V P & R P T P Science College

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S Y BSc Semester IV 2017-18

Subject: Physics

US04CPHY03 Practical Record Book

Name:____

Roll No:_________ **Batch:**_______**Division:** _____

Day:_________**and** ________ **Timing:** __________**to**________

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Note: Practical: 3 & 4 are in TY Lab, Practical: 2 & 5 are in Dark Room Lab.
Note: Students have to collect apparatus from lab peon for practical*: 1, 2, 5, 6 and 12 and return in working order after completing the experiment.
Note: Students have to pay bracket charges for any damage of apparatus.

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Kater's Reversible Pendulum (variable knife edge)

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

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

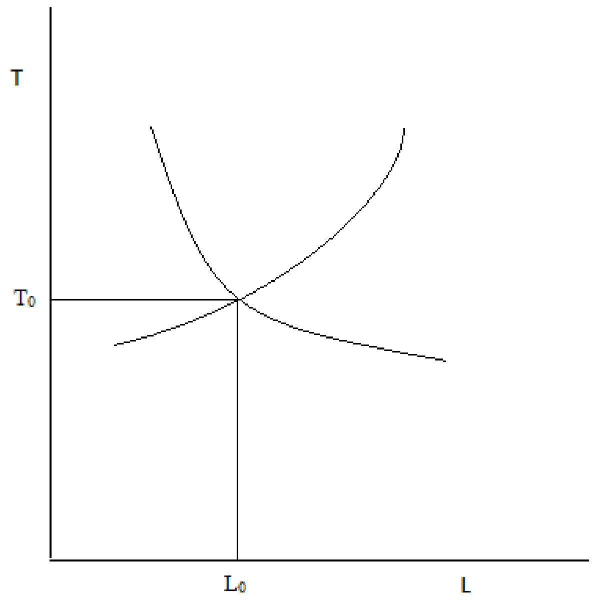
Procedure:

1. Fix the distance between two knife edges $k_1$and k_2 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. Now repeat for distance 80 cm, 70 cm, 60 cm and 50 cm.
7. Draw a graph of T_1 and T_2 with distances. From intercept of both graphs determine L_0 and T_0. Calculate acceleration due to gravity from the given formula.

Observation Table:

Obs. No.	Distance between two knife edges D cm	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	90				
2	80				
3	70				
4	60				
5	50				

Graph:



Calculations:

Acceleration due to gravity is given by $g = 4\pi^2 \frac{L_0}{T_0^2}$ cm/sec^2

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

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Cauchy's Constants

Aim: To determine the Cauchy's constants of the material of the given prism.

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. Set the prism for minimum deviation position.
5. Note down spectrometer readings from both the windows for different spectral lines.
6. Remove the prism to take direct reading. Calculate angle of minimum deviation and refractive indices for all spectral lines.
7. Plot the graph of μ versus $\frac{1}{\lambda^2}$ and find out Cauchy's constants A and B.

Observations:

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

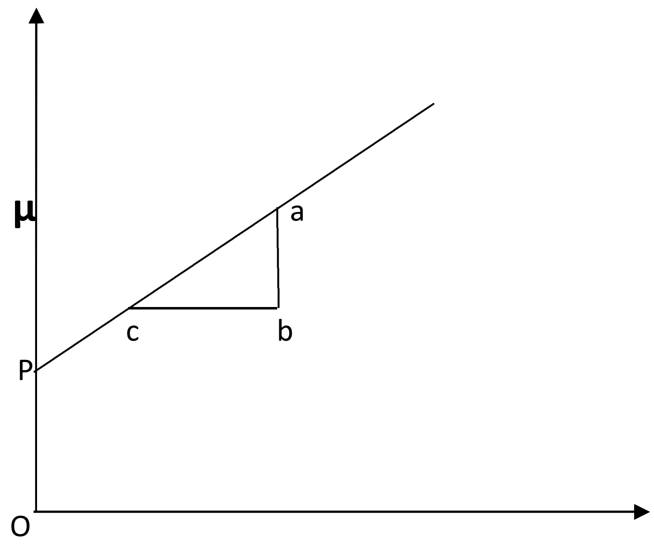
[2] Angle of prism (A) = 60°

Observations Table:

Colour	Wave length of spectral lines	Spectro-meter Readings θ_1°	Direct reading θ_2°	Angle of minimum deviation δ_m° $= \theta_1 \sim \theta_2$	Refractive Index μ	λ^2 in 10^{-9} cm^2	$\frac{1}{\lambda^2}$ in 10^{8} cm^{-2}
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						

Note: Write λ^2 in the order of 10^{-9} cm^2 and $\frac{1}{\lambda^2}$ in the order of 10^{8} cm^{-2}

Graph:



$\frac{1}{\lambda^2}$ (in 10^8 cm^{-2})

Calculations:

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

A = OP = Intercept on Y- axis

B = slope = $\frac{ab}{bc}$ (in the order of 10^{-10} cm^2)

Cauchy's formula is $\mu = A + \frac{B}{\lambda^2}$ (equation of straight line: Y=mx + c)

Result: Cauchy's Constants A=___________, B=_________________.

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Parallel Resonance (L-C-R Circuit)

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

Theory: A parallel 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. In a parallel (tank) LC circuit, this means infinite impedance at resonance.

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

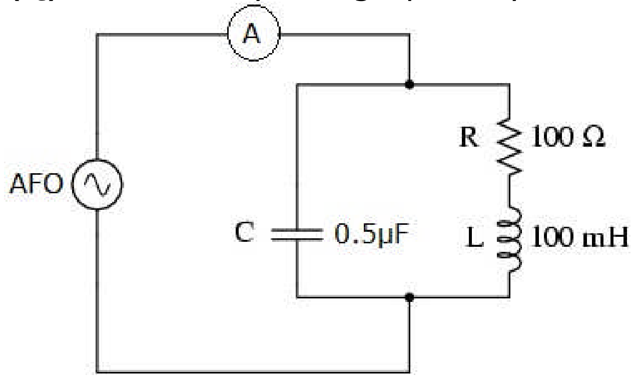
$$f_r = \frac{1}{2\pi} \cdot \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

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 decreases up to particular value of frequency, and then the current starts increasing with the increase of frequency.
4. Plot the graph of current verses log f and find out resonance frequency and quality factor (Q) theoretically and graphically.

Circuit Diagram:



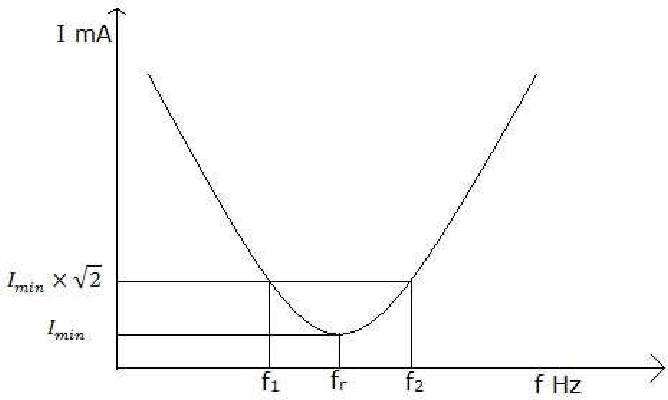
AFO:- Audio Frequency Oscillator;

A:- a.c. milliameter; C:- Capacitor; R:- Resistor; L:- Inductor.

Observation Table:-

Sr. No.	Frequency f Hz	Current I mA
1	100	
2	200	
3	300	
4	400	
5	500	
6	600	
7	700	
8	800	
9	900	
10	1000	

Graph:-



Calculations: Given values: C=0.5μF, L=100 mH, Resistance of the coil r= __ Ω

(1) $Theoretical\ Resonance\ frequency: f_r = \frac{1}{2\pi} \cdot \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} =$ ________ Hz

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

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

(3) $Experimental\ Resonance\ Frequency\ f_r =$ ________ Hz

(4) $Experimental\ Quality\ factor\ Q = \frac{f_r}{\Delta f}$, $Here\ \Delta f = f_2 - f_1.$

Result:

1. Theoretical resonance frequency f_r = ___________Hz
2. Experimental resonance frequency f_r = ___________Hz
3. Theoretical Quality factor Q=__________
4. Experimental Quality factor Q=__________

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Impedance by voltage drop method

Aim: To determine the impedance of the given series LCR circuit by voltage drop method.

Theory:

Resistance is essentially *friction* against the motion of electrons. It is present in all conductors to some extent (except *super*conductors!), most notably in resistors. When alternating current goes through a resistance, a voltage drop is produced that is in-phase with the current. Resistance is mathematically symbolized by the letter "R" and is measured in the unit of ohms (Ω).

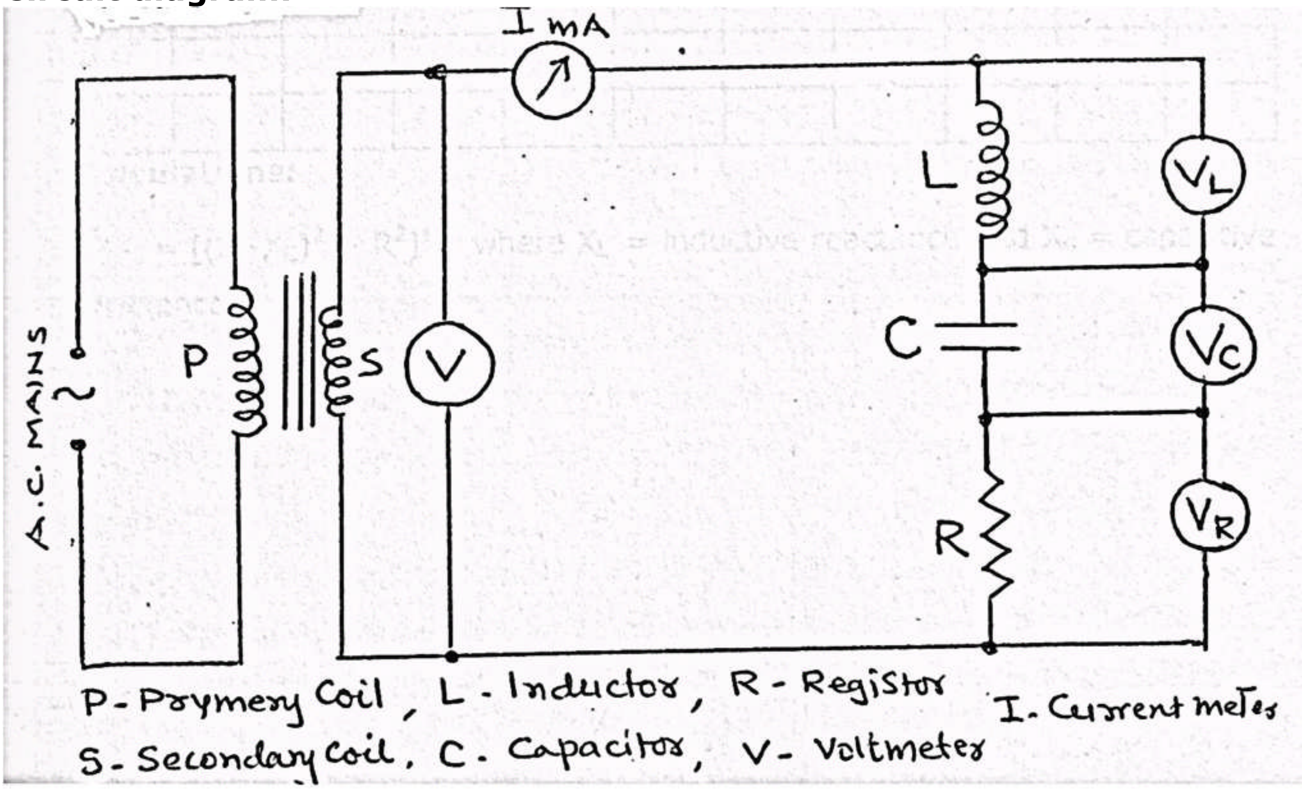
Reactance is essentially *inertia* against the motion of electrons. It is present anywhere electric or magnetic fields are developed in proportion to applied voltage or current, respectively; but most notably in capacitors and inductors. When alternating current goes through a pure reactance, a voltage drop is produced that is 90^o out of phase with the current. Reactance is mathematically symbolized by the letter "X" and is measured in the unit of ohms (Ω).

Impedance is a comprehensive expression of any and all forms of opposition to electron flow, including both resistance and reactance. It is present in all circuits, and in all components. When alternating current goes through an impedance, a voltage drop is produced that is somewhere between 0^o and 90^o out of phase with the current. Impedance is mathematically symbolized by the letter "Z" and is measured in the unit of ohms (Ω), in complex form.

Perfect resistors possess resistance, but not reactance. Perfect inductors and perfect capacitors possess reactance but no resistance. All components possess impedance. The impedance phase angle for any component is the phase shift between voltage across that component and current through that component. For a perfect resistor, the voltage drop and current are *always* in phase with each other, and so the impedance angle of a resistor is said to be 0^o. For an perfect inductor, voltage drop always leads current by 90^o, and so an inductor's impedance phase angle is said to be $+90^o$. For a perfect capacitor, voltage drop always lags current by 90^o, and so a capacitor's impedance phase angle is said to be -90^o.

Apparatus: Step down transformer, capacitor, inductor, resistor, volt meters, ammeter (mA range).

Circuit diagram:



Procedure:

1. Connect a series combination of LCR circuit to output of a step down transformer as shown in circuit diagram.
2. Connect a voltmeter between secondary terminals of step down transformer to measure input voltage **V**, imparted to LCR circuit. Also measure current **I**, using an ammeter.
3. For different values of circuit voltage **V**, measure potential differences $\mathbf{V_L}$, $\mathbf{V_C}$ and $\mathbf{V_R}$ developed across **L**, **C** and **R** respectively.
4. Compare observed impedance of circuit $\mathbf{Z_{Obs}}$ and calculated impedance $\mathbf{Z_{Calc}}$.

Result: Z_{Obs} and Z_{Calc} are nearly equal.

Observation Table:

Obs. No.	V Volt	$I' mA$	$I = I' x 10^{-3}$ Amp	V_L Volt	$X_L = \frac{V_L}{I}\ \Omega$	V_C Volt	$X_C = \frac{V_C}{I}\ \Omega$	V_R Volt	$R = \frac{V_R}{I}\ \Omega$	$Z_{Obs} = \frac{V}{I}\ \Omega$	$Z_{Calc}\ \Omega$
1											
2											
3											
4											
5											
6											
7											

Calculations:

$$Z_{Calc} = [(X_L - X_C)^2 + R^2]^{1/2}$$

where $X_L = \frac{V_L}{I}$ = inductive reactance and $X_C = \frac{V_C}{I}$ = capacitive reactance

Calculations:

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‘λ’ By double slits

Aim: To determine the wave length of the given unknown (Sodium) source using double slits

Apparatus: Double slits glass plate, Wire gauge, Telescope, Travelling microscope, Monochromatic source (sodium lamp)

Procedure:

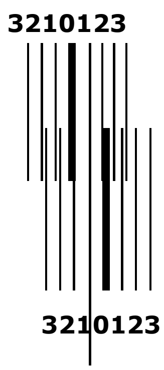
1) Measure the gauge element (d) with the help of travelling microscope.
2) Mount the telescope on a stand such that its axis lies horizontal.
3) The slit is generally attached vertically to a frame near the monochromatic source (Sodium lamp).
4) Illuminate the slit with source of light.
5) Now move the telescope in the horizontal direction such that the images of two vertical source are in the field of view of the eye piece.
6) Now mount the wire gauge on other stand between the slit and telescope.
7) Now move the position of wire gauge and telescope such that the first order diffraction fringes is observed as fig-1.
8) In this case measure the distance (D) between wire gauge and slit
9) Repeat the experiment for second order diffraction (fig-2) and measure distance (D) between wire gauge and slit.

Observation:

$$\text{LC of traveling microscope} = \frac{\text{value of smallest division in main scale}}{\text{total number of divisions in vernier scale}} = \frac{0.05}{50} = 0.001cm$$

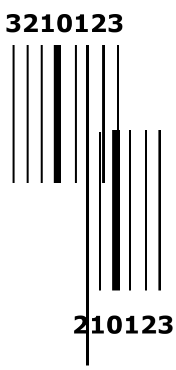
Slit Width x= ________cm.

Fig: - 1



1st order

Fig: - 2



2nd order

Table 1:

Gauge	Obs. No.	Traveling microscope readings for five successive wires R_i cm	distance between five successive wires R cm	Mean distance between five successive wires d_5 cm	Mean distance between two successive wires $d = \frac{d_5}{5}$ cm
A	1	R_0 =	$R_5 \sim R_0$ =		
	2	R_5 =	$R_{10} \sim R_5$ =		
	3	R_{10} =	$R_{15} \sim R_{10}$ =		
	4	R_{15} =	-------		
B	1	R_0 =	$R_5 \sim R_0$ =		
	2	R_5 =	$R_{10} \sim R_5$ =		
	3	R_{10} =	$R_{15} \sim R_{10}$ =		
	4	R_{15} =	-------		

Table 2:

Gauge	Obs. No.	No.of order N	Distance between wire gauge and slits D cm	$\lambda = \frac{x\ d}{2\ N\ D}$ cm
A	1	1		
	2	2		
B	1	1		
	2	2		

Calculation:

The wave length of the given unknown source $\lambda = \frac{x\ d}{2\ N\ D}$ cm.

Result:

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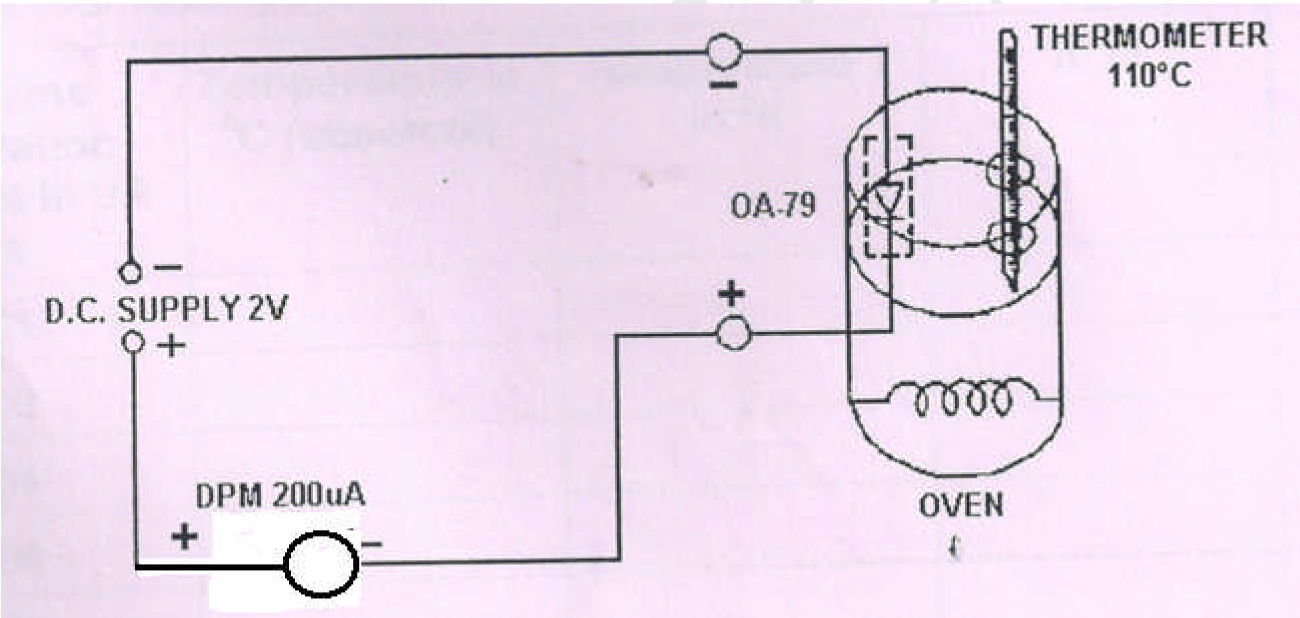
Energy band gap (E_g) of the semiconductor diode

Aim: To determine the width of forbidden energy gap of semiconductor diode (Ge).

Apparatus: Panel Board with P-N junction diode, power supply, digital micro ammeter and oven, Thermometer.

Energy gap: it refers to the energy difference (in electron volts) between the top of the valence band the bottom of the conduction band in insulators and semiconductors.

Circuit:



Procedure:

1. Connect the circuit as shown in the figure. Plug the two leads to the diode in the socket, Red plug in +Ve socket and Black plug in –Ve socket, so that the diode is reversed biased.
2. Insert the thermometer in the hole of the oven. (The diode OA-79 is already kept in the other hole of the oven.)
3. Now put the power ON/OFF switch to ON position and see that the jewel light is glowing.

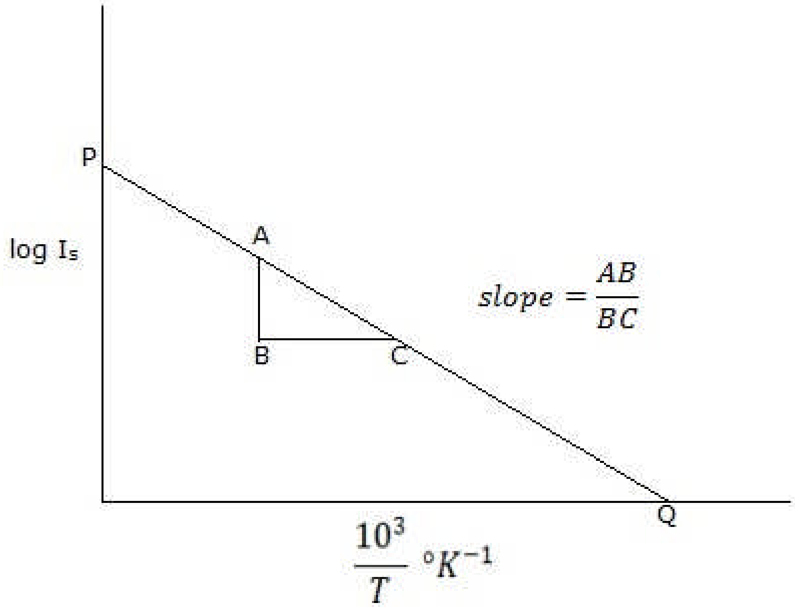
4. Now put the 'OVEN' switch to 'ON' position and allow the temperature of the oven to increase up to 95°C. As soon as the temperature reaches 95°C switch off the oven.
5. When the temperature becomes stable around 90°C, start taking readings of temperature and current. The temperature reading should be taken in steps of 5°C. i.e. 90°C, 85°C….35°C.
6. Plot the graph of log $I_s \rightarrow 10^3/T$ (Take log I_s on Y-axis and $10^3/T$ on X-axis), which should be a straight line cutting both the X-axis and Y-axis. Determine the slope of the line. Using given formula find out energy gap (ΔE) of diode.

$$E_g = \frac{slope\ of\ the\ line}{5.036} = \_\_\_\_\_ eV$$

Observation Table:

Obs. No.	Temperature of diode t °C	T= (t +273) °K	$\frac{10^3}{T}$ °K^{-1}	Reverse Saturation Current I_s μA	log I_s
1	90°C				
2	85°C				
3	80°C				
4	75°C				
5	70°C				
6	65°C				
7	60°C				
8	55°C				
9	50°C				
10	45°C				
11	40°C				
12	35°C				

Graph:



Calculation:

$$\log I_S = constant - 5.036 \cdot E_g \left(\frac{10^3}{T}\right)$$

From the graph of $\log I_S \rightarrow \frac{10^3}{T}$, $slope = \frac{\log I_S}{\frac{10^3}{T}}$ $or\ slope = 5.036 \cdot E_g$

$$E_g = \frac{slope\ of\ the\ line}{5.036} = \_\_\_\_\_\_ eV$$

Result: The band gap of material of semiconductor diode is E_g = _____ eV.

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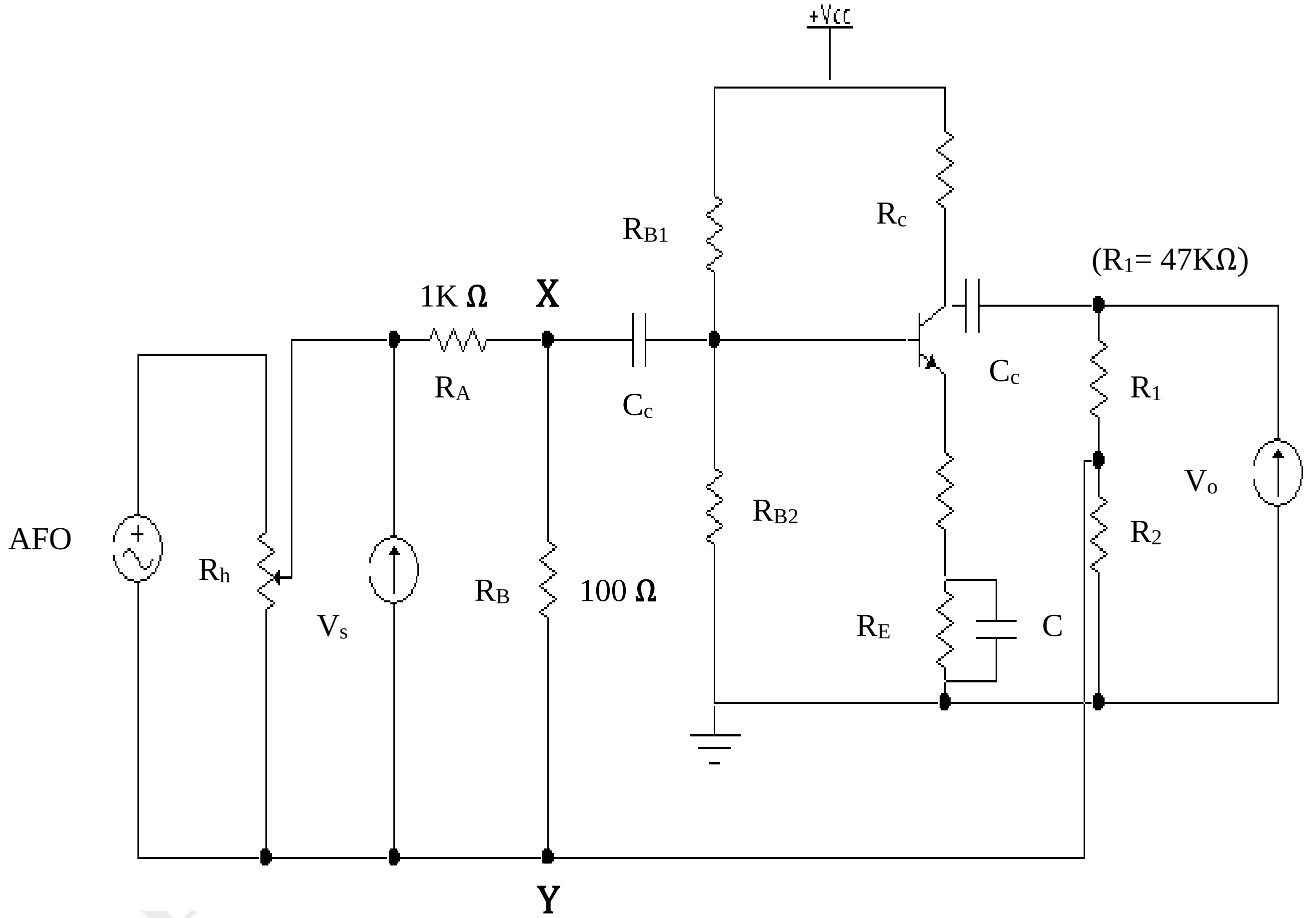
Negative Feedback Amplifier

Aim: To verify the relation $A_f = A/(1 + A\beta)$ in case of negative series voltage feedback.

Apparatus: Signal generator, Power Supply, Multimeter, etc.

Circuit Diagram:



Here V_s is a signal voltage and V_i is a input voltage between X and Y.

Procedure:

1. Connect the circuit as shown in the circuit diagram.
2. Keep Resistance = 0 Ω for amplifier without feedback.
3. Now keep source voltage V_S = 0.5V, 0.6V…1V and measure output voltage V_o for each V_S. Calculate open loop gain A.
4. Now keep V_S = 1V constant and increase resistance R_2 = 100 Ω, 200 Ω … 800 Ω and measure output voltage V_o.

5. Calculate closed loop gain A_f for each resistance R_2 and compare it with calculated A_f.

Observations Table: 1

Open loop gain (Amplifier without feedback)

R_A =__________Ω, R_B=__________ Ω, Keep R_2 = 0 Ω.

Note: Convert value of resistances in ohm: Ω only.

Obs No	V_S Volt	$V_i = V_S\left(\frac{R_B}{R_A+R_B}\right)$ Volt	V_o Volt	$A = \frac{V_o}{V_i}$	$Mean\ A$
1	0.5 V				
2	0.6 V				
3	0.7 V				
4	0.8 V				
5	0.9 V				
6	1.0 V				

Observations Table: 2

Closed loop gain (Amplifier with feedback with R_1 = 47KΩ)

R_A =__________ Ω, R_B=__________ Ω, Keep V_s = 1 V.

Note: Convert value of resistances in ohm: Ω only.

Obs No	$R_2\ \Omega$	V_o Volt	$\beta = \frac{R_2}{R_1+R_2}$	$V_i = V_S\frac{R_B}{R_A+R_B}$ Volt	$A_f = \frac{V_o}{V_i}$	$A_f = \frac{A}{(1+A\beta)}$
1	100 Ω					
2	200 Ω					
3	300 Ω					
4	400 Ω					
5	500 Ω					
6	600 Ω					
7	700 Ω					
8	800 Ω					

Calculations:

Results: Experimental gain and calculated gain with feedback are nearly equal.

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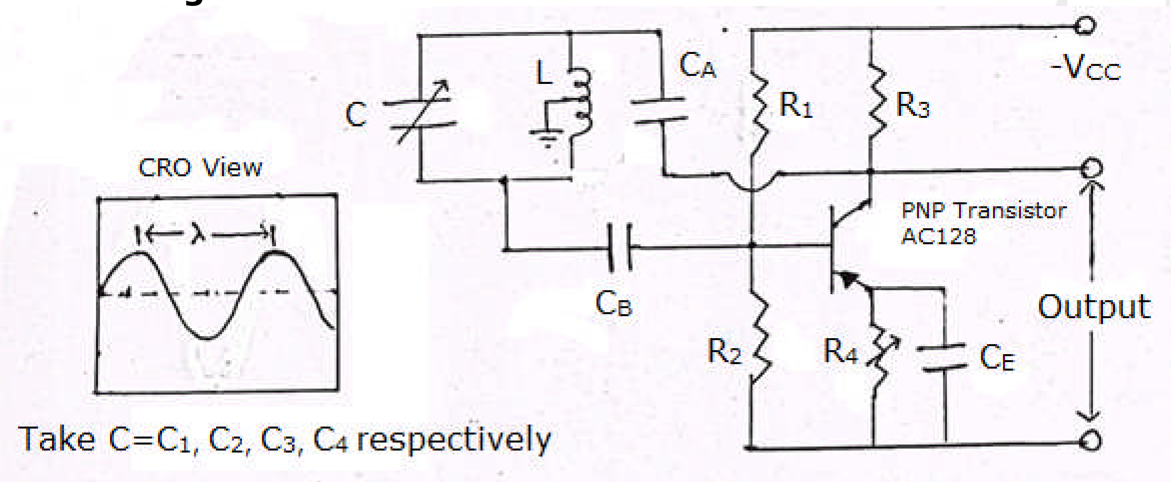
Hartley Oscillator

Aim: To determine frequency of the Hartley oscillator.

Apparatus: PNP Transistor, Inductors, Capacitors, Resistances, Power supply, CRO.

Circuit diagram:



Procedure:

1. Connect the circuit as shown in the circuit diagram.
2. For capacitor C_1, obtain stationary sine wave pattern in CRO by varying potentiometer.
3. Measure wavelength of sine wave λ_1. Repeat it for capacitor C_2 and C_3.
4. Calculate frequency f_{Obs} and compare with the theoretical frequency f_T.

Observation Table:

Inductance L = ______ mH =_________H

Obs. No	*Capacitance in 10^{-9} F*	λ *cm*	*t Sec/cm*	$T = \lambda \times t$ Sec	$f_{Obs} = \frac{1}{T}$ *Hz*	$f_T = \frac{1}{2\pi\sqrt{LC}}$ *Hz*
1	C_1 =					
2	C_2 =					
3	C_3=					
4	C_4=					

[**Note:** 1 nF = 10^{-9} F, 1 mH=10^{-3} H]

Calculations:

Result: For C_1

Theoretical Frequency of Hartley Oscillator $f_T =$ ________ Hz

Observed Frequency of Hartley Oscillator $f_{Obs} =$ ________ Hz

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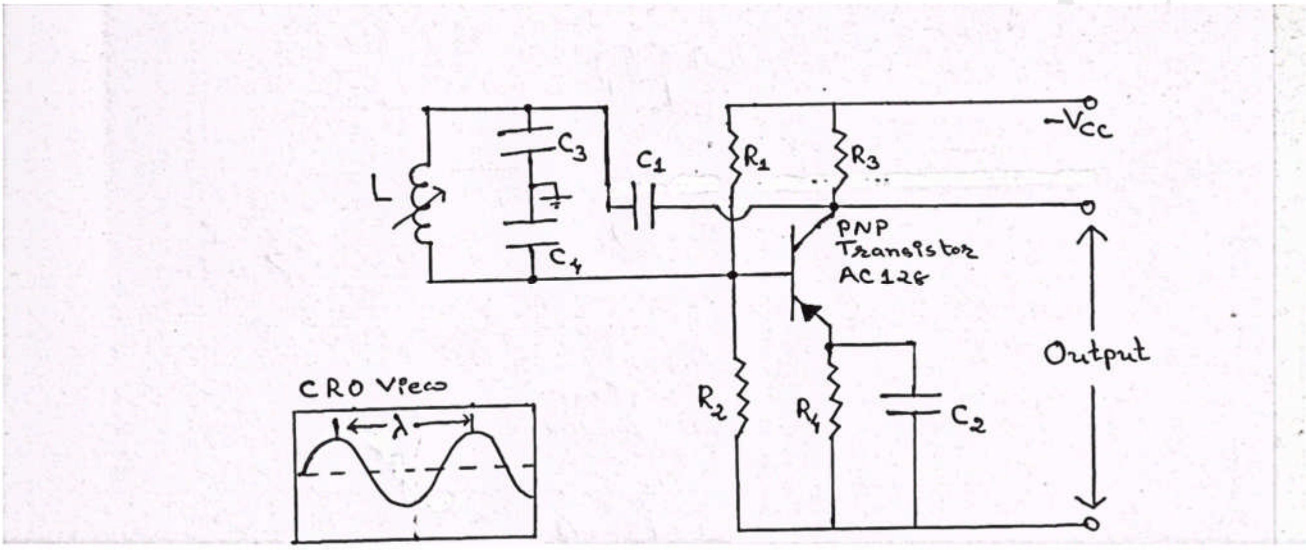
Colpitt’s Oscillator

Aim: To determine frequency of the Colpitt’s oscillator.

Apparatus: PNP Transistor, Inductors, Capacitors, Resistances, Power supply, CRO.

Circuit Diagram:



Procedure:

1. Connect the circuit as shown in the circuit diagram.
2. For inductor L_1, obtain stationary sine wave pattern in CRO by varying potentiometer.
3. Measure wavelength of sine wave λ_1. Repeat it for inductor L_2 and L_3.
4. Calculate frequency f_{Obs} and compare with the theoretical frequency f_T.

Observation Table:

Capacitance C= ______pF = ________F

Obs. No	*Inductance in 10^{-3} H*	λ *cm*	*t* *Sec/cm*	$T = \lambda \times t$ Sec	$f_{Obs} = \frac{1}{T}$ *Hz*	$f_T = \frac{1}{2\pi\sqrt{LC}}$ *Hz*
1	L_1=					
2	L_2=					
3	L_3=					

[**Note:** 1 mH = 10^{-3} H, 1 pF = 10^{-12} F]

Calculations:

Result: For L_1

Theoretical Frequency of Hartley Oscillator $f_T =$ ________ Hz

Observed Frequency of Hartley Oscillator $f_{Obs} =$ ________ Hz

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Field Effect Transistor

Aim: To study the Characteristics of the FET and to determine its parameters.

Apparatus: Circuit board, multi-meters and Connecting wires.

Procedure:

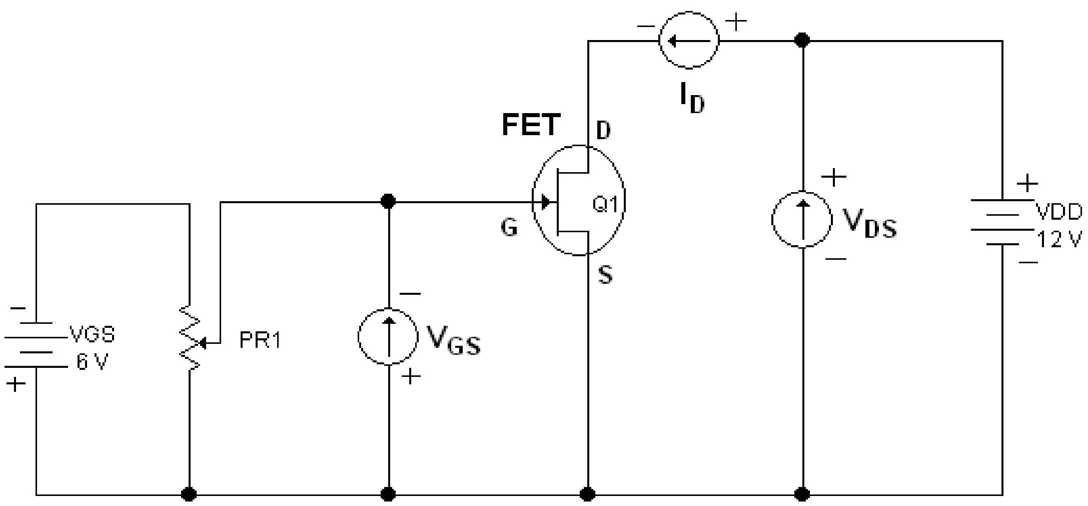
A. To study Drain Characteristics: -

1. Connect the circuit as shown in the circuit diagram.
2. Keep V_{GS} (Gate to Source voltage) constant and vary V_{DS} (Drain to Source Voltage), note down the corresponding value of I_D (Drain Current).
3. Plot the graph of I_D (Drain Current) against V_{DS} (Drain to Source Voltage).
4. Determine the slope of the curve and calculate the R_D (Drain Resistance).

B. To study Transfer Characteristics: -

1. Connect the circuit as shown in circuit diagram.
2. Adjust V_{DS} (Drain to Source Voltage) to 8 Volts.
3. Vary V_{GS} (Gate to Source voltage) and note down the corresponding value of I_D (Drain Current).
4. Plot the graph of I_D (Drain Current) against V_{GS} (Gate to Source voltage).
5. Determine V_P, I_{DSS}, R_{DS}, $V_{GS\,(off)}$ and Transconductance g_M.
6. Also calculate Amplification Factor $A = g_M * R_D$

Circuit Diagram: -



Observation Table: -

1. Drain Characteristics: -

Obs No	Drain to Source voltage V_{DS} in Volts.	Drain Current I_D (in mA)		
		V_{GS} = 0 Volt	V_{GS} = -0.5 Volt	V_{GS} = -1.0 Volt
1	0			
2	0.5			
3	1.0			
4	1.5			
5	2.0			
6	2.5			
7	3.0			
8	4.0			
9	5.0			
10	6.0			
11	7.0			
12	8.0			
13	9.0			
14	10.0			

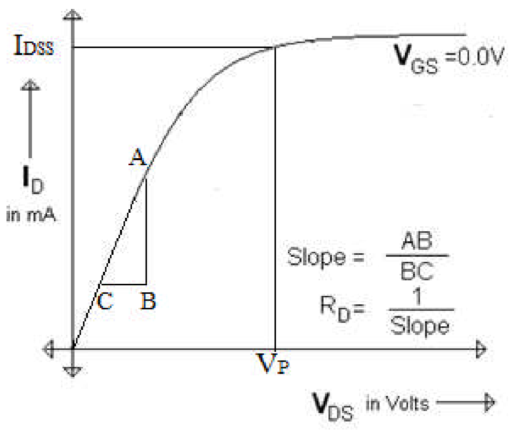
2. Transfer Characteristics: -

V_{DS} = 8 Volts

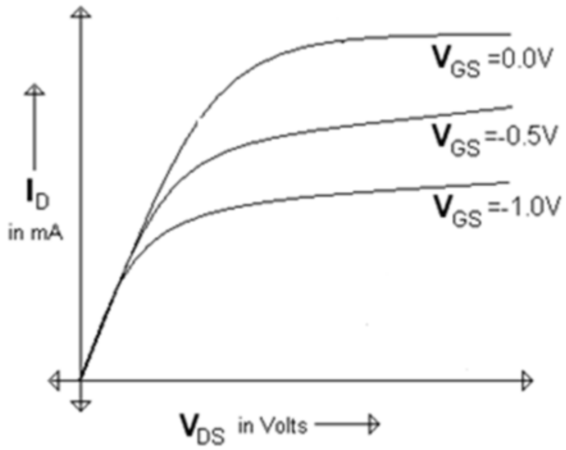
Obs No	Gate to Source voltage. V_{GS} in Volts.	Drain Current. I_D (in mA).
1	0	
2	-0.5	
3	-1.0	
4	-1.5	
5	-2.0	
6	-2.5	
7	-3.0	
8	-3.5	
9	-4.0	
10	-4.5	
11	-5.0	

Graph: -

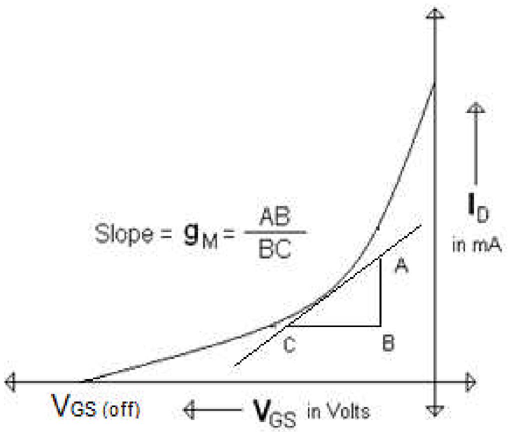
$I_D \rightarrow V_{DS}$



$I_D \rightarrow V_{DS}$



$I_D \rightarrow V_{GS}$



Calculations:

Results: -

The Parameters of the given FET are

1. $\mathbf{V_P}$ (Pinch off Voltage) = ________V
2. $\mathbf{I_{DSS}}$ (Drain Current to zero bias) = _______mA = _______ X 10^{-3} A
3. $\mathbf{V_{GS\ (off)}}$ =________V
4. $\mathbf{R_D}$ (Drain Resistance) = ______________Ω (in 10^3 Ω)
5. $\mathbf{g_M}$ (Transconductance)= ______________ Ω^{-1} (in 10^{-3} Ω^{-1})
6. **A** (Amplification Factor) = $\mathbf{g_M * R_D}$ = ______

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Stefan's Index

Aim: To determine Stefan's index using Stefan's radiation law.

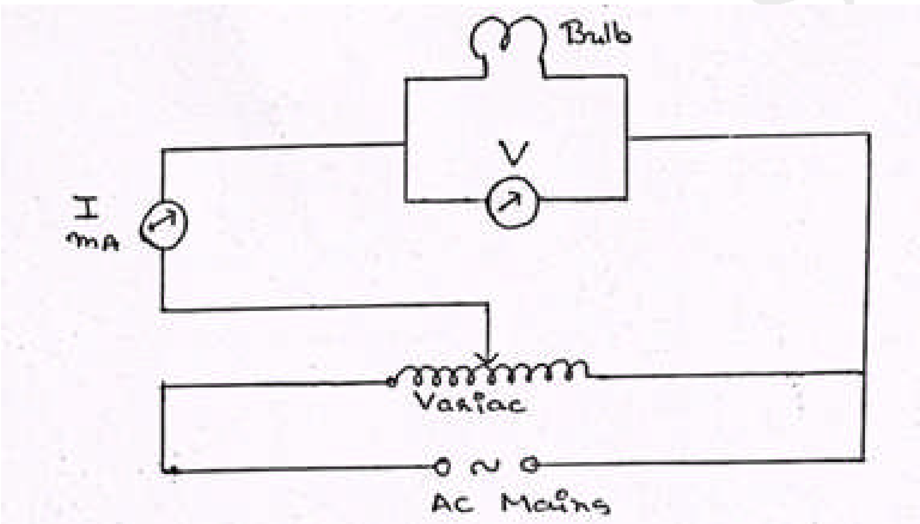
Apparatus: Variac, Bulb, AC Voltmeter, AC Ammeter

Stefan-Boltzmann law:

The thermal energy radiated by a blackbody radiator per second per unit area is proportional to the fourth power of the absolute temperature.

$\frac{P}{A} = \sigma T^4 \frac{j}{m^2 s}$, Here $\sigma = 5.6703 \times 10^{-8}\ watt/m^2K^4$

Circuit Diagram:



Procedure:

1. Connect the circuit as shown in diagram.
2. Apply different potential difference across the filament and measure corresponding current passing through filament.
3. Vary potential difference at interval of 20 Volt.
4. Do not apply potential difference greater than 160 Volt.
5. Convert the current into Ampere and calculate power.

Observation Table:

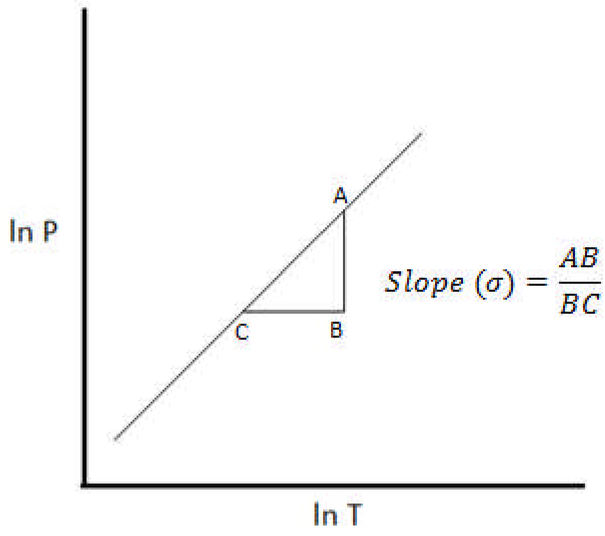
Obs No.	V volt	I′ mA	$I = \frac{I'}{1000}$ Amp.	R = V/I Ω	Power P = V.I Watt	T °K	ln P	ln T
1	20							
2	40							
3	60							
4	80							
5	100							
6	120							
7	140							
8	160							

Note: Potential difference across filament: V, current passing through filament: I′, resistance of filament: R and Temperature of the filament: $T = 9.397 \times [R^{0.7936}]$ and ln is a natural log.

Calculations:

Temperature of Filament: $T = 9.397 \times [R^{0.7936}]$

Graph:



Results: The value of Stefan's index σ is ___________.

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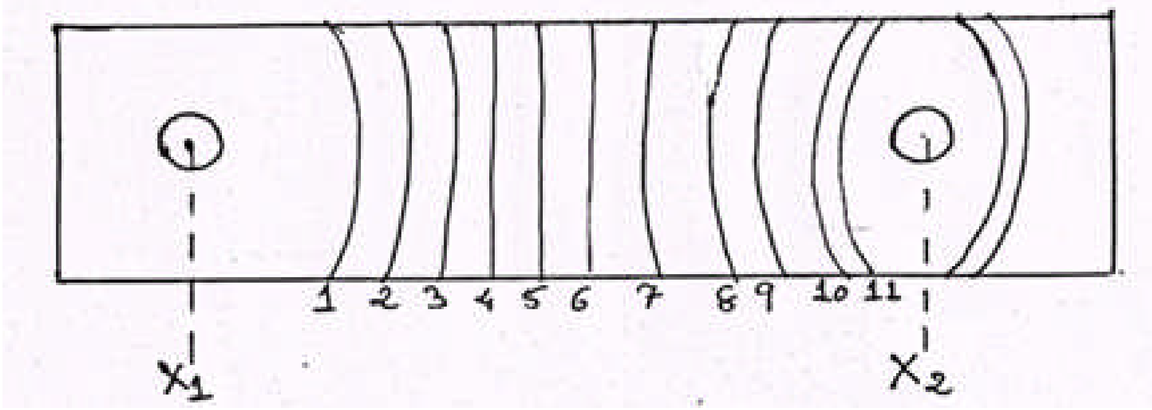
Miller Indices

Aim: To determine the Miller indices (h k l) of reflections of FCC recorded by powder method and determine the value of lattice parameter.

Apparatus: Powder pattern film, scale, magnifying lense

Procedure:

1. Label the diffraction lines between $\theta_1 = 0^\circ$ and $\theta_2 = 180^\circ$ on the given photographic film. i.e. forward region and backward reflection region.
2. Select the pair of lines in the forward region and other pair of lines in the backward reflection region belonging to the same diffraction cone.
3. Measure the distance of two lines in the same diffracted cone in mm. determine diffraction pattern centers θ_1 and θ_2.
4. Position of each line is measured in mm, i.e. S_1.
5. Determine the distance of each line from $\theta_1 = 0^\circ$ i.e. $S_0 = S_1 - \theta_1$ and ener in column 3.
6. From that calculate interplanner spacing d of the planes and d^2.
7. Now write values of d^2 for each line in Observation Table: 2 and calculate Nd^2 for different values of N starting from 1 to 27. (Note: Calculate Nd^2 till its value is approximately equals to 16.)
8. Select the value of N in such a way that the product Nd^2 is approximately constant around 16 and it satisfy two conditions.
   (i) $N = h^2 + k^2 + l^2$. Here h, k, l are called Miller indices.
   (ii) For FCC h, k, l must be all even numbers or all odd numbers. (**Note: Combination of even and odd numbers of h, k, l is not allowed for FCC.**)
9. Determine h, k, l from relation: $N = h^2 + k^2 + l^2$ and write in last column of Table: 1.
10. From relation $Nd^2 = a^2$, determine a^2 and lattice constant 'a'.



Observations:

1. Wavelength of X-rays: $\lambda = 1.542 \times 10^{-8}$ cm = 1.542 A°
2. X_1 = ________mm for $\theta_1 = 0^\circ$
3. X_2 = ________mm for $\theta_2 = 180^\circ$
4. $X = X_1 - X_2$ =_________mm for $\theta_1 - \theta_2 = 180^\circ$
5. $c = \frac{180}{(X_1 - X_2)} \frac{^\circ}{mm}$ =_______$\frac{^\circ}{mm}$

Observations Table: 1

Note: Take all observations in mm scale only. Start observations with reference to X_1 (Keep two close lines in pattern on right side).

Line No.	Line reading S_1 mm	$S_0 = S_1 - X_1$ mm	Corrected reading $S = (S \times c)^\circ$	Angle $\theta = (S/2)^\circ$	$\sin\theta$	Inter planner spacing $d = \frac{\lambda}{2\sin\theta}$ A°	d^2 $(A^\circ)^2$	N	$a^2 = Nd^2$ $(A^\circ)^2$	Mean a^2 $(A^\circ)^2$	Miller indices (h k l)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											

Note: h, k, l must be all even numbers or all odd numbers for FCC. Where $N = h^2 + k^2 + l^2$

Observations Table: 2

Line	N d²	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1																												
2																												
3																												
4																												
5																												
6																												
7																												
8																												
9																												
10																												
11																												

Calculations:

Results:

1. Lattice parameter a = ___________A°

   (Standard value of a = 4.039 A° and number of particles in unit cell of FCC = 4)

2. Atomic radius $r = \frac{\sqrt{2}}{4}a$ = __________A°

3. Volume of unit cell V = a^3 = ________(A°$)^3$

4. Mass per unit particle = $a^3 \boldsymbol{\rho} /4$ = __________amu

   ($\boldsymbol{\rho}$=2.702 for Aluminium)

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Numerical Integration

Aim: Use Simpson's $\frac{1}{3}$ rd rule to compute the following integrals numerically.

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

Theory:

Simpson's 1/3rd rule:

The method is credited to the mathematician **Thomas Simpson** (1710–1761) of Leicestershire, England. Simpson's rule can be derived by approximating the integrand $f(x)$ by the quadratic interpolant $P(x)$. In numerical analysis, **Simpson's rule** is a method for **numerical integration**, the numerical approximation of **definite integrals**. Specifically, it is the following approximation: for any given continuous function $y = f(x)$,

$$\int_a^b f(x)dx \approx \frac{b-a}{6}\left[f(a) + 4f\left(\frac{a+b}{2}\right) + f(b)\right]$$

If the interval of integration $[a, b]$ is in some sense "small", then Simpson's rule will provide an adequate approximation to the exact integral. By small, what we really mean is that the function being integrated is relatively smooth over the interval $[a, b]$. For such a function, a smooth quadratic interpolant like the one used in Simpson's rule will give good results.

However, it is often the case that the function we are trying to integrate is not smooth over the interval. Typically, this means that either the function is highly oscillatory, or it lacks derivatives at certain points. In these cases, Simpson's rule may give very poor results. One common way of handling this problem is by breaking up the interval $[a, b]$ into a number of small subintervals. Simpson's rule is then applied to each subinterval, with the results being summed to produce an approximation for the integral over the entire interval. This sort of approach is termed the *composite Simpson's rule*.

Suppose that the interval $[a, b]$ is split up in '*n*' subintervals with *n*-even numbers. Then the composite Simpson's rule is given by,

$$\int_a^b f(x)dx \approx \frac{h}{3}\left[f(x_0) + 2\sum_{j=1}^{\frac{n}{2}-1} f(x_{2j}) + 4\sum_{j=1}^{n} f(x_{2j-1}) + f(x_n)\right]$$

Where, $x_j = a + jh$, (for j = 0, 1, 2, …. n − 1, n) with $h = \frac{(b-a)}{n}$, here h is known as step length. If $x_0 = a$ and $x_n = b$, the above formula can be written as,

$$\int_a^b f(x)dx \approx \frac{h}{3}[f(x_0) + 4f(x_1) + 2f(x_2) + 4f(x_3) + 2f(x_4) + \cdots + 4f(x_{n-1}) + f(x_n)]$$

We can write this approximation as,

$I_S = \frac{h}{3}[Y_0 + 4Y_1 + 2Y_2 + 4Y_3 + 2Y_4 + \cdots .. + 2Y_{n-2} + 4Y_{n-1} + Y_n]$, Or

$$I_S = \frac{h}{3}[(Y_0 + Y_n) + 4(Y_1 + Y_3 + \cdots + Y_{n-1}) + 2(Y_2 + Y_4 + \cdots + Y_{n-2})]$$

Procedure:

1. Compute value of integral for a given function between the given limits by **Analytical Method**.
2. To compute value of integral by **Numerical Method**, calculate step size using relation $h = \frac{(b-a)}{n}$. Here a, b, n are lower limit, upper limit and number of steps (or subintervals) respectively. Here n must be even number.
3. For $y = f(x)$, calculate $y_0, y_1, y_2 \ldots\ldots y_n$ for values $x_0, x_1, x_2 \ldots\ldots x_n$ and prepare Data Table.
4. Using Simpson's 1/3rd formula evaluate value of integral: I_S for a given function.
5. In **Graphical Method**, plot a graph of $y = f(x) \to x$ and determine area between the curve and X-axis (Area under the curve) between limits $x_n = b$ and $x_0 = a$.

$$Area\ under\ the\ curve\ =\ (Total\ squares) X\ (Area\ of\ one\ unit\ square)$$

$$Total\ squares\ =\ (Whole\ squares\ +\ Fractional\ squares)$$

This area under the curve gives value of integral for the given function.

6. Write the results of integral computed by all three methods in the table.
7. Compute any three to four integrals given in the exercise by above three methods.

Exercise:

1. $\int_0^1 x^2\ dx$	**2.** $\int_0^2 e^x\, dx$	3. $\int_0^1 (x^2 + 3x)^2\ dx$	4. $\int_0^{\pi} \cos x\, dx$	5. $\int_1^3 \ln x\, dx$
6. $\int_0^2 \sqrt{x}\ dx$	7. $\int_0^1 \sin x\, dx$	8. $\int_0^{\frac{\pi}{3}} \tan x\, dx$	9. $\int_0^1 \sin^{-1} x\ dx$	10. $\int_0^1 \log x\, dx$

Example: 1

Find the value of given function $y = f(x) = x^2$

$\therefore \quad I_S = \int_0^1 x^2\, dx$

(a) Analytical method:

Let, $I_S = \int_0^1 x^2\, dx = \left[\frac{x^3}{3}\right] = \left[\frac{1^3}{3}\right] = 0.333333 \approx 0.33$

(b) Numerical method:

(i) Calculation of a Step Size: We know that, Step Size $h = \frac{(b-a)}{n}$, here upper limit $b = 1$, lower limit $a = 0$ and total number of observations $n = 10$.

So, $h = \frac{(b-a)}{n} = \frac{(1-0)}{10} = 0.$

(ii) Data table: (From given function $y = f(x)$)

i	0	1	2	3	4	5	6	7	8	9	10
X_i	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Y_i	0.0	0.01	0.04	0.09	0.16	0.25	0.36	0.49	0.64	0.81	1.0

(iii) Formula:

$$I_S = \frac{h}{3}\left[Y_0 + 4Y_1 + 2Y_2 + 4Y_3 + 2Y_4 + 4Y_5 + 2Y_6 + 4Y_7 + 2Y_8 + 4Y_9 + Y_{10}\right]$$

$$I_S = \frac{h}{3}\left[(Y_0 + Y_{10}) + 4(Y_1 + Y_3 + Y_5 + Y_7 + Y_9) + 2(Y_2 + Y_4 + Y_6 + Y_8)\right]$$

Substituting values of Y_i from the table,

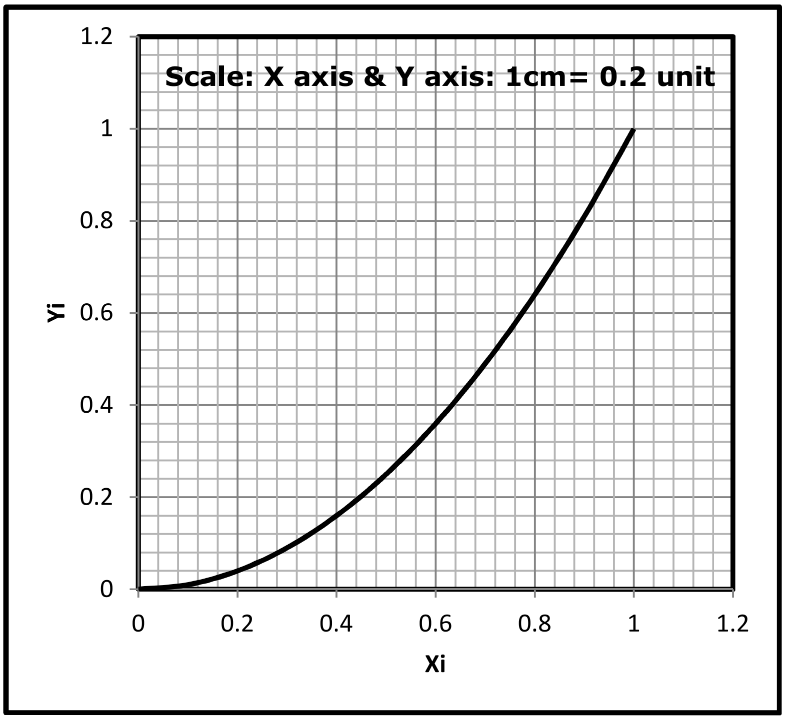
$\therefore I_S = \frac{0.1}{3}\left[(0.0 + 1.0) + 4(0.01 + 0.09 + 0.25 + 0.49 + 0.81) + 2(0.04 + 0.16 + 0.36 + 0.64)\right]$

$\therefore Is = \frac{0.1}{3}\left[(1.0) + 4(1.65) + 2(1.2)\right]$

$$\therefore Is = \frac{0.1}{3}\left[(1.0) + (26.4) + (2.4)\right] = \frac{0.1}{3} \times 10 = 0.333333 \approx 0.3$$

(c) Graphical method:

X_i	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Y_i	0.0	0.01	0.04	0.09	0.16	0.25	0.36	0.49	0.64	0.81	1.0



Total squares = (Whole squares + Fractional squares) = (26+7) = 33

Now, Area under the curve = (Total squares) X (Area of one unit square)

= (33) X (0.01) = 0.33

Results:

No.	$\int_a^b f(x)dx$	Value of Integral by		
		Analytical Method	Numerical Method	Graphical Method

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