PHYSICS EXPERIMENTS

'In the matter of physics, the first lessons should contain nothing but what is experimental and interesting to see. A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds.' - Albert Einstein

www.psi-net.org

LEAVING CERTIFICATE PHYSICS

LISTED EXPERIMENTS

CONTENTS

MECHANICS

HEAT

SOUND

LIGHT

ELECTRICITY

APPENDIX

Experiment at Higher Level only*

NOTE

For examination purposes any valid method will be acceptable for describing a particular experiment unless the syllabus specifies a particular method in a given case.
Students will be expected to give details of equipment used, assembly of equipment, data collection, data manipulation including graphs where relevant. Students will also be expected to know the conclusion or result of an experiment and appropriate precautions.

SAFETY

1. The Leaving Certificate Physics syllabus states on page three:

   'Standard laboratory safety precautions must be observed, and due care must be taken when carrying out all experiments.
   The hazards associated with electricity, EHT, lasers etc. should be identified where possible, and appropriate precautions taken. The careful use of sources of ionising radiation is essential. It is important that teachers follow guidelines issued by the Department of Education and Science.'

2. The guidelines referred to here consist of two books, which were published by the Department of Education in 1997. The books are

   'Safety in School Science'

   and

   'Safety in the School Laboratory (Disposal of chemicals)'

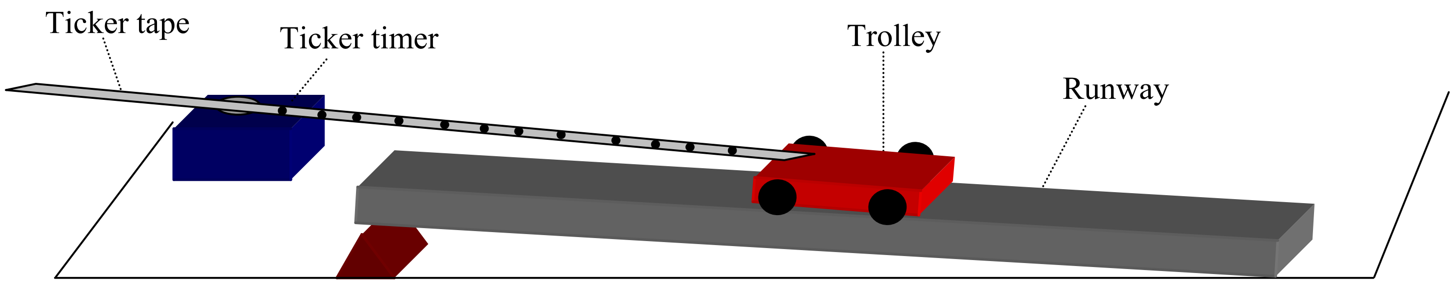
   When these books were published they were distributed to all schools. They have been revised and are available on the 'physical sciences initiative' web site at www.psi-net.org in the 'safety docs' link of the physics section.

3. Teachers should note that the provisions of the Safety, Health and Welfare at Work Act, 1989 apply to schools. Inspectors appointed under that act may visit schools to investigate compliance.

MEASUREMENT OF VELOCITY

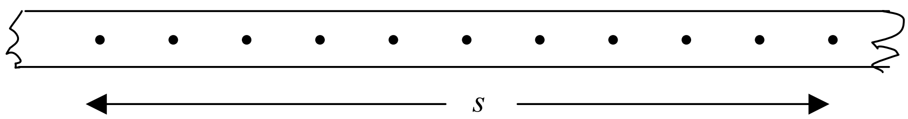
Apparatus

Ticker timer and tape, suitable low-voltage a.c. power supply, trolley, runway, laboratory jack or stand.



Procedure

1. Set up the apparatus as in the diagram.
2. Connect the ticker timer to a low-voltage power supply.
3. Give the trolley a small push to start it moving.
4. Adjust the angle of inclination of the runway until the trolley moves with constant velocity – the spots on the tape are all equidistant.
5. Most ticker timers make 50 spots per second. Therefore the time interval between two adjacent spots is 0.02 s.
6. Measure the length s of ten adjacent spaces.



7. The time t is $10 \times 0.02 = 0.2$ s.
8. As the trolley was travelling at constant velocity we can say that $v = \frac{s}{t}$.
9. Repeat using pushes of varying strengths.
10. Tabulate results as shown.

Results

s/m	t/s	v/m s^{-1}

Notes

Ignore the initial five or six dots on the tape as this shows the initial acceleration due to the push.

Ticker timers that use precarbonated tape are recommended because the friction due to paper drag is reduced.

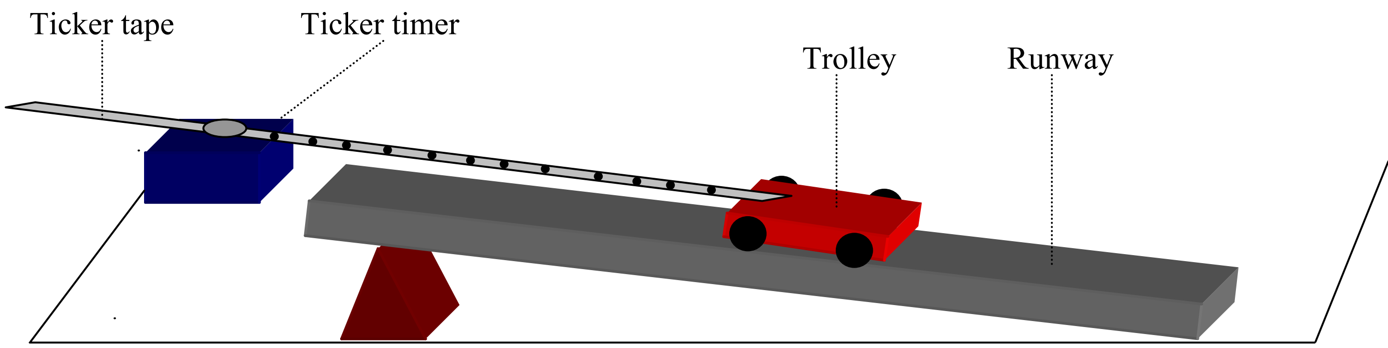
Ensure that the voltage rating of the timer is not exceeded.

Some timers make one hundred dots in one second.

MEASUREMENT OF ACCELERATION

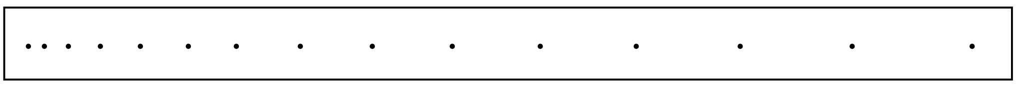
Apparatus

Ticker timer and tape, suitable low-voltage a.c. power supply, dynamics trolley, runway and laboratory jack or stand.



Procedure

1. Set up the apparatus as in the diagram.
2. Connect the ticker timer to a suitable low-voltage power supply.
3. Allow the trolley to roll down the runway.
4. The trolley is accelerating as the distance between the spots is increasing.



5. The time interval between two adjacent dots is 0.02 s, assuming the ticker timer marks fifty dots per second.
6. Mark out five adjacent spaces near the beginning of the tape. Measure the length s_1.
7. The time t_1 is $5 \times 0.02 = 0.1$ s.
8. We can assume that the trolley was travelling at constant velocity for a small time interval. Thus

$$\text{Initial velocity} = \frac{\text{distance}}{\text{time}} = \frac{s_1}{t_1} = u\ .$$

9. Similarly mark out five adjacent spaces near the end of the tape and find the final velocity v.
10. Measure the distance s in metres from the centre point of u to the centre point of v.
11. The acceleration is found using the formula $a = \dfrac{v^2 - u^2}{2s}$.
12. By changing the tilt of the runway different values of acceleration are obtained. Repeat a number of times.
13. Tabulate results as shown.

Results

s_1/m	t_1/s	u/m s^{-1}	s_2/m	t_2/s	v/m s^{-1}	t/s	a/m s^{-2}

Notes

Ignore the initial five or six dots on the tape since the trolley may not be moving with constant acceleration during this time interval.

Ticker timers that use precarbonated tape are recommended because the friction due to paper drag is reduced.

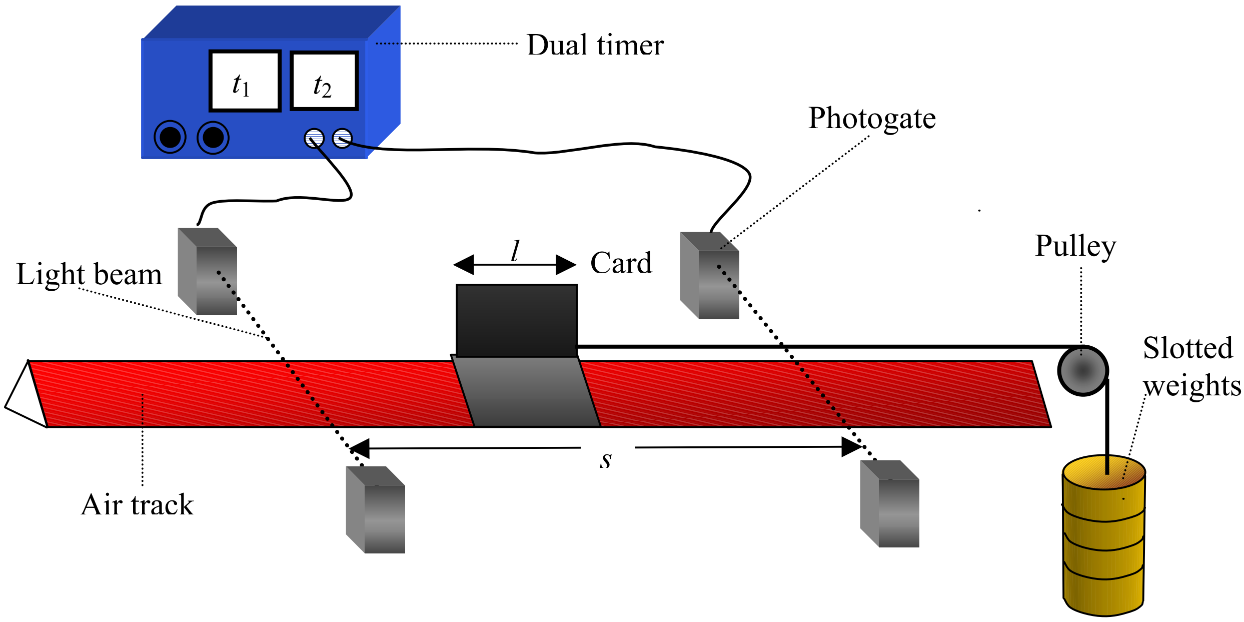
Ensure that the voltage rating of the timer is not exceeded.

Some timers make one hundred dots in one second.

TO SHOW THAT $a \propto F$

Apparatus

Air-track with one vehicle, pulley and blower, two photogates, two retort stands, dual timer, metre-stick, black card, set of slotted weights (1 N total).



Procedure

1. Set up the apparatus as in the diagram. Make sure the card cuts both light beams as it passes along the track.
2. Level the air track.
3. Set the weights F at 1 N. With the card at one end of the track start the blower and release the card from rest.
4. Note the times t_1 and t_2.
5. Remove one 0.1 N disc from the slotted weight, store this on the vehicle, and repeat.
6. Continue for values of F from 1.0 N to 0.1 N.
7. Use a metre-stick to measure the length of the card l and the separation of the photogate beams s.
8. Record results as shown.
9. Draw a graph of a/m s^{-2} against F/N.

Results

$l =$ ……… m.

$s =$ ……… m.

Initial velocity $u = \frac{l}{t_1}$

Final velocity $v = \frac{l}{t_2}$

Acceleration $a = \frac{v^2 - u^2}{2s}$

F/N	t_1/s	t_2 /s	u/m s^{-1}	v/m s^{-1}	a/m s^{-2}
1.0					
0.9					
0.8					
0.7					
0.6					
0.5					
0.4					
0.3					
0.2					
0.1					

Conclusion

A straight line through the origin shows that, for a constant mass, the acceleration is proportional to the applied force.

Notes

The total accelerating mass must be kept constant; hence the need to transfer the masses. Block the ten pairs of air holes nearest the buffer/pulley end of the track with cellotape. This part of the track will now act as a brake on the vehicle.

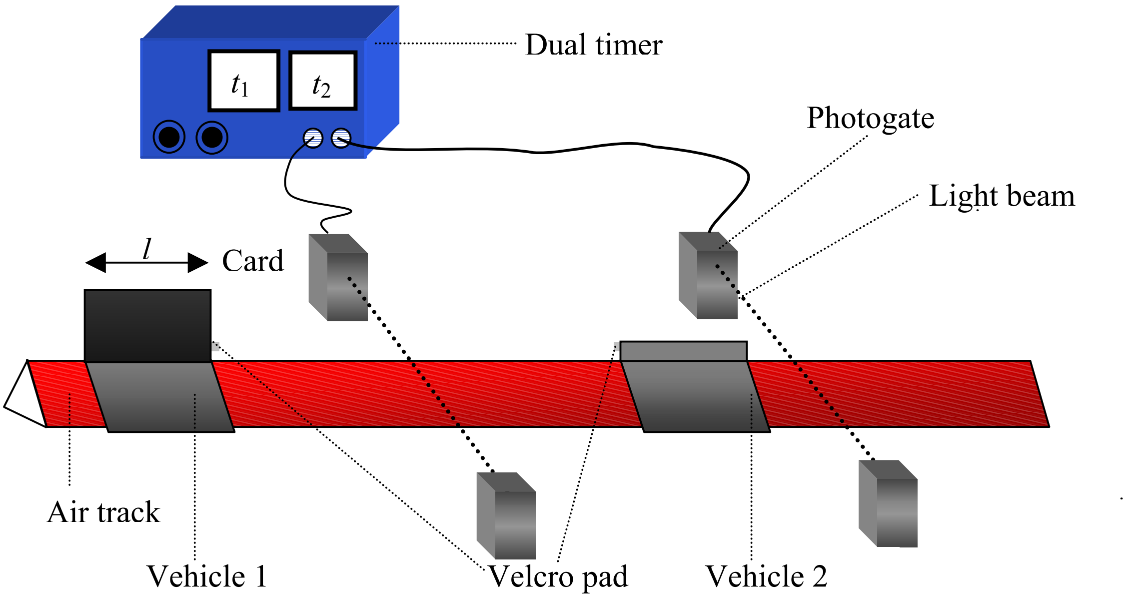
Occasionally check the air holes on the linear air-track with a pin, to clear any blockages due to grit or dust.

This experiment may be performed using a trolley on a friction-compensated ramp.

VERIFICATION OF THE PRINCIPLE OF CONSERVATION OF MOMENTUM

Apparatus

Linear air-track, two vehicles with velcro pads attached, blower, two photogates, two retort stands, dual timer, metre-stick, black card.



Procedure

1. Set up apparatus as in the diagram.
2. Connect air-track to blower.
3. Level the air-track.
4. Measure the mass of each vehicle m_1 and m_2 respectively, including attachments, using a balance.
5. Measure the length l of the black card in metres.
6. With vehicle 2 stationary, give vehicle 1 a gentle push. After collision the two vehicles coalesce and move off together.
7. Read the transit times $t_1$and t_2 for the card through the two beams.
8. Calculate the velocity before the collision, $u = \frac{l}{t_1}$.
9. Calculate the velocity after the collision, $v = \frac{l}{t_2}$.
10. Calculate the momentum before the collision, $p_{\text{before}} = m_1 u$ and the momentum after the collision, $p_{\text{after}} = (m_1 + m_2)\, v$.
11. Repeat several times, with different velocities and different masses.
12. Record results as shown.

Results

Mass of vehicle 1, m_1 =……. kg.

Mass of vehicle 2, m_2 =..…... kg.

s_1/m	t_1/s	u/m s^{-1}	p_{before} / kg m s^{-1}	s_2/m	t_2/s	v/m s^{-1}	p_{after} / kg m s^{-1}

Notes

To see if the track is level carry out these tests:

a) A vehicle placed on a level track should not drift toward either end.

b) When a vehicle is travelling freely along a level track, the times recorded on both timers should be equal. This holds for travel in either direction.

Adding small weights, magnets or putty will change the masses of the vehicles.

Block the ten pairs of air holes nearest the buffer end of the track with cellotape. This part of the track will now act as a brake on the vehicle.

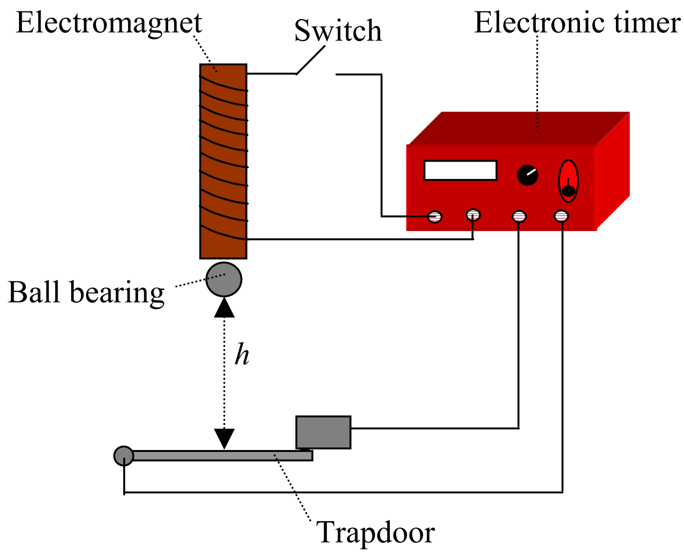
Occasionally check the air holes on the linear air-track with a pin, to clear any blockages due to grit or dust.

This experiment may be performed using trolleys on a friction-compensated ramp.

MEASUREMENT OF *g*

Apparatus

Millisecond timer, metal ball, trapdoor and electromagnet.



Procedure

1. Set up the apparatus. The millisecond timer starts when the ball is released and stops when the ball hits the trapdoor.
2. Measure the height h as shown, using a metre stick.
3. Release the ball and record the time t from the millisecond timer.
4. Repeat three times for this height h and take the smallest time as the correct value for t.
5. Repeat for different values of h.
6. Calculate the values for g using the equation $h = \frac{1}{2}gt^2$. Obtain an average value for g. Alternatively draw a graph of h against t^2 and use the slope to find the value of g.

Results

h/m	t_1/s	t_2 /s	t_3 /s	t/s	g/m s^{-2}
1.2					
1.1					

Notes

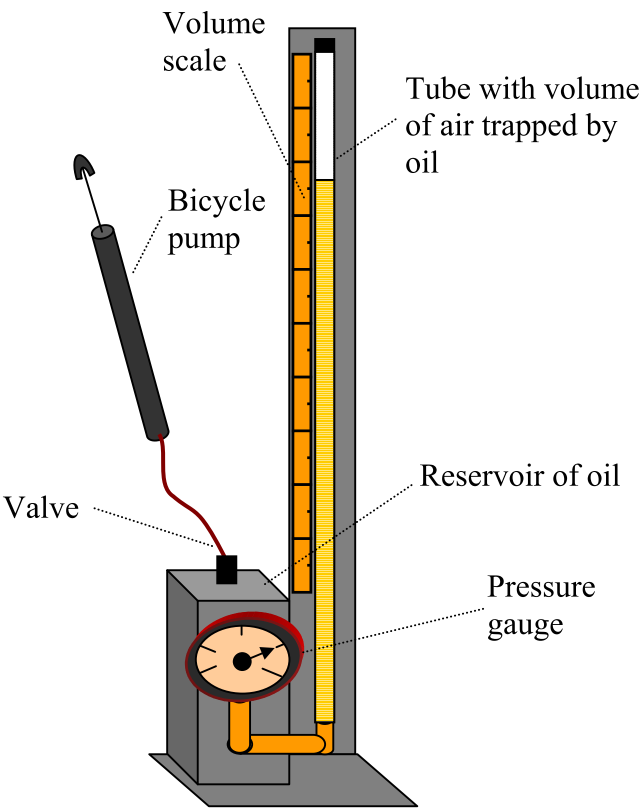
Place a piece of paper between the ball bearing and the electromagnet to ensure a quick release.

In some models of this apparatus, a pressure pad is used in place of the trapdoor; a manually operated spring-release mechanism may also be used in place of the electromagnet.

VERIFICATION OF BOYLE'S LAW

Apparatus

One type of Boyle's law apparatus (shown here) consists of a thick walled glass tube that is closed at one end. It contains a volume of air trapped by a column of oil. A pressure gauge attached to the oil pipe is used in measuring the pressure of this volume of air.



Procedure

1. Using the pump, increase the pressure on the air in the tube. Make sure not to exceed the safety limit indicated on the pressure gauge. Close the valve and wait 20 s to allow the temperature of the enclosed air to reach equilibrium. Read the volume V of the air column from the scale.
2. Take the corresponding pressure reading from the gauge and record the pressure P of the trapped air.
3. Reduce the pressure by opening the valve slightly – this causes an increase the volume of the trapped air column. Again let the temperature of the enclosed air reach equilibrium.
4. Record the corresponding values for the volume V and pressure P .
5. Repeat steps two to five to get at least six pairs of readings.

Results

P/Pa	V /cm^3	$\frac{1}{V}$ /cm^{-3}

Plot a graph of P against $\frac{1}{V}$.

A straight-line graph through the origin will verify that, for a fixed mass of gas at constant temperature, the pressure is inversely proportional to the volume, i.e. Boyle's law.

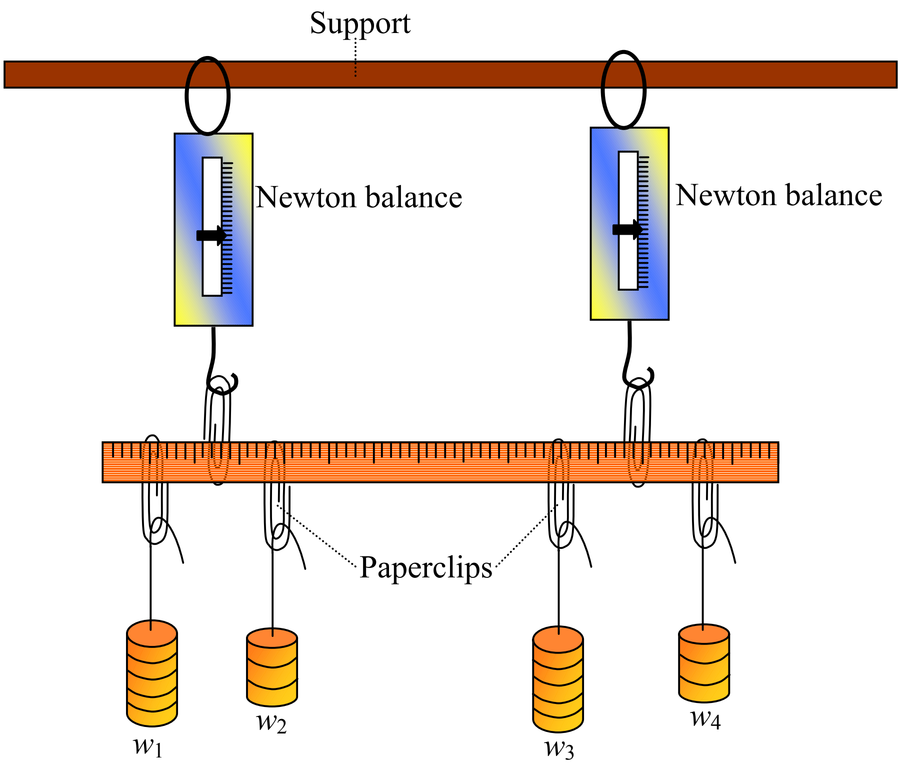
Note

Before starting the experiment, the pressure gauge reading must be checked.
Open the valve fully. If the pressure gauge reads 0, then the value of atmospheric pressure (1×10^5 Pa) must be added to the pressure reading on the gauge to get the pressure of the air in the tube.
If the gauge reads atmospheric pressure (1×10^5 Pa) with the valve opened, then the pressure of the air in the tube is obtained directly from the gauge.

INVESTIGATION OF THE LAWS OF EQUILIBRIUM FOR A SET OF CO-PLANAR FORCES

Apparatus

Two newton balances (0-50 N), metre stick, weights, paperclips.



Procedure

1. Use a balance to find the centre of gravity of the metre stick and its weight.
2. Hang the balances from a support or two retort stands; hang the metre stick horizontally from the balances.
3. Hang a number of weights from the metre stick and move them around until the stick is horizontal and in equilibrium.
4. Record the reading on each newton balance.
5. Find the sum of the weights on the metre stick and add the weight of the stick.
6. Record the positions on the metre stick of each weight, each newton balance and the centre of gravity of the metre stick.
7. Find the moment of each force about the 0 cm mark by multiplying the force, in newtons, by its distance, in metres, from the 0 cm mark.
8. Find the sum of the clockwise moments about an axis through the 0 cm mark.
9. Find the sum of the anticlockwise moments about an axis through the 0 cm mark.
10. Repeat steps 7, 8 and 9 for at least two other points along the metre stick.
11. Repeat for a different set of weights.

Results

For each situation

(1) Forces up = Forces down
i.e. the sum of the readings on the balances should be equal to the sum of the weights plus the weight of the metre stick.

(2) The sum of the clockwise moments about an axis through any of the chosen points should be equal to the sum of the anticlockwise moments about the same axis.

Notes

Giant paperclips [50 mm] can be used to support the slotted weights, thereby eliminating the problem students encounter when thread is used. The paperclips can also be used as support points for hanging the metre stick from the newton balances.

The paperclips may be treated as part of the weights and so their weight is added to that of the other weights.

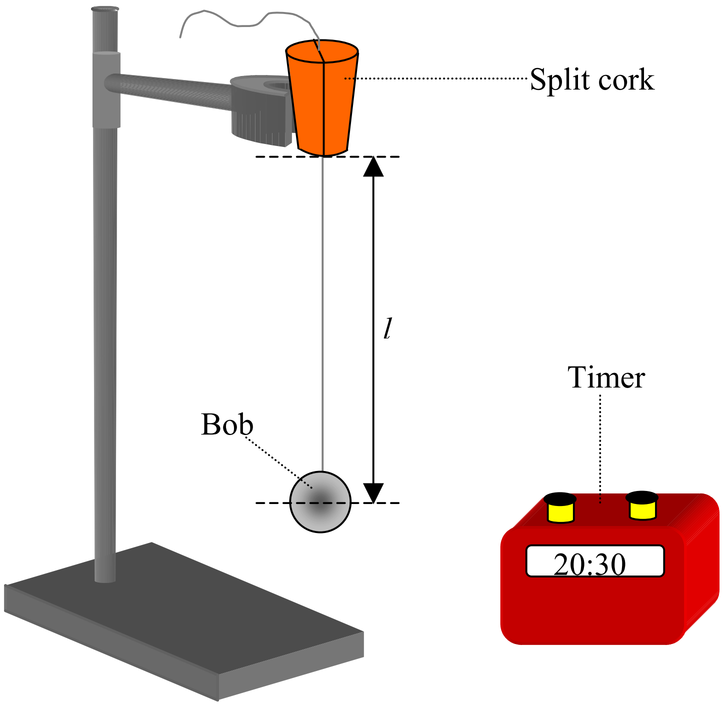
Fixing the paper clips in position with cellotape or bluetack may be an easier alternative approach. The paperclips may then be treated as part of the metre stick. In this case, find the centre of gravity and weight of metre stick and paperclips using one of the balances.

Open out the paperclips for ease of use, especially if it’s planned to slide the weights to different positions.

INVESTIGATION OF THE RELATIONSHIP BETWEEN PERIOD AND LENGTH FOR A SIMPLE PENDULUM AND HENCE CALCULATION OF *g**

Apparatus

Pendulum bob, split cork, string and timer.

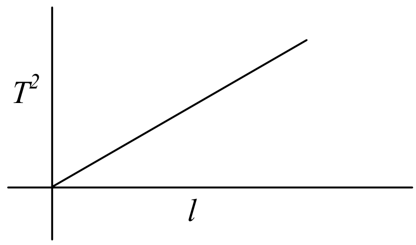


Procedure

1. Place the thread of the pendulum between two halves of a cork or between two coins and clamp to a stand.
2. Set the length of the thread at one metre from the bottom of the cork or coins to the centre of the bob.
3. Set the pendulum swinging through a small angle (<10°). Measure the time t for thirty complete oscillations.
4. Divide this time t by thirty to get the periodic time T.
5. Repeat for different lengths of the pendulum.
6. Draw a graph of T^2 against length l and use the slope to calculate a value for g.

Results

l/m	t/s	T/s	T^2/s^2
1.00			
0.9			
0.8			



$$T^2 = 4\pi^2 \frac{l}{g}$$

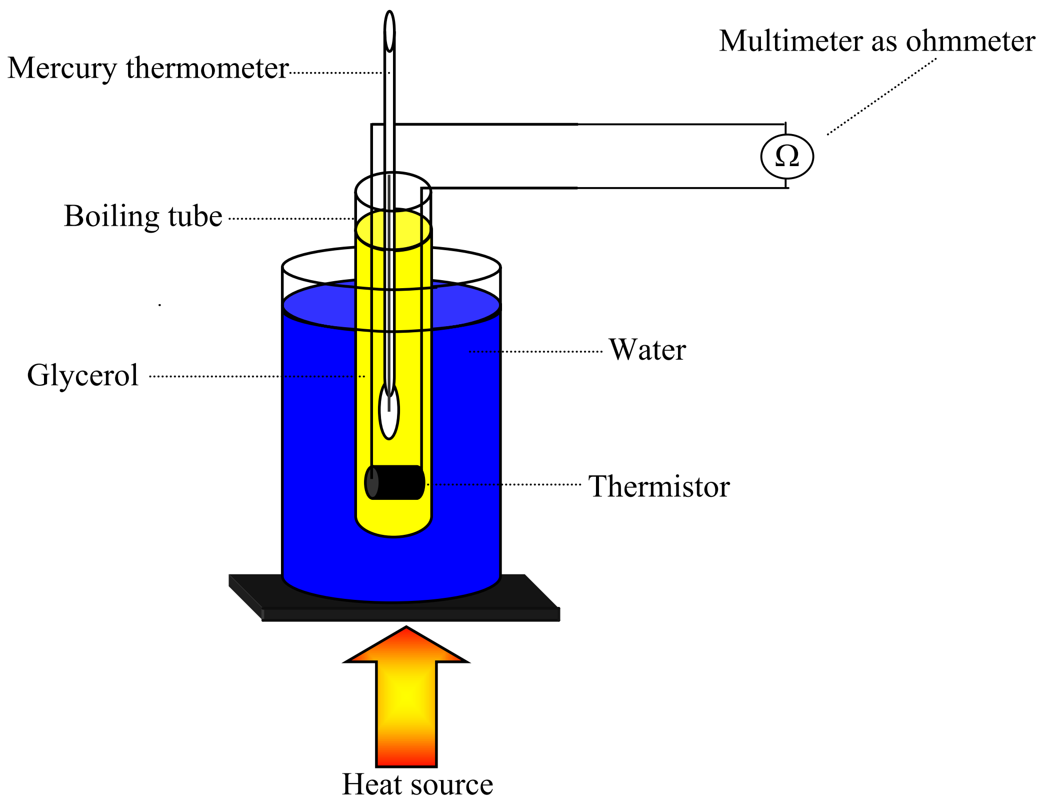
$$\Rightarrow \frac{T^2}{l} = \frac{4\pi^2}{g} = \text{slope}$$

$$\Rightarrow \ \mathrm{g} = \frac{4\pi^2}{(\text{slope})}$$

CALIBRATION CURVE OF A THERMOMETER USING THE LABORATORY MERCURY THERMOMETER AS A STANDARD

Apparatus

Mercury thermometer, thermistor or any other thermometer to be calibrated, boiling tube containing glycerol, heat source, beaker of water, ohmmeter/multimeter.



Procedure

1. Set up apparatus as shown in the diagram.
2. Place the mercury thermometer and the thermistor in the boiling tube.
3. Record the temperature θ, in °C, from the mercury thermometer and the corresponding thermistor resistance R, in ohms, from the ohmmeter.
4. Increase the temperature of the glycerol by about 5 °C.
5. Again record the temperature and the corresponding thermistor resistance.
6. Repeat the procedure until at least ten sets of readings have been recorded.
7. Plot a graph of resistance R against temperature θ and join the points in a smooth, continuous curve.

Results

θ /°C	R/Ω

Notes

The resistance of the leads has been ignored in the description above, since it is negligible.

There is very good thermal contact between the glycerol and the thermistor since the glycerol does not contain dissolved gases.

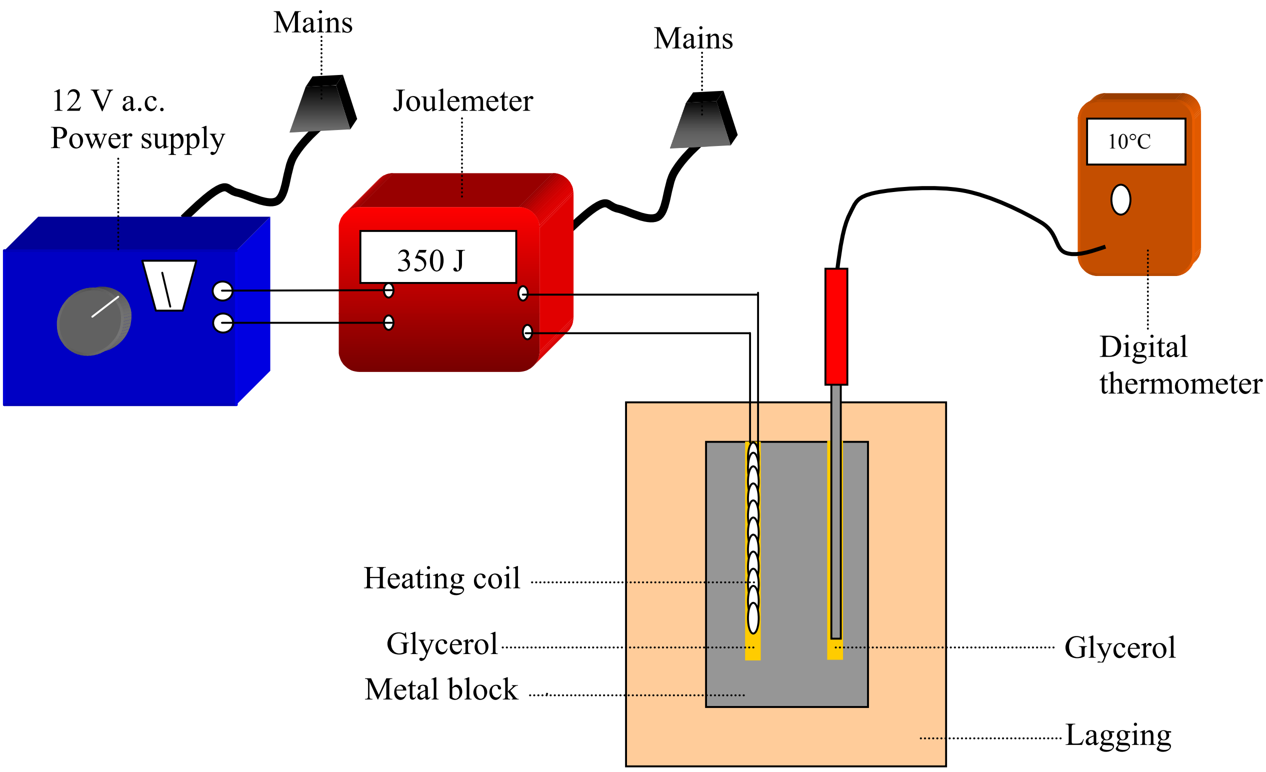
The boiling tube of glycerol is placed in a water bath to limit the maximum temperature reached to 100 °C.

The thermistor can now be used to measure temperatures within the range for which it has been calibrated. Place the thermistor in thermal contact with the body whose temperature is to be found. Measure the resistance and find the corresponding temperature from the calibration curve.

MEASUREMENT OF THE SPECIFIC HEAT CAPACITY OF A METAL BY AN ELECTRICAL METHOD

Apparatus

Joulemeter, block of metal, heating coil to match, beaker, lagging, thermometer accurate to 0.1 °C, glycerol, electronic balance and a low voltage a.c. supply.



Procedure

1. Find the mass of the metal block *m*.
2. Set up the apparatus as shown in the diagram.
3. Record the initial temperature θ_1 of the metal block.
4. Plug in the joulemeter and switch it on.
5. Zero the joulemeter and allow current to flow until there is a temperature rise of 10 °C.
6. Switch off the power supply, allow time for the heat energy to spread throughout the metal block and record the highest temperature θ_2.
7. The rise in temperature $\Delta\theta$ is therefore $\theta_2 - \theta_1$.
8. Record the final joulemeter reading *Q*.

Results

Mass of metal block	m	=
Initial temperature of the block	θ_1	=
Final temperature of the block	θ_2	=
Rise in temperature	$\Delta\theta$	= $\theta_2 - \theta_1$ =
Final joulemeter reading	Q	=

Calculations

The specific heat capacity of the metal c can be calculated from the following equation:

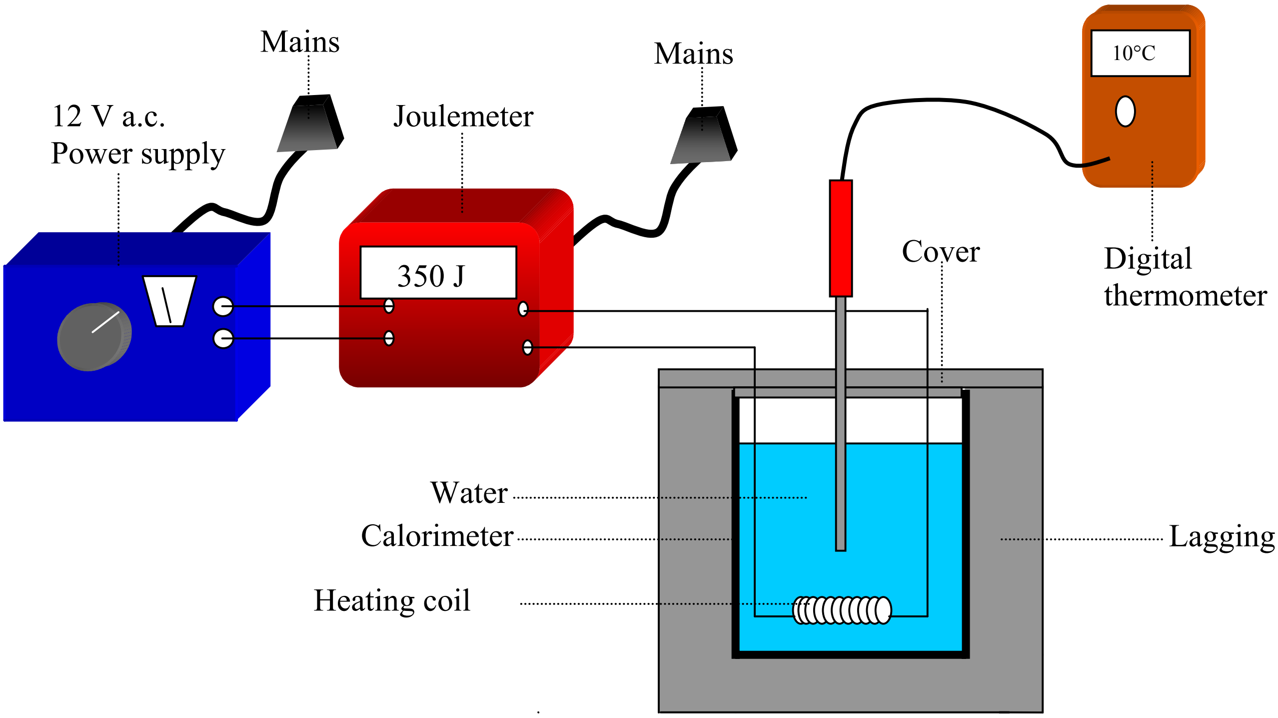
Energy supplied electrically = energy gained by the metal block

$$Q = mc\,\Delta\theta\ .$$

MEASUREMENT OF SPECIFIC HEAT CAPACITY OF WATER BY AN ELECTRICAL METHOD

Apparatus

Joulemeter, calorimeter, heating coil, beaker, lagging, thermometer reading to 0.1 °C, electronic balance and a low voltage a.c. supply.



Procedure

1. Find the mass of the calorimeter m_{cal}.
2. Find the mass of the calorimeter plus the water m_1. Hence the mass of the water m_w is $m_1 - m_{cal}$.
3. Set up the apparatus as shown. Record the initial temperature θ_1.
4. Plug in the joulemeter , switch it on and zero it.
5. Switch on the power supply and allow current to flow until a temperature rise of 10 °C has been achieved.
6. Switch off the power supply, stir the water well and record the highest temperature θ_2. Hence the rise in temperature $\Delta\theta$ is $\theta_2 - \theta_1$.
7. Record the final joulemeter reading Q.

Results

Mass of the calorimeter	m_{cal}	=
Mass of the calorimeter plus the water	m_1	=
Mass of the water	m_w	= $m_1 - m_{cal}$ =
Initial temperature of water	θ_1	=
Final temperature	θ_2	=
Rise in temperature	$\Delta\theta$	= $\theta_2 - \theta_1$ =
Final joulemeter reading	Q	=

Calculations

Given that the specific heat capacity of the calorimeter c_{cal} is known, the specific heat capacity of water c_w can be calculated from the following equation:

Electrical energy supplied = energy gained by water + energy gained by calorimeter

$$Q = m_w c_w \Delta\theta + m_{cal} c_{cal} \Delta\theta .$$

Notes

If a polystyrene container is used in place of the copper calorimeter, then the energy gained by the water is equal to the electrical energy supplied since the heat capacity of the container is negligible.

The energy equation now reads: $Q = m_w c_w \Delta\theta$.

If a joulemeter is unavailable, electrical energy can be supplied to the heating coil from a power supply unit connected in series to an ammeter and rheostat. A voltmeter must be placed in parallel with the heating coil to measure the potential difference and a stopwatch used to measure the time of current flow.

Switch on the current and the stopwatch simultaneously. Adjust the rheostat to maintain a constant current. Allow the current to flow until a temperature rise of 10 °C has been achieved. Record the steady current I and voltage V readings. Switch off the current and the stopwatch simultaneously. Record the time t in seconds.

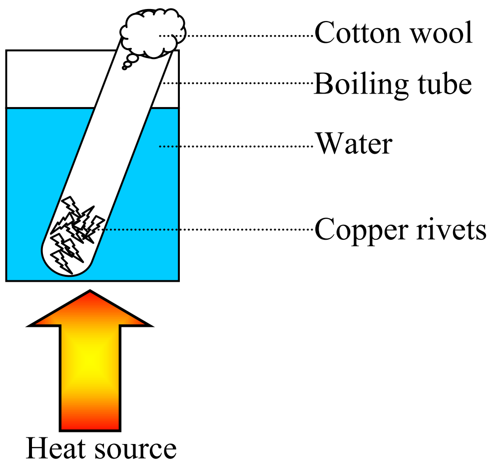
If a calorimeter is used the energy equation is: $VIt = m_w c_w \Delta\theta + m_{cal} c_{cal} \Delta\theta$.

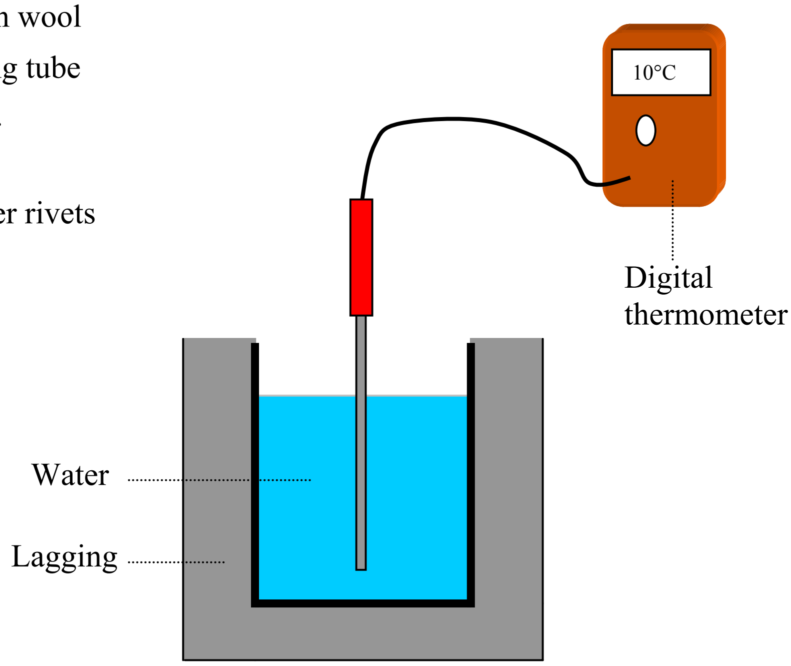
If a polystyrene container is used the energy equation is: $VIt = m_w c_w \Delta\theta$.

MEASUREMENT OF THE SPECIFIC HEAT CAPACITY OF A METAL OR WATER BY A MECHANICAL METHOD

Apparatus

Copper calorimeter, copper rivets, beaker, boiling tube, lagging, thermometer accurate to 0.1 °C, heat source and electronic balance.





Procedure

1. Place some copper rivets in a boiling tube. Fill a beaker with water and place the boiling tube in it.
2. Heat the beaker until the water boils. Allow boiling for a further five minutes to ensure that the copper pieces are 100° C.
3. Find the mass of the copper calorimeter m_{cal}.
4. Fill the calorimeter, one quarter full with cold water. Find the combined mass of the calorimeter and water m_1. Hence the mass of the water m_w is $m_1 - m_{cal}$.
5. Record the initial temperature of the calorimeter plus water θ_1.
6. Quickly add the hot copper rivets to the calorimeter, without splashing.
7. Stir the water and record the highest temperature θ_2. The fall in temperature $\Delta\theta_1$ of the copper rivets is 100 °C – θ_2. The rise in temperature $\Delta\theta_2$ of the calorimeter plus water is $\theta_2 - \theta_1$.
8. Find the mass of the calorimeter plus water plus copper rivets m_2 and hence find the mass of the rivets m_{co}.

Results

Mass of the calorimeter	m_{cal}	=			
Mass of the calorimeter plus the water	m_1	=			
Mass of the water	m_w	=	$m_1 - m_{cal}$	=	
Initial temperature of water	θ_1	=			
Initial temperature of rivets	100° C				
Initial temperature of calorimeter	θ_1	=			
Final temperature of water	θ_2	=			
Final temperature of rivets	θ_2	=			
Rise in temperature of water	$\Delta\theta_2$	=	$\theta_2 - \theta_1$	=	
Rise in temperature of calorimeter	$\Delta\theta_2$	=	$\theta_2 - \theta_1$	=	
Fall in temperature of rivets	$\Delta\theta_1$	=	100° C - θ_2		
Mass of calorimeter plus water plus rivets	m_2	=			
Mass of rivets	m_{co}	=	$m_2 - m_1$		

Calculations

Assume that heat losses to the surroundings or heat gains from the surroundings are negligible.
Given that either the specific heat capacity of water c_w or the specific heat capacity of copper c_c is known, the other specific heat capacity can be calculated from the following equation:

Energy lost by copper rivets = energy gained by copper calorimeter + the energy gained by the water

$$m_{co}c_c\,\Delta\theta_1 = m_{cal}c_c\,\Delta\theta_2 + m_w c_w\,\Delta\theta_2\,.$$

If c_w is known, then c_c can be calculated or alternatively if c_c is known, c_w can be found.

Notes

If a polystyrene container is used in place of the copper calorimeter, then the energy gained by the water is equal to the energy lost by the copper rivets. The energy equation now reads:

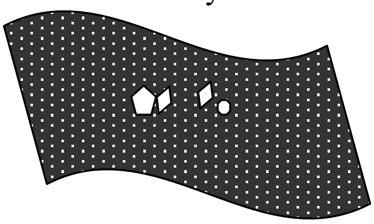
$$m_{co}c_c\,\Delta\theta_1 = m_w c_w\,\Delta\theta_2\,.$$

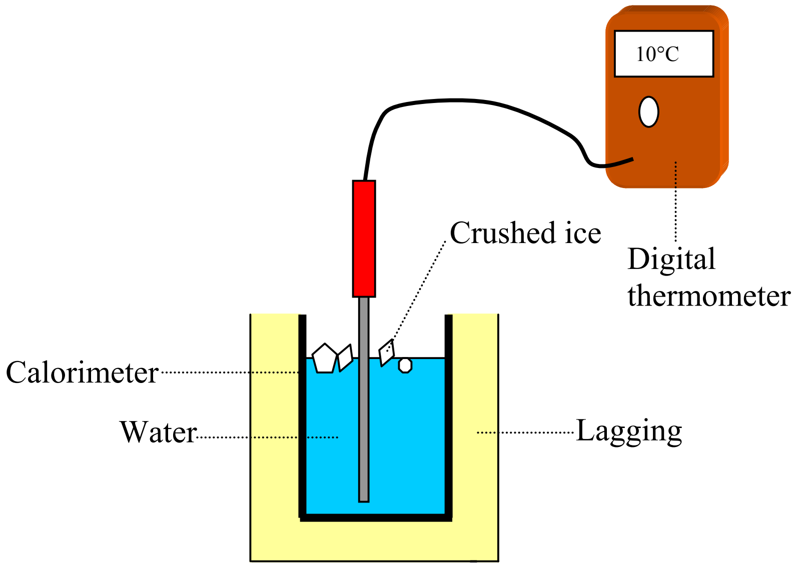
MEASUREMENT OF THE SPECIFIC LATENT HEAT OF FUSION OF ICE

Apparatus

Ice, water, calorimeter, lagging, beakers, kitchen paper, digital thermometer reading to 0.1 °C and electronic balance.

Wrap ice in cloth to crush and dry.





Procedure

1. Place some ice cubes in a beaker of water and keep taking the temperature with the thermometer until the ice-water mixture reaches 0 °C.
2. Find the mass of the calorimeter m_{cal}.
3. Half fill the calorimeter with water warmed to approximately 10 °C above room temperature. Find the combined mass of the calorimeter and water m_2. The mass of the water m_w is $m_2 - m_{cal}$.
4. Record the initial temperature θ_1 of the calorimeter plus water.
5. Surround the ice cubes with kitchen paper or a cloth and crush them between wooden blocks – dry them with the kitchen paper.
6. Add the pieces of dry crushed ice, a little at a time, to the calorimeter. Do this until the temperature of the water has fallen by about 20 °C.
7. Record the lowest temperature θ_2 of the calorimeter plus water plus melted ice. The rise in temperature of the ice $\Delta\theta_1$ is $\theta_2 - 0$ °C and the fall in temperature of the calorimeter plus water $\Delta\theta_2$ is $\theta_1 - \theta_2$.
8. Find the mass of the calorimeter plus water plus melted ice m_3. The mass of the melted ice m_i is $m_3 - m_2$.

Results

Mass of the calorimeter	m_{cal}	=
Mass of the calorimeter plus water	m_2	=
Mass of the water	m_w	= $m_2 - m_{cal}$ =
Initial temperature of the calorimeter plus water	θ_1	=
Final temperature of the calorimeter plus water plus melted ice	θ_2	=
Rise in temperature of the ice	$\Delta\theta_1$	= $\theta_2 - 0$ °C =
Fall in temperature of the calorimeter plus water	$\Delta\theta_2$	= $\theta_1 - \theta_2$ =
Mass of the calorimeter plus water plus melted ice	m_3	=
Mass of the melted ice	m_i	= $m_3 - m_2$ =

Calculations

Assume heat losses cancel heat gains. Given that the specific heat capacity of water c_w and the specific heat capacity of copper c_c are already known, the latent heat of fusion of ice l may be calculated from the following equation:

Energy gained by ice = energy lost by calorimeter + energy lost by the water.

$$m_i l + m_i c_w \Delta\theta_1 = m_{cal} c_c \Delta\theta_2 + m_w c_w \Delta\theta_2$$

Notes

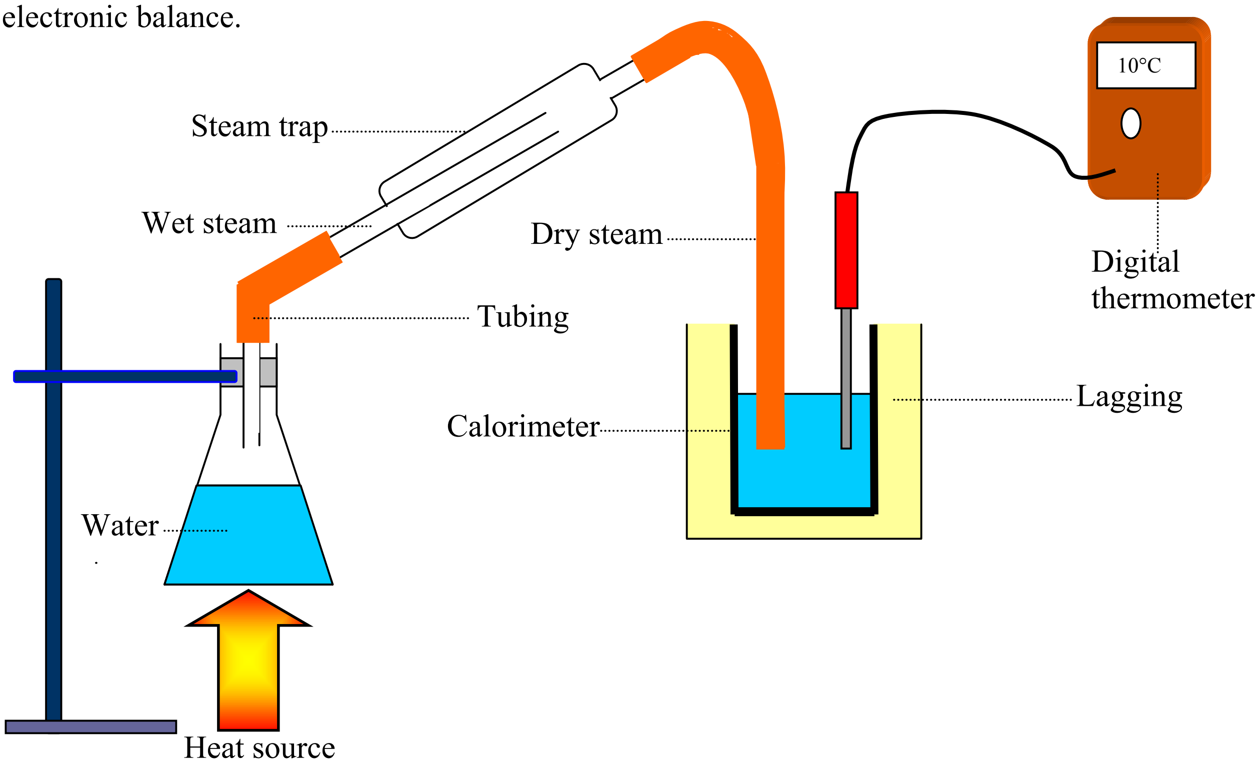
If a polystyrene container is used in place of the copper calorimeter, the energy gained by the ice is equal to the energy lost by the water.
The energy equation now reads: $m_i l + m_i c_w \Delta\theta_1 = m_w c_w \Delta\theta_2$.

To avoid melting the crushed ice, transfer it with a plastic spatula.

MEASUREMENT OF THE SPECIFIC LATENT HEAT OF VAPORISATION OF WATER

Apparatus

Calorimeter, lagging, beaker, conical flask fitted with stopper and delivery tube or steam generator, steam trap, retort stand, heat source, thermometer accurate to 0.1 °C and electronic balance.



Procedure

1. Half fill the conical flask or steam generator with water and fit with the delivery tube.
2. Heat until steam issues freely.
3. Find the mass of the calorimeter m_{cal}.
4. Half fill the calorimeter with water cooled to approximately 10 °C below room temperature.
5. Find the mass m_1 of the water plus calorimeter.
6. The mass of the cooled water m_w is $m_1 - m_{cal}$.
7. Record the temperature of the calorimeter plus water θ_1.
8. Allow dry steam to pass into the water in the calorimeter until the temperature has risen by about 20 °C.
9. Remove the steam delivery tube from the water, taking care not to remove any water from the calorimeter in the process.
10. Record the final temperature θ_2 of the calorimeter plus water plus condensed steam. The fall in temperature of the steam $\Delta\theta_1$ is 100 °C – θ_2.
11. The rise in the temperature of the calorimeter plus water $\Delta\theta_2$ is $\theta_2 - \theta_1$.
12. Find the mass of the calorimeter plus water plus condensed steam m_2. Hence the mass of the condensed steam m_s is $m_2 - m_1$.

Results

Mass of the calorimeter	m_{cal}	=
Mass of the water plus calorimeter	m_1	=
Mass of the cooled water	m_w	= $m_1 - m_{cal}$ =
Temperature of the calorimeter plus water	θ_1	=
Final temperature of the calorimeter plus water plus condensed steam	θ_2	=
Fall in temperature of the steam	$\Delta\theta_1$	= 100 °C – θ_2 =
Rise in the temperature of the calorimeter plus water	$\Delta\theta_2$	= $\theta_2 - \theta_1$ =
Mass of the calorimeter plus water plus condensed steam	m_2	=
Mass of the condensed steam	m_s	= $m_2 - m_1$ =

Calculations

Assume heat losses to the surroundings cancel heat gains from the surroundings. Given that the specific heat capacity of water c_w and the specific heat capacity of copper c_c are already known, the specific latent heat of vaporisation of water l may be calculated from the following equation:

Energy lost by steam = energy gained by calorimeter + energy gained by the water

$$m_s l + m_s c_w \Delta\theta_1 = m_{cal} c_c \Delta\theta_2 + m_w c_w \Delta\theta_2 .$$

Notes

If a polystyrene container is used in place of the copper calorimeter, then the energy lost by the steam is equal to the energy gained by the water.
The energy equation now reads: $m_s l + m_s c_w \Delta\theta_1 = m_w c_w \Delta\theta_2$.

Use a tilted insulated tube as an alternative delivery pipe for dry steam. This does away with the need to use a steam trap.

If the water in the calorimeter is initially cooled to10 °C below room temperature and then heated to 10 °C above room temperature the heat gains and heat losses approximately cancel each other out.

MEASUREMENT OF THE SPEED OF SOUND IN AIR

Apparatus

1000 ml graduated cylinder, resonance tube, set of tuning forks in the frequency range 256 Hz to 512 Hz, vernier callipers, metre stick, stand (longest upright type), clamp and wooden block.

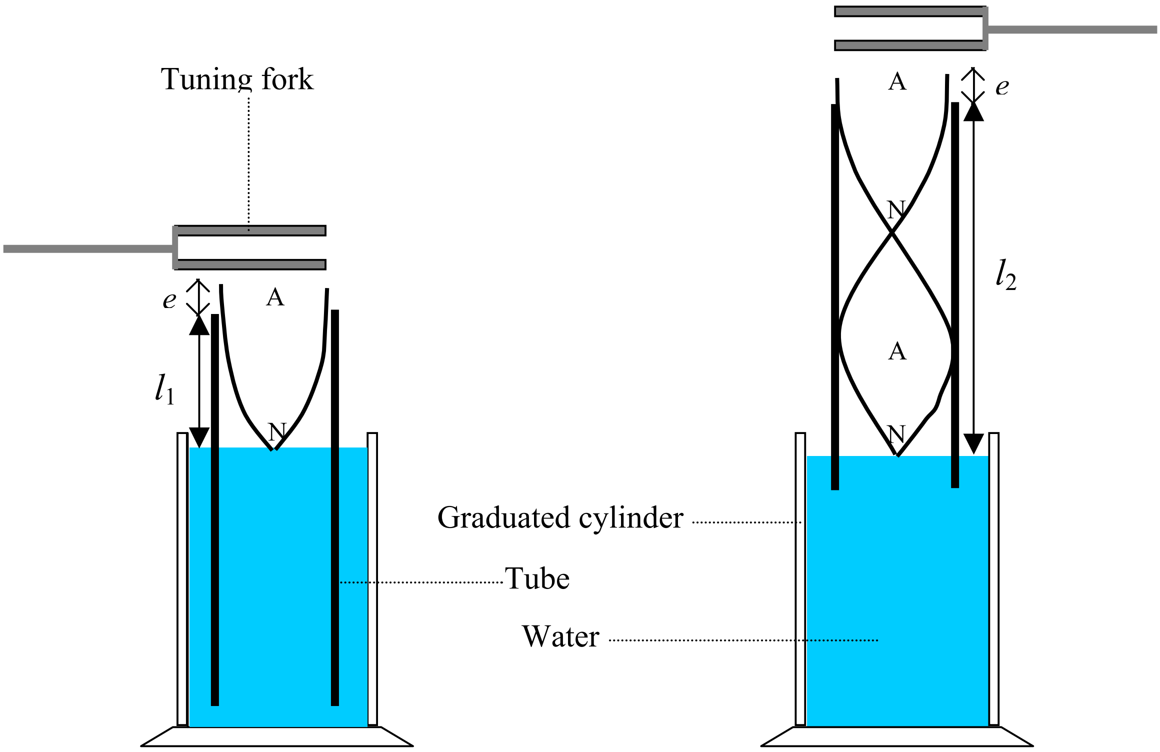


Fig.1 **Fig. 2**

Procedure

1. Clamp the tube so that the water in the graduated cylinder closes its lower end. The tube should be free to slide vertically through the clamp jaws. Take an approximate value of 300 m s^{-1} for the speed of sound to obtain a rough estimate of the quarter wavelength resonance position.
2. Strike the highest frequency (512 Hz) tuning fork on the wooden block, and hold it in a horizontal position just above the mouth of the tube (Fig. 1).
3. Slide the tube slowly up/down until the note heard from the tube is at its loudest; resonance is now occurring.
4. Tighten the clamp in this position and measure the length of the air column (from the water level to the top of the tube) l_1 with a metre stick.
5. Clamp the tube (or its extension) so that the air column is 2 or 3 cm less than $3l_1$ (Fig. 2).
6. Obtain a second weaker resonance with the same tuning fork by again sliding the tube until the note heard is at its loudest, at the three-quarters wavelength resonance position.
7. Clamp the tube in this position and measure with a metre stick, the air column length l_2 at this resonance.

8. Repeat this procedure to obtain the corresponding values of l_1 and l_2 for all the tuning forks in order of decreasing frequency.
9. Record the measurements in a table.
10. Calculate the wavelength using $\lambda = 2(l_2 - l_1)$ in each case.
11. Calculate the speed of sound from $c = f\lambda$, for each of the tuning forks.
12. Find the average value for the speed of sound.

Results

f/Hz	l_1/m	l_2/m	λ /m	c/m s^{-1}

The average value of the speed of sound in air =

Notes

The experiment can be done using just one tube. Proceed to obtain resonance as before. Measure the length l_1. The antinode forms above the top of the tube and so an end correction factor has to be added to the length. From theory, it is found that the correction factor $e = 0.3d$, where d is the average internal diameter of the tube (measured using a vernier callipers).

Hence $\lambda = 4(l_1 + 0.3d)$

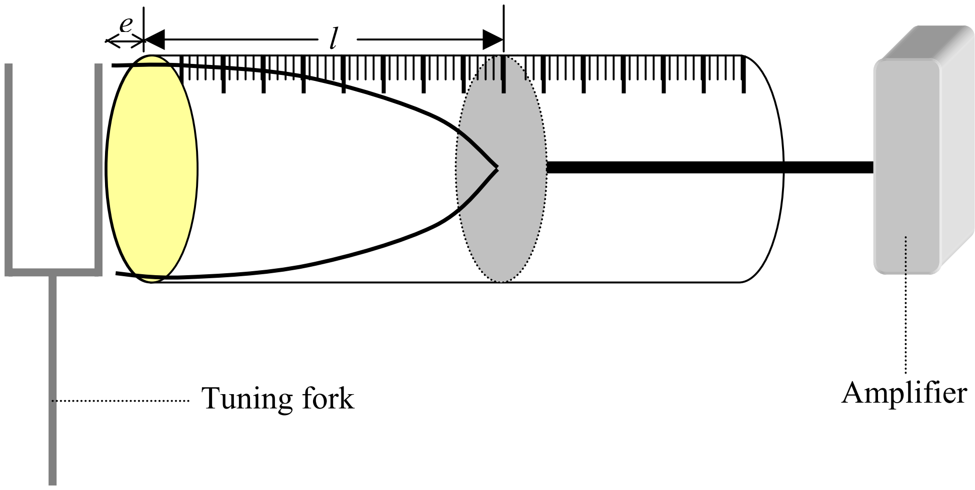
$c = f\lambda$

$c = 4f(l_1 + 0.3d)$.

Calculate a value of c for each tuning fork and find an average value for the speed of sound.

If a resonance tube is not available, use 50 cm lengths of 40 mm and 30 mm plastic pipes.

A specially designed apparatus called a resonometer can also be used to obtain the data.



Beginning with the highest frequency tuning fork and a very short column of air, adjust the piston until the sound from the vibrating air column is loudest; this is the first resonance point. Measure the length *l* of the air column at resonance. Proceed to use the set of tuning forks to complete the data table as in the previous method (it is difficult to distinguish resonance for frequencies below 340 Hz).

$\lambda = 4(l + e)$ where e is the end correction factor
$\lambda = 4(l + 0.3d)$ where d is the internal diameter of the tube
$c = f\lambda$
$c = 4f(l + 0.3d)$.

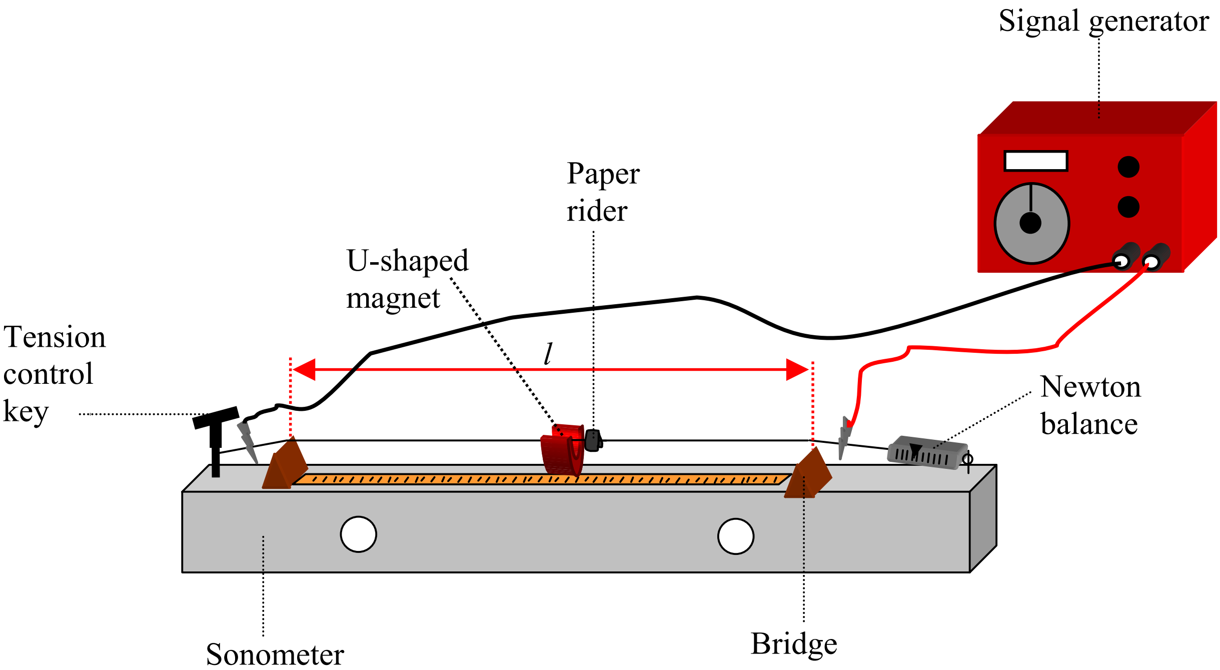
It is also possible to cause resonance in the air column using a signal generator and a loudspeaker; the 8 Ω, 5 cm diameter model of loudspeaker is ideal. Clamp the loudspeaker in a horizontal position just above the mouth of the tube. Connect the loudspeaker to the low impedance output of the signal generator. Gradually increase the signal generator frequency from zero until the air column resonates. Calculate the speed of sound using the same procedures as before. Repeat the experiment for different lengths of the air column.

INVESTIGATION OF THE VARIATION OF FUNDAMENTAL FREQUENCY OF A STRETCHED STRING WITH LENGTH

Apparatus

Signal generator, U-magnet, sonometer with a newton balance or tensionometer (0 to 50 N) and tension key.

Safety note: Wear safety goggles in case the sonometer wire snaps.



Procedure

1. Place the sonometer wire between the poles of the U-magnet, positioned midway between the bridges.
2. Fix the tension at a constant value (e.g. 20 N), using the tension control key.
3. Place the bridges as far apart as possible and measure the length of the wire l between the bridges with a metre stick.
4. Slowly increase the applied a.c. frequency from 0 Hz, until the wire vibrates.
5. Note the value of this frequency when the vibration is at its maximum.
6. Reduce the length of the wire, by sliding one bridge towards the other one. Reposition the magnet midway between the bridge supports and measure the fundamental frequency for that length.
7. Repeat this procedure for different lengths of wire and measure the corresponding fundamental frequencies.
8. Record the measurements in a table.
9. Plot a graph of frequency f against inverse of length $\frac{1}{l}$.

Results

f/Hz	l/m	$\frac{1}{l}$/m^{-1}

Conclusion

A straight line through the origin will verify that frequency f is inversely proportional to the length l.

Notes

If the frequency cannot be read with reasonable accuracy from the signal generator, use a multimeter with a suitable frequency scale. Connect it across the signal generator.

Use the amplitude control on the signal generator to adjust the current flowing through the wire, to prevent overheating.

Keep the paper rider as light as possible. Use a small piece of cellotape to hold the paper in the form of a loop. This allows the rider to sit loosely on the wire without falling off. The movement of the paper is then easier to see and hence the position of resonance is easier to identify.

A short length of drinking straw can also be used as a very light rider. Slit the straw length-wise first; cut off a 0.5 cm piece and slip it onto the string. This rider can be moved along the string to detect the positions of nodes and antinodes when the string is vibrating at resonance.

A set of tuning forks may be used as an alternative to the signal generator and magnet.

Use the low impedance output of the signal generator.

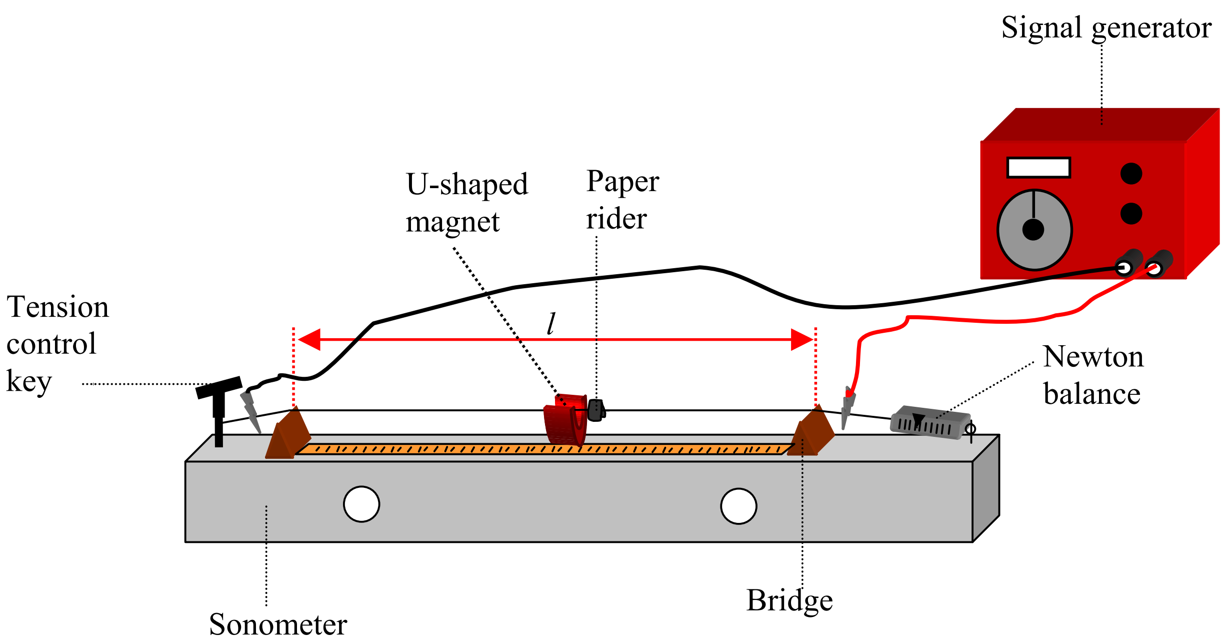
A guitar string may be used instead of the sonometer wire.

INVESTIGATION OF THE VARIATION OF THE FUNDAMENTAL FREQUENCY OF A STRETCHED STRING WITH TENSION*

Apparatus

Signal generator, U-magnet, sonometer with a newton balance or tensionometer (0 to 50 N) and tension key.

Safety note: Wear safety goggles in case the sonometer wire snaps.



Procedure

1. Place the sonometer wire between the poles of the U-magnet, positioned midway between the bridges.
2. Select a wire length l (e.g. 30 cm), by suitable placement of the bridges. Keep this length fixed throughout the experiment.
3. Set the tension at a low value (e.g. 4 N), so that the stationary waves set up at resonance have large amplitude and are easily visible.
4. Increase the frequency slowly from zero until resonance occurs.
5. Increase the value of the tension (in steps of 4 N, for example) and again increase the applied a.c. frequency until resonance occurs.
6. Record the frequency and tension values in a table.
7. Repeat the procedure to obtain at least six readings.
8. Plot a graph of frequency f against the square root of tension $\sqrt{T}$. Draw a straight line of best fit through the plotted points.

Results

f/Hz	T/N	$\sqrt{T}$ /$N^{1/2}$

Conclusion

A straight line through the origin will verify a proportionality between the frequency f and the square root of the tension $\sqrt{T}$.

Notes

Ensure that the breaking strain of the wire is greater than 50 N.

Use the low impedance output of the signal generator.

If the frequency cannot be read with reasonable accuracy from the signal generator, use a multimeter with a suitable frequency scale. Connect it across the signal generator.

Use the amplitude control on the signal generator to adjust the current flowing through the wire, to prevent overheating.

Keep the paper rider as light as possible. Use a small piece of cellotape to hold the paper in the form of a loop. This allows the rider to sit loosely on the wire without falling off. The movement of the paper is then easier to see and hence the position of resonance is easier to identify.

A short length of drinking straw can also be used as a very light rider. Slit the straw length-wise first; cut off a 0.5 cm piece and slip it onto the string. This rider can be moved along the string to detect the positions of nodes and antinodes when the string is vibrating at resonance.

Students may find the data easier to handle if the tension values 4 N, 9 N, 16 N, etc., are chosen.

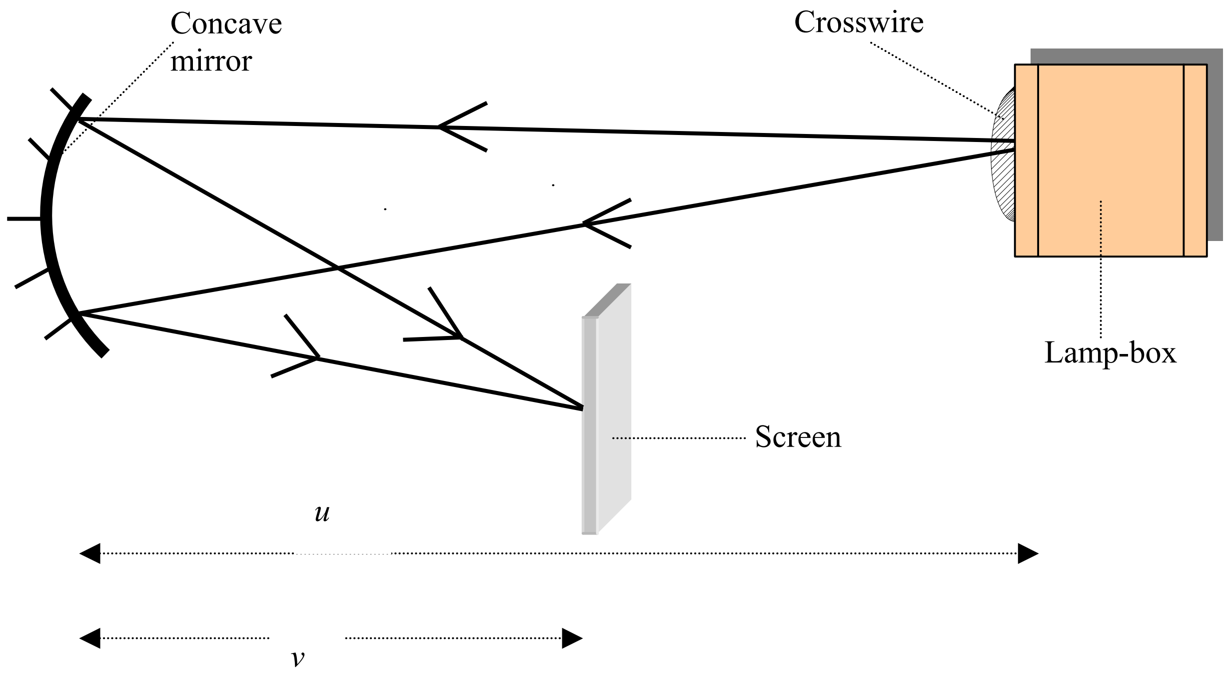
A guitar string may be used instead of the sonometer wire.

A set of tuning forks may be used as an alternative to the signal generator and magnet.

MEASUREMENT OF THE FOCAL LENGTH OF A CONCAVE MIRROR

Apparatus

Concave mirror, screen, lamp-box with crosswire.



Procedure

1. Place the lamp-box well outside the approximate focal length - see notes.
2. Move the screen until a clear inverted image of the crosswire is obtained.
3. Measure the distance u from the crosswire to the mirror, using the metre stick.
4. Measure the distance v from the screen to the mirror.
5. Calculate the focal length of the mirror using $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.
6. Repeat this procedure for different values of u.
7. Calculate f each time and then find an average value.

Results

u/cm	$\frac{1}{u}$/cm^{-1}	v/cm	$\frac{1}{v}$/cm^{-1}	$\frac{1}{f}$/cm^{-1}	f/cm

Average f =

Notes

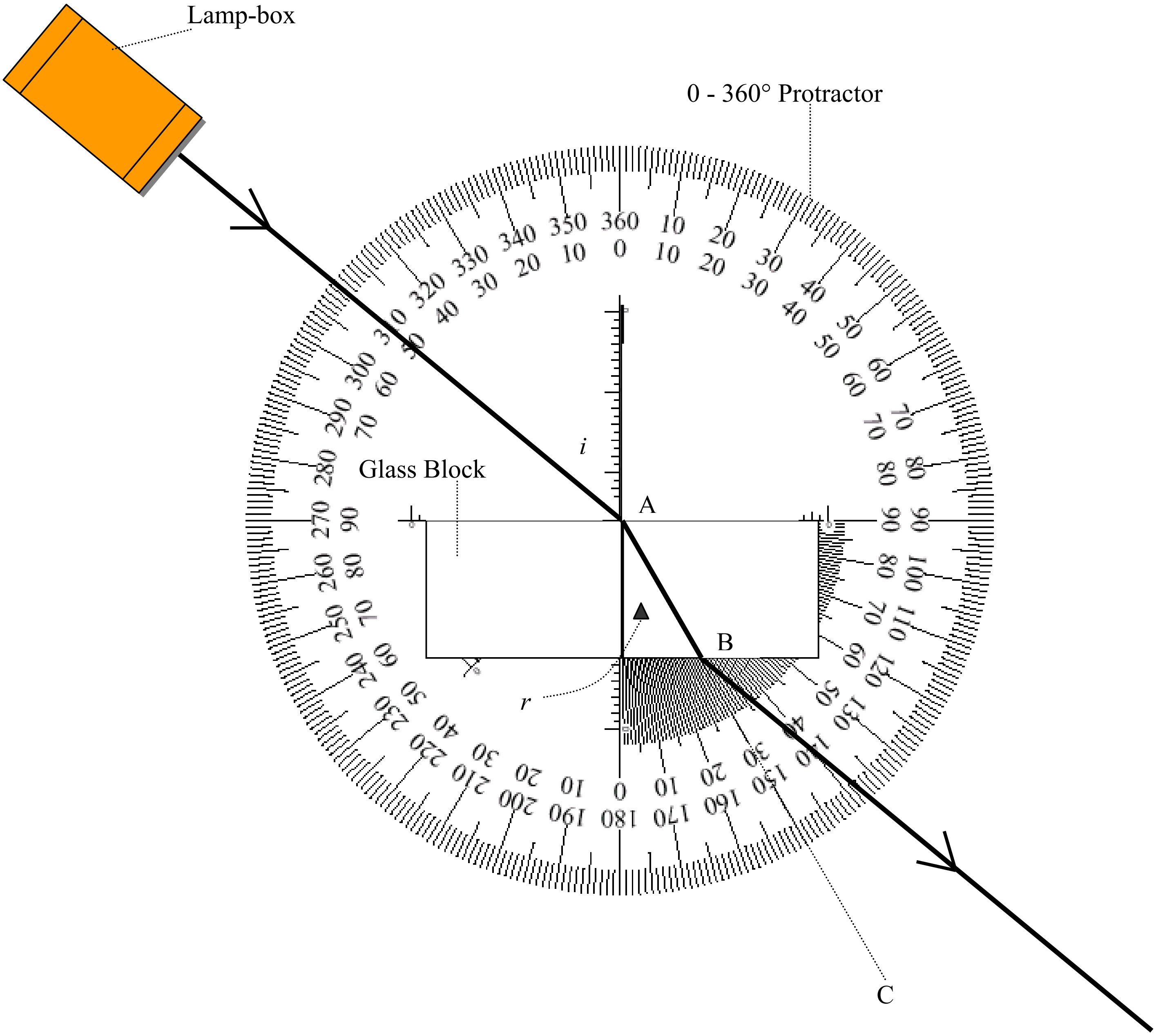
The approximate method for finding the focal length is recommended as a starting point for this experiment. The approximate method is described in the Appendix.

A microscope lamp makes a very suitable strong light source. Cover the glass of the lamp with a piece of tracing paper. Use ‘peel-and-stick’ letters to create an ‘object’ on the tracing paper.

VERIFICATION OF SNELL'S LAW OF REFRACTION

Apparatus

Glass block, lamp-box, 0-360^0 protractor, (photocopied from page 56 of Physics A Teacher's Handbook)



Procedure

1. Place a glass block on the 0-360^0 protractor in the position shown on the diagram and mark its outline.
2. Shine a ray of light from a lamp-box at a specified angle to the near side of the block and note the angle of incidence.
3. Observe the ray of light leaving the glass block and similarly mark the exact point B where it leaves the glass block.
4. Remove the glass block. Join BA and extend to C.
5. Note the angle of refraction *r*.
6. Repeat for different values of *i*.
7. Draw up a table as shown.
8. Plot a graph of sin *i* against sin *r*.

Results

i/°	r/°	sin i	sin r	$\frac{\sin i}{\sin r}$

Average value of $\frac{\sin i}{\sin r}$ =

A straight line through the origin verifies Snell's law of refraction i.e. $\sin i \propto \sin r$.

The slope of the line gives a value for the refractive index of glass.

The refractive index of glass is equal to the average value of $\frac{\sin i}{\sin r}$.

Notes

Look directly down through the glass or plastic block to measure the angle of refraction.

Print the 360° protractor directly from page 56 of 'Physics A Teachers Handbook' to obtain the clearest delineation of the marked angles.

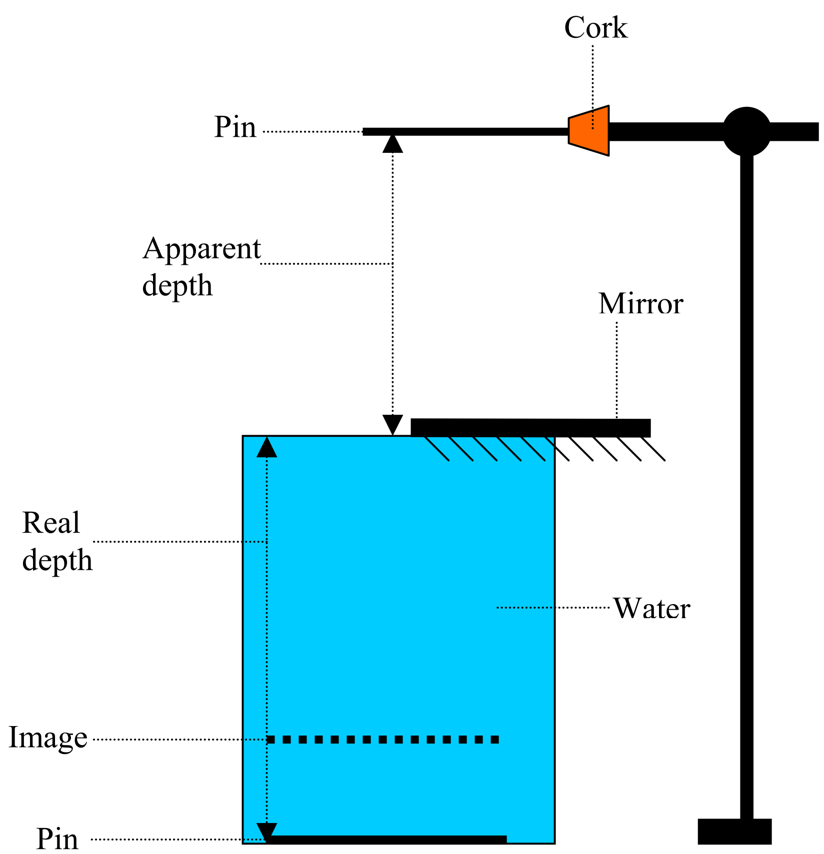
A semi-circular glass block can be used instead of the rectangular block.

A commercial model of the 360° protractor is also available. The model has a 'rotating' protractor housed in a horizontal rectangular base.

MEASUREMENT OF THE REFRACTIVE INDEX OF A LIQUID

Apparatus

Plane mirror, two pins, cork, retort stand, large containers.



Procedure

1. Fill a container to the top with water.
2. Place the plane mirror to one side on top of the container.
3. Put a pin on the bottom of the container.
4. Adjust the height of the pin in the cork above the mirror until there is no parallax between its image in the mirror and the image of the pin in the water.
5. Measure the distance from the pin in the cork to the back of the mirror – this is the apparent depth.
6. Measure the depth of the container – this is the real depth.
7. Calculate the refractive index, $n = \frac{\text{real depth}}{\text{apparent depth}}$.
8. Repeat using different size containers and get an average value for n.

Results

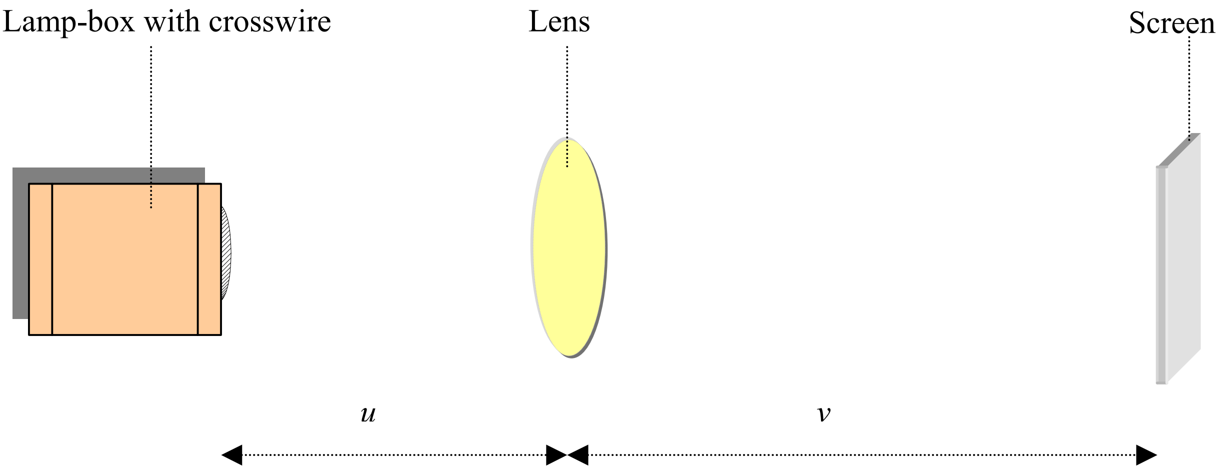
real depth/cm	apparent depth/cm	$n = \frac{\text{real depth}}{\text{apparent depth}}$

Average $n =$

MEASUREMENT OF THE FOCAL LENGTH OF A CONVERGING LENS

Apparatus

Converging lens, screen, lamp-box with crosswire, metre stick, retort stand.



Procedure

1. Place the lamp-box well outside the approximate focal length – see notes.
2. Move the screen until a clear inverted image of the crosswire is obtained.
3. Measure the distance u from the crosswire to the lens, using the metre stick.
4. Measure the distance v from the screen to the lens.
5. Calculate the focal length of the lens using $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.
6. Repeat this procedure for different values of u.
7. Calculate f each time and then find the average value.

Results

u/cm	$\frac{1}{u}$/cm^{-1}	v/cm	$\frac{1}{v}$/cm^{-1}	$\frac{1}{f}$/cm^{-1}	f/cm

Average f =

Notes

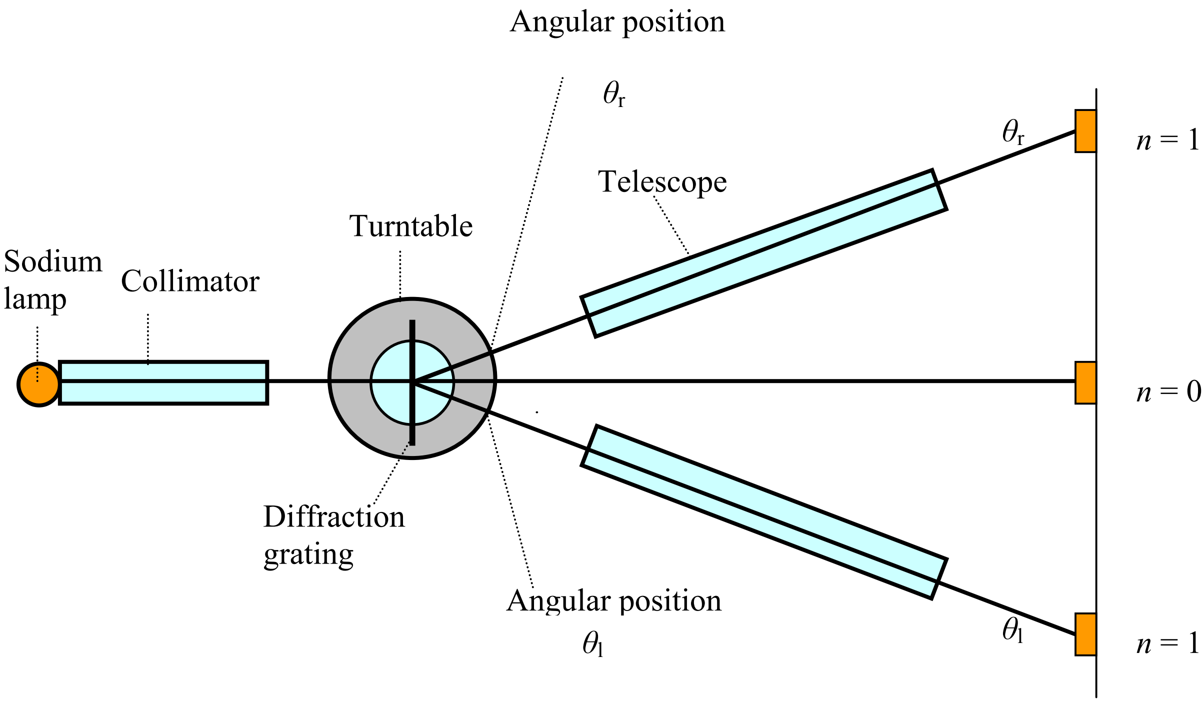
The approximate method for finding the focal length is recommended as a starting point for this experiment. The approximate method is described in the Appendix.

A microscope lamp makes a very suitable strong light source that can be used in daylight. Cover the glass of the lamp with a piece of tracing paper. The tracing paper can be attached with some bluetack. Use 'peel-and-stick' letters to create an 'object' on the tracing paper. If the 'object' is a simple three-letter word then the inversion of the image will be obvious.

MEASUREMENT OF THE WAVELENGTH OF MONOCHROMATIC LIGHT

Apparatus

Sodium lamp, spectrometer and diffraction grating (300 lines per mm).



Procedure

1. Adjust the eyepiece of the telescope so that the crosswires are sharply focused.
2. Focus the telescope for parallel light using a distant object. There should be no parallax between the image seen in the telescope and the crosswires seen through the eyepiece.
3. Place the sodium lamp in front of the collimator.
4. Level the turntable of the spectrometer if necessary.
5. Looking through the telescope, focus the collimator lens and adjust the width of the slit until a clear narrow image is seen.
6. Place the diffraction grating on the turntable at right angles to the beam.
7. Move the telescope to the right until the cross wires are centred on the first bright image. Take the reading θ_r from the scale on the turntable. (To see the scale more easily shine a lamp on it and use a magnifying lens).
8. Move the telescope back through the centre and then to the first bright image on the left.
9. Take the reading θ_l from the scale.
10. Calculate θ using $\theta = \dfrac{\theta_r - \theta_l}{2}$.

11. Calculate the distance d between the slits using $d = \frac{1}{N}$ where N is the number of lines per metre on the grating.
12. Calculate the wavelength λ using $n\lambda = d \sin\theta$.
13. Repeat this for different orders (n) and get an average value for the wavelength.

Results

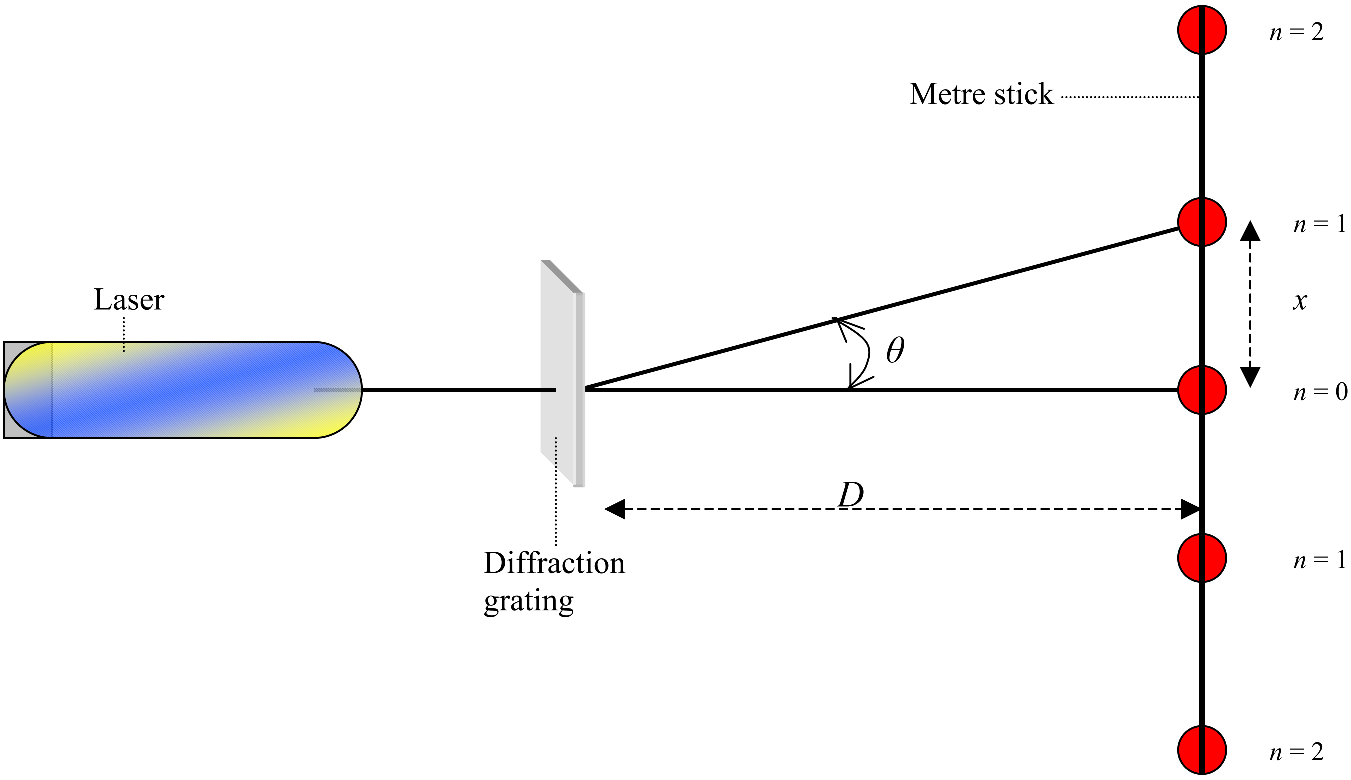
n	θ_r/ °	θ_l/ °	$\theta = \frac{\theta_r - \theta_l}{2}$ / °	λ/m

Average λ =

MEASUREMENT OF THE WAVELENGTH OF MONOCHROMATIC LIGHT (using the laser)

Apparatus

Laser, diffraction grating (600 lines per mm), 2 metre sticks.



Procedure

1. Clamp a metre stick horizontally in a stand.
2. Allow the laser beam to hit the metre stick normally (at 90 °).
3. Move the metre stick sideways until the spot is on the 50 cm mark.
4. Place the grating between the laser and the metre stick, at right angles to the beam.
5. Observe the interference pattern on the metre stick – a series of bright spots.
6. Calculate the mean distance x between the centre (n=1) bright spot and the first (n =1) bright spot on both sides of centre.
7. Measure the distance D from the grating to the metre stick.
8. Calculate θ using $\tan\theta = \frac{x}{D}$.
9. Calculate the distance d between the slits, using $d = \frac{1}{N}$, where N is the number of lines per metre on the grating.
10. Calculate the wavelength λ using $n\lambda = d\sin\theta$.
11. Repeat this procedure for different values of n and get the average value for λ.

Results

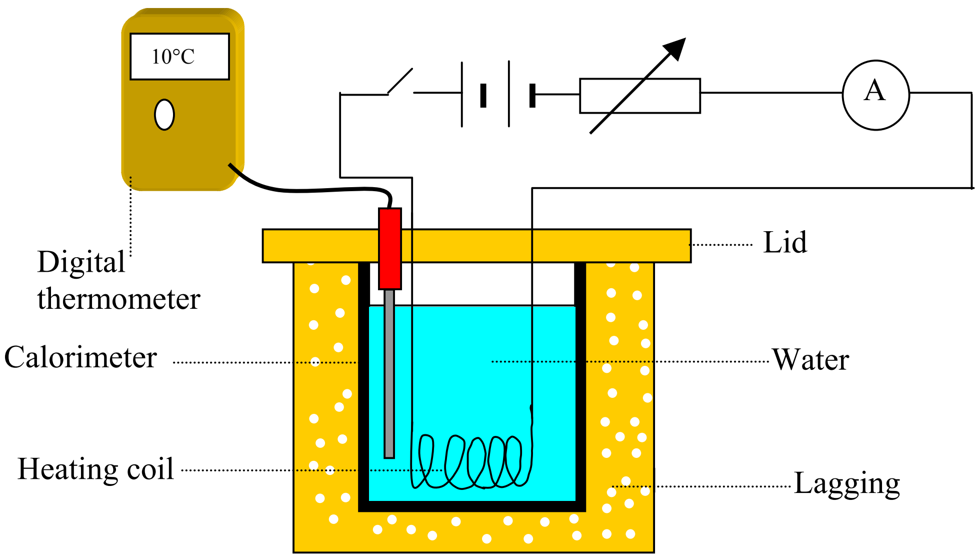
n	x/m	D/m	θ/ °	λ/m

Average λ =

VERIFICATION OF JOULE'S LAW (As $\Delta\theta \propto I^2$)

Apparatus

Lagged beaker or calorimeter with a lid, heating coil, battery or low voltage power supply, rheostat, ammeter or multimeter, thermometer, stopwatch, balance.



Procedure

1. Put sufficient water in a calorimeter to cover the heating coil. Set up the circuit as shown.
2. Note the temperature.
3. Switch on the power and simultaneously start the stopwatch. Allow a current of 0.5 A to flow for five minutes. Make sure the current stays constant throughout; adjust the rheostat if necessary.
4. Note the current, using the ammeter.
5. Note the time for which the current flowed.
6. Stir and note the highest temperature. Calculate the change in temperature $\Delta\theta$.
7. Repeat the above procedure for increasing values of current I, taking care not to exceed the current rating marked on the rheostat or the power supply. Take at least six readings.
8. Plot a graph of $\Delta\theta$ (Y-axis) against I^2 (X-axis).

Results

θ_1/°C	θ_2/°C	$\Delta\theta$ /°C	I/A	I^2/A^2

A straight-line graph through the origin verifies that $\Delta\theta \,\alpha\, I^2$ i.e. Joule's law.

Notes

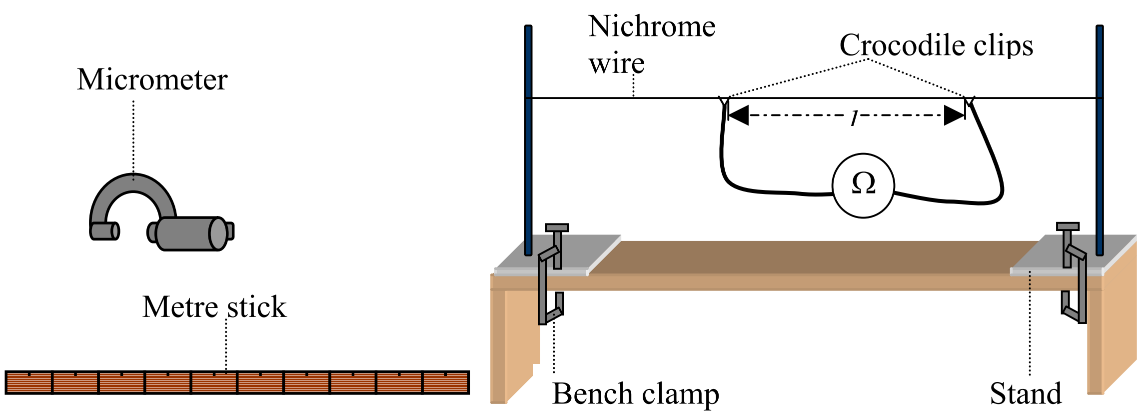
Ensure that the rheostat current limit exceeds 3 A.

The heat energy produced is the mass multiplied by specific heat capacity multiplied by rise in temperature: $H = mc\Delta\theta$.
The energy liberated per second in the device is defined as the electrical power. This energy is $P = RI^2$.
Therefore $RI^2 = mc\Delta\theta /t$
or $I^2 = (mc/Rt) \Delta\theta$.
As the mass, specific heat capacity, resistance and time are constant, $\Delta\theta \,\alpha\, I^2$.
Hence $P \,\alpha\, I^2$

TO MEASURE THE RESISTIVITY OF THE MATERIAL OF A WIRE

Apparatus

Length of wire (nichrome, manganin), micrometer, ohmmeter, metre stick.



Procedure

1. Note the resistance of the leads when the crocodile clips are connected together.
2. Tie a length (2 or 3 metres) of nichrome/manganin between the bars of the two stands as shown above. Stretch the wire enough to remove any kinks or 'slack' in the wire.
3. Connect the crocodile clips to the wire some distance l apart. Read the resistance of the leads plus the resistance of wire between the crocodile clips from the ohmmeter. Subtract the resistance of the leads to get the resistance R of the wire.
4. Measure the length l of the wire between the crocodile clips, with the metre stick or tape.
5. Increase the distance between the crocodile clips. Measure the new values of R and l.
6. Make a note of the zero error on the micrometer. Use the micrometer to find the diameter of the wire at different points, taking the zero error into account. Find the average value of the diameter d.
7. Calculate the resistivity $\rho = \left(\frac{R}{l}\right)A$, where $A = \frac{\pi d^2}{4}$.
8. Repeat this procedure for a number of different lengths.
9. Calculate the average value for ρ.

Results

Micrometer Reading/mm

Resistance of leads =
Micrometer zero error =
Average of micrometer readings =
Diameter of wire =

R/Ω	l/m	$\frac{R}{l}/\Omega\ m^{-1}$	$\rho/\Omega\ m$

Average value of $\rho =$

Notes

Safety glasses should be worn as the wire could snap when stretched.

Use a micrometer with a slip-screw.

If clamps are unavailable, two students may hold the stands to keep the wire stretched enough to avoid kinks.

Alternatively stretch the wire between two nails, which are positioned one to two metres apart on a piece of wood.

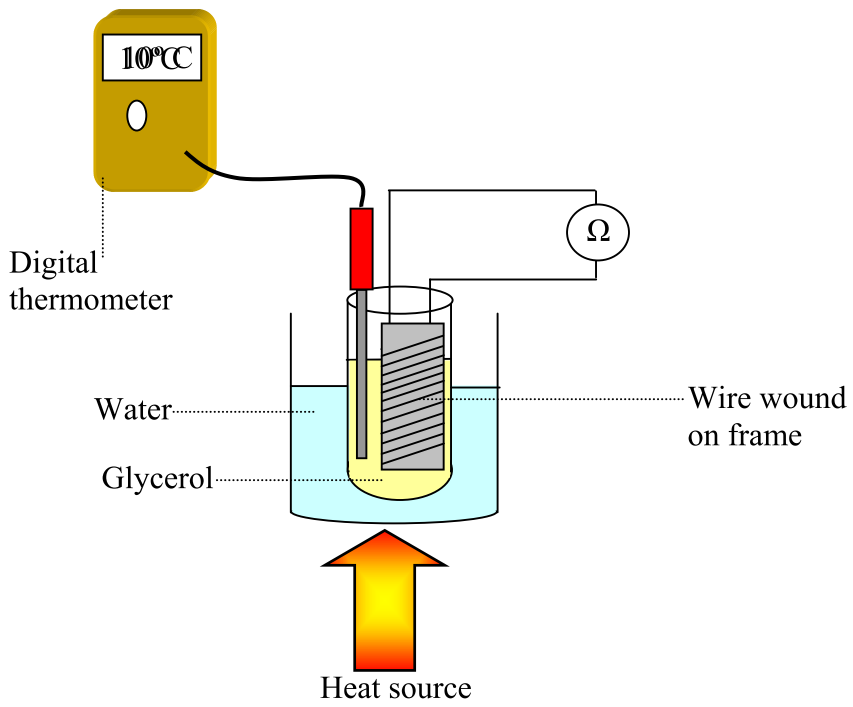
The resistivity of nichrome is $100 \times 10^{-8}\ \Omega\ m$ (at 20 °C).

The resistivity of manganin is $48 \times 10^{-8}\ \Omega\ m$ (at 20 °C).
Theseresistivity values give depends on composition

TO INVESTIGATE THE VARIATION OF THE RESISTANCE OF A METALLIC CONDUCTOR WITH TEMPERATURE

Apparatus

Coil of wire (see note), glycerol, beaker, heat source, thermometer, ohmmeter, boiling tube.



Procedure

1. Place the coil of wire in the boiling tube with the glycerol and place it in a beaker of water.
2. Arrange the beaker over the heat source.
3. Connect the ohmmeter to the coil of wire.
4. Use the thermometer to note the temperature of the glycerol, which is also the temperature of the coil.
5. Record the resistance of the coil of wire using the ohmmeter.
6. Heat the beaker.
7. For each 10 °C rise in temperature record the resistance and temperature using the ohmmeter and the thermometer.
8. Plot a graph of resistance against temperature.

Results

R /Ω									
θ /°C									

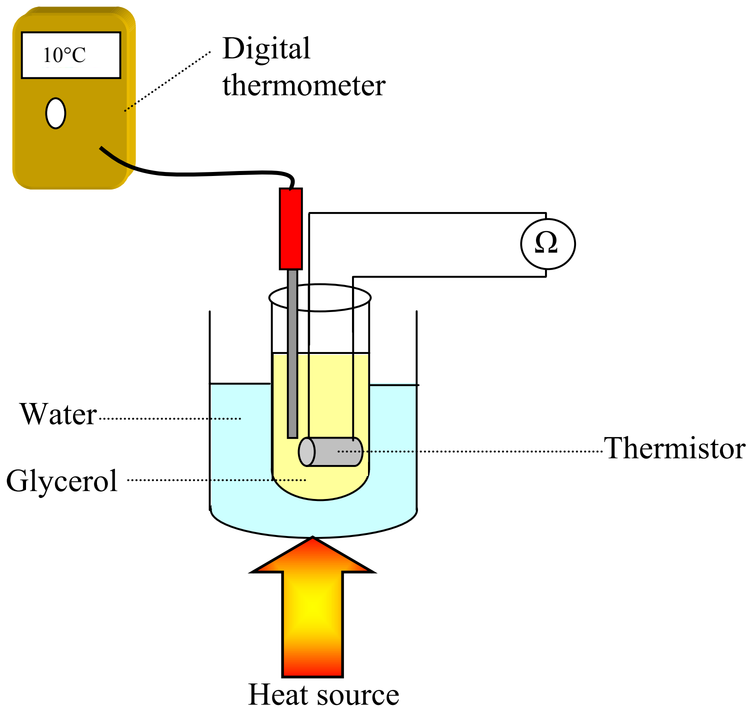
Notes

The coil is commercially available. It is called the temperature co-efficient of resistance apparatus with temperature apparatus.

TO INVESTIGATE THE VARIATION OF THE RESISTANCE OF A THERMISTOR WITH TEMPERATURE

Apparatus

Thermistor, boiling tube containing glycerol or liquid paraffin, beaker, heat source, thermometer, ohmmeter.



Procedure

1. Set up the apparatus as shown.
2. Connect the ohmmeter to the thermistor.
3. Use the thermometer to note the temperature of the glycerol and thermistor.
4. Record the resistance of the thermistor using the ohmmeter.
5. Heat the beaker.
6. For each 10 °C rise in temperature, record the resistance and the temperature using the ohmmeter and the thermometer.
7. Plot a graph of resistance against temperature and join the points in a smooth, continuous curve.

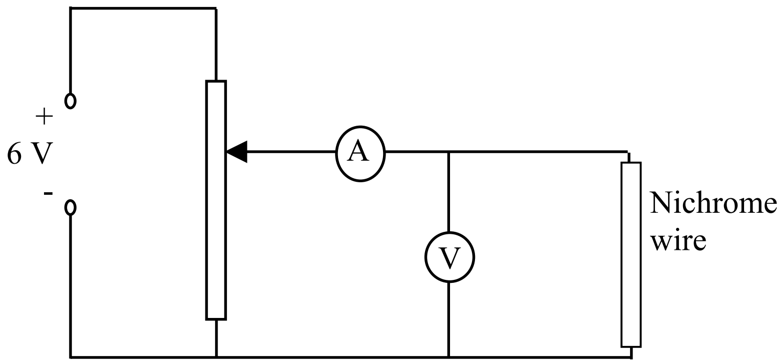
Results

R / Ω										
θ /°C										

TO INVESTIGATE THE VARIATION OF CURRENT (*I*) WITH P.D. (*V*) FOR (a) A METALLIC CONDUCTOR

Apparatus

Low voltage power supply, rheostat, voltmeter, ammeter, length of nichrome wire.



Procedure

1. Set up the circuit as shown and set the voltage supply at 6 V d.c.
2. Adjust the potential divider to obtain different values for the voltage *V* and hence for the current *I*.
3. Obtain at least six values for *V* and *I* using the voltmeter and the ammeter.
4. Plot a graph of *I* against *V*.

Results

V/V	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
I/A									

Conclusion

A straight line through the origin $\Rightarrow I \propto V$.

Notes

A varying voltage can be obtained from a fixed supply voltage by using a potential divider. It consists of a variable resistor or fixed resistors in series. Move the slider to change the output voltage. This results in the output voltage from the potential divider being a fraction of the input voltage.

The value of *R* may be determined from the reciprocal of the slope of the graph.

1 m of 26 s.w.g. nichrome wire, wound on a plastic comb, may be used in this experiment. This has a resistance of approximately 7.0 Ω.

TO INVESTIGATE THE VARIATION OF CURRENT (*I*) WITH P.D. (*V*) FOR (b) A FILAMENT BULB

Apparatus

Replace the length of nichrome wire in the circuit with a 6 V, 0.06 A filament bulb and replace the ammeter with a milliammeter.

Procedure

1. Adjust the potential divider to obtain different values for the voltage *V* and hence for the current *I*.
2. Obtain at least ten values for *V* and *I* using the voltmeter and the milliammeter.
3. Plot a graph of *I* against *V* and join the points in a smooth, continuous curve.

Results

V/V	0.2	0.5	0.8	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
I/mA											

Notes

The resistance of the filament increases with temperature.

The shape of the curve shows that Ohm's law is not obeyed as the temperature of the filament changed with changing current.

If a multimeter is used as the ammeter, change the lead from the 10 A socket to the mA socket and select the appropriate current scale.

TO INVESTIGATE THE VARIATION OF CURRENT (*I*) WITH P.D. (*V*) FOR (c) COPPER SULFATE SOLUTION WITH COPPER ELECTRODES

Apparatus

Replace the filament bulb in the circuit with copper electrodes in copper sulfate solution.

Procedure

1. Adjust the potential divider to obtain different values for the voltage V and hence for the current I.
2. Obtain at least six values for V and I using the voltmeter and the milliammeter.
3. Plot a graph of I against V.

Results

V/V	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
I/mA										

Conclusion

A straight line through the origin $\Rightarrow I \propto V$.

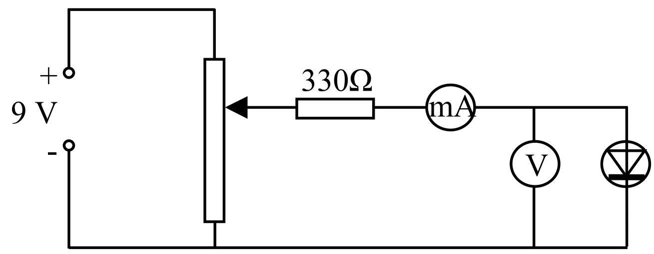
Notes

The copper sulfate solution may be made by adding 15 g of copper sulfate to 100 cm^3 of warm water. Adding 2 cm^3 of concentrated sulphuric acid ensures that the solution stays clear and this will enable it to be reused a number of times.

TO INVESTIGATE THE VARIATION OF CURRENT (*I*) WITH P.D. (*V*) FOR (d) SEMICONDUCTOR DIODE

Apparatus

Low voltage power supply, rheostat, voltmeter, milliammeter, 330 Ω resistor, silicon diode, e.g. 1N4001.



Procedure- Forward Bias

1. Set up the circuit with the semiconductor diode in forward bias as shown and set the voltage supply to 9 V.
2. Adjust the potential divider to obtain different values for the voltage *V* and hence for the current *I*.
3. Obtain at least ten values for *V* and for *I* using the voltmeter and the milliammeter.
4. Plot a graph of *I* against *V* and join the points in a smooth, continuous curve.

Results – Forward Bias

V/V	0.1	0.2	0.4	0.45	0.5	0.55	0.6	0.62	0.64	0.66	0.68	0.70
I/mA												

Notes

A protective resistor, e.g. 330 Ω, should always be used in series with a diode in forward bias.

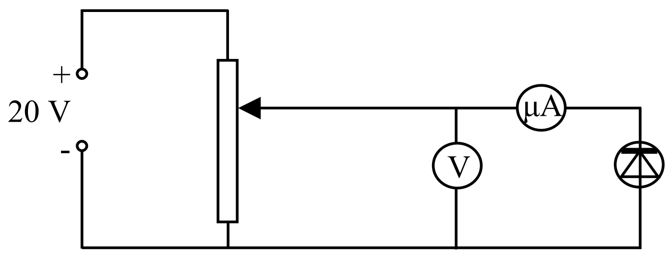
Almost no current flows until the applied voltage exceeds 0.6 V for a silicon diode but then the current rises rapidly.

A germanium diode, e.g. OA91, gives very little current between 0 and 0.2 V but the current then increases above this voltage.

A light emitting diode gives very little current up to 1.6 V but then the current rises rapidly accompanied by the emission of light.

Apparatus

Low voltage power supply, rheostat, voltmeter, microammeter, silicon diode, e.g. 1N4001.



Procedure – Reverse Bias

1. Set up the circuit as above and set the voltage supply at 20 V.
2. The microammeter is used in this part of the experiment, as current values will be very low when a diode is in reverse bias.
3. Adjust the potential divider to obtain different values for the voltage V and hence for the current I.
4. Obtain at least six values for V (0-20 V) and for I using the voltmeter and the microammeter. Higher voltage values are required for conduction in reverse bias.
5. Plot a graph of I against V and join the points in a smooth, continuous curve.

Results – Reverse Bias

V/V	0	2	4	6	8	10	12	14	16
I/μA									

Notes

The position of the voltmeter has changed since a reverse biased diode has a very large resistance that is greater than the resistance of most voltmeters. It is essential that the microammeter reads only the current flowing through the reverse biased diode as the sum of the currents flowing through the voltmeter and reverse biased diode may be much larger.
Since the resistance of the microammeter is negligible compared with the resistance of the reverse biased diode the potential difference across the microammeter and diode is almost the same as the potential difference across the diode alone.

When using a silicon diode it is very difficult to detect the current in reverse bias as the current is so small and changes very little with temperature variations.

For a germanium diode some reverse current can be detected (a few μA) at 4 V reverse bias. This conduction increases rapidly when the diode is heated (by hand).

For information on connecting diodes see the ‘Teacher’s Handbook’: Current Electricity p.45.

APPENDIX

TO ESTIMATE THE SPECIFIC HEAT CAPACITY OF WATER

Apparatus

Timer and plastic electric jug kettle (with power rating marked on it).

Procedure

1. Read the power rating (wattage) P of the kettle.
2. Fill the kettle with cold water to the one litre mark.
3. Take the temperature of the water θ_1 .
4. Switch on the kettle for 50 s.
5. Read the temperature θ_2 .

Calculations

Mass of water $m_w = 1$ kg
Rise in temperature of water $\Delta\theta = \theta_2 - \theta_1 =$
The electrical energy produced by the kettle $Pt =$
If it is assumed that all the electrical energy went into heating the water, then

$$Pt = m_w c\Delta\theta$$

$$\Rightarrow c = \frac{Pt}{m_w \Delta\theta} = \text{Specific heat capacity of water.}$$

This gives a reasonable value for c.

Notes

One litre of water has a mass of one kilogram.

TO ESTIMATE THE SPECIFIC LATENT HEAT OF VAPORISATION OF WATER

Apparatus

Plastic electric jug kettle with power rating marked on it, electronic balance and timer.

Procedure

1. Read the power rating (wattage) P of the kettle.
2. Half fill the kettle with water and place it on the electronic balance.
3. Switch on the kettle, leaving the lid off. This prevents it from switching off when it starts to boil.
4. Allow the kettle to boil.
5. When steam is coming freely from it take the reading m_1 on the balance and start the timer.
6. Allow the kettle to boil until the mass has decreased by about 50 g.
7. Read the mass m_2.
8. Stop the timer and note the time t taken.

Calculations

Mass of water converted into steam $m = m_1 - m_2 =$
Energy required to do this is ml_v, where l_v is the specific latent heat of vaporisation of water.
Electrical energy used to produce the steam equals Pt.
If it is assumed that all electrical energy went into producing steam

$$ml_v = Pt \qquad \Rightarrow l_v = \frac{Pt}{m}$$

This gives a value for l_v of the correct order of magnitude and helps to make the concept of specific latent heat of vaporisation more realistic.

Notes

This experiment is best done as a teacher demonstration.

Use a balance with a wide base so that the kettle will not overturn.

MEASUREMENT OF THE FOCAL LENGTH OF A CONCAVE MIRROR (APPROXIMATE METHOD)

For a concave mirror $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.

If u is very much greater than the focal length, then $\frac{1}{u} \approx 0 \;\Rightarrow \frac{1}{f} = \frac{1}{v} \;\Rightarrow f = v$.

Procedure

Using the concave mirror, focus a distant object, e.g. a tree, on a sheet of paper. The distance from the mirror to the paper is approximately equal to the focal length of the mirror.

This method is useful as it gives the student some idea of the answer to expect when the experiment is done using a more accurate method.

MEASUREMENT OF THE FOCAL LENGTH OF A CONVERGING LENS (APPROXIMATE METHOD)

For a converging lens $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$.

If u is very much greater than the focal length, $\frac{1}{u} \approx 0 \;\Rightarrow\; \frac{1}{f} = \frac{1}{v} \;\Rightarrow\; f = v$.

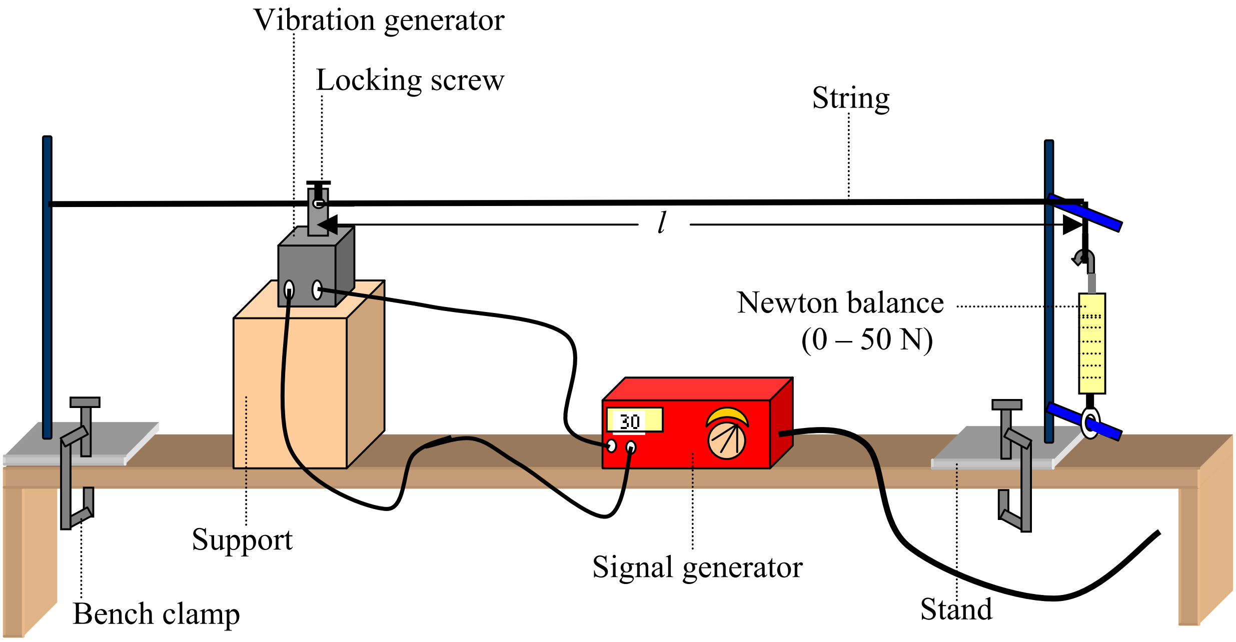
Procedure

Focus a distant object, e.g. a tree, on a screen. The distance from the lens to the screen is approximately the focal length of the lens.

This method is useful as it gives the student some idea of the answer to expect when the experiment is done using a more accurate method.

DEMONSTRATION OF STANDING WAVES

Apparatus

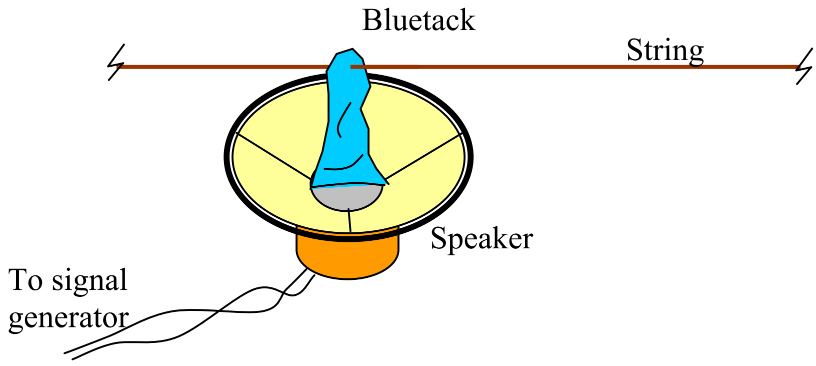


Procedure

1. Clamp two stands, positioned about 3 m apart, to a bench.
2. Place the vibration generator on a laboratory jack or other suitable support, to allow the string plenty of room to vibrate up-and-down.
3. Tie the string securely to the hook of a firmly anchored 50 N balance and drape it over the side arm attached to the RHS vertical bar.
4. Thread the string through the eye of the vibrator bar – do not tighten the locking screw yet.
5. Tension the string to 10 N by tying it securely to the LHS vertical bar.
6. Slide the vibration generator as far as practicable to the left and tighten the locking screw.
7. Connect the vibration generator to the low resistance output (4 Ω) of the signal generator.
8. Turn on the signal generator and select a frequency of 4 or 5 Hz.
9. Adjust the output control on the signal generator until the oscillations are visible.
10. Slowly increase the frequency until the string vibrates at its fundamental mode.
11. Increase the frequency until the first harmonic is visible.
12. Continue to increase the frequency to see a series of successive harmonics.

Notes

Clamp a loudspeaker (4 Ω or 8 Ω) with its diaphragm facing upwards. Build a column of bluetack taped to the diaphragm as shown.



Raise the loudspeaker and bluetack towards the string so that the string is surrounded and gripped by the bluetack. Connect the signal generator to the loudspeaker. Increase the frequency and observe the standing waves.

Observe longitudinal standing waves in a vertical spring supported from a ceiling hook and with its lower end attached to the vibration generator: note the compression maxima as the applied frequency is increased.

The experiments to investigate the variation of the fundamental frequency of a stretched string with length and tension could be performed using this apparatus.

THE ROTA OPTION

A POSSIBLE APPROACH TO EXPERIMENTAL WORK

The problem of how best to organise experimental work in physics is ever present. This arises mainly, but not exclusively, because of constraints imposed by the lack of availability of apparatus in many schools. The rota option addresses this problem in a creative way, with the added advantages of excellent educational and organisational outcomes.

A major difficulty against a rota system is a perceived problem in selecting a set of six/seven suitable listed experiments (the rota need not, of course, only consist of listed experiments) at the beginning of senior cycle physics. Many teachers feel that it is necessary to fully cover the background theory before any experimental work is undertaken. Certainly, some background theory is necessary, but a judicious selection of experiments can keep this to a minimum.

If we apply 'some contact and understanding at Junior Certificate level' as a selection criterion, the following initial list might be acceptable, with very little additional background required:

- Measurement of velocity and acceleration
- Verification of Boyle's Law
- To investigate the relationship between period and length of a simple pendulum.
- Calibration curve of a thermometer using the laboratory mercury thermometer as a standard
- Measurement of the speed of sound in air
- Measurement of the focal length of a concave mirror
- Verification of Snell's law of refraction
- To investigate the variation of resistance of a thermistor with temperature

A clear set of instructions for each experiment is essential.

Ideally the specific equipment required for each experiment should be in its own container. Initially it will be necessary to use some class time to select groups, draw up a rota calendar and explain the contents of each container. A wheel-in trolley makes an ideal storage and retrieval system.

It is much better from the point of view of student understanding to make contact with a concept in physics as often as possible. Each group of students becomes responsible for a specific experiment – the one that they carried out in week one of the rota. Each week they check the apparatus for that experiment and sort out any difficulties that a group may be having with it. This frees the teacher to deal with bigger issues and gives much more time for her/him to move among the groups during experimental work. This allows the teacher to get to know the students as individuals and to recognise the strengths and weaknesses in their developing knowledge of physics. From the calendar each group knows their upcoming experiment and is obliged (as homework) to familiarise themselves with it in the preceding days using the instruction sheet. Once the initial effort is made to get all of the experiments running in this fashion, things are effectively organised for long periods of time. Essentially the students run the practical class.