PHYSICS EXPERIMENTS

(MECHANICS)

'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

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)'

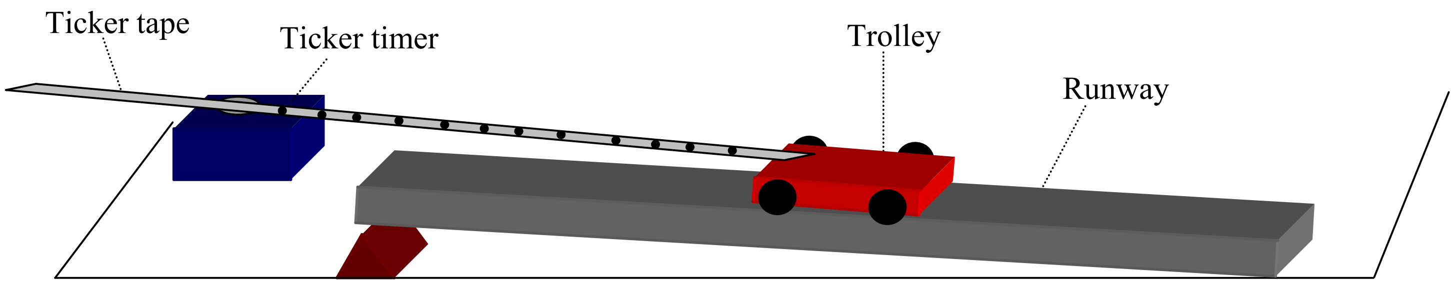
   When these books were published they were distributed to all schools. They have been revised and are available on the 'physical sciences initiative' web site at www.psi-net.org in the 'safety docs' link of the physics section.

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

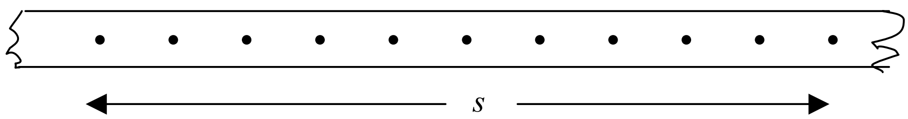
Apparatus

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.

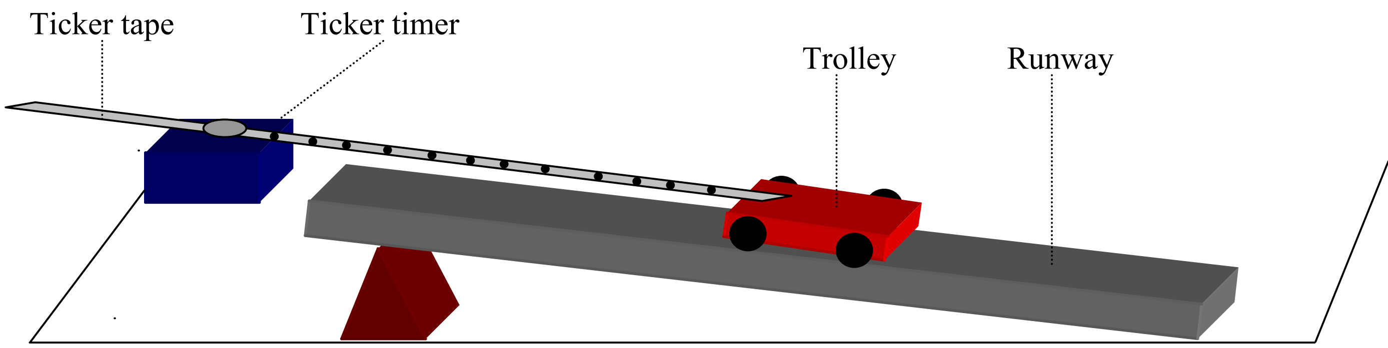
Ensure that the voltage rating of the timer is not exceeded.

Some timers make one hundred dots in one second.

MEASUREMENT OF ACCELERATION

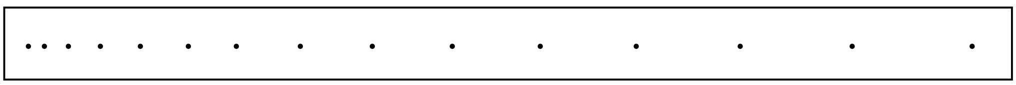
Apparatus

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.

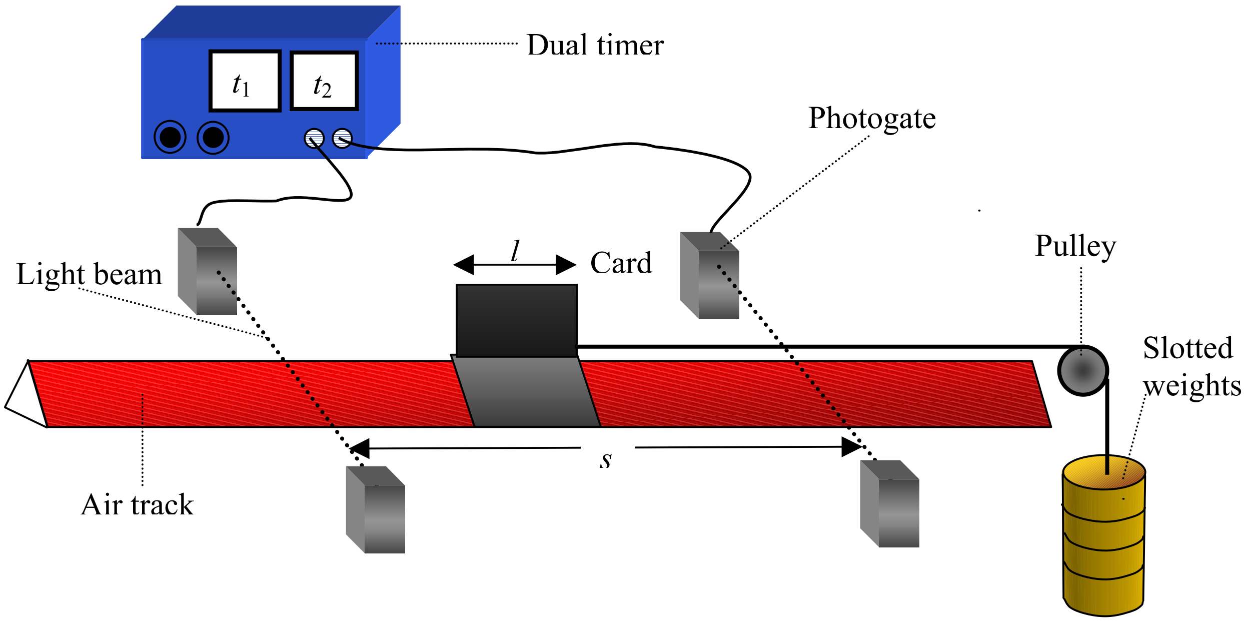
Ensure that the voltage rating of the timer is not exceeded.

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.

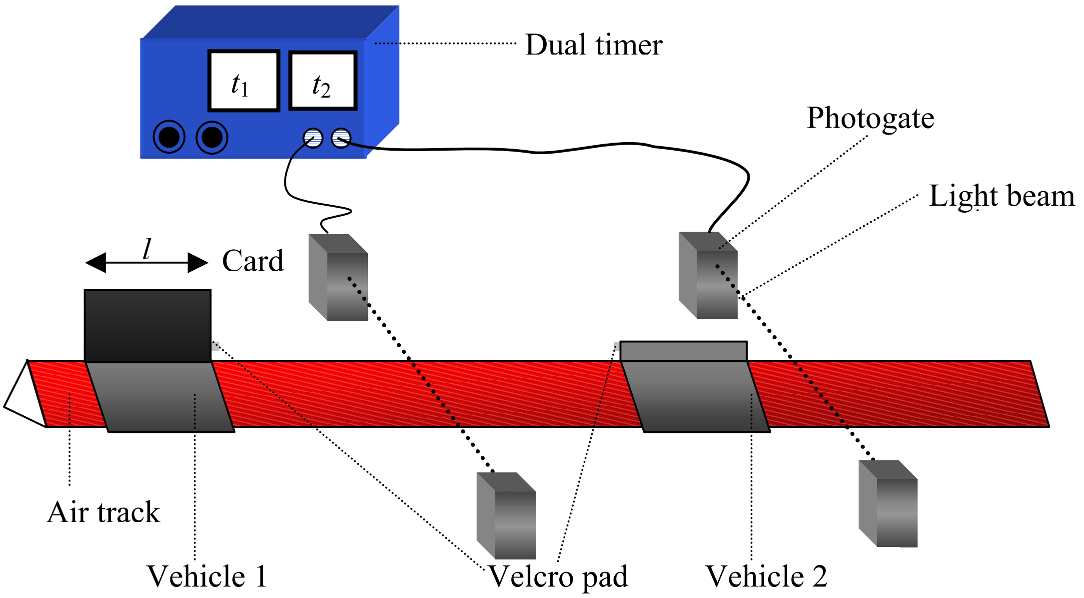
Occasionally check the air holes on the linear air-track with a pin, to clear any blockages due to grit or dust.

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.

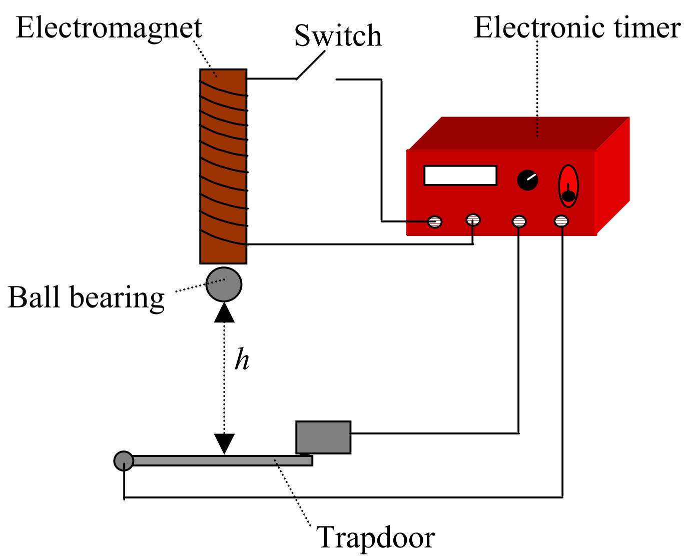
Occasionally check the air holes on the linear air-track with a pin, to clear any blockages due to grit or dust.

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

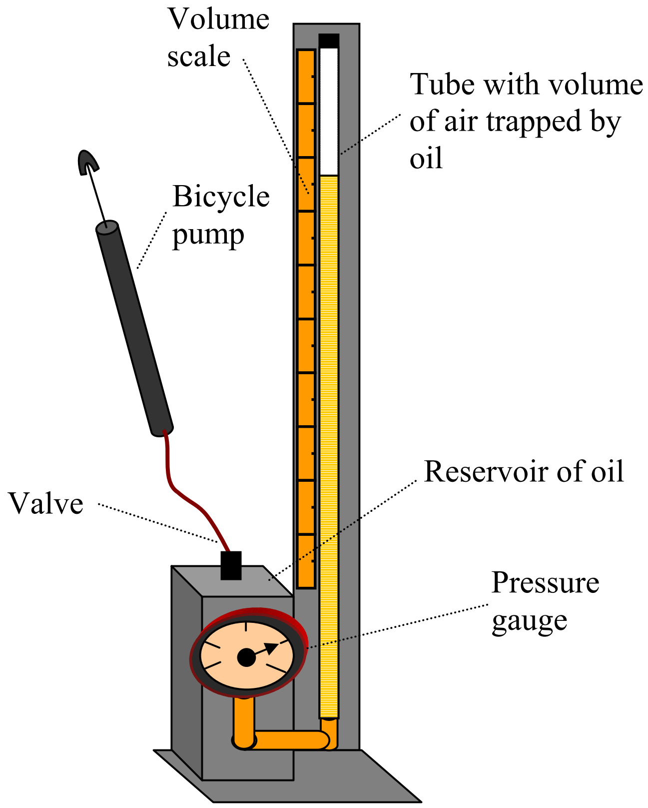
Place a piece of paper between the ball bearing and the electromagnet to ensure a quick release.

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.

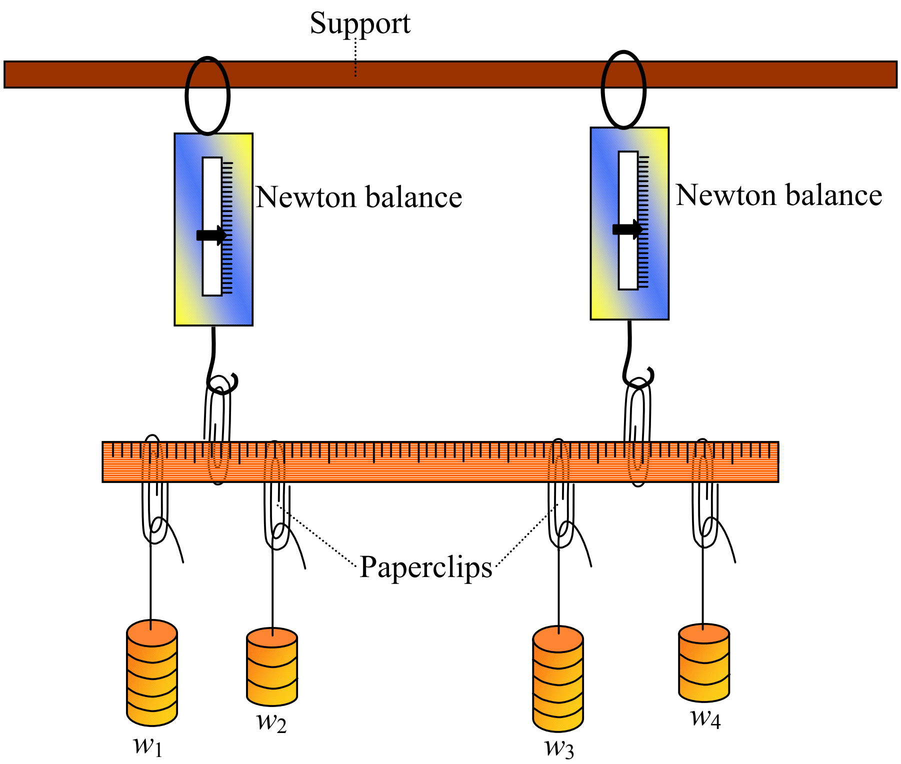
Note

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.

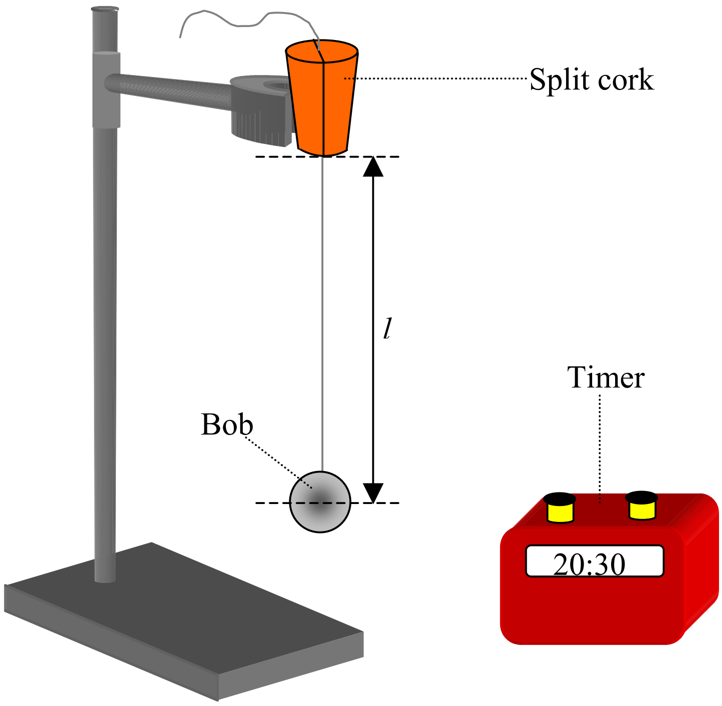
Fixing the paper clips in position with cellotape or bluetack may be an easier alternative approach. The paperclips may then be treated as part of the metre stick. In this case, find the centre of gravity and weight of metre stick and paperclips using one of the balances.

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.

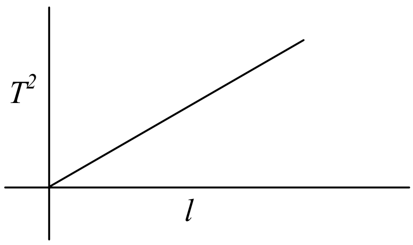


Procedure

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			



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

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

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