V P & R P T P Science College
Vallabh Vidyanagar
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US03CPHY03 Practical Record Book

Name:_____

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Day:_____and _____ Timing: _____to_____

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Experiment No:1
Kater's Reversible Pendulum (fixed knife edge)

Aim: To determine the value of gravitational acceleration (g) using Kater's pendulum.

Theory: An accurate value of g, the acceleration due to gravity, is needed to calculate an object's motion in the earth's gravitational field or to measure the mass of the earth using the universal gravitational constant, G, such as in Cavendish's original experiment described in the Gravitational Torsion Balance experiment. Local variations in g are important for the study of geological formations, and thus for locating mineral deposits. Theoretically, one could determine g from the measurement of the period of a simple pendulum. In practice, however, it is physically impossible to make a point-mass pendulum with a weightless support. In the early nineteenth century, Henry Kater devised another method, by constructing a compound pendulum, which he oscillated about a knife-edge, then turned upside down and oscillated about a knife-edge on the other side of the center of mass (cms). (See Fig 1.) If the two periods are made equal by adjusting the weights on the pendulum, g can be determined from only the period and the distance between the two knife edges. In essence, use of the parallel axis theorem for the moment of inertia of a rigid body allows us to avoid approximating a point mass on a mass-less string.

Kater used this device to measure the acceleration of gravity at various locations in England. Kater's pendulum, shown in Fig. 1, is a physical pendulum composed of a metal rod 1.20 m in length, upon which are mounted a sliding metal weight W_1, a sliding wooden weight W_2, a small sliding wooden cylinder W_3 and a small sliding metal cylinder W_4, and two sliding knife edges K_1 and K_2 that face each other. Each of the sliding objects can be clamped in place on the rod. The pendulum can suspended and set swinging by resting either knife edge on a flat, level surface. The wooden weight W_2 is the same size and shape as the metal weight W_1. Its function is to provide as near equal air resistance to swinging as possible

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in either suspension, which happens if W_1 and W_2, and separately K_1 and K_2, are constrained to be equidistant from the ends of the metal rod. The centre of mass G can be located by balancing the pendulum on an external knife edge. Due to the difference in mass between the metal and wooden weights W_1 and W_2, G is not at the centre of the rod, and the distances l_1 and l_2 from G to the suspension points O_1 and O_2 at the knife edges K_1 and K_2 are not equal. Fine adjustments in the position of G, and thus in l_1 and l_2, can be made by moving the small metal cylinder W_4 and wooden cylinder W_3.

Apparatus: Kater's pendulum, stop watch, telescope, pin scale.
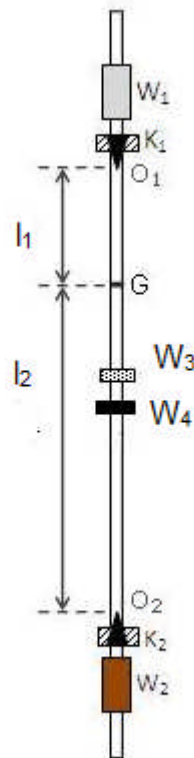

Figure 1

Procedure:

1. Fix the distance between two knife edges K_1 and K_2 80-90 cm.
2. Keep the metal bob down and measure time t_1 for 25 oscillations.
3. Calculate periodic time 'T_1'.
4. Now keep wooden bob down and measure time t_2 for 25 oscillations.
5. Calculate periodic time 'T_2'.

6. Adjust inner small metal bob to get same periodic time on both sides.

7. When both values of periodic time are nearly same, take a pilot reading for 50 oscillations. In this condition the mass distribution throughout the pendulum is same.

8. Find out centre of gravity by balancing the pendulum on knife edge. Measure the distance between centre of gravity and knife edge $K_1 = l_1$ cm & distance between centre of gravity and knife edge $K_2 = l_2$ cm.

Observation Table:

Obs. No.	Time for 25 oscillations		Periodic time $T_1 = \frac{t_1}{25}$ sec.	Periodic time $T_2 = \frac{t_2}{25}$ sec.
	Metal bob down t_1 sec.	Wooden bob down t_2 sec.		
1				
2				
3				
4				
5				
6				
Pilot reading for 50 oscillations				

Calculation:

Acceleration due to gravity is given by

$$g = \frac{8\pi^2}{\dfrac{T_1^2 + T_2^2}{l_1 + l_2} + \dfrac{T_1^2 \sim T_2^2}{l_1 \sim l_2}}$$

Results: The value of acceleration due to gravity (g) =_____cm/sec^2

Exercise:

Determine the value of the acceleration due to gravity 'g' by Kater's reversible Pendulum keeping the knife edges fixed. Use the formula

$$g = \frac{8\pi^2}{\dfrac{T_1^2 + T_2^2}{l_1 + l_2} + \dfrac{T_1^2 \sim T_2^2}{l_1 \sim l_2}} \; cm/sec^2$$

Viva Voce:

1. Define acceleration due to gravity.
2. Differentiate simple pendulum and compound pendulum.
3. What is the difference between gravitational centre and geometrical centre?
4. What is the difference between g and G?
5. How G can be determined?
6. Value of g remains constant or it change with height?
7. Give value of g at sea level and peak of the mountain.

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Experiment No:2
Frequency response of RC coupled amplifier

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Aim: Find out frequency response of RC coupled amplifier.

Theory:

Amplifier is a circuit that is used for amplifying a signal. The input signal to an amplifier will be a current or voltage and the output will be an amplified version of the input signal. An amplifier circuit which is purely based on a transistor or transistors is called a transistor amplifier. Transistors amplifiers are commonly used in applications like RF (radio frequency), audio, OFC (optic fibre communication) etc. Anyway the most common application we see in our day to day life is the usage of transistor as an audio amplifier. As you know there are three transistor configurations that are used commonly i.e. common base (CB), common collector (CC) and common emitter (CE). In common base configuration has a gain less than unity and common collector configuration (emitter follower) has a gain almost equal to unity). Common emitter follower has a gain that is positive and greater than unity. So, common emitter configuration is most commonly used in audio amplifier applications.

A good transistor amplifier must have the following parameters; high input impedance, high band width, high gain, high slew rate, high linearity, high efficiency, high stability etc. The above given parameters are explained in the next section.

Input impedance: Input impedance is the impedance seen by the input voltage source when it is connected to the input of the transistor amplifier. In order to prevent the transistor amplifier circuit from loading the input voltage source, the transistor amplifier circuit must have high input impedance.

Bandwidth: The range of frequency that an amplifier can amplify properly is called the bandwidth of that particular amplifier. Usually the bandwidth is measured based on the half power points i.e. the points where the output power becomes half the peak output power in the frequency Vs output

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graph. In simple words, bandwidth is the difference between the lower and upper half power points. The band width of a good audio amplifier must be from 20 Hz to 20 KHz because that is the frequency range that is audible to the human ear. The frequency response of a single stage RC coupled transistor is shown in the figure 2.

Apparatus: Experimental Circuit board, AC signal generator, multimeter, wire etc.

Procedure:

1. Connect the circuit as shown in the figure.
2. Keep source voltage V_s=1volt constant.
3. By changing the frequency from 50 Hz, 60 Hz ... 100 Hz, 200 Hz ... 1000 Hz (1 kHz), 2 kHz ... 10 kHz, 20 kHz ... 100 kHz and measure output voltage V_0 volt.
4. Calculate voltage gain A_v and convert this gain in dB gain.
5. Plot a graph of $dB\ gain \rightarrow \log f$.
6. Find out cut off frequencies f_1 and f_2 from $\log f_1$ and $\log f_2$ [3 dB from maximum gain].
7. Calculate bandwidth.

Circuit diagram:
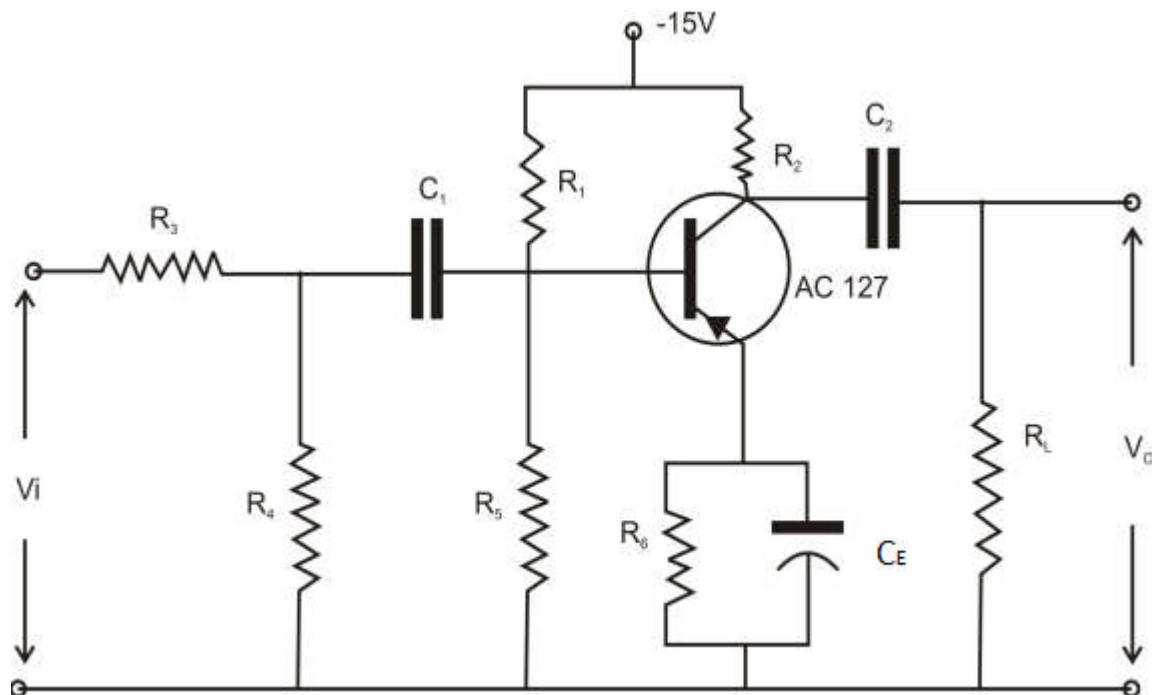
Observation Table: $V_s = 1 \, volt \, constant$, $V_i = $ _____ $volt \, constant$

Obs. No.	Input frequency $f \, Hz$	Output voltage $V_o \, volt$	Voltage gain $A = \frac{V_o}{V_i}$	db gain $A_V = 20 \log A$	$\log f$
1	50				
2	60				
3	70				
4	80				
5	90				
6	100				
7	200				
8	300				
9	400				
10	500				
11	600				
12	700				
13	800				
14	900				
15	1KHz				
16	2KHz				
17	3KHz				
18	4KHz				
19	5KHz				
20	6KHz				
21	7KHz				
22	8KHz				
23	9KHz				
24	10KHz				
25	20KHz				
26	30KHz				
27	40KHz				
28	50KHz				
29	60KHz				
30	70KHz				
31	80KHz				
32	90KHz				
33	100KHz				

Note: Here $\log A = \log_{10} A$ and $\log f = \log_{10} f$

Calculations:

$$V_i = \frac{R_4}{R_3+R_4} X V_S$$

Bandwidth = antilog $(\log f_2)$ – antilog $(\log f_1)$

Bandwidth: $\Delta f = f_2 - f_1$

Graph:
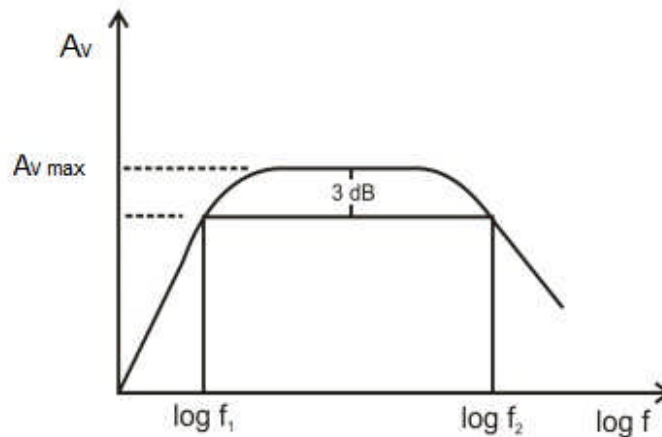
Results: Bandwidth of the RC coupled voltage amplifier=_____kHz.

Exercise: Trace the circuit of an RC coupled amplifier. Determine the gain of the amplifier for different signal frequencies covering a range of 20 Hz to 50 KHz. Also find the bandwidth of the same.

Apply the source voltage V_s =1Volt.

Viva voce:

1. What is amplification?
2. What is an amplifier?
3. Differentiate between voltage amplifier, current amplifier and power amplifier.
4. List all types of coupling methods.
5. What is the difference between amplifier and oscillator?
6. Define peak to peak value and rms value.
7. Define cut off frequency and bandwidth.

Experiment No: 3
Series resonance (L–C–R Circuit)

Aim: To plot a series resonance curve for a given circuit & from it determine resonance frequency fr & Quality factor Q.

Theory: A series circuit containing R, L, and C is in ***resonance*** when the current in the circuit is in phase with the total voltage across the circuit. Depending on the particular values of R, L, and C, resonance occurs at one distinct frequency. Because of its distinct frequency characteristics, the series resonant circuit is one of the most important frequency selective circuits.

The voltage through an LCR series circuit will be measured as a function of frequency for a fixed applied voltage. The frequency for which the rms voltage attains a maximum value is the resonance frequency. The expected resonance frequency is given by equation

$$f_0 = \frac{1}{2\pi} \cdot \frac{1}{\sqrt{LC}}$$

Apparatus: A.F.Oscillator, a.c. milliameter, inductor, capacitor, resistance box.

Procedure:

1. Connect the circuit as shown in circuit diagram.
2. Vary the oscillator frequency & note down the current in the circuit.
3. It will be observed that with the increase of frequency, the current in the circuit also increases upto particular value of frequency, and then the current starts decreasing with the increase of frequency.
4. Plot the graph of current verses logf and find out resonance frequency and quality factor (Q) theoretically and graphically.

Circuit Diagram:
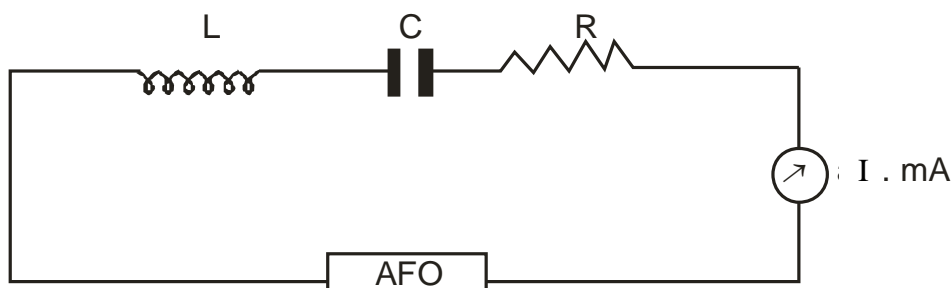
AFO:- Audio Frequency Oscillator;

mA:- a.c. milliameter;

C:- Capacitor;

R:- Resistor;

L:- Inductor.

Observation Table:-

Sr. No.	Frequency f Hz	log f	Current I mA
1	100		
2	200		
3	300		
4	400		
5	500		
6	600		
7	700		
8	800		
9	900		
10	1000		
11	1100		
12	1200		
13	1300		
14	1400		
15	1500		

Calculations: Given values:-

1.   Value of capacitor C=0.25μF, 2. Value of inductor L=100 mH.

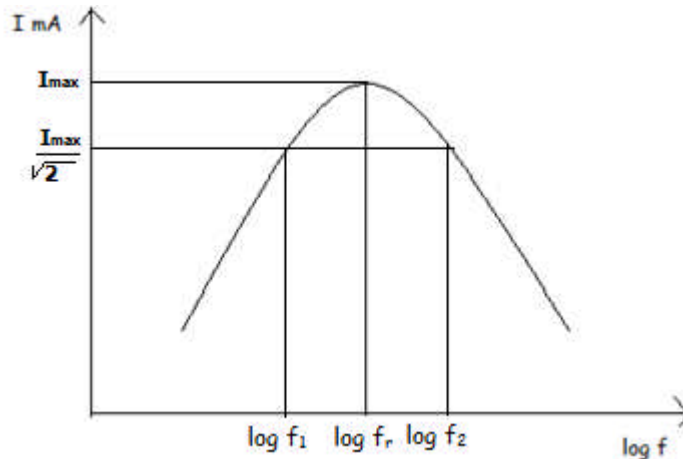(1) $Resonance\ frequency: f_r = \dfrac{1}{2\pi\sqrt{LC}} =$ _____ Hz

(2) $Theoretical\ Quality\ factor\ Q = \dfrac{2\pi f_r L}{R_{tot}}$

R_{tot}= resistance from resistance box + resistance of the coil = R+r=____ Ω

(3) $Experimental\ Quality\ factor\ Q = \dfrac{f_r}{\Delta f}$

$$\Delta f = antilog[log f_2] - antilog[log f_1]$$

Graph:

Result:

1. Theoretical resonance frequency fr = _____Hz

2. Experimental resonance frequency fr = _____Hz

3. Quality factor $Q_{Theoretical}$ =_____ , Q_{Exp} =_____

Exercise: Applying different frequencies to a series L.C.R. circuit measure the current passing through in each case. Plot a graph of current against frequency. From graph determine resonance frequency f_r and the quality factor $Q = \frac{f_r}{f_2 - f_1}$ Also determine the theoretical resonance frequency

$f_{rTH} = \frac{1}{2\pi\sqrt{LC}}$ and the quality factor $Q = \frac{2\pi f_{rTH}L}{R}$ using the given formulas. Here R is the total resistance in the L.C.R. combination.

Viva voce:

1. What is reactance?
2. How reactances of inductor and capacitor are different?
3. Differentiate series and parallel resonance.
4. Why do we get maximum/minimum current at resonance?
5. Define resonance frequency.
6. Define rms value and quality factor.
7. How bandwidth depends on R.
8. Give applications of LCR circuit.

Experiment No: 4
R C Phase shift oscillator

Aim: To determine the frequency of signals of phase shift oscillator.

Theory: The oscillator is an amplifier with positive feedback that generates a number of waveforms usually used in instrumentation and test equipments. An oscillator that generates a sinusoidal output is called a harmonic oscillator; the transistor is usually acts in the active region. The output of the relaxation oscillator is not sinusoidal depending on the transient rise and decay of voltage in RC or RL circuits.

There are two types of RC oscillators:

1. **Phase shift oscillators:** In which the output of an amplifier must be 180° out of phase with input. A general circuit diagram of a phase shift oscillator is shown in Figure 1, where the amplifier is an ideal one. A phase shift network (usually a resistor-capacitor network) is used to produce an additional phase shift of 180° at one particular frequency to develop the required positive feedback. The phase shift oscillator is used to the range of frequencies for several hertz to several kilohertz and so includes the range of audio frequencies. The frequency depends on the impedance elements in the phase shift network.

The phase shift oscillator circuit is not very suitable for generating variable frequency because the resistors and capacitors must be simultaneously changed to obtain the required frequency control over a wide range therefore it is used mostly in fixed frequency applications.

2. **Wien bridge oscillator:** It is used to obtain variable frequency signal. The frequency of oscillation can be changed by using two gang variable capacitors or two gang variable resistors.

Apparatus: Experimental circuit board, CRO.

Procedure:

1.   Connect circuit as shown in the figure.
2.   For a selected combination of R=R_1 and C=C_1, obtain sinusoidal wave form on CRO. [Use tuning capacitor if required].

3. Measure wavelength λ of wave pattern.

4. Calculate periodic time T=λ x t.

5. Calculate observed frequency $F_{obs}=1/T$ Hz and compare it with theoretical frequency F_{th}.

6. Repeat same procedure for two different combinations R_2-C_2 and R_3-C_3.

Circuit diagram:
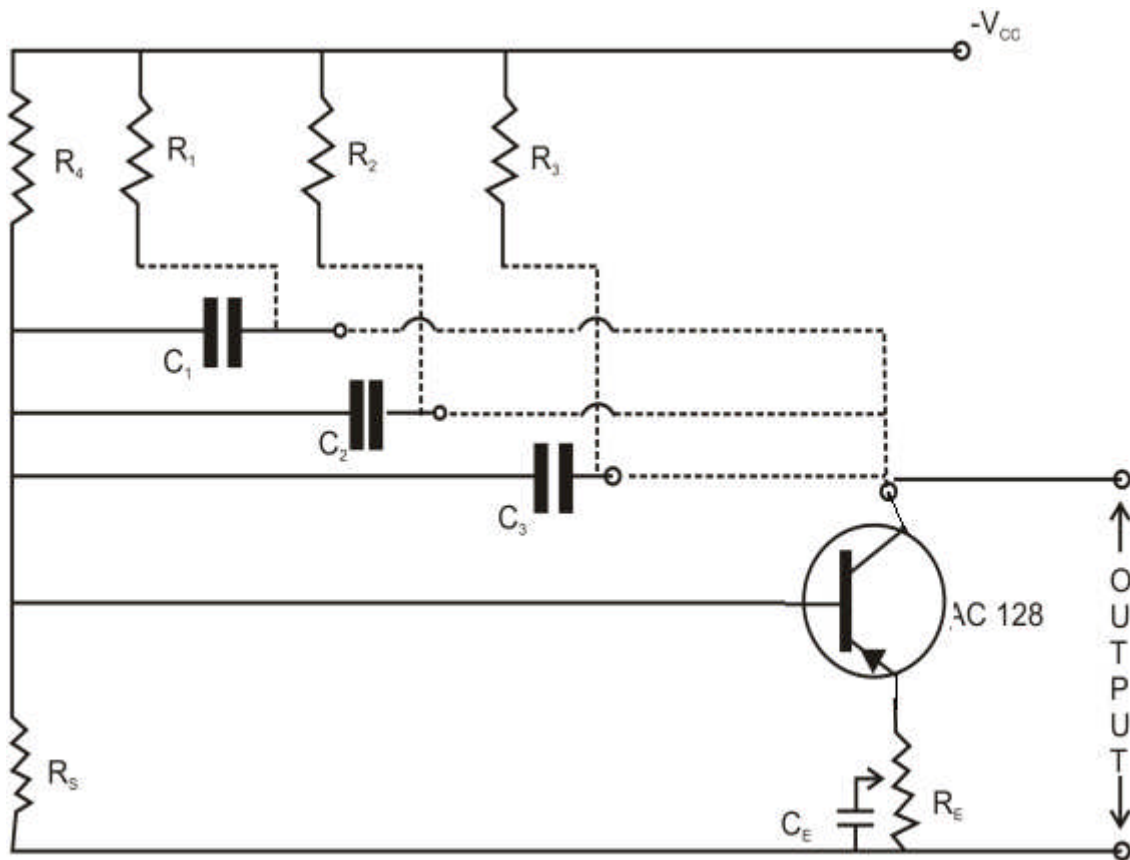
Observation Table:

Obs. No.	Resistance R Ω	Capacitance C μF	F_{th} Hz	λ cm	t sec/cm	T= λ X t sec	F_{obs} Hz
1	$R_1=$	$C_1=$					
2	$R_2=$	$C_2=$					
3	$R_3=$	$C_3=$					

Calculations:

$$F_{th} = \frac{1}{2\pi\sqrt{6}RC}$$

= _____ Hz

(Note: Convert R in Ω and C in F before calculation of F_{th})

Results: The calculated frequencies and observed frequencies for different combinations of R and C are found matching.

Exercise: Find the frequency of oscillation for the given R.C. combinations. Compare these values with theoretical values.

Viva voce:

1. What is feedback?
2. What are negative and positive feedbacks?
3. Define oscillator.
4. What is phase shift?
5. What is role of RC circuit in the experiment?
6. How phase shift is produced in phase shift oscillator?
7. Give full name of CRO.

Experiment No: 5
Resonating air column

Aim: Using Audio Oscillator find out unknown frequency for each resonating air column.

Theory: A wave is a broad distribution of energy, filling space through which it passes. There are three main types of waves. Mechanical waves are the most familiar these are the waves that are produce in a medium such as water (ocean waves), air (sound waves), or solid (seismic waves). Electromagnetic waves require no material medium to propagate (move). Examples are visible light, radio, and microwaves. All electromagnetic waves travel through a vacuum at the same speed, $= 3 \times 10^8 \frac{m}{s}$. Matter waves are waves that produced by particles such as electrons, protons, and other fundamental particles. Atoms and molecules may even be considered matter waves. Waves propagate in two ways, transversely, longitudinally or both. In transverse waves, the element of the wave moves perpendicular to the motion while for longitudinal waves the element moves parallel to the motion. Both types of waves are traveling waves. The wavelength λ, of a wave may be described as the distance (parallel to the direction of the wave's travel) between repetitions of the shape of the wave (or wave shape). The principle of superposition states that when several effects occur simultaneously, their net effect is the sum of the individual effects. Overlapping waves algebraically add to produce a resultant wave (or net wave). Overlapping waves do not in any way alter the travel of each other. The combining of waves is called interference and waves are said to interfere. If two waves of the same amplitude and wavelength travel in opposite directions along a stretched string, their interference with each other produces a standing wave. The resultant wave produces an interference pattern where at the minimum amplitude a node is formed and at the maximum an antinode. The period T, of a wave is described as the time it takes any element to move through one full oscillation. Angular

frequency of the wave is define $\omega = \frac{2\pi}{T}$ and the SI unit is radians per second. The frequency

$f = \frac{1}{T} = \frac{\omega}{2\pi}$, is the number of oscillations per unit time and is related to the period. We may then write the velocity as $= \frac{\lambda}{T}$. A wave that is reflected off of a barrier and travels in the opposite direction of the incidence wave may produce at large frequencies a standing wave pattern or oscillation mode. The standing wave that is produced at a resonance and the frequencies at which the wave resonates are known as resonate frequencies.
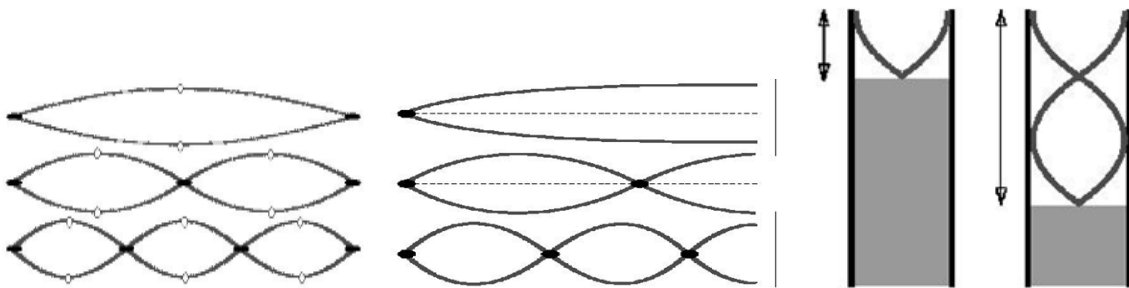
Figure 1

Resonant frequencies that correspond to these wavelengths by the formula $f = \frac{v}{\lambda} = \frac{nv}{2L}$ with n=1,2,3,... The oscillation with the lowest frequency corresponds to the fundamental mode (n=1) or first harmonic, the second harmonic to mode 2 and so on.

Sound waves are longitudinal waves that involve oscillations that are parallel to the direction of the wave. In a pipe with only one open end, standing waves may be produced at the resonant frequencies. Across the open end there is an antinode and on the closed end a node is produced. A full wavelength must be $\lambda = 4L$. As a result the closed in pipe resonant frequencies correspond to $\lambda = \frac{4L}{n}$ for n =1,3,5... Thus, $f = \frac{v}{\lambda} = \frac{nv}{2L}$ for $n = 1,3,5 \dots$

Apparatus: Audio frequency oscillator, glass cylinder, water, hollow metal tube, speaker, wire scale etc.

Procedure:

1.   Fill up fully the glass cylinder with water.

2. First adjust any initial frequency (say 650 Hz) using Audio frequency oscillator.

3. Then raise and adjust metal tube to get maximum intensity of sound due to resonance.

    (**Note:** The tube-length submerged in water should be minimum).

4. At resonance, fix the metal tube in stand and measure the length of the air column from the top of the tube to surface of the water.

5. Repeat the procedure for different frequencies like 600 Hz, 550 Hz … 250 Hz etc.

6. Draw a graph of $f \to \frac{1}{L'}$, and find out unknown frequency.

7. Calculate Velocity of the sound from graph: V_t = 4 x slope.

Observations:

1. L.C. of vernier calipers = _____cm.

2. Inner diameter of the tube d': 1._____cm, 2._____cm, 3._____cm

3. Mean inner diameter of the tube: d=_____cm.

4. End correction: 0.3d=_____cm.

5. Room temp. t=_____°c.

6. Volume expansion coefficient: $\alpha = 0.0036\,°\text{C}^{-1}$.

Observation Table:

Ob. No.	Frequency of signal f Hz	Length of the vibration air column			Mean l' cm	Corrected Length $L = l' + 0.3d$ cm	$\frac{1}{L}$ cm^{-1}	$V_t = 4 \cdot fL$ cm/sec
		l'_1 cm	l'_2 cm	l'_3 cm				
1	650							
2	600							
3	550							
4	500							
5	unknown							
6	400							
7	350							
8	300							
9	250							

Mean V_t ($V_{t\ mean}$) = _____cm/sec.

Calculations:

(1) Unknown frequency f= $V_t/4L$ = _____Hz.

(2) $Vo = V_{t\ mean}(1 - \frac{at}{2})$ = _____ cm/sec.
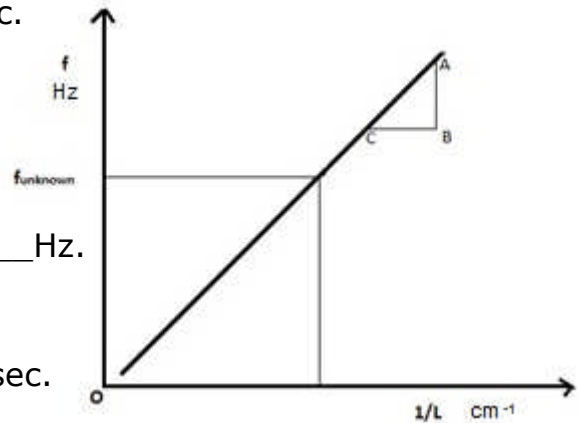
Results:

1. The unknown frequency=_____Hz.
2. The velocity of sound at room temperature V_t=_____cm/sec.
3. The velocity of sound at 0° c =V_0=_____cm/sec.

Exercise:

Using Audio Oscillator find out the length of the resonating air column for five different known frequencies. Also use the resonance to determine the velocity of sound v_t in air at room temperatures.

The velocity of sound in room temperature V_0 = 33,000 cm / s

$V_0 = V_{tmean} \left(1 - \frac{at}{2}\right)$ Where α is coefficient of volume expansion =0.0036°C^{-1}

Viva voce:

1. Define resonance.
2. What are audio waves?
3. Define harmonics.
4. Why do we get resonance in the tube?
5. Why do we need correction in length?
6. Differentiate sound waves and light waves.
7. What is the relation between frequency and the length of the air column?
8. Define compression and rarefaction.

Experiment No: 6
de-Broglie Relation

Aim: To verify de-Broglie Relation by studying the electron diffraction pattern of Aluminum crystal and calculate the wavelength and momentum of an electron.
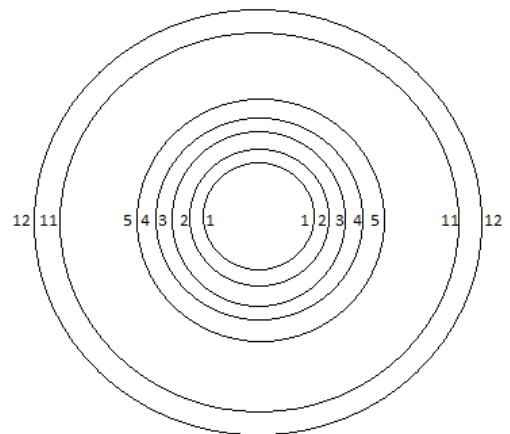
Apparatus: Electron diffraction pattern, scale

Procedure:

1. Place the scale on electron diffraction pattern and measure the diameters of rings for different accelerating voltage (100, 80,60 kv).

2. From the given inter-planner spacing, calculate the wavelength of electrons.

3. Also calculate Planck's constant **h**.

4. Draw the graph of $\lambda \rightarrow 1/p$ and find out the slope which gives the Planck's constant **h**

Observations:

1. Distance of Photographic plate from the specimen: L=23cm

2. Mass of an electron: m=9.1x10^{-28}gm

3. Charge of an electron:e=1.6x10^{-19}coulomb

Data Sheet:

Ring Number	d-spacing A^0	Miller Indices	Ring Number	d-spacing A^0	Miller Indices
1	2.338	(111)	10	0.779	(333)
2	2.025	(002)	11	0.779	(115)
3	1.432	(022)	12	0.716	(044)
4	1.221	(113)	13	0.685	(135)
5	1.169	(222)	14	0.675	(006)
6	1.012	(004)	15	0.675	(244)
7	0.929	(133)	16	0.640	(026)
8	0.906	(024)	17	0.618	(335)
9	0.827	(224)	18	0.611	(226)

Observation Table: 1 (**Note:** Measure diameters by considering inner ring as first ring)

For accelerating voltage V = 60 KV

Ring no	Scale reading		Ring diameter	Original ring diameter	Radius of the ring	Inter planer spacing	R.d cm^2	Wave length	Planck's constant
	LHS A cm	RHS B cm	D'=A-B cm	D=d'/4.4 Cm	R=D/2 cm	d (in 10^{-8} cm)		λ =R.d/L	h= λ.P (in 10^{-27} ergs.sec)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Mean h=_____x 10^{-27} erg.sec

Observation Table: 2 (**Note:** Measure diameters by considering inner ring as first ring)

For accelerating voltage V = 80 KV

Ring no	Scale reading		Ring diameter	Original ring diameter	Radius of the ring	Inter planer spacing	R.d cm^2	Wave length	Planck's constant
	LHS A cm	RHS B cm	D'=A-B cm	D=d'/4.4 Cm	R=D/2 cm	d (in 10^{-8} cm)		λ =R.d/L	h= λ.P (in 10^{-27} ergs.sec)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Mean h=_____x 10^{-27} erg.sec

Observation Table: 3 (**Note:** Measure diameters by considering inner ring as first ring)

For accelerating voltage V = 100 KV

Ring no	Scale reading		Ring diameter	Original ring diameter	Radius of the ring	Inter planer spacing	R.d cm^2	Wave length	Planck's constant
	LHS A cm	RHS B cm	D'=A-B cm	D=d'/4.4 Cm	R=D/2 cm	d (in 10^{-8} cm)		λ =R.d/L	h= λ.P (in 10^{-27} ergs.sec)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Mean h=_____x 10^{-27} erg.sec

Table: 4

Accelerating Voltage V Volts	Momentum $P = \sqrt{meV/150}$ (gm.cm/sec)	1/P sec/(gm.cm)	Mean λ cm (From Observation Table:1,2,3)
60×10^3	1.32674×10^{-17}	0.75373×10^{17}	
80×10^3	1.53199×10^{-17}	0.65275×10^{17}	
100×10^3	1.71282×10^{-17}	0.5838×10^{17}	

Calculations:

Result: Value of Planck's constant is _____ erg •sec.

Experiment No: 7
Cardinal points of two lens system

Aim: Find the cardinal points of given lens system by magnification method.

Theory: The cardinal points lie on the optical axis of the optical system. Each point is defined by the effect the optical system has on rays that pass through that point, in the paraxial approximation. The paraxial approximation assumes that rays travel at shallow angles with respect to the optical axis, so that $sin\theta \approx \theta$ and $cos\theta \approx 1$. Here Aperture effects are ignored.

Focal Planes and Focal Points: The front focal plane in the object space that is imaged at infinity. The back focal plane in the image space where an object at infinity is imaged.

The front focal point of an optical system, by definition, has the property that any ray that passes through it will emerge from the system parallel to the optical axis. The rear (or back) focal point of the system has the reverse property: rays that enter the system parallel to the optical axis are focused such that they pass through the rear focal point.

Principal Planes and Principal Points: the object and image planes for which the transverse magnification is +1 are called Principal planes.

The principal points are pair of points (one each in object space and image space) that are images of each other with magnification $M_T=+1$.

Nodal Planes and Nodal Points: The object and image planes for which the angular magnification is +1.

The front and rear nodal points have the property that a ray aimed at one of them will be refracted by the lens such that it appears to have come from the other, and with the same angle with respect to the optical axis. The nodal points therefore do for angles what the principal planes do for transverse distance. If the medium on both sides of the optical system is the same (e.g., air), then the front and rear nodal points coincide with the front and rear principal points, respectively.
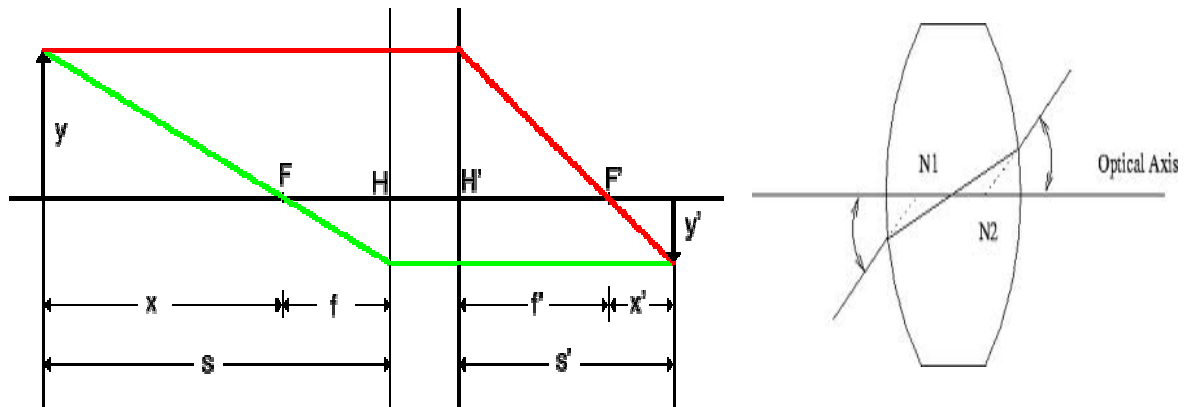
Apparatus: Convex lenses, Lens stand, object, image scale, lamp etc.

Procedure:

1. Take an object of thickness 1cm.

2. Place lens system (two convex lenses kept few cms apart) in front of the object.

3. By adjusting position of image scale remove the parallax between image of the object seen through lens system and the image scale.

4. Measure the size of the image, the distances between the object and the object lens and image and the image lens.

5. Calculate the magnification factor.

6. Plot the graphs and calculate the focal lengths of both the lenses.

7. Plot all the six cardinal points P_1, P_2, F_X, F_Y, N_1 & N_2 of the lens system. Here P_1 & P_2 are the principal points, F_X & F_Y are the focal points and N_1 & N_2 are the nodal points.
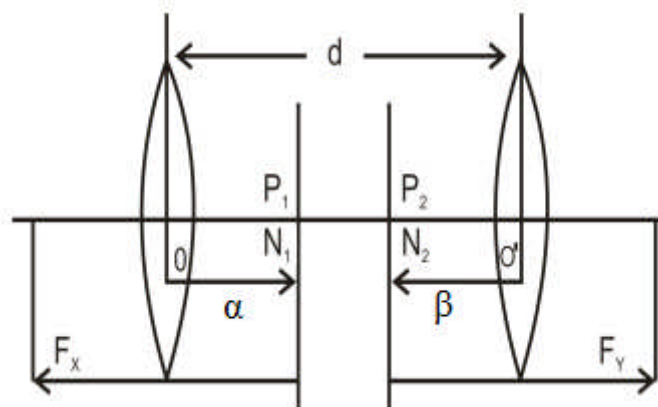
Observations Table:

Distance between the convex lenses = d = _____cm.

Size of the object   O = 1 cm

Obs. No.	Distance between object and lens X cm	Distance between image and lens Y cm	Size of the image I cm	Magnification M = I/O	1/m	1+m	1+(1/m)
1							
2							
3							
4							
5							
6							

Graphs :

$$\text{Slope} = \frac{AB}{BC} = \frac{1}{F_x}$$

$$\text{Slope} = \frac{PQ}{QR} = \frac{1}{F_y}$$

$$F_x = \frac{1}{\text{Slope}} = \text{_____} \text{cm}$$

$$F_y = \frac{1}{\text{Slope}} = \text{_____} \text{cm}$$

Results: The six cardinal points of the lens system are two focal points F_x and F_y, two principal points P_1 and P_2 and two nodal points N_1 and N_2 as shown in the figure.

Exercise: Determine the cardinal points of the given optical system by magnification method. Take at least six different distances with lens separation _____ cm.

Viva voce:
1. Name cardinal points in two lens system.
2. Define focal points, principal points, nodal points, focal length.
3. Distinguish between real image and virtual (imaginary) image.
4. Give example, where two lens combination is used.
5. Name aberrations in various lenses.

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Experiment No: 8
Dispersive power of a prism

</div>

Aim: To find the angle of minimum deviation for different spectral lines and dispersive power of a prism.

Theory:

When a beam of light strikes on the surface of transparent material (Glass, water, quartz crystal, etc.), the portion of the light is transmitted and other portion is reflected. The transmitted light ray has small deviation of the path from the incident angle. This is called refraction. Refraction is due to the change in speed of light while passing through the medium. It is given by Snell's Law.

$$\frac{\sin(i)}{\sin(r)} = \frac{n_2}{n_1}$$

Where i is the angle of incident and r is the angle of refraction. And n_1 is the refractive index of the first face and n_2 is the refractive index of the second face. The change in refracted angle with respect to the refractive index is shown in the figure given below.
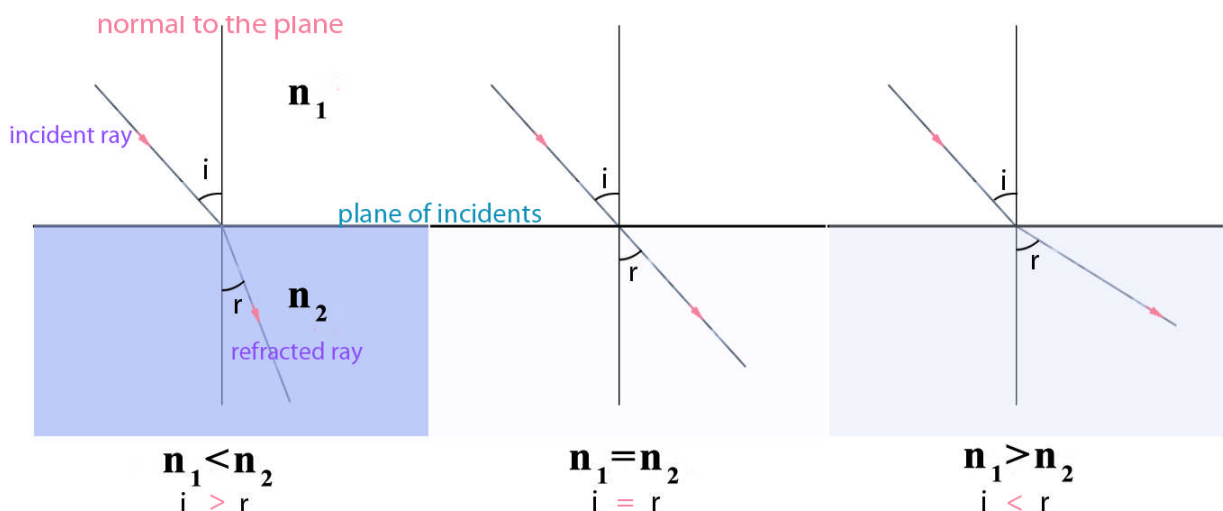
Figure: 1

Consider a prism of angle A and refractive index n_2. Let i_1 and r_1 are the incident and refracted ray from face AB, and i_2 and r_2 are the incident and emerged ray from the second face AC.
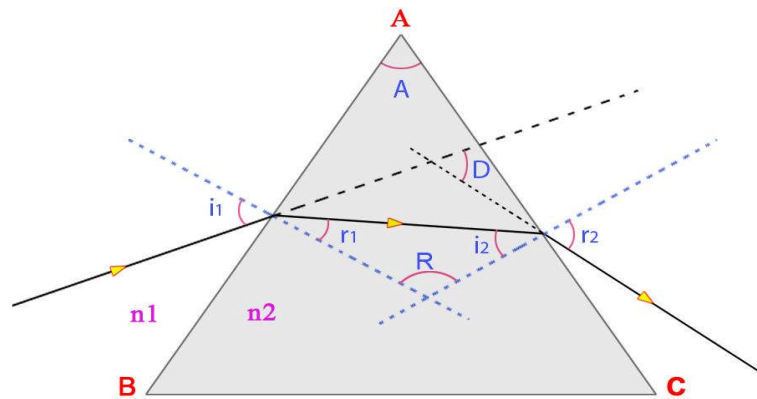
Figure: 2

If δ_m is minimum angle of deviation for any colour, then the refractive index is given by

$$\mu = \frac{\sin(\frac{A + \delta m}{2})}{\sin \frac{A}{2}}$$

For two colours violet-1 (v_1) and yellow-2 (Y_2), the dispersive power of a prism is calculated using equation

$$\omega = \frac{\mu_{V1} - \mu_{Y2}}{\mu_m - 1}$$

Here μ_{v1} and μ_{Y2} are refractive indices of violet-1 and yellow-2.

$$\mu_m = \frac{\mu_{V1} + \mu_{Y2}}{2}$$

Apparatus: Spectrometer, prism, spirit level

Procedure:

1.   Level the spectrometer and prism table using spirit level.

2.   Find the least count of spectrometer.

3.   Keep the prism on prism table and obtain the spectral lines.

4.   Using Schuster's method focus the telescope and collimator.

5.   Set the prism for minimum deviation position.

6.   Note down spectrometer readings from any one windows for different spectral lines.

7. Remove the prism and take direct reading. Calculate angle of minimum deviation and refractive indices for each spectral lines.

8. Calculate dispersive power of prism and plot the graph of µ versus λ.

Observations:

[1] L. C. of spectrometer $= \frac{\text{value of smallest division on main scale}}{\text{total number of division on vernier scale}} = \frac{30'}{30} = 1'$

[2] Angle of prism (A) = 60°

Observations Table:

Colour	Wavelength of spectral lines	Spectrometer Readings A_1°	Direct reading A_2°	Angle of minimum deviation $\delta_m^\circ = A_1 \sim A_2$	Refractive Index µ for each spectral lines
Violet 1	4047 Å				
Violet 2	4078 Å				
Blue	4358 Å				
Blue Green 1	4916 Å				
Blue Green 2	4960 Å				
Green	5461 Å				
Yellow 1	5790 Å				
Yellow 2	5791 Å				

Calculations:

$$\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\frac{A}{2}}$$

$$\mu_m = \frac{\mu_{V1} + \mu_{Y2}}{2} = \underline{\hspace{3cm}}$$

Dispersive Power $= \omega = \dfrac{\mu_{V1} - \mu_{Y2}}{\mu_m - 1}$

Graph:

μ

λ Å
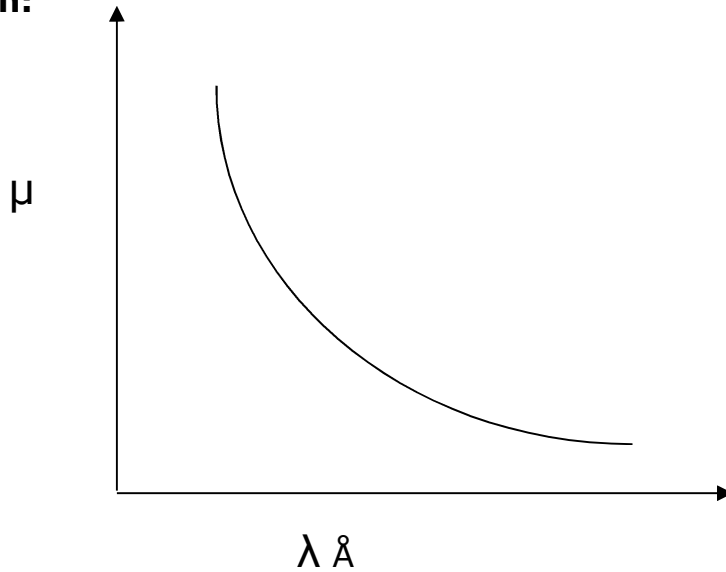
Results: Dispersive power of the prism is _____.

Exercise:

1. Determine the 'μ' of the different spectral lines. Draw graph of $\mu \rightarrow \lambda$. Find dispersive power. The angle of prism is 60^0.

$$\text{Dispersive Power } D.P. = \frac{\mu_v - \mu_y}{\mu_m - 1}, \text{where } \mu_m = \frac{\mu_v + \mu_y}{2}$$

Viva voce:
1. Define refractive index.
2. Define dispersive power.
3. What is the wavelength of visible spectrum?
4. Explain condition for minimum angel of deviation.
5. What is the relation between refractive index and angle of deviation?
6. Differentiate between monochromatic and polychromatic source of light with examples.
7. What is the difference between resolving power and dispersive power?
8. Which type of scale is used in the practical?

| **Experiment No: 9** |
| **Numerical differentiation** |

Aim: To determine the derivation of a function f(x) at given point x=a.

Apparatus: Scientific Calculator, Plain Papers, Graph Papers, Pencil etc.

Theory: The operation used in the calculus to obtaining the differentiation co efficient is knownthe differentiation.

For example, if y= f'(x) = xⁿ then the differentiation co efficient: $\frac{dy}{dx} = nx^{n-1}$

Where, $\frac{dy}{dx}$ is known as the first order derivative and is denoted by y',

similarly, $\frac{d^2y}{dx^2}$ is the second order derivative and is denoted by y'' and so on…

To determine the derivative of any function f(x) at a given point x=a, the formula can be used to get an approximate answer, suppose f(x) is any function then the derivative can be calculated by,

f'(x) $\approx \frac{1}{h}$[f(x+h) − f(x)]ₓ₌ₐ ± e, Where, h- is step length and e- is an error.

Error can be calculated by,

e = $-\frac{h}{2}$[f''(x)], Where, f''(x) $\approx \frac{1}{h^2}$[f(x+h) − 2f(x)+f(x-h)]

Procedure:

1. Make tables using given equation for various methods.

2. Compute the value of given equations, by:

   (i), Analytical method,

   (ii), Numerical method, and

   (iii), Graphical method.

3. Show and compare results and find out error.

Solved example: Find the value of f'(x) for a given function y = f(x) = x² at x=2 and h=0.1.

(a). Analytical method:

Here, $y = f(x) = x^2$ is given,

So, $y = f(x) = x^2$

then $y' = f'(x) = \frac{dy}{dx} = 2x^{2-1} = 2x$

But x=2,

$\therefore \quad y' = f'(x) = \frac{dy}{dx} = 2 \times 2 = 4$

(b). Numerical method:

Here, $y = f(x) = x^2$ and x=2, h=0.1 are given,

Now, we know that,

$y' = f'(x) \approx \frac{1}{h}[f(x+h) - f(x)]_{x=a} \pm e$

  1. $f(x) = x^2 = 2^2 = 4$

  2. $f(x+h) = f(2+0.1) = f(2.1)$

     But, $f(x) = x^2$, therefore, $f(2.1) = (2.1)^2 = 4.41$

  3. To find error, first of all we should find the value of f''(x).

       (i) $f(x) = x^2 = 2^2 = 4$,

       (ii) $f(x+h) = 4.41$ and

       (iii) $f(x-h) = (2-0.1) = (1.9)$,

       but $f(x) = x^2 = (1.9)^2 = 3.61$.

Now, $f''(x) \approx \frac{1}{h^2}[f(x+h) - 2f(x) + f(x-h)]$.

Substituting above values,

$f''(x) \approx \frac{1}{h^2}[f(x+h) - 2f(x) + f(x-h)]$

$f''(x) \approx \frac{1}{(0.1)^2}[4.41 - 2 \times 4 + 3.61] = 2$

Now, error $e = -\frac{h}{2}[f''(x)] = -\frac{0.1}{2}[2] = -0.1$

Let,

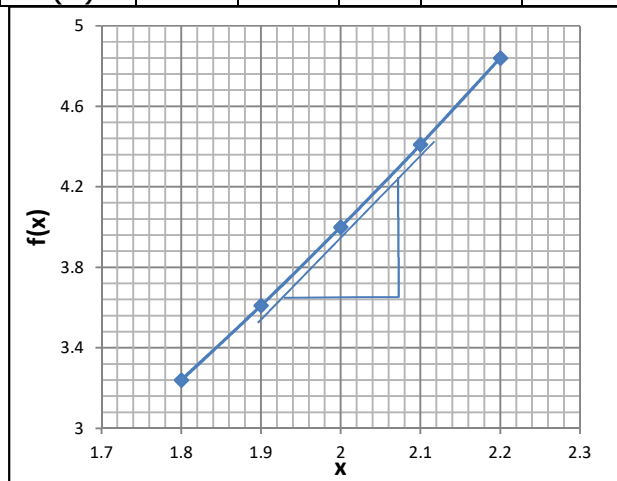$y' = f'(x) \approx \frac{1}{h}[f(x+h) - f(x)]_{x=a} \pm e$

$y' = f'(x) \approx \frac{1}{0.1}[4.41 - 4]_{x=2} - 0.1 = \frac{0.41}{0.1} = 4.1 \approx 4$

(b). Graphical method:

Make a table for given function and Plot a graph between x and f(x) and find out the value of slope you will get the value of a function.

Table:

Sl. No.	1	2	3	4	5
x	1.8	1.9	2.0	2.1	2.2
y = f(x)	3.24	3.61	4.0	4.41	4.84

Slope of the tangential line: **m** $= \dfrac{ab}{bc}$ **= _____**

Result:

Examples:

$y = x^3$	y = (x+x²)²	$y = 2x^3$	y = eˣ	y = log₁₀ x	y = (x²+1)³

$y = x^3$	$y = (x+x^2)^2$	$y = 2x^3$	$y = e^x$	$y = \log_{10} x$	$y = (x^2+1)^3$

Exercise:

Numerically find the differentiation of the function $f(x) = e^x$ at x=2.0 taking the values of h= _____ & _____ . Compare the answer with the result obtained from the graph. Also verify both these results by finding the analytical answer to the problem.

Viva voce:

1.   Name different methods for differentiation.

2.   What is advantage of numerical method over other methods?

3.   Give physical meaning of differentiation and integration.

4.   What is the effect of step size on the result?

5.   Differentiate following functions w.r.t. x: sinx, sinx², logx, lnx, e³ˣ

| **Experiment No: 10** |
| **Linear least square fitting method** |

Aim: Find the value of slope and intercept theoretically for given observations and find error related to it.

Apparatus: Scientific Calculator, Plain Papers, Graph Papers, Pencil etc.

Theory:

The general form of the linear equation is $y_i = a_0 + a_1x$ or $y_i = c + mx_i$, (Where, a_0 or c is the intercept of the graph drawn and a_1 or m is the slope of the graph drawn). For given pair of data **(x_i, y_i)** the best fitted value of **intercept (a_0)** and **slope(a_1)** are given by:

1.   **a_0 or c $= \frac{\sum y_i \sum x_i{}^2 - \sum x_i \sum x_i y_i}{\Delta}$** and

2.   **a_1 or m $= \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\Delta}$** ,

3. $\Delta = [n\sum x_i{}^2 - (\sum x_i)^2]$

      Where, n is the number of observations given.

4.   The uncertainty in the slope a_i (or m) of linear least square fit line is

      given by, $U_n(a_1) = \sqrt{\dfrac{\sum y_i{}^2 - a_1\sum x_i y_i - a_0\sum y_i}{(n-2)\Delta}}$

5.   The corresponding uncertainty in the intercept a_0 (or c) of linear least square fit line is given by,

      $U_n(a_0) = \sqrt{\dfrac{(\sum y_i{}^2 - a_1\sum x_i y_i - a_0\sum y_i)\sum x_i{}^2}{n(n-2)\Delta}}$

Procedure:

1.   Prepare table using given pairs of observations.

2.   Using relations (1), (2) and (3) find the values of intercept and slope.

3.   Evaluate error in it, with the help of relations (4) and (5), These values are known as uncertainty in the result.

4.   Plot the graph using the pairs of observations and find the value of intercept and slope of it.

5.   Show and compare the results.

Example:

Aim: - Find the value of slope and intercept theoretically for given observations and find error related to it.

x_i	0.1	0.2	0.3	0.4	0.5	0.6
y_i	0.30	0.48	0.64	0.76	0.88	0.97

Table 1.

Sl. No.	x_i	y_i	x_i^2	y_i^2	$x_i y_i$
1	0.1	0.30	0.01	0.0900	0.030
2	0.2	0.48	0.04	0.2304	0.096
3	0.3	0.64	0.09	0.4096	0.192
4	0.4	0.76	0.16	0.5776	0.304
5	0.5	0.88	0.25	0.7744	0.440
6	0.6	0.97	0.36	0.9409	0.582
	$\sum x_i = 2.1$	$\sum y_i = 4.03$	$\sum x_i^2 = 0.91$	$\sum y_i^2 = 3.0229$	$\sum x_i \sum y_i = 1.644$

2. **Calculation:**

  i. To find Δ **:**

  Formula:- $\Delta = [n\sum x_i^2 - (\sum x_i)^2]$**,**

  Substituting values from table,

  $\Delta = [6 \times 0.91 - \times (2.1)^2]$

  $\Delta = \mathbf{1.05}$

  ii. To find $\mathbf{a_0}$ **or c :**

  Formula:- $\mathbf{a_0}$ **or c =** $\frac{\sum y_i \sum x_i^2 - \sum x_i \sum x_i y_i}{\Delta}$

  Substituting values from table,

  a_0 or c **=** $\frac{4.03 \times 0.91 - 2.1 \times 1.644}{1.05}$

  a_0 or c = 0.2047

  iii. To find $\mathbf{a_1}$ **or m :**

  Formula:- $\mathbf{a_1}$ **or m =** $\frac{n\sum x_i y_i - \sum x_i \sum y_i}{\Delta}$

  Substituting values from table,

  a_1 or m**=** $\frac{6 \times 1.644 - 2.1 \times 4.03}{1.05}$

  a_1 or m= 1.3343

iv. To find $U_n(a_1)$:

Formula:- $U_n(a_1) = \sqrt{\dfrac{\sum y_i^2 - a_1 \sum x_i y_i - a_0 \sum y_i}{(n-2)\Delta}}$

Substituting values from table,

$U_n(a_1) = \sqrt{\dfrac{3.0229 - 1.3343 \times 1.644 - 0.2047 \times 4.03}{4 \times 1.05}}$

$U_n(a_1) = 0.03225$

v. To find $U_n(a_0)$:

Formula:- $U_n(a_0) = \sqrt{\dfrac{(\sum y_i^2 - a_1 \sum x_i y_i - a_0 \sum y_i)\sum x_i^2}{n(n-2)\Delta}}$

Substituting values from table,

$U_n(a_0) = \sqrt{\dfrac{(3.0229 - 1.3343 \times 1.644 - 0.2047 \times 4.03) \times 0.91}{6 \times 4 \times 1.05}}$

$U_n(a_0) = 0.012$

3. Plot the graph using the pairs of observations and find the value of intercept and slope of it and compare the results…

Exercise:

Obtain appropriate least square fit for the given two sets of data given here, y is dependent variable for a set of known value of x. Also plot the set of data points and the linear regression line on a graph paper for both.

X	1	2	3	4	5	6	7	8	9	10
Y	1.2	2.1	2.8	3.7	4.5	5	5.5	6.3	8.0	9.0

X	1	2	3	4	5	6	7	8	9	10
Y	2.1	4.5	8.0	9.5	13.0	14.5	15	19	20.6	21.8

Viva Voce:

1. Differentiate linear and exponential functions.
2. Give mathematical expression of straight line.
3. What is regression line?
4. What is the difference between interpolation and extrapolation?
5. Name some experiments in which this method is used.