field, which wraps around the current.
Principles have been linked and applied appropriately in the complex and challenging situations linked to the research focus.	Material removed due to copyright restrictions. The diagram showed the magnetic field of a current carrying wire. According to Ampere's law, stronger currents have stronger magnetic fields, and the field strength decreases with distance depending on the magnetic permeability of the substance that surrounds the wire, and as wires have magnetic fields, they experience a force in the presence of a magnetic field. (Nave R, no date) Lenz's Law states that an induced current will flow in such a way that it creates a magnetic field to oppose the magnetic field that created it, which is why the magnetic fields of the eddy currents will oppose the downhill motion of the magnet, which created them. It is related to the conservation of energy in that if the fields accelerated the magnet's movement, the movement would induce larger currents, which would further accelerate the magnet. Therefore, from a low energy input to push the magnet, it would result in a very large energy output from the kinetic energy of the magnet and the joule heating of the conductor, and the magnet would be able to keep accelerating forever from only one push. (Launceston College, no date).
Reproduction and interpretation of complex and challenging theories	Material removed due to copyright restrictions. The diagram showed the magnet is repelled from the end of the magnets, to oppose the increase in magnetic flux as it moves between the magnets, and it is attracted back into the magnets at the other end to oppose the decrease in magnetic flux. Due to Lenz law, the magnet will experience a net force up the slope to opposing the force of gravity pulling it down, and so the magnet should descend the slope more slowly, as the net force downhill has decreased. The source of the braking force on the magnet is a Lorentz force on every charged

Sample student response: Standard A

particle in the magnet up the slope leading to a net uphill force, acting against the downhill motion of the magnet.

Orientation to the overall design:

The overall design of both experiments involved a v-shaped 1 metre long wedge of aluminium (figure 1), being placed against an object to make a constant angle with the floor, thereby ensuring a slope of the same gradient, which was measured with a protractor. A magnet was placed on the aluminium, and after counting to three, it was released, and its descent down the 1m wedge was timed using a stopwatch, and this information was used to find the average acceleration.

Figure 1: the V shaped aluminium wedge set up for the experiment

Refines investigations, manages research tasks effectively

In the first experiment, the manipulated variable was the thickness of the aluminium wedge, and in the second, it was the temperature of the magnet. The chosen values for the manipulated variable of cross-sectional area were 110.04, 341.04, 401.04, 572.04, 632.04 and 863.04mm2. Different areas were made by stacking different combinations of 5 wedges, and these values were the widest variation that could be developed from the limited sizes. The chosen values for the manipulated variables for temperature were room, as this could be easily controlled, and the highest and lowest temperatures found to be obtainable through the water bath system were 2o and 80 o. It was decided to do one below, and above room temperature, which were the 10 o and 56 o trials. For the last trial it was decided to do 30 o.

Aluminium was chosen as the metal for the slope as it is not paramagnetic, a good conductor of electricity and readily available in the required form. A diamagnetic material was required as otherwise, in the presence of the magnet's field, the magnetic domains within the material would have aligned, and it would have become a magnet itself, and the eddy current phenomenon required for this experiment would not have occurred. Low resistance would have increased the magnitude of the eddy currents formed, creating a measurable braking effect.

Assesses and applies risk management procedures related to the investigation and safely selects and adapts equipment.

For the experiment on cross-sectional area, there were a number of controlled variables. The temperature of the magnet and aluminium needed to be constant, as according to the theory discussed earlier, temperature increases decrease the strength of the magnet, and temperature increases will increase the resistivity of the aluminium. This was controlled by conducting all the experiments at room temperature over a period of about 30 minutes, decreasing the possibility for variations in room temperature.

The same aluminium wedge was used as the top of the wedge piles for all different thicknesses and the same side of the magnet was used for each descent, and this would have ensured that the same two surfaces were coming into contact each time, keeping the co-efficient of friction constant, and therefore the force of friction acting on the magnet. Therefore, any slowing could be attributed to a magnetic effect, and not friction changes, as this would also oppose the downhill motion. The size of the eddy current produced is proportional to the speed the magnet moves down the aluminium. Therefore it was important to ensure the acceleration down the slope would be constant. This acceleration is given by a=gsinø, so the angle of the slope needed to be kept constant, using a protractor.

Sample student response: Standard A

	For the temperature experiment, it was important to ensure the magnet remained at the desired temperature over all trials, so this is why the magnet was put back in the water bath after each trial.
	Planning and Preliminary Trials
	Introduction: It was decided to use values for the manipulated variable of cross-sectional area of 110.04mm and 863.04mm. These were the proposed thinnest and thickest values, in order to see if a measurable difference could be obtained between the two. It was decided to use the values for the manipulated variable of temperature of 0 degrees and 100 degrees. These were the proposed hottest and coldest values, in order to see if a difference was apparent between the two.
Gather and record and process valid data	These trials were also used to choose other aspects of experimental design, such as the angle of the slope, the side of the aluminium wedge used, and wether aluminium foil would work. However the methods used to determine these factors were simply based on observations, through trial and error, so no stepwise method is recorded here. Method and Materials Aluminium wedge of dimensions 40mm x 40mm x 1.4mm x 1m (Thin) 2 Aluminium wedges of dimensions 40mm x 40mm x 3mm x 1m (Medium) Aluminium wedge of dimensions 50mm x 50mm x 3mm x 1m (Fat) Bar Magnet of dimensions 9mm x 16mm x 76mm Semi-circle protractor Stopwatch Blu-tack 1. All of the five aluminium wedges were placed on top of each other, with the thinnest wedge as the top surface 2. The wedge was placed against the bench so that it made a V, and an angle of 70 degrees with the floor, which was determined using a protractor
Devises and designs efficient/effective investigations	3. A magnet, that had been marked with a piece of masking tape, was placed on the wedge, and after counting to three, the magnet was released by a person, who simultaneously timed its descent using a stopwatch. 4. Timer watched the end of the wedge at eye-level 5. Results were recorded 6. Steps 2-5 were repeated 9 times for the single thinnest wedge Temperature: 1. All of the five aluminium wedges were placed on top of each other, and they were secured together with masking tape after it was observed that they did not touch properly without it. The thinnest wedge was the top surface 2. The wedge was placed against the bench so that it made a V, and an angle of 70 degrees with the floor, and was secured in place with blu-tack 3. Ice was poured into a plastic bowl with a thermometer and the magnet in it, and one minute was timed with a stopwatch 4. After one minute, the magnet was removed, was placed on the wedge, and after counting to three, the magnet was released by a person, who simultaneously timed its descent using a stopwatch. 5. Timer watched the end of the wedge at eye-level 6. Results were recorded 7. Water boiled from a kettle was placed in a plastic bowl with a thermometer and the magnet in it, and two minutes was timed with a stopwatch 8. Steps 4-6 were repeated 9 times, then step 7 was repeated

Sample student response: Standard A

Selects, adapts and applies technology to gather and record and process valid data

Results

Cross-sectional Area:

Cross Sectional Area (m)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
110.04	1.87	1.19	1.38	1.29	1.57	1.46
863.04	0.7	0.6	0.53	0.8	0.84	0.694

Temperat ure	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
2	1.31	1.33	1.21	1.20	1.18	1.25
80	0.85	0.79	0.82	0.91	0.90	0.85

Discussion:

Although not included in the method, a few trials were conducted using aluminium foil wrapped around a plank, but this was abandoned as no effect could be observed, and there were lots of bumps in the aluminium, and the magnet got sometimes stuck behind bumps and didn't move at all.

Refines the investigation and adapts the equipment

It was decided to use v-shaped planks of aluminium, and by trying out a range of different angles and observing the descent of the magnet, it was decided that 70 degrees appeared to cause the slowest descent. However no actual times were recorded. It was decided that the planks could not be placed flat, but had to be placed so that they made a V, as otherwise the magnet would often flip off the side. Blu-tack was very useful in holding the plank in position. It was decided to base the rest of the experiments on using the planks so that they made a V, and an angle of 70 degrees with the floor.

In order to see if an observable difference would appear in the area results, it was decided to test the thinnest and thickest thicknesses and see if there was a significant difference between the time taken to descend. There were 5 different planks of different widths, and they all had to be stacked together to make the largest thickness. It was found that it was difficult to keep the planks together, and it was decided that masking tape was quite effective for this, although care had to be taken that it didn't impede the descent of the magnet. This allowed the wedge to remain stable and helped ensure all parts of the metal were touching so that the whole thickness would be available to conduct electricity, as whilst currents might still form independently in each layer, the hypothesis for this experiment required one conductive thickness in order to decrease resistance to current flow, and increase current size and therefore the braking effect.

All of these changes were implemented before the results for preliminary trials were recorded. It was also decided to put a piece of tape of the magnet for the side that would touch the plank because it was difficult to remember which side of the magnet was used.

Sample student response: Standard A

Refines the investigation and adapts the equipment	It was decided that for temperature, there would be an aim of a temperature to reach, before the magnet was put in the water, but the temperature of the water bath would be taken after the two minutes, and this would be considered the temperature of the magnet, as the temperature continued to drop over the two minutes by a margin that was felt too large to ignore. The values of 100o or 0 o were found to be unachievable with the time and material constraints. 100 o was not reached by the kettle used, and the ice never cooled the water below 0 o. The magnet could have been left in the freezer for a long period of time, but this was not possible due to time constraints. It was observed, by holding the magnet that it became hotter, or colder very quickly, so it was decided that it needed to be replaced in a hot or cold-water bath after each trial, or the experiment would not be well controlled. It was found that one person could easily both time and release the magnet, whilst also watching for where it stopped at eye level, and this may have possibly reduced the impact of reaction times, as the timekeeper knew exactly when the magnet was released. Times were found to be very small, and the differences between the largest and smallest values for the manipulated variables, whilst observable, were also quite small, so it was decided that 9 trails were needed to help decrease the effect of error due to reaction times and human error. Conclusion A number of important changes were made to the experiment design based on preliminary trials. Firstly, the idea of aluminium foil and planks was abandoned for the store-bought aluminium wedges. It was also decided that the planks would be placed as a “V” against the wall, and would be secured with blu-tack, and placed at a slope of 70 degrees, and that the same person would time and release the magnet, and 9 trials would be conducted. For the area experiment, it was decided to tape the wedges together with masking tape so that they were totally in contact, and for the temperature experiment, it was decided that the magnet needed to be heated up after each of the nine trials, and that simply the highest achievable and lowest achievable temperatures would be used as opposed to 0 and 100 degrees, which were found to be too difficult to achieve. Final Method Materials: As previous experiment Thickness 1. 1 thin Aluminium wedge of dimensions 40mm x 40mmx1.4mm x 1m was placed against a ledge. A protractor was used to ensure that the angle between the floor and the wedge was 70 degrees 2. Blu-tack was placed either side of the wedge to secure it. 3. A magnet, that had been marked with a piece of masking tape, was placed on the wedge, and after counting to three, the magnet was released by a person, who simultaneously timed its descent using a stopwatch, and watched the end of the wedge at eye level. 4. Results were recorded 5. Steps 1-5 were repeated 9 times

Sample student response: Standard A

Selects, adapts and applies technology to gather and record valid data

6. The next thickness wedge was constructed by stacking the thin and medium wedges together, whilst ensuring the thinnest always remained the top layer
7. Masking tape was wrapped around the top, middle and bottom of the aluminium wedges
8. Steps 1-6 were repeated
9. Steps 7-8 were repeated using the thin and fat wedges, the thin, and two medium wedges, the thin, medium and fat wedges and the thin, two medium and fat wedges.
10. Using the recorded data, an average velocity was calculated using the equation v=d/t, and an average acceleration was calculated using the equation v=u+at, given u=0m/s.

Temperature

Materials

As previous experiment
500mL of water

1. The wedge was constructed by stacking all of the wedges together, with the thinnest as the top layer
2. Masking tape was wrapped around the top, middle and bottom of the aluminium wedges
3. 500mL of water was heated until the kettle switched off, and poured into a glass bowl, with a thermometer, and left to cool until the desired temperature was reached (86 degrees)
4. The magnet was immersed in the water for two minutes, which was timed with the stopwatch
5. A magnet, that had been marked with a piece of masking tape, was placed on the wedge, and after counting to three, the magnet was released by a person, who simultaneously timed its descent using a stopwatch. The timer watched the end of the wedge at eye level.
6. Step 3-5 were repeated 9 times, and all results were recorded
7. Steps 3- 6 were repeated for the 500 C and 300 C
8. Step 5 was repeated for room temperature
9. A bowlful (approx. 500g), of ice was placed in a glass bowl, with a small amount of water (approx. 20mL), and a thermometer
10. When the temperature stabilised at the lowest temperature, the magnet was added to the bowl for 2 minutes, which was timed with a stopwatch
11. Steps 5-6 were repeated once
12. Steps 10 and 11 were repeated, but the magnet was not added until the temperature stabilised at 10 degrees.
13. Steps 5-6 were repeated once
14. Using the recorded data, an average velocity was calculated using the equation v=d/t, and an average acceleration was calculated using the equation v=u+at, given u=0m/s.

Sample student response: Standard A

Tables display relationships between patterns in the data.

Graphs display relationships between patterns and trends in the data.

Results (only averages have been included for brevity)

Table 1: Results from the experiment to find the relationship between the cross-sectional area and the acceleration of the magnet

Cross-sectional Area	Time	Difference from average	Average Acceleration
110.04mm2			
Average	0.661	0.11	2.325
341.04mm2			
Average	0.967	0.024	1.073
401.04mm2			
Average	1.002222222	0.009	0.996
572.04 mm2			
Average	1.113	0.017	0.808
632.04 mm2			
Average	1.186	0.1433	0.712
863.04 mm2			
Average	1.349	0.013	0.550

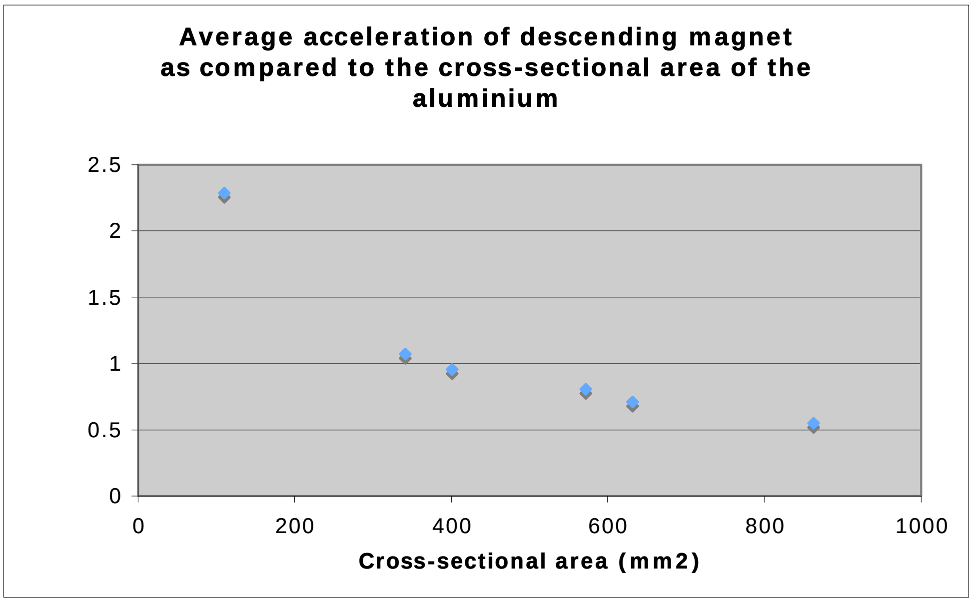


Figure 6: Graph of the average acceleration of the descending magnet as compared to the cross-sectional area of the aluminium.

Sample student response: Standard A

Table 2: Results from the experiment to find the relationship between the temperature of the magnet and the average acceleration

Temperature in degrees C	Time	Difference from average	Average Acceleration
2			
Average	1.224	0.027	0.668
10			
Average	1.217	0.019	0.676
21			
Average	1.142	0.076	0.775
30			
Average	1.12	0.033	0.800
56			
Average	0.864	0.028	1.344
80			
Average	0.898	0.033	1.249

Graphs display relationships between patterns and trends in the data.

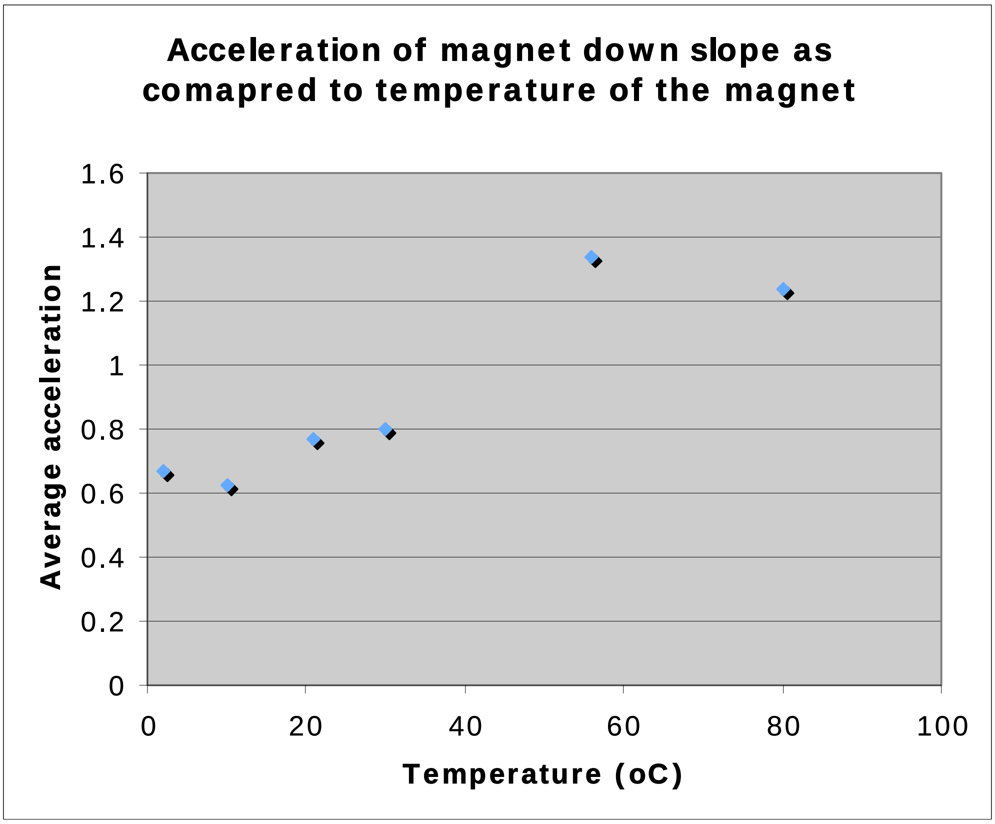
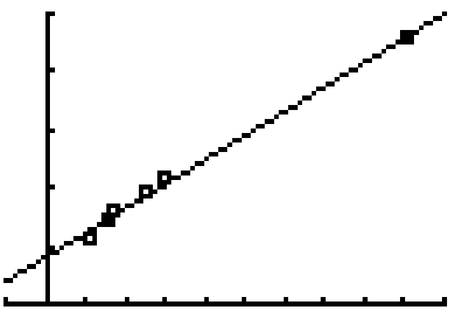


Figure 7: Av acceleration of the descending magnet as compared to the temperature

Sample student response: Standard A

Linking and application of algorithms	Percentage Variation from mean: $\% variation = \frac{trial}{mean} \times 100$ Sample Calculations: Average Acceleration v=d/t (70deg. downhill) v=u+at and as u=0m/s Therefore, v=at *Therefore* $\frac{d \div t}{t} = a$ Eg. For 2 degrees, trial 1: $\frac{1 \div 1.2}{1.2} = a$ $a = 0.6845 m/s/s$ Average Acceleration for each trial: $Av.a = \frac{sum \text{ of results}}{9}$ $Eg.$ Trial 110.04mm $\text{Av.a} = \frac{0.65 + 0.6 + 0.63 + 0.77 + 0.6 + 0.7 + 0.65 + 0.68 + 0.67}{9}$ $= 0.661$ Determining the Relationships: From Figure 6, the relationship between cross-sectional area and average acceleration appears to be an inverse relationship. To confirm relationship: 

Sample student response: Standard A

Figure 8: Graph of a vs. 1/A

As this graph shows a linear relationship, the data does fit an inverse proportion relationship.

Using regression facility, the equation of this line is a=210.05 Ax 10 +0.399

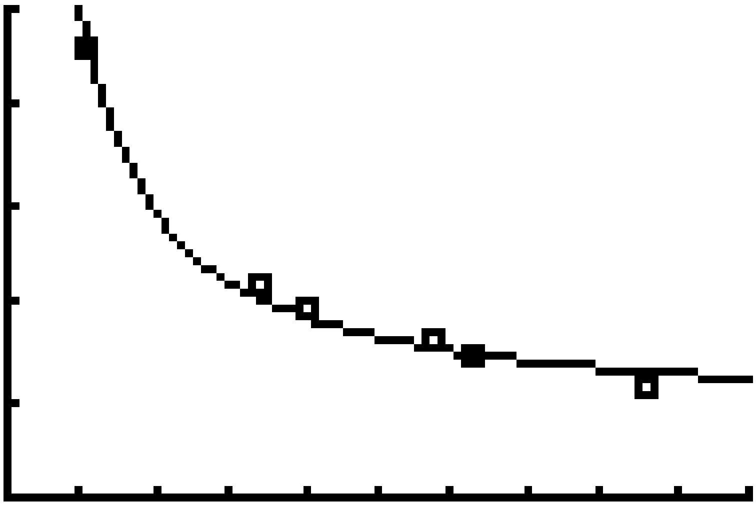


Figure 9: Graph of original data with the developed relationship

Graphs display relationships between patterns and trends in the data.

Developing relationship for temperature experiment:

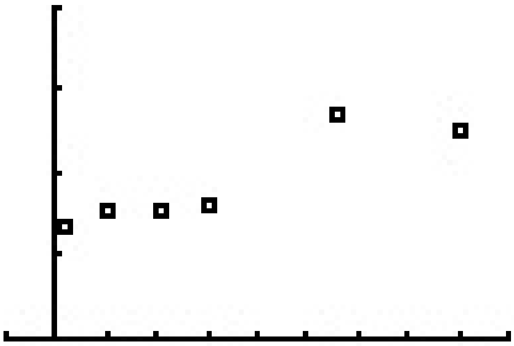


Figure 10: Graph of Temperature as compared to average acceleration

There is not a very strong trend, and the results could be linear or quadratic

Systematic analysis of data to identify relationships between errors and anomalies

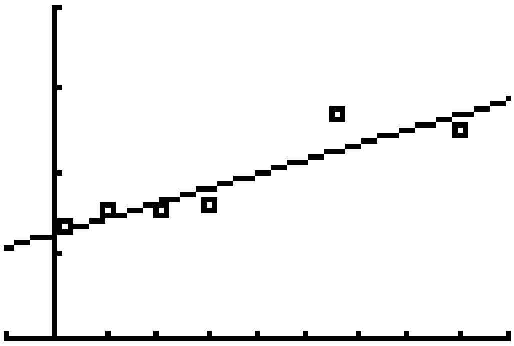


Figure 11: Graph of results with the developed relationship

Sample student response: Standard A

Using a regression facility, the relationship was found to be a=0.009T+0.639

This had a r value of 0.8346

Developing a square relationship:

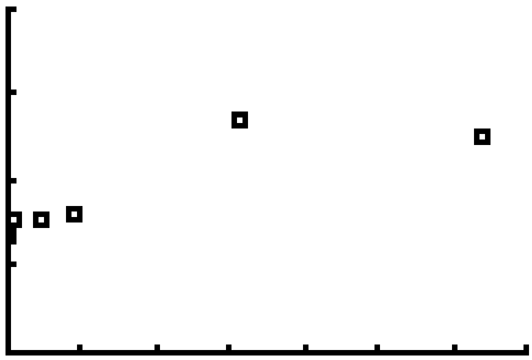


Figure 12: Graph of a vs. T

As this graph is a straight line, the data also fits a square relationship, and using the regression facility, the equation of the line is a=9.8x10 T +0.7533.

The r value is only 0.7397, therefore, the original linear relationship was a better fit for the data

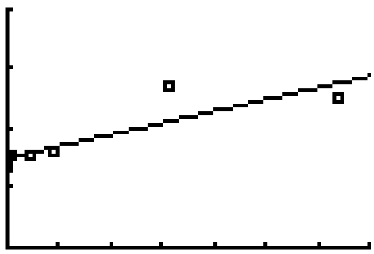
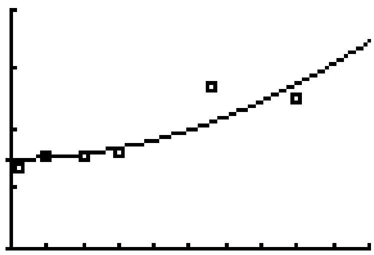


Figure 13: Graph of a vs. T with line

Figure 14: Graph of a vs. T with square relationship



The better fit for the data appeared to be the linear relationship of a=0.009T+0.639

Sample student response: Standard A

Systematic analysis of primary data to identify relationships between patterns, trends, errors and anomalies	Analysis Discussion and Interpretation of Data The results from the experiment to determine the relationship between the cross-sectional area of the aluminium wedge and the average acceleration of the magnet downhill found an inverse proportion relationship of $a = \frac{210.05}{A \times 10^{-6}} + 0.399$. This partially supported the hypothesis as area increased as acceleration decreased, however it did not show the predicted negative direct proportion relationship. The 1104.04mm trial was mainly responsible for the inverse relationship, as it was much higher than the rest of the data, however its average was in fact lowered by a large anomaly in trial 4, which was a time 16.46% greater than the mean, lowering the overall average. Trials 2 and 5 seemed very fast in comparison to the rest of the data, 9.09% below the average. These could have been due to timing errors, or other problems in experimental design as discussed later, but the combined effects of all these anomalies probably didn't affect the trend development or average greatly. All other trails were relatively consistent. Decreases in acceleration due to increases in cross-sectional area were expected by theory, as there is less resistance in conductors of larger cross-sectional areas. The movement of the magnet down the slope induced potential differences, and when the resistance was lower, currents of greater magnitude flowed. Larger currents produced stronger magnetic fields according to Ampere's law, and according to Lenz' law, the magnetic fields of the magnet and the current must interact so that the phenomenon that induced the current in the aluminium is opposed. This manifests as a braking force uphill, as the current is induced by the downhill movement of the magnet. By increasing the cross-sectional area, the magnetic field of the current is increased, and therefore, the uphill braking force experienced by the magnet would be larger, resulting in a smaller net force downhill, and therefore decreasing the average downhill acceleration.
Discussion related to errors and anomalies	Measured quantities would have contributed to error in the results. It is very likely that error existed in the recorded times, due to human error and reaction times, as it is likely that the stopwatch was not pressed exactly as the magnet was released, nor exactly when it reached the ground. The angle of the slope may not have been constant throughout all experiments, due to human error in measuring it with a protractor. This would have changed the initial acceleration of the magnet down the slope over the trials, changing the size of the initial braking force, as eddy current formation is dependant on the speed of the relative motion between the magnet and the aluminium. The cross-sectional areas of the wedges were calculated using information from the manufacturer, and therefore, the accuracy of these numbers would have affected the results. There were also a number of problems in the experimental design that may have contributed to errors. It was observed that when multiple wedges were used at once to make the larger thicknesses, the metal wedges did not stay in contact perfectly along the whole length of the wedge. The theory used to predict the negative direct proportion relationship required a constant cross-sectional area in order to uniformly reduce resistance in the wedge. This was not achieved in this experiment, which would have influenced the data as resistance would have been altered by a factor other than area. The effects of this may have been seen in the results, as the 110.04mm trial was the only one that could not have been affected by this, and it was greatly different from the trend of the rest of the data, creating an inverse

Sample student response: Standard A

	relationship. In the future, it would be better to use different wedges made of different thicknesses, as opposed to constructing them, to eliminate this problem.
Refinement of the investigation	Resistance in the aluminium would also be dependant on the temperature of the aluminium. As temperature increases, the random motion of atoms within the metal increases, and therefore there are more collisions between the atoms and the moving electrons, which increases the resistance, by decreasing the ability of current to flow. Due to the eddy currents, the metal would be subject to joule heating, which would increase the temperature of the aluminium. The currents were of a small magnitude, for a short time, so the small amount of heat produced may have been lost quickly to the surrounds, therefore not affecting the results. Additionally, no trend was apparent that trails became successively faster due to increased resistance. However, if this effect were able to alter the temperature of the aluminium, temperature would not have been constant over all trials, as different sized currents would have been induced in the different areas, affecting the resistance in the aluminium, and therefore the magnitude of the braking force. In the future, it would be better to leave a larger period of time (a minute for example), between each trial to ensure this did not occur, instead of performing them in quick succession.
	The results from the experiment to determine the relationship between the magnet's temperature and average acceleration found that a=0.009T+0.639. This supported the partially supported the hypothesis, because as temperature increased, acceleration increased, but it was found to be directly proportional instead of proportional to the square of the temperature. However, there was not a strong linear correlation in the data. The 56 o trial seemed overly high, but there was a high level of precision in these results. It is more likely that the 80 o trial was too low, as it was affected by an anomaly in trial 3 which differed from the average time by 11.36%, possibly due to poor timing or temperature control. The 21o trial had a very low precision, and the average was lowered by anomalies in trials 1 and 3, which were lower than the average by 5.07% and 13.85% respectively. This was probably due to timing errors.
Explores scenarios linked to the research focus suggesting possible outcomes, and generates justified conclusions and recommendations	Increases in acceleration caused by increases in temperature were expected by theory, as there is the magnetic field strength of a magnet decreases with temperature. The increased kinetic energy of the material caused an increase in the random motion of the electrons and atoms, negatively impacting on the alignment of magnetic domains, and electron spin axes across the material, decreasing the strength of the magnetic field. The hotter, weaker magnets therefore induced weaker currents, according to Faraday's law, and these weaker currents produced weaker magnetic fields, according to ampere's law, and therefore, the braking force on the magnet was smaller, as each charged particle in the magnet would experience a smaller lorentz force, and therefore, the downhill acceleration would be faster as compared to a stronger magnet.
Discussion of errors and anomalies	Error in this experiment would have existed in the same measured values as in the area experiment; however, it would have also existed in the temperatures recorded. It is likely there was human error in reading temperatures and the results were limited to 1 decimal place by the thermometer used. Also, the magnet would not have been at the exact temperature recorded before it was removed from the water bath, and would not have remained constant, as heat was continually lost to, or absorbed from the surroundings. The magnet would have moved closer to room temperature the longer it was taken out of the water bath for, and therefore the

Sample student response: Standard A

	magnetic field of the magnet would have also changed. It is also possible that 2 minutes in the water bath was not long enough to alter the entire magnet's temperature, and atoms in the centre of the magnet would not have had the alignment of magnetic domain and intrinsic spin axes altered by the temperature change, so the magnetic field would not have been altered to the extent predicted. In the future, it would be better to expose the magnet to the desired temperature for longer.
Explores scenarios linked to the research focus suggesting possible outcomes, and generates justified conclusions and recommendations	Additionally, the increased temperature of the magnet may have changed the co-efficient of friction between trials, affecting the results. For both experiments, there was a poor choice in values for the manipulated variable. For area, there was not an even spacing between data points. Some of the points were very close together (eg. 341.04 and 401.04, and 572.04 and 632.04), so the results for acceleration were very similar, making it difficult to develop a relationship. The comparatively large difference between the points of 110.04 and 341.04 may have contributed to the development of a inverse relationship, as opposed to linear. Although it seemed much higher than the general trend of the data, the lack of data in between these two values meant it was not possible to decide wether this trial was an anomaly or not, and there was no information about how the relationship may have developed between these two points. In the future, it would be better to use a much greater range of thicknesses, with an even distance between each data point. In this experiment, the cost and availability of materials made that difficult. There were similar problems in the temperature experiment. Temperatures could only be tested over a small domain (from 2 to 80 degrees), due to the limitations of using a water bath to change temperatures. In the future it would be much better to try to use a greater range of temperatures. Once again, there were uneven distances between data points, with many more trials of lower values than higher values, and this may have affected trend development, as whilst a linear trend was very clear in low values, it was difficult to determine the trend over higher values, and therefore difficult to develop an appropriate relationship. It would have been preferable to have even distances between data points. Additionally, both experiments could have been conducted on a longer ramp, so that the times would be longer, helping reduce the effect of timing errors on results, and copper would be better to use than aluminium, as copper has a lower resistivity, and larger current could flow, so the effect would be larger, and a stronger magnet, which would also make a larger current flow. Both these changes would make effects more measurable. For both experiments, it was stated that the relative motion between the aluminium and the magnet needed to be constant. Even though the magnet started at a constant acceleration, a braking force would have been experienced, the magnet would slow, and then a braking force of a different magnitude would be experienced, so the velocity and acceleration would be constantly changing, until the braking force and downward force were balanced and the object reached terminal velocity (Batten G, no date). In these experiments, the velocity would have definitely fluctuated for some of the descent, even if a terminal velocity were reached. In the future, it may be better to allow the magnet to slide for a bit until it has reached terminal velocity before timing begins, and calculate the average velocity instead of acceleration.

It would also be better to wipe the surface down after each trial, to help keep the surface clean and therefore friction constant. Sometimes the magnet appeared to become stuck on something, which was possibly sticky glue from the masking tape.

Possible future experiments could include investigating the other factors that affect magnetic braking, such as the changing the material the conductor was made of, changing the temperature of the conducting material, or making slits along the conducting material to stop currents from forming, or using magnets of different strengths.

Conclusion

The relationship between the cross-sectional area and the average acceleration of the magnet was found to be $a = \frac{210.05}{A \times 10^{-6}} + 0.399$, when the temperature for both the magnet and aluminium, friction and initial acceleration were constant. This result partially supported the hypothesis, as a negative direct proportion relationship was predicted. The relationship between the temperature of the magnet and the average acceleration of the magnet was found to be a=0.009T+0.639, when the friction, temperature of aluminium and initial acceleration were kept constant, which supported the hypothesis.

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Standard C

Standard descriptors	Student response C
	Abstract The aim of the investigation was to find how the volume (L) of the balloon will affect the rate of deflation (mLs per second). It was hypothesised that as volume increased the average rate of deflation would increase, due to a loss of elastic potential energy of the rubber of the balloon from over-stretching it, forcing the air out at a slower rate. The hypothesis was tested by collecting results for the time taken for balloons of different sizes to deflate, while temperature and external pressure were kept constant, and the volume of the balloons water displacement method at the start of deflation. From these results the rate of deflation (mLs per second) was calculated. It was concluded that as volume increased, the rate of deflation (mLs per second) decreased in proportion to $\frac{160}{volume}$.
	Introduction
Formulates researchable questions	**Research question** *What is the effect of the volume of a balloon on its rate of deflation?* **Aim** The aim is to find the relationship between the volume of a balloon and the rate of deflation, being the volume (L) of air per second, when punctured.
Formulates an hypothesis	**Hypothesis** It is hypothesised that as the volume of the balloon increases within the parameters of 3.8-6.9L, the rate of deflation (mLs per second) will decrease, while temperature and external pressure are kept constant.
	Background theory **Kinetic theory** All atoms carry a charge, these charges repel and attract and depending on the magnitude of these forces, matter will be a solid, liquid or gas.
Explanation of simple processes and phenomena	Air is a gas due to weak intermolecular forces of the air particles at room temperature. The forces will not hold them together as a liquid or gas. Air particles are free-moving and when molecules collide with each other at different velocities they are forced apart, resulting in an increase in volume. This is what causes pressure and in the case of a balloon will force the walls out causing the volume to increase.
Reproduces theories	When amount, or number of particles in a given space, measured in moles, remains constant and volume increases, pressure will decrease. When amount remains constant and volume decreases, pressure will increase. When amount increases, volume remains constant, pressure increases. Therefore when volume and temperature are kept constant and the moles increases, the pressure will increase.

Standard C

Presents scientific ideas to make meaning accessible to the intended audience	These rules are justified by the combined gas law $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ The pressure build up in balloons is due to more air particles being pumped into the balloon, because the rubber of the balloon can stretch, it will compensate for this pressure so it can 'level out'. Therefore the pressure inside a balloon will remain constant as it is inflated. As volume increases, elastic potential energy of balloon increases (increased rate of air loss) As a balloon is inflated, the time taken to deflate will increase, due to the fact that there is more air to lose. Pressure of the air inside the balloon will remain constant due to the fact that as the moles increases with each pump, the balloon will stretch due to its elastic ability, increasing the volume, meaning the air pressure inside the balloon will remain constant. Pressure will begin to increase as the balloon approaches its stretching tether, because the volume will not be big enough and the particles will be closer to each other than they desire to and consequently the pressure will increase (when moles increases and volume remains constant, or in this case doesn't increase enough, the pressure will increase). **Elastic theory** The molecular structure of rubber means that when deformed it will retract to its original form due to restorative force. Restorative force is due to elastic and viscous elements. Balloons are made of rubber which stretches; they hold their shape when air is blow into them because pressure forced out by the air is held in by the balloons skin pushing back on it. When a hole is created, the air will escape and the pressure of the outside outweighing the pressure which has been lost in the inside and will consequently deflate. Because balloons are stretched beyond the rubbers normal range of motion, the structure of the rubber will be changed so consequently the retracting force of the balloon is weakened. This becomes more obvious when a balloon deflates to a smaller size after being blown up; the skin is rather weak and thin and it does not have the same level f elasticity as a balloon which has not been blown up as much. For this reason the average rate of deflation of a balloon that has been deflated the most will be lower than that of a balloon that has not been inflated as much **Hypothesis justification** Using the background information, it can be suggested that the key reason that the rate of deflation decreases as the starting volume increases, is that the rubber of the balloon is stretched, this stretching results in an increase in the elastic potential energy of the balloon, which is the stored energy of a material as a result of the deformation of an elastic material,. When rubber is stretched, the elastic potential energy increases, however the stretching of the rubber means it looses some of its ability to deflate back to its original size, more prevalent when the balloon gets smaller and the rate at which it deflates slows down.

Standard C

Manages the investigation

Safe selection of equipment and uses technology to gather and record data

Assesses risk and safely selects equipment

Experimental design

The hypothesis was tested by inflating balloons with the following number of pumps of a foot pump: 5, 10, 15, 20, and 25.

The volume of the balloons was found using the water displacement method, where the balloons were immersed in the water and the difference in litres from the before the balloon was immersed and while it was immersed was calculated. This value corresponded with the volume of the balloon immersed. The volume of the balloon was dependant on the number of pumps pumped into the balloon.

The following constants were kept through out the experiment

- Same type of balloons i.e. same brand and size
- Balloons were always un-used
- Same temperature i.e. same temperature and external pressure

The time of deflation was then calculated by inflating balloons with the following number of pumps of a foot pump: 5, 10, 15, 20, and 25

These two results were combined by dividing the starting volume in mLs of the balloon by the time in seconds of deflation to find the average rate of deflation of each volume of balloon.

Planning and Preliminary trials

The aim of the preliminary trials was to determine:

- How best to attach the balloon to the pump to ensure minimum air loss.
- Which pump to use for inflating the balloon
- How time affected the time of deflation as volume increased, how pressure altered as volume increased, if does vary, we will test with volume, and if it does vary we may test with pressure.
- How the pressure was altered during the inflation of a balloon and whether the time

Method

Balloons were pumped with the 5, 10, 15, 25 pumps of the foot pump by stretching the balloon neck over a rubber stopper with a hole drilled in it. The needle of the foot pump matched the diameter of the drilled hole. The balloon was then pricked with a needle.

Results of preliminary trials

Time taken for deflation of balloon when inflated with number of pumps

Number of Pumps	Time (s)
5	22
10	56
15	105
25	336

The pressure on the dial was noted to not change after initially being pumped or turned on.

Standard C

Discussion and conclusions made from the preliminary trials

The first clear relation ship found from the preliminary trials was that as the number of pumps increased, the time taken increased.
Initially it was thought that as the volume of air being pumped inside the balloon was being increased, the pressure would increase and the elastic potential energy of the balloon skin would increase due to that. However because the rubber stretched, the air pressure inside the balloons was found to be constant (from the pressure reading of the electric pump), therefore the volume became the independent variable. The amount of air being pumped inside the balloon increased the volume of the balloon and the elastic potential energy.
Using the electric pump it was found that pressure did not vary beyond the initial increase when the pump was first pumped or turned on.
The electric pump did not display what volume of air was being pumped into it, for this reason a foot pump was selected where the volume could be calculated.
Due to air loss when the pump was stretched only over the rubber stopper, a rubber band was introduced to fasten the neck of the balloon.
It was also decided that the neck of the balloon was to be stretched over the rubber stopper so the narrower end of the stopper faced outwards to ensure a more secure fit.
To deflate the balloon, pricking the balloon proved an inaccurate and method. For this reason it was decided that removing the needle from the rubber stopper was the best method to create a hole for air to escape from.
When the volume of the balloons was found by immersing them in water, the rubber tended to shrivel and not be as elastic, for this reason we decided to fond the volume with separate balloons to that of the ones used in the timing of the trial.

Planning and Preliminary trials

The aim of the preliminary trials was to determine:

- How best to attach the balloon to the pump to ensure minimum air loss.
- Which pump to use for inflating the balloon
- How time affected the time of deflation as volume increased, how pressure altered as volume increased, if does vary, we will test with volume, and if it does vary we may test with pressure.
- How the pressure was altered during the inflation of a balloon and whether the time

Method

Application of technology to gather and record data

Balloons were pumped with the 5, 10, 15, 25 pumps of the foot pump by stretching the balloon neck over a rubber stopper with a hole drilled in it. The needle of the foot pump matched the diameter of the drilled hole. The balloon was then pricked with a needle.

Results of preliminary trials

Time taken for deflation of balloon when inflated with number of pumps

Number of Pumps	Time (s)
5	22
10	56
15	105
25	336

Manages investigation	The pressure on the dial was noted to not change after initially being pumped or turned on. **Discussion and conclusions made from the preliminary trials** The first clear relation ship found from the preliminary trials was that as the number of pumps increased, the time taken increased. Initially it was thought that as the volume of air being pumped inside the balloon was being increased, the pressure would increase and the elastic potential energy of the balloon skin would increase due to that. However because the rubber stretched, the air pressure inside the balloons was found to be constant (from the pressure reading of the electric pump), therefore the volume became the independent variable. The amount of air being pumped inside the balloon increased the volume of the balloon and the elastic potential energy. Using the electric pump it was found that pressure did not vary beyond the initial increase when the pump was first pumped or turned on. The electric pump did not display what volume of air was being pumped into it, for this reason a foot pump was selected where the volume could be calculated. Due to air loss when the pump was stretched only over the rubber stopper, a rubber band was introduced to fasten the neck of the balloon. It was also decided that the neck of the balloon was to be stretched over the rubber stopper so the narrower end of the stopper faced outwards to ensure a more secure fit. To deflate the balloon, pricking the balloon proved an inaccurate and method. For this reason it was decided that removing the needle from the rubber stopper was the best method to create a hole for air to escape from. When the volume of the balloons was found by immersing them in water, the rubber tended to shrivel and not be as elastic, for this reason we decided to fond the volume with separate balloons to that of the ones used in the timing of the trial. **Method** **Experiment 1: Finding the volume of balloons** **Materials** • 20 un-used Balloons • Foot pump • Needle for pump • Rubber stopper (cm diameter) with hole drilled in it the same diameter as the needle • Stanley knife • 10L Bucket. • Permanent marker • Rubber band **Method** 1. Using a 500mL measuring cylinder, the bucket was filled with 3L of water. This point was marked and labelled on the outside of the bucket.

2. Using the 500mL measuring cylinder, points from 3L – 8L was marked with every 0.5L.
3. The bucket was then emptied to 3L.
4. 0.5cm was cut back from the smaller end of the (cm) rubber stopper with the Stanley knife.
5. A (mm) hole was drilled through the centre of the rubber stopper.
6. The ambient temperature was recorded.
7. A balloon was stretched over the larger end of the stopper and secured with a rubber band.
8. The needle was inserted through the hole in the stopper at the smaller end.
9. The balloon was inflated with 5 pumps of the foot pump.
10. The balloon was placed in the bucket containing the three litres of water so that it was completely submerged up to where it joins with the stopper.
11. The water level reading was recorded.
12. The volume of the balloon was calculated by subtracting three litres from the recorded volume.
13. Steps 7-12 were repeated for 3 trials with new balloons.
14. Steps 7-13 were then repeated for balloons inflated with 10, 15, 20, 25 pumps.

Experiment 2: Finding the time for deflation

Materials

As previous experiment

Method

1. A balloon was inflated with 5 pumps of the foot pump in the same manner as steps 7-9 in experiment 1.
2. The needle was gently pulled out of the rubber stopper.
3. The stopwatch was started from the time when the needle was removed and stopped when air could no longer be detected, through sound and touch, as escaping from the hole. The time was recorded.
4. Steps 1-3 were then repeated for five trials.

Steps 1-4 were the repeated for 10, 15, 20, 25 pumps.

Results

Ambient Temperature on the day of testing 6/05/09 was **22.2˚C**

Recorded results

Volume of balloon for number of pumps

Tables identify obvious patterns in the data

Number of Pumps	Trial 1 (L)	Trial 2 (L)	Trial 3 (L)	av
5	3.8	3.7	3.8	3.8
10	4.7	4.7	4.7	4.7
15	5.5	5.5	5.5	5.5
20	6.2	6.3	6.1	6.2
25	6.9	6.9	7.0	6.9

Time of deflation of balloon for number of pumps

Number of Pumps	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)	Trial 4 (s)	Trial 5 (s)	Av (s)
5	24.10	25.30	25.38	24.84	24.83	24.89
10	63.34	62.28	67.59	62.03	65.09	64.07
15	113.28	105.65	107.37	108.23	112.69	109.44
20	176.28	166.26	173.40	179.54	170.15	173.13
25	252.41	259.76	258.27	244.92	249.70	253.01

Average time of deflation for volume, found using average volume for number of pumps and average time for that number of pumps

volume	time
3.8	24.89
4.7	64.07
5.5	109.44
6.2	173.13
6.9	253.01

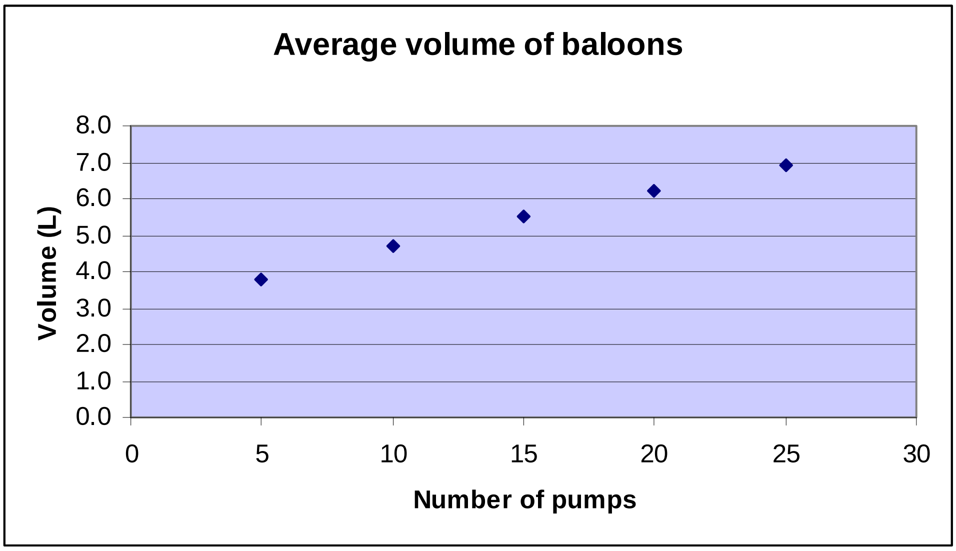
Average rate of deflation (mLs per second) found using average volume for number of pumps and average time for that volume

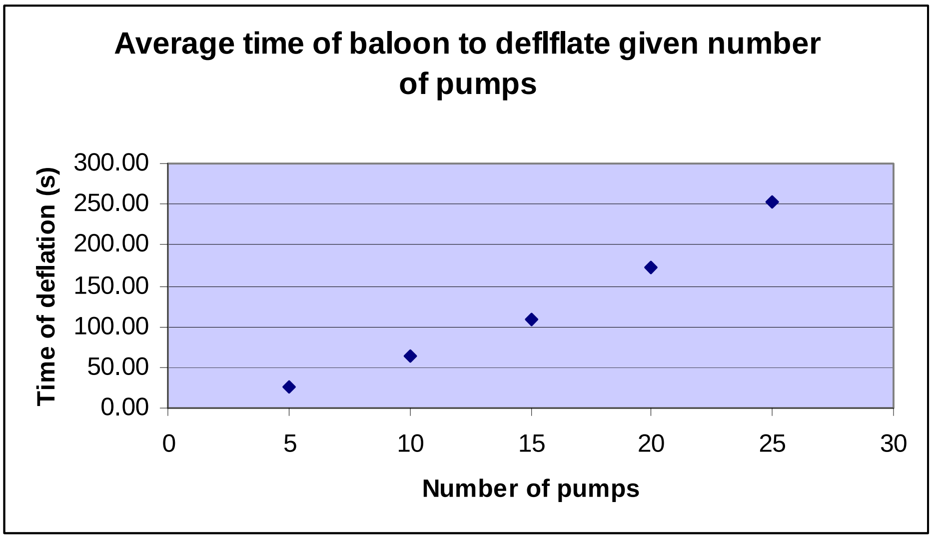
volume	rate
3.8	152.67
4.7	73.36
5.5	50.26
6.2	35.81
6.9	27.27

Standard C

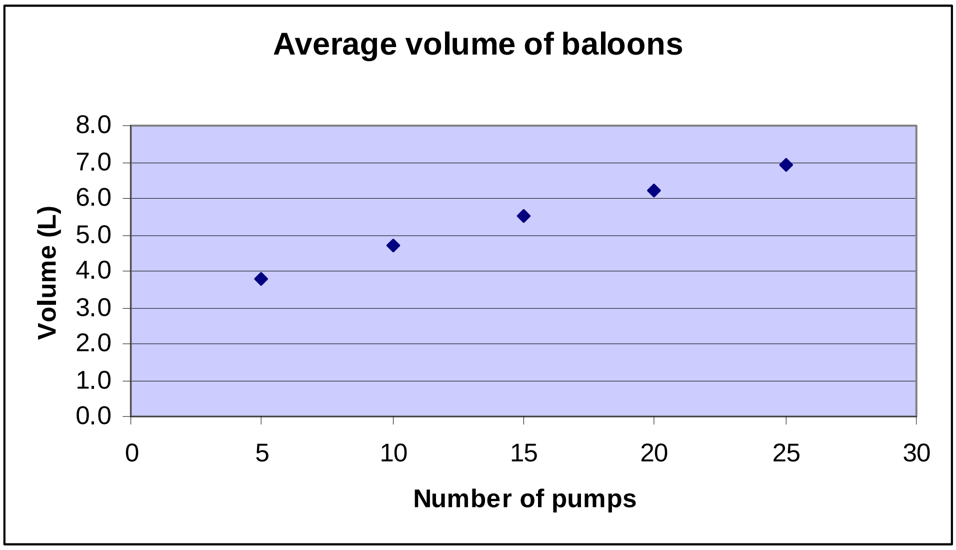
Graphs identify obvious patterns in the data

Graphs of data recorded

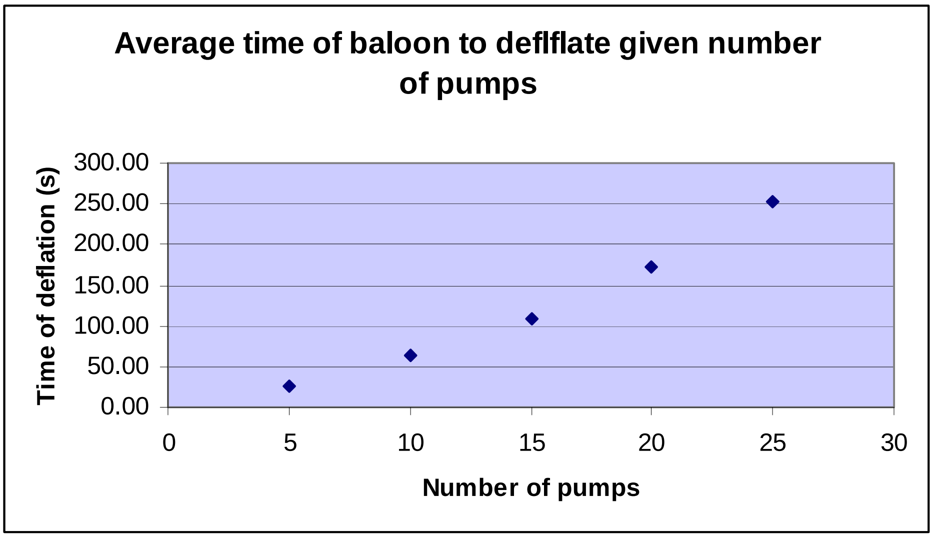




Graphs of data recorded



Describes scientific interrelationships



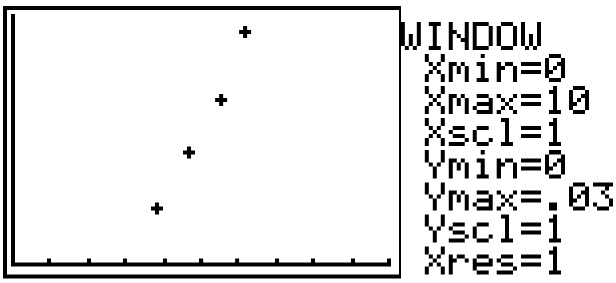
Analysis, Discussion and Interpretation of Data

Relationship determined from graphed data

From the graph of *average rate of deflation of balloons* the following relationship can be determined.

Application of algorithms

The graph is linear when rate is dependant on $\frac{1}{volume}$



Describes scenarios linked to the research focus,

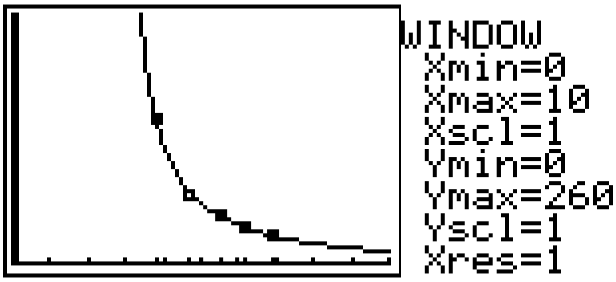
Therefore the rate is proportional to $\frac{1}{volume}$

Standard C

suggesting possible outcomes with statements about conclusion and recommendation

The equation for the line of best fit of the data is

$$y = \frac{160}{x - 2.8} - 10$$



Identifies obvious errors and anomalies

There fore the relationship between volume and the rate of deflation is as follows:

$$rate = \frac{160}{volume - 2.8} - 10$$

As the volume increases, the rate of deflation decreases in proportion to $\frac{160}{volume}$

The results showed the general trend that as the starting volume of the balloon increased, the average rate of deflation in mL/s decreased in proportion to $\frac{160}{volume}$.

In the results, it was seen that as the starting volume increased, the volume increase per five began to decrease; this would have affected the results in the manner of using the ideal gas law, its can be seen that the pressure of the air in the balloon increased.

The combined gas law $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ states that while temperature is kept constant,

Looking at the results logically when the volume is at its smallest the

The rate approaches infinity as volume approaches 2.8.

As volume approaches infinity the rate approaches 0, the weakness in this model is that volume cannot approach infinity beyond a certain point, due to the fact that once a balloon reaches a certain size it will not increase anymore despite the increase in amount of air being pumped into it. When this occurs the balloon would burst due to it reaching its maximum stretching tether. For this reason, extrapolating the volume in the testing would be of importance in further testing as to find the maximum volume and point of bursting.

Issues in experiment

There were several issues in the performance and design of the experiments.

The following errors occurred in the recording of the time of balloon deflation:

the timing of the deflation with the stop watch. However, this was reduced by using the same person to time the deflation.

In some cases, particularly when the balloon had been inflated to the larger sizes, it was believed that the balloon had stopped deflating when there were still traces of air coming out or it was believed that there was air still coming out when it had actually already stopped.

The volumes were recorded using the water displacement method, whilst the times were recorded from new balloons which had not been wet. This meant that they were under different conditions. It is possible that the wet balloons were of a different volume than the balloons that were not wet due to either a change in surface tension or compression my the mass of the water.

These errors may have potentially lead to consequential errors in the calculation of the rate of deflation. However these errors proved to not be significant as the results produced valid data.

As the starting volume of the balloons increased, the elasticity of the balloons as they deflated decreased. This meant that while the rate of deflation decreased, determining when the balloon actually stopped deflating became more difficult to identify, as seen in the results, where the range of results increases

Further Points of investigation

If the Investigation were to be performed again, it would be interesting to investigate how the rate of deflation in effected when the balloon is inflated beyond its stretching point. Because the rubber of a balloon has a point at which it will no longer stretch, as air is pumped into the balloon the volume remains constant and the pressure will increase. Due to the volume not increasing, the relationship found from the data would not apply to this larger range of data when extrapolated.

Already in the results, it was seen that as the volume increased, the volume increase per five pumps began to decrease; this indicates that the volume per amount of air was decreasing as the volume was increased, would have affected the results in the manner of pressure increasing, because the amount of air is increasing at the same rate, while the volume is increasing at an decreasing rate.

Conclusion

In conclusion, the data collected suggested that at constant temperature and pressure, as the volume of a balloon increases, the rate of deflation decreased, in proportion to $\frac{160}{volume}$.

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Instrument-specific criteria and standards

	Standard A	Standard B	Standard C	Standard D	Standard E
Establishing, conducting and managing the investigation					
IP1	Formulation of justified significant questions/hypotheses which inform effective and efficient design, refinement and management of investigations	Formulation of justified questions/hypotheses which inform design and management of investigations	Formulation of questions and hypotheses to select and manage investigations	Implementation of given investigations	Guided use of given procedures
IP2	Assessment of risk, safe selection and adaptation of equipment, and appropriate application of technology to gather, record and process valid data.	Assessment of risk, safe selection of equipment, and appropriate application of technology to gather, record and process data.	Assessment of risk, safe selection of equipment, and appropriate application of technology to gather and record data.	Safe use of equipment and technology to gather and record data.	Safe directed use of equipment to gather data.
Analysis of data and discussion					
IP3	Systematic analysis of primary and secondary data to identify relationships between patterns, trends, errors and anomalies.	Analysis of primary and secondary data to identify patterns, trends, errors and anomalies.	Analysis of primary and secondary data to identify obvious patterns, trends, errors and anomalies.	Identification of obvious patterns and errors.	Recording of data.
KCU1	Reproduction and interpretation of complex and challenging concepts, theories and principles	Reproduction and interpretation of complex or challenging concepts, theories and principles	Reproduction of concepts, theories and principles	Reproduction of simple ideas and concepts	Reproduction of isolated facts
KCU2	Comparison and explanation of complex concepts, processes and phenomena	Comparison and explanation of concepts processes and phenomena	Explanation of simple processes and phenomena	Description of simple processes and phenomena	Recognition of isolated simple phenomena
KCU3	Linking and application of algorithms, concepts, principles, theories and schema to find solutions in complex and challenging situations.	Linking and application of algorithms, concepts, principles, theories and schema to find solutions in complex or challenging situations.	Application of algorithms, principles, theories and schema to find solutions in simple situations.	Application of algorithms, principles, theories and schema.	Application of simple given algorithms.
Evaluation and conclusion					
EC1	Analyses and evaluates complex scientific interrelationships	Analyses complex scientific interrelationships	Describes scientific interrelationships	Identifies simple scientific interrelationships	Identifies obvious scientific interrelationships
EC2	Explore scenarios linked to the research focus, suggesting possible outcomes, and generates justified conclusions/recommendations.	Explains scenarios linked to the research focus, suggesting possible outcomes, and discuss conclusions/recommendations.	Describes scenarios linked to the research focus, suggesting possible outcomes with statements about conclusions and recommendations.	Identifies scenarios linked to the research focus or suggests possible outcomes.	Makes statements about outcomes.
Communication					
EC3	Discriminating selection, use and presentation of scientific data and ideas to make meaning accessible to intended audiences through innovative use of range of formats.	Selection, use and presentation of scientific data and ideas to make meaning accessible to intended audiences in range of formats.	Selection, use and presentation of scientific data and ideas to make meaning accessible in range of formats.	Presentation of scientific data or ideas in range of formats.	Presentation of scientific data or ideas.