IB Physics Investigations

Volume 1 (Standard Level)

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(For use with the IB Diploma programme)

(Fourth edition)

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Author Profile

Gregg has a Bachelor of Education degree from Charles Sturt University, Australia, and a Master of Science in Education from the State University of New York, USA. He has taught in Germany, Hong Kong, Australia, Brunei, Thailand and is presently Student Welfare Coordinator and Head of Science at the Utahloy International School Guangzhou, China.

Gregg has taught IB Physics since 1988. He has been a member of the Physics Subject Committee, and is presently a Senior Examiner and a Senior Moderator in Physics. He has been an IB Physics workshop leader at conferences in Tokyo, Mumbai, Brisbane, Adelaide, Invercargill, Sydney, Singapore and Chiang Mai. I would like to thank my Bhutanese friend Kinga Tshering for all the suggestions he made to make this edition better. I would especially like to thank Ofelia and Angelica for giving me the support at home while I tore my hair out in writing my contribution to this fourth edition.

Acknowledgements

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I am also grateful to the series Editor David Greig for his advice and assistance in the preparation of these Volumes of Investigations.

Most of all I thank my wife Ofelia and my daughter Angelica for their compassion and understanding during this process that never seemed to end.

Health and Safety Warnings and Symbols

Laboratories can be hazardous places. Often scientists, Science teachers and students handle equipment and materials which can be dangerous to their health and safety. Throughout these Volumes of Investigations you will see a number of symbols and warnings which will represent particular hazards. For each of these we will briefly describe the hazard and indicate what precautions you should take to avoid damage and/ or what responses are appropriate. In all cases, of course, you should seek advice and assistance from the teacher or laboratory technician.

A biohazard is any organism or body fluid which could possibly cause illness or disease in your body. This particularly includes micro-organisms.

A flammable substance is one which will readily burn in air. It may be a solid, liquid or gas. If you are using such a substance it is vital that there are no sparks or naked flames which could ignite it. It is vital that you know what to do in the event of fire. This may include the use of fire extinguishers and evacuation procedures.

A radioactive substance is one which emits particles or 'radiation'. This radiation is known to cause damage to cells and may also be cancer causing. If you are using radioactive substances it is vital that you wear protective clothing, use metal tongs and listen carefully to instructions given by your teacher or laboratory technician.

Sharp instruments are often used in Science and particularly in Biology, to cut sections through plant or animal tissue. These instruments, which include scalpels and razor blades are very sharp and obviously will also cut through your tissues. When using these instruments it is essential that you always cut away from your body and preferably onto a cutting board. It is also important to be very careful when carrying these instruments and also ensure they are placed on the workbench in a safe place.

When certain chemicals are mixed together they can become explosive. An explosion is caused by rapid expansion of gas in a confined space and can be very dangerous. Sometimes it is important to ensure that the space is not confined and sometimes it is important to conduct these reactions behind a protective screen.

It is often necessary to protect your hands from heat, chemicals or other hazards and gloves will be made available for these situations. The type of glove needed will depend on the particular hazard and your teacher will provide further advice. In some cases you will be advised to dispose of the gloves after use and in other cases to wash and dry them carefully.

Your eyes are the most vulnerable and easily damaged external part of your body. This is why they must be protected if you are using solids and liquids which could get into them. Whenever you are heating things or using corrosive liquids, and in other cases as instructed by a teacher, you should wear safety goggles. You should also do this if possible even if you wear spectacles to correct your vision. In the event that something gets in your eye you should immediately make use of the eyewash facility in the laboratory as instructed and then notify your teacher.

Some chemicals, which are used in a laboratory, are *corrosive*. This means that they can react with and 'eat away' materials like the bench, your books, clothing and skin. It is essential that you handle these materials, which are usually liquids, with care. Always tip from the container with the label uppermost, never add water to concentrated acid and never have your face anywhere near the container. It is usually advisable to wear both safety goggles and gloves. If protective aprons are available you should also wear one.

As a general rule, 12 or 24 volt *electrical* appliances are unlikely to cause serious injury. However, 'mains' voltage (110V or 240V or higher) can cause serious injury or death. The appliances you use should be regularly tested and certified safe. If you notice sparks or smell insulation burning, turn the power off immediately and notify staff. Be particularly careful not to allow water to get into any appliance as it may cause a short circuit.

Some chemicals are *poisonous* and should not be inhaled or ingested. It will be necessary to use a fume cupboard when using poisonous gases or volatile liquids. They could make you very ill and you may require medical assistance. It is vital that you listen to instructions, follow them carefully and notify your teacher immediately if there is accidental exposure to poisonous or toxic substances.

Lasers are very intense beams of light. They are capable of causing burns to the skin and permanent damage to the eyes. It is essential that these are only ever used under the supervision of a teacher and in a situation where people can not see the beam directly or when it is reflected from a shiny surface. Sunglasses or welding masks do not provide sufficient protection and special 'laser glasses' must be used where there is a risk.

UV light is harmful to skin and especially eyes. Do not expose these areas directly to a UV light source. If it is not avoidable, sunscreen can be applied to the skin and special goggles should be worn.

There are other *dangers* or hazards as well, for example carrying heavy or hot objects. This may also include chemicals which are not poisonous but which may smell unpleasant or irritate the skin. Whenever you see this icon more information will be provided in the adjacent text about the specific danger.

In Science and particularly in Biology, there are situations when ethics and ethical issues need to be considered in experimental work. This is particularly the case when human volunteers are being used, not just for experimental work but also when they are being surveyed to collect personal information. In these cases a consent form should be used to explain the nature of their involvement and to get their approval. Ethics will also be an issue whenever animals are used in experimentation or when they are collected in the field. They should not be exposed to conditions that are outside their natural range of tolerance and wild animals must be released back where they were sampled with the minimum of disturbance.

The environment and environmental issues become important when hazardous substances are used or produced during an experiment. Their disposal must result in minimal impact on the environment. In field work the protocol that is used must reflect practices that minimise the impact of the investigation on the site.

IMPORTANT NOTE

Although every care has been taken in preparing and trialling these investigations, absolutely no responsibility or liability whatsoever can be accepted for any damage or accident which may occur for whatever reason during the conduct of any of these activities. The Safety Warnings and Icons are advisory only and are not intended to be exhaustive or exclusive. It is a strict condition of sale that safety in the laboratory is the responsibility of the staff and students doing the laboratory work and not the author, editor or publisher of this work.

Table of Contents

Name ______________________ **Date** _______ **Class** ______________________**Time: 90 mins**

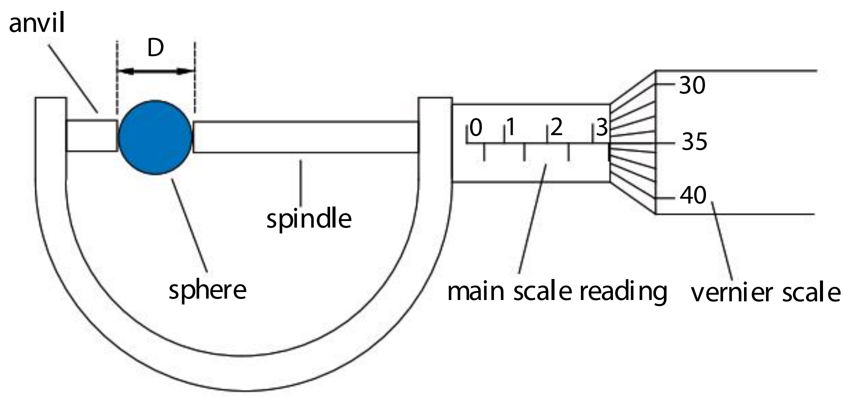
You may be assessed for school–based assessment on some of the following investigations.

This first investigation gives you a format so that you can examine units and uncertainties.

BACKGROUND

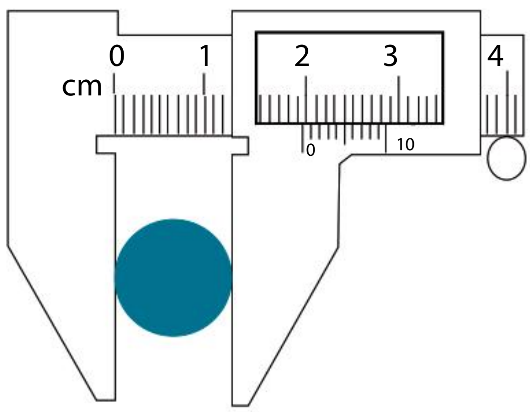
The following set of investigations will help you to understand the problems associated with errors. You will be required to use a set of vernier calipers and a micrometer screw gauge.

1 The reading on the micrometer screw gauge below is 3.35mm. You can see that the thimble is to the right of the 3 mm mark but you cannot see the 3.5 mm mark on the main scale. The vernier thimble scale is close to the 35.



2 The reading on the vernier calipers below is 1.95cm. The vertical line showing zero on the vernier scale lies between 1.9cm and 2.0cm. The vertical graduation on the vernier scale that matches the main scale best is the fifth graduation.

Thus, the reading is 1.95cm.



Part 1

AIM

To determine the time for normal inhalation and exhalation of air in human respiration.

EQUIPMENT

A timing device.

DESIGN

1. Check your timing device for zero error.
2. Record the time taken for 10 complete breaths and complete the following:

DATA

Time for 10 breaths = ________ s

Zero error of the timing device = ________ s

Absolute time for 10 breaths = ________ s

Average time for one breath = ________ s

Part 2

AIM

To measure the mass of a coin.

EQUIPMENT

Digital or a triple beam balance, one coin.

DESIGN

1. Set up the mass measuring device on a level surface.
2. Record the limit of reading of the scale on the balance.
3. Check the balance for zero error.
4. Record the mass of the coin and complete the following.

DATA

Limit of reading of the scale of the balance = ________ g

Mass of the coin = ________ g

Zero error = ________ g

Mass of the coin = ________ g

DATA PROCESSING

The absolute error = ________ g

Calculate the relative and percentage errors in your measurement:

Relative error = ________

Percentage error = ________

The mass of the coin was found to be ________(value) ± _____(uncertainty) ___(unit)

Part 3

AIM

To measure the force due to gravity on a one kilogram mass.

EQUIPMENT

Spring balance, calibrated in newtons, a 1 kilogram mass, retort stand, boss-head and clamp.

DESIGN

1. Attach the clamp and boss-head to the retort stand.
2. Suspend the spring balance from the clamp.
3. Record the limit of reading of the scale of the spring balance.
4. Check the spring balance for zero error.
5. Place a 1kg mass on the hook of the spring balance. Record the scale reading and determine, with appropriate absolute error, the force of gravity on a mass of 1 kg.

Part 4

AIM

To determine the diameter of a coin.

EQUIPMENT

Coin, vernier calipers

DESIGN

1. Record the limit of reading of the scale.
2. Close the jaws of the vernier calipers and check for zero error.
3. Adjust the jaw separation until the coin sits firmly in the jaws.

DATA

Limit of reading of the vernier calipers = ________

Vernier caliper reading = ________

Diameter of the coin = ________

Zero error = ________

DATA PRESENTATION AND PROCESSING

The absolute error of a single measurement = ________

The absolute diameter of the coin = ________

CONCLUSION

The diameter of the coin = ________ ± ________ ________

Part 5

AIM

To find the average diameter of a piece of wire.

EQUIPMENT

Micrometer screw gauge, piece of wire.

DESIGN

1. Record the limit of reading of the scale.
2. Close the jaws of the micrometer and check for zero error.
3. Open the jaws and place the piece of wire between them.
4. Record the first reading of the diameter of the wire.
5. Make and record several more measurements of the diameter of the wire at various points along its length.
6. Determine, with appropriate absolute error, the average diameter of the wire.

Part 6

AIM

To determine the density of a metal in the form of a cube.

EQUIPMENT

Metal cube, digital balance, vernier calipers.

INSTRUCTIONS

Use the equipment provided to determine, with appropriate absolute error, the density of the metal.

Name ______________________ **Date** ______ **Class** ____________________ ***Time: 90 mins***

In this investigation you may be assessed using school-based criteria.

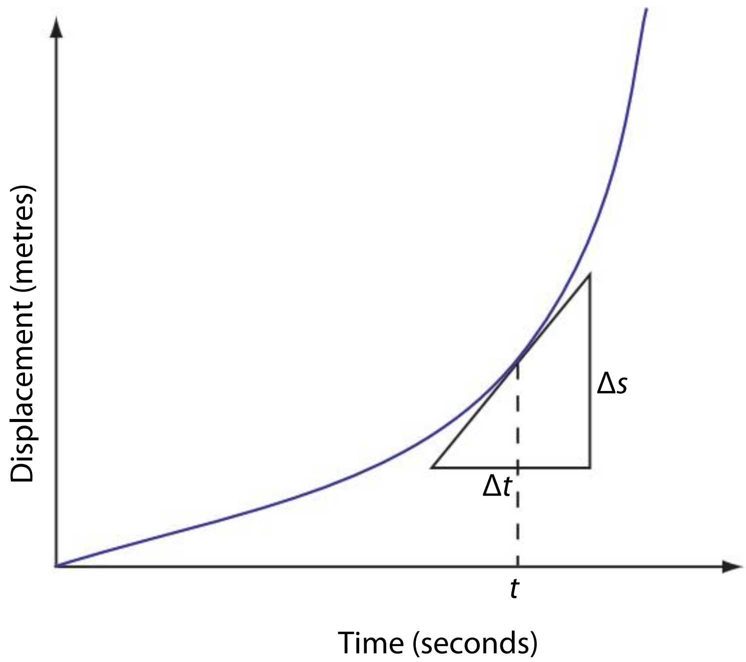
AIM

To determine the acceleration, due to gravity, of a falling ball, using data from a photo taken with a stroboscope.

BACKGROUND

The following investigation allows you to calculate instantaneous velocities and the acceleration of a falling ball, using the strobe photo provided. The distance between each windowsill is 3.15 m. Three photographs were taken each second.

A schematic diagram of the displacement of a falling object over time is shown.



By constructing the tangent to a point, the instantaneous velocities for a certain time (t) can be calculated:

v_{inst} =

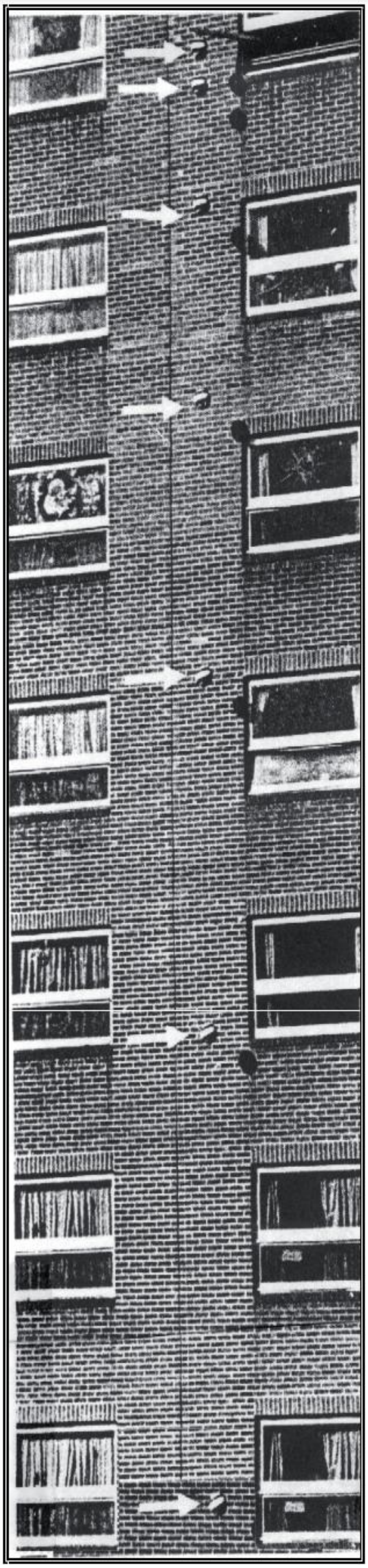
EQUIPMENT

Stroboscope photo (next page), graph paper, ruler

DESIGN

Examine the adjacent strobe photo.

Measure and record the distances of each falling ball position from the original starting position in the strobe photo (in centimetres and metres).



DATA PRESENTATION AND ANALYSIS

Calculate the real distances of the balls from the information given in the background section.

Process and present your data in a suitable way to find the acceleration due to gravity.

CONCLUSION

Comment on the value obtained compared to the theoretical value for the acceleration of a falling object.

(use extra paper as necessary)

Name ________________________ ***Date*** _______ ***Class*** _______________________ ***Time: 40 mins***

You may be assessed using school-based criteria.

BACKGROUND

In this investigation, you will use a graphical method to determine the relationship that exists between the displacement of a free fall object and the time of flight. You will also determine the acceleration due to gravity of the object, and the degree of uncertainty in your measurement.

Kinematics tells us that:

$s = ut + ½gt^2$

If the initial velocity u is zero, then a graph of the displacement s plotted against the time squared (t^2) will be a straight line passing through the origin. The slope of the graph will equal half of the acceleration due to gravity (½g). If the initial velocity is not equal to zero, then the line of best fit will cut the y-intercept at some point.

There are a number of experimental designs with different timing devices that can be used. The simplest case is a metal-grooved inclined plane in which a marble rolls.

In this case; $s = ut + ½g \sin\theta\ t^2$

You could use the strobe photo from the previous investigation or even a video camera as a timing device. Three more designs that have a high degree of precision and accuracy are illustrated.

Choose your design. Perhaps a number of designs can be analysed by different groups.

EQUIPMENT

Free fall apparatus, ball-bearing, impact switch, electric timer, metre rule, 12V a.c. supply. (Set-up 1)

OR

Ticker tape timer, switch, a small weight, adhesive tape, retort stand, metre rule, 12V a.c. supply. (Set-up 2)

OR

2 photo-gates, digital timer, small mass, retort stand, metre rule, 12V a.c. supply. (Set-up 3)

(*as shown on next page*)

OR

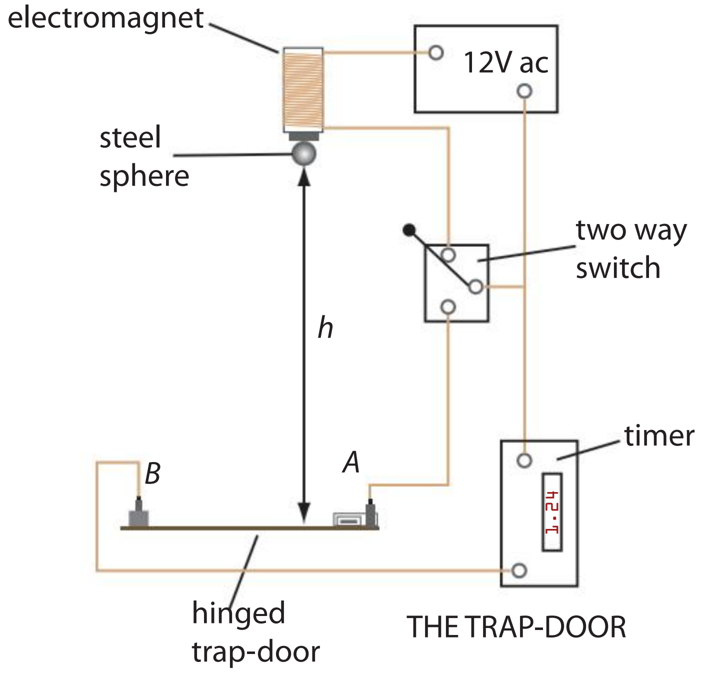
Grooved inclined plane, spherical ball, timing device, metre rule.

OR

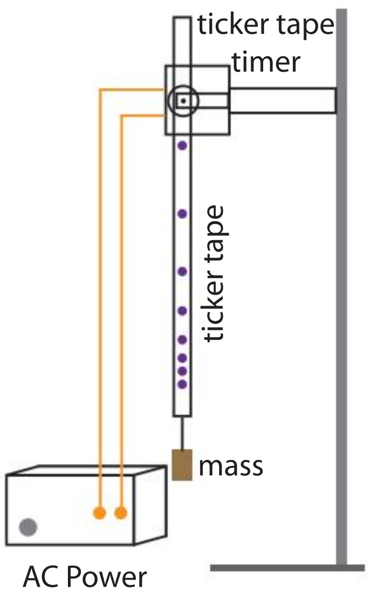
some other equipment

AIM

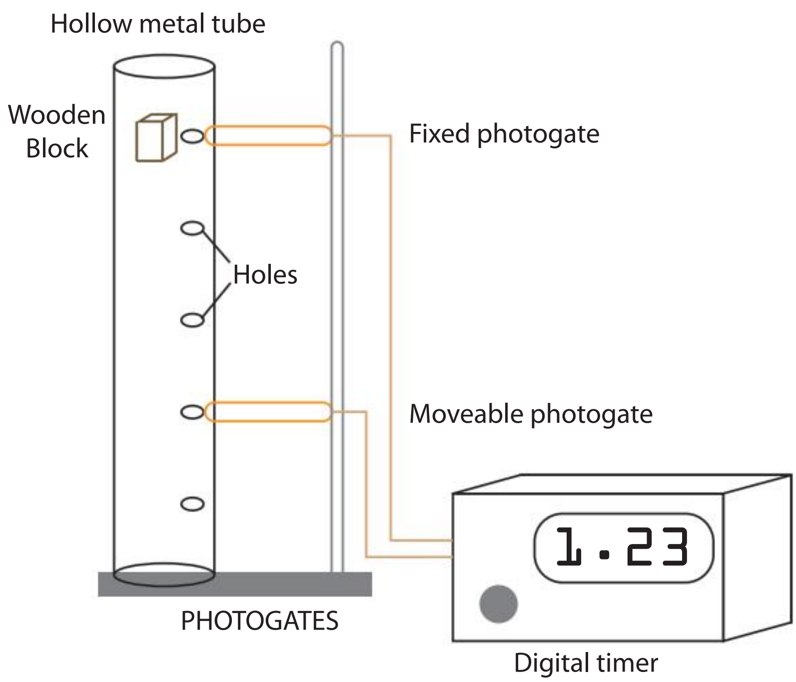
To determine the acceleration due to gravity of an object using the ______________________________ method.



Set-up 1



Set-up 2



Set-up 3

DESIGN

1. Insert a fully labelled diagram of the investigation you are undertaking.

2. Record your data and give uncertainties.
3. Plot a suitable graph on graph paper.
4. Find a value of g.
5. Suggest reason(s) why your graph does not go through the origin (if this is the case). You should estimate the uncertainty in your calculated value of g and record your final result with appropriate significant figures and a range of uncertainty.

DATA COLLECTION (insert your data table here)

DATA PRESENTATION AND ANALYSIS

CONCLUSION

Evaluate your procedure and discuss any modifications you would use in a future design.

(Use and attach extra paper as required)

Investigation 2C
TERMINAL SPEED IN A FLUID

Name ______________________ **Date** _______ **Class** ______________________ **Time: 1 hour**

You may be assessed using school-based criteria.

BACKGROUND

In this investigation, you will qualitatively describe the effect of fluid resistance on a falling object that attains a terminal speed.

Choose your own design. Perhaps a number of designs can be analysed by different groups.

AIM

To design an experiment to describe the terminal speed of an object when it is placed in a fluid.

EQUIPMENT

Here are some useful suggestions:

- Use a viscous fluid such as glycerol or washing up detergent.
- Use a small steel ball bearing that can be removed from the fluid with a magnet.
- If you choose to use a timing device, do not start timing until the object reaches its terminal speed.

DESIGN

1. Insert a fully labelled diagram of the investigation you are undertaking in the space below.
2. Record your data and give uncertainties.
3. Describe a procedure that you used in your investigation in the space provided.
4. Make sure that you carry out a number of trials.

DATA COLLECTION (insert your data table here)

DATA PRESENTATION and ANALYSIS

CONCLUSION and EVALUATION

Evaluate your procedure and discuss any modifications you would use in a future design.

(*Use and attach extra paper as required*).

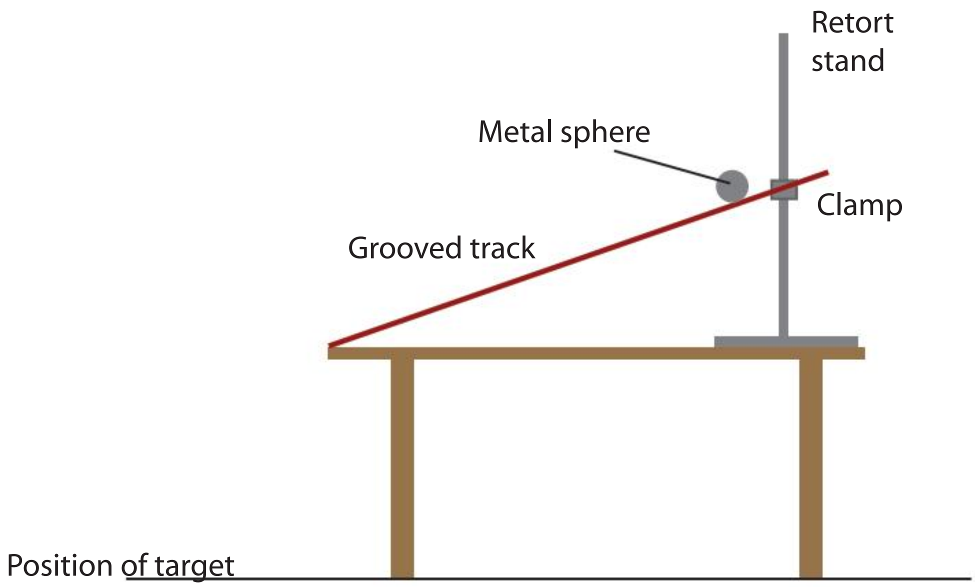
Investigation 2D
THE RANGE OF A PROJECTILE

Name ________________________ **Date** _______ **Class** _______________________ ***Time: 1 hour***

You may be assessed using school-based criteria:

BACKGROUND

This investigation allows you to predict where a sphere rolled down an incline plane will hit the "bull's eye" of a target.



MATERIALS

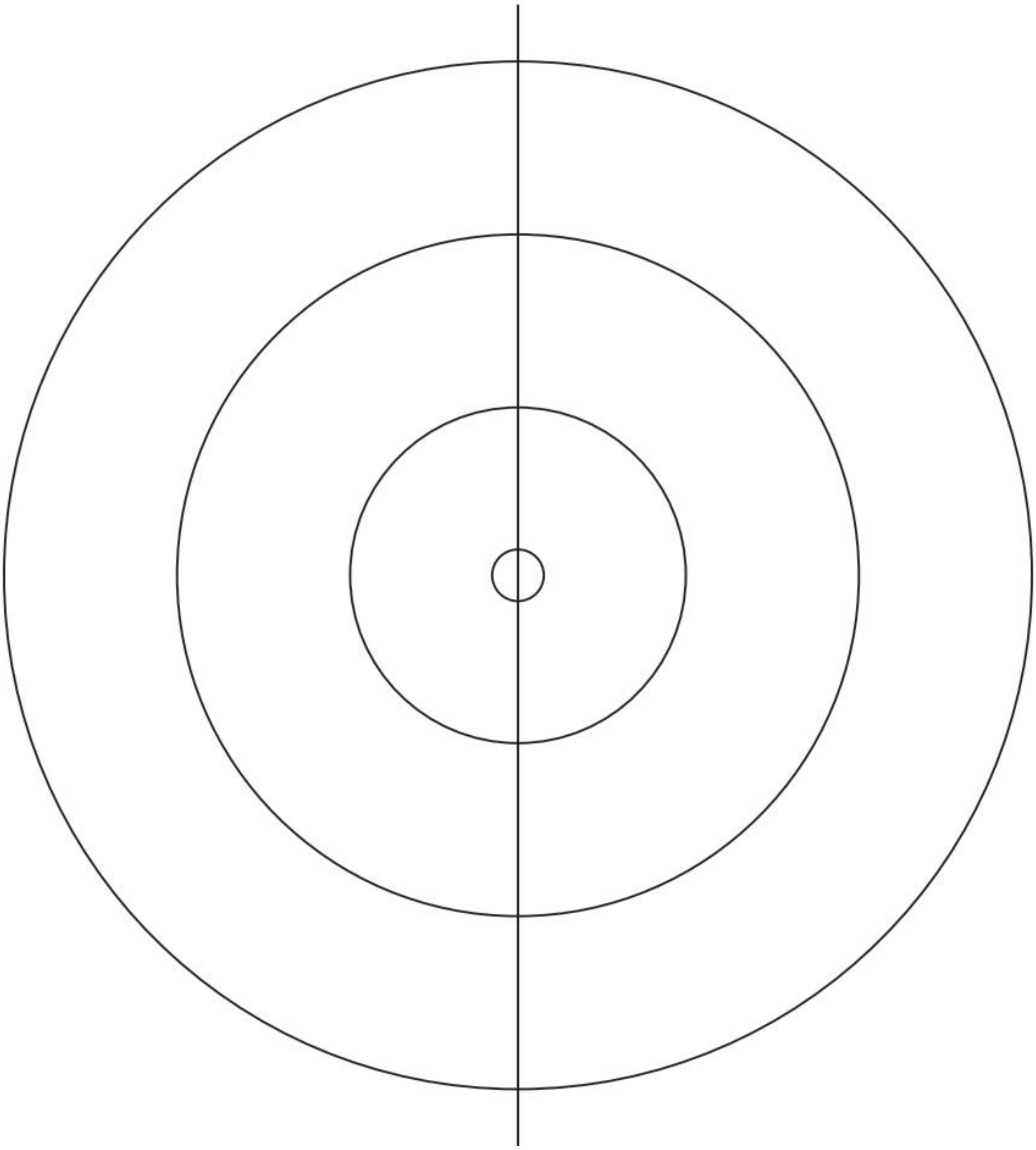
Incline plane, timing device, metre rule, carbon paper, 'bull's eye' target, other hardware.

PROCEDURE

1. Your first task before carrying out the investigation is to process data in order to determine the position where a sphere rolled down your incline plane will hit the ground.
2. You can roll the sphere down the incline plane but you must catch the sphere before it hits the ground!
3. Once you have calculated the relevant range and position where the sphere will hit the ground, take the piece of carbon paper and place it on the ground in the relevant location. Place the target, provided on the next page, on top of the carbon paper.
4. Ask your partner to help you to roll the ball down the incline plane three times and observe.

Give your calculations and the target to your teacher for assessment.

DATA COLLECTION



DATA ANALYSIS

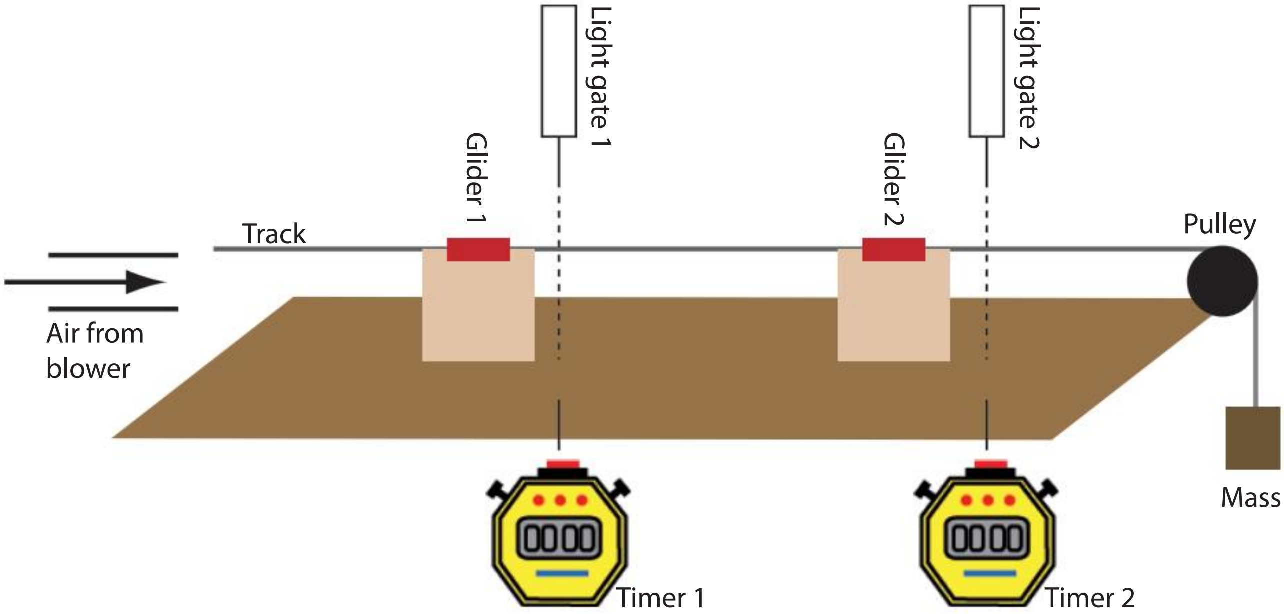
Do your calculations in the space provided hereunder, use extra paper as necessary.

Name ______________________ **Date** ________ **Class** ______________________ ***Time: 2 hours***

You may be assessed using the school-based criteria. IB assessment is not applicable at this stage of the course.

BACKGROUND

The glider moves freely without friction due to a cushion of air being blown through the air track.

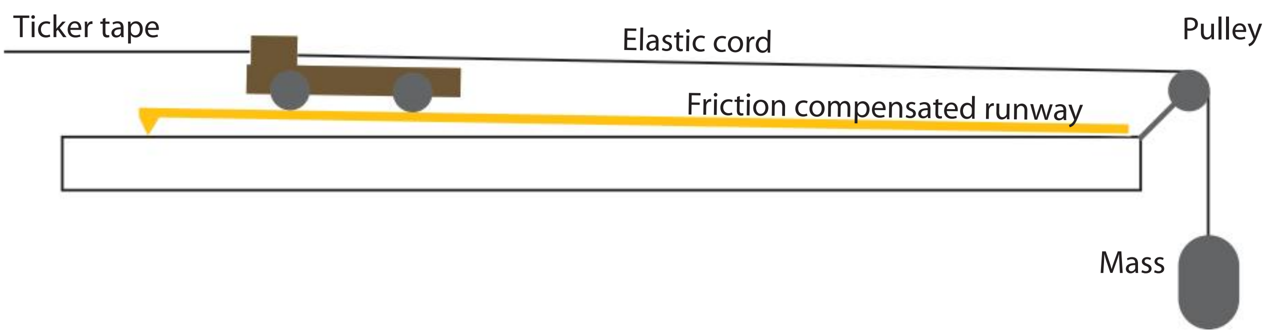


The *net accelerating force* is due to the weight of the total mass on the mass holder because the mass of the glider, and any masses on the glider, are cancelled out by the normal reaction force. While the total moving mass is constant, the total glider mass has a constant average acceleration.

By changing the net accelerating force by adding different masses to the mass holder, the average acceleration will be changed.

When the glider is released, it accelerates to the right, passing through the 2 light gates. A scalar timer connected to each light gate records the time taken for a card mounted on the glider to pass through the light gate. The time recorded at the two light gates is used to calculate 2 different speeds of the glider, and hence the acceleration of the glider may be found.

Another design for this investigation is shown below using a ticker tape timer (accelerometer).



You could also use a motion sensor in a data-logging investigation.

AIM

To confirm the relationship between the net force applied to a body and the body's acceleration.

EQUIPMENT

Linear air track with glider, 2 light gates, 2 scalar timers, 9 × 0.01 kg masses.

OR

Trolley inclined to overcome friction, ticker tape timer, 9 × 0.01 kg masses.

OR

A computer multi-processor software program.

PRELIMINARY MEASUREMENTS

Record the mass of the glider/trolley, and the length of the card mounted on the trolley.

MASS OF GLIDER/TROLLEY = ____________________

=____________________

TOTAL MASS OF THE SYSTEM (glider and masses) = ____________

LENGTH OF THE CARD ON TROLLEY = ____________

= ____________

DESIGN

Part A

1. Switch on the pump for the air track. Place one 10 g mass on the hanger (giving a total of 20 g, since the hanger has a mass of 10 g), and the remaining 4 masses on the glider.
2. Gently slide the glider to the left past the light gates. Switch on the scalar timers and reset them to zero readings. Release the glider.
3. Record the times on the 2 scalar timers, t_1 and t_2, and the accelerating mass in the data collection table provided.
4. Do three more trials with 30 g on the hanger, discard any inconsistent data and average the remaining accelerations. Record any other measurements needed to determine the two speeds and the acceleration of the glider.
5. Record the accelerating force and the average acceleration in another table, leaving space for several more sets of data.
6. Do another four runs with 40 g on the hanger.
7. Repeat for 70 g and 90 g on the hanger.
8. Determine the total accelerated mass and compare this with the measured values.

Part B

1. For the second part of the experiment, investigate the relationship between mass and acceleration by increasing the mass of the glider by 0.050 kg at a time. *The falling mass remains constant at 0.100 kg.* This increases the overall mass of the system, while the force is a constant 1.0 N.
2. Record three acceleration trials for the unloaded glider.
3. Repeat for the glider plus masses from 0.100 kg to 0.040 kg. Find the average acceleration for each trial.
4. Use the data to find a relationship between mass and acceleration.

Part A

DATA COLLECTION

Mass	Time 1	Initial velocity	Time 1	Final velocity

Net accelerating force	Average Acceleration

Plot the graph for Part A, Step 8.

DATA PRESENTATION AND ANALYSIS (use extra paper)

PART B

DATA COLLECTION

Mass	Time 1	Initial velocity	Time 1	Final velocity

Acceleration

Plot the graph for Part B, Step 4.

DATA PRESENTATION AND ANALYSIS (use extra paper)

CONCLUSION AND EVALUATION (use extra paper)

Name ______________________ **Date** ________ **Class** ______________________ **Time: 90 mins**

In this investigation you may be assessed using school-based criteria.

AIM

To determine the coefficients of kinetic and static friction for a wooden box on a laboratory surface and to determine that the force of friction does not depend on the amount of surface area in contact with the laboratory surface.

BACKGROUND

Whenever two surfaces touch, they exert forces on each other. The ultimate source of these surface forces is the electromagnetic attraction or repulsion between the charged particles – electrons and protons – of which all matter is made. The vector sum of all the microscopic forces between the particles in the surfaces is a macroscopic force that we can measure in the laboratory.

Suppose you attached a newton balance to a block of wood in contact with a surface such as the bench top in a laboratory. You then pull on the newton balance but the object does not move because the component of the applied force parallel to the surface balances the static frictional force. As you continue to pull on the newton balance, there will be a certain applied force registered when the block just begins to move. At this point the applied force is slightly greater than the maximum static frictional force.

Experimental evidence shows that the frictional force is independent of the actual area of the two surfaces in contact, provided the surfaces in contact with each other are hard. The evidence suggests that the magnitude of the frictional force is directly proportional to the magnitude of the normal reaction force.

$F_f \propto F_N$ or $F_f \propto R$

$F_f = \mu_s R$

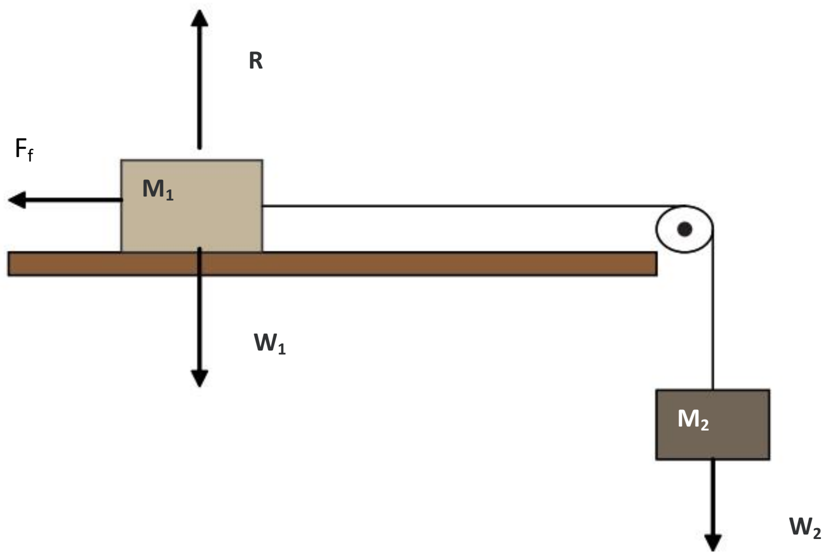
where μ_s is called the coefficient of static friction.

When a force is then applied that causes the block of wood to slide along the surface, the magnitude of the force registered on the newton balance rapidly decreases and then becomes a steady value provided the block is moved with a uniform speed. The frictional force is then given by:

$F_f = \mu_k R$ where μ_k is called the coefficient of kinetic friction.

The coefficient of static friction will always be a larger value. As an approximate guide, the coefficient of static friction between a polished wood block and polished wood surface is around 0.4 and the coefficient of kinetic friction for the same materials is 0.2. Both coefficients are dimensionless.

In this investigation, we will first determine the coefficients of static and kinetic friction between two surfaces (a wooden box and a laboratory bench), as shown in the diagram.



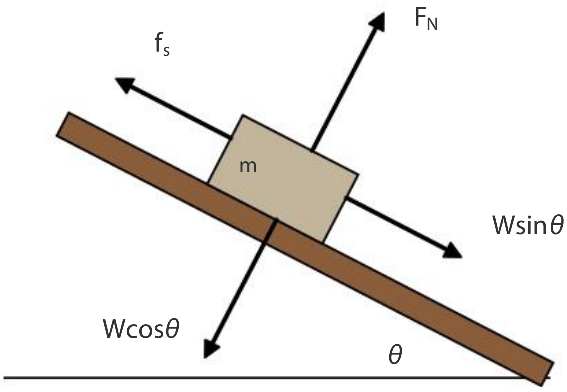
The wooden box (M_1) is placed on a laboratory bench and is connected by a string to a mass (M_2), which is hung vertically by means of a pulley. To find the magnitude of kinetic friction, we hang just enough mass on the string so that if the block is set in motion and it slides at constant speed.

$F_f = W_2$ *and* $R = W_1$

We can determine the coefficient of kinetic friction by running several trials and calculating the ratio of the masses for each trial.

The coefficient of static friction can be determined in much the same way. In this case we leave the block at rest and look for that hanging mass which just starts the block sliding.

There is a second way of determining the coefficient of static friction. Refer to the diagram below. You can put the wooden box on a plank and raise one end of the plank so that it makes an angle θ with the horizontal. When the angle is large enough, the block will slide down the incline.



At an angle just before the block begins to slide, the forces are still balanced and we have

$F_f = W\sin\theta$ and $R = W\cos\theta$

PROCEDURE

1. Set up the apparatus as shown in the first diagram.
2. Record the mass of a wooden box.
3. Wipe clean the surfaces of the wooden box and the laboratory bench.
4. Determine the mass that needs to be added so that the system moves at constant speed.
5. Give the block a slight push to start it moving. If the block accelerates (speeds up), take a little mass off and try again. If the block decelerates (slows down), add a little more mass and try again.
6. Record the total hanging mass and its weight.
7. Repeat the above process, adding 100 grams to the wooden box for each new trial, for a total of six trials.
8. To test the hypothesis that the force of friction is independent of the surface area in contact, repeat the above using the narrow face of the wooden box.
9. Use the same set-up as in the kinetic friction experiments, with the wide face of the wooden box down. This time, however, determine what hanging mass is necessary to just start the block moving without a push.
10. Design an investigation to find the coefficient of static friction using the wooden box on an incline plane.

DATA COLLECTION

Mass of wooden box (g): ____________________

Kinetic Friction – Flat Face

Trial	Mass in box	Total Mass (m_1)	Normal Force (R)	Hanging mass (m_2)	Friction Force (F_f)	μ_k
1						
2						
3						
4						
5						
6						

Average μ_k: _______

Uncertainty: _______

Kinetic Friction – Narrow Face

Trial	Mass in box	Total Mass (m_1)	Normal Force (R)	Hanging mass (m_2)	Friction Force (F_f)	μ_k
1						
2						
3						
4						
5						
6						

Average μ_k: _______

Uncertainty: _______

Static friction table

Mass of block (g): ____________________

Mass in box	Total Mass (m_1)	Normal Force (R)	Hanging mass (m_2)	Average hanging mass
			1.	
			2.	
			3.	
			4.	
			1.	
			2.	
			3.	
			4	
			1.	
			2.	
			3.	
			4	
			1.	
			2.	
			3.	
			4.	
			1.	
			2.	
			3.	
			4.	
			1.	
			2.	
			3.	
			4.	
			1.	
			2.	
			3.	
			4.	

DATA PRESENTATION AND ANALYSIS

Plot a relevant graph to determine the coefficient of static friction.

CONCLUSION AND EVALUATION

Comment on the graph obtained and justify your conclusion. Discuss the difference between the coefficients of static and kinetic friction. Discuss the surface area and its effect on the coefficients of static and kinetic friction.

Name ________________________ **Date** _______ **Class** _______________________ **Time: 1 hour**

In this investigation you may be assessed using school-based criteria.

BACKGROUND

Three non-parallel (concurrent) forces acting in the same plane must intersect at a single point if they are in equilibrium. You will investigate the equilibrium of three such forces in the first part of this investigation.

When a body is in translational equilibrium, it must be either at rest or moving with constant velocity. It has a linear acceleration of zero. This means that the resultant external force must be zero. In addition, for the body to be in rotational equilibrium the sum of the torques of all the individual forces must be zero.

AIM

To gain an understanding of balanced forces in situations of static equilibrium when two or more forces act through a point in the system.

EQUIPMENT

2 pulleys mounted on a board or two pulleys attached to retort stands, thread, slotted masses, 3 sheets of white paper for each student.

METHOD

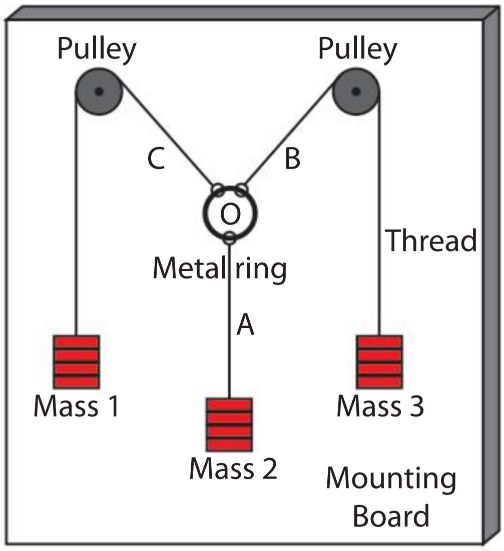
1. Set up the apparatus as shown in the diagram on the next page.
2. Hang suitable masses from the three threads and let the system come to equilibrium.
3. Displace it several times and notice the variation in the position of the point O.
4. When the system comes to rest in an approximately mean position, accurately mark the position of point O and the directions of the three forces on a piece of white paper fixed to the board.
5. The threads are several millimetres from the board–how can you improve the accuracy of marking the thread direction?

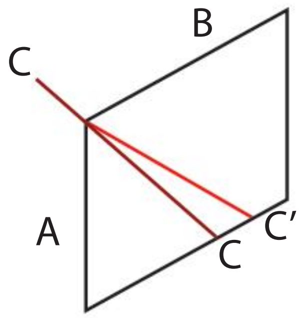
....

....

....

6. Test for equilibrium as follows (each student completes the analysis on her/his own sheet of white paper, which is submitted with the Lab Record).
7. Label the point of intersection of the three force vectors as O.
8. Using a suitable scale, construct a vector parallelogram with A and B. Label the vector sum of A + B as C'. Draw a line to represent the original value of C, and compare with C' to determine the magnitude error and direction error.
9. Repeat the above for two more systems by changing the magnitude of coplanar forces acting on the body.





DATA COLLECTION

You should attach your three A4 sheets that clearly show the original data obtained and the analysis of the parallelogram of vectors.

DATA PRESENTATION AND ANALYSIS

In the discussion that follows, you should explain inferences you have reached from your observations during this investigation and calculate the magnitude and direction error.

CONCLUSION (add extra paper)

Name ________________________ **Date** _______ **Class** _______________________**Time: 1 hour**

You may be assessed using the following school-based criteria:

Planning

- Defining a problem or research question
- Relating the hypotheses or prediction to the research question
- Selecting relevant variables
- Designing a method with appropriate apparatus/materials
- Designing a method for the control of the variables
- Designing a method for the collection of sufficient data

Data Collection

- Collecting and recording appropriate raw data
- Presenting raw data, allowing easy interpretation
- Data processing
- Processing raw data correctly
- Presenting processed data appropriately

INTRODUCTION

This is a completely open-ended investigation.

You are given the following apparatus:

- An empty container
- Elastic bands
- Masses

Elastic potential energy can be used to propel a container along a surface, or through the air. The elastic potential energy does work on the container by applying a force to move the container through a certain distance.

In this investigation you should:

- **decide** the factors that you think will affect the distance travelled by the tub when it is projected horizontally along the runway by the elastic.
- **suggest** how quantitatively you think these factors will affect the distance travelled.
- **devise** appropriate methods to verify your quantitative predictions.
- **carry out** the investigation.
- **collect** and **analyse** data from your investigation.
- **evaluate** your data and the procedures you have used.**present** your report according to the guidelines given.
- **use** separate paper for your report.

Name ______________________ **Date** _______ **Class** ______________________ **Time: 1 hour**

BACKGROUND

You may be assessed for formative and summative criteria that are chosen by your teacher.

PLANNING

- Designing a method with appropriate apparatus/materials
- Designing a method for the control of the variables
- Designing a method for the collection of sufficient data

For the Planning skill, you are required to design a realistic procedures, include appropriate apparatus, list materials for both the control of variables and collection of data in the space provided for the method.

AIM

You are required to design an investigation to show the relationship that exists between rebound height and impulse during the interaction with the ground of three different types of bouncing balls. Results of the direct measurements of rebound height and the calculations of impulse are to be presented graphically and the behaviour of the three balls when bouncing is to be compared and discussed.

Include these headings in your report (use separate paper).

AIM

THEORY

EQUIPMENT REQUIRED (per group)

METHOD

DATA COLLECTION, PRESENTATION AND ANALYSIS

You should prepare the required data tables and show a detailed sample of each type of calculation performed for the completion of certain columns or rows of your tables

For each type of graph, use one set of axes for all three balls.

Present your results clearly and concisely, copy and use extra pages if necessary.

EVALUATION

Your discussion should include answers to the following questions, comparing the three different balls when possible.

(1) Is the percentage of mechanical energy lost per interaction constant?

(2) What happened to the lost mechanical energy?

(3) Is momentum conserved? Explain.

(4) Which ball would be in contact with the ground for the longest period of time?

Justify your answers.

CONCLUSION

Write a conclusion summarising your results for the behaviour of the three bouncing balls.

Name ______________________ **Date** _______ **Class** ______________________ **Time: 1 hour**

In this investigation you may be assessed using school-based criteria.

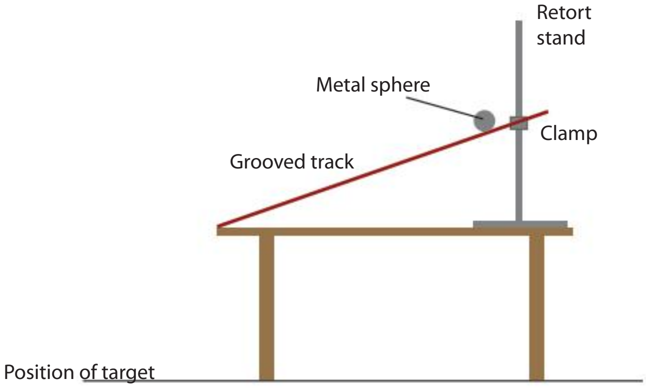
BACKGROUND

This investigation consists of three problem-solving exercises. You are provided with a schematic diagram for each investigation, and a problem to solve, based on the data that you collect.

For each investigation you should record any raw data and in the discussion section show the relevant analysis to solve the problem. You should also note any modifications that you make to the apparatus.

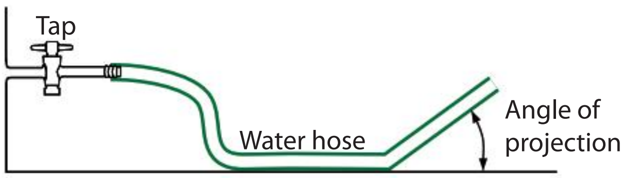
Problem 1

Set up the apparatus and determine the time taken for an object to fall from the bottom of the incline to the floor. No timing device can be used. The only measuring device allowed is a metre rule.



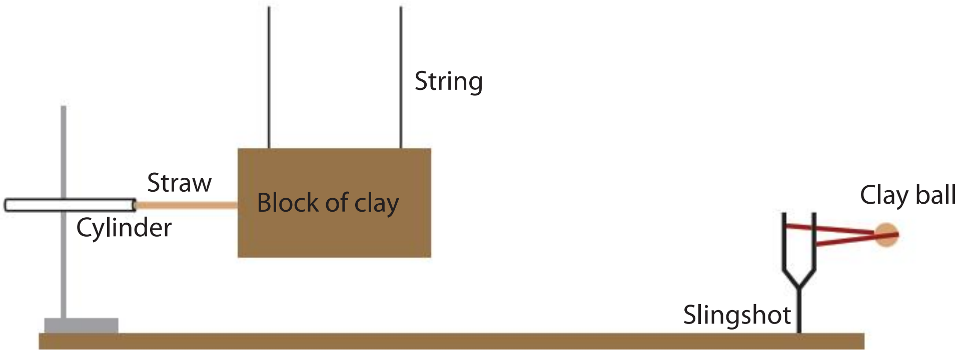
Problem 2

This investigation can be done in the laboratory. However, it may be better to use a garden hose outdoors. Determine the maximum range for a constant stream of water by varying the angle of the water outlet. Calculate the theoretical value for the angle and compare this value with the practical value.



Problem 3

You are to calculate the initial speed of an object catapulted at a stationary target. A block of clay may be handy in this investigation. You are provided with a sling shot, a clay projectile, a block of clay (*possibly from the Art Department in your school)*, string, a straw and a cylinder in which the straw can move.



Name* ________________________ *Date* _______ *Class* _______________________*Time: 1 hour

In this investigation you may be assessed using school-based criteria.

BACKGROUND

Thermal energy is transferred from a warmer body to a colder body. This transfer of thermal energy continues until the temperature of the mixture reaches a point of equilibrium at a temperature intermediate between the original temperatures. The warm water loses internal energy by transferring its thermal energy to the colder water. The colder water absorbs this thermal energy and gains internal energy.

A calorimeter is a useful piece of equipment for investigations in Thermal Physics because it allows masses at different temperatures to be mixed with minimum energy loss to the surroundings. The name of the instrument is derived from the Imperial unit, the calorie. A typical calorimeter is shown in the equipment list. Your teacher will ask you to find the specific heat capacity of the metal cup from published data.

The heating coil in the calorimeter will be used in a later investigation concerning the heating effect of an electrical current.

In this investigation, the thermal energy lost by the hot water will be determined from its drop in temperature, and the thermal energy gained by the calorimeter and the colder water will be determined from their rise in temperature.

The thermal energy lost and the thermal energy gained will be compared.

$$[\text{mass} \times \text{sp ht} \times \text{fall in temp}]_{\text{hot water}} = [\text{mass} \times \text{sp ht} \times \text{rise in temp}]_{\text{calorimeter}} + [\text{mass} \times \text{sp ht} \times \text{fall in temp}]_{\text{cold water}}$$

(Where 'sp ht' stands for the specific heat of the substances mentioned in the equation.)

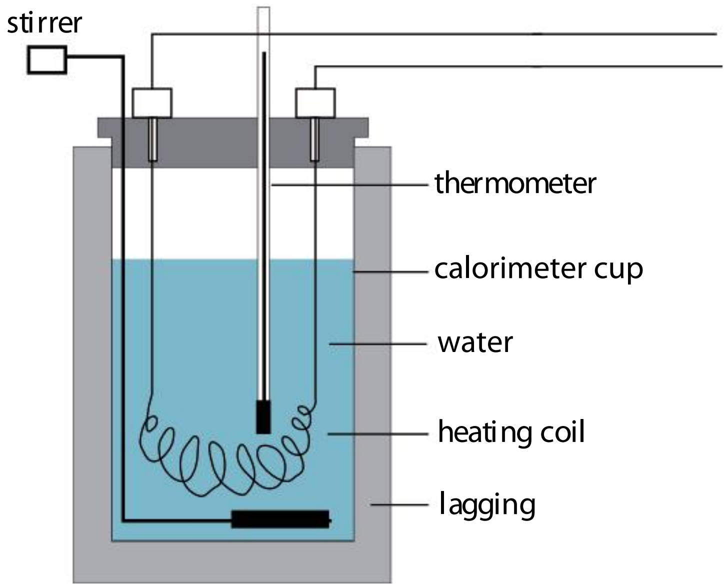
Temperature measurements introduce a large systematic uncertainty relative to the other recorded measurements in this investigation. By repeating the number of trials, a greater accuracy is expected.

AIM

To determine the relationship between the thermal energy lost by a mass of water and the thermal energy gained by another mass of water when the different temperature masses of water are mixed.

EQUIPMENT

Calorimeter (see diagram over), electric jug or water bath, digital or beam balance with a sensitivity to 1 kilogram, thermometers, flasks.



METHOD

1. Measure and record the mass of the inner cup of the calorimeter.
2. Add cold water to the cup until it is about one third full and determine the mass and temperature of the cold water.
3. Heat some water to about 80° C. Measure the temperature of the hot water and transfer it to the calorimeter until it is almost full.
4. Stir the mixture gently and record the equilibrium temperature.
5. Measure the mass of the calorimeter and its contents.
6. Repeat the above steps.

DATA COLLECTION (use extra paper)

Design and use suitable tables to record the data.

DATA PREPARATION AND ANALYSIS

Compare the difference between the thermal energy lost and the thermal energy gained.

CONCLUSION and EVALUATION

Compare the thermal energy lost and the thermal energy gained. Discuss the main errors.

Explain the Thermal Energy gain and loss using a microscopic model.

Name ______________________ **Date** ______ **Class** ______________________ ***Time: 40 mins***

You may be assessed using the following criteria:

DATA COLLECTION

- Collecting and recording appropriate raw data
- Presenting raw data allowing easy interpretation

DATA PRESENTATION AND ANALYSIS

- Processing raw data correctly
- Presenting processed data appropriately

CONCLUSION AND EVALUATION

- Stating a valid conclusion based on interpretation of results
- Evaluating the procedure including limitations and errors
- Suggesting a modified procedure to improve the investigation

ASSIGNMENT

You are required to develop this investigation from first principles by constructing a laboratory report using the normal communication procedures.

Using the normal equipment for Thermal Physics investigations, you are required to design and carry out an investigation to determine the specific heat capacity of a metal cube or metal cylinder provided by your teacher.

Furthermore, you will need to compare your obtained value with published values, and confirm your identification of the metal by choosing a second physical property of the metal and designing and carrying out an investigation to justify your findings.

You will need to provide your own paper and submit it as instructed by your teacher.

Name* ________________________ *Date* _______ *Class* _______________________ *Time: 50 mins

You may be assessed using the following criteria:

DATA COLLECTION

- Observing (collecting) and recording raw data
- Presenting raw data

DATA PRESENTATION AND ANALYSIS

- Processing raw data correctly
- Presenting processed data appropriately

BACKGROUND

Ice molecules are bound within a crystalline structure by intermolecular forces. The internal energy is due to the kinetic energy of the vibrating molecules and the molecular potential energy of the ice lattice. When the ice changes state, energy is absorbed and work is done to increase the separation between the molecules. The thermal energy absorbed increases the internal potential energy because there is no temperature increase in the melting process. The quantity of increased internal potential energy is known as the Latent Heat of Fusion of the substance.

When ice is added to warm water, it melts. In a closed system, the thermal energy lost by the warm water is equal to the thermal energy gained by the ice. The ice may be at a temperature below 0^{o} C if it has been in the freezer.

If this be the case:

$[\text{mass} \times \text{sp ht} \times \text{fall in temp}]_{\text{warm water}} + [\text{mass} \times \text{sp ht} \times \text{fall in temp}]_{\text{calorimeter}} =$

$[\text{mass} \times \text{sp ht} \times \text{rise in temp}]_{\text{ice}} + [\text{mass} \times \text{latent heat}]_{\text{ice}} + [\text{mass} \times \text{sp ht} \times \text{rise in temp}]_{\text{ice water}}$

(Where 'sp ht' stands for the specific heat of the substances mentioned in the equation.)

Usually, when the ice is removed from the freezer it begins to melt within a short time. If this is the case, then the specific heat capacity of the ice does not need to be considered in the above equation. Be careful that all the melting water is removed from the ice.

This investigation can also be carried out using a polystyrene cup in place of the calorimeter.

$L_{f\,ICE} = 3.34 \times 10^{5}\ \text{Jkg}^{-1}$

$c_{\ ICE} = 2.1 \times 10^{3}\ \text{Jkg}^{-1}\text{K}^{-1}$

$c_{\ WATER} = 4.18 \times 10^{3}\ \text{Jkg}^{-1}\text{K}^{-1}$

AIM

To determine the latent heat of fusion of ice and compare the value obtained with the published value.

EQUIPMENT

Calorimeter or polystyrene cup, ice cubes, paper towel, digital or beam balance, thermometers, warm water.

METHOD

1. Determine and record the mass of the calorimeter cup.
2. Warm some water to about 40ºC and half fill the calorimeter with the water. Determine and record the mass of the water.
3. Return the calorimeter cup to the calorimeter and cover it. Measure the equilibrium temperature of the water.
4. Dry the water from three normal sized ice cubes and carefully and quickly place them in the calorimeter.
5. Record the new equilibrium temperature.
6. Calculate and record the mass of the ice.

Write a report of your investigations on separate paper using the following headings:

DATA COLLECTION

OTHER OBSERVATIONS

DATA PRESENTATION AND ANALYSIS

CONCLUSION and EVALUATION

Name* ________________________ *Date* _______ *Class* _______________________ *Time: i hour

In this investigation you may be assessed using school-based criteria.

BACKGROUND

An **ideal gas** is a theoretical gas that obeys the **equation of state of an ideal gas exactly**.

They obey the equation $pV = nRT$ when there are no forces between molecules at all pressures, volumes and temperatures.

From the combined gas laws, we determined that:

$PV / T = k$ or $PV = kT$

If the value of the universal gas constant is compared for different masses of different gases, it can be demonstrated that the constant depends not on the size of the atoms but rather on the number of particles present (the number of moles). Thus for n moles of any ideal gas:

$PV / nT = R$ $PV = nRT$

This is called the **equation of state of an ideal gas**, where R is the universal gas constant and is equal to 8.31 J mol^{-1} K^{-1}. The equation of state of an ideal gas is determined from the gas laws and Avogadro's law.

Pressure can be defined as the **force exerted over an area**.

$P = F / A$

The SI unit of pressure is the pascal Pa.1 atm = 1.01×10^5 Nm^{-2} = 101.3 kPa = 760 mmHg.

Suppose we take a syringe, place on a set of digital scales, and push on the top of the plunger, the total pressure will equal:

$P_0 + mg / A$

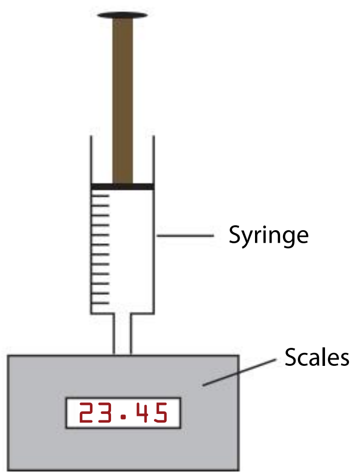
Where P_0 equals the atmospheric pressure and A is the cross-sectional area of the plunger.

Combining equations it can be shown that:

$PV = (P_0 + mg / A) V = nRT$

AIM

To determine the Universal gas constant using a calibrated syringe filled with a fixed mass of air placed on a set of scales (see diagram).



DATA COLLECTION AND ANALYSIS (use extra paper)

Rearrange the equation given above to arrange the dependant and independent variables, and the constant values.

Collect sufficient data that will allow you to draw a graph of the variables and using the graph, determine the value of R.

CONCLUSION AND EVALUATION

State a valid conclusion based on interpretation of results. Evaluate the procedure including limitations and errors. Suggest a modified procedure to improve the investigation.

Name ______________________ **Date** _______ **Class** ____________________ **Time: 1 hour**

You may be assessed using school-based criteria:

BACKGROUND

Boyle's Law relates pressure and volume for a gas at fixed temperature for ideal gases. For a real gas, it is obeyed at low pressures as is the case in school laboratory conditions. The pressure of a fixed mass of gas is inversely proportional to its volume at constant temperature.

$P \propto 1/V$

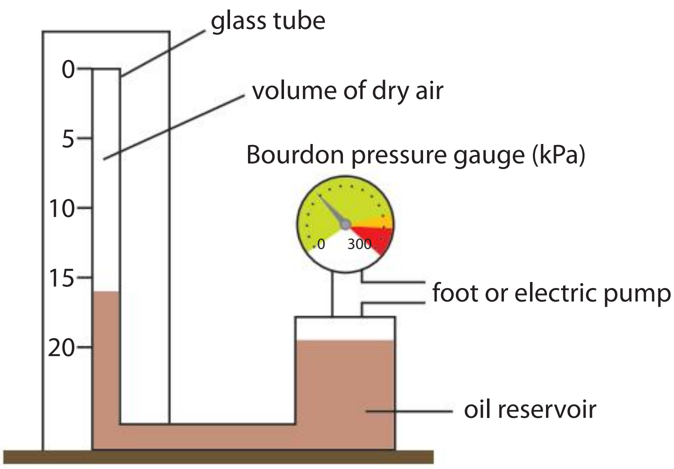
therefore PV = constant.

When the conditions are changed;

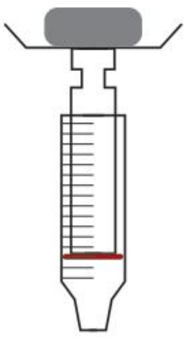
$P_1V_1 = P_2V_2$

There are three common experimental designs, and a schematic diagram for each design is shown below (see Set-ups 1, 2, 3). The readings obtained must be taken slowly to maintain constant temperature because when air is compressed, it warms up slightly.

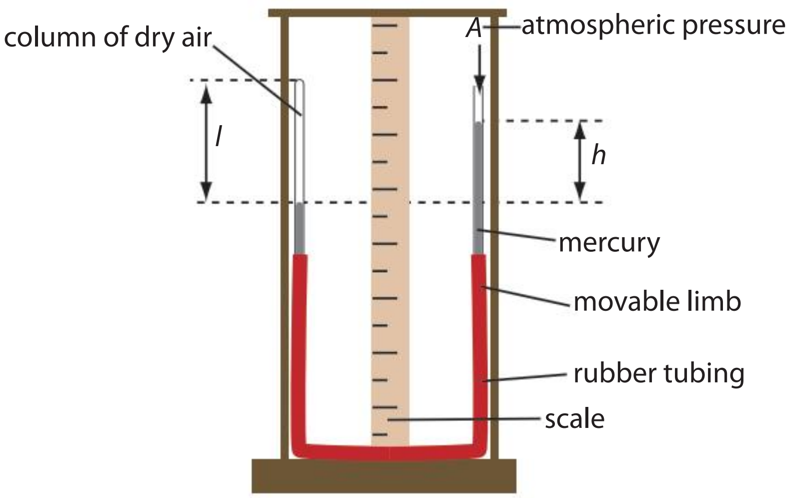
Mercury needs to be used with particular care. If using the oil apparatus be sure to watch the amount of pressure being used to avoid explosions of the glass tube.



Set-up 1



Set-up 3



Set-up 2

This investigation is a data-based exercise that will allow you to plot two isotherms.

AIM

To determine how the volume of a fixed mass of gas, at two constant temperatures, changes when the pressure on the gas is increased or decreased.

DESIGN

Using the data provided, plot the values for each temperature on a graph. Extrapolate the data points to obtain the relevant isotherms.

TEMPERATURE 1 PRESSURE ($Nm^{-2} \times 10^5$)	VOLUME (cm^3)	TEMPERATURE 2 PRESSURE ($Nm^{-2} \times 10^5$)	VOLUME (cm^3)
1.1	45.0	1.1	30.0
1.3	37.7	1.7	20.3
1.5	33.0	2.2	15.0
1.8	27.2	2.8	12.2
2.2	22.7	3.3	10.0
2.5	20.0	3.9	7.5

DATA ANALYSIS

Process your data to verify Boyle's Law.

CONCLUSIONS AND EVALUATION

Give a valid conclusion and comment on the graphs obtained.

Name ______________________ **Date** _______ **Class** ______________________ **Time: 1 hour**

You may be assessed using school-based criteria:

BACKGROUND

The Charles (Gay-Lussac) Law of gases states that the volume of a fixed mass of gas at constant pressure is directly proportional to its absolute (Kelvin) temperature. This can also be stated as; 'the volume of a fixed mass of gas increases by 1/273 of its volume at 0°C for every degree Celsius rise in temperature, provided the pressure is constant'.

$V \alpha T$

$V_1/T_1 = k_1$

$V_1/T_1 = V_2/T_2$

The Pressure (Admonton) Law of gases states that the pressure of a fixed mass of gas at constant volume is directly proportional to its absolute (Kelvin) temperature. This can also be stated as; 'the pressure of a fixed mass of gas increases by 1/273 of its pressure at 0°C for every degree Celsius rise in temperature, provided the volume is constant'.

$P \alpha T$

$P_1/T_1 = k_2$

$P_1/T_1 = P_1/T_2$

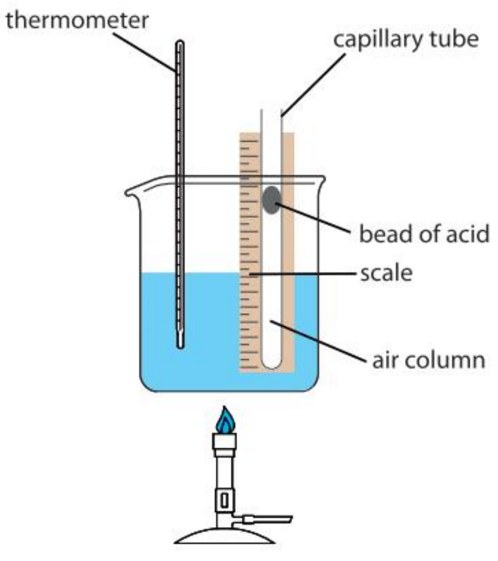
Therefore; 'for a fixed mass of gas, its pressure times its volume divided by its Kelvin temperature is a constant'.

$PV/T = k_3$

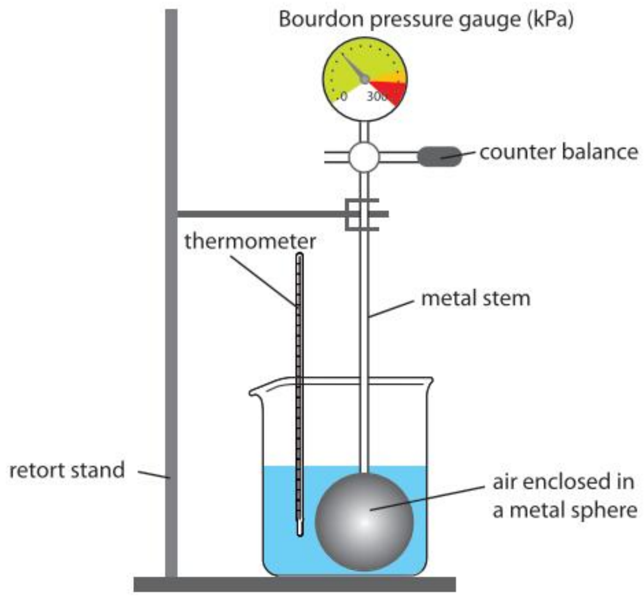
$P_1V_1/T_1 = P_2V_2/T_2$

This is known as the *combined gas equation*.

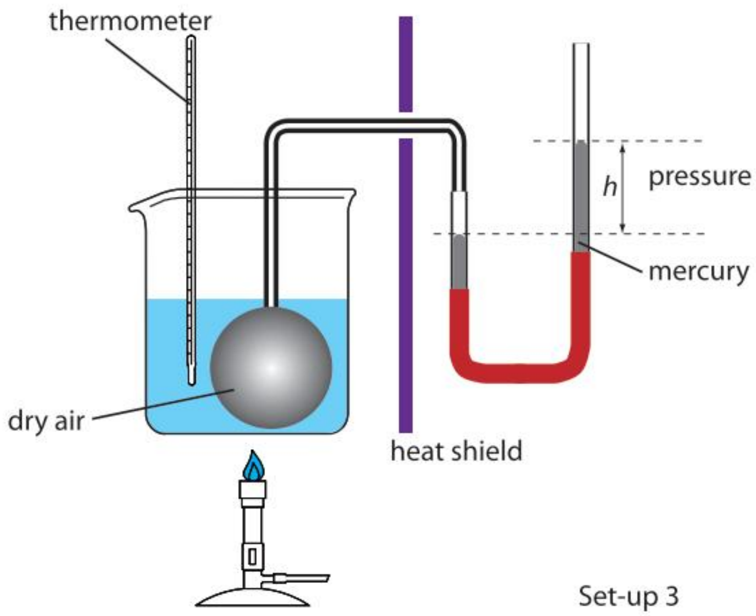
Some typical apparatus to demonstrate these relationships are shown below in Set-ups 1, 2 and 3.



Set-up 1



Set-up 2



Set-up 3

AIM

To determine how the volume of a fixed mass of gas at constant pressure, and the pressure of a fixed mass of gas at constant volume, change with the temperature of the gas.

In **Set-up 1**, a sample of dry air is trapped in a capillary tube by a bead of concentrated sulfuric acid. The capillary tube is heated in a water bath and the water is constantly stirred to ensure that the temperature of the whole air column is at the same temperature. The investigation should be carried out slowly to allow thermal energy to pass into or out of the thick glass walls of the capillary tube.

In **Set-up 2**, the essential parts of the apparatus are a metal sphere or round bottomed flask and a bourdon pressure gauge. These are connected by a short column of metal tubing or capillary tube to ensure that as little air as possible is at a different temperature to the main body of enclosed gas.

In **Set-up 3**, mercury manometer heights are obtained, as explained in the previous investigation.

This is a data-based exercise that will allow you to obtain a value for the absolute zero of temperature.

CHARLES' LAW		PRESSURE LAW	
LENGTH OF AIR COLUMN (cm^3)	TEMPERATURE (^oC)	PRESSURE ($Nm^{-2} \times 10^5$)	TEMPERATURE (^oC)
20.4	16.1	1.00	12.0
21.1	28.2	1.02	20.3
21.7	32.0	1.05	30.1
22.1	40.3	1.07	40.4
23.3	56.0	1.15	52.0
24.0	66.1	1.17	61.8
24.9	79.8	1.25	92.1
26.4	99.5	1.30	99.7

DISCUSSION (use extra paper)

Use the data provided to obtain absolute zero, and comment on the relationships being investigated.

Name ______________________ **Date** _______ **Class** ______________________ **Time:**

You may be assessed using school-based assessment criteria:

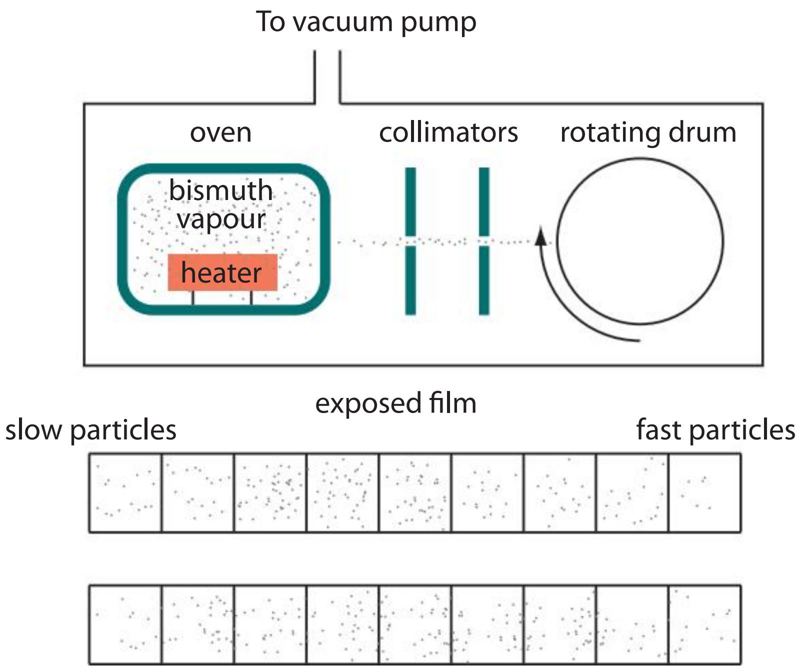
BACKGROUND

In 1931, Zartmann in the United States of America carried out a series of experiments to verify the statistical proposals of the Maxwell-Boltzmann distribution of molecular speeds.

Bismuth was heated in an oven enclosed in an evacuated chamber as shown in the schematic diagram below. The gaseous bismuth emerges from the oven, and pass through two screens to collimate the particles (to produce a beam). They then enter an evacuated drum rotating at high speed in a clockwise direction.

If the gaseous particles arrived at the hole in the drum at the right time, they pass through the hole, and they adhere to a curved piece of glass attached to the drum. Two plates are shown for samples of bismuth at different temperatures.

It can be shown that the distance along the film is proportional to the speed of the particles, and that the density of dots in each segment is proportional to the number of particles of the segment.



AIM

To confirm the Maxwell-Boltzmann distribution of speeds of bismuth gas at different temperatures.

EQUIPMENT

Graph paper, magnifying glass

METHOD

1. Using a magnifying glass, count the number of dots in each segment for the top glass plate.
2. Record these numbers in the relevant place of the data collection table.
3. Repeat steps 1 and 2 for the second glass plate.
4. On the same set of axes, plot a graph of the number of dots in each region versus the region distance along the film.

DATA COLLECTION

Construct a suitable table and record your data.

DATA PRESENTATION AND ANALYSIS

What did Zartmann conclude from the graph about the velocity of bismuth gaseous particles at the lower temperature?

What did Zartmann conclude from the graph about the velocity of bismuth gaseous particles at different temperatures?

How did Zartmann's observations provide support for the Kinetic theory of gases?

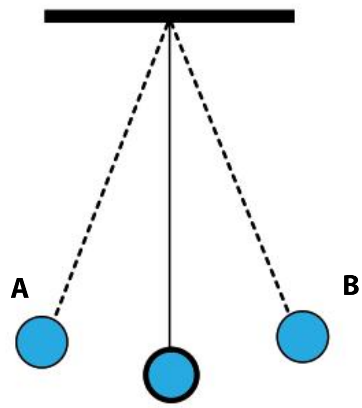
CONCLUSION and EVALUATION

Give a brief critique of the validity of the investigation.

Name ______________________ **Date** _______ **Class** ______________________ ***Time: 1 hour***

You may be assessed using school-based assessment criteria:

The Simple Pendulum



The simple pendulum essentially consists of a mass (the bob) suspended from a support by a string. The pendulum can be set into oscillation by pulling the bob back to A and releasing it.

The 'time period' of oscillation is the time it takes for the bob to swing from A to B and back to A.

In this investigation, you are asked to identify the factors that you think might affect the period of oscillation, and then investigate one of these factors in detail. Furthermore test, by a graphical method, that the simple pendulum swings with simple harmonic motion, and use your graph to deduce a value for the acceleration due to gravity.

Consider carefully the following statements and questions:

1. There are several ways in which your pendulum is not an ideal simple pendulum. What are they?
2. The SHM theory of the simple pendulum is only valid subject to a certain restriction. What is this, and how will it affect your experimental procedure?
3. Why is it important that the oscillations of the pendulum do not become elliptical?
4. What theoretical and practical limitations determine the range of values of the length of your pendulum?
5. With sufficient care, this experiment can yield a value for the acceleration due to gravity correct to 1%. Is your value as accurate as this? If not, why not?

An Oscillating Spring

A mass attached to the end of a light helical spring and set in motion to perform vertical oscillations will undergo simple harmonic motion. A light spring has negligible mass. The period of the simple harmonic oscillations is determined by the mass attached and the elasticity of the spring.

For any real spring, the mass of the spring itself is not negligible but rather affects the motion in a rather complicated way. However, we may take the spring's mass into account by attributing an "effective mass" m_0 to the spring and replacing m by $(m + m_0)$ in the theory which leads to the expression for the periodic time.

Write down the formulas for the period T when:

m_0 is negligible

....

m_0 is not negligible

....

In the **dynamic** experiment, investigate the variation of the period of oscillation of the spring with changing masses attached to it, and plot a graph to test your theory equation.

From the graph, deduce the values of m_0 and the spring constant k

In a second **static** experiment, investigate the variation of the extension of the spring from its equilibrium position for different forces attached to the spring (Hooke's Law).

Measure the slope of a graph plotted for this purpose, and use the value of k from the dynamic graph to help you deduce a value for the acceleration due to gravity.

Alternatively, you may wish to investigate one factor that may influence the period of the vertical oscillation of a mass on a helical spring.

AIM

EQUIPMENT

A good quality helical spring, metre rule, timing device, masses.

PROCEDURE

DATA COLLECTION

In this space below you should prepare data tables as required.

Other observations:

DATA ANALYSIS

In the discussion that follows you should explain inferences you have reached from your observations made during this investigation.

1. What exactly is meant by the word "extension"? Explain clearly how you attempted to measure this accurately.

2. Is there any limit on the amplitude of oscillation that may be used? For example, is it necessary/desirable to use small oscillations?

3. What problems did you encounter in obtaining an accurate value for the periodic time and how did you overcome them?

4. What physical properties of the spring do you think determine the value of the spring constant?

CONCLUSION AND EVALUATION (add extra paper if required)

Name ______________________ **Date** _______ **Class** ______________________ ***Time: 40 mins***

BACKGROUND

In this investigation, you will be using a slinky spring to observe longitudinal and transverse pulses and continuous waves and the properties associated with these.

A change in the nature of the medium propagating a wave is termed a discontinuity. You will observe the effects that occur in fixed end and free end reflection, and the effects that occur when two different mass/length springs are joined together.

There is a series of questions that you must answer using the spring as a wave model. You will be expected to draw sketches of your observations and use these sketches to aid you in the explanation of wave characteristics and properties.

AIM

To observe some wave properties and characteristics using springs.

EQUIPMENT

Slinky spring, long dense spring, light thread, 100 g mass.

METHOD

1. Stretch a slinky spring on the ground with your partner holding one end fixed. Produce a longitudinal pulse and a transverse pulse, and record the shape of the coils in the spring during propagation.
2. Use pulses and/or continuous waves fixed at one end to enable you to observe and record:

- the size and shape of the pulse as it moves down the spring.
- any speed changes as the pulse travels along the spring.
- any speed changes when the pulse is given a bigger or smaller amplitude.
- any speed changes when the tension in the spring is changed.
- the properties of the medium that determine the speed of the pulse.
- any change in the shape of the pulse when it strikes a fixed boundary.
- the effect that occurs when two different shaped pulses are sent along the spring in different directions by you and your partner.
- any changes that occur in the wavelength when the frequency changes for a continuous wave.
- any wave patterns that are formed when continuous waves are reflected at a boundary.

3. Tie a piece of three metre light thread to one end of the spring and produce a transverse pulse with the end with the thread acting as a free boundary. Observe and record the reflection characteristic at the free end.
4. Attach a 100 g mass to one of the slinky coils to produce a discontinuity. Observe and record how the wave energy is reflected and transmitted at the discontinuity.
5. Connect the slinky spring to the dense spring by tying the two securely together.

6. Observe and record:

- the wave speed characteristics in each medium.
- how the wave pulse is transmitted and reflected from the boundary in each case.
- any changes in amplitude.
- any phase changes.

Write a report of your investigations on separate paper using the following headings:

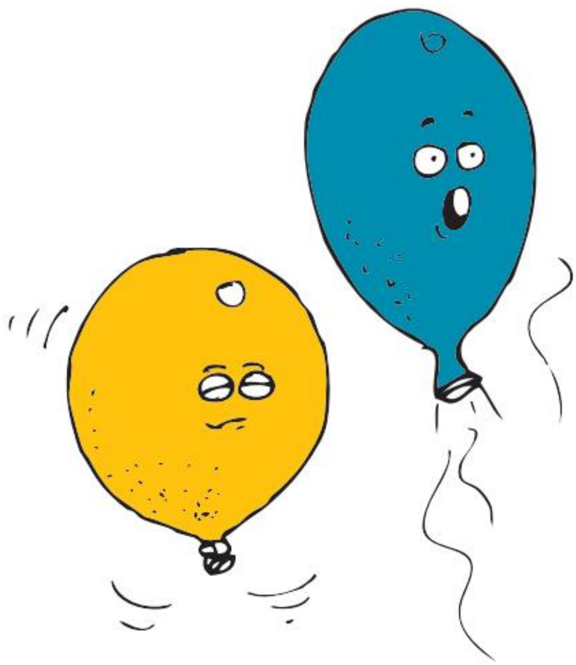
DATA COLLECTION

Collect the required data to answer the questions.

DATA PRESENTATION AND ANALYSIS

Use your data to answer all the questions above.

CONCLUSIONS AND EVALUATION

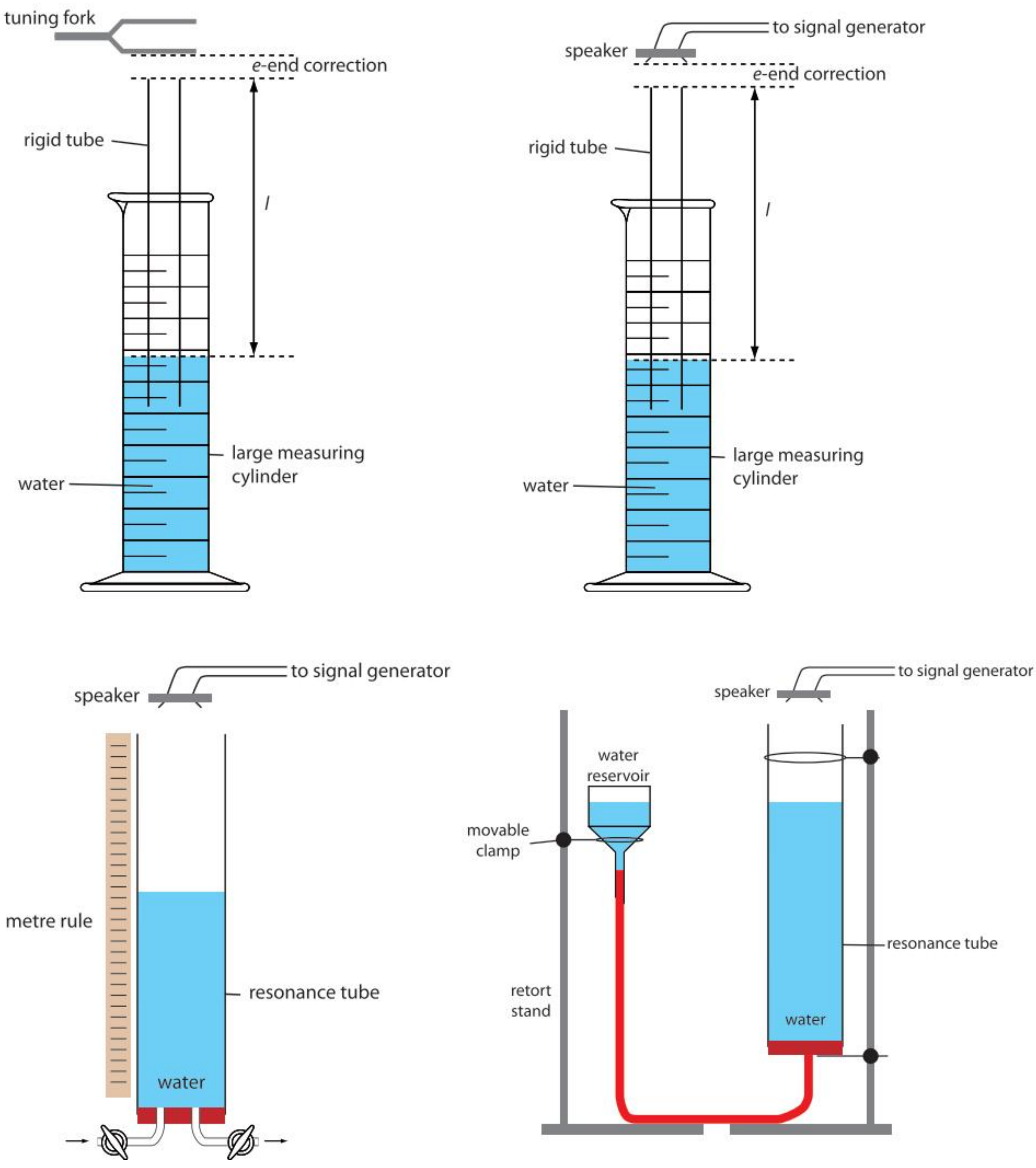


Name ________________________ **Date** _______ **Class** _______________________ ***Time: 1 hour***

In this investigation you may be assessed using school-based criteria.

BACKGROUND

The diagrams hereunder show examples of apparatus used for determining the speed of sound in air, using the phenomenon of resonance.



Waves produced by the tuning fork or the signal generator are propagated down the tube and are reflected at the water boundary. Standing waves are produced for certain water levels within the cylinder. These standing waves can be detected using resonance that occurs when the frequency of the source is equal to the natural frequency of the air column.

Resonance occurs when the standing or stationary waves produced have maximum amplitude. A node of high pressure and density is formed at the water boundary and an antinode of low pressure and density is formed a short distance, e, above the open end of the tube. The temperature of the air column will affect the speed of sound. The average speed of the air particles is greater at higher temperatures and therefore they can pass on compressions and rarefactions more quickly.

The longest wavelength producing resonance is equal to four times the length of the air column, *L*. This can also be stated as: 'the length '*L*' of the air column is equal to one quarter of the wavelength plus the end correction, e.'

$$\frac{\lambda}{4} = L + e$$

The speed of sound at a particular temperature is given by $v = f\lambda$

$$\therefore L + e = \frac{v}{4f} \quad \text{or} \quad L = \frac{v}{4f} - e$$

If the fundamental frequency, f, is determined using different tuning forks or signals from the signal generator for different lengths of the air column, a graph of L against *1/f* produces a linear graph with a slope of *v/4* and a y-intercept of –e.

Experimental measurements show that:

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$$ where c = 331 m s^{-1} at 273 K.

Write a report of your investigations on separate paper using the following headings:

AIM

To determine the speed of sound in air using standing waves in a column of air.

EQUIPMENT

METHOD

DATA COLLECTION

Complete your own data collection. A number of trials are needed.

DATA PRESENTATION AND ANALYSIS

Using the equation $L + e = \frac{v}{4f}$, plot a graph that allows you to determine the speed of sound 'v'.

Measure the room temperature and compare your value of V with the published value at that temperature.

CONCLUSION AND EVALUATION

Name ________________________ ***Date*** _______ ***Class*** ________________________***Time:***

In this investigation you may be assessed using school-based criteria.

BACKGROUND

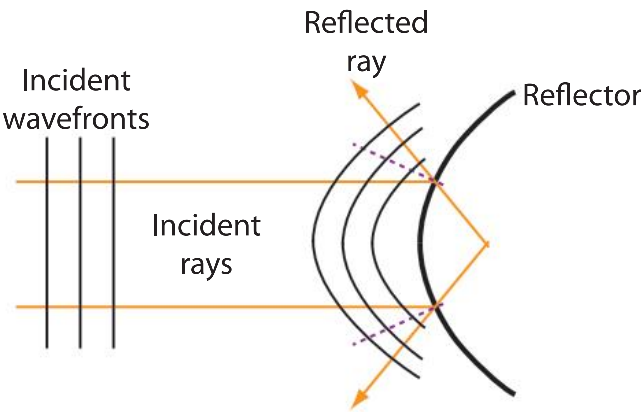
In this investigation, you will use pulses produced with a wooden dowel, periodic waves produced with a vibrator bar, and ripples produced with plastic spherical dippers. These disturbances will be used to observe reflection, refraction, diffraction and interference for surface water waves.

Some of the wave properties are more easily observed than other wave properties, and you will have to decide whether a pulse, a "wave train" or a ripple is the most appropriate technique in order to produce the best result for recording your observations. Be patient and thorough.

Your data collection requires carefully drawn and fully labelled diagrams of the observed wave patterns. The diagrams should include both wavefronts and rays to show the direction of wave travel. Your diagrams will be much easier to interpret if you organise a consistent legend for the representation of rays, wavefronts, barriers etc… (*Perhaps a set of different coloured pens will help*.)

AIM

To investigate wave properties using surface water waves in a ripple tank.



EQUIPMENT

Ripple tank kit including motor and light control unit, light, motor, metal reflectors, wooden dowel, eye dropper, vibrator bar, straight barriers, dippers, hand held stroboscope, sponge, perspex sheet, A3 paper, connecting leads, on/off switch, pens of different colour.

METHOD

Setting up the ripple tank

1. Place a lamp about 50cm above the ripple tank and set up the motorised vibrator bar.
2. Connect the lamp and motor to a ripple tank control unit, if available, or to two separate D.C. power sources.

Warning: *Electrical device.*

3. Place a piece of white A3 paper underneath the ripple tank to act as a screen.
4. Slowly pour water into the ripple tank until the depth is about 5 mm. Wipe the bottom perspex sheet with a sponge if there are air bubbles present. *Be careful not to scratch the Perspex.*
5. Level the tank by adjusting the height of the legs until the two images of the lamp, the image of the reflection from the water surface and the image of the reflection from the perspex surface, coincide on your white screen.
6. Use single drops from the eye- dropper to propagate circular wave pulses. Ripples in the tank act like lenses so that crests of wavefronts appear as bright areas and troughs appear dim areas, on the screen.
7. View the screen directly, and if you feel that you have eliminated any problems you should check with your teacher for preliminary planning and manipulative skills assessment.

REFLECTION

1. Propagate straight (rectilinear) waves using the wooden dowel.
2. Observe wave pulses reflected from a straight barrier, a concave barrier and a convex barrier.
3. Record your observations in the data collection section clearly, showing incident and reflected wavefronts and rays.
4. Repeat the three steps using drops from the eye dropper to propagate circular waves.

REFRACTION

1. Place the perspex trapezium sheet in the ripple tank with the diagonal side facing the incident wavefronts. Adjust the water level in the ripple tank until the perspex sheet is just covered.
2. Propagate a passage of continuous waves by lowering the vibrator bar until it touches the water surface.
3. View the image on the screen with a hand held stroboscope, adjusting the speed of rotation until the wavefronts appear stationary.
4. Observe and sketch the incident and refracted wavefronts.
5. Observe the refracted patterns for different angles of incidence and different frequencies of the vibrator bar.

DIFFRACTION

1. Refill the ripple tank with water to the 5 mm depth.
2. Place the two metal straight barriers in your kit in the water, parallel to the vibrator bar with a gap of 3 cm between them.
3. Propagate periodic plane waves with the vibrator.
4. Observe and record the patterns for different sizes of aperture. Be careful to observe both the patterns produced at the edges and between the barriers.
5. Adjust the vibrator frequency and record any relevant observations.

INTERFERENCE

1. Raise the vibrator bar and attach the two dippers. Lower the bar until the dippers just touch the water surface.
2. Observe and record the pattern produced when the two coherent circular waves are superposed.
3. Note the changes in the patterns when the vibrator frequency and the separation of the dippers are varied.

WAVE VELOCITY

1. Record the frequency of a series of periodic plane waves using a stopwatch or a hand held stroboscope or both methods.
2. Record the wavelength of these waves.
3. Calculate a value for the velocity of surface water waves.

DATA COLLECTION

Attach sheets to show your observations. Make sure that you have fulfilled all the criteria for the data collection assessment component.

DATA PRESENTATION AND ANALYSIS

1. What kind of wave is the surface water wave?

2. For the reflection section, compare the radius of curvature of the reflected wave with the radius of curvature of the barrier.

3. Compare the reflections produced for water waves with those produced by light rays in curved mirrors.

4. In the refraction section, in which medium do the water waves travel faster?

5. What effect has the depth on the wavelength and the wave velocity?

6. In the diffraction section, comment on the incident wavelength and the diffracted wavelength for different sized apertures.

7. In the interference section, comment on the difference in the pattern produced for different dipper frequencies and different dipper separation.

8. Give a value and an explanation of how you calculated the wave velocity of water waves.

CONCLUSION and EVALUATION

What are the advantages and disadvantages of using water waves to investigate wave properties in comparison to using light waves or mechanical waves? Which properties are best demonstrated using surface water waves? (*attach more paper*).

Name ________________________ **Date** _______ **Class** _______________________ **Time: 1 hour**

You may be assessed using school-based criteria:

BACKGROUND

Electromagnetic waves consist of oscillating electric and magnetic fields travelling at the speed of light. The electric field oscillates at right angles to the magnetic field. Natural crystals of tourmaline and calcite, and synthetic "polaroid" will only allow oscillating electric vector components of a particular direction to pass through them. Therefore, these electric oscillations of electromagnetic waves emerging from such a material are parallel to each other and lie in one plane. They are said to be plane polarised.

Polaroid is a material composed of sheets of nitro-cellulose, containing crystals of iodosulfate, arranged as long molecules. These long molecules reflect and preferentially absorb electric vector components along their length. Polaroid is used in sunglasses and certain lamps to reduce glare. Many scientific observations that are not possible with ordinary unpolarised light may be made possible with polarised light. Certain optically active chemicals can be identified using polarimetry, and stress in structural materials can be observed using polarisation. Polarisation can also be used to determine the thickness of crystals and fibres.

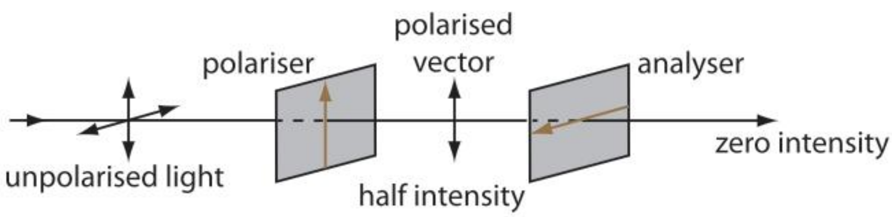
Apart from light being partially or totally polarised by transmission through certain materials it can also be partially or totally polarised by reflection from shiny surfaces, by double refraction in certain minerals and high frequency blue light diffraction scattering by certain molecules in the atmosphere. It is believed that bees and other animals use polarisation for navigation.

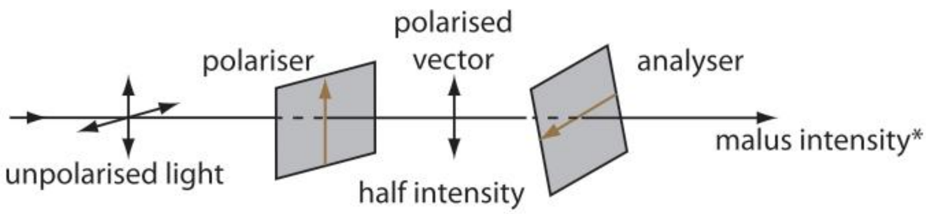
In this investigation, you will observe and record some of the properties of polarised light that have been mentioned. You will use two sheets of polaroid called the polariser and the analyser. The intensity of light incident on an ideal polariser is halved after preferential absorption. The analyser can then be rotated from 0° to 90° to reduce the emerging light intensity to zero. When the electric field for light incident on a polaroid is at an angle θ to the plane of vibration then the electric field vector of the light emerging is E_0 cos, and the light intensity emerging from the polaroid is given by the Malus equation:

$I = I_0 \cos^2\theta$

where I is the emerging light intensity and I_0 is the half intensity after polarisation.

Remember that other electromagnetic waves, such as radio and microwaves, can also be polarised.





* when the light intensity seen is equal to zero

AIM

To investigate methods of producing and detecting polarised light.

EQUIPMENT

Three squares of polaroid 5 cm in diameter, 5 microscope slides, glass block, ray box to give a single beam of light, polarimeter if available, protractor, Perspex ruler, liquid crystal display (calculator, digital watch), masses string, colour filter for the ray box sucrose solution.

METHOD

Part A Production and detection of polarised light

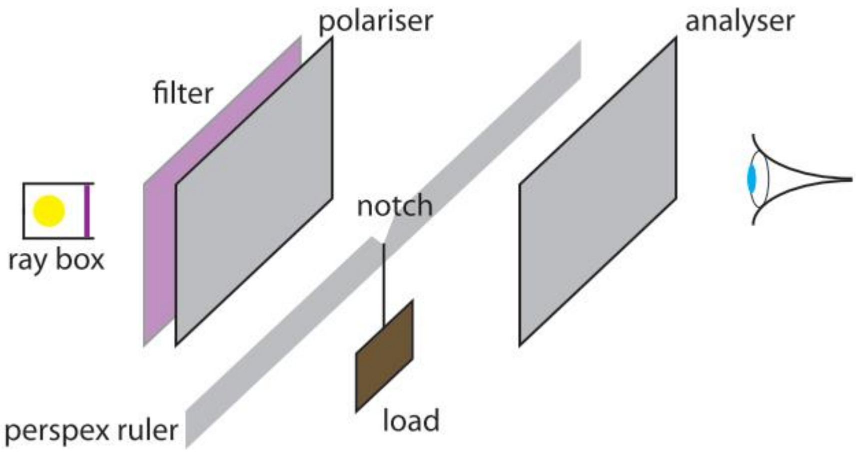
1. Look at the light from the ray box through one piece of Polaroid, the polariser.
2. Rotate the polariser about an axis through the centre of the thin side.
3. Comment on the intensity of light.
4. Do the same with a second piece of Polaroid, the analyser, on its own.
5. Comment on the intensity of light.
6. Hold both the polariser and the analyser a short distance apart and look at the ray box at the same distance as in steps 1 and 4.
7. Rotate the analyser while keeping the polariser fixed in position.
8. Comment on the light intensity as the analyser is rotated through 360°.
9. Tilt the analyser forward while rotating it. Keep the polariser fixed in position.
10. Comment on the intensity of light compared to Step 8.

Part B Production of polarised light by reflection

1. Shine a ray of light onto a glass slide at an angle of incidence of 40°.
2. View the position of the reflected ray through a piece of Polaroid. Call this position 1, P1.
3. Rotate the piece of Polaroid about the axis of the reflected light and at 45° intervals, record the light intensity as high, medium, low or zero.
4. Now, move the Polaroid and view the beam of light directly transmitted through the slide called position 2, P2.
5. Rotate the piece of Polaroid as in Step 3.
6. Repeat Steps 1 to 5 for angles of incidence of 57° and 70°.
7. Place a second glass slide parallel with the first and 1 cm apart.
8. Repeat Steps 1 to 6.
9. Carry out the same procedure for a number of separated slides, and a glass slab about the same thickness as the stack of slides.
10. Record all your collected data in a table in the data collection section.

Part C Identifications

1. Observe a number of calculator or digital watch displays with a rotated polariser and record your observations.
2. Rotate a third piece of Polaroid between two crossed polaroids (the polarisation direction of the polariser and the analyser are at right angles to each other).
3. Use a polarimeter, or a ray box with Polaroids, set-up to examine a sucrose solution.
4. Rotate the analyser and record your observations.
5. Set up the following apparatus and record all relevant observations.



DATA COLLECTION AND PRESENTATION (use extra paper)

Use this space to record your data and observations.

Name ________________________ ***Date*** _______ ***Class*** _______________________***Time: 1 hour***

You may be assessed using school assessment criteria:

BACKGROUND

After reading the 3 method sections hereunder, research and record the equations relevant for determining the refractive index of the blocks used.

Equation 1

Equation 2

Equation 3

AIM

To determine the refractive index of a semi-circular perspex slab using three different methods.

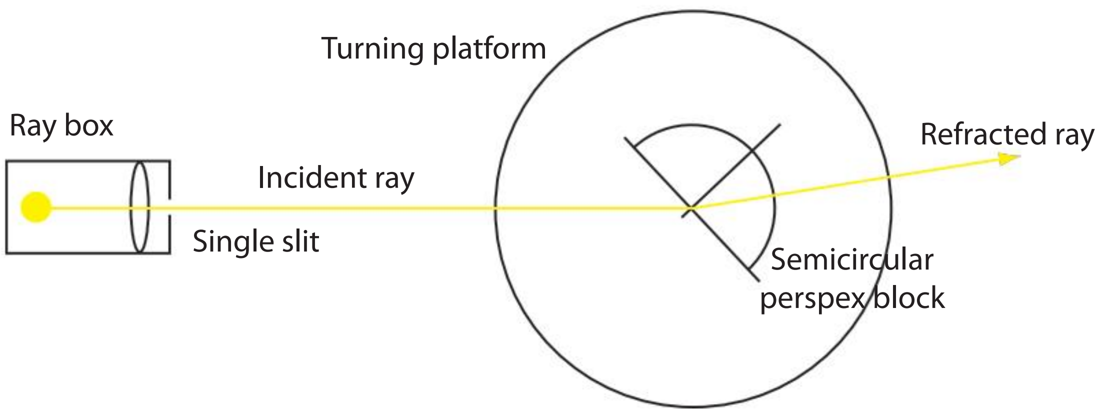
EQUIPMENT

Ray box, semi-circular block, rectangular perspex block, rotating platform, single slit, sheets of A4 paper and a pencil, protractor, graph paper.

METHOD

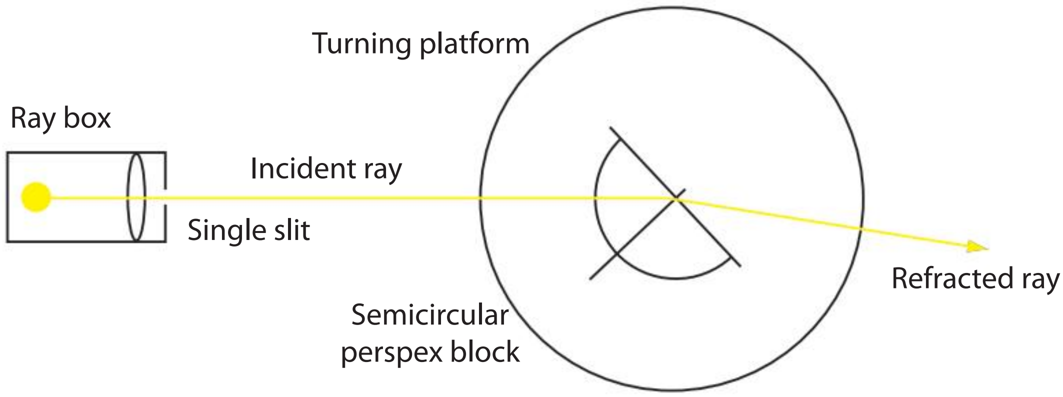
Part A: Graphical Method

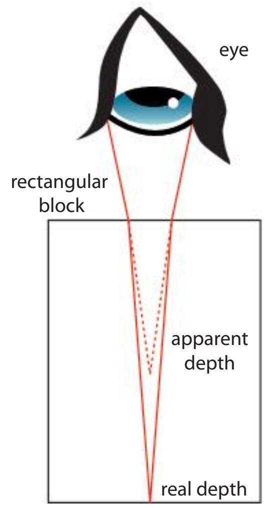
1. Position a semi-circular perspex block on top of a piece of A4 paper at the centre of a rotating platform as shown in the diagram on the next page.
2. Turn on the raybox and rotate the platform so that the incident ray is directed onto the straight side of the semi-circular block (see diagram).
3. Measure and record the angle of incidence and the angle of refraction at this point.
4. Rotate the platform to obtain a number of angles of incidence and refraction over as wide a range as possible.
5. From the data, determine the refractive index of perspex.



Part B: Using the Critical Angle

1. Position the semi-circular block on another sheet of A4 paper, as shown hereunder.
2. Rotate the platform to the position where the refractive ray just disappears and internal reflection occurs.
3. Determine the critical angle and the refractive index of perspex.





Part C: Real and Apparent Depth (optional)

1. Draw a straight line onto a piece of A4 paper.
2. Stand a rectangular perspex or glass slab on its end over the line drawn, as shown in the adjacent diagram.
3. Use the no-parallax method to determine the apparent position and apparent depth of the drawn straight line.
4. Determine the refractive index of the rectangular block.

Present your report for one or more of these methods as instructed on extra paper using the following headings

DATA COLLECTION

DATA PRESENTATION AND ANALYSIS

CONCLUSION and EVALUATION

Name ______________________ **Date** _______ **Class** ______________________ **Time: 1 hour**

You may be assessed using school based criteria:

BACKGROUND

If a string is caused to vibrate at a particular frequency, it will only vibrate with a large amplitude if the generated frequency is one of the natural frequencies of the string. This is an example of resonance. An appropriate apparatus, shown hereunder, uses a signal generator and vibrator attached to a piece of string under tension, to produce standing or stationary waves.

If the frequency of the signal generator is slowly increased, then an amplitude in the form of a loop will be seen. With further increases in the frequency of the signal generator, two loops and three loops can be observed. The frequencies used are the first (fundamental), second and third harmonics of the string.

AIM

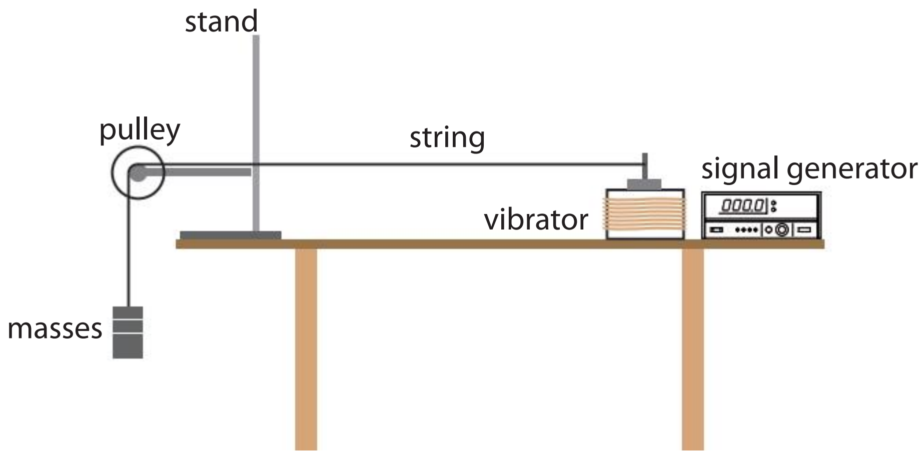
To find the relationship that exists between the frequency of the fundamental harmonic and the tension in the string.

EQUIPMENT

Signal generator, vibrator/oscillator, string, pulley, slotted masses, metre rule, weighing device.

METHOD

1. Set up the apparatus as shown in the diagram.



2. Connect the signal generator to the vibrator.
3. Hang 40 g from the string and adjust the frequency of the vibrator until the string vibrates in its fundamental mode.
4. Repeat the above steps for different masses.

Write a report of your investigations on separate paper using the following headings:

METHOD

DATA COLLECTION

DATA PRESENTATION AND ANALYSIS

Use the data to determine the relation between the fundamental frequency of vibration and the tension in the string.

CONCLUSION and EVALUATION

Investigation 5A
ELECTRIC FIELD PATTERNS

Name ______________________ **Date** _______ **Class** ______________________ **Time: 1 hour**

You may be assessed using the following school-based criteria:

MATERIALS

In this experiment you will need:

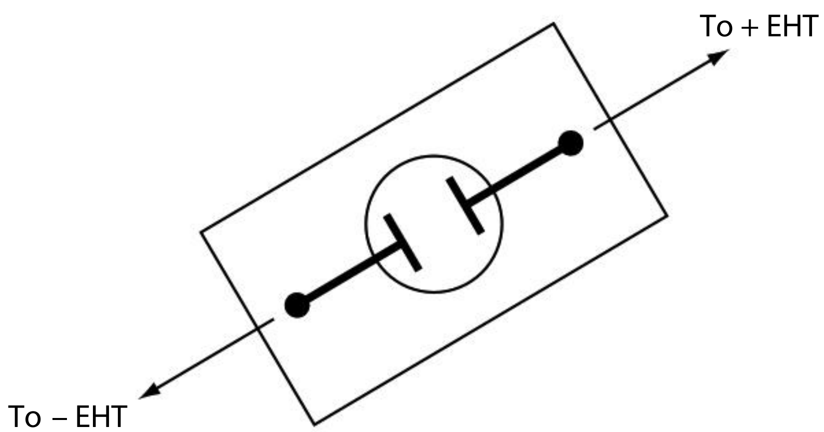
- An EHT supply
- Electric field apparatus
- Grass seed
- Bare copper wire and leads
- Castor oil

METHOD

You should use the apparatus to observe the electric field patterns of the following:

- Two parallel conductors
- Single point conductor
- Two point conductors
- One point conductor and one straight conductor

The diagram below shows the set-up for observing the electric field pattern between two parallel conductors.



1. Add some castor oil to the dish and sprinkle some grass seed on to the surface of the oil.
2. Switch on the EHT supply and gradually increase the EHT supply voltage.
3. You should then make a sketch of the pattern that you observe.
4. To make a "single point" conductor you should bend a piece of the bare copper wire into this shape (*approx 3cm × 3 cm)*.

DATA

You should sketch diagrams to show your observations on separate paper.

Name ________________________ **Date** _______ **Class** _______________________ **Time: 1 hour**

You may be assessed using school-based criteria:

AIM

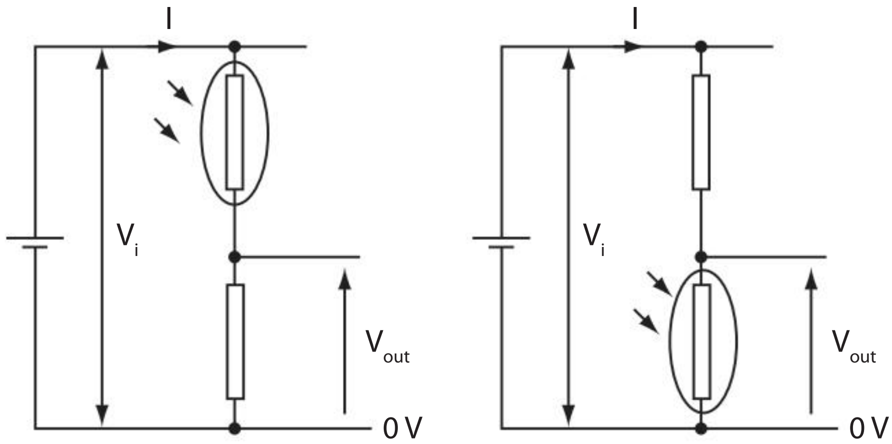
To determine the optimum value of the fixed resistor in each voltage divider circuit, as shown below.

EQUIPMENT

Light dependant resistor, 100 Ω , 1k Ω , 10k Ω , 100 k Ω and 1 M Ω resistors, 9V battery or power supply, multimeters, connecting wires, on-off switch.

DESIGN

1. Take the multimeter and put it on the 20 kΩ setting and measure the average resistance of the LDR when it is exposed to the light in the laboratory. Repeat with the LDR in a controlled shady location.
2. Set up the circuit as shown in the diagram, inserting the 100 Ω fixed resistor.



3. Measure the output voltage across the fixed resistor when the LDR is in the light and in the shade.
4. Repeat Step 2 while replacing the 100 Ω with each of the other resistors in turn.

DATA COLLECTION AND ANALYSIS

Record your results in a data table and determine the difference between the output voltage in the shade and in the light.

CONCLUSION and EVALUATION

Comment on the difference between the two circuits, referring to the potential divider equation.

Name ______________________ **Date** _______ **Class** ______________________ ***Time: 90 mins***

You may be assessed using school-based criteria:

BACKGROUND

This is a formal design investigation.

You are required to design an investigation to show the relationship that exists between the resistance of a wire and its length and cross-sectional area. Results of the direct measurements and calculations of are to be presented graphically in order to determine the resistivity of the wire. The value obtained for the resistivity should be compared with published values.

You are provided with a certain wire of different lengths and different gauges. Any other equipment needed will be provided by your teacher.

Warning: Be careful not to use electric currents during the data collection component that will cause the wire to dissipate thermal energy (i.e. gets hot).

You are required to define the research question, formulate hypotheses and select any relevant variables.

You are also required to design realistic procedures to include appropriate apparatus, materials for both the control of variables and collection of data.

Your data should be clearly presented. A minimum of two graphs should be included with your report. Full error analysis and evaluation of your results is part of this formal report.

Present your report on separate paper.

Name ______________________ **Date** _______ **Class** ______________________ **Time: 1 hour**

You may be assessed using school-based criteria

BACKGROUND

In 1826, Ohm (1787-1854) discovered the relationship that existed between potential difference and current flow through a metallic conductor. It is now known as Ohm's Law and can be stated as: "Provided the temperature is kept constant, the potential difference between the ends of a metallic conductor is directly proportional to the current flowing".

$V \alpha I$

The formula is commonly written as: $V = IR$

where R is the resistance in ohms (Ω), V is the potential difference across the resistor in volts (V), and I is the current in the resistor in amperes (A).

As the current moves through the resistance of a device, it loses electric potential energy. The potential energy of a positive charge is less upon leaving the resistor than it was upon entering. We say that there is a potential drop across the device. Devices that obey the linear relationship of the graph are said to be **ohmic devices** or **ohmic conductors.** There are very few devices that are ohmic, although some metals can be if there is no temperature increase due to the heating effect of the current. However, many useful devices obey the law at least over a reasonable range.

AIM

To investigate the relationship that exists between the current passing through a resistor with a known value, and the potential difference across the resistor.

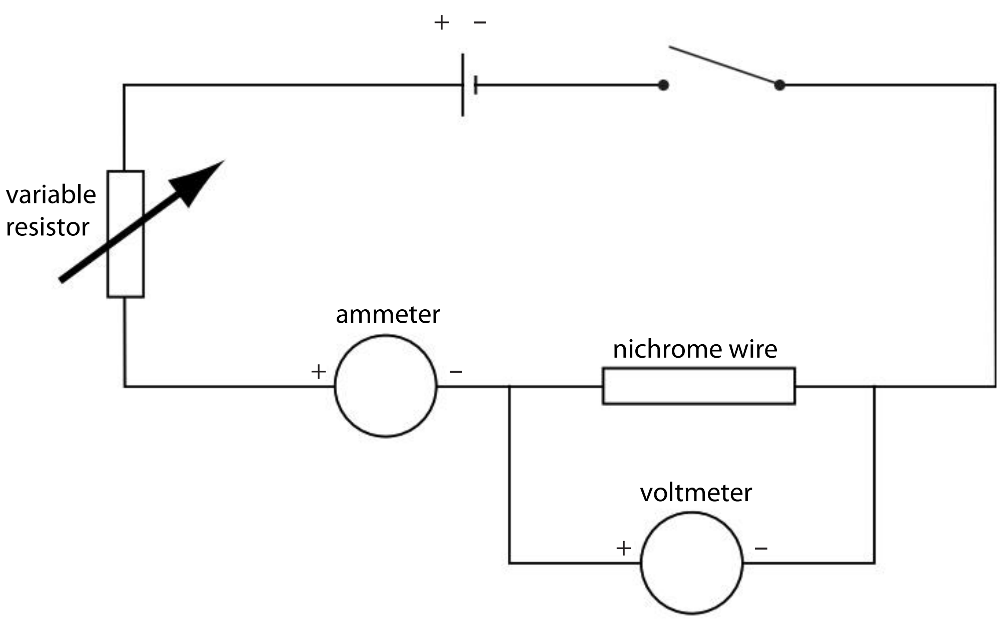
EQUIPMENT

A resistor with a known value, a variable rheostat, connecting wires, an on-off switch, a voltmeter and an ammeter (or 2 multimeters), a filament lamp.

Power supply (0-12 V) or a 1.5V dry cell.

METHOD

1. Set up the circuit as shown in the following diagram. When this is done, wait for your teacher to test your circuit.



2. When you have had your circuit checked, take a reading of the current through the resistor and the corresponding reading of the potential difference across it. Be sure to note the degree of uncertainty in your meters.
3. By moving the top adjustor of the variable resistor, take another 5 readings of the current and the corresponding potential difference.
4. Transfer these readings in ascending order of magnitude to the table given in the data collection section.
5. Repeat Steps 3 and 4 replacing the resistor with a filament lamp.
6. Plot graphs of the current flowing through the resistor and the filament lamp versus the potential difference across the two loads. Show the error bars for each reading.
7. From the resistor graph, calculate the resistance of the resistor.
8. For the resistor, complete the table in the data collection section for the power drawn by the wire.
9. Draw graphs of power versus current, and power versus potential difference. Show the error bars for each reading.

DATA COLLECTION

Resistor Reading	Current / A ±	Potential difference / V ±	Power / W
1			±
2			±
3			±
4			±
5			±
6			±

Filament lamp Reading	Current / A ±	Potential difference / V ±
1		
2		
3		
4		
5		
6		

DATA PRESENTATION AND ANALYSIS

1. What does your graph in Step 6 indicate about the relationship that exists between the potential difference and the current?

2. Calculate the resistance of the resistor as requested in Step 7. Calculate the degree of uncertainty in your measurement.

3. What are the relationships suggested by the graphs of power versus current and power versus potential difference for the resistor?

4. Using the equations P = VI and V = IR and your graphs, derive expressions for power as a function of current and power as a function of potential difference.

CONCLUSION AND EVALUATION (use extra paper)

What conclusions can be drawn from your analysed data? (Be sure to address the sources of error and suggest possible modifications or improvement that could have been made).

Name ______________________ **Date** _______ **Class** ______________________ ***Time: 45 mins***

ASSESSMENT

You may be assessed using school-based criteria:

BACKGROUND

The basic electrical circuit can be thought of as an 'input transducer' and a 'load' The input transducer is the device that converts energy into electrical energy. For example, a cell converts chemical energy into electrical energy. The load is generally the device in which the electrical energy is converted back into another form of energy. For example, an electrical motor converts the electrical energy into kinetic energy and a resistor converts the electrical energy into thermal energy. We can think of the electric current as the means by which the electrical energy is transferred to the load. All input transducers possess a property called "internal resistance" and it is essentially this property that determines the maximum current and the maximum power that can be delivered by the transducer.

In this experiment, you will measure the internal resistance of a battery consisting of four dry cells (the transducer) each with a nominal emf of 1.5 V. You will also determine the emf of the battery and the value of the load resistance for which the power delivered by the battery to the load is a maximum. The load is a 0-15 Ω variable resistor.

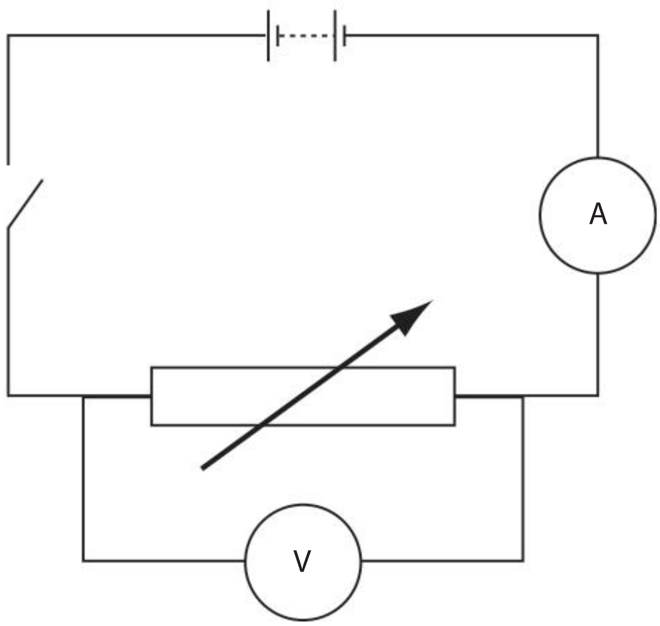
If the battery has an emf E and the current drawn from the battery is I when the potential difference across the load is V then:

$E = I\,r + V$

Where r is the internal resistance of the battery.

METHOD

Set up this circuit to measure V and I for different settings of the variable resistance.



DATA COLLECTION

Prepare a suitable table for your data.

DATA PRESENTATION AND ANALYSIS (use extra paper)

1. Use a grid to plot an appropriate graph from which a value of E and r can be determined.
2. Calculate E and r
3. Use the data that you have recorded to find the power (P) delivered to the load for different values of the resistance (R) of the load.
4. Plot a graph of P against R and use this graph to find the value of R for which P is a maximum and comment on this value.

CONCLUSION AND EVALUATION

You should evaluate your experiment in accordance with the different aspects of the evaluation criteria.

Name ________________________ **Date** _______ **Class** _______________________ **Time:**

AIM

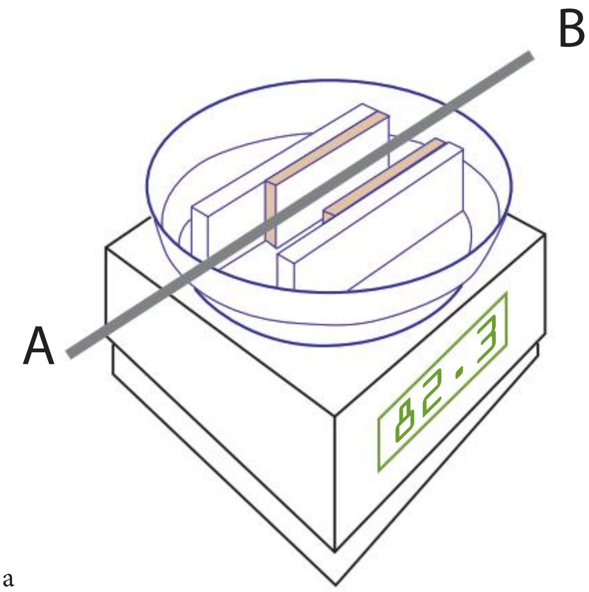
The purpose of this experiment is to show that the magnetic force on a current carrying conductor is proportional to the strength of the magnetic field and to the current in the conductor.

MATERIALS

You will require the following apparatus

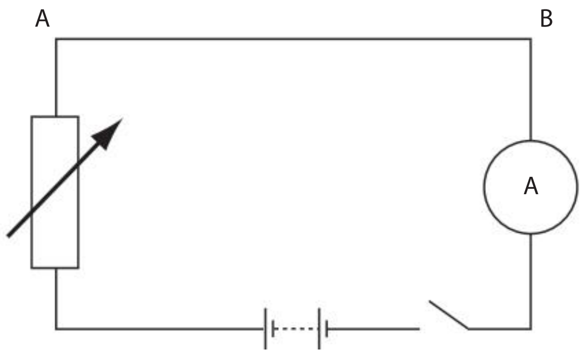
- Top pan balance reading up to 1 kg
- 8 'magnadur' magnets
- A mild steel yoke
- Bare copper wire 2mm in diameter
- 12 V battery (dry cells)
- Ammeter
- Rheostat (0-15 Ω)
- Connecting wires and crocodile clips.

The experimental set-up is shown in the diagram.



METHOD

1. Mount two magnets in the yoke and set the yoke inside a plastic dish as shown. The dish is of such a height that when placed on the balance the wire AB rests between the magnets as shown.
2. Below is the simple circuit diagram required for varying the current through the wire AB.



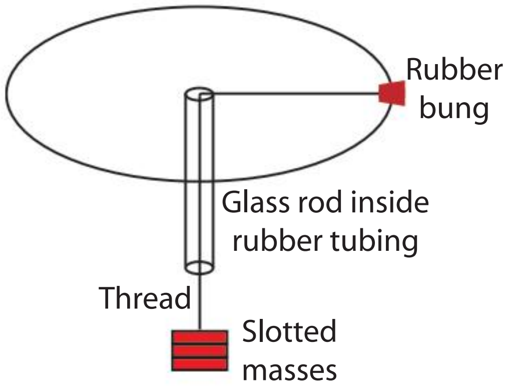
3. Connection should be made to the ends of wire AB with crocodile clips and the direction of the current should be such that the magnetic force on the wire is downwards.
4. Record the initial reading on the balance and then switch on the circuit with the rheostat set at its maximum value. Gradually increase the current until you obtain a noticeable difference in reading on the scale of the balance. Record this difference and the value of the current.
5. Analyse your results in an appropriate way to show that the force on the wire AB is proportional to the current through it.
6. Repeat the experiment using four magnets and six magnets and use the results from this experiment to show that the force on the conductor is proportional to the strength of the magnetic field.

Present your report on separate paper

Name ________________________ **Date** _______ **Class** _______________________ **Time:**

You may be assessed using school-based criteria:

BACKGROUND



This investigation studies motion in a horizontal circle with uniform speed. The circulating mass is a rubber bung and the necessary centripetal force is provided by the tension in a piece of cord attached to the bung at one end and loaded with weights at the other. The cord passes through a short length of glass tubing.

To set the bung in horizontal circular motion, hold the glass tube firmly above your head and support the weights with your other hand. Move the glass tube in small circles to start the bung rotating and then release your hold on the weights. Practise this until you can whirl the bung at a steady rate and at a chosen radius without the cord slipping over the rim of the tube.

The apparatus is very simple but you must take a series of measurements. Be patient and think carefully about several major sources of error.

In each case, you will plot a graph that will enable you to assess whether or not the theory on uniform circular motion has been confirmed.

You will also be asked to deduce the value of the acceleration due to gravity "g" from each graph and to compare your values obtained with the standard value.

Warning: *This investigation must be carried out in a manner that does not endanger property or other individuals. It is best done outdoors. Make sure that the apparatus is safe before beginning the investigation.*

AIM

To investigate the relationship between the orbital period of a body moving with uniform circular motion and:

a) the radius of the circular orbit of the body while keeping the centripetal force on the body constant.

b) the centripetal force on the body while keeping the orbital radius of the body constant.

EQUIPMENT

Slotted masses and a mass carrier, thick-walled glass tube 15 cm long with an internal diameter of 5 mm and fire-polished ends, rubber bung/stopper, nylon thread 1.5 m long with a 10 kg breaking strain, alligator clip, stopwatch, weighing machine.

METHOD

1. Measure and record the mass of the rubber bung.
2. Thread one end of the nylon thread through the glass tube and tie it securely to the stopper.
3. Attach the 50 g mass carrier to the other end of the nylon thread through the glass tube until the radius of the stoppers orbital path is 1 metre. Place the alligator clip just below (3mm) the glass tube.
4. Whirl the stopper above your head with horizontal uniform circular motion of radius 1 m. Make sure the alligator clip stays just below the glass tube at all times.
5. Working in pairs, measure and record the time for 20 complete revolutions of the stopper which is executing uniform circular motion. Record the data in a suitable way.
6. Complete and record the radius, the time for 20 revolutions, the period and the period squared for the stopper's uniform circular motion. You must give the degree of uncertainty for the measurements recorded.
7. Repeat the procedure four times with varying orbital radii.
8. Repeat the above procedure, this time varying the centripetal force while keeping the orbital radius constant.
9. Record the centripetal force in grams weight. Then, calculate and record the centripetal force in newtons.
10. Complete and record the period, mass and the reciprocal of the period squared for the stopper's uniform circular motion. You must give the degree of uncertainty for the measurements recorded.
11. Repeat the procedure four times with different masses added to the mass carrier.

DATA COLLECTION (use separate paper)

DATA PRESENTATION AND ANALYSIS

Use the data to determine the relationship between orbital period and (a) the radius and (b) the centripetal force as stated in the Aim.

Also find from the data, a value for the acceleration due to gravity.

CONCLUSION AND EVALUATION

In the discussion that follows, you should explain what inferences you have reached with regards to the aims of the investigation. You should evaluate the results of the investigation and the procedures used and suggest modifications to the procedures. This infers that you will discuss the types of errors you encountered during the practical.

Name ________________________ **Date** _______ **Class** _______________________**Time:**

In this experiment you may be assessed using school-based assessment criteria:

BACKGROUND

In a sample of a radioactive element it is not possible to predict which particular atom will undergo decay or when. The event is completely random. If for example we could observe just one atom we are unable to say that it will decay within a given time. However, if we could observe to atoms then we can say that we now have twice the chance of observing one of them decay in a given time. Increase the number of atoms and we further increase the chance. In fact we can say that the chance of observing an atom decaying is proportional to the number of atoms present in the sample. This is essentially the law of radioactive decay.

In this investigation one uses beer foam to simulate the exponential decay of a radioactive substance.

AIM

In this experiment we simulate the decay process using the height of beer foam as time progresses.

MATERIALS

500 mL measuring cylinder, masking tape, non-alcoholic beer, centimeter ruler, stopwatch.

METHOD

1. Place a strip of masking tape along the vertical scale of the measuring cylinder so that the beer liquid level can be marked at equal time intervals.
2. Pour the beer into the measuring cylinder until the foam nearly reaches the top.
3. Quickly mark the beer liquid level on the tape and start the stopwatch.
4. Mark the beer level every 5 seconds. Do this for as long as you can, up to two minutes.
5. When you no longer notice any change in beer liquid level, continue waiting for another two to three minutes until as much foam turns into liquid as possible. Some beer foam will remain on the inside of the measuring cylinder.
6. Now record the maximum beer liquid height on the tape.
7. Measure the beer height that is marked on the tape, and then record the height and the time for each mark on the tape.

DATA PRESENTATION AND ANALYSIS

1. Plot a graph of the beer liquid level against time.
2. It should show an increasing level (as we would expect because more foam becomes liquid) and a gradient decreasing with time (because less foam remains to turn into liquid).
3. The decreasing gradient suggests that the decay of foam may be exponential—there is less foam remaining, there is less beer mass per unit time that changes from foam to liquid.
4. Plot another graph of the natural logarithm of beer foam against time and calculate the decay constant λ. The value obtained should be around $-0.012\ s^{-1}$.

Present your report on separate paper

Name _________________________ **Date** _______ **Class** _________________________**Time:**

You may be assessed using school-based criterion:

BACKGROUND

Linacs are used to make radioisotopes for medical diagnosis and therapy. The X-rays produced by synchrotron radiation can be used to study the structure of matter at the molecular level. A machine that is more commonly used for medical purposes is the **cyclotron** that was invented by Ernest O Lawrence in the 1930s. A schematic diagram of a cyclotron is shown in diagram below. The cyclotron is basically like a linac that has been wrapped into a tight spiral. It has the following important components:

- a source of charged particles usually protons, deuterons or helium nuclei
- 2 semi-circular boxes called **dees**
- a uniform mgnetic field
- an evacuated chamber
- an high-frequency alternating potential difference

Protons are injected into the first D-sector near the centre of the cyclotron and they move in a circular path according to $r = m\boldsymbol{v} / q\boldsymbol{B}$. If the proton takes time t to move a distance πr through this dee, then $t = \pi r / \boldsymbol{v}$. Therefore, from these equations:

$t = \pi m / q\boldsymbol{B}$

This demonstrates that the time to travel around a 'dee' is constant for a constant magnetic field intensity, and that the time is independent of the velocity and radius.

There is a high-frequency alternating potential difference between the dees that accelerates the protons into the second D-sector. Since their velocity has increased they will now travel in a path of larger radius because $r = m\boldsymbol{v} / q\boldsymbol{B}$. After leaving the second D-sector, the polarity of the potential difference is reversed and the proton is again accelerated into the first D-sector. The protons follow a spiral path that can consist of hundreds of loops. Upon reaching the maximum radius loop, the protons are deflected by a charged plate and are incident on a target material with energies of up to 25 MeV.

The energy gained E can be calculated for any radius according to:

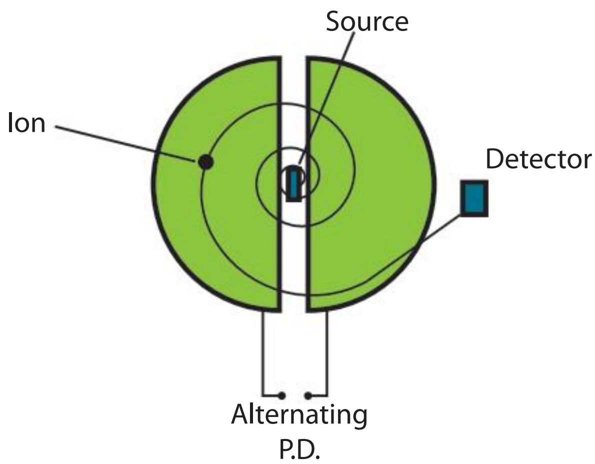
$E = ½\, m\boldsymbol{v}^2 = ½\, m(q\boldsymbol{B}r / m)^2$

Since the potential difference must reverse twice each cycle, then the period T of each cycle will be given by:

$T = 2\pi m / q\boldsymbol{B}$ and therefore $f = q\boldsymbol{B} / 2\pi m$

This frequency is known as the **cyclotron frequency** or the **resonance frequency**. This is usually 10 MHz which is in the radio frequency range.

When the particles have energies of about 20 MeV, they become appreciably more massive according to the theory of relativity. This slows them down and they become unsynchronised with the alternating potential difference when they travel across the gaps between the dees. The solution is to use a synchro-cyclotron. An oscillator (radio-frequency generator) that accelerates the particles around the dees is automatically adjusted to stay in step with the accelerated particles.



The principle of a cyclotron

Investigation 7B
A VISIT TO A CYCLOTRON

The importance of radioisotopes for diagnostic and therapeutic use has increased greatly in medicine over the past 25 years. Many governments have commissioned cyclotron facilities to produce radioisotopes and to carry out research. These facilities are usually connected to a major hospital which in turn is connected with a university that specialises in medical research.

PREPARATION FOR THE VISIT

Do an internet search to find the most convenient location of a cyclotron in your area, and make a note of the telephone number of the Public Relations department. Also do some background reading on cyclotrons.

DURING THE VISIT

Make sure that you have prepared a series of questions that you may wish to ask the specialists who operate the machines. Do not rely on your teacher to do all the talking!

REPORT

If you go as a part of a school group you will obviously need to follow the advice and guidelines given by your teacher. If you go by yourself of with a small group of students the following headings may help your learning.

- the history and development of cyclotrons
- the theoretical physics that underlie cyclotrons
- particular applications of cyclotrons
- possible future developments of cyclotrons

You could consider the best way to present this information and using a movie or still digital camera and using the images to build a PowerPoint Presentation is a very effective medium.

Name ________________________ **Date** _______ **Class** _______________________ **Time:**

BACKGROUND

Dosimetry is the study of radiation. Recall that radiation can be transmitted in the form of electromagnetic waves or as energetic particles, and that when sufficient energy is absorbed by an atom, it can cause the release of electrons and the formation of positive ions. When radiation causes ions to form it is called **ionising radiation**. Ionising radiation is produced by X-rays, CAT, radioactive tracers and radiopharmaceuticals, as well as by many other natural and artificial means.

When ionising radiation penetrates living cells at the surface or within the body, it may transfer its energy to atoms and molecules through a series of random collisions. The most acute damage is caused when a large functioning molecule such as DNA is ionised leading to changes or mutations in its chemical structure. If the DNA is damaged it can cause premature cell death, prevention or delay of cell division, or permanent genetic modification. If genetic modification occurs, the mutated genes pass the information on to daughter cells.

Since the body is 65% water by weight, most of the radiation energy is absorbed by the water content. This energy can produce ions (H^+, OH^-, H_3O^+) and electrically neutral free radicals of water. These ions and free radicals can cause chemical reactions with other chemical constituents of the cell. For example, OH^- ions and OH free radicals that form the strong oxidising reagent hydrogen peroxide (H_2O_2), can interfere with the carbon-carbon double bonds within the DNA molecule causing rupture of the double helical strands. Free radicals may also cause damage to enzymes that are required for the metabolism of the cell or they can effect the membranes that are vital for the transport of materials within the cell.

Ionising radiation appears to affect different cells in different ways. Cells of the reproductive organs are very radiation–sensitive and sterility is a common outcome after radiation exposure. Bone and nerve cells are relatively radiation-resistant. However, radiation of bone marrow leads to a rapid depletion of stem cells that can then induce anaemia or even leukemia. Exposure to radiation results in a range of symptoms including skin burns, radiation sickness (nausea, vomiting, diarrhoea, loss of hair, loss of taste, fever, loss of hair) and cancer, leukemia and death.

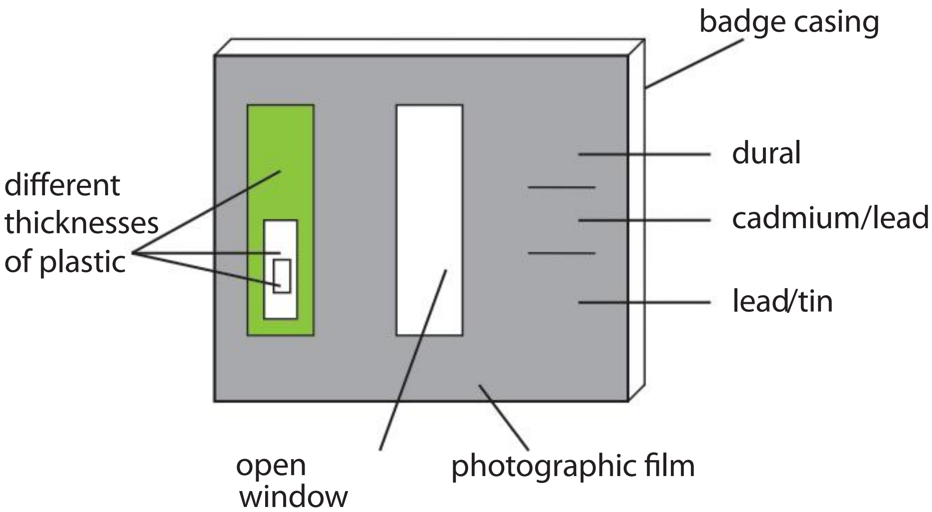
External exposure to α particles is fairly harmless as they will be absorbed by a few microns of skin. Internal exposure after ingestion is very damaging as the α-particles are very ionising and they can interact with body fluids and gases. β-particles are more penetrating but because of their irregular paths upon entering body tissue they are considered to have low ionising ability. X-rays and γ-radiation have high ionising ability (but not as high as ingested α-particles), and are a common cause of disruption to normal cellular metabolism and function.The exposure time to the radioactive source has to be carefully monitored.

As the intensity of the radiation obeys the inverse square law for distance from the source, keeping a safe distance from the source is the best means of protection. Workers in the industry often use mechanised calipers and tongs that operate within a confined area behind thick lead-glass viewing windows to manipulate the radioactive source.

Shielding materials are always used. For example, a suitable thickness of perspex sheet will stop beta rays, and lead, concrete and water will absorb gamma and X-rays. Lead aprons are often used on patients to stop any stray radiation. All radioactive sources must be completely contained to prevent the spread of contamination.

Radiation detectors such as a film badge as shown below or a thermoluminescent dosimeters (TLD) are worn by all workers employed in any industry using ionising radiation. The **film badge** is basically a double emulsion photographic film that is placed inside a holder with an area of 3 cm by 5 cm that contains different thicknesses of plastic, an open window and 3 different metal plates. It is pinned to clothing and over a period of time the exposure to radiation results in a darkening of specific areas of the photographic film. One side is coated with a large grain, fast emulsion that is sensitive to low levels of exposure. The other side of the film is coated with a fine grain, slow emulsion that is less sensitive to exposure. If the radiation exposure causes the fast emulsion in the processed film to be darkened to a degree that it cannot be interpreted, the fast emulsion is removed and the dose is computed using the slow emulsion.

The β-dose is monitored by comparing the blackening through the open window and different thicknesses of plastic. The dural (an alloy of aluminium) window absorbs beta and low-voltage X-rays and gamma rays. The lead/tin window absorbs all but the highest energy X and gamma rays. The cadmium/lead window absorbs most of the X and gamma rays but thermal neutrons interact with the cadmium to produce gamma radiation which blackens the film. *Refer to Figure below.*



The badges are assessed every two to four weeks and the TLD every 3 months. The ICRP recommends that the effective dose to industry workers should not exceed an average of 20 mSv per year over any five-year period, with the proviso that the effective dose should not exceed 50 mSv in any one year. Members of the public should not receive more than 1 mSv per year from non-medical, artificial sources. It is considered that a dose of 250 mSv of whole body irradiation, or 750 mSv to a part of the body is an overdose.

For the patient, it is known that radiation doses to the bone marrow in the order of 3 000 to 4 000 mSv have lethal effects within a month in about half of the exposed people in the absence of specialised medical treatment. Single doses over 2 000 mSv absorbed by the testes or 3 000 mSv absorbed by the ovaries can cause permanent sterility. The specialised medical treatment in the case of doses up to 10 000 mSv would include isolation of the patient in a sterile environment, selective treatment with antibiotics and stimulation of leukocyte production in order to offset damage to white blood cells. Bone marrow transplant may also be necessary. So you can see that protection is paramount in any medical diagnosis or therapy.

Many countries in the world have atomic and nuclear facilities whether they are commercial or experimental in nature. There is usually an educational research unit with dedicated education officers where groups from schools can visit for the purpose of understanding the operation of a nuclear fission reactor and dosimetry measuring methods. These units are well prepared for school groups and you are likely to leave with an array of brochures and samples that will be made available free of charge.

You will most likely be shown a video of the operation of a nuclear fission reactor, and if you are lucky, you will be taken inside the nuclear reactor facility. You will be issued with protective clothing and you will be tested for radiation when you leave the complex.

Finally, radiation measuring techniques will be demonstrated and you will analyse the safety of nuclear reactors in terms of the radiation that is produced by them.

PREPARATION FOR THE VISIT

Do an internet search to find the most convenient location of an atomic energy facility in your area, and make a note of the telephone number of the Public Relations department. Also do some background reading on the particular form of atomic energy that interests you.

DURING THE VISIT

Make sure that you have prepared a series of questions that you may wish to ask the specialists who operate the machines. These people are experts in their field, and they are very good in explaining things on a basic level. It will make their job a lot easier if they can see that you have come prepared with some questions. Do not rely on your teacher to do all the talking!

REPORT

If you go as a part of a school group you will obviously need to follow the advice and guidelines given by your teacher. If you go by yourself of with a small group of studetns the following headings may help your learning.

- the history and development of this atomic energy facility
- the theoretical physics that underly this atomic energy facility
- particular applications of this atomic energy facility
- advantages and disadvantages of this atomic energy facility
- possible future developments of this atomic energy facility

You could consider the best way to present this information. Using a movie or still digital camera and using the images to build a PowerPoint Presentation is a very effective medium.

Name ______________________ ***Date*** _______ ***Class*** ______________________***Time:***

You may be assessed using school-based criteria:

BACKGROUND

Using the Law of Conservation of Energy allows many investigations involving rotational motion to be solved. Bodies rolling down an incline and falling weights that cause rotation are the usual types of investigation that lead to a value for the moment of inertia of a body.

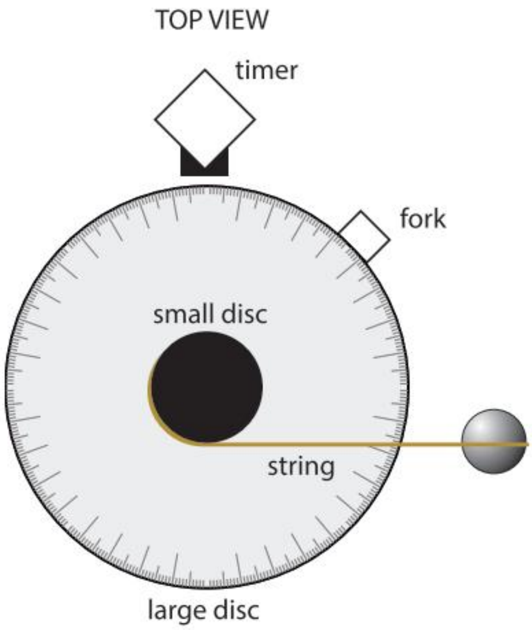
In most cases, the loss in gravitational potential energy equals the increase in translational kinetic energy plus the increase in rotational kinetic energy.

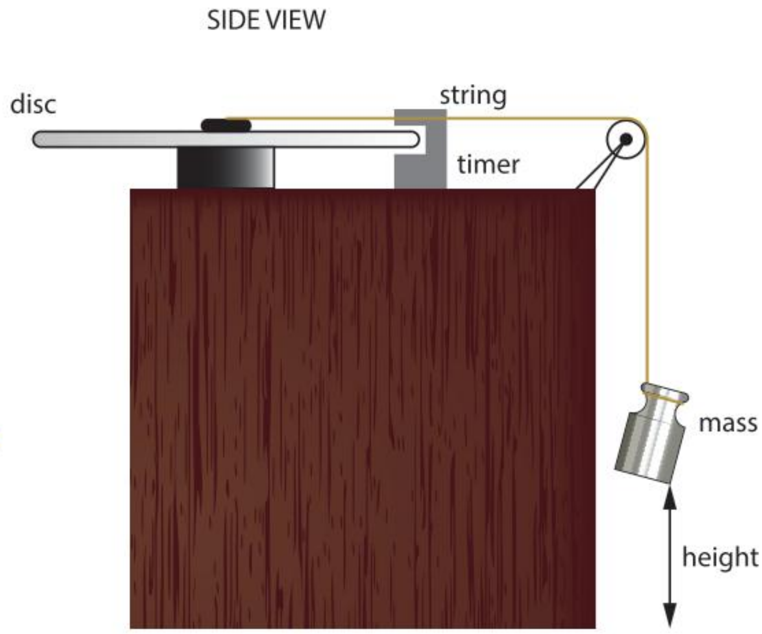
$mgh = {}^{1}/_{2}mv^2 + {}^{1}/_{2}m\omega^2$

$mgh = {}^{1}/_{2}(mr^2 + {}^{1}/_{2}I)\omega^2$

The schematic diagrams that are provided show two possible ways for determining the moment of inertia of an object.

In the falling weight investigation, different weights attached to the thread produce different accelerations of the small disc. Therefore, the angular velocity of the disc can be determined. Will both discs have the same angular velocity? By collecting the relevant data, and plotting a graph to determine the required relationship, the moment of inertia can be obtained from the graph. The value for the moment of inertia can be compared with the value obtained by an empirical method i.e. by using the theoretical formula for the disc and calculating the mass and radius of the small disc. The timing device used here is a fork attached to the large disc to break an electrical contact to a digital timer. You could use a stopwatch, photo-gate or a computer software package or other method. Each method has its own degree of accuracy.





The incline method can employ the same timing devices. One timing device you may wish to explore is the use of a video camera. Most cameras operate at 25 frames to the second.

AIM

To determine the moment of inertia of an object by using an energy conservation method.

EQUIPMENT

(Complete your own list of materials required).

METHOD

(Complete your own method.)

DATA COLLECTION and ANALYSIS

In the space below you should prepare the required data tables and show a detailed sample of each type of calculation performed for the completion of certain columns or rows of your tables. Present your results clearly and concisely. Draw your graph on graph paper.

CONCLUSION AND EVALUATION

Name ______________________ **Date** _______ **Class** ______________________**Time:**

AIM

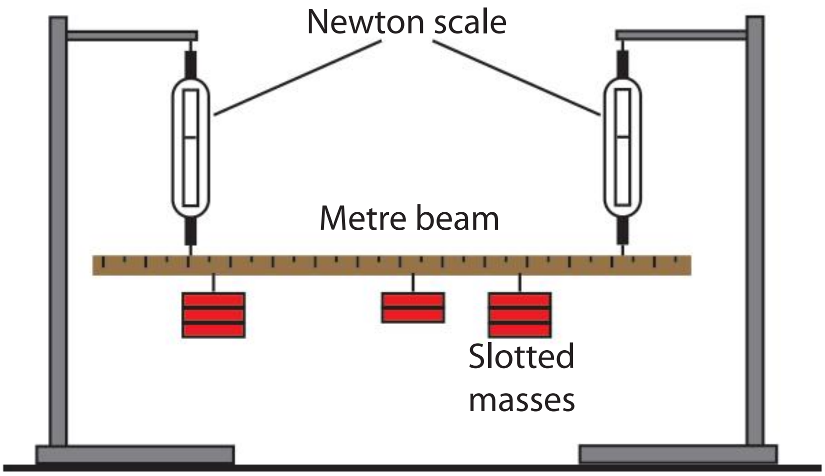
To investigate the conditions for the static equilibrium of a rigid body in terms of the applied forces and the resultant torques.

EQUIPMENT

A metre rule, thread, slotted masses, retort stands.

METHOD

1. Set up the apparatus, as shown in the diagram, with the ruler hanging from two Newton balances at the 10cm and the 90 cm ends respectively. Place the remaining three string loops at the 30, 50 and 70 cm marks with masses of 500 grams attached to each. Record the readings of the Newton balances together with that of the masses in the table below.



Repeat for different masses attached to different points along the ruler.

2. Finally, move the retort stands so that the Newton balances are at an angle to the vertical. Record the readings and angles of the balance.

DATA COLLECTION

Design suitable tables and record data (use separate paper).

DATA PRESENTATION AND ANALYSIS

Use the data to show that for equilibrium the sum of the clockwise torques is equal to the sum of the anticlockwise torques.

CONCLUSION and EVALUATION

Complete a brief report summarising your observations and calculations for forces and moments. Comment also on the result obtained for the springs held at an angle to the vertical. Please attach more paper if necessary.

Name ________________________ **Date** _______ **Class** _______________________**Time:**

Background

The muscular-skeletal system usually consists of antagonistic pairs of muscles that are attached to the bones by tendons. The muscles and bone within the body segments are moved by a system of levers. Nodding your head is an example of a 1st class lever, standing on your tip-toes is an example of a 2nd class lever, and bending your arm is an example of a 3rd class lever.

The centre of gravity of a body is frequently the point in a system that is used for motion analysis. Often we see little white stickers placed at certain points on a crash test dummy in automobile collision tests. Apart from the overall centre of gravity, each body segment has its own mass and weight as well as its centre of gravity. The standard segmental centre of gravity locations are shown in *Figure 1*.

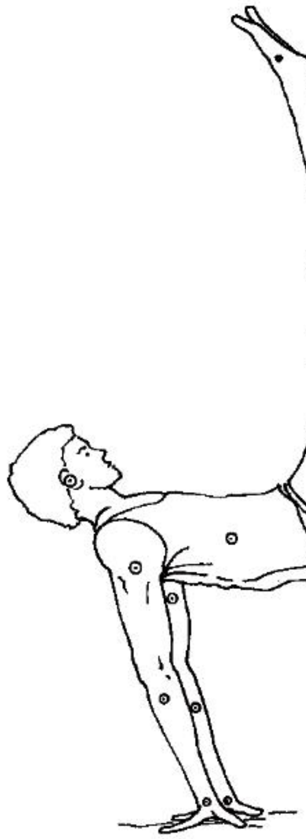
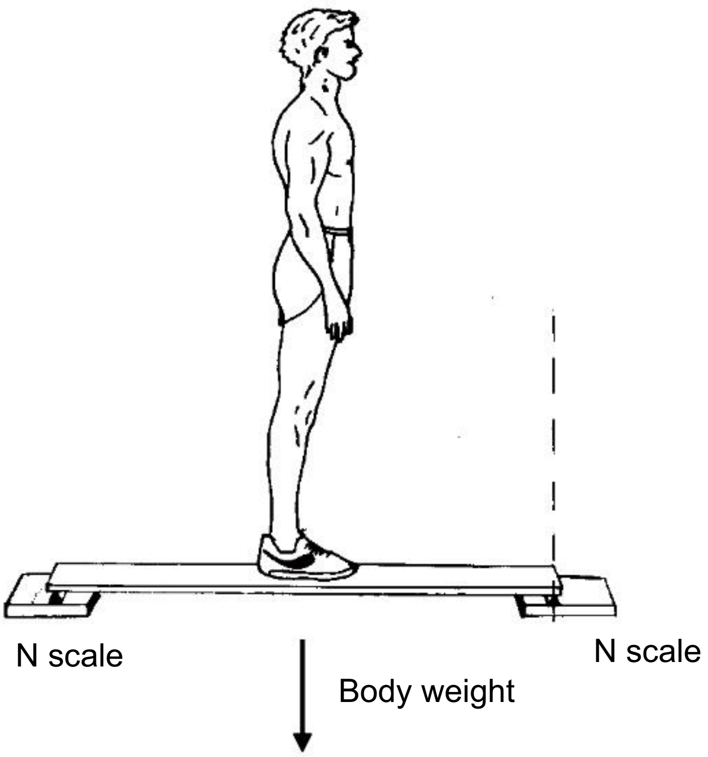


Figure 1. Centre of gravity locations

In this investigation the board and scale method will be used to determine the location of the centre of gravity relative to the soles of the feet using the Law of conservation of force and the Law of conservation of torque. The ends of the board are supported on a set of bathroom scales by triangular wedges.

Regardless of where a subject stands or lies on the board, the sum of the two scale readings will equal the sum of the subject's body weight and the weight of the board. (see Figures 2 and 3). If the board is placed on the scales, and, the scales are set to a zero reading, the effects of the board's weight can be ignored in the whole body centre of gravity determination.



Flgure 2

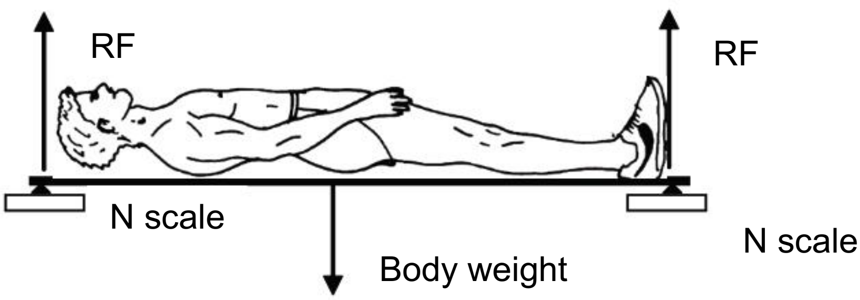


Figure 3

An axis of rotation is selected so that the sum of the torques on the system can be found. If the soles of the feet are taken as the axis of rotation, then:

$\Sigma T \quad = \quad 0$

$\text{Weight}_{\text{person}}\,(x) + \quad \text{Reaction force}_{\text{scale}}\,(\text{length of the board}) \quad = \quad 0$

AIM

To calculate and compare the height of a whole body centre of gravity for males and females using the board and scale method.

EQUIPMENT

reaction board, 2 newton or bathroom scales, 2 triangular supports, male and female subjects.

METHOD

1. Measure the length of the board in metres.
2. Find your weight on a newton balance. Your partner of the opposite sex repeats for his/her weight.
3. Place the board on the newton scales so that the supports are as close to the edges as possible. Record the weight of the board.
4. Set the scale readings to zero.
5. Stand in the middle of the board with your arms by your sides, and record the scale readings. Repeat for your partner.
6. Determine the height of the centre of gravity for a male and female in the standing position.
7. Now lay on the board and take the scale readings. Repeat for your partner.
8. Determine the height of the centre of gravity for a male and female in the lying position with respect to the soles of the feet.

DATA COLLECTION

Weight of male = ______________________________

Weight of female = ______________________________

Length of the board = ______________________________

Weight of board = ______________________________

Standing

Scale readings of male = _______________ _______________

Scale readings of female = _______________ _______________

Lying Down

Scale readings of male = _______________ _______________

Scale readings of female = _______________ _______________

Complete your report using the following headings on separate paper:

DATA PRESENTATION AND ANALYSIS

CONCLUSION and EVALUATION

Name ________________________ **Date** _______ **Class** ________________________ ***Time: 1 hour***

You may be assessed using school-based criteria:

BACKGROUND

The focal length of a convex lens will be determined by a number of alternative methods. You will be required to compare the accuracy of these methods as part of your assessment of the evaluation criteria.

The lens equation can be stated as $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

where f is the focal length, u is the object distance, and v is the image distance.

AIM

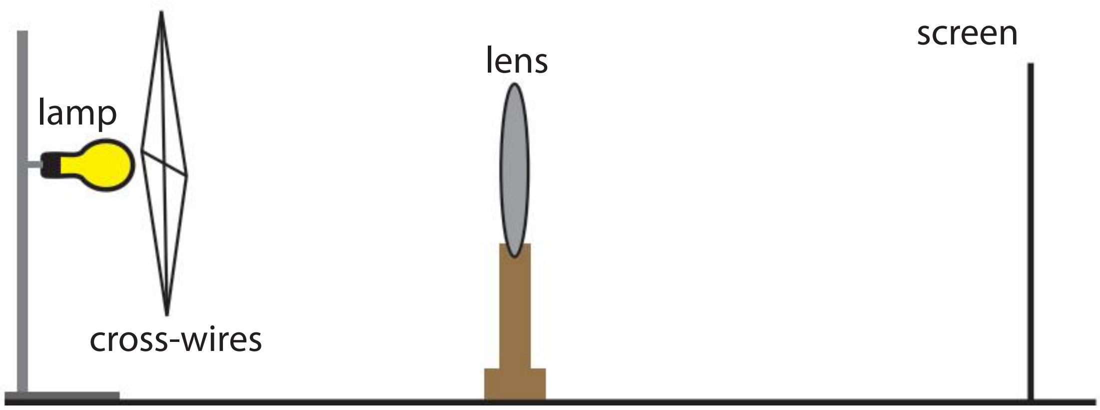
To determine and compare the uncertainty in the focal length of a convex lens using a number of alternative investigations.

EQUIPMENT

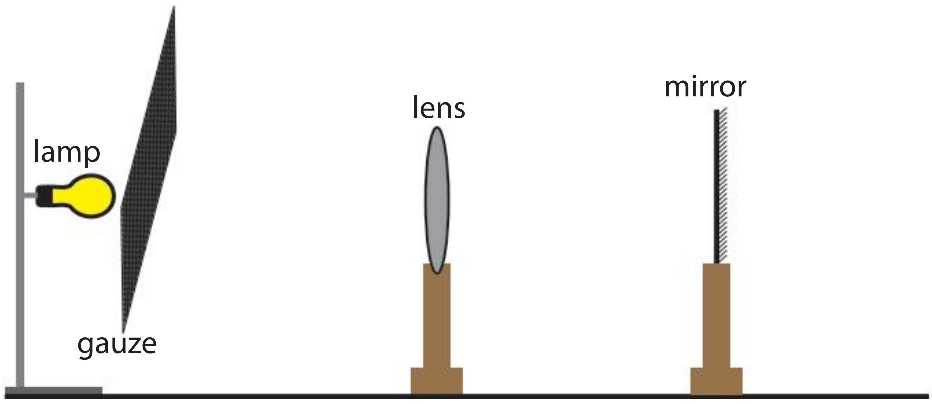
Convex lens and holder, plane mirror, circular hole with cross-wires or a fine gauze triangle, lamp and holder, screen, metre rule.

METHOD

1. Focus the image of one of the classroom windows or another distant object on the screen provided.
2. Measure the distance between the lens and the screen to determine a value of the focal length of the lens.
3. Set up the lamp and holder, as shown in the diagram below, and place the gauze or the cross-wires at the focal length determined in Step 2.
4. Position a plane mirror about 10 cm behind the lens perpendicular to the principle axis.
5. Slowly move the gauze or cross-wires until a sharp image of the gauze or cross-wires is formed alongside them.
6. Measure the distance from the object to the centre of the lens.
7. Repeat this procedure a number of times and find the average distance and its uncertainty.



8. Place the cross-wires at a distance approximately two times the focal length and replace the mirror with a screen.
9. Measure the object distance, u , and the image distance, v .
10. Repeat this procedure at least five more times for different object distances from the lens.



DATA COLLECTION

1. Approximate value of the focal length = ______________________________
2. Design and use tables to record your data.

DATA PRESENTATION AND ANALYSIS (use extra paper)

1. Explain, with the aid of a ray diagram, why the distance from the gauze to the lens is equal to the focal length when the object and image coincide, when you used the auxiliary mirror.
2. Explain why the position of the mirror does not affect the value of the focal length.
3. Plot a graph that enables you to determine the focal length of the lens.

CONCLUSION and EVALUATION

Name ______________________ ***Date*** _______ ***Class*** ______________________ ***Time: 1 hour***

You may be assessed using school-based criteria.

BACKGROUND

The refracting telescope is one of a number of telescope instruments. The purpose of a refracting telescope is to make distant objects appear closer and therefore larger. This is achieved by placing two converging lenses with different focal lengths in certain positions on an optics bench or similar device.

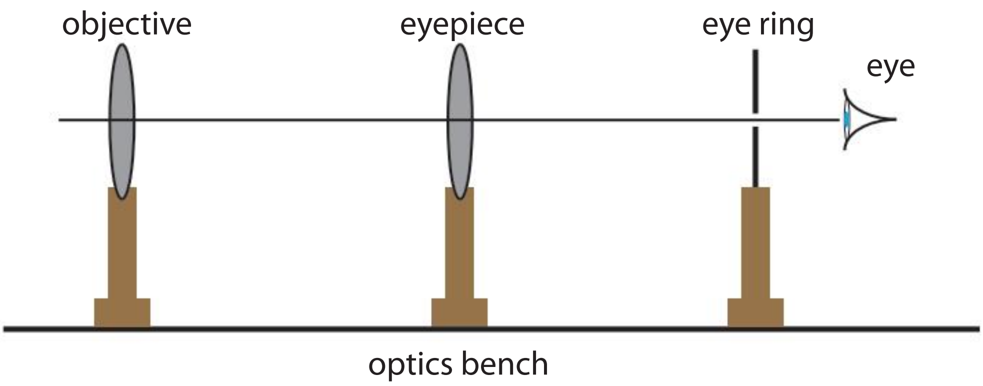
The **first lens**, the objective has a long focal length and forms a real image in its focal plane when a distant object is viewed through it alone. When a **second lens**, the eyepiece is placed at a distance so that the real image of the objective acts as a real object in the focal plane of the eyepiece, then the eyepiece magnifies the real image and produces a virtual image at infinity. The normal position of the separation of the lenses is equal to the sum of their focal lengths.

The brightness and area of the image can vary if the eye is too near or too far in distance from the eyepiece. When the eye is in the correct position the full image can be seen and no halo is observed. If the eye is too near or too far then part of the image is obscured and a halo is formed around part of the image. The method used for locating the correct eye position is called 'locating the eye ring'. You will need to practise this part of the investigation. The position of the eye ring (in theory) is the position of the image of the objective lens, itself produced by the eyepiece.

It can be shown that the angular magnification, M, for a set of appropriate lenses is given by:

$$M = \frac{f_0}{f_e}$$

where f_o is the focal length of the objective and f_e is the focal length of the eyepiece.



AIM

To construct a refracting telescope and measure and compare its magnification.

EQUIPMENT

Two converging lenses with focal lengths of 10cm and 50cm, optics bench, metre rule, lamp and power unit, greaseproof paper, screen, a card with a hole in it (the eye ring).

METHOD

Part A

1. Determine the focal length of each lens by viewing a distant object and focusing its image on a screen.
2. Determine the angular magnification of the telescope using the equation given in the Background section of this investigation.

Part B

1. Place the lamp and power unit on the far side of the laboratory and turn the lamp on.
2. Mount the lens with the longer focal length on one end of the optics bench.
3. Point the lens in the direction of the lamp and use a piece of greaseproof paper to locate the image of the lamp.
4. Record the position of the image using the metre rule.
5. Attach the second lens to the other end of the optics bench.
6. Point the optics bench in the direction of the lamp and position the second lens into a position and so that it acts like a magnifying glass for the image on the greaseproof paper that you located and recorded for the first lens.
7. Remove the greaseproof paper and view the image formed of the lamp formed by the telescope.
8. Record the distance to the image from each lens.

Part C

1. Illuminate, with a lamp, a piece of greaseproof paper placed close to the objective.
2. Place the card with a hole behind the eyepiece so that you observe a circle of light.
3. Move the card and your eye until the circle has a sharp outline.
4. Measure the diameter of this image and the diameter of the objective lens.
5. Record these values and find a ratio between the two quantities that is numerically equal to the angular magnification.

Write a report of your investigations on separate paper using the following headings:

DATA COLLECTION

Construct your own data table(s).

DATA PROCESSING AND PRESENTATION

1. Draw a fully labelled ray diagram of the refracting telescope that you constructed.
2. Calculate the angular magnification of the telescope by a variety of methods

CONCLUSION and EVALUATION

Name ________________________ **Date** _______ **Class** _______________________ **Time:**

BACKGROUND

The purpose of this investigation is to use the information provided for some nearest and brightest stars to construct parts of the Hertzprung-Russell diagram using a spreadsheet.

You are to design a method that explains the steps that you used in your spreadsheet in order to obtain the Hertzprung-Russell diagram. It is best to plot the absolute magnitude of luminosity by using the command '=log10' (with the relevant cell to be used). Clicking on the x-axis and then finding the reverse button in the Scale page can reverse the horizontal temperature scale.

SOME NEAREST SINGLE OR MULTIPLE STARS		
NAME	TEMPERATURE (K)	LUMINOSITY (L_o)
Sun	5860	1
Proxima Centauri	3240	0.00006
α - Centauri A	5860	1.5
α - Centauri B	5250	0.43
Barnard's star	3240	0.00044
Wolf 359	2640	0.00002
BD +36° 2147	3580	0.0055
Luyten 726-8A	3050	0.00006
UV Ceti	3050	0.00004
Sirius A	9230	24
Sirius B	9000	0.002
Ross 154	3240	0.00048
Ross 248	3050	0.00011
ε - Eri	4900	0.30

THE 15 BRIGHTEST STARS		
NAME	TEMPERATURE (K)	LUMINOSITY (L_o)
Sun	5860	1
Sirius A	9230	23.5
Canopus	7700	1500
Rigil Kentaurus	5860	1.5
Arcturus	4420	104
Vega	9520	55
Capella	5200	150
Rigel	11200	59700
Procyon	6440	7.2
Betelguese	3450	19700
Achernar	15400	655
Hadar	24000	8630
Altair	7850	11
α - Crucis	25400	3200
Aldebaran	15400	180

Once you have prepared a spreadsheet and a graph, answer the Data Analysis questions and present your report for assessment.

DATA PRESENTATION AND ANALYSIS

1. Label the horizontal axis further with the spectral type classifications

O	52000-33000 K
B	30000-11000 K
A	9500-7600 K
F	7200-6200 K
G	6000-5600 K
K	5200-4100 K
M	3900-2600 K

2. Include a copy of your H-R diagram

3. Identify the main sequence stars, the red giants and the white dwarfs.

4. Using your diagram, explain the difference between the nearest and brightest stars.

5. Given that the radius of a star is approximately equal to L01/2.T2, estimate the radius of one selected red giant and one selected white dwarf.

Name ________________________ **Date** _______ **Class** _______________________**Time:**

BACKGROUND

This is really an extension of the previous spreadsheet (16A), and a new plot of the HR diagram for different data will be put into your spreadsheet, in order to trace the evolution of the Sun. The radius of the Sun is approximately equal to the square root of its luminosity multiplied by its temperature squared.

AIM

To construct a portion of the Hertzprung-Russell diagram using a spreadsheet with graphics for the stellar evolution of the Sun.

EQUIPMENT

Computer with printing facilities, software spreadsheet/graphics package (eg. Microsoft Excel), luminosity and temperature values for the stages in the evolution of the Sun.

Age / (yrs)	Temperature / (K)	Luminosity / solar units)
10^6	4800	3.0
10^7	4800	0.3
10^8	5800	0.8
4.6×10^9	5800	1.0
10×10^9	5800	1.8
10.02×10^9	4800	3.0
11×10^9	3400	350

METHOD

1. Open spreadsheet from the previous investigation and type in new headings for luminosity, temperature and age in the appropriate cells.
2. Input the temperatures and luminosities.
3. To plot a graph, open the Chart Wizard, then enter the cell ranges to be plotted.
4. The temperature scale on the Hertzprung-Russell diagram is reversed with temperature decreasing to the right rather than the left. To reverse this scale, click on the labelled X-axis, enter the axis scale page, and reverse the order of the X-axis.
5. When you are satisfied with the displayed graph print it. This is done by double clicking on the chart, entering the file menu and then clicking print.

DATA PRESENTATION AND ANALYSIS

1. Label the horizontal axis further on your graph with the following spectral type classifications

O	52000-33000 K
B	30000-11000 K
A	9500-7600 K
F	7200-6200 K
G	6000-5600 K
K	5200-4100 K
M	3900-2600 K

2. Attach your H-R diagram of stellar evolution.

3. The radius of a star is approximately equal to its square root of luminosity multiplied by its Kelvin temperature squared. Estimate the radius of the Sun when it becomes a red giant.

4. Describe the stellar evolution of the Sun.

5. Comment on the fate of the planets when the Sun becomes a red giant.

Name ______________________ **Date** _______ **Class** ______________________ ***Time: 11 hours***

You will be given further information by your teacher.

DUE DATE 1 ____________________

DUE DATE 2 ____________________

DUE DATE 3 ____________________

BACKGROUND

Research scientists usually work in teams that contain experts in their specialist areas. Using a collaborative effort, these scientists hope to shed new light on a problem. The processes used in an investigation will be explored using the Group 4 Project. The Group 4 Project is a common component for all of the Group 4 Sciences, and makes up 10 hours of the internally assessed "Practical Scheme of Work".

The aims of the Project are:

To provide an opportunity for students in Physics, Chemistry, Biology, Environmental Science, Design and Technology and other science school-based courses or approved combination of courses, to pursue an interdisciplinary and collaborative investigation chosen by the total group of teachers and/or students.

To gain an appreciation of the implications of science and the limitations of scientific study.

The project could follow the following processes of an investigation:

Selection phase

Action phase

Presentation phase

Evaluation or reflection phase

Space and some guidance will be given to allow you to develop each of these phases. Your teacher will give you a due date for the assessment of each phase.

You will be assessed on Planning skills mainly in the Selection and Presentation phases. Your evaluation should demonstrate an appreciation of the implications of science and the limitations of scientific study. The development of teamwork will be expected for your Personal skills assessment.

SELECTION PHASE (2 hours)

Welcome to the meeting of all science students and teachers at your school or groups of schools. By the end of 120 minutes, the group should:

- reach a consensus on the selection of the topic for your Group 4 Project
- decide on the composition of individual groups to carry out the various components of the project
- decide on the first draft of the specific investigations that will be undertaken

For homework, the details of the selection phase should be completed fully, and presented for assessment by the due date.

What were the initial themes discussed by the total group as potential topics for the Group 4 Project?

How was the eventual topic for the Group 4 Project chosen by the total group?

What is the due date for the completion of each phase?

PHASE	DUE DATE
Selection phase	
Action phase	
Evaluation or reflection phase	
Presentation phase	
Other	

What is the composition of the sub-groups, and what are the names of the students in each of the individual groups?

Groups			
Names			

What specific investigation/s will your group examine in order to contribute to the chosen topic?

State the aim of your investigations.

State the hypothesis for the investigation. Be sure to give an explanation as to why you have chosen your hypothesis.

What equipment will you need to carry out your investigation? (It is important to state all the materials needed because there may be other students who need similar equipment).

What are the controls and variables in your investigation?

What is the procedure you plan to use in order to control these variables?

ACTION PHASE (6 hours)

Now that you have an action plan, it is time to collect your equipment and perform your investigation. You may need to modify your experimental design in order to collect accurate and reliable data. You have a responsibility to ensure your data collection is not falsified, and that your data analysis lies within the present paradigms of the scientific method. *Please use and attach extra paper as necessary.*

1 Draw a diagram of your experimental design.

2 Explain why you have settled on this design. Are there other designs that you could have used?

3 Use this page to construct some tables for your data collection.

4. Use this space in order to analyse your data.

5. What general conclusion are you going to present to the total group about your analysed data? (Be sure to address the sources of error and suggest possible modifications or improvement that could have been made).

PRESENTATION PHASE (2 hours)

Now is the time to present your work to your peers and parents. Each group will be given a presentation space at a chosen location. Your group will be expected to make a presentation to the other groups in the first hour. Your teachers may ask you some important questions to assess your skills, so be prepared.

Having then refined your communication skills, you and your teachers can relax as the doors are opened to the school community for the final hour.

You need to have prepared your presentation space in advance. It would be good if you could have some experimental set-up or design, remember that video, slide and computer presentations require electricity. You are encouraged to make use of technology and posters.

Jot down some of the things you need to organise.

REFLECTION PHASE (1 hour)

Give an evaluation of the chosen Group 4 Project based upon the information you collected during the presentation phase.

IB Physics Investigations

Volume 1 (Standard Level)

TEACHING NOTES

(For use with the IB Diploma programme)

(Fourth edition)

Author: Gregg Kerr

Series editor: David Greig

Syllabus Correlation Table

Core Topic	Sub topic	Syllabus reference	Practical Number	Title
1	1.2	• Explaining how random and systematic errors can be identified and reduced	1A	Errors in measurement
2	2.1	• Determining the acceleration of free-fall experimentally • Qualitatively describing the effect of fluid resistance on falling objects or projectiles, including reaching terminal speed • Analysing projectile motion, including the resolution of vertical and horizontal components of acceleration, velocity and displacement **And the relevant Aim 6 Statement as found in the IBO Physics Guide.**	2A 2B 2C 2D	Falling objects using stroboscopic photo Motion of a falling body. Terminal velocity in a fluid The range of a projectile
	2.2	• Using Newton's second law quantitatively and qualitatively • Describing solid friction (static and dynamic) by coefficients of friction **And the relevant Aim 6 Statement as found in the IBO Physics Guide.**	2E 2F 2G	Newton's second Law Static and kinetic friction Static equilibrium
	2.3	• Discussing the conservation of total energy within energy transformations • Quantitatively describing efficiency in energy transfers **And the relevant Aim 6 Statement as found in the IBO Physics Guide.**	2H	Propulsion using elastic potential energy
	2.4	• Determining impulse in various contexts including (but not limited to) car safety and sports • Applying conservation of momentum in simple isolated systems including (but not limited to) collisions, explosions, or water jets • Qualitatively and quantitatively comparing situations involving elastic collisions, inelastic collisions and explosions **And the relevant Aim 6 Statement as found in the IBO Physics Guide.**	2I 2J	Energy and impulse Investigation circus
3	3.1	• Describing temperature change in terms of internal energy • Applying the calorimetric techniques of specific heat capacity or specific latent heat experimentally • Describing phase change in terms of molecular behaviour • Sketching and interpreting phase change graphs • Calculating energy changes involving specific heat capacity and specific latent heat of fusion and vaporization **And the relevant Aim 6 Statement as found in the IBO Physics Guide.**	3A 3B 3C	Conservation of thermal energy Specific heat capacity of a metal Latent heat of fusion of ice
	3.2	• Solving problems using the equation of state for an ideal gas and gas laws • Sketching and interpreting changes of state of an ideal gas on pressure–volume, pressure–temperature and volume–temperature diagrams • Investigating at least one gas law experimentally **And the relevant Aim 6 Statement as found in the IBO Physics Guide.**	3D 3E 3F 3G	Universal Gas Law determination Boyle's Law determination (data-based) Charles' Law and Pressure Law determination (data-based) Zartmann Investigation

4	4.1	• Qualitatively describing the energy changes taking place during one cycle of an oscillation • Sketching and interpreting graphs of simple harmonic motion examples And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4A	Period of an oscillating spring
	4.2	• Explaining the motion of particles of a medium when a wave passes through it for both transverse and longitudinal cases • Sketching and interpreting displacement–distance graphs and displacement– time graphs for transverse and longitudinal waves • Investigating the speed of sound experimentally And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4B 4C	Waves in springs Speed of sound using resonance
	4.3	• Sketching and interpreting diagrams involving wavefronts and rays • Sketching and interpreting the superposition of pulses and waves • Describing methods of polarization And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4D 4E	Surface water waves in a ripple tank The polarisation of light
	4.4	• Sketching and interpreting incident, reflected and transmitted waves at boundaries between media • Solving problems involving reflection at a plane interface • Solving problems involving Snell's law, critical angle and total internal reflection • Determining refractive index experimentally And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4F	Properties of refraction
	4.5	• Describing the nature and formation of standing waves in terms of superposition • Distinguishing between standing and travelling waves • Observing, sketching and interpreting standing wave patterns in strings and pipes And the relevant Aim 6 Statement as found in the IBO Physics Guide.	4G	Standing waves in a string
	5.1	• Identifying two forms of charge and the direction of the forces between them And the relevant Aim 6 Statement as found in the IBO Physics Guide.	5A	Electric field patterns
	5.2	• Drawing and interpreting circuit diagrams • Investigating combinations of resistors in parallel and series circuits • Describing practical uses of potential divider circuits, including the advantages of a potential divider over a series resistor in controlling a simple circuit • Investigating one or more of the factors that affect resistance experimentally • Identifying ohmic and non-ohmic conductors through a consideration of the *V/I* characteristic graph And the relevant Aim 6 Statement as found in the IBO Physics Guide.	5B 5C 5D	Voltage divider circuits Factors affecting electrical resistance Ohm's Law
	5.3	• Investigating practical electric cells (both primary and secondary) • Identifying the direction of current flow required to recharge a cell • Determining internal resistance experimentally	5E	Internal resistance of a dry cell
	5.4	• Determining the direction of force on a charge moving in a magnetic field • Determining the direction of force on a current-carrying conductor in a magnetic field • Sketching and interpreting magnetic field patterns • Determining the direction of the magnetic field based on current direction	5F	Force on a current carrying conductor
6	6.1	• Identifying the forces providing the centripetal forces such as tension, friction, gravitational, electrical, or magnetic • Qualitatively and quantitatively describing examples of circular motion including cases of vertical and horizontal circular motion And the relevant Aim 6 Statement as found in the IBO Physics Guide	6A	Uniform circular motion
7	7.1	• Determining the half-life of a nuclide from a decay curve • Investigating half-life experimentally (or by simulation)	7A	Half life of beer foam
	7.2 7.3	• These are suggestions only, obviously whether and how such excursions can be arranged will depend on local circumstances.	7B 7C	A visit to a cyclotron A Visit To An Atomic Energy Facility

Option Topic	Sub topic	Syllabus reference	Practical Number	Title
B	B.1	• Solving problems involving moment of inertia, torque and angular acceleration • Solving problems in which objects are in both rotational and translational equilibrium • Calculating torque for single forces and couples	14A	Moment of inertia
			14B	Translational equilibrium
			14C	Biomechanics
C	C.1	• Describing how a curved transparent interface modifies the shape of an incident wavefront • Identifying the principal axis, focal point and focal length of a simple converging or diverging lens on a scaled diagram • Explaining spherical and chromatic aberrations and describing ways to reduce their effects on images • And the relevant Aim 6 Statement as found in the IBO Physics Guide	15A	Focal length of a converging lens
	C.2	• Investigating the performance of a simple optical astronomical refracting telescope experimentally	15B	The refracting telescope
D	D.2	• Sketching and interpreting HR diagrams • Identifying the main regions of the HR diagram and describing the main properties of stars in these regions	16A	Hertzsprung-Russell diagram
		• Sketching and interpreting evolutionary paths of stars on an HR diagram • Describing the evolution of stars off the main sequence • Describing the role of mass in stellar evolution	16B	Stellar evolution

Investigation 1A ERROR IN MEASUREMENT

Syllabus relevance: 1.2 Skills

Explaining how random and systematic errors can be identified and reduced

This first investigation is set out in a self-guiding fashion. Students are required to fill in the gaps with the correct magnitude of the answer, the uncertainty and the units, where appropriate, for the spaces provided.

In **Part 1**, students investigate a timing device. The more inaccurate the timing device used, the better. No uncertainty is required as this concept is developed in Parts 2-6.

In **Part 2,** students measure the mass of a coin. Many digital balances have tare devices to remove zero error. It would be better if students do not use this facility. The final answer has spaces for the magnitude, uncertainty and units.

In **Part 3**, students find the weight of a one kilogram mass using a spring balance. Please ensure that there is a zero error on the spring balances before they are issued to students. The final answer has magnitude and uncertainty.

In **Part 4**, students are introduced to the use of vernier calipers in finding the diameter of a coin. Most calipers do have a small zero error.

In **Part 5**, students use a micrometer screw gauge to measure the thickness along the length of a wire. Using the residual (the greatest difference from the mean), they determine the wire thickness.

Part 6 is for higher level candidates, and requires an understanding of the addition of relative errors for multiplication and division.

If students want to take more than one reading in each investigation part, they should then use the residual as their absolute error.

Investigation 2A FALLING OBJECTS USING A STROBOSCOPIC PHOTO

Syllabus relevance: 2.1 Skill and Aims 6 and 7

Determining the acceleration of free-fall experimentally

Students are required to be familiar with a variety of timing devices used to analyse the motion of objects.

The stroboscopic photo firstly requires the conversion of scale distances to real distances. The students are told that the real distance between windowsills is 3.15 m and that three photographs are taken each second.

The following values are provided as possible solutions for the data collection:

Scale distance between the windowsills = 3.6 cm

Real distance conversion factor = 3.15 / 0.036

(*The top window sills are about 3.6 cm apart. However, the bottom windowsills have a separation of 3.9 cm. Perhaps the students should only consider the top windowsills*).

Some guidance will be necessary in order that students do the correct construction of the five chords, that will be used for determining the instantaneous velocities during the motion. The first chord could be drawn from t = 1/6 s to t = 3/6 s. The second chord could be drawn from t = 3/6 s to t = 5/6 s, and so on.

It should be stressed that the value for the acceleration of the falling object should be obtained from the gradient of the line of best fit for Graph 2.

No uncertainty is required for this investigation.

Investigation 2B MOTION OF A FALLING BODY

Syllabus relevance: 2.1 Skill and Aim 6

Determining the acceleration of free-fall experimentally

There are many methods available for determining the acceleration due to gravity of a falling object. If photogates and electronic timers are not available, then ticker tape or a marble in a grooved inclined plane can be used. The use of a video camera and motion sensors are becoming popular methods for the study of motion. All of these methods are discussed in the background section of the investigation.

It is a good experience for the students to set up the photogate and trapdoor alternatives on their own, and to award manipulation skill assessment based on their speed and correctness in completing the circuits. I have found that they are very good at this, and once one group has solved the problem the other students soon get the hang of it.

Depending on the method chosen for finding the value of g, students fill in the gaps provided and answer the relevant questions.

The inclined plane alternative needs to have the g sin θ adjustment. Both this alternative and the ticker tape method are more time-consuming. The photogate method is very good. Students need to realise that the required graph may not pass through the origin in this case as the object dropped has moved some distance before encountering the first light gate. The trapdoor method is commonly used and it yields very good results. Again the line of best fit should not be forced through the origin.

Investigation 2C TERMINAL SPEED IN A FLUID

Syllabus relevance: 2.1 Skill and Aim 6

Qualitatively describing the effect of fluid resistance on falling objects or projectiles, including reaching terminal speed

There are many methods available for describing the terminal speed of an object in a fluid.

A possible suggestion would be to fill a large measuring cylinder with a viscous fluid (not water). Choose a graduation on the measuring cylinder that could be used when the terminal speed of a steel ball bearing can be clearly observed. Start timing at this graduation mark, and stop timing when the object reaches the bottom of the measuring cylinder. Remove the ball bearing with a magnet.

Investigation 2D THE RANGE OF A PROJECTILE

Syllabus relevance: 2.1 Skill and Aims 6 and 7

Analysing projectile motion, including the resolution of vertical and horizontal components of acceleration, velocity and displacement

By measuring the height of the bench, the time for the sphere to fall from the bottom of the incline to the floor can be determined from:

$\mathbf{v}^2_y = \mathbf{u}^2_y + 2\mathbf{gs}$ and $\mathbf{v}_y = \mathbf{u}_y + \mathbf{g}t$

Realising that $\mathbf{u}_y = 0$ m.s^{-1}, and that it takes the same time whether the sphere is projected off the incline, or simply dropped vertically downwards.

Another alternative is to use the conservation of energy. The E_p of the sphere at the top of the incline is converted to E_k at the bottom of the incline. The velocity of the launch can be determined by measuring the range of the projectile, and knowing that the horizontal velocity is constant, t = range / $\mathbf{v}_x$

Investigation 2E NEWTON'S SECOND LAW

Syllabus relevance: 2.2 Skill and Aim 6

Using Newton's second law quantitatively and qualitatively

Students do not find the analysis of this conventional investigation easy. Some help and guidance will be necessary.

The investigation is best done using digital timers and a linear air track. Computer software has found to be unreliable unless it has been recently manufactured.

If using ticker tape, students will need to know the procedure for recording the initial and final velocities. For example, take six dots at the beginning of the tape and six dots towards the end of the tape. The time interval for each set of dots would then be 0.1 s. Measure the distance between each set of six dots, and record the displacements for the chosen time, the initial velocities and final velocities.

In Part A, the slope of the '*F* versus *a*' graph should be approximately equal to the total mass of the system (trolley + slotted masses).

In Part B, the slope of the '*m* versus a^{-1}' should be approximately equal to the constant falling mass.

If equipment is not available, the following photogate data for the first part of the experiment can be used:

Distance between the light gates(dlg) = 83.7 cm

Length of the card (lc) = 20.0 cm

Mass of the trolley (M) = 228.45 g

Mass of the mass carrier = 10.0 g

Total mass of the system = 228.45 + 90 + 10 g

m/g	t_1/s	v_1/ms^{-1} ($v_1 = l_c / t_1$)	t_2 /s	v_2/ms^{-1} ($v_2 = l_c/t_2$)	a /ms^{-2} $a = v_2^2 - v_1^2 / 2d_{lg}$	a /ms^{-2}
30	0.410 0.408 0.384	0.488 0.490 0.521	0.156 0.156 0.155			
50	0.296 0.252 0.294	0.676 0.794 0.680	0.120 0.116 0.120			
70	0.221 0.236 0.246	0.905 0.847 0.813	0.099 0.100 0.101			
90	0.235 0.200 0.226 0.186	0.851 1.000 0.885 1.075	0.090 0.087 0.089 0.086			

a /ms^{-2}	F/ N
0.837	0.2943
1.390	0.4905
1.952	0.6867
2.541	0.8829

Investigation 2F STATIC AND KINETIC FRICTION

Syllabus relevance: 2.2 Skills and AIm 6

Describing solid friction (static and dynamic) by coefficients of friction

There are many possibilities as to how to carry out this investigation. Different surfaces can be used. Rather than using masses on the end of the pully, you could use a vessel containing water. Water can be added drop by drop at the critical point.

A graph of the frictional force, as a function of the normal force, will yield a straight line that will not pass through the origin because the wooden box has mass.

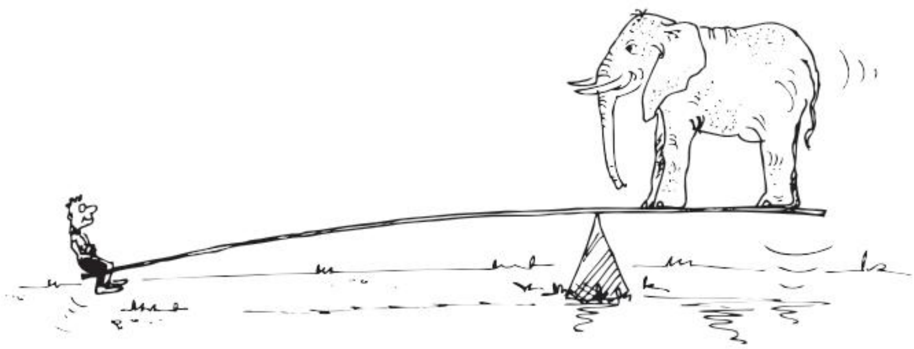
Investigation 2G STATIC EQUILIBRIUM

Syllabus relevance: 2.2 Skills and AIm 6

Solving problems involving forces and determining resultant force

Investigation 14B extends this for those undertaking the engineering physics Option B.

It is a very standard practical that can be carried out with basic equipment. Some schools have circular force boards made of Masonite with a series of holes in which to put the spring balances. These boards are good to buy.



Investigation 2H INVESTIGATING THE MOTION OF AN OBJECT

Syllabus relevance: 2.3 Skills and Aim 6

Discussing the conservation of total energy within energy transformations.

Quantitatively describing efficiency in energy transfers.

This is a good investigation to apply some assessment criteria. The scope of the investigation can be restricted if so desired to investigating just one factor and probably not the nature of the runway.

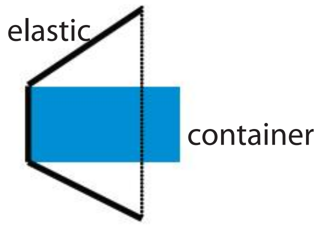
Student can extend the investigation to measure the coefficient of dynamic sliding friction between the tub and the runway.

The students should recognise the following factors that affect the distance travelled:

- mass of the tub
- distance that the elastic is stretched
- nature of the surface of the runway

Essentially students have to devise a method for:

- propagating the tub along the runway
- measuring the distance that the elastic is stretched when the tub is pulled back (*This is not as easy as it sounds since when it is pulled back it will look something like this)*



Students will have to decide which "stretched" distance they are going to measure:

- measuring the distance travelled along the runway
- securing slotted weights to the bottom of the tub.

They will need the following extra apparatus

- a set of slotted weights
- drawing pins or small nails (to secure the elastic to the sides of the runway)
- Scotch tape (to secure the slotted weights to the base of the tub)
- a top pan balance (to measure the mass of tub and weights)
- a metre ruler
- a marker pen

In investigating the effect of increasing the mass, students should recognise that they need to devise a means of ensuring that the tub is pulled back the same distance each time. A graph of distance travelled against mass should show an inverse relation.

In investigating the effect of increasing the distance that the elastic is stretched, students should appreciate that they now need to keep the mass constant. A graph of distance stretched against distance travelled should show a quadratic relation. ($\frac{1}{2} kx^2 = Fs$)

Investigation 2I ENERGY AND IMPULSE

Syllabus relevance: 2.4 Skills and Aim 6

Determining impulse in various contexts including (but not limited to) car safety and sports

This is an open-ended planning investigation requiring three different types of balls and a measuring device. However, students are likely to ask you for other equipment.

Students need to be issued with the sheets well in advance of doing the investigation. After they have read the sheets, they should submit their equipment list request so that the laboratory assistant has time to collate their requests. Another alternative is that the students submit the completed Aim, Theory, Equipment and Method sections before they are allowed to proceed.

The basic idea is that the gravitational potential energy is converted to kinetic energy. The velocity before impact with the ground can be calculated. Knowing the rebound height of the ball, the velocity of the ball just after impact can be calculated. The impulse can be found from the vector addition of the change in momentum of each ball after each bounce.

The collisions with the ground are inelastic, as can be seen from the rebound heights.

There is space provided for three graphs. These could be computer generated. Typical graphs will include rebound height versus the number of bounces, change in energy versus the number of bounces, and impulse versus the number of bounces.

Extra assessment criteria are provided at the end of the investigation.

Investigation 2J INVESTIGATION CIRCUS

Syllabus relevance: 2.4 Various Skills

Qualitatively and quantitatively comparing situations involving elastic collisions, inelastic collisions and explosions

In **Problem 1**, by measuring the height of the bench, the time for the sphere to fall from the bottom of the incline to the floor can be determined from:

$v^2_y = u^2_y + 2gs$ and $v_y = u_y + gt$

Realising that $\mathbf{u}_y = 0$ m.s^{-1}, and that it takes the same time whether the sphere is projected off the incline, or simply dropped vertically downwards.

Another alternative is to use the conservation of energy. The E_p of the sphere at the top of the incline is converted to E_k at the bottom of the incline. The velocity of the launch can be determined. By measuring the range of the projectile, and knowing that the horizontal velocity is constant.

$t = \text{range} / \mathbf{v}_x$

Problem 2 is best done outdoors as squirting water in the laboratory has many potential problems. A garden hose is a good constant water source.

Assuming the water pressure and the rate of flow of such is constant, students can test the validity of:

$\text{Range} = \mathbf{v}^2 \sin 2\theta / \mathbf{g}$

The range is maximum when $2\theta = 90°$. Therefore, maximum range occurs when the water is projected at 45°.

Problem 3 has some potential safety considerations. Safety goggles should be worn at all times.

GOGGLES

The problem can be solved by assuming that the work done in moving the clay ball and the clay block through a distance, as measured by the straw, is equal to the initial velocity of the clay ball projected from the sling shot.

Investigation 3A CONSERVATION OF THERMAL ENERGY

Syllabus relevance: 3.1 Skills and Aim 6

Describing temperature change in terms of internal energy

This is a standard introduction to the law of conservation of thermal energy. Students do a number of trials, and from their data they compare the total thermal energy lost and gained when warm water is added to cold water.

Students should calculate the thermal energy lost and gained for the first trial before they proceed with the second trial. The investigation can be completed in about 50 minutes provided an electric jug of hot water is always available. Using water heated by a Bunsen burner should be discouraged as it is time consuming.

Investigation 3B SPECIFIC HEAT CAPACITY OF A METAL

Syllabus relevance: 3.1 Skills

Calculating energy changes involving specific heat capacity and specific latent heat of fusion and vaporization

If a direct method of mixtures procedure is used, such as heating a metal block with an immersion heater, then the theory for cooling correction will need to be completed before this investigation is carried out.

Students are asked to confirm the identification of the unknown metal using a second physical property. This could be a density investigation.

Investigation 3C LATENT HEAT OF FUSION OF ICE

Syllabus relevance: 3.1 Skills

Calculating energy changes involving specific heat capacity and specific latent heat of fusion and vaporization

This is another standard investigation that produces a good result.

Students should be able to complete the data collection and analysis in a 50-minute period.

Investigation 3D UNIVERSAL GAS CONSTANT DETERMINATION

Syllabus relevance: 3.2 Skills and Aim 6

Investigating at least one gas law experimentally

The correct equation for determining R is:

$1/V\ (nRT) = m\ (g\,/\,A) + P_o$

If a graph of $1/V$ is plotted against m, the gradient is equal to $g\,/\,RAnT$.

Therefore, $R = g\,/(\text{gradient})\ AnT$

The number of moles of air in the syringe can be found under the laboratory conditions can be determined by using the Combined Gas Law, and the fact that one mole occupies 22.4 dm^3 at STP.

Investigation 3E BOYLE'S LAW INVESTIGATION

Syllabus relevance: 3.2 Skills and Aim 6

Investigating at least one gas law experimentally

There are three experimental Set-ups given for this investigation, depending on the equipment available. If using the mercury method, students should be made aware of the poisonous nature of mercury. Sulfur or a mercury clean-up kit should be at hand. If using the modern Boyle's Law apparatus, the glass capillary tube should not be given too much pressure.

Investigation 3F CHARLES' LAW AND THE PRESSURE LAW

Syllabus relevance: 3.2 Skills and Aim 6

Investigating at least one gas law experimentally

One apparatus is shown for Charles' Law and two are shown for the Pressure Law. Again, if mercury is going to be used then students must be made aware of the poisonous nature of the substance.

Investigation 3G ZARTMANN INVESTIGATION

Syllabus relevance: 3.2 Skills and Aim 6

Investigating at least one gas law experimentally

I first saw this investigation on a video put out by ILPAC (available from John Murray publishers in the UK). This simulation has been adapted from this video. In a true sense, there are some oversimplifications of the true Zartmann experiment, and it is hoped that students might identify these in their conclusion. For example, bismuth density on the glass plate may not be related to the dots here because the sample of bismuth dots is very small. Furthermore, the width of each segment is very large.

Students should have little difficulty in analysing their data. The first graph is the lower temperature case. Zartmann concluded that the bismuth particles had a range of speeds with most concentrated around the average value with some much slower and some much faster than this average. He confirmed that the range of speeds was due to continual collisions between particles as assumed in the kinetic theory of gases.

Investigation 4A THE SIMPLE PENDULUM AND SPRING

Syllabus relevance: 4.1 Skills and Aim 6

Qualitatively describing the energy changes taking place during one cycle of an oscillation

Simple harmonic motion is now in the syllabus, and the simple pendulum and/or coiled spring provide excellent open-ended planning experiments.

The investigation lends itself readily to the assessment of many criteria. In a similar way, the oscillations of a mass on the end of a spring can also be used to assess these same criteria. The students can be told what constitutes a period of oscillation and then be asked to investigate the factors that affect the period. Unless students have access to a reasonably wide variety of springs, this investigation is more limited in scope than the simple pendulum.

Investigation 4B WAVES IN SPRINGS

Syllabus relevance: 4.2 Skills and Aim 6

Qualitatively describing the energy changes taking place during one cycle of an oscillation

This investigation introduces some of the properties of compressional and transverse waves using mechanical pulses and continuous waves in slinky springs.

For such a simple investigation, students for some reason tend to only obtain average results in this investigation. They seem to rush the procedure and their patience is really tested. Therefore, it must be emphasised that each of the factors that are asked for in the questions should be clearly observed and explained.

Investigation 4C SPEED OF SOUND USING RESONANCE

Syllabus relevance: 4.2 Skills and Aim 6

Investigating the speed of sound experimentally

Three different methods for undertaking this investigation are given. The students determine the speed of sound by plotting a graph of the length of the air column *L* against f^{1}. The relationship is explained in the background section of this investigation. The speed of sound at a particular temperature is given by:

$v = f\lambda$

$L + e = v / 4f$ or $L = v / 4f - e$

If the fundamental frequency, f, is determined using different tuning forks or signals from the signal generator for different lengths of the air column, a graph of L against f produces a linear graph with a slope of v/4 and a y-intercept of –e.

If using the procedure with the tuning fork, a long PVC tube should be inserted into the large measuring cylinder, and the resonance of the air in the tube should be obtained by moving the tube up and down in the water.

The signal generator works best on a low frequency between 50 –100 Hz.

Warning: Students should be warned of the potential hazards of using water near an electrical power supply.

Investigation 4D WATER WAVES IN A RIPPLE TANK

Syllabus relevance: 4.3 Skills and Aim 6

Sketching and interpreting diagrams involving wavefronts and rays

It is unlikely that schools will have sufficient ripple tanks for this Investigation and it may best be done as a demonstration in which case the assessment skills and criteria will be very limited.

Students who have the patience and perseverance usually obtain satisfactory results. This will most probably take a double period since the ripple tanks need some introductory adjustments and maintenance. It is better if the students do not connect the motor for the first period, but rather concentrate on the pulses and rectilinear wave reflections.

Students are required to submit a series of sketches with their laboratory record. A good reference book for excellent diagrams is *The World Of Physics* by J. Avison published by Nelson ISBN 0-17-438245-6.

Investigation 4E POLARISATION OF LIGHT

Syllabus relevance: 4.3 Skills and Aim 6

Describing methods of polarization

In this investigation, students will observe and record some of the properties of polarised light. They use two sheets of Polaroid, the polariser and the analyser. The intensity of light incident on an ideal polariser is halved after preferential absorption. The analyser can then be rotated from 0^0 to 90^0 to reduce the emerging light intensity to zero. When the electric field for light incident on a Polaroid is at an angle θ to the plane of vibration, then the electric field vector of the light is $\boldsymbol{E}0\cos\theta$, and the light intensity emerging from the Polaroid is given by the Malus equation:

$$I = I_0 \cos^2\theta$$

where I is the emerging light intensity and I_0 is the half intensity after polarisation.

The equipment must be prepared in advance and is included for your information:

3 squares of polaroid 5 cm in diameter, 5 microscope slides, glass box, ray box to give a single beam of light, polarimeter if available, protractor, perspex ruler, liquid crystal display (calculator or digital watch), masses, string, colour filter for the ray box, sucrose solution.

In Part A, the students produce and detect polarised light, and comment on the intensity of light.

In Part B, they examine the reflection of polarised light.

In Part C, they examine a liquid crystal display, a sucrose solution, and stress and strain in plastics.

Investigation 4F PROPERTIES OF REFRACTION

Syllabus relevance: 4.4 Skills and Aim 6

Sketching and interpreting incident, reflected and transmitted waves at boundaries between media

Determining refractive index experimentally

Students use a graphical method, the critical angle, and real and apparent depth to find the refractive index of a perspex slab. The investigation needs to be issued to the students in advance so that they can research the equations necessary to complete the task. The equations are easily found in textbooks.

In Part A, the students collect a series of angles of incidence and the corresponding angles of refraction. By plotting a graph of sine i versus sine r, the slope of the straight line gives the refractive index:

$\sin i = n \sin r$

In Part B, the refractive index is found from:

$\sin C = 1 / n$

In Part C, the refractive index is found from:

n = real depth / apparent depth

Investigation 4G STANDING WAVES ON A STRING

Syllabus relevance: 4.5 Skills and Aim 6

Observing, sketching and interpreting standing wave patterns in strings and pipes

Describing the nature and formation of standing waves in terms of superposition

The equation $v = \sqrt{\frac{T}{\mu}}$ is no longer a syllabus requirement.

However, the students can still carry out an investigation to determine how the frequency of the standing wave in a string depends on the tension of the string. Since the wavelength of the standing wave is kept fixed, this is the same as determining the dependence of speed on tension.

The investigation can be set as an open-ended question enabling all five moderated criteria to be assessed.

Investigation 5A ELECTRIC FIELD PATTERNS

Syllabus relevance: 5.1 Skills and Aim 6

Identifying two forms of charge and the direction of the forces between them

To make the electric field apparatus you will need a flat piece of wood measuring about 20 cm × 10 cm × 0.5 cm. On this, two terminal pins are mounted, as shown in the diagram in the experiment.

The dish is a typical flat-bottomed glass dish found in all chemistry laboratories. If possible it should not be more that 1 cm in height.

The bare copper wire used in the experiment is about 2 mm in diameter.

Soldering two pieces of copper wire together makes the parallel conductors.

The EHT should give a range of 0 –5000 V.

If the students wish to observe the field pattern of two like point charges then two supplies will be needed.

Investigation 5B VOLTAGE DIVIDER CIRCUITS

Syllabus relevance: 5.2 Skills and Aim 6

Describing practical uses of potential divider circuits, including the advantages of a potential divider over a series resistor in controlling a simple circuit

This investigation needs little explanation provided that an LDR and a variable resistance box is available.

Investigation 5C FACTORS THAT AFFECT ELECTRICAL RESISTANCE

Syllabus relevance: 5.2 SKills and Aim 6

Investigating one or more of the factors that affect resistance experimentally

This is a formal report with a planning component.

The equipment that they are likely to ask for include all the equipment from the previous Ohm's Law investigation, together with nichrome or copper wire of different lengths and gauges. Your laboratory technician should be requested in advance to prepare sets of:

- 3 pieces of gauge 32 wire of lengths 0.5 m, 0.75 m and 1.0 m
- 2 other 0.5 m lengths of different gauge (say gauges 24 and 28)

They will also need a micrometer screw gauge to measure the diameter of the different thicknesses of wire.

Students have been warned of the danger of using high electric currents. Your vigilance will be necessary once they begin to collect their data.

The resistance of the wires can be obtained by measurement of the current in the wire and the potential difference across it. Graphs of resistance versus length and resistance versus the reciprocal of cross-sectional area can be plotted in order to determine the resistivity of the wire provided.

The published values for copper and nichrome resistivity at 20 °C are $1.68\ .10^{-8}$ Ω.m and $100\ .10^{-8}$ Ω.m respectively.

Investigation 5D OHM'S LAW

Syllabus relevance: 5.2 Skills and Aim 6

Identifying ohmic and non-ohmic conductors through a consideration of the V/I characteristic graph

This is a traditional practical that should be familiar to everyone. I suggest the inclusion of a variable resistor as this circuit has been examined on many occasions, and the chief examiner has always had the inclusion of the variable resistor in mark schemes.

Use low–value resistors (0.5 – 10 Ω). Of course these resistance values are for a typical laboratory rheostat. The printed value of the resistor can be covered over with opaque tape so the student doesn't know the printed value.

The students are requested to show their first circuit to the teacher before proceeding with their data collection. This is an opportunity to record an assessment for their manipulative skills. An on-off switch is important as long exposure to increasing electric current has a heating effect on the wire. This can introduce a non-ohmic component to their measurements.

Students should be able to calculate the degree of uncertainty in their measurements, and to produce error bars on their graphs. The value for the resistance can be obtained from the gradient of the pd. versus current graph. The degree of uncertainty of the resistance can be obtained from the maximum range in the possible lines of best fit.

The added graphs of power versus current and potential difference, and the associated question are there to add an extra challenge.

Investigation 5E INTERNAL RESISTANCE OF A DRY CELL

Syllabus relevance: 5.3 Skills and Aim 6

Determining internal resistance experimentally

There will be a negative gradient. The y-intercept will be the value of the emf and the gradient will be the value of the internal resistance.

Investigation 5F FORCE ON A CONDUCTOR

Syllabus relevance: 5.4 Skills

Determining the direction of force on a charge moving in a magnetic field

Determining the direction of force on a current-carrying conductor in a magnetic field

Sketching and interpreting magnetic field patterns

Determining the direction of the magnetic field based on current direction

These written instructions may be given to the students and the experiment submitted as an IA sample since the students must devise their own table of results, analyse their results in an appropriate way and also make their own evaluation of the experiment.

Investigation 6A UNIFORM CIRCULAR MOTION

Syllabus relevance: 5.3 Skills and Aim 6

Qualitatively and quantitatively describing examples of circular motion including cases of vertical and horizontal circular motion

This investigation is a commonly used practical for studying uniform circular motion. Students who do not practise in the beginning generally obtain poor results.

It is best to do this investigation outdoors. The laboratory is too small, and the corridors are too crowded with other students. This practical has the potential to cause injury, and students need to be fully aware of this.

Warning: *Safety goggles should be worn at all times.*

In the first part, the radius is varied, and a single 50 g mass carrier keeps the tension in the string constant:

$m_w g = m_b v^2 / r = m (2\pi r / T)^2 / r$

$\therefore T^2 = k . r$ where $k = m_w g / m_b 4\pi^2$

g can be determined from the slope of the line of best fit.

In the second part, the radius is kept constant and adding slotted masses varies the tension in the string.

$F_c = m_w g = m_b v^2 / r = m (2\pi r / T)^2 / r$

$\therefore m_w = k / T^2$ where $k = m_b 4\pi^2 r / g$

g can be determined from the slope of the line of best fit.

Investigation 7A THE HALF-LIFE OF BEER FOAM

Syllabus relevance: 7.1 Skills and Aim 6

Determining the half-life of a nuclide from a decay curve Investigating half-life experimentally (or by simulation).

Determining the half-life of a nuclide from a decay curve

In this investigation one uses beer foam to simulate the exponential decay of a radioactive substance, non alcoholic beer may be used.

Investigation 7B A Visit To A Cyclotron

There is a proton cyclotron in the grounds of Royal Prince Alfred hospital in Sydney. Again, they are accustomed to having students visit their facility and there are many interesting things to see. They dress the students up and they take radiation checks when the students leave the facility. If you are in Sydney, you can take in a 2 day excursion to the cyclotron, RPA hospital and the Lucas Heights nuclear reactor. The author understands that access to similar facilities exists in most countries.

Investigation 7C A Visit To An Atomic Energy Facility

The author experienced no difficulty in arranging a visit to the Australian Atomic Energy complex at Lucas Heights in Sydney. They have an educational centre and they let us inside their experimental reactor. It was a great visit for understanding dosimetry measurements. The author understands that access to similar facilities exists in most countries.

Investigation 14A (Option B) MOMENT OF INERTIA

Syllabus relevance: B.1 Skills

Solving problems involving moment of inertia, torque and angular acceleration

This investigation is a very standard practical that can be carried out with basic equipment.

Investigation 14B (Option B) TRANSLATIONAL EQUILIBRIUM

Syllabus relevance: B.1 Skills

Solving problems in which objects are in both rotational and translational equilibrium

Again, this investigation is a very standard practical that can be carried out with basic equipment.

Investigation 14C (Option B) BIOMECHANICS AND THE MUSCULOSKELETAL SYSTEM

Syllabus relevance: B.1 Skills

Calculating torque for single forces and couples.

This investigation uses the board and scale method to find the whole body centre of gravity of a subject. By using their knowledge that the sum of the clockwise torques equals the sum of the anti-clockwise torques, students calculate their centre of gravity. The male and female subjects are compared.

Investigation 15A (Option C) FOCAL LENGTH OF A CONVERGING LENS

Syllabus relevance: C.1 SKills and Aim 6

Identifying the principal axis, focal point and focal length of a simple converging or diverging lens on a scaled diagram

The focal length of a convex lens may be determined by a number of alternative methods. Students are required to compare the accuracy of these methods as part of the assessment of the assessment criteria.

The equipment list consists of:

Convex lens and holder, plane mirror, circular hole with cross-wires or a fine gauze triangle, lamp and holder, screen, metre rule.

Students should plot a graph of $1/\mu$ against $1/v$ in order to determine the focal length.

Investigation 15B (Option C) THE REFRACTING TELESCOPE

Syllabus relevance: C.1 Skills and Aim 6

Investigating the performance of a simple optical astronomical refracting telescope experimentally

The aim of this investigation is to construct a refracting telescope and measure and compare its magnification.

It can be shown that the angular magnification, M, for a set of appropriate lenses is given by:

$$M = \frac{u}{v}$$

where u is the focal length of the objective and v is the focal length of the eyepiece.

Students firstly determine the focal length of each lens by viewing a distant object and focusing its image on a screen. They then determine the angular magnification of the telescope using the equation given. They then construct their telescope using the two lenses, and record the distance to the image from each lens. Finally, they measure the diameter of an image and an object, and find a ratio between the two quantities that is numerically equal to the angular magnification.

Investigation 16A (Option D) THE HERTZPRUNG-RUSSELL DIAGRAM (using a spreadsheet)

Syllabus relevance: D.2 Skills and Aim 6

Sketching and interpreting HR diagrams

Identifying the main regions of the HR diagram and describing the main properties of stars in these regions

The data is given in the investigation. Students will need to have spreadsheet computer skills. It is usually the case that most have done it but will need some reminding of the instructions. It is hoped that enough information is given to get through the sequence of events.

Investigation 16B (Option D) STELLAR EVOLUTION

Syllabus relevance: D.2 Skills and Aim 6

Sketching and interpreting evolutionary paths of stars on an HR diagram

Describing the evolution of stars off the main sequence

Describing the role of mass in stellar evolution

This is really an extension of the previous (16A) spreadsheet and a new plot of the HR diagram to trace the evolution of the Sun. Given a data table of solar properties, the Sun's evolution through the T. Tauri (pre-main sequence), the main sequence and red giant phases can be graphed using the spreadsheet. The radius of the Sun is calculated at the point of it being a red giant.