University of Technology

Laser and Optoelectronics Engineering Department

Medical Physics Lab.
First Year\Second Semester

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Medical Physics Lab
First Stage\Second Semester

1. ***Hooke's Law***

2. ***Speed of Sound in Air (Resonance Tube Method)***

3. ***Viscosity of liquid***

4. ***The Surface Tension***

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Experiment (1)

Hooke's Law

Objective:-

1. Verifying Hooke’s Law

2. To determine the spring constant (k) of a spring

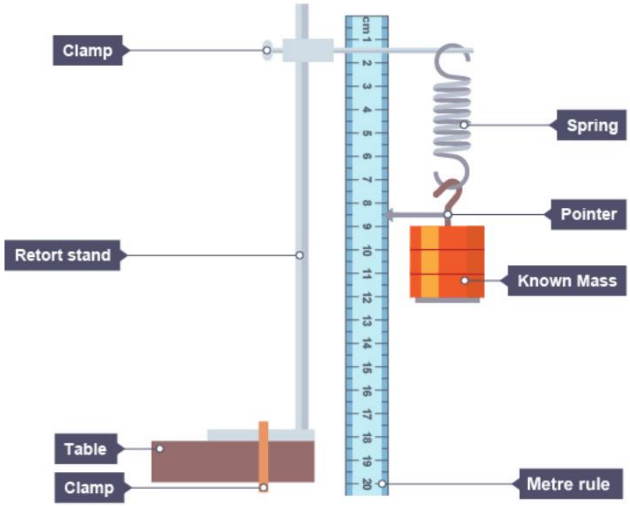
Apparatus:-

Spiral spring, meter stick, balance, weight hanger, weights

Theory:-

Hooke’s law, law of elasticity discovered by the English scientist Robert Hooke in 1660, which states that, for relatively small deformations of an object, the displacement or size of the deformation is directly proportional to the deforming force or load. Under these conditions the object returns to its original shape and size upon removal of the load.

There is one common property behind stretching of a spring and rubber band that come back to their original shape. The property that allows any material to regain its shape is called elasticity. The fundamental law that governs this interesting phenomenon is the Hooke’s law.



Fig(1) Setup of Hooke’s Law Experiment

A common and very important kind of oscillatory motion is simple harmonic motion such as the motion of an object attached to a spring Fig (2) .

In equilibrium the spring exerts no force on the object when the object is displaced an amount (x) from its equilibrium position the spring exerts a force (-kX) as given by Hook's Law.

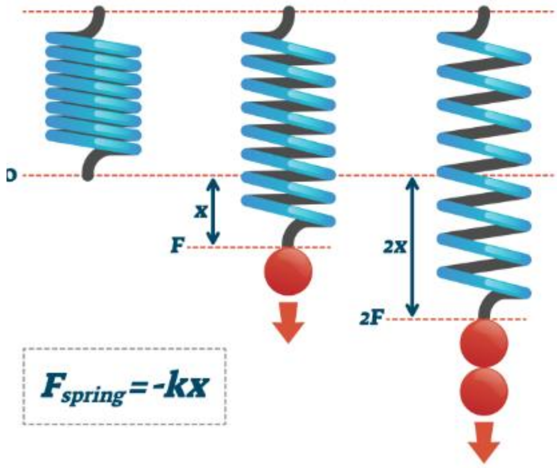
$$F_{x=} -kX\ldots\ldots\ldots\ldots(1)$$

Where:

F_x: Force in Newton

k: is the force constant of the spring (spring constant)

X=Elongation in meter



Fig(2)

Procedure:

1. Begin by measuring the position of the spring. This is your equilibrium position. Record this as X_o in your data sheet (Table-1). (Note: Choose a convenient reference point near the bottom of the spring (lower end of the spring) with which to measure the position of the spring.)

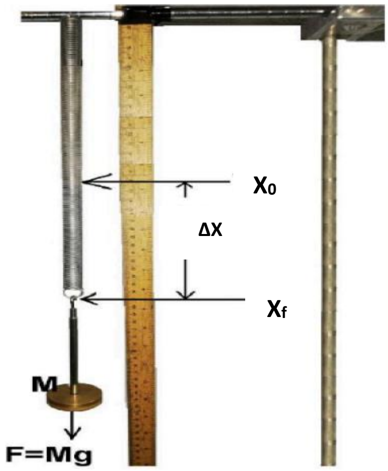
2. Attach a 50 g (0.050 kg) mass holder to the spring and measure the new position k_f to which the reference point on the spring is extended. Record mass and the position with the 50 g mass holder in Table-1

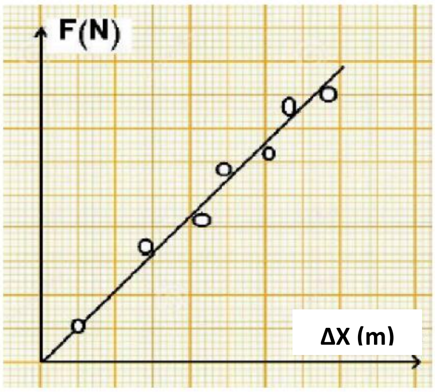
3. Add additional 50 g masses to the mass holder and record the position of extension k_f each time the mass is increased by 50 g until the total mass reaches 350 g.
4. Compute the applied force F that the masses exert on the spring by calculating the weights of the masses. Remember that the weight W is given by W = mg and is measured in Newtons if m is the mass measured in kilograms and g is the acceleration due to gravity, $g = 9.80\ m/s^2$.
5. Calculate the displacement ΔX of the spring, which is the amount the spring is stretched and is calculated by taking the difference between the extended position X_f and the equilibrium position X_o , ($\Delta X = X_f - X_o$).
6. Plot a graph of F versus ΔX.
7. Draw the best straight line fit of the data
8. Calculate k from the slope

Slope =K=F/ Δx

Table 1: The results of experiment

Serial No.	Mass (g)	Mass (Kg)	F=W=mg (N)	X_f(cm)	X_0(cm)	Δx (cm)
1	0					
2	50					
3	100					
4	150					
5	200					
6	250					
7	300					
8	350					





<u>Discussion:-</u>

Q1: Define Hook's Law

Q2:Discuss the experiment.

Experiment (2)

Speed of Sound in Air (Resonance Tube Method)

Objective:-

To calculate the speed of sound in air by using tuning fork.

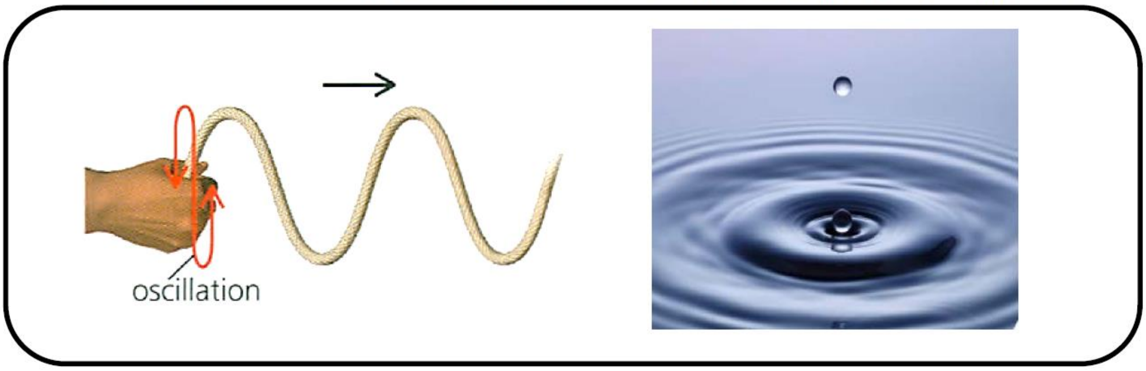
Apparatus:-

Open glass-Tube, tuning fork, rubber hammer, meter stick, clamp and stand.

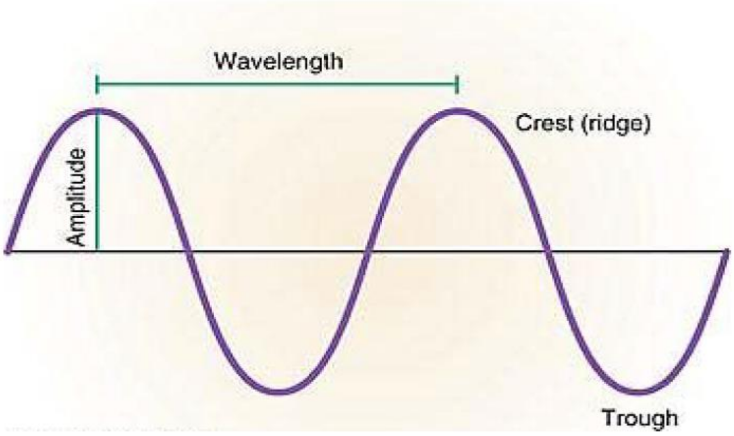
Theory:-

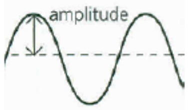
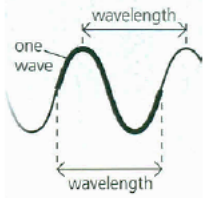
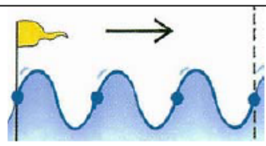
Wave Motion
It is defined as "*Waves carry **energy** without the net movement of particles".*

Notes
- Waves found around us in so many forms
- Wave motion can be illustrated by vibration in ropes and springs or any particle.



Wave properties

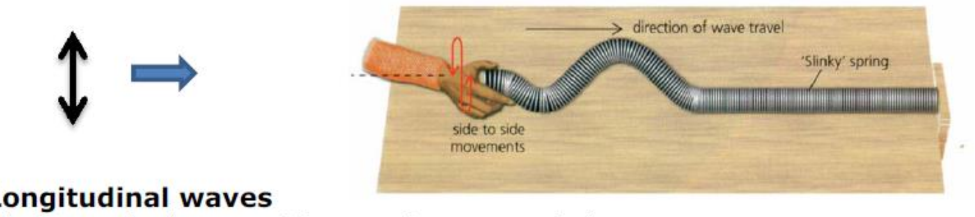


Term	Symbol	Definition
Amplitude	*A*	Maximum displacement from the mean position in **m** 
Wavelength	λ	Shortest distance between any point on a wave and the equivalent point on the next.  in **m**
Frequency	*f*	The number of complete oscillations that take place  in 1 second in **Hz (Hertz)**
Wave speed	*v*	The speed at which wave fronts pass a stationary point in **m/s**
Period	*T*	The time for one complete oscillation in **s** $T = 1/f \quad , \quad f = 1/T$

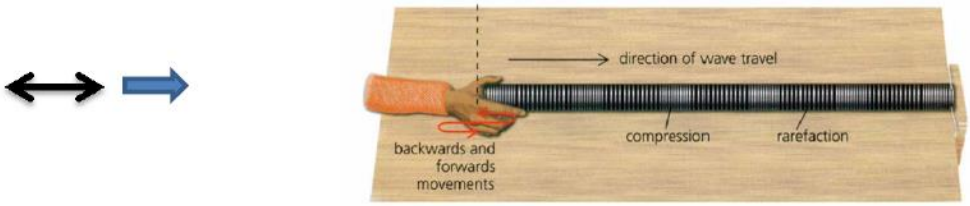
For example, if a wave makes 4 oscillations per second, then 4 waves pass any point per second, and the ***frequency is 4 Hz***. the period is equal to 1/frequency.
If the frequency is 4 Hz, the period is ¼ s (0.25 s).

Wave Types

Transverse waves.
Vibrating perpendicular to the direction of the wave (energy transfer)

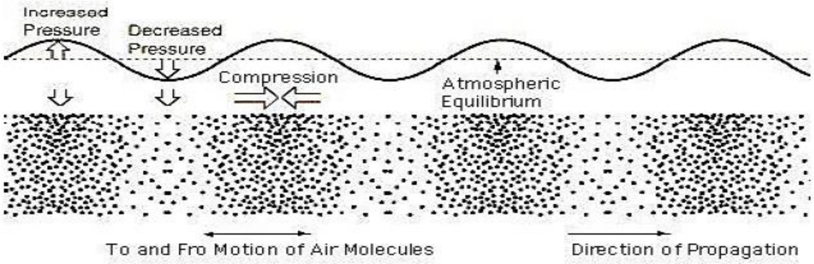


Longitudinal waves
Vibrating in the direction of the wave (energy transfer)

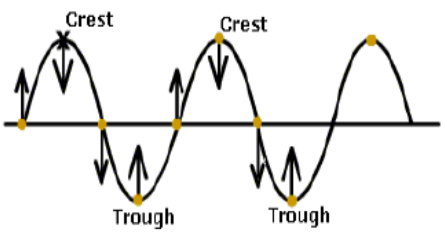
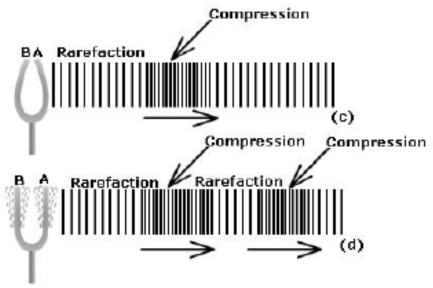


Crests
the maximum displacement of the particles of the medium upwards.
Troughs
the maximum displacement of the particles of the medium downwards.

Compressions
Area of high pressure between medium molecules.
Rarefactions
Area of low pressure between medium molecules.



Comparison

	Transverse waves	**Longitudinal waves**
Definition	the particles of the medium vibrate **perpendicular** to the direction of the wave propagation	the particles of the medium vibrate **along** to the direction of the wave propagation
Consists of…	The transverse waves are formed of successive ***crests*** and ***troughs***	The longitudinal waves are formed of successive pulses of ***compressions*** and ***rarefactions***
Shape		
Wave length	The distance between two successive crests or troughs	The distance between the centers of two successive compressions or rarefactions
Examples	***Water waves*** And electromagnetic waves radio waves, microwaves, infrared rays, light, ultraviolet rays, X-rays, gamma rays	***Sound waves***

Sound is a longitudinal wave that is created by a vibrating such as a guitar string, the human vocal cords other diaphragm of a loudspeaker. Moreover sound can be created or transmitted only in a medium such as a gas, liquid, or solid. Sound travels through gases, liquids and solids at considerably different speeds.

When a tuning fork is vibrating near the open end of air column at the other end, a strong reinforcement called a resonance can be heard. This reinforcement occurs because the rays reflected from the closed bottom of the tube return in phase with the direct wave made by the tuning fork, the direct and reflected waves combine producing a Standing wave.

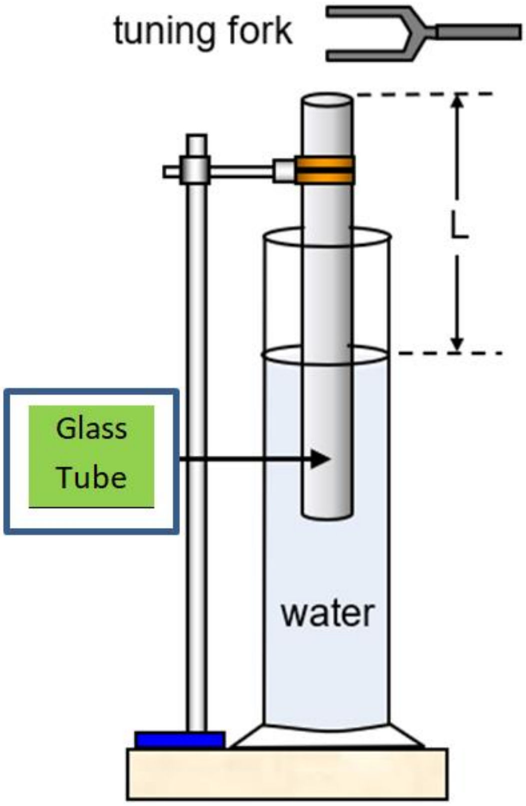


Fig. (1): The setup of the resonance tube method

Figure (2) shows an air column closed at one end with the small diameter compared to its length. A strong resonance will occur when the length of the resonant air column is one-quarter of a wavelength ($\lambda/4$) of the sound waves made by the tuning fork.

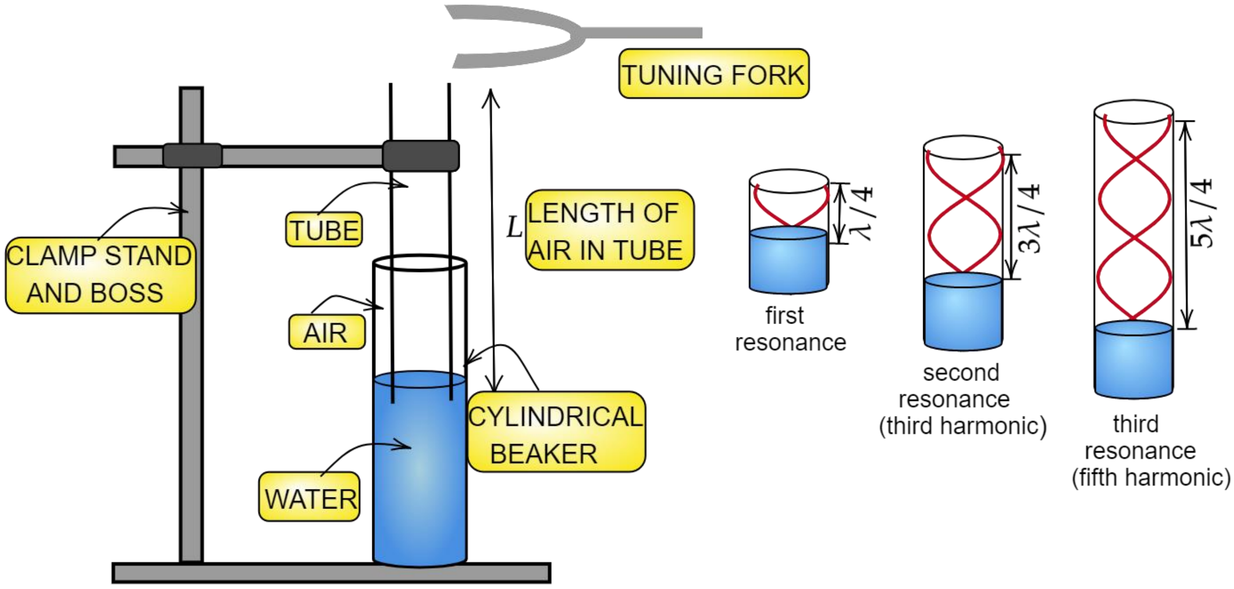


Fig. (2): The cases of resonance

Procedure:-

1:- Fill the reservoir about (42 cm) on the resonance tube.

2:- Using a rubber mallet, or the heal of your hand to strike the tuning fork, hold the vibration tuning fork horizontally as close to the open end of the tube. Move the tube and fork up and down until the sound is best reinforced and hold the tube in the position of the best sound reinforced.

3:- Measure and record the frequency of the tuning fork and the length of air column that is the distance from the top of tube to the top of the water.

4:- Arrange your results in the table below.

F(Hz)	L(cm)	1/F (Hz^{-1})

Where:

F= frequency of the tuning fork in (Hz), L= distance from the top of the tube to the top of the water.

5:- Plot a graph between1/F (Hz^{-1}) and L (cm) then find the slope.

6:- To Find the speed sound in air (ν) : we have the relation between the wavelength (λ) and the length of tube (L)

$$L=\lambda/4 \longrightarrow \lambda=4L \quad .... (1)$$

$$\nu=F * \lambda \quad .... (2)$$

λ=wavelength of sound in meters, ν=velocity of sound in m/sec.

Replace equation (1) in (2) we get: $\nu = 4 * L * F$

<u>Discussion:-</u>

Q1:- Define the wave?

Q2:- Define the sound wave?

Q3:- What is the source of error?

Experiment (3)

Viscosity of liquid

Objective:-

Determine the coefficient of viscosity for glycerin

Apparatus:-

Stainless steel balls, Glass tube or Beaker, Stop watch, Glycerin, two rubber bands

Theory:-

The ***viscosity*** of liquid is a resistance to flow of a liquid. All liquids appear resistance to flow change from liquid to another, the water faster flow than glycerin, subsequently the viscosity of water less than glycerin at same temperature.

When a spherical ball of radius r and density (ρ) falls freely through a viscous liquid of density (ρ_L) and coefficient of viscosity (η), it moves in it, with certain velocity (v), it experiences an opposing force, drag force, (viscous force F_v).

$$F_w = 4/3\pi r^3 \rho g \text{ ...... (1)}$$

Where:

F_w = gravitational force

r = radius of the ball

ρ = density of ball

g =980 cm/sec^2

$$F_b = 4/3\pi r\,(\rho_L)\,g \;\ldots\ldots\; (2)$$

Where:

F_b =Buoyancy force (weight of displaced of liquid)

r = radius of the ball

ρ_L = density of liquid

g =980 cm/sec^2

According to Stoke's law the viscous force is given by:

$$F_v = 6\pi r\,\eta\,v \;\ldots\ldots\; (3)$$

Where:

F_v = viscous force

r = radius of the ball

v = velocity of the ball in liquid

η = coefficient of viscosity

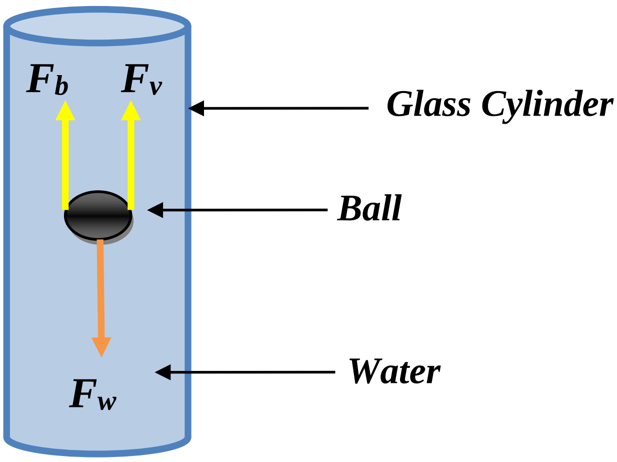


Figure (1): The glass cylinder with the liquid

After some time the ball will move with a steady velocity, called the terminal velocity. Under the steady condition.

$$F_w = F_b + F_v \ldots\ldots (4)$$

Using (1), (2), (3) and (4) we can show that:

$$\eta = \frac{2}{9} \frac{r^2}{v} g(\rho - \rho_L) \ldots\ldots (5)$$

Where:

η = coefficient of viscosity

r = radius of the ball

v = velocity of the ball in liquid

ρ = density of ball

ρ_L = density of liquid

g =980 cm/sec^2

The factors effect on the viscosity:

1. Effect of Temperature: the temperature of the liquid fluid increases its viscosity decreases. In gases its opposite, the viscosity of the gases fluids increases as the temperature of the gas increases.
2. Molecular weight: the molecular weight of the liquid increases its viscosity increases.
3. Pressure: when increase the pressure on liquids, the viscosity increase because increase the attraction force between the molecules of liquid.

Procedure:-

1- Adjust the distance between the rubber bands, record the distance (d) between them as shown in figure(2).

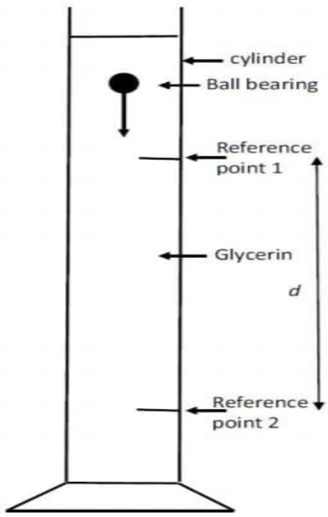


Figure (2) The Setup of experiment

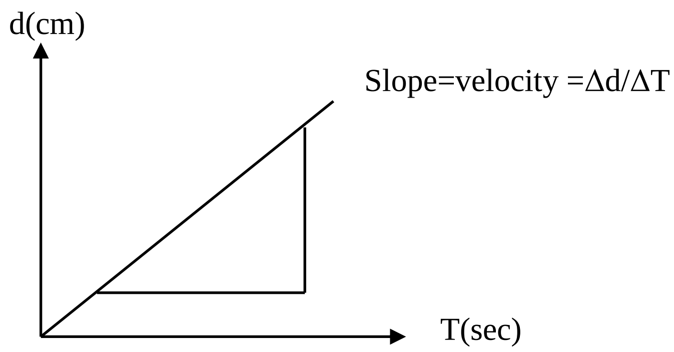
2- Drop a sphere centrally down the tube and with stopwatch find the time (T) it takes to traverse the distance between the rubber bands.

3- Repeat the experience for the different values of (d) and obtain different values of the time of fall for each new distance apart.

4- Make a table as shown below.

Distance (d) cm	Time (T) sec

5- Plot a graf between d (cm) and T(sec), find velocity (velocity =d/T)



6- Calculate the coffeicent of viscocity (**η**) from the formula

$$\eta = \frac{2}{9}\,\frac{r^2}{v}\,g\,(\rho - \rho_L)$$

Discussion:-

Q1:- Discuss your experiment.

Q2:- Why the liquid must be transparent?

Q3:- What are the sources of error?

Experiment (4)

The Surface Tension

Objective: -

To calculate the surface tension of water by the capillary tube method.

Apparatus: -

Set of three capillary tubes, Beaker, stand and clamp

Theory: -

Cohesion: Cohesion means intermolecular between molecules of the same liquid. It enables a liquid to resist small amount of ensile stress. Cohesion is a tendency of the liquid to remain as assemblage of particles. “Surface Tension” is due to cohesion between particles at the free surface.

Adhesion: Adhesion means attraction between the molecules of the molecules of a solid boundary surface in contact with the liquid. This property enables a liquid o stick to another body.

Capillary action is due to both Cohesion and Adhesion.

Surface Tension: is caused by the force of cohesion at free surface. A liquid molecule in the interior of the liquid mass is surrounded by another molecule all rounded and is in equilibrium. At the free surface of the liquid, there are no liquid molecules above the surface to balance the force of the molecules below. Consequently, as shown in Fig (1), there is a net inward force on the molecules. The force is normal to the liquid surface. At the free surface a thin layer of molecules is formed. This is because of this film that a thin small needle can float on the free surface (the layer acts as a membrane).

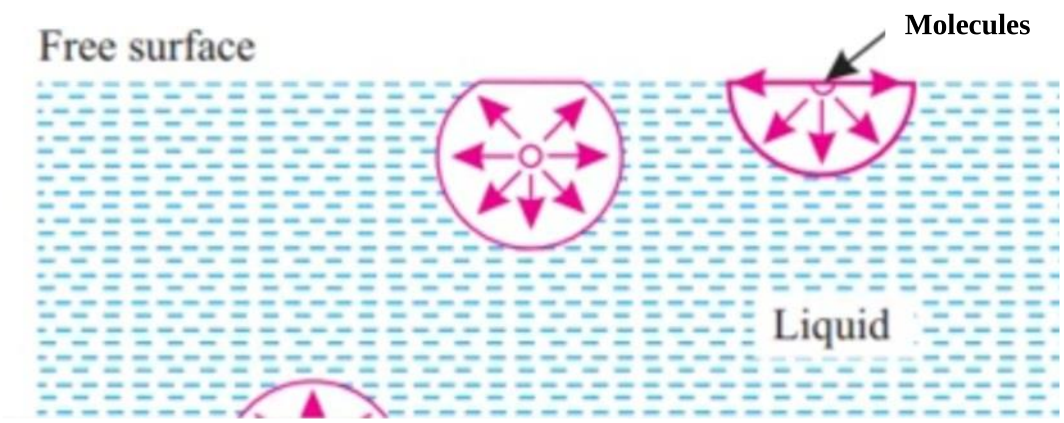


Fig (1) Surface Tension

Some important examples of phenomena of surface tension are follows:

(i) Rain drops (falling rain drop becomes spherical due to cohesion and surface tension).

(ii) Rise of sap in a tree

(iii) Bird can drink water from ponds

(iv) Capillary rise and capillary siphoning

(v) Collection of dust particles on water surface

(vi) Break up of liquid jets

Procedure: -

1. Clean the capillary tube by distilled water and pull the liquid up this capillary tube
2. Immerse the lower end of the capillary tube vertically in the beaker containing the water as shown in fig (2).
3. Measure the height (h) to which the water level rises in the capillary tube above the level of the water in the beaker.
4. Measure the internal diameter of the capillary tube by using a traveling microscope.
5. Repeat all the measurement with the other capillary tubes.

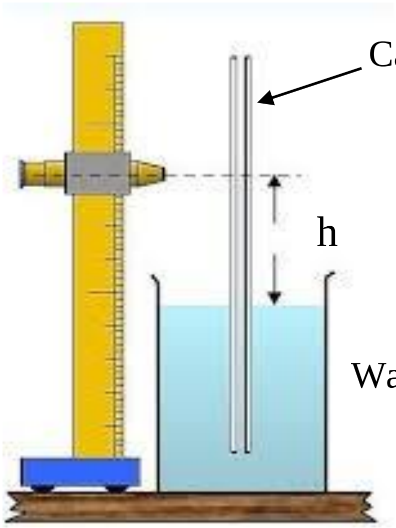


Fig (2) Setup

6. Tabulate the recorded reading as shown in the table below:

	Radius of capillary tube, r (mm)*10^{-3}	Height of water h (mm)*10^{-3}	Surface tension of water Y= 1\2 ($\rho\ g\ r\ h$) = ………….N\m
Tube1			
Tube2			
Tube3			

Note: Surface tension relationship is **Ɣ= 1\2 ($\rho\ g\ r\ h$)**

Where

Ɣ: is the surface tension (N/m).

ρ: the density of water in (kg/m^3).

g: the gravitational acceleration =9.8(m/s^2).

Discussion: -

Q1: What is the reason for the rise of water in the capillary tubes? And if the water is replaced by mercury, what happens? Why?

Q2: What is effect each of: length of capillary tube and temperature on surface tension?

Q3: What is the relation between radius of capillary tube and height of liquid?

Q4: What is the application of surface tension in medicine?