University of Maagal

PHYSICS LAB

م.م عباس احمد هاشم

2020/2021

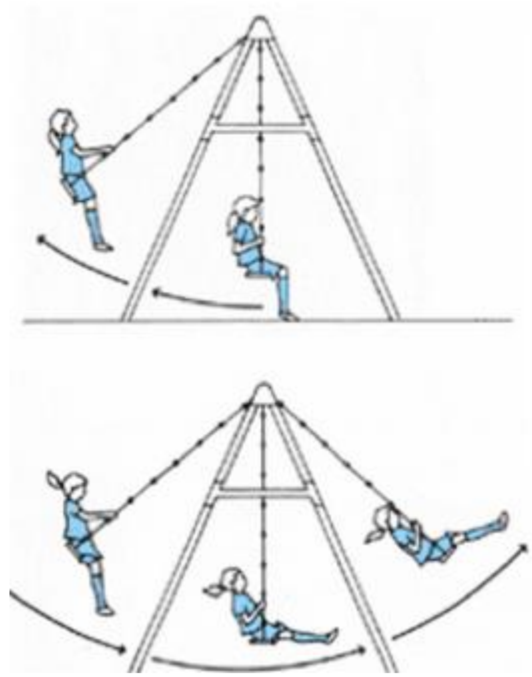
1ST COURSE

Experiments:

1. **SIMPLE PENDULUM.**
2. **COMPOUND PENDULUM.**
3. **HOOK'S LAW.**
4. **RADIUS OF GYRATION.**
5. **BOYLE'S LAW.**

SIMPLE PENDULUM

OBJECTIVE



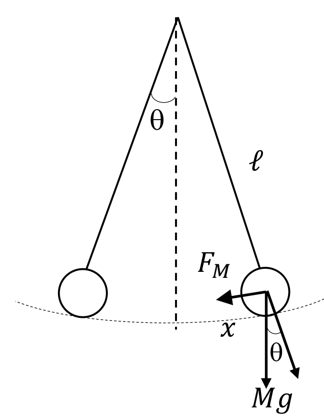
Determination of the acceleration of gravity by means of a simple pendulum.

APPARATUS:

Small pendulum bob of lead or brass tied to a length (1m) of cotton threaded through a supporting cork or clamped between two small metal plates. Retort-stand and clamp, meter rule, stop-watch.

THEORY:

The ideal simple pendulum consists of a point mass suspended by a weightless string. For a small angular displacement θ the restoring force acting on the point mass at P along the $arc(x)$ is:



$$F = -Mg\sin\theta$$

$$\sin\theta = \frac{x}{\ell}$$

If θ is small then $\Longrightarrow \sin\theta = \theta \quad \Longrightarrow \quad F = -Mg\theta = -Mg\,x/\ell$

Hence the equation of motion of P is:

$$F = Ma = M\ddot{x}$$

So

$$M\ddot{x} = -M\frac{g}{\ell}x$$

$$\boxed{\ddot{x} + \frac{g}{\ell}x = 0}$$

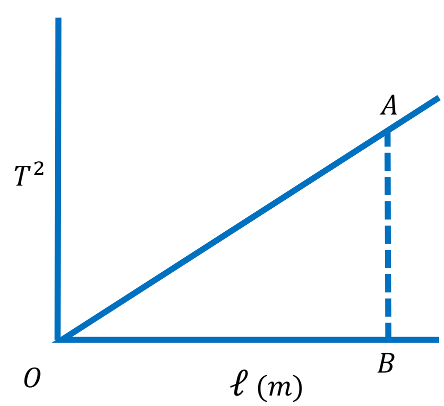
This equation shows us the motion is simple harmonic, and the periodic time T is given by:

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

METHOD:

The cork is securely clamped in position with the pendulum overhanging the bench. The length of the pendulum (measured from the point where the cotton emerges from the cork to the center of the bob) is adjusted by drawing the cotton through the cork. The free end is secured on the clamp, and the pendulum given a small displacement. The time of 10 swing-measured against a fixed mark on the bench- is taken, and the periodic time (T) found. (The reading must be rejected if the swings become elliptical). This is repeated with different lengths (ℓ) of the pendulum, and a graph is drawn between (T^2) and (ℓ) from which an average value of (T^2/ℓ) is obtained to determine (g).

$\ell(m)$	Time for 10 swings T_{10}^1	Time for 10 swings T_{10}^2	$T_{av} = \frac{T_{10}^1 + T_{10}^2}{2}$	Time for 1 swing $T_1 = \frac{T_{av}}{10}$	$(T_1)^2$



From the graph:

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

$$\frac{\ell}{T^2} = \frac{OB}{AB} = \frac{1}{slope}$$

$$g = 4\pi^2 \frac{OB}{AB} = \frac{4\pi^2}{slope} \qquad m/s^2$$

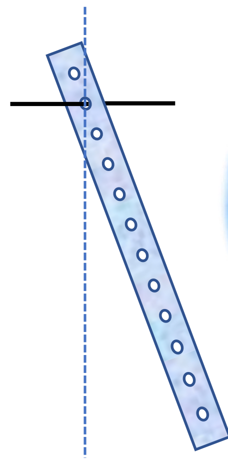
COMPOUND PENDULUM

OBJECTIVE

Determination of the acceleration of gravity by means of a compound pendulum.

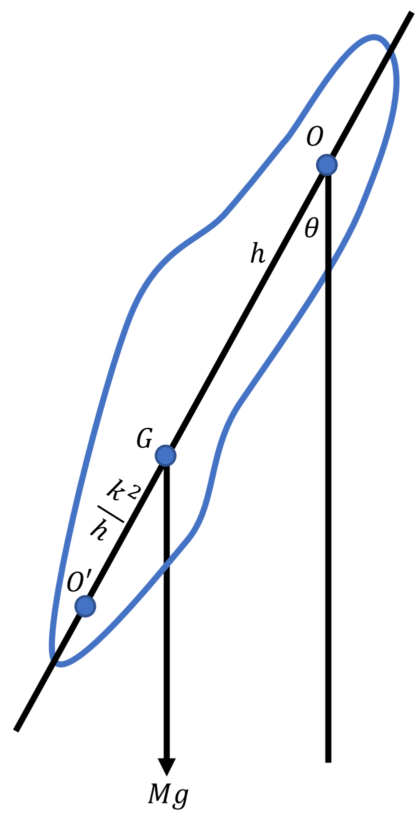
APPARATUS:

The usual pendulum for this experiment is a metal (wood or plastic) bar about a meter long drilled with holes at regular intervals and supported by a knife-edge through these holes.



THEORY:

The diagram represents a rigid body suspended by a horizontal axis through O. on being displaced through a small angle (θ) from the vertical position a restoring couple ($-Mgh\sin\theta = -Mgh\theta$) (since (θ) is small) is called into play. The equation of motion of the body is:



$$-Mgh\theta = I\frac{d^2\theta}{dt^2} = I\ddot{\theta}$$

Where (I) is the moment of inertial about the axis through O.

The motion is thus harmonic, and the periodic time (T) is:

$$T = 2\pi\sqrt{\frac{I}{Mgh}}$$

Writing (I_G) for the moment of inertia about the c.g., then:

$$I = I_G + Mh^2$$

By theorem parallel axis. And

$$I_G = Mk^2$$

$$\therefore I = Mk^2 + Mh^2$$

Where k is the radius of gyration about c.g.

So:

$$T = 2\pi\sqrt{\frac{I}{Mgh}} = 2\pi\sqrt{\frac{I_G + Mh^2}{Mgh}} = 2\pi\sqrt{\frac{k^2 + h^2}{gh}}$$

Since the periodic time of a simple pendulum is given by:

$$T = 2\pi\sqrt{\frac{\ell}{g}} \qquad (see\ simple\ pendulum)$$

By comparing simple pendulum and compound pendulum we can get

$$T_{simple} = T_{compound}$$

$$2\pi\sqrt{\frac{\ell}{g}} = 2\pi\sqrt{\frac{k^2 + h^2}{gh}}$$

The period of the rigid body is the same as that of a simple pendulum of length $\ell = h + \frac{k^2}{h}$. This is known as the length of the simple **Equivalent Pendulum**.

The expression for ℓ may be written as a quadratic in h, thus:

$$h^2 - h\ell + k^2 = 0$$

This gives two values of h (h_1& h_2) for which the body has equal times of vibration. From the theory of quadratic equations, $h_1 + h_2 = \ell$ and $h_1\, h_2 = k^2$. Thus, if a distance k^2/h_1 is measured along the axis from G on the side remote from O, a point O' is clearly the same as that about O, i.e. the centers of suspension and oscillation are interchangeable.

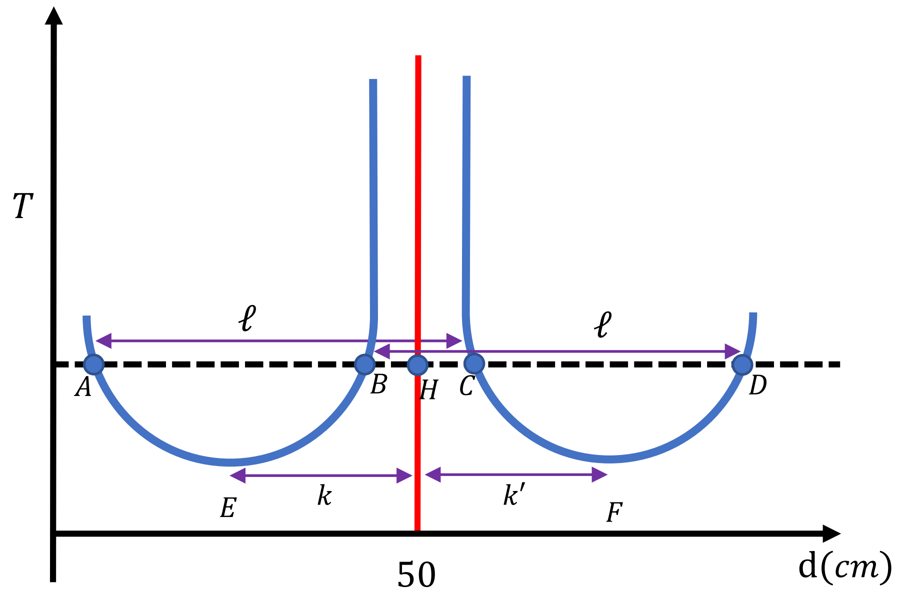
METHOD:

The needle is first inserted through the hole nearest the end A of the bar, and the time for 10 vibrations of small amplitude is taken by the stop-watch. This is repeated for each point of suspension along the rule. From the observations made a graph is plotted of the periodic time (T) against the distance (d) of the suspension from the end A of the rule. By drawing horizontal lines on this graph through given values of T, the corresponding mean values of the length (ℓ) of the simple equivalent Pendulum can be obtained. An average value of (ℓ/T^2) can be obtained from these results for use in computing g.

$d(cm)$	Time for 5 swings T_5^1	Time for 5 swings T_5^2	$T_{av} = \dfrac{T_5^1 + T_5^2}{2}$	Time for 1 swing $T_1 = \frac{T_{av}}{5}$	$(T_1)^2$
					Average=

A graph of T against d will be symmetrical about a line through the c.g. (for which T is infinite) as shown, and a horizontal line drawn through a given value of T will cut the graph in four points. The length ℓ of the s.e.p for this value of T will be the distance from ($1^{st} \rightarrow 3^{rd}$) **or** ($2^{nd} \rightarrow 4^{th}$) of these points then:

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



NOTES:

1. The roots of the quadratic are

$$h = \frac{\ell}{2} \pm \frac{1}{2}\sqrt{\ell^2 - 4k^2}$$

The least value of ℓ for real roots is $2k$ when $h_1 = h_2 = \frac{\ell}{2} = k$ and the time is then a minimum= $2\pi\sqrt{\frac{2k}{g}}$

The radius of gyration can be found directly from the graph,

$$k = \frac{EF}{2}$$

or alternatively k can be found from the relation

$$k = \sqrt{h_1 h_2} = \sqrt{AH \times HC}$$

2. Having found k as above, the moment of inertia of the body about the c.g. can be determine having obtained its mass by weighing,

$$I_G = Mk^2$$

3. The radius of gyration (and hence the moment of inertia) of a rigid body can be obtained readily by suspending it at a given distance (h) from its c.g. on the same axis as a simple pendulum. The length (ℓ) of the simple pendulum is adjusted so that both pendulums swing together. The

$$\ell = h + k^2/h$$

from which (k) can be found.

4. We can find the acceleration of gravity by:

$$g = 4\pi^2 \frac{\ell}{T^2} \qquad m/s^2$$

$\ell \Longrightarrow$ get it from graph.

$T^2 \Longrightarrow$ get it from average of T^2.

HOOK'S LAW

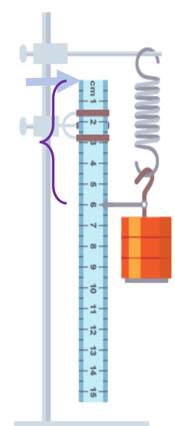
Hooke's law states that the strain of the material is proportional to the applied stress within the elastic limit of that material.

OBJECTIVE

To verify Hook's law and to plot mass-dsitance graph and calculate spring constant from the graph.

APPARATUS:

Spiral spring to which a pointer is attached at its lower end, rigid stand and clamp, meter rule, and weights.



METHOD:

The spring is firmly clamped and the meter scale placed vertically so that the pointer moves lightly over it. Loads are added to the scale-pan and the corresponding extensions of the spring are noted. A graph of extension against load is plotted from which the extension (m) per unit load (kg) is found.

$m(g)$	$x(mm)$

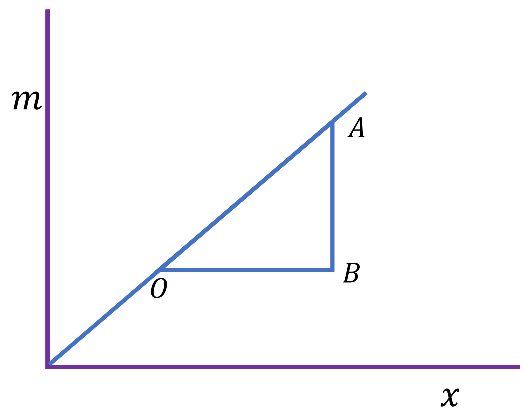
$$F = kx$$

From 2nd Newton law:

$$F = ma = mg$$

$$\therefore mg = kx$$

$$k = g\frac{m}{x} = g \times slope \qquad \frac{N}{m}$$

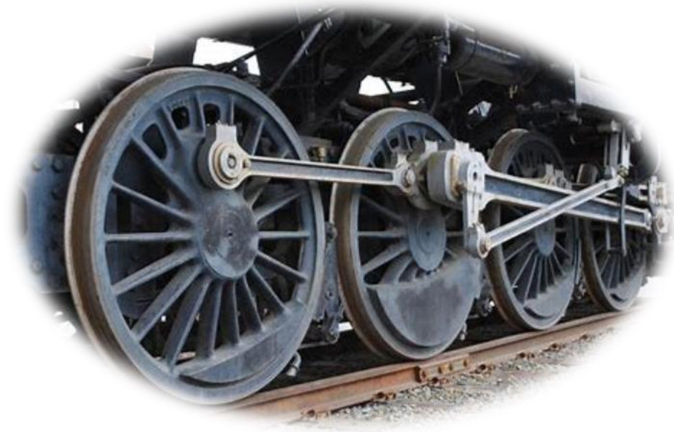


$$slope = \frac{AB}{OB}$$

RADIUS OF GYRATION

OBJECTIVE

Determination of the radius of gyration of a cylinders rolling down an inclined plane.

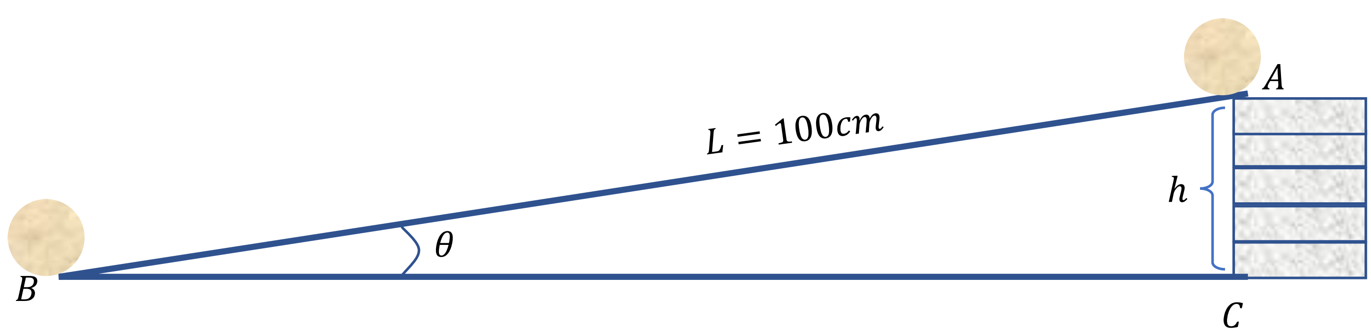


APPARATUS:

Big, small, open wooden cylinder, Wedge of wood, pieces of wood used for increase height, stop-watch, meter rule.

METHOD:

The wedge is placed under cylinder and the sine of the angle of inclination measured from the lengths AC and AB. The cylinder is held at rest on the marked position A, and the time is taken for it to reach the mark B, a measured distance L down the plane, is taken. This is repeated two times, and the acceleration a down the plane is obtained, using the mean of these times. The experiment is then repeated, using different inclinations, and a graph of a against $sin\,\theta$ is drawn. The diameter of the cylinder is accurately taken then radius, and from the radius of cylinder and the slope of the graph, the radius of gyration k of the cylinder is found.



THEORY:

Let the radius of the cylinder be r and its mass be M and its moment of inertia I. Then on rolling from A to B, a distance L down the slope inclined at an angle θ to the horizontal, the potential energy lost equal to:

$$in\ point\ A \Longrightarrow P.E = Mgh = MgL\sin\theta$$

If the liner velocity of the wheel at B is v and its angular velocity ω, the kintetic energy gaind equatl to:

$$in\ point\ B \Longrightarrow K.E = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$$

The potential energy at point A is equal to kintic energy at point B, so:

$$(P.E)_A = (K.E)_B$$

$$MgL\sin\theta = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$$

$$\because \omega = \frac{v}{r}$$

$$\therefore MgL\sin\theta = \frac{1}{2}Mv^2 + \frac{1}{2}I\frac{v^2}{r^2} = \frac{1}{2}v^2\left(M + \frac{I}{r^2}\right)$$

Now if a is the acceleration down the plane, $v^2 = 2aL$, and writing $I = Mk^2$, so we have:

$$MgL\sin\theta = aL\left(M + M\frac{k^2}{r^2}\right) = aL\left(1 + \frac{k^2}{r^2}\right)$$

$$g\sin\theta = a\left(1 + \frac{k^2}{r^2}\right) \Longrightarrow\ a = \frac{g}{\left(1 + \frac{k^2}{r^2}\right)}\sin\theta$$

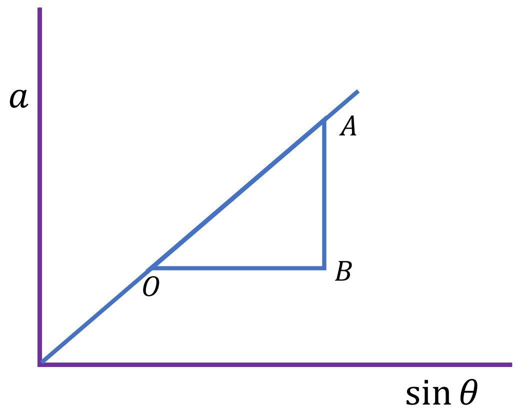
If a is the time taken to roll the distance L down the plane the acceleration can be determined from:

$$a = \frac{2L}{t^2}$$

By plotting a against $\sin\theta$, a straight-line graph is obtained whose slope is:

$h(mm)$	t_1	t_2	$t = \frac{t_1 + t_2}{2}$	$a = \frac{2L}{t^2}$	$\sin\theta = \frac{h}{L}$

Both h and L should be in m.



$$slope = \frac{AB}{OB} = \frac{a}{\sin\theta} = \frac{g}{\left(1 + \frac{k^2}{r^2}\right)}$$

From which k can be obtained.

NOTE:

The cylinders should be rolled on the inclined surface without slipping and the movement must be only rolling.

BOYLE'S LAW

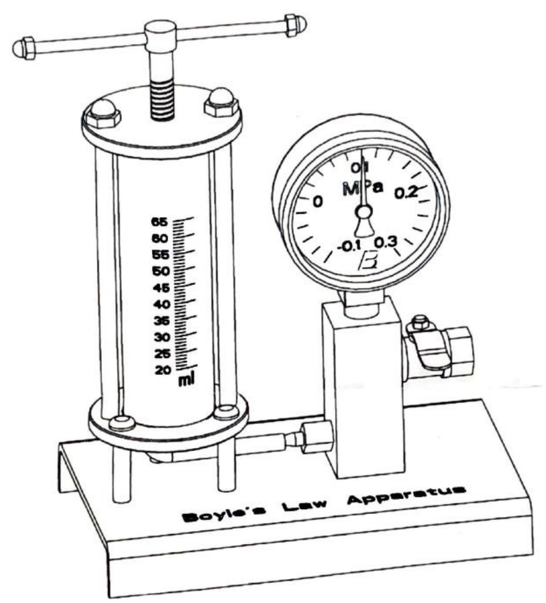
Boyle's law is a pressure versus volume relationship. The law was discovered by Robert Boyle in the 17th century. It states the pressure of a fixed amount of a gas is inversely proportional to its volume at a constant temperature. The law can be empirically proven.

OBJECTIVE

1. To verify Boyle's law and to plot the pressure-volume graph.
2. To show that Pressure is proportional to the inverse of volume.

APPARATUS:

This device is used to demonstrate the connection between pressure and volume at constant temperature.



The apparatus consists of a graduated cylinder with a piston. The cylinder acts upon a manometer via a narrow passage. The cylinder is supplied with a screw valve.

The cylinder diameter is 29mm. The manometer scale goes form $-1000\ hpa$ to $3000\ hpa$ at $50\ hpa$ intervals. The manometer diameter is 60mm.The dimensions of the apparatus is 150 x 100 x 200mm.

THEORY:

Boyle's law, PV = constant, shows how the pressure and volume of a gas are related when a constant quantity of the gas is kept at a constant temperature. This law is a special case of the general gas law, PV = nRT.

METHOD:

As the pressure grows, the volume of the air inside will decrease, one can see these quantities are inversely proportional. At the start, it is relatively easy to push the piston down, but as we apply a greater pressure, it becomes increasingly difficult to compress the air inside.

$$1\ hectopascals = 100\ pascals$$

$$\boxed{1hpa = 100pa}$$

$$1\ hectopascals = 0.1\ kilopascals$$

$$\boxed{1hpa = 0.1kpa}$$

$$1\ hectopascals = 0.00098692\ atm$$

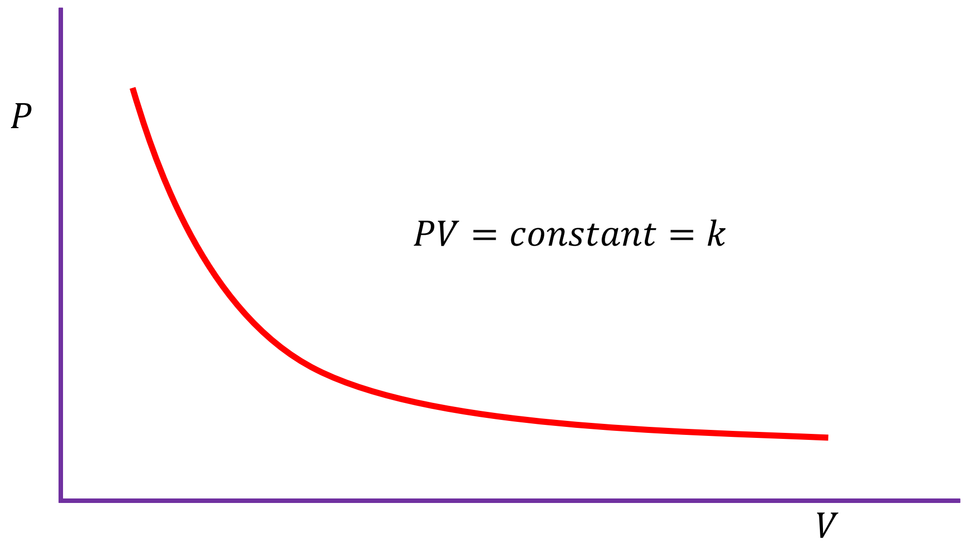
$$\boxed{1hpa = 0.00098692atm}$$

$$1\ Milliliter = 0.001\ Liter \Longrightarrow \boxed{1mL = 0.001L}$$

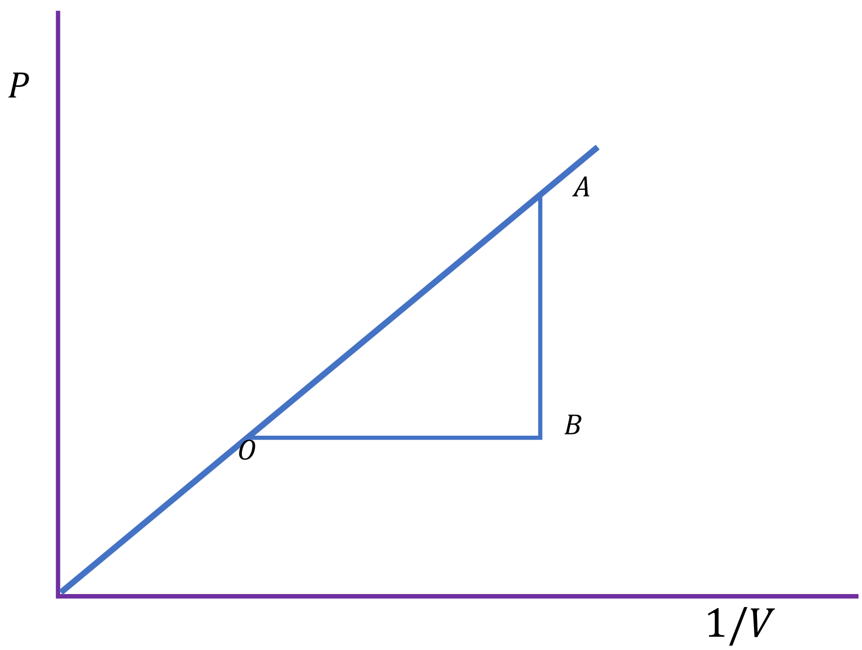
$V(mL)$	$P(hpa)$	$1/V$
65		
60		
55		
50		
45		
40		
35		
30		
25		
20		

- A set of readings was obtained and the results were plotted on two graphs, one showing pressure against volume and the other showing pressure against the inverse volume

1. First graph: pressure against volume.



2. Second graph: pressure against 1/volume. to find k



From slope:

$$slope = \frac{y_2 - y_1}{x_2 - x_1} = \frac{P}{1/V} = PV = k$$

We use Ideal gas law to find n:

$$PV = nRT$$

$P \Longrightarrow$ Pressure in atm.

$V \Longrightarrow$ Volume in liters.

$n \Longrightarrow$ Moles.

$R \Longrightarrow$ Proportionality constant $R = 0.08206 \ \frac{L \cdot atm}{mol \cdot K}$

$P \Longrightarrow$ Temperature in Kelvins.

$$n = \frac{PV}{RT} = \frac{slope}{RT}$$

NOTE:

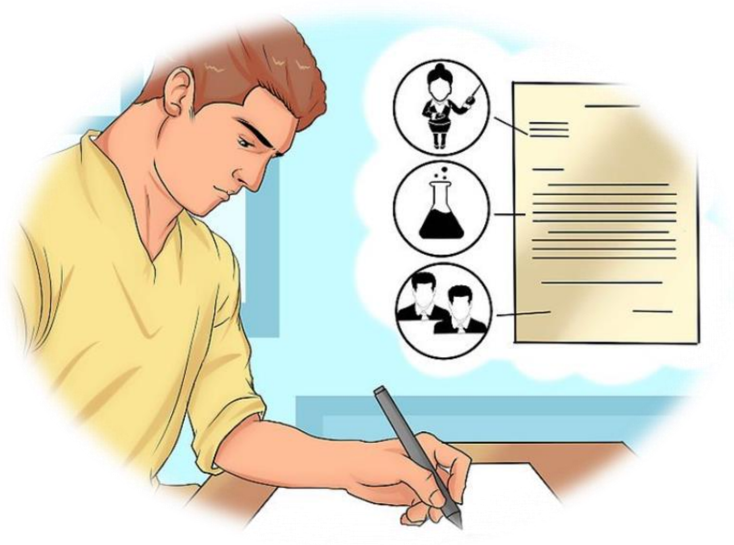
As a straight-line graph is produced that does not pass through the origin we can say that the most likely cause of the non-zero pressure intercept came in the calibration of the pressure sensor. Before any readings were taken the pressure sensor had to be calibrated and an approximate value of atmospheric pressure was set. If this adjustment were made to each of the pressure values recorded a straight line graph passing through the origin would have been obtained, proving pressure is inversely proportional to volume.

HOW TO WRITE A GOOD LAB REPORT?

If you've just finished an experiment in your physics class, you might have to write a report about it. This may sound intimidating, but it's actually a simple process that helps you explain your experiment and your results to your teacher and anyone else who is interested in learning about it. Once you know what sections to include in your report and what writing techniques to use, you'll be able to write a great physics lab report any time.

1. COVER SHEET:

- Your name and the name of your partners.
- The title of your experiment.
- The date you conducted the experiment.
- The date of delivery of your report.
- Your department.
- Information that identifies which class you are in.



2. OBJECTIVE:

- The objective section of your report should be a few sentences that describe the purpose of your experiment.

3. APPARATUS:

- Materials and apparatuses that were used to conduct the experiment.

4. THEORY SUMMARY:

- In this section we write a summary of the physical laws on which the experiment depends and simplify the equations to make them more understandable.

5. METHOD:

- The method section of your report should be explanation of exactly how you conducted your experiment. If a diagram will help you to understand your procedure, include it in this section.
- Explain any reasonable uncertainties that may appear in your data. No experiment is completely free of uncertainties, so ask your teacher if you're not sure what to include.

6. CALCULATIONS:

- If you used any equations to analyze your data, write one example of how you used it to calculate your results. If you used the equation multiple times throughout the experiment, you only need to write out one example.
- Include your raw data. Present the raw data that you collected during your experiment in this section of the report, making sure that it is clearly organized and includes units of measurement. A table is usually helpful for organizing data.

7. CONCLUSION:

- The conclusion is an integral part of the report, this is the section that reiterates the experiment's main findings and gives the reader an overview of the lab trial. Writing a solid conclusion to your lab report will demonstrate that you've effectively learned the objectives of your assignment

NOTE:

If you are following instructions from a lab book, do not just copy the steps from the book. Explain the procedure in your own words to demonstrate that you understand the experiment.