PART – B (Experiments 12 to 18 and Activities 7 to 14)

Experiment No. – 12

Aim of The Experiment: -

To determine Young's Modulus of elasticity of the material of a given wire using Searle's apparatus

Theoretical Concept: -

Searle's apparatus consists of two metallic frames P and Q held together by cross bars B_1 and B_2 as shown in the diagram. The two frames are suspended with the help of two wires W_1 and W_2. W_1 is the wire whose young's modulus is to be calculated and W_2 is the compensating wire.

A spirit level 'S' is mounted between the two frames. On loading the experiment wire increases in length and the metallic frame 'P' moves downward, which alters the position of the bubble which is initially at the centre, to bring the bubble back to the central position, the spherometer screw is moved upwards, the distance through which the screw has to be moved gives the extension of the wire.

$$\text{Young's Modulus (Y)} = \frac{\text{Normal stress}}{\text{Longitudinal strain}} = \frac{F/A}{\Delta l/l} = \frac{F.l}{A\Delta l}$$

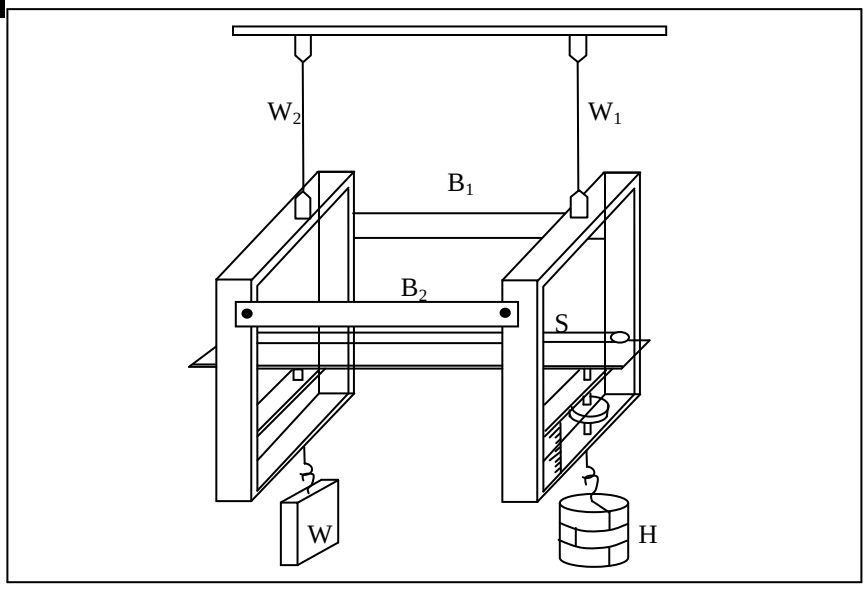
Where 'F' is the force applied, 'l' is the length of wire, 'A' is the area of cross section and 'Δl' is the extension produced in the wire. $F = Mg$, $A = \pi r^2$

Where 'm' is the masses attached,'r' is the radius of cross section of the wire. $Y = \frac{MgL}{\pi r^2 l}$

Apparatus and Material Required: -

Searle's apparatus, a screw gauge, a meter scale, two exactly identical wires, a dead weight of 1 kg and a number of slotted weights each of ½ kg.

Circuit Diagram: -



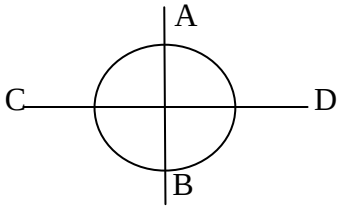
Procedure: -

1) Take two identical wires W_1 and W_2, attach the wire W_1 (experiment wire) to the torsion head of the frame P and wire W_2 (compensating wire) to the torsion head of the frame Q.

2) Measure the length of wire A with the help of metre scale after removing the kinds (the kinds can be removed by pulling the wires lengthwise).
3) To measure the radius of the wire, calculate the pitch and least count of the screw gauge.
4) Calculate the diameter of the wire and radius in two mutually perpendicular directions as we have done in experiment no. 4.
5) To calculate the breaking weight for the material of the wire, note the value of breaking stern, the breaking stress for brass is 3600 kg cm^{-2}, copper is 2800 kg cm^{-2}, iron is 5000 kg cm^{-2} and steel is 8000 kg cm^{-2}.
Breaking weight = breaking stress $\times \pi r^2$, Where 'r' is the calculated radius of the wire.
The experiment wire should not be loaded more than one third of the breaking weight.
6) To measure extension in the wire calculate the pitch and least count of the spherometer.
7) Adjust the screw of the spherometer upwards or downwards so that bubble in the spirit level lies exactly in the centre. Note the micrometer reading.
8) Add a half kilogram weight on the hanger, wait for two minutes so as to allow extension, adjust the screw till the bubble comes in the centre. Note the micrometer reading.
9) Repeat the process by increasing the load on hanger in steps of half kilogram. Note down the micrometer readings.
10) Now start unloading the experimental wire by removing a slotted weight of $1/2$ kg each time and note down the micrometer readings.
11) Calculate the extension in the wire for a load of 2 kg by taking the difference of the spherometer reading for the loads of 2 kg and zero kg, similarly take the loads of 0.5 kg and 2.5 kg. Find the mean of these four values of extension in the wire for a load of 2kg.

Mathematical Analysis & Observations: -

1) Length of the experimental wire (L) = ____ cm.
2) Pitch of the screw gauge = ____ cm.
3) Least count of the screw gauge = ___ cm.
4) Zero error = ___ cm.
5) Zero correction = ____ cm.



" Diameter measurement in mutually perpendicular direction".

Table for the measurement of the diameter of the wire

Diameter	**Observed screw gauge reading (cm)**						
	1	2	3	4	5	6	7
Along AB							
Along CD							

6) Observed mean diameter of the wire = ____ cm.
7) Corrected diameter of the wire (D) = ____cm.
8) Radius of the wire (R) = ____ cm.

Table for calculating the extension

S.No.	**Weight on the hanger in (kg)**	**Micrometer reading**			**Extension of 2 kg (cm)**
		Loading (x)	**Unloading (y)**	**Mean = $\frac{x+y}{2}$**	
1.					
2.					
3.					

4.					
5.					
6.					
7.					
8.					

Mean extension of the wire (l) = ____ cm.

Force F = 2 kg wt = 2× 1000 × 980 dynes

$$Y = \frac{F.L}{\pi r^2 l} = \frac{2\times 1000 \times 980 \text{ dynes}}{\pi r^2 l} = \_\_\_\_\_.$$

Result: -

Observed value of Young's modulus for the given material comes out to be _____ dyne / cm^2.

Precautions: -

1) Before starting the experiment, remove the kinks in the experimental wire completely.
2) The wire should be loaded and unloaded gently.
3) The load should be increased or decreased in equal steps of ½ kg each.
4) Measure the diameter at different places in two mutually perpendicular directions.

Viva – Voce Questions

Q1. What is Young's modulus?

Ans. It is defined as the ratio of normal stress to longitudinal strain. It is denoted by symbol Y.

Q2. State Hooke's Law.

Ans. According to Hooke's law, within elastic limit, stress is directly proportional to strain.

Q3. Why do we take two long and thin wire for determining Young's modulus of the material by Searl's apparatus?

Ans. The longer is the wire, the larger will be the elongation produced in it. The thinner is the wire, the larger will be the stress developed in it for the same load.

Q4. Can the breaking stress of two different steel wires having diameter d_1 and d_2 be different?

Ans. No, breaking stress is fixed for a material, but breaking force will vary, depending on the area of cross-section of the wire.

Q5. What is volumetric strain and volumetric stress?

Ans. Volumetric strain: It is the ratio of change in volume to original volume.

Volumetric stress: It is the restoring force per unit area when the deforming forces produce change in volume of body.

Q6. What is elasticity?

Ans. The property of the matter by virtue of which it regains its original shape and size, when the deforming forces have been removed is called elasticity.

Q7. What are the kinds of modulus of elasticity?

Ans: There are three kinds of modulus of elasticity such as Young's modulus Y, Bulk modulus K and Rigidity modulus η.

Q8. A wire is replaced by another wire of same length and material but of twice diameter. What will be the effect on the maximum load which it can bear?

Ans. The maximum bearable load becomes four times as t5he breaking force is directly proportional to the area of cross-section of the wire.

Experiment No. – 13

Aim of The Experiment: -

To find the force constant of a helical spring by plotting graph between load and extension.

Theoretical Concept: -

A spring has a tendency to regain its original shape due to its property of elasticity. Consider a spring (as shown in the diagram), if this spring is compressed or expended by a length '*l*', then the spring regain its shape due to the restoring force given as

$F_{restoring} \propto l$, $F_{restoring} = -kl$ Where 'k' is the spring constant whose value depends upon the nature of material and length of the spring.

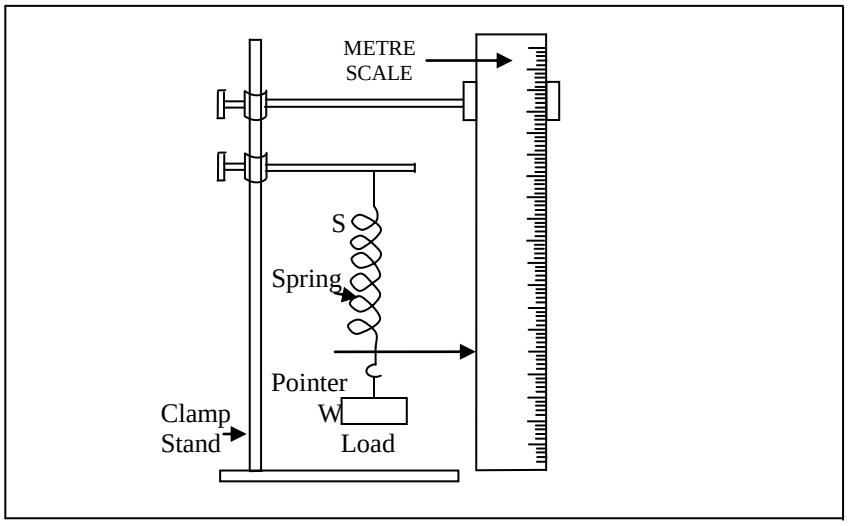
Apparatus & Material Required: -

A helical spring, a pointer, a rigid support, a hanger, a slotted weight and a metre scale.

Procedure: -

1) Suspend the helical spring from a support and attach the pointer P.
2) Make sure that the spring is suspended freely and pointer P does not touch the scale.
3) Without trying any load with the spring, note the reading on the scale. Let it be 'y'.
4) Attach a mass of 50 grams to the spring, wait for a minute so that the extension is complete.
5) Gradually increase the mass suspended from the spring and note the corresponding readings.
6) Similarly gradually decrease the mass and again note down the readings on the scale.
7) Plot a graph between load (along 'X' axis) and extension *l* (along 'Y' axis).

Circuit Diagram: -



Mathematical Analysis & Observations: -

1) Initial reading of the pointer (without load) y = ____ cm.

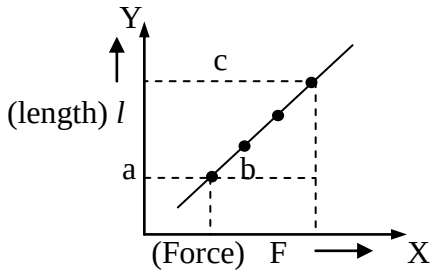
S.No.	Load suspended 'm' in gram wt	Length of the pointer when the spring is			Mean Extension *l*
		Loading (x)	Unloading (y)	Mean (M) = $\frac{x+y}{2}$	
1.	0			M_0 =	

2.	50			M_1 =	$l_1 = M_1 - M_0$
3.	100			M_2 =	$l_2 = M_2 - M_0$
4.	150			M_3 =	$l_3 = M_3 - M_0$
5.	200			M_4 =	$l_4 = M_4 - M_0$
6.	250			M_5 =	$l_5 = M_5 - M_0$

The force constant

$$k = \frac{1}{\text{slope}} = \frac{ab}{bc}$$

= _____ gm wt/ cm



Result: -

The spring constant of given spring comes out to be k = _____ dyne/cm = _____ N/mt.

Precautions: -

1) The spring should be suspended freely and the support from which it is suspended should be rigid one.
2) The oscillatory motion of the spring should be vertical.
3) The amplitude of oscillations should be small.

Viva – Voce Questions

Q.1. What is meant by spring constant and its SI unit?

Ans. The force constant or spring constant is equal to the restoring force produced per unit extension when it is stretched. The SI unit of spring constant is Nm^{-1}.

Q.2. If a weight attached to a spring is slightly pulled and then released, which type of motion does it execute?

Ans. Simple harmonic motion.

Q.3. What do you get from the reciprocal of the slope of load versus extension graph of a loaded spiral spring?

Ans. In the case of a loaded spiral spring, the nature of load versus extension graph is a straight line whose reciprocal of the slope gives the force constant of the spring.

Q.4. What is the energy stored in a spring?

Ans. The energy stored in the spring is $E = \frac{1}{2} kx^2$. Where k is the spring constant.

Q.5. How would the period of spring- mass system change, when it is made taken to moon?

Ans. No, because time period of loaded spring does not depend upon the acceleration due to gravity but depends upon the mass attached and spring constant of the spring.

Q.6. There are two springs, one solute and another delicate one. For which spring, the frequency of oscillator will be more?

Ans. We have, $v = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$

If solute spring is loaded with weight mg, then extension 1 will be lesser and accordingly frequency of oscillation will be more.

Q.7. What is the conservative force?

Ans. A force is said to conservative when the work done by the force or against the force does not depend upon the path followed by the body, but depends only on the initial and final positions of the body.

Experiment No. – 14

Aim of The Experiment: -

To study the variation in volume with pressure for a sample of air at constant temperature by plotting graphs between P and V, and between P and I/V.

Theoretical Concept: -

According to boyle's law, temperature remaining constant, the pressure (P) of a given mass of a gas is inversely proportional to its volume (V).

i.e $P \propto \frac{1}{V}$ or PV = constant

If we consider a tube having length '*l*' and area of cross section 'a' enclosing the given mass of a gas, then the volume V of the enclosed mass becomes

$$V = al$$

Substituting the value of 'V'

$$Pal = \text{constant}$$

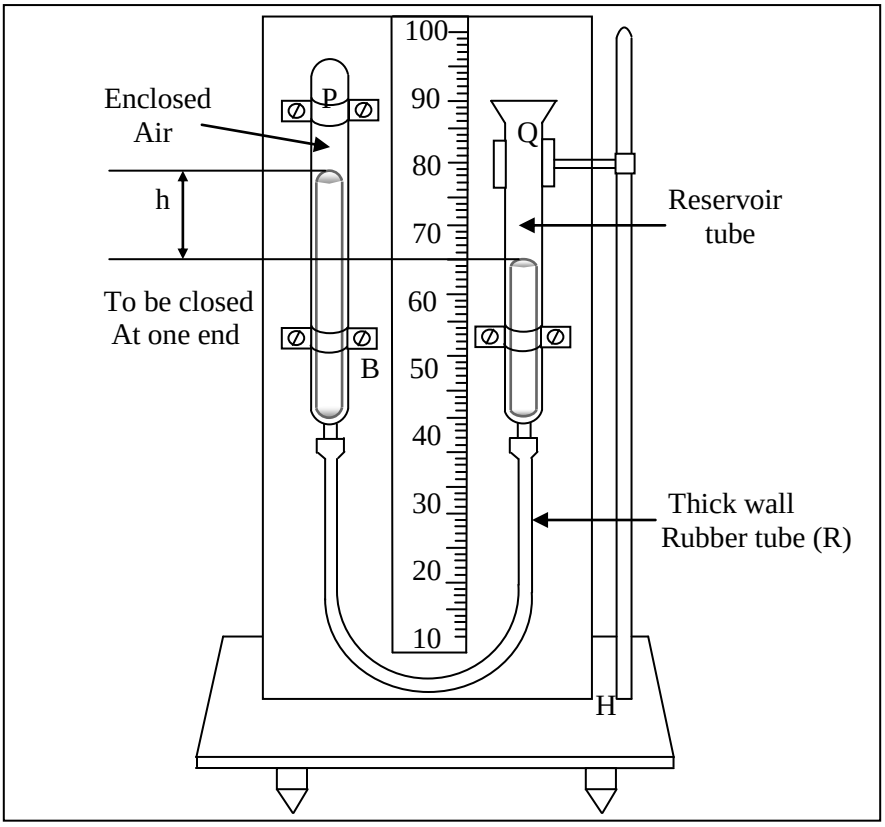
$$Pl = \frac{\text{Constant}}{a} = K \text{ (another constant)} \quad , \quad P \propto \frac{1}{l}$$

Thus if the temperature remains constant, graph between P and 1/*l* should be a straight line.

Apparatus and Material Required:-

Boyle's law apparatus, a pair of set squares, plumb line, mercury, thermometer and forten's barometer.

Circuit Diagram: -



Procedure: -

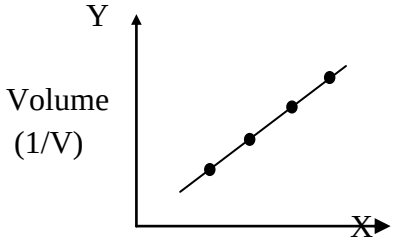
1) Set the apparatus vertical by means of leveling screws fitted at the base and check the vertical of the apparatus by using a plumb line.
2) Note the lab room temperature with the help of thermometer.
3) Adjust the movable tube so that the mercury stands at the same level in both the tubes.
4) Take the reading of the closed end of the tube by a set square setting its one edge parallel to the scale and the other tangential to the curved end.
5) Lower the reservoir 'Q' gradually till the mercury surface in 'P' is near the bottom of the tube. Now the pressure is less then atmospheric pressure by an amount equal to the difference in two mercury levels.
6) Similarly place the reservoir 'Q' at different levels by raising it through a few cm each time and note the level of mercury in 'P' and 'Q' and take at least 5 sets of observation.
7) Calculate the pressure by taking the difference of mercury column in open and closed tubes.
8) Calculate the volume of air column by taking the difference between the reading corresponding to the closed end and the mercury column.
9) Measure the room temperature to check that it remains the same or not.
10) Evaluate the value (1/V) and plot a graph between (P) along 'X' axis and (I/V) along 'Y' axis.
11) The graph shows a linear relationship.
12) Plot a graph between (P) pressure and (V) volume which comes out to be a rectangular hyperbola.

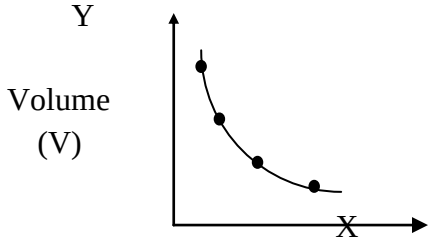
Mathematical Analysis & Observations: -

Table for measurement of pressure (P) and volume (V) of the air.

S.No	Mercury (Hg) level reading		Pressure difference (P – Q) cm	Volume of sir V cm^3	1/V
	Closed tube (P)	Open tube (Q)			
1.					
2.					
3.					
4.					
5.					

The graph between 'P' and '1/V' comes out to be a straight line.





The graph between 'P' and 'V' comes out to be a rectangular hyperbola.

Result: -

1) The graph between 'P' and '1/V' comes out to be a straight line.
2) The graph between 'P' and 'V' comes out to be a rectangular hyperbola.

Precautions: -

1) Boyle's law apparatus should be vertical.
2) After changing the position of the tube, wit for some time before taking the reading.
3) In the Boyle's law apparatus pure and dry mercury should be used.
4) There should be no source of heat in the neighborhood since that is likely to change the room temperature and room temperature should be kept constant.

Viva – Voce Questions

Q1. State Boyle's law.

Ans. It states that the temperature remaining constant, the volume of a given mass of a gas is inversely proportional to the pressure. It is called Boyle's law.

Mathematically, if temperature of the gas is constant, then $V \propto \frac{1}{P} \Rightarrow V = \text{constant}$

Q2. Do all the gases obey Boyle's law?

Ans. No, only perfect gases obey Boyle's law. Strictly speaking, there is no gas, which obeys this law perfectly over all ranges of pressure and temperature.

Q3. What is the use of a barometer?

Ans. A barometer is used for the determination of atmospheric pressure.

Q4. Why do we apply end correction for volume of air in the closed tube?

Ans. The tube enclosing the air is not of uniform bore near its closed end. It is hemispherical in shape at the closed end. The volume of this round portion is $2/3^{rd}$ of the volume, had it been of uniform bore like the rest of the tube.

Q5. How can a mercury barometer be used in making weather forecast?

Ans. 1.A sudden fall in the mercury column indicates the sign of an upcoming storm. It is because, the atmospheric pressure decreases suddenly during a storm.

2. A gradual fall in the mercury column indicates the sign of an upcoming rain. It is because, the amount of water vapour in the atmosphere goes on increasing, before it rains.

Q6. What is meant by a perfect gas?

Ans. A gas, which obeys the gas laws (Boyle's law, Charles law, etc) perfectly over all ranges of temperature and pressure, is called a perfect gas. Dry oxygen, hydrogen and nitrogen are nearly perfect gases.

Q7. Write down perfect gas equation.

Ans. PV = nRT, for n moles of gas, where R is the universal gas constant.

Q8. What is the isothermal process?

Ans. A process in which the changes in pressure and volume of a given mass of gas take place at constant temperature.

Q9. What is atmospheric pressure?

Ans. The earth has got an envelope of air extending up to a few thousand kilometers. Due to its weight, the air exerts pressure. The force exerted per unit area by the atmosphere is called atmospheric pressure.

Q10. Does the atmospheric pressure change as we go up the surface of earth?

Ans. The density of air decreases as we go up and likewise the atmospheric pressure also goes on decreasing.

Q11. Why sometimes soda bottles explode during summer?

Ans. During summer, pressure of the gas inside increases enormously due to rise of temperature and the soda bottle, which cannot withstand such high pressure, explodes.

Experiment No. – 15

Aim of The Experiment: -

To determine the surface tension of water by capillary rise method.

Theoretical Concept: -

Surface Tension: The property of the free surface of a liquid by which it acts as a stretched membrane to attain the minimum possible surface area. A tube of small diameter is known as capillary tube and rise and fall of a liquid in the capillary tube is known as capillarity.

According to the ascent formula, height attained by the liquid $h = \frac{2T\cos\theta}{r\rho g}$ Where 'θ' is the angle of constant, 'T' is the surface tension of liquid, 'r' is the radius of the tube, 'ρ' is the density of the liquid and 'g' is the acceleration due to gravity.

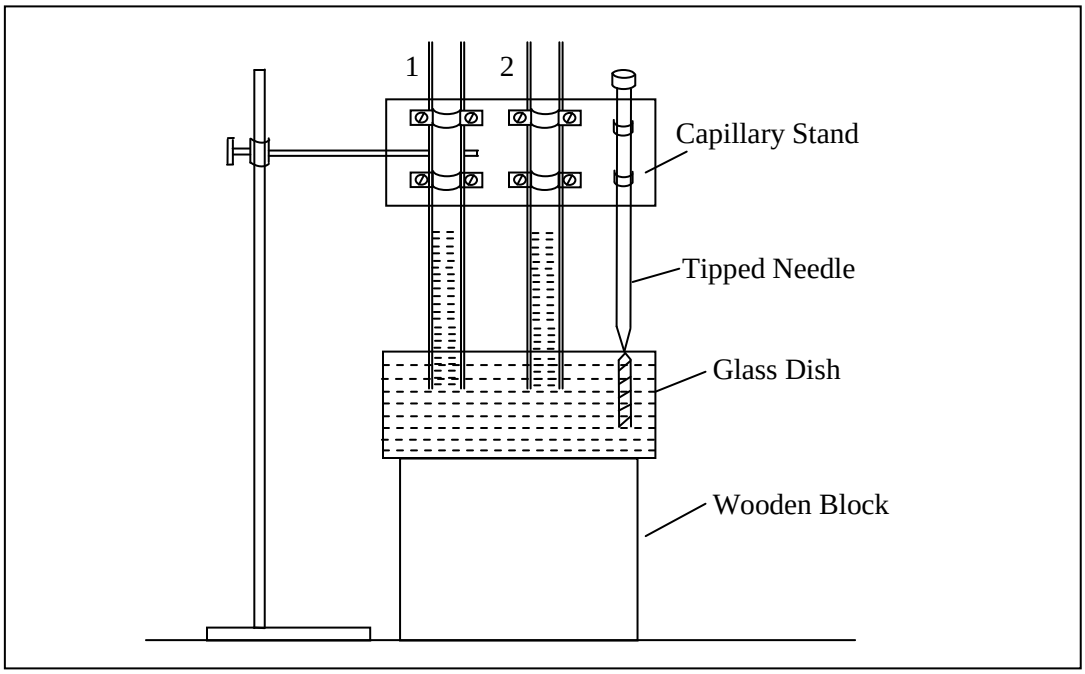
The surface tension of water, $T = \frac{r\,(h+\frac{r}{3})\rho g}{2\cos\theta}$

Where letters have their usual meanings.

Apparatus & Material Required: -

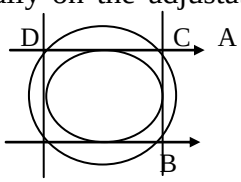
A raveling microscope, two capillary tube of narrow and uniform bore, clamp stand, a glass dish, a wooden block stand for the glass dish and a thermometer.

Circuit Diagram: -



Procedure: -

1) To calculate radius of the capillary tube, place the capillary tube horizontally on the adjustable table and focus the microscope on one end of the tube.
2) Take two readings on the vertical scale with the horizontal cross wire first touching upper end A and then lower end B. Difference of these readings will give the diameter of the tube.



3) Similarly take two readings for the horizontal diameter along C and D, the difference of the readings will give the value of horizontal diameter of the table.
4) Note down the readings and calculate the mean value of the diameter and radius of the tube.
5) To calculate the height of the water rising in the tubes, mount the tubes in the capillary stand and hold the capillary stand in the clamp stand.
6) Place the glass dish on the wooden block and fill it with water. Lower the capillary tubes, so that they dip in the water, adjust the height of the needle. So that its tip just touches the surface of water as shown in the diagram.
7) Set the microscope tube in the horizontal position and direct the microscope on the capillary tube and focus it by removing parallax between the cross wire and image of water column in the capillary tube.
8) Lower the microscope so as to focus it on the free pointed end of the needle and note the reading of the microscope on the vertical scale, let it be 'x'.
9) Set the horizontal cross wire tangential to the meniscus of the water and note the position of the microscope tube 'y' on the vertical scale.
10) Difference of the readings i.e (y-x) gives the height to which the water rises in the first capillary tube.
11) Similarly repeat the above steps for the second capillary tube and note down the readings.
12) Note the temperature of the water in the glass dish.
13) Substitute the calculated values in the relation.

$$T = \frac{r(h+\frac{r}{3})\rho g}{2cos\theta}$$ ('θ' is very small so value of cosθ = 1)

$$T = \frac{r(h+\frac{r}{3})\rho g}{2}$$

Mathematical Analysis & Observations: -

1) Temperature of the water in the glass t = _____ ˚C.
2) Density of water at t˚C, ρ = ____ g cm^{-1}.
3) Angle of constant (θ) cos $\theta \approx 1$.

Measurement of the radius of the tubes (r)

S. No	Microscope reading (cm) A	B	C	D	AB (cm)	CD (cm)	Mean diameter D = $\frac{AB+CD}{2}$ = ___ cm.	Radius (r) = $\frac{D}{2}$ = ___ cm

Measurement of h (height of capillary tube)

S.No	Reading of water level in capillary tube (y cm)	Reading of tip of needle (x cm)	Height h = (y - x) cm

4) Mean value of r = _____cm.
5) Mean value of h = _____ cm.
6) Surface tension of water T = ____ dynes/cm.

Result: -

Surface tension of water at room temperature comes out to be _____ dynes/cm.

Precautions: -

1) The capillary tubes and the water used should be free from grease and dirt.
2) The internal diameters of the capillary tubes should be noted in two mutually perpendicular directions.
3) The capillary tube used should be perfectly vertical.
4) The tip of the needle should just touch the solution surface.
5) The temperature of the water should be noted carefully.

Viva – Voce Questions

Q.1. Define surface tension?
Ans. It is the property of a liquid by virtue of which, it behaves like an elastic stretched membrane with a tendency to contract, so as to occupy a minimum surface area.
Q.2. What is the S.I unit of surface tension?
Ans. The SI unit of surface tension is Nm^{-1}.
Q.3. What is the angle of contact?
Ans. The angle between the tangent of liquid surface and the solid surface inside the liquid is known as angle of contact.
Q.4. Is there any other way of defining surface tension?
Ans. Surface tension of a liquid is numerically equal to the amount of mechanical work done in enlarging the surface of liquid by unit amount under isothermal condition.
Q.5. What will happen if the length of the capillary tube is less than the height to which water is expected to rise?
Ans. The height, to which water rises, depends upon the radius of the curvature of the meniscus. If the tube is of insufficient length, the water rises to the top of the tube and forms a surface with a new radius of curvature (R'), such that R' and H (length of the capillary tube) remains constant and equilibrium is maintained.
Q.6. Why is flux used for soldering?
Ans. The addition of flux reduces the surface tension of molten tin, hence it spreads easily thereby making the soldering faster.
Q.7. What are the limitations of this method of determination of surface tension of water?
Ans. (i) Perfectly clean and uniformly-bored capillary tube availability is difficult.
(ii) Assumption that the angle of content is zero and the meniscus is spherical, are not fully justified.
(iii) Variation of surface tension with temperature cannot be studied by this method.
Q.8. Why should the tubes be vertical?
Ans. If the tube is inclined, the meniscus will become elliptical and thus the liquid rises to a small height and the formula does not hold good.

Experiment No. – 16

Aim of The Experiment: -

To determine the coefficient of viscosity of glycerine by plotting the graph between terminal velocity and square of the radius of steel balls (spherical bodies).

Theoretical Concept: -

According to stokes law, where a spherical body falls through a viscous fluid, it experiences a viscous force and the magnitude of this force increases with increases in the velocity falling under the action of its weight, after some time the viscous force balances the driving force and it starts moving with a constant velocity known as the terminal velocity of the body.

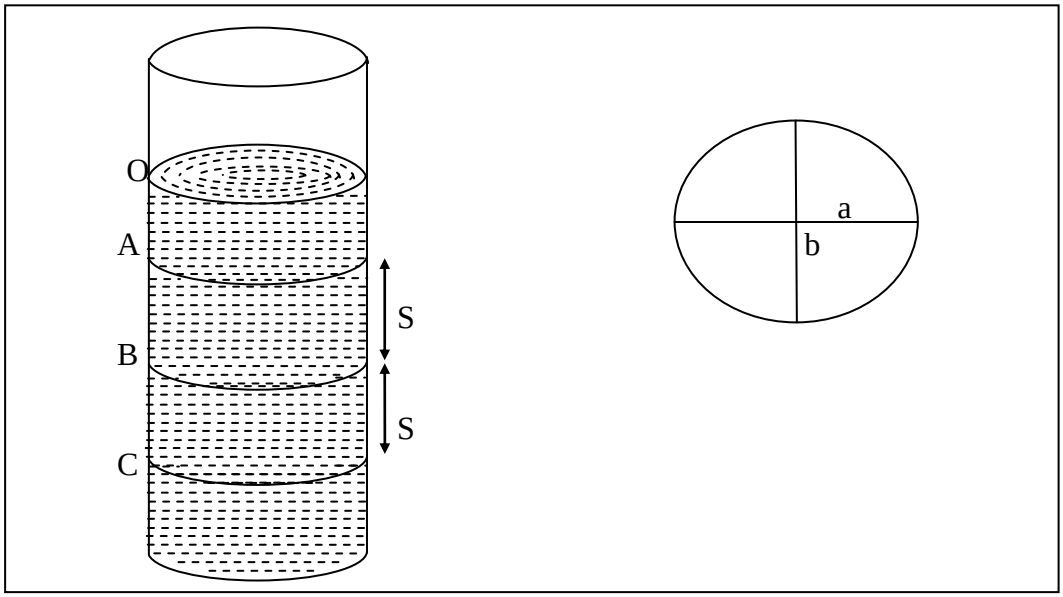
Terminal velocity (V) = $\frac{2r^2(\rho-\sigma)g}{9\eta}$

Where 'r' is the radius of the steel ball , 'ρ' is the density of the steel ball ,'σ' is the density of the liquid , 'η' is the coefficient of viscosity of liquid , 'g' is the acceleration due to gravity.

Apparatus & Material Required: -

A graduated cylinder of about 80 cm in height, a rubber cork, a stop watch, a thermometer, glycerine, screw gauge, a steel ball and a stop watch.

Circuit Diagram: -



Procedure: -

1) To calculate the pitch and least count of the screw gauge proceed as we have done in experiment No. 4.
2) Calculate the diameter of the ball in the mutually perpendicular directions, find the mean diameter and mean radius of the ball.
3) To calculate the terminal velocity attained by the steel ball, fill the cylinder with glycerine (the liquid whose coefficient of viscosity is to be calculated).
4) Note the temperature of the glycerine in the beginning of the experiment.

5) Tie three cotton thread loops, A, B, and C along the height of the cylinder as shown in the diagram.
6) Make sure that the distances between A and B, B and C are equal, let it be 'x'.
7) Drop a steel ball gently into the cylinder with glycerine solution and with the help of the stop watch note down the time when the ball covers a distance AB, lets the time comes out to be t_{AB}.
8) Similarly calculate the time 't_{BC}' , within the limits of experimental error 't_{AB}' and 't_{BC}' will be formed to be equal.
9) Calculate the mean of the two time intervals $t = \frac{t_{AB}+t_{BC}}{2}$
10) Calculate the terminal velocity of the steel ball using the relation $V = \frac{x}{t}$. Where 'V' is the terminal velocity, 'x' is the distance between AB & BC and 't' is the mean time calculated.
11) Repeat the above steps and take at least five different readings for terminal velocity.
12) Note the temperature of the glycerine at the end of the experiment.
13) Note the density of steel ball from the table and plot a graph between r^2 and V, it will be a straight line.

Mathematical Analysis & Observations: -

Table to find the radius of the steel ball:

1) Pitch of the screw gauge = _____ cm.
2) Least count of the screw gauge = _____ cm.

S.No	Diameter of the steel ball		Mean observed diameter $d_1 = \frac{d+d'}{2}$	Radius of the steel ball $r = \frac{d_1}{2}$	r^2
	One direction (d)	Mutually Perpendicular direction (d')			
1.					
2.					
3.					
4.					
5.					

Final mean radius of the steel ball comes out to be _____ cm.

Table to find the terminal velocity of the steel ball

1) Temperature of the glycerine = _____ ˚C.
2) Density of glycerine at this temperature (σ) = ____ gcm^{-3}.
3) Density of steel (ρ) = ____ $g\ cm^{-3}$.

S.No	Time taken by the steel ball to fall through		Mean time taken by the steel ball $t = \frac{t_{AB}+t_{BC}}{2}$ (s)	Terminal velocity attained by the steel ball $V = \frac{x}{t}$ ($cm\ s^{-1}$)
	Depth AB t_{AB}	Depth BC t_{BC}		
1.				
2.				
3.				
4.				
5.				

Slope of 'r^2' versus 'v' graph comes out to be _____.

Coefficient of viscosity of glycerine:

$\eta = \frac{2(\rho-\sigma)g}{9} \cdot \frac{r^2}{V}$ Where $'\rho'$ is the density of steel and $'\sigma'$ is the density of glycerine.

Result: -

The coefficient of viscosity of glycerine at t˚C = _____ poise.

Precautions: -

1) The steel ball should be dropped gently into liquid.
2) The diameter of the steel ball should be measured in two mutually perpendicular directions.
3) The steel ball used should be perfectly spherical.

Viva - Voce Questions

Q.1. What is viscosity? What is it due to?

Ans. The property of liquids, by virtue of which the relative motion between different layers of a liquid is opposed, is called viscosity.

The viscosity of a liquid is due to the cohesive force between the molecules.

Q.2. Define coefficient of viscosity.

Ans. The coefficient of viscosity of a liquid is the tangential force per unit area required to maintain a unit velocity gradient between its two parallel layers.

Q.3. What is terminal velocity?

Ans. The maximum constant velocity acquired by the body while falling freely in a viscous medium, is called terminal velocity.

Q.4. Why are steel balls wetted in viscous liquid before being dropped into it?

Ans. It avoids the formation of air bubble around the surface of the steel balls.

Q.5. Define Stoke's law.

Ans. The backward dragging force acting on a small sphere of radius (R), moving with uniform velocity (v), through a viscous medium of coefficient of viscosity η, it experiences an opposite force (F)

which is given by $F = 6\pi\eta r v$ is known as Stoke's Law.

Q.6. What are the limitation of stokes' law?

Ans. Stokes' law applies, when the following conditions are obeyed:

1. The viscous medium, through which the body falls, extends infinitely.
2. The spherical body is perfectly rigid and smooth.
3. The medium is homogeneous.
4. There is no slip between the body and the medium.
5. No eddy currents are set up in the liquid due to motion of the body through it.

Q.7. When water and honey are dropped out of a tube separately, the honey comes out later than water. Why?

Ans. Because, the coefficient of viscosity of honey is very large as compared to the coefficient of viscosity of water.

Q.8. Why a glass cylinder of large length is used in experiment?

Ans. We prefer a glass cylinder, because Stoke's law is applicable only when the body is falling in a viscous medium of infinite extent.

Q.9. Why liquid taken should be transparent?

Ans. It is so because the motion of the ball should be visible in liquid.

Experiment No. – 17

Aim of The Experiment: -

To study the relationship between the temperature of a hot body and time by plotting a cooling curve.

Theoretical Concept: -

According to Newton's law of cooling, the rate of loss of heat from a body is directly proportional to the difference of temperature of the body and its surroundings.

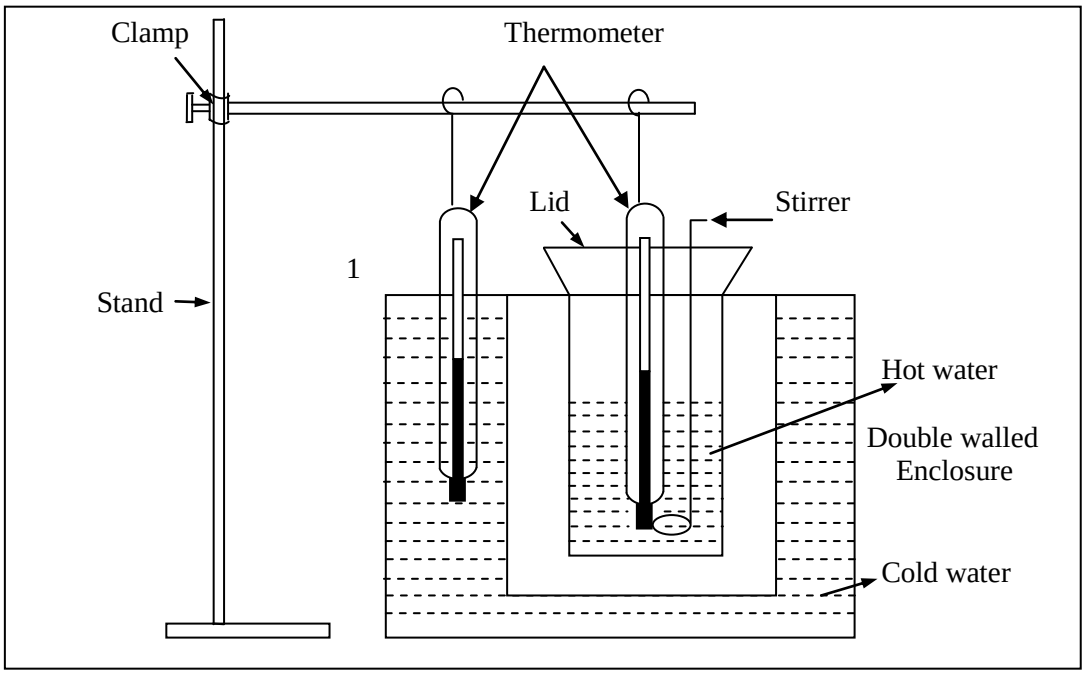
Rate of cooling, $\frac{dQ}{dt} \propto (\theta - \theta_0) \quad \Rightarrow \quad \frac{dQ}{dt} = -k(\theta - \theta_0)$

Where $'\frac{dQ}{dt}'$ is the rate of loss of heat, 'k' is the proportionality constant, 'θ' is the temperature of the hot liquid and $'\theta_0'$ is the temperature of the surroundings. Thus, $\frac{dQ}{dt} \propto (\theta - \theta_0)$

Apparatus and Material Required: -

Newton's law of cooling apparatus, two Celsius thermometers, a stop watch, a stirrer, a heater, a beaker and clamp stand.

Circuit Diagram: -



Procedure: -

1) Clean the Newton's law of cooling apparatus and place it gently on the table.
2) Fill the space between double walls with normal water which will act as surroundings at constant temperature θ_0.
3) Fill the two-third volume of calorimeter with water heated to about 60˚C.
4) Note the temperature of water in the double walled enclosed, it will give you the temperature of the surroundings i.e θ_0.
5) Note the temperature of hot water (θ) and simultaneously start the stop watch.

6) Gently stir the hot water and note the reading of temperature for the hot water after every two minutes.
7) Stop taking the readings when the temperature difference between hot body and surroundings becomes very less.
8) Record all the observation and plot a graph between time 't' and log $(\theta - \theta_0)$ by taking time 't' along 'X' axis and log $(\theta - \theta_0)$ along 'Y' axis.

Mathematical Analysis & Observations: -

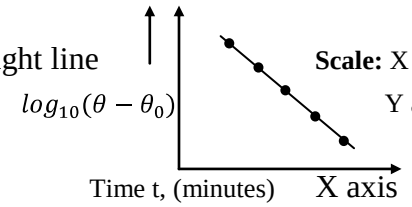
1) Temperature of surroundings θ_0= ____ ˚C

Table for cooling of water with time

S.No	Time (t)	Temperature of hot water (θ˚C)	Temperature difference $(\theta - \theta_0)$˚C	$log_{10}(\theta - \theta_0)$

Result: -

The graph between time (t) and $log_{10}(\theta - \theta_0)$ is a straight line which verifies Newton's law of cooling.



Scale: X axis, 1cm = ___min
Y axis, 1 cm = ____

Precautions: -

1) Stirring of water should be constant and gentle.
2) The lid (covering) must be tight otherwise some water may evaporate during the experiment.
3) The thermometers should be accurate.
4) The thermometers should not touch the walls of calorimeter or double walled vessel.

Viva - Voce Questions

Q1. State Newton's law of cooling.

Ans. The rate of cooling of a body is directly proportional to temperature difference between the body and the surroundings, provided the temperature difference is small.

Q2. State Stefan's law of radiation.

Ans. The total radiant energy emitted per second from unit surface area of a black body is directly proportional to the fourth power of absolute temperature.

Q3. Why do we fill water in the space between the walls of the double walled vessel?

Ans. It keeps the temperature of the surroundings of the hot liquid uniform.

Q4. Why is the outer surface of the calorimeter made dull and black?

Ans. A dull and black surface is good radiator of heat. It makes the rate of cooling of the hot liquid faster.

Q5. Is the statements true for all differences of temperature between the body lasting heat and that of its surroundings?

Ans. No, it holds good only when the difference in temperature is small, in the range (20˚C - 30˚C)

Experiment No. – 18

Aim of The Experiment: -

To determine the specific heat of a metallic solid or given liquid by method of mixtures.

Theoretical Concept: -

According to the concept of calorimetry, the heat lost by the hotter body is equal to the amount of heat gained by colder body.

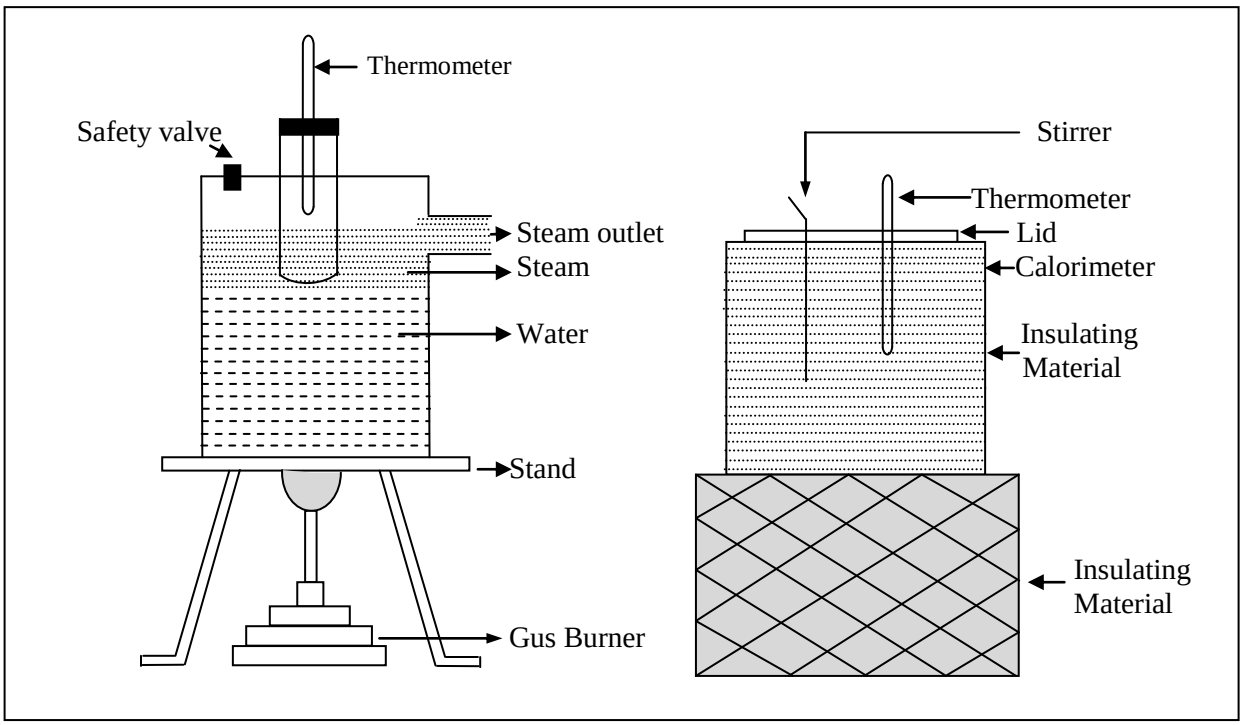
$Q = mst$ (where's' is the specific heat of the material of the body.)

$S = Q/mt$ (where 'm' is the mass of the body and't' is the time taken for heat transfer.)

Apparatus & Material Required: -

Calorimeter with stirrer, steam bath, thermometer, a hypsometer, the given solid or liquid, wooden block, gas burner and clamp stands.

Circuit Diagram: -



Procedure: -

1) Calculate the mass of calorimeter with stirrer (m_1).
2) Fill about one third of the calorimeter with water and calculate the mass of calorimeter and water (m_2).
3) Heat the given solid in a steam bath, boil the water and allow the solid to attain steady state as shown in the diagram.
4) Note the temperature when it remains constant for at least five minutes.

5) Stir the hot water in calorimeter and record its temperature. Immediately transfer the solid from the steam bath to the calorimeter and stir well. Record the constant final temperature of the mixture.
6) Weigh the calorimeter again and calculate the specific heat capacity of the given solid from the observations using the principle of calorimetry.
7) To calculate the specific heat of liquids instead of the solid and repeat the above mentioned steps.

Mathematical Analysis & Observations: -

1) Mass of calorimeter and stirrer (m_1) = ___ gm = ____ kg.
2) Mass of calorimeter and water (m_2) = ___ gm = ____ kg.
3) Initial temperature of calorimeter and water t_1 = _____˚C.
4) Initial temperature of hot solid t_2 = _____˚C.
5) Final temperature of mixture t_2 = _____˚C.
6) Mass of calorimeter and water + solid (m_3) = ____ gm = ____ kg.
7) Specific heat of the given solid = x
8) Specific heat of water = S = 4.2×10^3 $Jkg^{-1}K^{-1}$
9) Specific heat of calorimeter + stirrer = S_1= 0.386×10^3 $J\ kg^{-1}K^{-1}$ (for copper).
10) Heat lost by the solid = $(m_3 - m_2)$. x $(t_2 - t_3)$
11) Heat gained by the calorimeter + water = $m_1S_1\ (t_2 - t_1) + (\ m_2 - m_1).\ S\ (t_3 - t_1)$

$= [\ m_1S_1 + (m_2 - m_1)\ S].\ (t_3 - t_1)$

By using principle of calorimetry

Heat gained = Heat lost

$[\ m_1S_1 + (m_2 - m_1)\ S].\ (t_3 - t_1) = (m_3 - m_2).\ x\ (t_2 - t_3)$

$$x = \frac{[\ m1S1 + (m2 - m1)\ S].(t3 - t1)}{(m3 - m2).(t2 - t3)} = \_\_\_\_\_\ J\ kg^{-1}C^{-1}.$$

Result: -

The specific heat of the given solid comes out to be _____ $J\ kg^{-1}C^{-1}$.

Precautions: -

1) The calorimeter should be insulated so that nearly negligible loss of heat radiations.
2) The calorimeter should not touch the walls of the double walled vessel.
3) The initial temperature of the hot water should be carefully recorded.

Viva – Voce Questions

Q.1. Define specific heat?

Ans. It is defined as the amount of heat required by the unit mass of substance for 1˚C rise of temperature.

Q.2. State the principle of calorimetry.

Ans. The principle of calorimetry states that whenever substances at different temperatures are mixed so as to exchange heat, heat lost = heat gained

Q.3. Why are steam-burns more severe than those of boiling water?

Ans. Each gram of steam contains an extra 539 calories of heat.

Q.4. Is specific heat a constant quantity?

Ans. No, the specific heat of a substance changes with temperature.

Experiment No. – 19

Aim of The Experiment: -

To study the relation between the frequency and length of a given wire under constant tension using sonometer.

Theoretical Concept: -

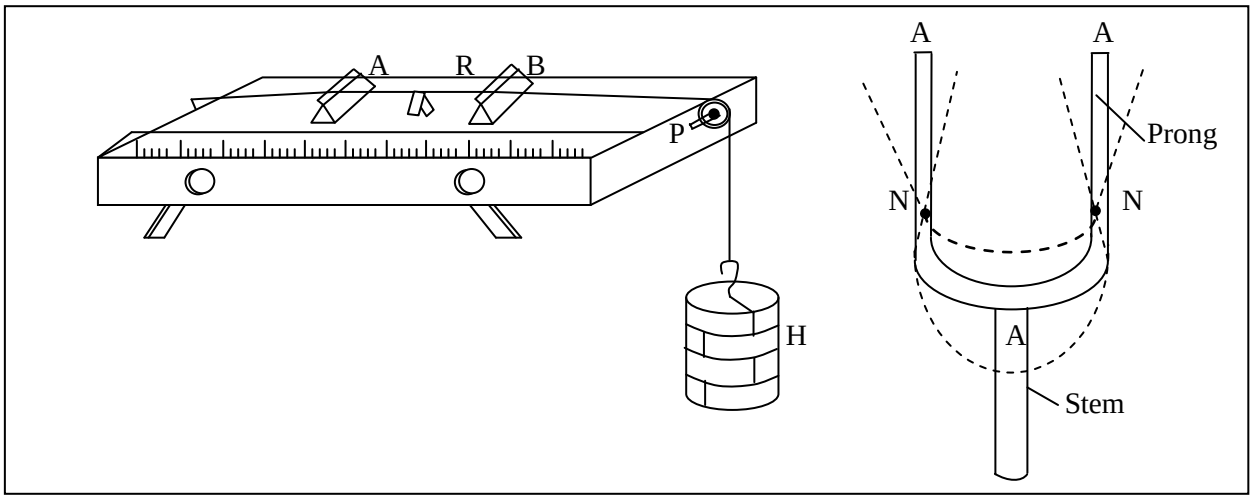
Sonometer consists of a hollow wooden box, called the sounding box of the sonometer; it has a small hook fixed at one end of its top and a frictionless pulley at the other end. Sonometer is used to study the vibrations produced by the vibrating string. $v = \frac{1}{2l}\sqrt{\frac{T}{m}}$ Where 'v' is the frequency of the vibrating string, 'l' is the length of the string, 'T' is the tension in the string and 'm' is the mass per unit length of wire.

For a given wire if 'T' and 'm' are kept constant then $v \propto \frac{1}{l}$ i.e. $vl =$ constant. Hence, a graph between 'v' and '$\frac{1}{l}$' is a straight line.

Apparatus & Material Required: -

A sonometer, hanger and slotted weights, a set of five tuning forks of different frequencies, a metre scale, rubber pad & a weight box.

Circuit Diagram: -



Procedure: -

1) Place the sonometer on the table and its pulley.
2) Make sure that the pulley in use is a frictionless pulley.
3) Bring the bridges close to each other and place the rider at the centre of the wire between the bridges.
4) Note the tension 'T' in the string; it is equal to the load attached to the string.
5) Take the first tuning fork of frequency 'v_1', set it into vibrations by sticking against the rubber pad and press its stem gently against the top of the sonometer.
6) Go on increasing the distance between the knife edges gradually till the rider flies off the string.
   When the rider flies off the string, note the length of the string between the two knife edges, it is the resonant length of the string for tuning fork of frequency v_1.

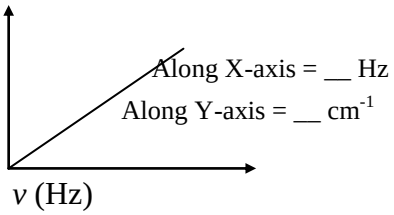
7) Calculate the mean of frequencies calculated by increasing and decreasing lengths and note all the observations.
8) Plot a graph between v (along 'X' axis) and $\frac{1}{l}$ (along 'Y' axis). It will be a straight line as shown in the graph.

Mathematical Analysis & Observations: -

S.No	Frequency of the tuning fork	Resonant length of the string when distance between knife edges is			$\frac{1}{l}$ (cm^{-1})	*vl*
		Increased	decreased	Mean		
1.	V_1 = _____ Hz					
2.	V_2 = _____ Hz					
3.	V_3 = _____ Hz					
4.	V_4 = _____ Hz					
5.	V_5 = _____ Hz					

Result: -

The product of frequency (v) and length (l) comes out to be constant and the graph between *'v'* and *'1/l'* is a straight line.



Precautions: -

1) The string should be free from kinks.
2) The pulley should be frictionless.
3) The stem of the tuning fork should be gently pressed against the top of the sonometer.
4) The string should be of uniform area of cross section.

Viva - Voce Questions

Q1. What are nodes and antinodes?

Ans. Nodes: These are points of maximum strain and minimum displacement.

Antinodes: These are points of maximum displacement and minimum strain.

Q2. What is meant by resonance?

Ans. Resonance is a phenomenon of setting a body into vibrations with the help of another body vibrating with the same frequency.

Q3. Can sound be propagated through vacuum?

Ans. No, sound always requires a material medium for its propagation.

Q4. What is sonometer?

Ans. Sonometer consists of a hollow wooden box, having some holes. Box carries two fixed bridges and a movable bridge. One end of a metallic wire is tied to a look and the other end passes over a pulley and carries a weight placed in a hanger.

Q5. What is the function of the bridges placed on the board of the sonometer?

Ans. The reflection of sound waves in the wire takes place at the two bridges and hence stationary waves are formed between them. These bridges also determine the position of the nodes.

Experiment No. – 20

Aim of The Experiment: -

To study the relation between the length of a given wire and tension for constant frequency using sonometer.

Theoretical Concept: -

If a stretched wire (string) of sonometer is set into vibrations then the frequency of the fundamental note is given as $v = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ Where 'T' is the tension in the wire, 'μ' is the mass per unit length and 'l' is the length of the vibrating wire.

If 'v' and 'm' are constants then $\frac{\sqrt{T}}{l} = \text{constant}$

i.e $\frac{T}{l^2} = \text{constant}$

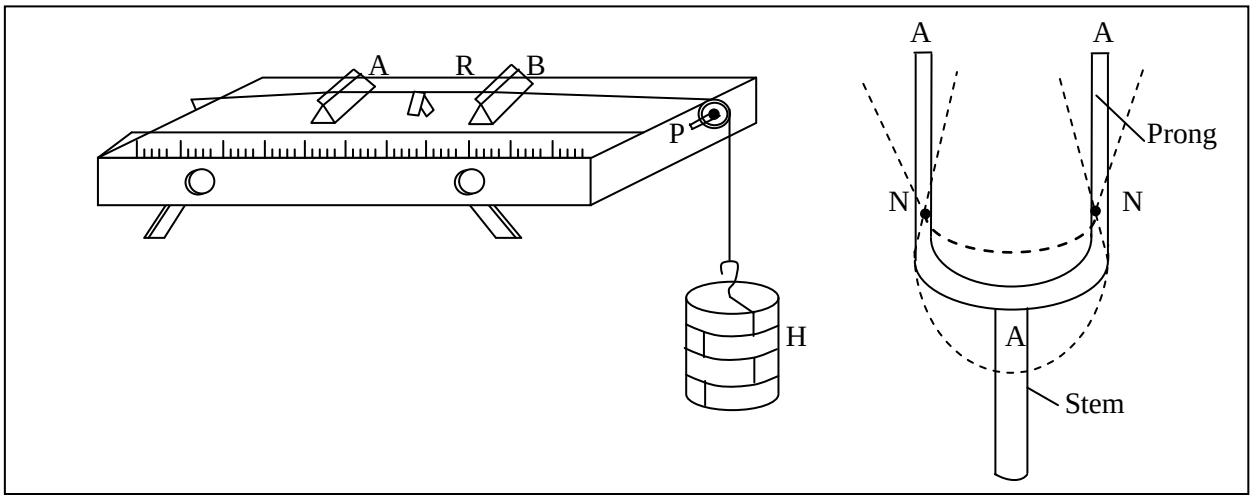
$T \propto l^2$

Thus the graph between 'T' and 'l^2' should be a straight line.

Apparatus & Material Required: -

A sonometer, hanger and slotted weights, A set of five tuning forks of different frequencies, a metre scale, rubber pad and weight box.

Circuit Diagram: -



Procedure: -

1) Set the sonometer on the table as shown in the diagram and make sure that the pulley is frictionless.
2) Note the tension 'T' in the string, it is equal to the load attached to the string.
3) Take the first tuning fork of frequency 'v_1', set it into vibrations by striking against the rubber pad and press its stem gently against the top of the sonometer.
4) Go on increasing the distance between the knife edges till the rider flies off the string. Note down the length of the string between two knife edges.

5) Similarly go on decreasing the distance between the knife edges till the rider flies off and note down the readings.
6) Calculate the mean of the two resonant lengths determined by increasing and decreasing the distance between the knife edges.
7) Find the values of $\frac{l_1^2}{T_1}, \frac{l_2^2}{T_2}, \frac{l_3^2}{T_3}$ and $\frac{l_4^2}{T_4}$ which will come out to be equal.
8) Plot a graph between T (along X axis) and l^2 (along Y axis). It will be a straight line.

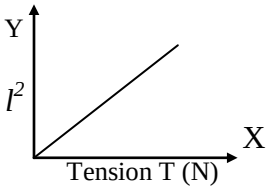
Mathematical Analysis & Observations: -

1) Frequency of the given tuning fork, v =____ Hz.

S.No	Load attached to the string M(kg)	Tension in the string T =Mg	Resonant length of the string, when the distance between the knife edges is			l^2	$\frac{l^2}{T}$
			Increased	decreased	Mean		
1.							
2.							
3.							
4.							

Result: -

The graph plotted between 'T' and 'l^2' comes out to be a straight line.



Precautions: -

1) The string should be free from kinks.
2) The pulley should be frictionless.
3) The stress of the tuning fork should be gently pressed against the top of the sonometer.
4) The string should be of uniform area of cross section.

Viva - Voce Questions

Q1. What is a tuning fork?

Ans. It is a simplest source of sound. It essentially consists of U-shaped bar of metal with arms of exactly equal mass and length and with a stem provided at middle.

Q2. What is sonometer?

Ans. A sonometer consists of a hollow wooden box, called as sound board carrying two knife edges over which one or more strings are stretched. One end of the string is fixed while the other end is passing over a pulley that carries a weight.

Q3. What is the nature of vibrations of a tuning fork?

Ans. Free vibrations is the nature of vibrations of tuning fork.

Q4. Which types of waves produced in sonometer string?

Ans. The stationary waves which are transverse in nature are produced in a sonometer string.

Q5. Why is wooden box hollow?

Ans. The sounding box is made hollow so that air inside the box may also start vibrating along with the wire, thus, increasing the amplitude of vibrations.

Experiment No. – 21

Aim of The Experiment: -

To find the speed of sound in air at room temperature using a resonance tube by two resonance position method.

Theoretical Concept: -

The resonance tube apparatus is used

a) To calculate the frequency of a tuning fork.

b) To compare the frequencies of two tuning fork.

c) To calculate the velocity of sound in air.

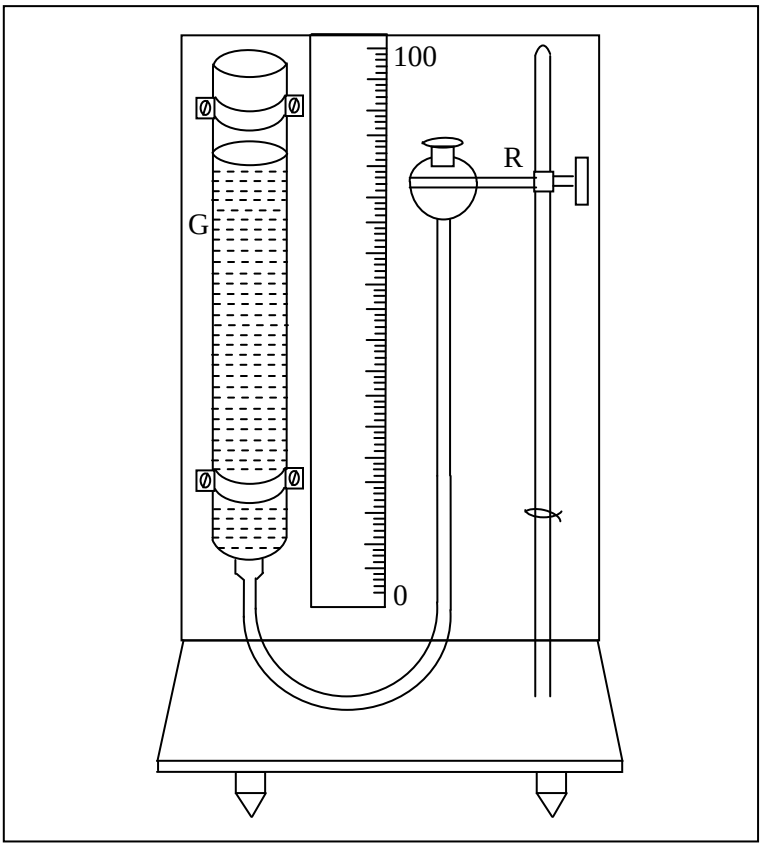
The resonance tube apparatus consists of a glass or metal tube about one metre long about 5 cm in diameter as shown in the diagram.

The speed of sound in air is given as $v = \nu\lambda$ or $v\ 2n(l_2 - l_1)$ where 'v' is the speed of sound in air at room temperature, 'ν' is the frequency of tuning fork and 'λ' is the wavelength associated.

Apparatus and Material Required: -

Resonance tube apparatus, a tuning fork of known frequency, a rubber pad, a thermometer, a plumb line, a pair of set squares and water in a vessel.

Circuit Diagram: -



Procedure: -

1) Record the room temperature with the help of thermometer.
2) Adjust the resonance apparatus vertically by using the leveling screws and test the verticality by the plumb line.
3) Fix the reservoir 'R' near the top of the tube and fill the reservoir and tube with water as shown in the diagram.
4) By raising the reservoir R, bring the water level in the tube close to its upper end, tighten the pinch cock and clamp the reservoir near the bottom of the tube.
5) To calculate the first resonance length, take the tuning fork of the known frequency (v), set it into vibrations by striking it gently against the rubber pad and hold it horizontally just above the mouth of the tube.
6) Simultaneously start lowering the level of water in the tube by opening the pinch cock gradually, if no loud sound is heard and the vibrations of the tuning fork die out, again bring the tuning fork over the mouth of the tube after setting it into vibrations, go on lowering the level of water till a loud sound is heard. Note the length of the air column from the metre scale using the set squares. It is the first resonant length of the air column.
7) Lower the level of water by 2-3 cm and clamp the reservoir. Repeat the same procedure and calculate the mean of the two first resonant lengths of the air column calculated.
8) To calculated the second resonant length, clamp the reservoir 'R' near the bottom of the tube, lower the water level in the tube so that the length of the air column is about three times the first resonant length of the air column.
9) Repeat the experiment at least two times more by proceeding similarly as we have done in step no. 5 & 6.
10) Record the observations and check the room temperature that whether it has remained same or not.

Mathematical Analysis & Observations: -

1) Room temperature in the beginning of the experiment t_1 = _____ ˚C.
2) Room temperature at the end of the experiment t_2 = _____ ˚C.
3) Mean room temperature $t = \frac{t_1+t_2}{2}$ =_____ ˚C.
4) Frequency of the tuning fork, v = _____ hz.

S.No	First resonant length of air column			Second resonant length of air column			Velocity of sound at t˚ C $V_t = 2v(l_2 - l_1)$
	Falling	Rising	Mean (l_1)	Falling	Rising	Mean (l_2)	
1.							
2.							

Mean velocity of sound at t˚C = _____ cms^{-1} = _____ ms^{-1}.

Speed of sound in air at t˚C

$$V_0 = V_t\sqrt{\frac{273}{273+t}} = \text{\_\_\_\_} \ ms^{-1}$$

Result: -

1) The velocity of sound at room temperature (t˚C) V_t = ms^{-1}.
2) The velocity of sound at 0˚C, V_0 = ms^{-1}.

Precautions: -

1) The apparatus should be set in vertical direction.
2) The tuning fork should be held only from its stem.
3) Pinch cock should be tight and there should be no leakage of water.
4) The reading of the lower meniscus of the water should be taken, for this purpose always make use of set squares.

Viva – Voce Questions

Q.1. Define resonance.
Ans. It is defined as the phenomenon of producing vibratory motion in a body by the influence of some external force having the same natural frequency.
Q.2. On what factors does the speed of sound depends?
Ans. It depends upon the temperature and humidity of air. For 1˚C rise of temperature the speed of sound increases by 61 cm. It is independent of change but increases with increase of moisture in the air.
Q.3. Why sound can be heard over longer distance in a rainy day?
Ans. In rainy day, the air contains a large amount of water vapour. The density of moist air is less than that of dry air. Due to this, sound travels faster in moist air and hence it can be heard over longer distance.
Q.4. Would the value of the resonant length change if there be any other gas instead of air in the tube?
Ans. Yes, because the velocity of sound is different in different gases and thus resonant length would be different for different gases with the same tuning fork.
Q.5. On touching the prong of a vibrations die away soon but it continues to vibrate even when held in hand by the stem. Why?
Ans. Because transverse vibrations are taking place in the prongs but stem is undergoing longitudinal vibrations.
Q.6. What is the effect of temperature on velocity of sound?
Ans. Velocity of sound increases with increase in temperature. In fact it is directly proportional to the square root of the absolute temperature.
Q.7. What is the nature of vibration in the air column?
Ans. It is a longitudinal stationary vibration.
Q.8. Can you get third resonance position? If yes, what is its position?
Ans. Yes, we can find third resonance positions as well. Length of sir column in this position l_3 will be nearly 5 times the length of first resonance position.
Q.9. What is meant by wavelength of sound?
Ans. Sound propagates in a material medium from one place to another in the form of waves. The length of one such wave is called wavelength.
Q.10. What is a resonance column apparatus?
Ans. Resonance column is an apparatus by means of which the wavelength of sound waves in air cab be determined by setting the air column into resonant vibrations.
Q.11. Why does the velocity of sound depend upon temperature?
Ans. Because, it increases with rise in temperature. When t˚C is the rise in temperature, then $v_t = (v_0 + 0.61\ t)$
Where v_t = velocity of sound at t˚C and v_0 = velocity of sound at 0˚C.

Activity No. - 8

Aim of The Activity: -

To observe change of state and plot a cooling curve for molten wax.

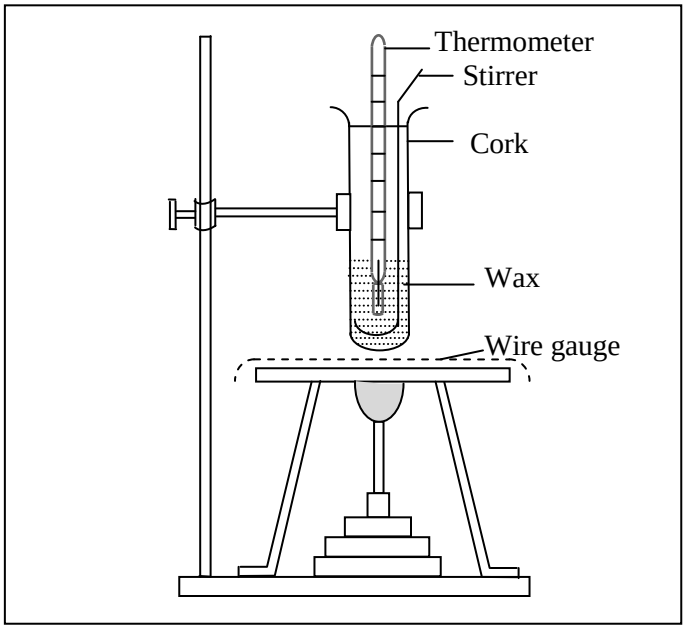
Theoretical Concept: -

There are three states of existence for a substance i.e. solids, liquids and gas. The change of state can be brought by supplying or withdrawing heat. For a given substance the chage of state takes place at constant temperature.

Apparatus and Material Required: -

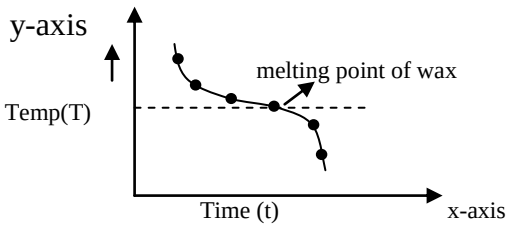
A test tube, beaker, wax, water bath, stirrer, heating arrangement, clamp stand, thermometer and a tripod stand.

Circuit Diagram: -



Procedure: -

1) Fill one third of the test tube with wax and cover it with the help of cork. Clamp the test tube in a stand after placing it in water bath.
2) Start heating the water bath, the wax in the test tube will start melting at a point 80˚C.
3) Continue heating till whole of the wax melts.
4) Stop heating the water bath and wax and allow them to cool.
5) Start the stop watch and note the falling temperature of wax after every half minute, till the temperature falls to about 35˚C.
6) Plot a graph between time (along X-axis) and temperature of the wax (along Y-axis) as shown in the figure.



Mathematical Analysis & Observations: -

1) Value of 1 division of the thermometer scale = _____˚C.
2) Melting point of wax = _____˚C.

Result: -

Initially there is fall in temperature with time, the temperature remains constant for some time represented by horizontal part of the curve, the temperature is the melting point of wax, the temperature begins to fall thereafter.

Precautions:-

1) The bulb of the thermometer should not touch the walls of the test tube.
2) The bulb of the thermometer should be completely inside the wax.
3) The molten wax should be continuously stirred, while recording its temperature during the cooling process.

Activity No. – 9

Aim of The Activity: -

To observe and explain the effect of heating on a bi-metallic strip.

Theoretical Concept: -

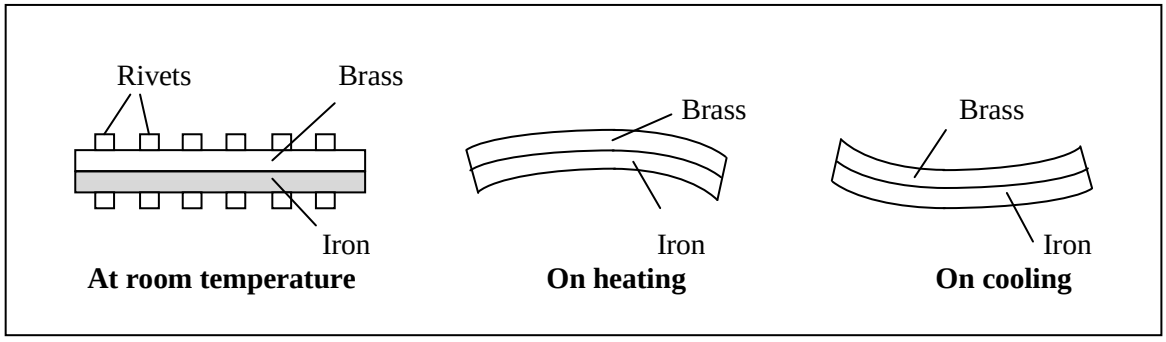
A bimetallic strip is made up of two strips of equal lengths, but are of different materials. In a bimetallic strip, the metal having larger linear expansion remains on the outer ride.

$l' = l(1 + \alpha\Delta T)$ where 'l' is the increased length sue to increase in the temperature, 'α' is the coefficient of linear expansion and 'ΔT' is the change in temperature.

Apparatus and Material Required: -

A bimetallic strip of brass and iron, clamp stand and heating arrangement.

Circuit Diagram: -



Procedure: -

1) Take a bimetallic strip of brass and iron, make sure that it should be a straight one. If not, straighten it by gently using a light hammer.
2) Fix one end of a bimetallic strip in a clamp stand.

3) Heat the strip near the clamped end by using a burner for a few minutes.
4) The free end of bimetallic strip is found to bend in the form of arc.
5) The metal on the outer side is the metal having larger linear expansion. For a brass, iron bimetallic strip brass has a higher value of linear expansion.
6) Remove the burner and let the strip cool. On cooling strip again becomes straight.

Mathematical Analysis & Observations: -

1) On heating, the bimetallic strip bands showing unequal expansion of the metals constituting it.
2) Metal _____ has larger linear expansion as compared to metal _____.

Result: -

It is found that with the rise in temperature the bimetallic strip bends.

Precautions:-

1) The strip at one end must be firmly clamped in a clamp stand.
2) Heating of the bimetallic strip should be uniform.
3) The strip must be riveted at different places.

Activity No. – 10

Aim of The Activity: -

To make the change in level of a liquid in a container on heating and interpret the observation.

Theoretical Concept: -

Liquids expand when heated, since liquids have no definite shape but only definite volume so only cubical expansion of liquids is concerned. For t˚ C rise in temperature.

$V_t = V_0\{1 + \Upsilon\Delta T\}$. Where $'V_t'$ is the volume at temperature t˚ C, $'V_0'$ is the initial volume at 0˚C, $'\Delta T'$ is the increases in temperature and $'\Upsilon'$ is the coefficient of cubical expansion.

$$\Upsilon = \frac{V_t - V_0}{V_0 x t} \, ^\circ C^{-1}$$

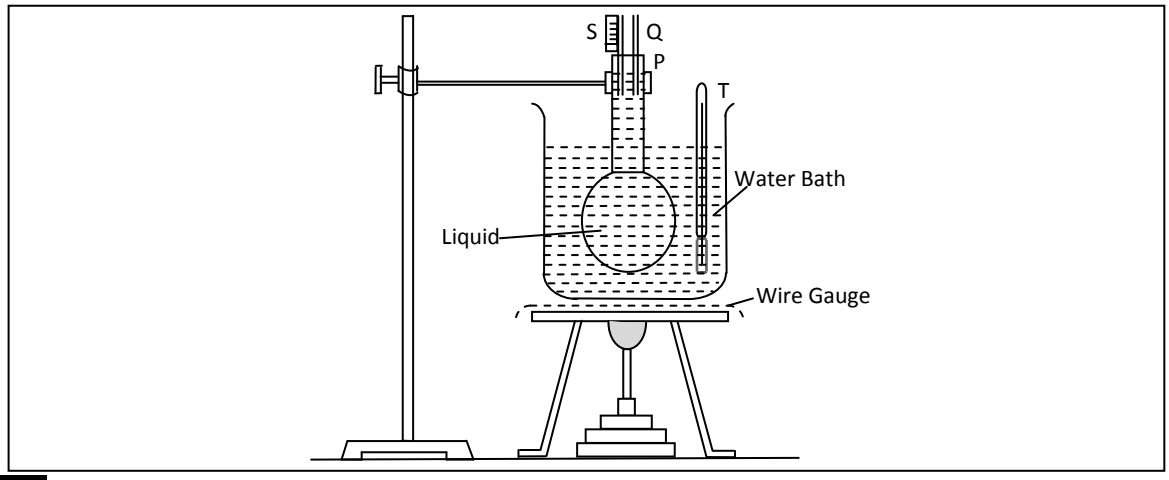
Real increase in volume of liquid (Υ_r) =Apparent increase in volume (Υ_a) +Cubical expansion of the container (Υ_g)

$\Upsilon_r = \Upsilon_a + \Upsilon_g$. Where $'\Upsilon_r'$ is the coefficient of real cubical expansion, $'\Upsilon_a'$ is the coefficient of apparent cubical expansion and $'\Upsilon_g'$ is the coefficient of cubical expansion of glass.

Apparatus and Material Required: -

A glass flask, a water bath, a thermometer, tripod stand, a burner, a rubber cork, glycerine.

Circuit Diagram: -



Procedure: -

1) Clean the glass flask thoroughly and fill it with glycerine.
2) Fix the rubber cork tightly in the neck of the flask and insert the glass tube into the cork so that about 8-10 cm length of the tube remains outside the flask.
3) Place the water bath on the tripod stand as shown in the diagram, then place the flask containing the glycerine in the water bath, also suspend a thermometer to note down the temperature.
4) Attach a paper scale. And mark the level of the glycerine in the glass tube as 'O' the mark 'O' refers to the volume of the glycerine at room temperature.
5) Start heating the water bath with the help of a burner and keep the eye on the mark 'O', as the temperature of the water bath increases, the temperature of the glass flask also starts increasing.
6) After some time the level of the glycerine in the tube will fall due to the expansion of the flask. Mark the point as P, to which glycerine falls in the tube and note its reading on the scale, then expansion of the glass flask = OP.
7) Soon the temperature of the glycerine will also start increasing and as a result its level in the tube will rise and will go past the mark 'O' mark the point Q, to which glycerine rises and note down its reading. Real expansion of the glycerine = PQ and Apparent expansion of the glycerine =OQ.
8) Note the final temperature of the water bath.

Mathematical Analysis & Observations: -

1) Initial temperature of the glycerine, t_1 = _____ ˚C.
2) Final temperature of the glycerine, t_2 = _____ ˚C.
3) Position of the Mark 'O' on the scale = _____ cm.
4) Position of the Mark 'P' on the scale = _____ cm.
5) Position of the Mark 'Q' on the scale = _____ cm.
6) Real expansion of the glycerine = PQ = _____ cm of glycerine column.
7) Apparent expansion of the glycerine = OQ = ____ cm of glycerine column.

Result: -

The real expansion of the glycerine is greater than its apparent expansion and that real expansion of the glycerine = apparent expansion of the glycerine + expansion of the glass flask.

Precautions:-

1) The cork should be fit tightly in the flask so that there is no leakage of glycerine.
2) The boiling point of the glycerine should be higher than that of the water in the bath.
3) No air bubbles should be present inside the flask.
4) Glass tube should be of narrow bore.

Activity No. – 11

Aim of The Activity: -

To study the effect of detergent on surface tension by observing capillary rise.

Theoretical Concept: -

The surface tension of the liquid is given by the formula $T = \frac{r(h+\frac{r}{3})\rho g}{2\cos\theta}$.

Where 'r' is the radius of capillary tube at liquid meniscus.

'h' is the height of the liquid in the capillary tube.

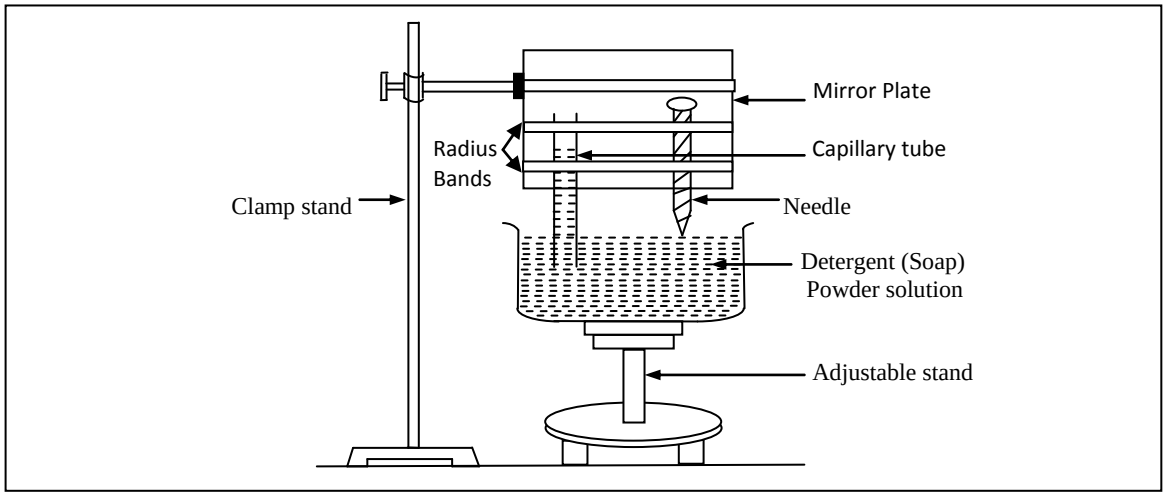
'ρ' is the density of water.

'g' is the acceleration due to gravity.

Apparatus and Material Required: -

A physical balance and a travelling microscope, a capillary of uniform base, a needle, a glass strip, an adjustable stand, beakers, a measuring cylinder, a thermometer, distilled water, detergents and a clamp stand.

Circuit Diagram: -



Procedure: -

1) Take a clean and dry capillary tube.
2) Take equal amount of different detergents; use a physical balance to take equal mass of detergents.
3) Take three beakers and pour equal volumes of distilled water in each of them. Now dissolve the different detergents having same concentration in distilled water in three different beakers labelled as A, b and C.

4) Put the capillary tube of uniform bore and dip it in the solution A and measure the rise of solution A.
5) Determine the least count of travelling microsope.
6) Take out the capillary tube from the solution a, reuse it thoroughly and then dry it.
7) Now dip this dry and clean capillary tube in solution B and measure the rise of solution B.
8) Repeat the steps 6 and 7 for the solution C.
9) Record all the observation in an observation table.

Mathematical Analysis & Observations: -

1) Volume of the distilled water used for each solution = _____ ml.
2) Mass of each detergent = _____g.
3) Least count of the microscope (L.c) = _____ cm.

Detergent Solution Taken	Reading at meniscus (cm)			Reading at the tip of the needle (cm)			Height $h=h_1 - h_2$ (cm)
	Main Scale Reading x (cm)	vernior scale Reading (n)	Total Reading $h_1 = x+n\times L.C$	Main Scale Reading x' (cm)	vernior scale Reading (n')	Total Reading $h_2 = x'+n'\times L.C$	
A							
B							
C							

The rise in the capillary tube decreases with addition of detergent in water, with more addition of the detergent rise becomes least.

Result: -

The detergent reduces the surface tension of water.

Precautions:-

1) The volume of the distilled water in all the four beakers should be equal.
2) The diameter of all the four capillary tubes should be equal.
3) Capillary rise should be measured with the help of a travelling microscope.
4) The capillary tube should be cleaned thoroughly, then rinsed properly with distilled water.

Activity No. – 12

Aim of The Activity: -

To study the factors affecting the rate of loss of heat of a liquid.

Theoretical Concept: -

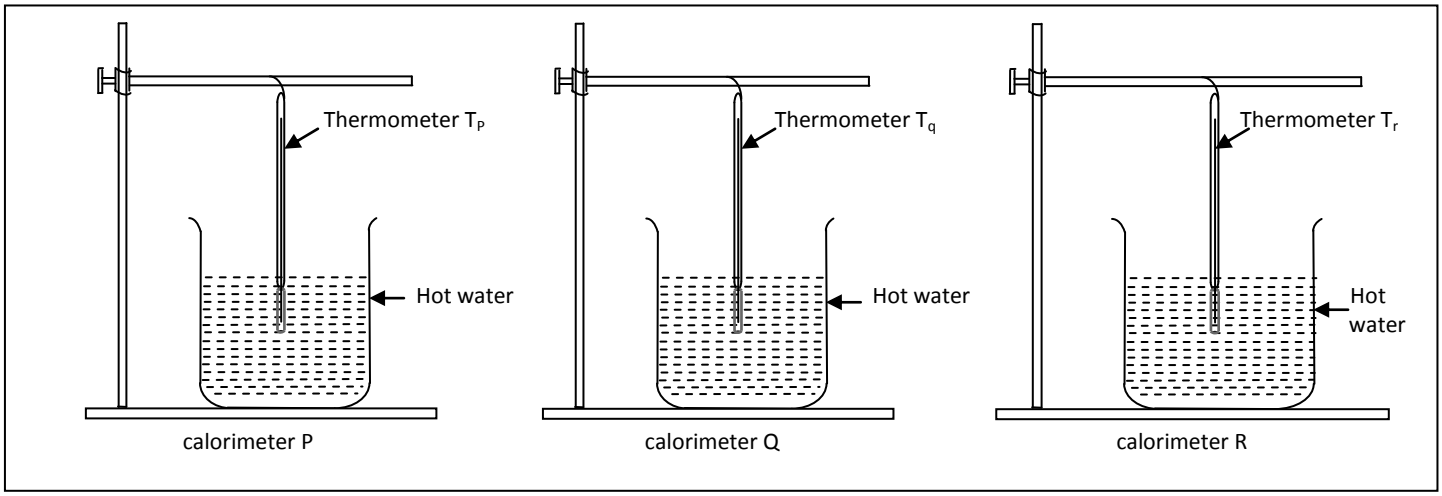
According to Newton's law of cooling, the rate of heat loss per second of a body depends upon the following factors:

(a) Area of the surface of the body
(b) Nature of the surface of the body
(c) Difference of temperature between the hot body and its surroundings.

Apparatus & Material Required: -

A large container for heating water, a burner, tap water, two identical calorimeters P and Q and third calorimeter R with internal diameter about twice that of the other calorimeters, least count of three thermometers with 0.1˚C, a stop watch/clock, three stands, wooden lids for calorimeters, and a candle to blacken the surface of the calorimeter.

Circuit Diagram: -



Procedure: -

(a) Effect of the area of surface of the body.

1) Take boiled water in a large container. Now transfer boiled water in calorimeter P and the same amount of boiled water in calorimeter R.

2) Keep the thermometers T_P and T_R in calorimeter P and R and place them vertical with their bulbs in hot water.

3) Now measure the temperature in two calorimeters after an interval of 30 sec and after one minute till the water temperature falls upto 20˚C above the room temperature.

4) Find the least count of stop watch/clock.

(b) Effect of Nature of the surface of the body.

1) Take two identical calorimeters P and Q. Blacken the outer surface of one of them with the help of flame of a candle and leave the other as such.

2) Now transfer (100 ml) boiling water in each of the calorimeters P and Q and place the thermometers T_P and T_Q using two stands.

3) Now measure the temperatures in calorimeter P and Q after an internal of 30 sec and after one minute till the temperature of water in calorimeter P and Q falls upto 20˚C above the room temperature.

4) Tabulate the observations and plot a graph between the temperature (θ) and time (t) elapsed for both the calorimeters.

(c) Effect of difference in temperature between hot body and surroundings.

1) Wash the two identical calorimeters P and Q under tap water so as to bring them upto the room temperature.

2) Pour 100 ml of boiling water in one calorimeter and 100 ml of water at a lower temperature (say 60˚C) into the other.

3) Now note the water temperature in calorimeters P and Q after an interval of 30 sec and one minute later on.

4) Tabulate the observations and plot graphs between temperature (θ) and time (t) elapsed.

Mathematical Analysis & Observations: -

Least count of stop watch / clock = _____ s.

Table for effect of the area of surface of the body.

S.No	Calorimeter P (Smaller surface area)		Calorimeter R (Larger surface area)	
	Time (t) (min)	Temperature $\theta_P(^\circ C)$	Time (t) (min)	Temperature $\theta_R(^\circ C)$
1.				
2.				
3.				
4.				
5.				

Table for the effect of nature of surface of the body.

S.No	Calorimeter P (Normal surface)		Calorimeter Q (Blackened surface)	
	Time (t) (min)	Temperature $\theta_P(^\circ C)$	Time (t) (min)	Temperature $\theta_Q(^\circ C)$
1.				
2.				
3.				
4.				
5.				

Table for the effect of difference in temperature of hot body and its surroundings.

S.No	Calorimeter P (Higher temperature)		Calorimeter Q (Lower temperature)	
	Time (t) (min)	Temperature $\theta_P(^\circ C)$	Time (t) (min)	Temperature $\theta_Q(^\circ C)$
1.				
2.				
3.				
4.				
5.				

Result: -

1) Rate of cooling increases with increase in surface area of the calorimeter of the hot liquid.
2) Rate of cooling faster if the outer surface of calorimeter of hot liquid is blackened.
3) Rate of cooling is found to be faster if the initial temperature of water is much higher than that of its surrounding.

Precautions:-

1) Equal volumes of hot water should be taken in all cases.
2) Do not place two calorimeters very close to each other.
3) Graphs should be plotted on same graph paper having same.
4) Do not stirring of water in the calorimeters should be done during the experiment.

Activity No. – 13

Aim of The Activity: -

To study the effect of load on depression of a suitably clamped metre scale loaded at (a) its end, (b) in the middle.

Theoretical Concept: -

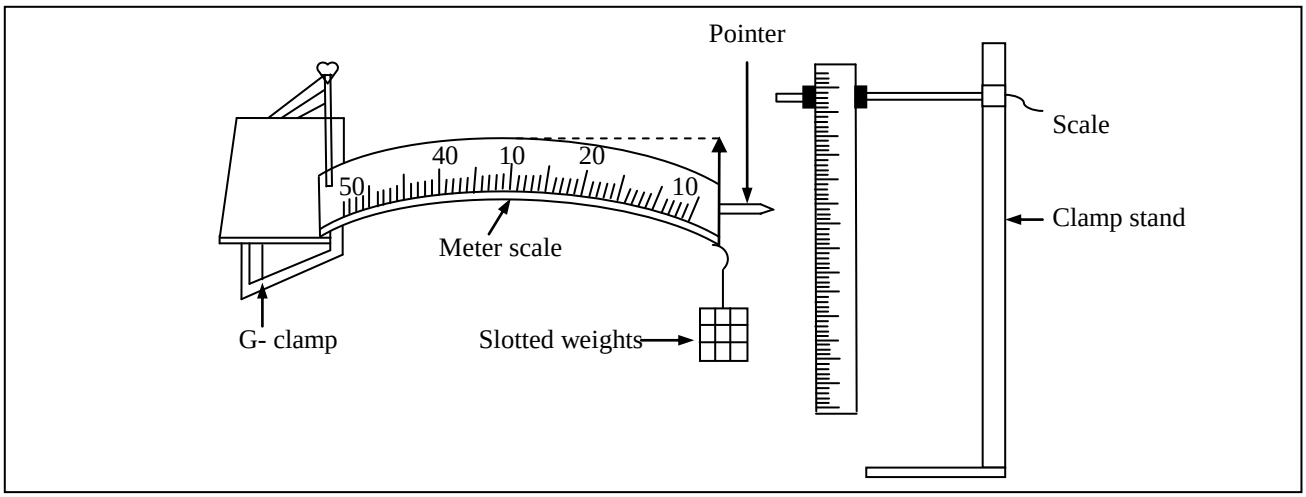
The depression x of a cantilever of length I clamped at one end and loaded at free and with a weight Mg is given by relation. $x = \frac{Mgl^3}{4Ybd^3}$

Where l, b, d and Y are length, width, thickness and Young's modulus of elasticity of material. From the above relation we have $x \propto Mg$ i.e, the depression is directly proportional to the load suspended from the other end.

Apparatus & Material Required: -

Two g-clamps, Clamp stand, Pointer pin, Adhesive tap, Thread, a uniform wooden metre rod, vertical scale, and Slotted weights of 50 g each.

Circuit Diagram: -



Procedure: -

(a) When metre scale is loaded at its end.

1) Using G clamp, clamp the metre scale firmly to the edge of the table such that the metre scale is in horizontal plane and about 80 cm of length project out as shown in fig.

2) Determine the least count of vernier scale.

3) Attach a metallic pin with fine tip with the free end of the metre scale using adhesive tape. Check the pointer remains horizontal. Read the pointer when metre scales without any load.

4) Suspend the suitable weight 50 g hanger for keeping slotted weights to depress the metre scale cantilever. If a small depression takes place there. Read the pointer on vertical scale and take the observation.

5) Now keep on adding 50 g weights to the hanger and take the observation of the pointer every time, when it stops vibrating.

6) Take at least five observations with increasing the load. Now start unloading of weights one by one and take all observations on the vertical scale.

7) Record all the observations in tabulated form as shown below.

(b) When metre scale is loaded in the middle.

8. Measure the width and thickness of the beam.

9. Determine the position of the centre of gravity of metre scale by placing it on a sharp wedge.

10. Place the metre rod on the knife edges symmetrically and adjust the hanger in the middle of the metre scale.

11. Attach the pointer at the middle point of the metre scale between the two knife edges using adhesive tape.

Mathematical Analysis & Observations: -

(a) Studying effect on load on depression when metre scale is loaded at its end. Initial reading of a vertical scale when metre scale is without any load at free end, a_0 = ____ cm.

Table for the depression of metre scale is loaded at its end.

S.No	Load suspended (g wt)	Vertical scale reading (cm)			Depression $x = (a_0 - a)$ (cm)
		Loading a_1	Unloading a_2	Mean $a = \frac{a_1+a_2}{2}$	
1.					
2.					
3.					
4.					
5.					

(b) Studying effect on loaded on depression when metre scale is loaded in the middle end. Initial reading on vertical scale where without any load in the middle a_0 = ____ cm.

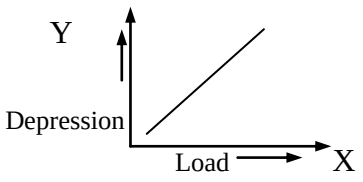
Table for the depression of metre scale is loaded in the middle.

S.No	Load suspended (g wt)	Vertical scale reading (cm)			Depression $x = (a_0 - a)$ (cm)
		Loading a_1	Unloading a_2	Mean $a = \frac{a_1+a_2}{2}$	
1.					
2.					
3.					
4.					
5.					

Result: -

Graph between load and depression in both cases, if metre scale is loaded (i) at its end and (ii) in the middle, are straight line. It shows that the Depression $\propto$ load.

i.e $x \propto Mg$



Precautions:-

1) The metre scale should be clamp one end and free other end.
2) The metre scale must be symmetrically placed on the knife edges.
3) The pointer tip should not touch the vertical scale.
4) The metre scale should not be loaded beyond the elastic limit.

Reference Tables for Physical Settings/PHYSICS

List of Physical Constants		
Name	**Symbol**	**Value**
Universal gravitational constant	G	6.67×10^{-11} N•m^2/kg^2
Acceleration due to gravity	g	9.81 m/s^2
Speed of light in a vacuum	c	3.00×10^{8} m/s
Speed of sound in air at STP		3.31×10^{2} m/s
Mass of Earth		5.98×10^{24} kg
Mass of the Moon		7.35×10^{22} kg
Mean radius of Earth		6.37×10^{6} m
Mean radius of the Moon		1.74×10^{6} m
Mean distance—Earth to the Moon		3.84×10^{8} m
Mean distance—Earth to the Sun		1.50×10^{11} m
Electrostatic constant	k	8.99×10^{9} N•m^2/C^2
1 elementary charge	e	1.60×10^{-19} C
1 coulomb (C)		6.25×10^{18} elementary charges
1 electronvolt (eV)		1.60×10^{-19} J
Planck's constant	h	6.63×10^{-34} J•s
1 universal mass unit (u)		9.31×10^{2} MeV
Rest mass of the electron	m_e	9.11×10^{-31} kg
Rest mass of the proton	m_p	1.67×10^{-27} kg
Rest mass of the neutron	m_n	1.67×10^{-27} kg

Prefixes for Powers of 10		
Prefix	**Symbol**	**Notation**
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Approximate Coefficients of Friction		
	Kinetic	**Static**
Rubber on concrete (dry)	0.68	0.90
Rubber on concrete (wet)	0.58	
Rubber on asphalt (dry)	0.67	0.85
Rubber on asphalt (wet)	0.53	
Rubber on ice	0.15	
Waxed ski on snow	0.05	0.14
Wood on wood	0.30	0.42
Steel on steel	0.57	0.74
Copper on steel	0.36	0.53
Teflon on Teflon	0.04	

Electricity

$F_e = \frac{kq_1q_2}{r^2}$

$E = \frac{F_e}{q}$

$V = \frac{W}{q}$

$I = \frac{\Delta q}{t}$

$R = \frac{V}{I}$

$R = \frac{\rho A}{L}$

$P = VI = I^2R = \frac{V^2}{R}$

$W = Pt = VIt = I^2Rt = \frac{V^2t}{R}$

A = cross-sectional area
E = electric field strength
F_e = electrostatic force
I = current
k = electrostatic constant
L = length of conductor
P = electrical power
q = charge
R = resistance
R_{eq} = equivalent resistance
r = distance between centers
t = time
V = potential difference
W = work (electrical energy)
Δ = change
ρ = resistivity

Series Circuits

$I = I_1 = I_2 = I_3 = \ldots$
$V = V_1 + V_2 + V_3 + \ldots$
$R_{eq} = R_1 + R_2 + R_3 + \ldots$

Parallel Circuits

$I = I_1 + I_2 + I_3 + \ldots$
$V = V_1 = V_2 = V_3 = \ldots$
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$

Circuit Symbols

1)  cell

2)  battery

3)  switch

4) 

voltmeter

5) 

ammeter

6)  resistor

7)  variable resistance

8)  Inductor

Resistivities at 20°C	
Material	**Resistivity** (Ω•m)
Aluminum	2.82×10^{-8}
Copper	1.72×10^{-8}
Gold	2.44×10^{-8}
Nichrome	150×10^{-8}
Silver	1.59×10^{-8}
Tungsten	5.60×10^{-8}

Waves

$v = f\lambda$

$T = \frac{1}{f}$

$\theta_r = \theta_r$

$n = \frac{c}{v}$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

c = speed of light in a vacuum

f = frequency

μ = absolute index of refraction

T = period

v = velocity or speed

λ = wavelength

θ = angle

θ_i = angle of incidence

θ_r = angle of reflection

E.M.F. of cells			
Cell	**E.M.F. (Volts)**	**Cell**	**E.M.F. (volts)**
Cadmium at 20^o C	1.01854	Edison cell	1.45
Clark at 15^o C	1.433	Leclanche	1.45
Daniel	1.08 – 1.09	Lead accumulator	1.9 – 2.2

Thermocouple	
Thermocouple	Range of Temperature
Copper – Constantan	up to 300^o C
Iron – Nickel	from 300^o C to 600^o C
Nickel – Chromium	from 600^o C to 1000^o C
Platinum – Platinum and Rhodium alloy	from 1000^o C to 1600^o C
Iridium – Iridium and rubidium alloy	from 1600^o C to 2000^o C
Tungsten - Molybdenum	from 2000^o C to 3000^o C

International System of Units (S.I. Units)

1. Fundamental Units

S.No.	Basic Physical Quantity	Fundamental Unit	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Electric current	ampere	A
5.	Temperature	kelvin	K
6.	Luminous intensity	candela	cd
7.	Amount of substance	mole	mol

2. Supplementary Units

S.No.	Supplementary Physical Quantity	Supplementary Units	Symbol
1.	Angle	radian	rad
2.	Solid angle	steradian	sr

3. Derived Units

S.No.	Physical Quantity	Derived Unit	Symbol
1.	Power	watt	W
2.	Wave number	per metre	m^{-1}
3.	Current density	ampere per sq. metre	Am^{-2}
4.	Magnetic field strength	ampere per metre	Am^{-1}
5.	Quantity of electricity	coulomb	C
6.	Electric potential difference	volt	V
7.	Electric capacity	farad	F
8.	Electrical resistance	ohm	Ω
9.	Conductance	Siemen	S
10.	Magnetic flux	weber	Wb
11.	Magnetic flux density	tesla	T
12.	Inductance	henry	H
13.	Electric field strength	volt per metre	Vm^{-1}
14.	Electric charge density	Coulomb per cubic metre	Cm^{-3}

1. Density or Mass in Gram Per C.C.

Elements		Liquids			Commons Substances	
Aluminium	2.7	Alcohol (Ethyl)	0.807	0°C	Bee Wax	0.96-0.97
Antimony	6.62	Alcohol (Methyl)	0.810	0°C	Box Wood	0.95-1.16
Bismeth	9.80	Aniline	1.035	0°C	Brass	8.4-8.7
Copper	8.3-8.95	Castor Oil	0.97	0°C	Cock	0.3-1.6
Gold	19.3	Ether	0.736	0°C	Cork	0.22-2.26
Iron	7.5-7.9	Glycerine	1.26	0°C	Ebonite	1.15
Lead	11.3	Kerosine Oil	0.80	0°C	Glass (Common)	2.4-5.9
Magnesium	1.74	Mercury	13.6	0°C	Glass (Flint)	2.9-5.9
Nickel	8.6-8.9	Mustard Oil	0.8-0.83	0°C	Ice	0.927
Osmium	22.5	Olive Oil	0.91-0.93	0°C	Mahogany	0.85
Platinum	21.45	Paraffin Oil	0.878	0°C	Oak	0.60-0.90
Silver	10.5	Petrol	0.70-0.80	15°C	Paraffin wax	0.87-0.91
Tin	7.3	Spirt	0.88	0°C	Pitch Pine	0.83-0.85
Zinc	7.1	Water	9999	0°C	Wal Nut	0.64-0.70
					Yellow Pine	0.37-0.60

2. Elastic Constants

Substance	Young modulus g 11^{11}dynes/cm^2	Rigidity-x 10^{11}dynes/cm	Bulk modulus 10^{11}dynes/cm^2	Poission's Ratio 6
Aluminium	7.2-7.5	2.5-3.4	7.46	0.84
Brass	9.7-10.1	3.5	10.6	0.34-0.40
Copper	10.5-12.5	3.5-4.5	14.3	0.26
German Silver	11.6	4.3-4.7		0.37
Glass	5.1-7.1	3.1	3.75	0.13-0.32
Iron (cast)	10-13	3.5-5.3	9.6	0.23-0.31
Iron (wrought)	19-20	7.7-8.3	14.6	0.27
Lead	1.6	5.6	5	
Mangnin	12.4	4.65	12.1	0.33
Phosphorbronze	-	12.0	4.4	
Rubber	.00015-.0005	0.00005		46-40
Silver	7.1	2.5	10.9	
Steel	20.9	8.12	16.4	0.29

Coefficient of Expansion

Coefficient of Linear Expansion of Solids

Aluminium …….. 0.000022
Brass …… 0.000019
German Silver ……. 0.000018
Glass …….. 0.0000085
Iron ……. 0.0000114
Lead ……. 0.000029
Silver …… 0.000019
Tin …….. 0.0000219

Coefficient of Cubical Expansion of Liquids

Alcohol …….. 0.00122
Aniline ……... 1.00085
Glycerine ……... 0.00052
Mercury ……. 0.00018
Olive Oil ……... 0.0007
Sulphuric Acid ……. 0.0095
Turpentine …….. 0.00093
Water $(10^0 - 30^0)$ …….. 0.000203

Coefficient of Cubical Expansion of Gases

The coefficient of increase of volume of H gases at constant pressure and the coefficient of Increase of Pressure of all gases at constant volume may be taken to be $1/273 \times 0.00365$

Specific Heat of Solids

Aluminium …… 2.21
Brass ……. 0.09
Charcoal …… 0.19
Glass ……. 0.16-0.19
Gold …….. 0.03
Bismuth ……. 0.03
India Rubber …….. 0.48
Ice (0^0C)…… 0.50
Common Salt ……. 0.02
Iron …… 0.11
Lead ……... 0.08
Marble …… 0.22
Sand ……... 0.19
Silver …….. 0.056
Tin …….. 3.055
Zinc …… 0.033
Paraffin …… 0.64
Sulphur …….. 0.164
Nickel …….. 0.11

Specific Heat of Liquids

Alcohol …… 0.62
Aniline …… 0.50
Glycerine ……..0.58
Paraffin Oil ……...0.58
Mustard Oil …….. 9.50
Mercury …….. 0.030
Turpentine …… 0.43
Water ……... 1.00

Specific Heat of Gases (At Constants Pressure)

Air ……. 0.937
Steam …… 0.465
Oxygen …….. 0.917
Hydrogen ……. 0.41

Latent Heats of Fusion (Calorie)

Ice …… 80.0
Sulphur …….. 9.4
Silver …… 12.0
Mercury …….. 2.8
Lead ……... 5.4
Bismuth …… 21.0

1. Electrical Constants

E.M.F. of Cells

Bichromate …….. 2.0 Volts
Bunsen …….. 1.8-1.9 Volts
Cadmium ……... 0.0183 (at 20^0C) Volts
Clark (Standard ……... 1.433 Volts
Danlall ……... 1.08 Volts
Grove …….. 1.8-1.9 Volts
Lead Accumulator …… 2.2 Volts
Lechlanche …… 1.5 Volts
Ni-Fe Accumulator ……1.3 Volts
Standard (Weston) ……... 1.018 Volts

2. Specific Resistance

Microns Per cm. Cube

Aluminium ……. 3.21
Brass …… 6.6
Copper …… 1.78
Constantan …… 49
Eureka …….. 36 to 49
Iron (cast) ……... 16.8
Iron (wrought) …… 13.9
Lead …… 20.8
Carbon …….. 3.5
Manganin …… 44.5
Mercury ……... 99
Nichrome ……... 110
Platinum …….. 11
Phosphor-Bronze ……. 5-10
Silver …… 1.66
Steel ……. 19.9
Tungsten ……... 5
Platinoid …….. 14.4
Tantalum …….. 14.6

3. Electro Chemical Equivalent

Element	Chemical Symbol	Atomic Weight	Valency	Chemical Enquivalent	E.C.E. in Gms./Coulomb
Aluminium	Al	27.1	3	9.03	0.0000936
Chlorine	Cl	35.46	1	35.46	0.0003676
Chromium	Cr	52.01	3	17.34	0.0001796
Copper	Cu	63.57	2	38.785	0.0003294
Gold	Au	197.2	3	65.73	0.0006812
Hydrogen	H	1.0078	1	1.0078	0.0004145
Nickel	NI	58.68	2	29.45	0.0003040
Oxygen	O	16.00	2	8	0.0008291
Silver	Ag	107.88	1	107.88	0.0011180
Zinc	Zn	65.38	2	32.69	0.0003387

4. Refractive Indices and Critical Angles

	Refractive Indices (Sodium Lines)	Critical Angles
Air (N.T.P.)	1.00029	41^0
Glass, Crown	1.48 to 1.46	37^0
Glass Flint	1.58 to 1.96	24^0
Glycerine	1.47	$44^0\ 40^0$
Diamond	2.42	$44^0\ 30^0$
Paraffin Oil	1.44	-
Quartz	0.55	-
Turpentine	1.47	$41^0\ 30^0$
Water	1.44	-

How to use log/Antilog

Logarithms

If three number a,b and c are related as $a^b = c$ (exponential form), then exponent 'b' is called the logarithms of the number 'c' to the base 'a' and is written as $\text{Log}_a\, c = b$ (logarithmic form).

For e.g. $2^3 = 8$; logarithm of 8 to the base 2 is i.e $\text{Log}_2\, 8 = 3$

- The logarithm of any number to a given base in value of the index to which the base must be raised to get the given number.
- Logarithm base 'e' is known as natural logarithm.
- Logarithm of base '10' is known as common logarithm. (If no base is given, base is taken as 10)

Laws of Logarithms:-

1. **Product law :** $\log_a(m \times n) = \log_a m + \log_a n$
2. **Quotient law:** $log_a \frac{m}{n} = log_a m - \log_a n$
3. **Power law:** $log_a m^n = n log_a m$

Use of Log Table:-

The Logarithm of a number consists of two parts:

- Characteristics: Integral part of log.
- Mantissa: Fractional or decimal part of log.

To find characteristic

(i) The characteristic of the log of a **number** > 1 is **positive** and numerically **one less than the number of digits before the decimal point.** (A standard notation of the number makes it easy to identify the characteristic)
For e.g.
Characteristics of log 3.257 is 0 (1 -`1 = 0 or in standard notation 3.257×10^0)
Characteristics of log 32.57 is 1 (2 – 1 = 1 or in standard notation 3.257×10^1)
Characteristics of log 325.7 is 2 (3 – 1 = 2 or in standard notation 3.257×10^2)
Characteristics of log 3257 is 3 (4 – 1 = 3 or in standard notation 3.257×10^3)

(ii) The characteristic of the log of a **number < 1** is **negative** and **numerically one more than the number of zeros immediately after the decimal point.** It is represented by a bar over the digit. (A standard notation of the number makes it easy to identify the characteristic)

For e.g.

Characteristic of log 0.3257 is $\bar{1}$ $[-(0+1) = -1$ or in standard notation $3.257 \times 10^{-1}]$

Characteristic of log 0.003257 is $\bar{3}$ $[-(2+1) = -3$ or in standard notation $3.257 \times 10^{-3}]$

To find Mantissa

The mantissa of the logarithm of a number can be obtained from the logarithmic table. **Mantissa is always positive.**

A log table consists of three parts:

- A column at the extreme left contains two digit numbers starting from 10 to 99.
- Ten column headed by digits 0,1,…….9.
- Nine more column headed by digits 1,2,…..9.

To find the mantissa of log of 1 digit number

Left the number be 2; Mantissa of log 2 will be value of 20 (extreme left column) under 0 = .3010

To find the mantissa of log of 2 digit number

Left the number be 23; Mantissa of log 23 will be value of 23 (extreme left column) under 0 = .3617

To find log form log table

For e.g. log 2345: Characteristic = 3 and mantissa = .3701 $\therefore$ log 2345 = 3.3701

log 0.0234: Characteristic = $\bar{2}$ and mantissa = .3692 $\therefore$ log 0.0234 = $\bar{2}$.3692

Mantissa should always be written as positive

$$\bar{2}.3692 = \bar{2} + .3692$$

$-2.3692 = -(2 + 0.3692) = -2 - .3692$; $-.3692$ should be converted to a positive mantissa.

How to convert?

$$-2 - 1 + 1 - .3692 = -1 + .6308 = \bar{1}.6308$$

Antilog

If log 2345 = 3.3701 than antilog of 3.3701 is 2345.\

Antilog can be found out from antilog table in the same manner as log, the main difference is than as antilog table contains numbers from .00 to .99 in the extreme left column.

Antilog tables are used to find the antilog of decimal part.

If the Characteristic (n) is positive then put the decimal after (n+1) digits from the left.

Antilog 1.6078 = 40.53

If the characteristic (n) is negative then put (n-1) zeros before the first significant digit.

Antilog $\bar{2}.6078 = 0.04053$

	0	1	2	3	4	5	6	7	8	9	Mean Differences

LOGRITHMS

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	1	2	3	1	2	3
10	0000	0043	0086	0128	0170						5	9	13	17	21	26	30	34	38
						0212	0253	0294	0334	0374	4	8	12	16	20	24	28	32	36
11	0414	0453	0492	0531	0569						4	8	12	16	20	23	27	31	35
						0607	0645	0682	0719	0755	4	7	11	15	18	22	26	29	33
12	0792	0828	0864	0899	0934						3	7	11	14	18	21	25	28	32
						0969	1004	1038	1072	1106	3	7	10	14	17	20	24	27	31`
13	1139	1173	1206	1239	1271						3	6	10	13	16	19	23	26	29
						1303	1335	1367	1399	1430	3	7	10	13	16	19	22	25	29
14	1461	1492	1523	1553	1584						3	6	9	12	15	19	22	25	28
						1614	1644	1673	1703	1732	3	6	9	12	14	17	20	23	26
15	1761	1790	1818	1847	1875						3	6	9	11	14	17	20	23	26
						1903	1931	1959	1987	2014	3	6	8	11	14	17	19	22	25
16	2041	2068	2095	2122	2148						3	6	8	11	14	16	19	22	24
						2175	2201	2227	2253	2279	3	5	8	10	13	16	18	21	23
17	2304	2330	2355	2380	2405						3	5	8	10	13	15	18	20	23
						2430	2455	2480	2504	2529	3	5	8	10	12	15	17	20	22
18	2553	2577	2601	2625	2648						2	5	7	9	12	14	17	19	21
						2672	2695	2718	2742	2765	2	4	7	9	11	14	16	18	21
19	2788	2810	2833	2856	2878						2	4	7	9	11	13	16	18	20
						2900	2923	2945	2967	2989	2	4	6	8	11	13	15	17	19
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4041	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4246	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5324	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11

35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6201	6212	1	2	3	4	5	6	8	9	10
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	8	9	10
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	8	9	10
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	8	9	10
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	8	9	10
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6894	6803	1	2	3	4	5	6	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	2	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7824	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8362	8370	8370	8382	1	1	2	2	3	4	4	5	6
	0	1	2	3	4	5	6	7	8	9	**Mean Differences**								
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5

73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	1	1	2	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9788	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9890	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9934	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9978	9987	9991	9996	0	1	1	2	2	3	3	3	4

ANTILOGARITHMS

	0	1	2	3	4	5	6	7	8	9	Mean Differences								
											1	2	3	1	2	3	1	2	3
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
.03	1072	1074	1076	1079	1081	1086	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2

.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	3	3
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	3	3
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	3	3
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	3	3
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	3	3
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	3	3	3
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	3	3	3
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	2	3	3	3
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	3	3	3	4
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	3	3	3	4
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	3	3	4	4
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	2	2	3	3	4	4
.30	1995	200	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	3	3	4	4
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	2	2	3	3	4	4
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4

	0	1	2	3	4	5	6	7	8	9	**Mean Differences**								
											1	2	3	1	2	3	1	2	3
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3	3	4	4	5
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	4	4	5	5
.41	2570	2576	2582	2588	2594	2600	2696	2612	2618	2624	1	1	2	2	3	4	4	5	5
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3	4	4	5	6
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6

.47	2951	2858	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
.49	3090	3097	3105	3112	3119	3126	3113	3141	3148	3155	1	1	2	3	4	4	5	6	6
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4256	4256	1	2	3	4	5	6	7	8	9
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
	0	1	2	3	4	5	6	7	8	9	**Mean Differences**								
											1	2	3	1	2	3	1	2	3
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
.74	5495	5508	5521	5534	5546	5459	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	5	7	8	10	11	13
.79	6166	6180	6194	6209	6223	7237	6252	6266	6281	6295	1	3	4	5	7	9	10	11	13
.80	6310	6324	6339	6353	6368	6383	6497	6412	6427	6442	1	3	4	5	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15

.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9661	9683	8705	9727	9750	2	4	7	9	11	13	16	18	20
.99	9772	9895	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20