زانكۆی سەلاحەدین–هەولێر
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College of education

Department of Physics

MECHANICS LABORATORY

EXPERIMENT MANUAL

FIRST SEMESTER 2024-2025

Simple Pendulum Experiment

Aim:

To study the motion of a simple pendulum and to determine the acceleration due to gravity (g) using a simple pendulum.

Apparatus:

1. A Clamp with Stand
2. A string of length L,
3. a stopwatch,
4. a metal ball,
5. a meter stick.

Theory:

A **simple pendulum** consists of a heavy metallic (brass) sphere with a hook (bob) suspended from a rigid stand, with clamp by a **weightless inextensible and perfectly flexible thread** through a slit cork, capable of oscillating in a single plane, without any friction. There is no ideal simple pendulum. In practice, we make a simple pendulum by tying a metallic spherical bob to a fine cotton stitching thread.

The simple pendulum executes **Simple Harmonic Motion (SHM)** as the acceleration of the pendulum bob is directly proportional to its displacement from the mean position and is always directed towards it. The **time period (T)** of a simple pendulum for **oscillations** of small **amplitude**, is given by the relation:

$$T = 2\pi\sqrt{L/g}$$

where **L** is the length of the pendulum, and **g** is the acceleration due to gravity at the place of experiment.

$$g = 4\pi^2 \frac{L}{T^2} \quad ....(1)$$

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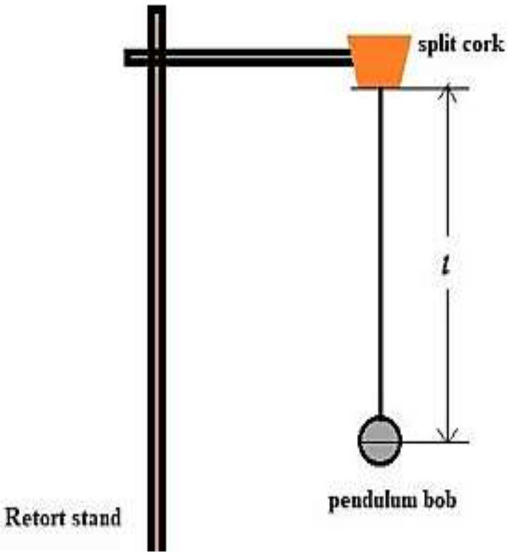
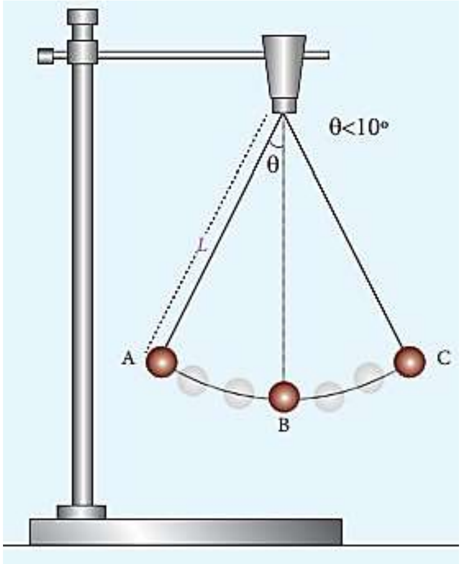
Stop-Watch: A stop-watch is a special kind of watch. It has a multipurpose knob or button (B) for start/stop/back to zero position. It has two circular dials, the bigger one for a longer second's hand and the other smaller one for a shorter minute's hand. The second's dial has **30 equal divisions**, each division representing 0.1 second. Before using a stop-watch you should find its least count. In one rotation, the seconds hand covers 30 seconds (marked by black color) then in the second rotation another 30 seconds are covered (marked by red color), therefore, the least count is 0.1 second.

Procedure

1. **Setup the Pendulum**:
    - Securely suspend a small bob (metal or wooden) using a lightweight, inextensible string from a fixed support.
    - Ensure the length of the string is adjustable and the bob swings freely.



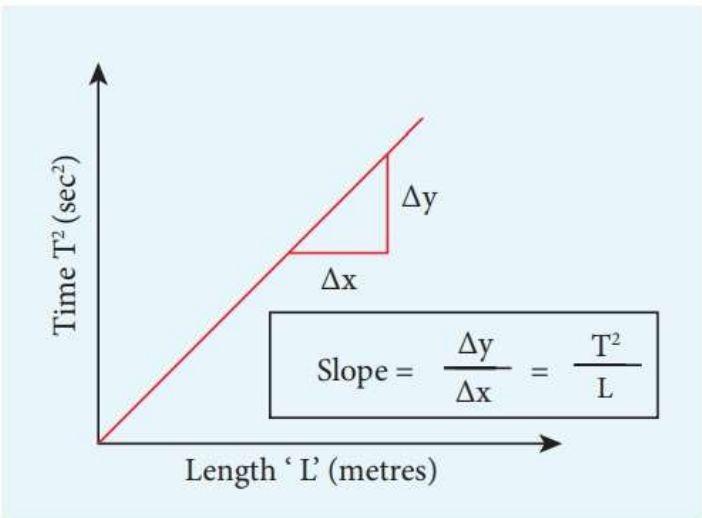


2. **Measure the Length of the Pendulum**:
    - Measure the distance from the fixed support to the center of the bob using a ruler. This is the length (L) of the pendulum.
3. **Displace the Pendulum**:
    - Pull the bob slightly to one side (ensuring small angular displacement, less than **10°**) and release it gently to start oscillating.
4. **Measure Time Period**:
    - Use a stopwatch to measure the time (T) taken for **20 complete oscillations**.
    - **Repeat** the measurement **3 times** to reduce error, then calculate the average time.
5. **Change the Length**:
    - Repeat the above steps for different lengths of the pendulum. Record your data in a table such as table 1.

Table 1. data collection

L (cm)	(t) Time of 20 oscillations (sec)				(T = t /20) Time of one oscillation (sec)	g (cm/sec^2)	g $_{average}$ (cm/sec^2)
	Trial 1	Trial 2	Trial 3	t (average)			
100							
90							
80							
70							
60							
50							
40							
30							
20							

6. **Calculate g**:
   - Substitute the measured values of L and T into the equation 1 to calculate g for each length. Then take g average.
   - Plot the relation between L and T^2 (using data from table 1) and measure the average value of g (compare it with the average g value that was found in previous step). This is called g (experimental value).
   - Determine your error value with comparing g experimental value with g theoretical value using error equation as below.



$$slope = \frac{\Delta y}{\Delta x} = \frac{T^2}{L}\text{ ; } 1/\text{slope} = L/T^2$$

$$\% \text{ error} = \left|\frac{\#\,\text{experimental} - \#\,\text{actual}}{\#\,\text{actual}}\right| \times 100$$

Discuss your results and error values and find the answers of the followings:

1. **What is the relationship between the length of the pendulum and the time period?**
   - Does the time period increase or decrease as the length changes?
2. **Why does the mass of the pendulum bob not affect the time period?**
   - How does this reflect the principles of simple harmonic motion?
3. **What is the physical meaning of g (acceleration due to gravity)?**
4. **Why is the time period independent of the amplitude for small oscillations?**
   - Does this hold true for larger amplitudes?
5. **How accurately does your experimental value of g match the standard value (check standard value of g in your area)?**
   - What might cause any deviations in the measured value?
6. **What are the possible sources of error in the experiment?**
   - How do reaction time, air resistance, or friction at the pivot affect the results?
7. **How does the precision of the measured time period affect the final value of g?**
8. **How does the error in measuring the length of the string impact the calculated g?**

Determination of the Spring Constant of a Spiral Spring

Objective: To verify Hooke's law and to determine the spring constant (k) of a spiral spring.

Note: spring constant is found two different methods:

1. Static Method (using equation 2)

2. Dynamic Method (using equation 4)

In this experiment, the **static method** is used to measure the spring constant.

Apparatus

1. Spiral spring
2. Stand with a clamp
3. a rigid support,
4. slotted weights,
5. a vertical wooden scale,
6. a fine pointer,
7. a hook.

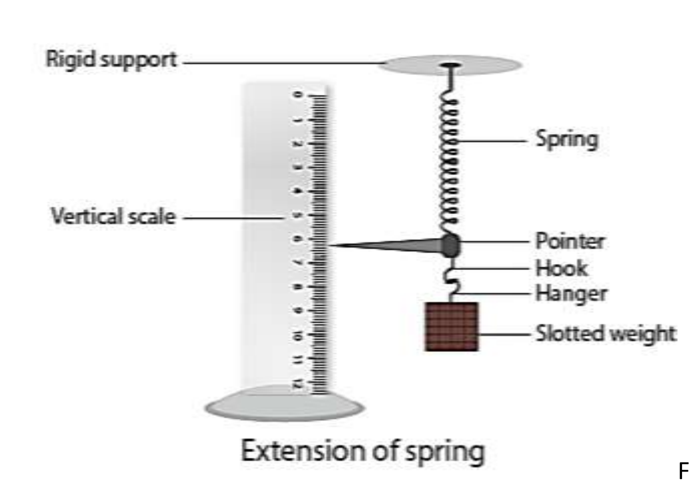


FIGURE 1

Theory

The spiral spring will behave as an elastic material if subjected to a force. Provided its elastic limit is not exceeded you will expect that Hooke's law will be obeyed. You will recall that **Hooke's law states that, the force on an elastic material is directly proportional to the extension (x) produced by the force provided the elastic limit is not exceeded**. If the mass at the end of the spring is now displaced vertically downward and then released, then for small oscillations, **the restoring force at any instant is proportional to the displacement (x)**, *i.e.*:

$$F \, \alpha \, x \qquad (1)$$

or

$$F = -k\,\Delta x \qquad (2)$$

Where:

- F = Force applied (F=mg), where mmm is mass and g is acceleration due to gravity),
- k = Spring constant (or force constant) (N/m),
- Δx = Extension of the spring (m).

$$\mathbf{F = mg} \qquad (3)$$

The spring constant (k) is a measure of the stiffness of the spring.

Spring constant (or force constant) of a spring is given by Spring constant, K = Restoring Force Extension Thus, spring constant is the restoring force per unit extension in the spring. Its value is determined by the elastic properties of the spring. A given object is attached to the free end of a spring which is suspended from a rigid point support (a nail, fixed to a wall). If the object is pulled down and then released, it executes simple harmonic oscillations. The time period (T) of oscillations of a helical spring of spring constant K is given by the relation T,

$$\boldsymbol{T = 2\pi\sqrt{\frac{m}{K}}} \qquad \textbf{(4)}$$

where m is the load that is the mass of the object. If the spring has a large mass (m_0) of its own, the expression changes to

$$\boldsymbol{T = 2\pi\sqrt{\frac{m_0+m}{K}}} \qquad \textbf{(5)}$$

Static Method Procedure

1. Setup:

1. Attach the spiral spring vertically to the stand using the clamp.
2. Fix a pointer to the lower end of the spring to indicate the extension on the meter scale.
3. Place a meter scale vertically beside the spring to measure the initial length of the spring.

2. Measure the Natural Length:

1. Record the initial length (x_0) of the spring (unstretched) without any load.

3. Adding Mass:

1. Attach a pan to the free end of the spring.
2. Add a known mass (m) to the pan.
3. Measure the new length of the spring (x).
4. Calculate the extension (Δx = x− x_0).

4. Repeat for Different Masses:

1. Gradually add more masses in increments (e.g., 50g, 100g, 150g, etc.).
2. For each mass, measure and record the corresponding extension of the spring.

5. Record Data in table 1.

6. Plot the graph of extension **(**Δx) in centimeters on the X$-axis$ against the **Force** in Newton on the y$-axis$ (see figure 2). A straight-line graph from origin shows a linear relationship between the load making force and the extension. Calculate the slope of straight line ($slope$ 1).

7. Calculate the **spring constant** from the relation (from graphic method) as shown in figure 2.

8. Compare **K average** found **from table 1** and from the **figure 2, they must be almost similar.**

9. Repeat the same procedure for a stiffer spring and find the K value of the new spring.

Table 1. Data collection. Note that, you can consider all of your data in CGS system and convert it into MKS system as K value is found in dyne/cm.

Mass (m) gram	F= mg (N)	x (m)	$\Delta x = x - x_0$ (m)	K = $\frac{F}{\Delta x}$ (N/m)
50				
10				
150				
200				
250				
300				
350				

K average =?

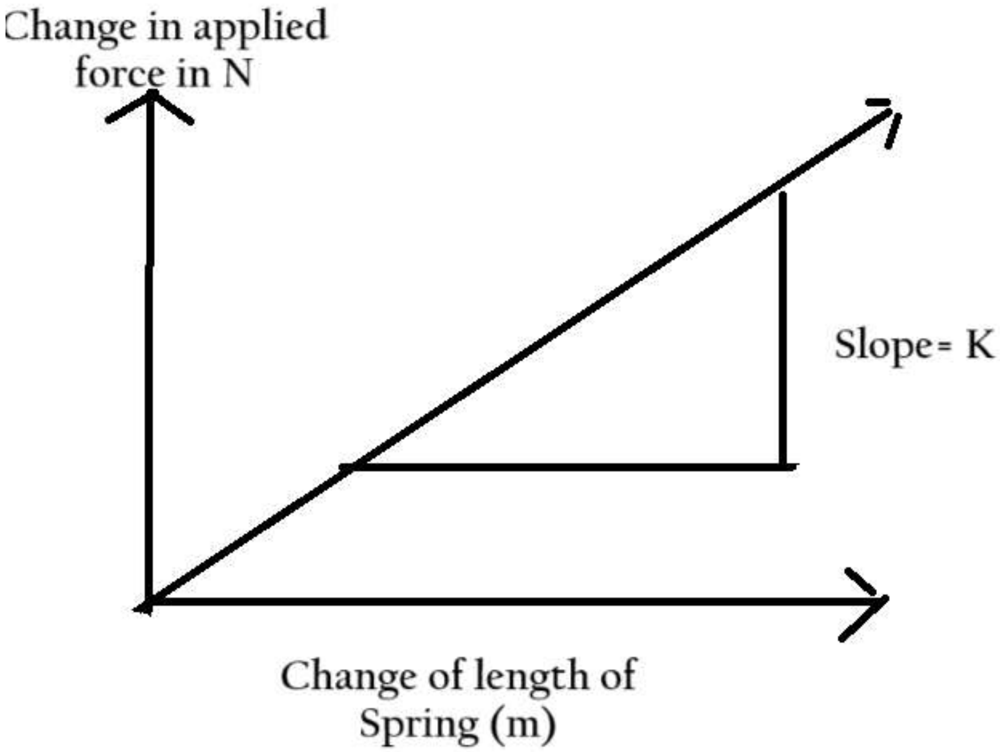


Figure 2. Relation between spring load and change of length.

Conceptual Questions

1. What is the relationship between the applied force and the extension of the spring according to Hooke's Law?

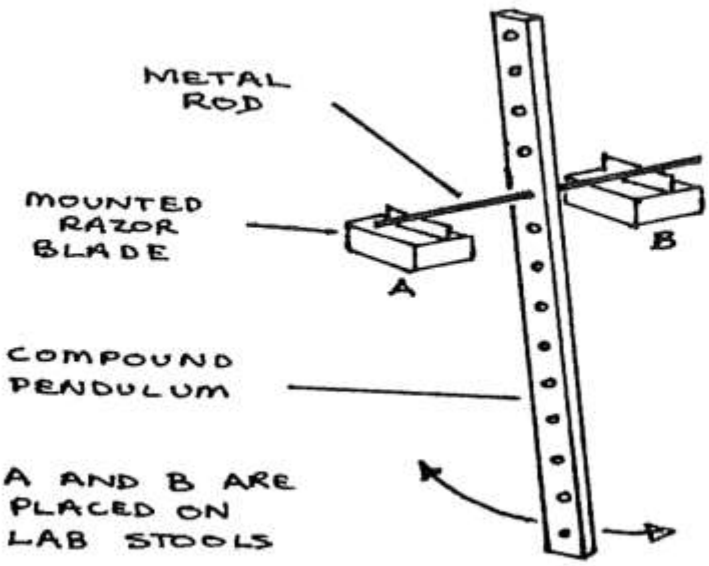
2. What does the spring constant k represent physically? How does k relate to the stiffness of the spring?
3. What are the conditions under which Hooke's Law is valid? Does the spring behave linearly for all extensions? What happens beyond the elastic limit?
4. What role does gravity play in this experiment? How does it affect the applied force when weights are added?
5. Why is the slope of the graph equal to the spring constant?
6. How would you interpret deviations from linearity in the data?
7. How does the choice of weights affect the accuracy of the measurement? Would smaller weights or larger weights lead to more reliable results?
8. Why is it important to measure the extension accurately? How can errors in measuring extension influence the value of k?
9. What are the possible sources of error in this experiment?
10. Discuss methods to improve accuracy, such as using precise measuring instruments or repeating measurements.

Determination the value of acceleration due to gravity (g) using compound pendulum

OBJECTIVE: To find the value of acceleration due to gravity (g) using a compound pendulum.

APPARATUS

- Bar pendulum (steel rod with holes in it)
- Knife-edged fulcrum
- Stopwatch
- Meter scale



Bar pendulum

RELATED THEORY

Vibration

Any motion that repeats itself after an interval of time is called vibration or oscillation. The swinging of a pendulum and the motion of a plucked string are typical examples of vibration.

Simple pendulum

A simple consists of a small body called a "bob" (usually a sphere) attached to the end of a string the length. The mass of string is negligible in comparison to the bob. Under these conditions, the mass of the bob may be regarded as concentrated at its center of gravity, and the length of the pendulum is the distance of this point from the axis of suspension. A rigid body mounted upon a horizontal axis so as to vibrate under the force of gravity is a compound pendulum.

Compound pendulum

When the dimensions of the suspended body are not negligible in comparison with the distance from the axis of suspension to the center of gravity, the pendulum is called a compound, or physical, pendulum. Time period (T) for a compound pendulum is given by:

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

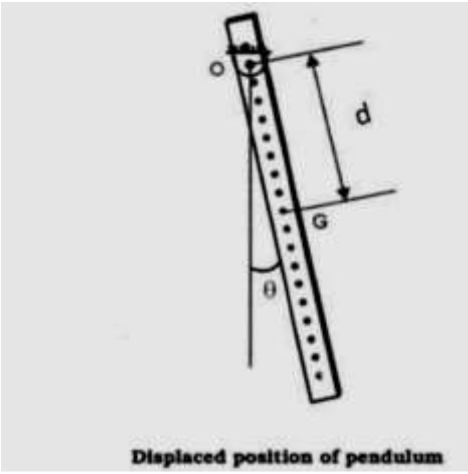
PROCEDURE

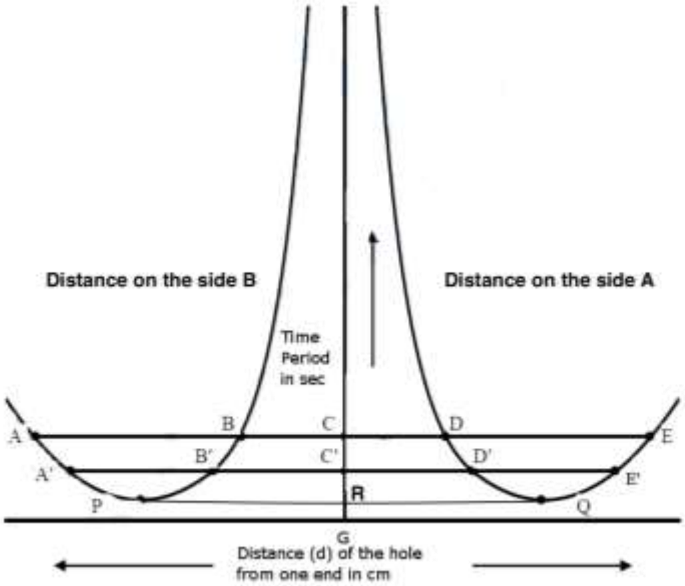
1. Measure the length of given bar pendulum (metal rod with holes)
2. Find out the center of gravity or mid-point of metal rod.
3. From the center of gravity, there are nine Holes on each side left and right. Mark the two sides as “Side A” and “Side B”.
4. Arrange the clamp stand to hold metal rod.
5. Take two knife-edges and fix it to the first two holes from Side A and Side B. Make sure to point the sharp edges of the two knife-edges towards the center of gravity.
6. Now, balance the knife edge at wedge of clamp or stand.
7. Displace the bar pendulum setup slightly (approx. 5 cm)
8. Note down the time for 30 vibrations two times.
9. Calculate the mean time for the two vibrations or oscillations.
10. Divide the value by the number of vibrations to determine the time period (T).
11. Repeat the steps for all other holes.
12. Now graph is drawn by taking distance ‘d’ of the holes form the center of gravity at x-axis and time period (T) at y-axis.
13. Determine the value of effective length “l” from the graph and corresponding value of T.

$$l = \frac{AC + BD}{2}$$

T=C

Sl. No.	Distance 'd' of the knife edge from A(cm)	Time for 10 oscillations (sec)			Period T (sec)
		1	2	Mean	
1	5	16.15	15.95	16.04	1.604
2	10	15.64	15.57	15.60	1.56
3	15	15.41	15.28	15.34	1.53
4	20	15.34	15.18	15.26	1.526
5	25	15.39	15.30	15.34	1.534
6	30	15.84	15.50	15.67	1.567
7	35	16.65	16.00	16.32	1.632
8	40	19.16	19.06	19.11	1.911
9	45	22.94	23.94	23.44	2.344
10	50	-	-		
11	55	24.30	23.94	24.12	2.412
12	60	18.57	18.62	18.59	1.859
13	65	16.11	16.35	16.23	1.623
14	70	15.63	14.68	15.15	1.515
15	75	15	15.66	15.33	1.533
16	80	15.78	14.90	15.34	1.534
17	85	15.15	14.93	15.04	1.504
18	90	15.18	15.10	15.14	1.514
19	95	15.53	15.69	15.61	1.561





14.Calculate the value of "g" using the formula:Time period,

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

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

OBSERVATIONS AND CALCULATIONS

Length of the bar, L = 100 cm or (1 meter). No. of oscillations = 15.

RESULTS

Standard value of g = 9.8 m/s

Calculated value of g = ______ m/s

PRECAUTIONS

i. Ensure that the pendulum oscillates in a vertical plane and that there is no rotational motion of the pendulum.

ii. The amplitude of oscillation should be small.

iii. Use a precision stopwatch and note the time accurately as far as possible.

Determining the Speed of Sound in Air in a Resonance Tube open at one end.

Aims of the Experiment

□ The aim of the experiment is calculating the speed of sound in air using a tuning fork and a tube of water

Variables:

□ **Independent variable** = Air level in the tube

□ **Dependent variable** = Length of the air column in the tube where resonance occurs, *L*

□ Control variables:

o Temperature of the water

o Frequency of the tuning fork

Equipment List

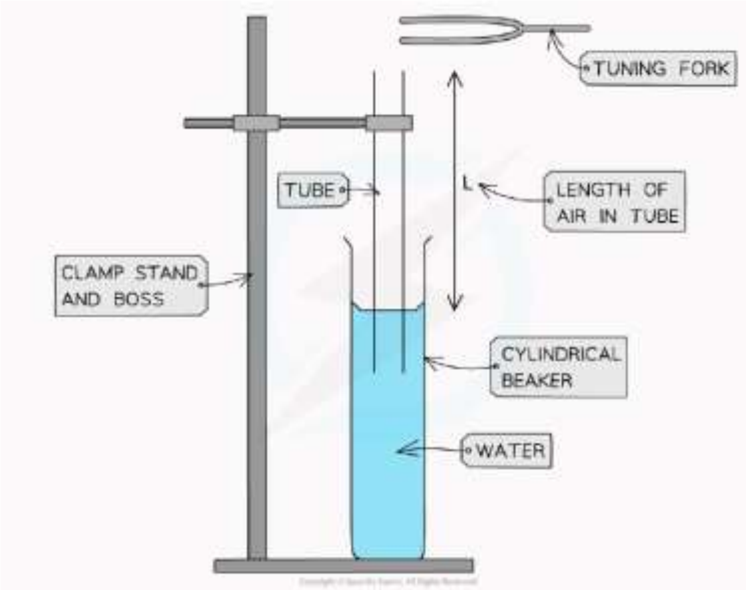
Apparatus	Purpose
Tuning fork with known frequency	To create the sound wave
Small hammer	To hit the tuning fork
Tube open at both ends	To create a resonant sound wave inside
Clamp stand and boss	To hold the tube
Water	To reduce the column of air in the tube
Rubber band or marker pen	To mark the length of the tube at which resonance occurs
Cylindrical beaker	To hold the water

Method

1. Set up the equipment and fill up the beaker halfway with water
2. Place the tube inside the beaker, so the water comes up a quarter of the way. The side of the tube in the water acts as a closed-end
3. Hold the tuning fork above the open end of the tube and strike it lightly with the small hammer
4. Slowly lower the tube into the water by loosening the clamp until the intensity of sound is amplified
5. When resonance (loudest sound) is heard, mark the water level with a rubber band or marker pen. Record this as L_1

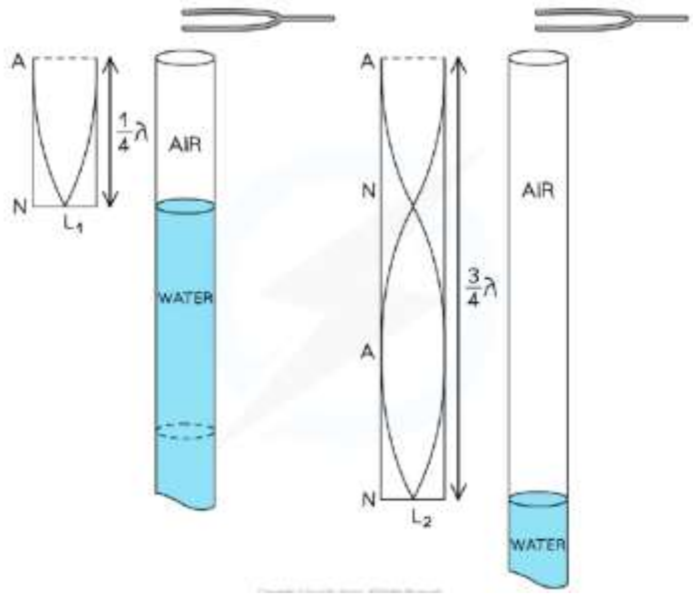
6. Then, lower the water further until the next point of resonance is heard and mark it. Record this as L_2

7. Keep going in this manner as far as possible



Apparatus setup to measure the speed of sound in a column of air

Analysis of Results



Standing waves in the air columns are used to calculate the wavelength of the sound waves

Resonance should occur when the open tube length L is equal to $\lambda / 4$, $3\lambda / 4$ and $5\lambda / 4$

o The loudness of the sound in the tube from the fork will be small at the node of the sound wave

o The sound will be the loudest at the antinode of the sound wave

- At *L1* the wavelength is $\lambda / 4$
- At *L2* the wavelength is $3\lambda / 4$

$$L2 - L1 = \lambda / 2$$

- Therefore, the wavelength of the sound λ is equal to:

$$\lambda = 2(L2 - L1)$$

- Another value of λ could also be found from the distance between *L3* and *L2* and a mean wavelength can be calculated
- From the wave equation:

$$v = f\lambda$$

- The speed of the sound wave, v, can found from the product of the frequency f of the tuning fork and the wavelength λ calculated

Evaluating the Experiment

Systematic Errors:

- The tuning fork should be struck at the same place above the tube each time
- The tuning fork should be struck with the same force each time

Random Errors:

- Make sure the marker is a thin line to get a more accurate reading of the water level
- Submerge the tube into the water slowly, so the antinode of the sound wave (loudest sound) is not missed
- Repeat the experiment to record more reliable readings, since the point where the sound is the loudest is subjective
- Using a resonance tube with a scale will help account for error when measuring the length of the air column within it

Safety Considerations

- Don't let the tuning fork touch the tube, since the vibrations could break or crack it
- Make sure the water is at room temperature, and not too hot or cold
- Make sure no electrical equipment is near the water, otherwise they could be damaged