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LESS STRESS MORE SUCCESS

1 Mechanics Experiments

Exam paper question 1

aims

To learn:

- How to describe the mandatory mechanics experiments in points
- How to gain maximum marks from the short **FAQs** that appear towards the end of many mechanics questions in Section A
- How to decide what to **graph** against what

exam focus

- There are no extra marks for heavy, overwritten descriptions of an experiment.
- There is no need to list the equipment. This will be clear from the labelled diagram.
- Pay attention to the FAQs, as many marks are lost here.

key point

Be aware of the importance of percentage error. If you are measuring something 10 cm long and you make an error of 1 cm, the percentage error is 10%, but if you are measuring something 100 cm long the percentage error would be only 1%.

key point

If a question involves a formula, ignore the constants and you will see what to graph. For example, the following experiment involves the formula

$g = \dfrac{4\pi^2 l}{T^2}$, so eliminate $4\pi^2$ and graph l (Y axis) against T^2 (X axis).

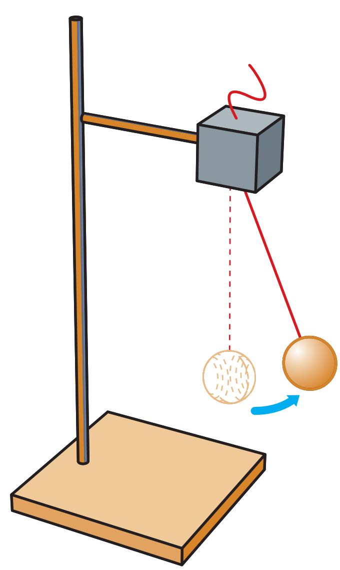
HL

Mandatory experiment

Aim: To investigate the relationship between period and length for a simple pendulum (and hence to calculate *g*)

Method:

1. Attach the pendulum bob to one end of a light thread and clamp the other end of the thread between two pieces of cork.
2. Set the pendulum swinging through a small angle and take the time for 50 oscillations.



3. Find the periodic time T for one oscillation.
4. Carefully measure l, the distance from the cork to the centre of the pendulum bob.
5. Repeat for different values of l.
6. Plot a graph of l against T^2. A straight line through the origin implies that $l \propto T^2$.

   The slope of this graph gives the value of $\frac{l}{T^2}$.
7. g can now be calculated from the formula $g = \frac{4\pi^2 l}{T^2}$

FAQs

Why is a light thread used?
So that practically all the mass is concentrated in the bob.

Why must the angle be kept small?
The pendulum formula is only valid for small angles.

Why is the time for one oscillation not measured directly?
It might be too small to register on the timer and there could be a large percentage error.

Why could the number of oscillations be reduced if the length of the pendulum were increased?
Because the time for each oscillation would be increased so the overall time would be about the same.

How would you ensure that the length of the pendulum remained constant?
Use inextensible string.

Mandatory experiment

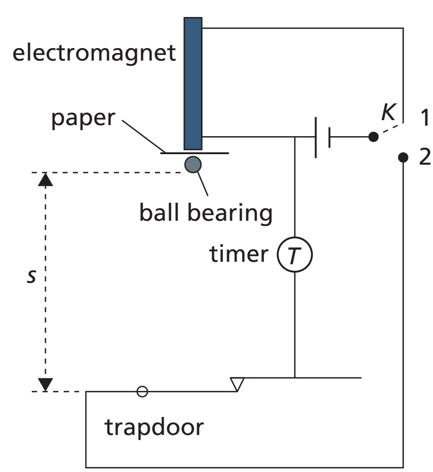
Aim: To measure g by free fall

Method:

1. With the switch K in position 1, the ball bearing is attached to the electromagnet with a small piece of paper between them.
2. When the switch is thrown to position 2, the ball bearing is released and the timer T starts.
3. When the ball bearing hits the trapdoor, the timer stops. The time for the free fall is now known.
4. Repeat a number of times and take the **minimum** time, t.
5. Measure s carefully. $s = ut + \frac{1}{2}at^2$.

   In this case $u = 0$ so that $s = \frac{1}{2}gt^2 \Rightarrow g = \frac{2s}{t^2}$.

   'g' can now be calculated.



Note: s should be at least 1 m.

FAQs

In an experiment to measure g *by free fall, give two precautions that should be taken to ensure a more accurate result.*

Measure from the bottom of the ball bearing. Use large values of *s* (smaller percentage error). Set the trapdoor as sensitively as possible. Take the shortest time, not the average time.

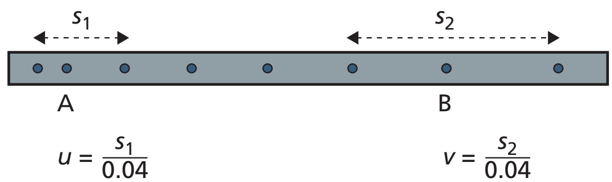
What is the piece of paper for?

To make sure that the ball bearing does not become magnetised.

Give two ways of minimising the effect of air resistance in the experiment.

Make sure the object is small, spherical, dense, smooth and that there are no draughts.

Using a tickertape timer



A tickertape timer puts a dot on a tape every 0.02 of a second. If the tape is moving with uniform velocity, the dots are equally spaced. However, if the tape is accelerating, the distance between the dots is increasing. In this case the acceleration can be calculated as follows.

1. Measure s_1, the distance over two spaces at the start of the tape. (Taking two spaces also reduces percentage error.) Now calculate u as above.
2. Measure s_2, the distance over two spaces towards the end of the tape.
3. Calculate v as above.

   The time t is the time taken to go from A to B.

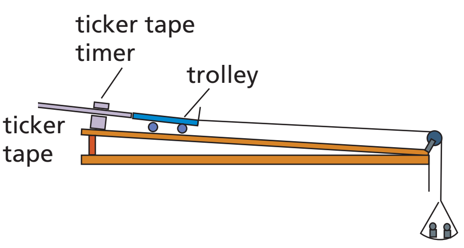
   $$a = \frac{(v - u)}{t}$$

Mandatory experiment

Aim: To show that acceleration is proportional to force

Method:

1. Set up the apparatus as shown in the diagram.
2. Raise one end of the plank until, with a slight push, the trolley moves with constant speed.
3. Place a weight in the pan and let the trolley accelerate down the slope. Note the force *F* and calculate the acceleration from the ticker tape.



4. Remove one disc from the pan and place it on the trolley.
5. The experiment is repeated a number of times, varying the accelerating force F in each case by varying the mass in the scale pan.

A graph of $\boldsymbol{F}$ against $\mathbf{a}$ gives a straight line through the origin showing that $\mathbf{a} \propto \boldsymbol{F}$.

FAQ

When you remove a disc from the scale pan, why place it on the trolley?

So that the total mass moving, scale pan plus trolley, remains constant. **You cannot proceed with more than two variables.**

key point

You cannot proceed with more than two variables. This is a **general rule**.

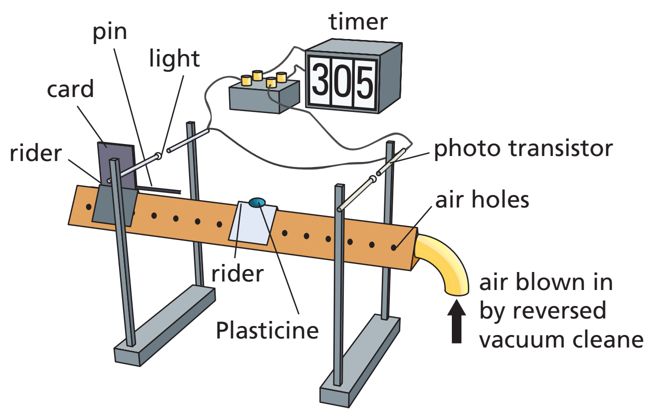
If you want to show that $a \propto F$, then mass must remain constant.

Mandatory experiment

Aim: To verify the principle of conservation of momentum

Method:

1. Level the air track.
2. Find the mass of each complete rider.
3. Set up the apparatus as shown in the diagram.
4. Give the first rider a slight push to set it in motion. As it passes the first light gate, the beam of light is interrupted and the transit time measured.



5. On impact the pin penetrates the Plasticine and the two riders move along together. The new transit time is recorded as the card interrupts the beam of light at the second light gate.
6. You should find that:
   mass of the first rider × velocity before impact
   = combined mass of riders × velocity after impact.

The air track with a single rider can be used to measure velocity.

FAQ

In an experiment to verify the principle of conservation of momentum, how was the effect of friction minimised?

By using an air cushion between the surfaces of the track and the rider.

Mandatory experiment

Aim: To measure the velocity of a body

Method:

1. Give the rider a slight push in order to set it moving.
2. The transit time for the card gives the time it takes the rider to travel 0.1 m.
3. $\frac{\text{Distance}}{\text{Time}}$ gives the velocity.

Mandatory experiment

Aim: To measure the acceleration of a body

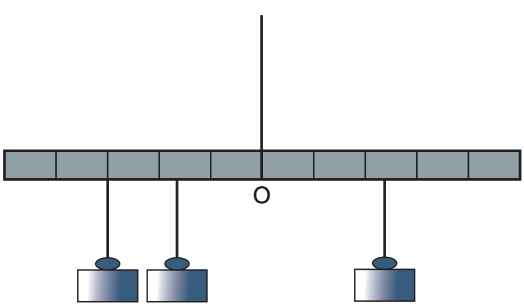
Method:

1. Place the photo transistors 1 m apart for convenience.
2. Give the first rider a push in order to set it moving.
3. Note the transit time as it passes through the first light gate. This is the time it takes to travel 0.1 m.

   $\frac{\text{Distance}}{\text{Time}}$ gives the initial velocity u.
4. Repeat for the second light gate to get the final velocity v.
5. The distance s is 1 m.
6. Calculate the acceleration from the formula $v^2 = u^2 + 2as$.

Mandatory experiment

Aim: To investigate the laws of equilibrium for a set of coplanar forces



Method:

1. Find the mass of a metre stick and hang it from a stand.
2. Adjust the thread until the metre stick is balanced horizontally. The thread is now at the centre of gravity of the metre stick.
3. Hang a number of masses on the metre stick and adjust their positions until the metre stick balances.
4. Calculate the moments about O.

Result: The sum of the clockwise moments equals the sum of the anticlockwise moments.

5. Leaving the masses as they are, hang the metre stick from a suitable spring balance.
Result: The reading on the spring balance equals the sum of all the weights, including the weight of the metre stick (remember weight = mass × g).
Conclusion: The two laws of equilibrium have been obeyed.

FAQ

In an experiment to investigate the laws of equilibrium why is it important to have the metre stick horizontal (or, if you use spring balances, to have them vertical)?
So that the distances measured along the metre stick are perpendicular distances.

key point

If you are asked to draw a **suitable** graph, this means that the given table of data must be modified before the graph is drawn. If there is a formula involved, write it down, ignore the constants and you will see what you need to graph and therefore how the data needs to be modified. (See exam question below.)

Exam question

Q: The following results were obtained by a student in an experiment to measure g, the acceleration due to gravity, using a simple pendulum.

Length/*m*	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6
Time for 30 oscillations/*s*	27	37.8	46.5	53.7	60.6	66.0	70.8	76.4

Draw a **suitable** graph and hence determine the value of g.

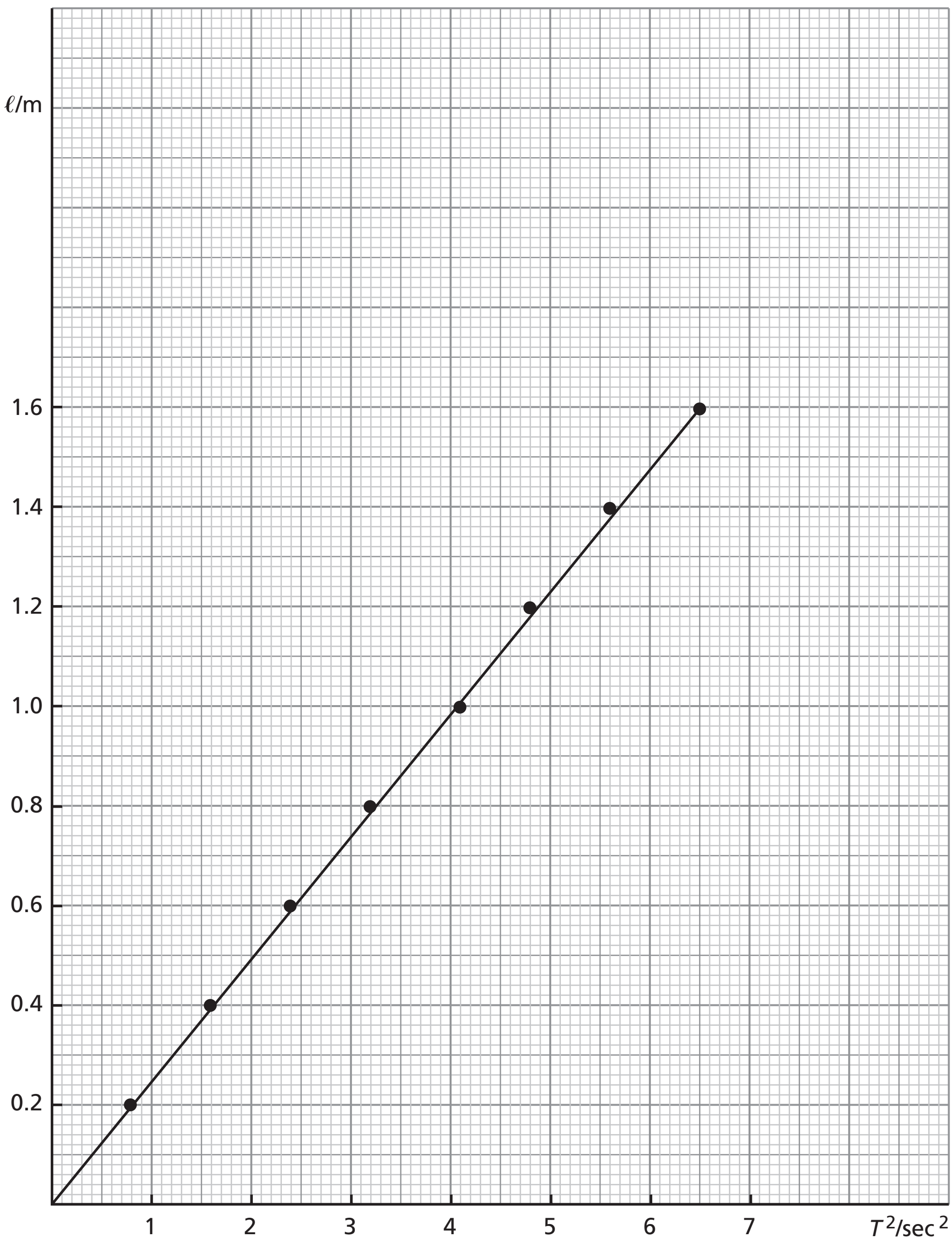
A: This question involves a formula since $g = \frac{4\pi^2 l}{T^2}$. **In a case like this ignore the constants ($4\pi^2$) and you will see what to graph.** You must plot a graph of l against T^2.

To do this you must divide the bottom line of the table by 30 to get the time for **one oscillation** and then square it, resulting in the following table.

l/m	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6
T^2/sec^2	0.8	1.6	2.4	3.2	4.1	4.8	5.6	6.5

Now draw your graph and use the slope to get $\frac{l}{T^2}$.

- The slope is $\frac{1.6}{6.5} = 0.246$.
- Multiplying this by $4\pi^2$ gives $g = 9.72$ cm s^{-2}.



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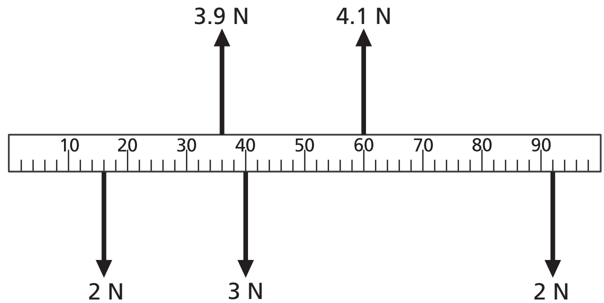
Exam question

2016 Higher level question 1

Q: In an experiment to verify the laws of equilibrium, the centre of gravity and the weight of a metre stick were found. The centre of gravity of the stick was at the 50.2 cm mark and its weight was 1.1 N. A number of forces were then applied to the metre stick, as shown in the diagram. The metre stick was horizontal and stationary.



Explain how:

(i) the centre of gravity was found

A: Suspend the metre stick horizontally from a thread.

Q: (ii) the weight of the metre stick was found

A: By using a newton balance or weighing scales.

Q: (iii) the upward forces and downward forces were determined

A: Upward forces: using newton balances
Downward forces: using known weights.

Q: Give one possible reason why the centre of gravity is not at the 50.0 cm mark.

A: The metre stick was not uniform, e.g. it was worn at one side or had a hole in one side.

Q: Use the data given to calculate:

(i) the net force acting on the metre stick

A: Upward force $= 3.9 + 4.1 = 8.0$
Downward force $= 2 + 3 + 2 + 1.1 = 8.1$
Net vertical force $= 0.1 \approx 0$ N

Q: (ii) the sum of the moments about the 40 cm mark of the metre stick.

A: Moment = force × displacement
Clockwise moments $= (2 \times 0.52) + (1.1 \times 0.102) + (3.9 \times 0.04) = 1.3082$
Anti-clockwise moments $= (2 \times 0.24) + (4.1 \times 0.20) = 1.3$ (N m)
Sum of moments $= 0.0082 \approx 0$ N m
clockwise ≈ anti-clockwise

Q: Explain how your calculations verify the laws of equilibrium.

A: The net vertical force is zero.
The sum of moments about a point is zero.