Hindi Vidya Prachar Samiti's

RAMNIRANJAN JHUNJHUNWALA COLLEGE

Ghatkopar (West), Mumbai-400 086, Maharashtra, INDIA.

T.Y.B.Sc (Sem-V)

Handbook

DBT STAR College Scheme

RAMNIRANJAN JHUNJHUNWALA COLLEGE

Ghatkopar(W), Mumbai – 86

INDEX

S E M E S TER : V

Ramniranjan Jhunjhunwala College

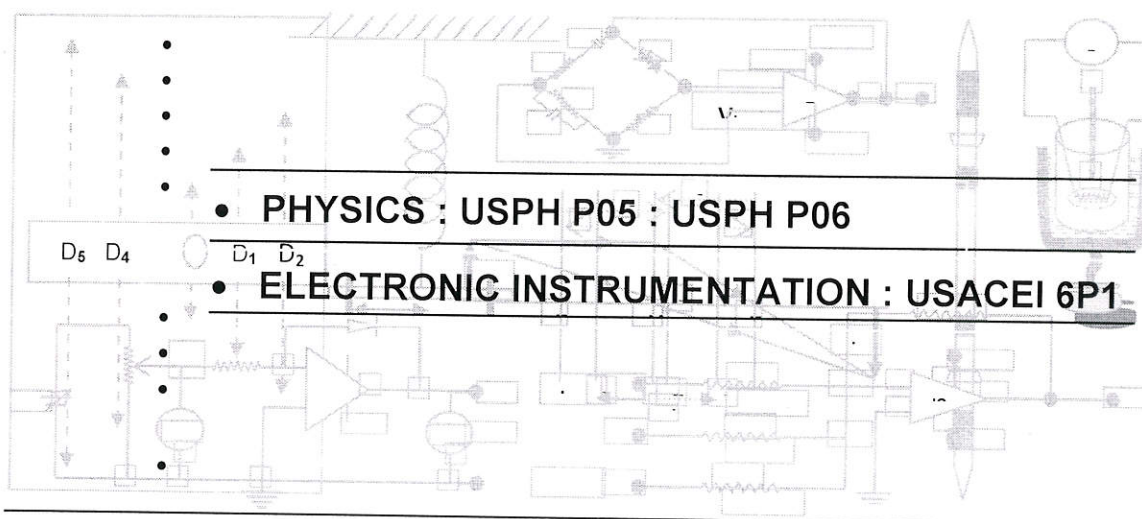Ghatkopar (W), Mumbai-400 086.

ESTD. 1963

Best College

UNIVERSITY of MUMBAI

DEPARTMENT OF PHYSICS

SEMESTER : V

HAND BOOK

- **PHYSICS : USPH P05 : USPH P06**

- **ELECTRONIC INSTRUMENTATION : USACEI 6P1**

D_5 D_4 D_1 D_2

2017 – 2018

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S E M E S T ER : V

Kater's Pendulum

Aim : To determine the intensity of the gravitational field **g** using Kater's pendulum.

Apparatus : Kater's pendulum, a stop watch of 0.01 s least count, a meter scale and a knife edge.

Procedure :

1) Keep bob's **B** and **B'** and masses **M** and **m** equidistant from the geometric centre of the rod.

2) The knife edge near the wooden bob is called K_1 and the knife edge near the heavy bob B is called K_2.

3) The Kater's pendulum is suspended from K_1 and K_2 and the time for 20 oscillations is determined, say t_1 and t_2. Find $\Delta t = t_1 \sim t_2$.

4) Move K_2 by 1 cm each time and repeat step 3 till Δt is less than 0.20 s (K_1 and K_2 must be parallel all the time). Calculate the periodic time T_1 and T_2.

5) When $\Delta t \le 0.20$ s, estimate g by keeping T as the average of T_1 and T_2 and by using

   the formula $g = \dfrac{4\pi^2 L}{T^2}$ where, L is the distance between the knife edges.

6) If **g** is incorrect, keep changing K_2 till for another position $\Delta t \approx 0.20$ s or less.

7) Finally when 'g' is nearly correct, find the centre of gravity (CG) of the pendulum by balancing the pendulum on a knife edge. Measure l_1, the distance of the knife edge K_1 from the centre of gravity and l_2, the distance of the knife edge K_2 from the CG.

8) Now determine T_1 and T_2 accurately.

   Method to determine time periods accurately
   - *Measure time for 20 oscillations, about say K_1 twice. Take its mean t_1 and find*

     the time period T_1 approx, as $T_{1approx} = \dfrac{t_1}{20}$
   - *Start the stop watch when the pin crosses the vertical cross wire from the left.*
   - *Do not count. Let a large number of oscillations take place.*
   - *Then look through the telescope and again stop the stop watch when the pin crosses the vertical cross wire from the left. Record the elapsed time.*
   - *Divide the elapsed time by $T_{1approx}$. You will get a number. But the number of oscillations has to be an integer. So, round off this number to the nearest integer n.*

     $$T_{1exact} = \frac{elapsed\ time}{no.\ of\ oscillations}$$

   - *Repeat this one more time.*

9) Shift K_2 by 1.0 cm. Let us call this length L' as the distance between the knife edges.

10) Measure T'_1 and T'_2 in the same way.
11) Using Bessel's formula, determine **g**.
12) Plot a graph of **T** on y-axis and **L** on x-axis.

Iron
B

K_2

M

m

K_1

B'
wood

Observations:

Trial observation Table 1:

Distance between knife edges L	Time for 20 oscillations		$\Delta t = t_1 \sim t_2$	Value of g if $\Delta t \leq 0.20$ s
	t_1 (about K_1)	t_2 (about K_2)		
cm	s	s	s	cm / s²

Observation table : 2

$$l_1 = \ldots\ldots\ldots \text{ cm} \quad \text{and } l_2 = \ldots\ldots \text{ cm}$$

Length	Time for 20 osc.	$T_{approx} = t / 20$	Elapsed time	No. of osc. $n = \frac{\text{elapsed time}}{T_{approx}}$	$T_{exact} = \dfrac{elapsed\ time}{no.\ of\ osc.}$
cm	s	s	s	(rounded off number)	s
L =	About K_1 i) $t_1 = \ldots$ ii) $t_1 = \ldots$ mean $t_1 = \ldots$	$T_1 = t_1 / 20$	(i) (ii)	(i) (ii)	$T_1 =$ $T_1 =$
	About K_2 i) $t_2 = \ldots$ ii) $t_2 = \ldots$ mean $t_2 = \ldots.$	$T_2 = t_2 / 20$	(i) (ii)	(i) (ii)	$T_2 =$ $T_2 =$
change L by 1 cm					
L' =	About K_1 i) $t'_1 = \ldots$ ii) $t'_1 = \ldots$ mean $t'_1 = \ldots$	$T_1 = t'_1 / 20$	(i) (ii)	(i) (ii)	$T'_1 =$ $T'_1 =$
	About K_2 i) $t'_2 = \ldots$ ii) $t'_2 = \ldots$ mean $t'_2 = \ldots..$	$T_2 = t'_2 / 20$	(i) (ii)	(i) (ii)	$T'_2 =$ $T'_2 =$

Consolidated observation table : 3

$l_1 = $ .... cm $l_2 = $ .... cm

Length	T_1 Time period about K_1			T_2 Time period about K_2		
	(i)	(ii)	mean	(i)	(ii)	mean
cm	s	s	s	s	s	s
L =	$T_1=$......	$T_1=$......	$T_1=$	$T_2=$......	$T_2=$......	$T_2=$......
L' =	$T'_1=$......	$T'_1=$......	$T'_1=$......	$T'_2=$......	$T'_2=$......	$T'_2=$.....

Calculations :

From the reading above : *Bessel's method*

$$\frac{4\pi^2}{g} = \frac{1}{2}\left[\frac{T_1^2 + T_2^2}{l_1 + l_2} + \frac{T_1^2 - T_2^2}{l_1 - l_2}\right]$$

g = ...dyne /g
 = ...N/ kg

Maximum possible relative uncertainty :

$$\frac{dg}{g} = \frac{dt_1}{t_1} + \frac{dt_2}{t_2} + \frac{dL}{L},$$

where dt₁ = dt₂ = L. C. of the stop watch.
dL= L. C. of the scale
calculate dg.

Graph and Calculation :
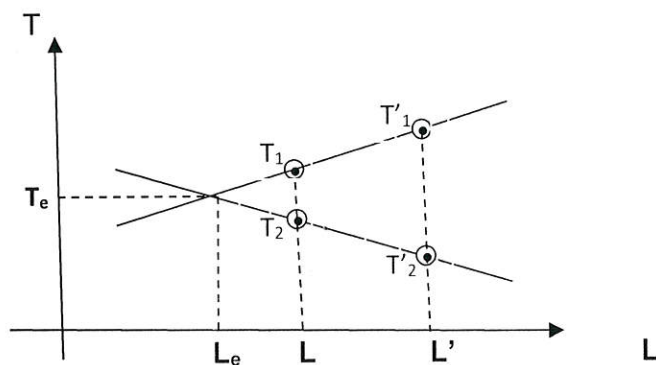
$$g = \frac{4\pi^2 L_e}{T_e^2}$$

Mean g = ... N/kg

Result : g ± dg = _____ N / kg

Flat Spiral Spring (Young's Modulus Y)

Aim   : To determine Young's Modulus **Y** of the material of a flat spiral spring.

Apparatus : Flat spiral spring, hanger with slotted weights, rod with adjustable masses, stop-clock, pin, vernier caliper, micrometer screw gauge etc.

Formula   : **Young's Modulus.**

$$Y = \left\{ \frac{32\pi^2 NR}{r^4} \right\} \left\{ \frac{I}{T^2} \right\}$$

N : number of turns of the spring

R : mean radius of the spring

r : radius of the wire of the spring

T : periodic time of horizontal oscillation

I : moment of Inertia of the rod with masses about the axis of rotation

$I = I_0 + 2m_0 x^2$

I_0 : moment of inertia of the rod about the axis of rotation

m_0: mass of each of the movable disc

x : distance of the centre of mass of m_0 from the axis of rotation

Part- A

Determination of N, R, r of the spring

Procedure:

1. Count the number of turns **N** of the spring.

2. Taking readings at three different places using vernier caliper, find the mean of the outer diameter **D₁** and inner diameter **D₂** of the spring and hence determine the mean radius **R**.

3. Using micrometer screw gauge, take readings at ten different places on the wire of the spring to find the mean diameter **d** of the wire and hence determine the radius **r** of the wire.

Observations :

1. Number of turns of the spring **N** = ...

2. Determination of radius **R** of the spiral spring

    Least count of vernier caliper = ... cm

Outer diameter				Inner Diameter				$D = \frac{D_1 + D_2}{2}$	$R = \frac{D}{2}$
1	2	3	mean D_1	1	2	3	mean D_2		
cm	cm	cm	cm	cm	cm	cm	cm	cm	cm

[4]

3. Determination of radius r of the wire of the spring.

Least count of micrometer screw gauge = ……. cm

Obs. no.	d_i	$|\bar{d} - d_i|$	$|\bar{d} - d_i|^2$
	cm	cm	cm²
1.			
2.			
.			
.			
.			
.			
10.			

mean of d_i = $\bar{d}$ = _____ cm $\sum|\bar{d} - d_i|^2 =$ _____ cm^2

$$r = \frac{\bar{d}}{2} = \_\_\_\_ \; cm$$

Standard error about mean d :

$$d(d) = \left[\frac{\sum|\bar{d} - d_i|^2}{n(n-1)} \right]^{\frac{1}{2}}$$

Part - B
To determine the Young's Modulus Y
(Oscillations in the horizontal direction)

Procedure :

i) Fix a long cylindrical rod in which two identical discs each of mass m_0 can be placed at various distances **x** from the axis of the spring. Adjust the disc so that each of them is at the same distance **x** from the axis of the spring.

ii) Fix a pin vertically at one end of the rod and focus the telescope on the pin.

iii) Set the spring into torsional oscillations and measure the time t for 20 oscillations. Take three readings and hence find mean **t**. Determine the time period **T**.

iv) For four more distances **x** of the two discs from the axis of the spring, repeat step (iii).

v) Plot a graph of **T²** (along y-axis) and **x²** (along x-axis). Hence determine the slope.

vi) Determine **Y** using the formula.

[5]
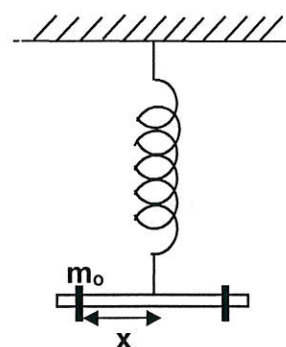
Observations:

Obs. no.	x	x^2	Time for 20 oscillations			mean t	$T = \dfrac{t}{20}$	T^2
			t_1	t_2	t_3			
	cm	cm^2	s	s	s	s	s	s^2
1.								
2.								
3.								
4.								
5.								
6.								

Graph :

slope =

Calculations :

(i) Young's modulus of the material of the flat spiral spring is given by

$$Y = \left\{ \frac{32\pi^2 NR}{r^4} \right\} \left\{ \frac{2m_0}{slope} \right\}$$

(ii) Calculate error using the formula

$$\frac{dY}{Y} = \frac{dN}{N} + \frac{dR}{R} + \frac{4d(d)}{d} + \frac{d(slope)}{slope}$$

     dN   = 1 (which is the error in counting the number of turns of the spiral spring)

     R   = error in measuring the radius of the spring (which is the least count of vernier caliper)

     d(d)   = standard error in measuring the diameter of the wire of the spring

     $\dfrac{d(slope)}{slope}$ = error in the slope (which can be neglected by choosing a graph

                 with point symmetrically on either side)
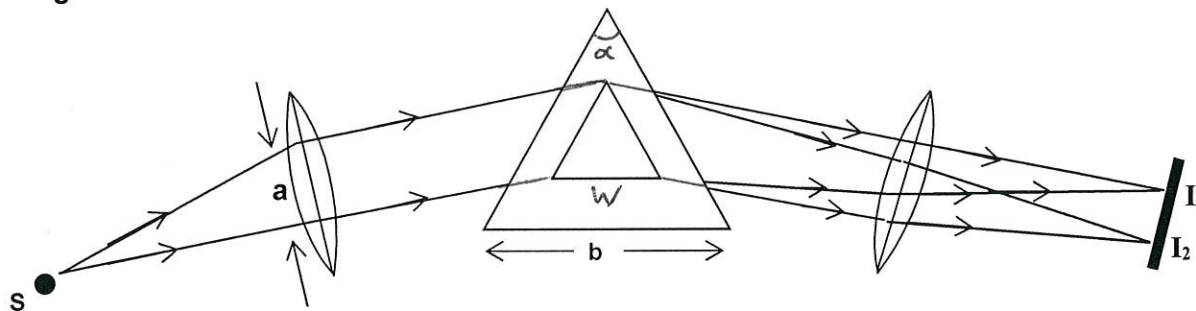
Result :

Young's Modulus Cof the material of the flat spiral spring Y ± dY = ………. dyne/cm^2

[6]

Resolving Power of Prism

Aim   : To determine the resolving power of a given prism.

Apparatus : Spectrometer, prism (EDF), mercury lamp, adjustable slit, travelling microscope, spirit level.

Diagram   :

Theory :
The given doublet of mercury source needs to be resolved by the prism spectrometer. The resolving power (R.P.) of the prism may be much more, i.e. it may be able to resolve two spectral lines which are much closer.

Hence maximum resolving power R.P. = $b\dfrac{d\mu}{d\lambda}$

b : length of the base of the prism

When we wish to resolve the given doublet of the mercury source we place a slit before the objective of the spectrometer telescope and thus reduce the effective width of the objective. Hence **w** now becomes the effective width of the base of a small prism within the prism.

$$w = \frac{2\,a\sin(\alpha/2)}{\cos\left(\dfrac{\alpha+\delta_m}{2}\right)}$$

α : angle of prism
a : smallest width of the auxiliary slit that just resolves the doublet
δ$_m$: mean value of angle of minimum deviation for the doublet.

Resolving power of the prism R.P. = $w\dfrac{d\mu}{d\lambda}$

Procedure :

1. Illuminate the spectrometer slit with mercury light and adjust the spectrometer for parallel light by Schuster's method.

2. Level the prism table by optical method.

3. Adjust the position such that yellow I line is in the minimum deviation position. Note down the spectrometer reading for **yellow I, yellow II, green and blue lines.**

4. Remove the prism and note down the direct reading.

5. Keep the prism again in the minimum deviation position for the yellow doublet. Adjust the intensity of light and the width of the collimator slit so that the two yellow lines are seen distinctly.

6. Mount the auxiliary slit in front of the telescope objective. First keep the slit wide open and gradually decrease its width till the two yellow lines just merge into each other. Measure the slit width a_1 using a travelling microscope.

7. Keep the slit closed and then open it slowly till the lines are just resolved, that is they appear as separate. Measure the slit width a_2 using a travelling microscope.

8. The critical width for resolution is given by

$$a = \frac{a_1 + a_2}{2}.$$

Observation :

Table 1 : To find δ$_m$

Obs. No.	Colour	Wavelength	Reading for minimum deviation		$\delta_1=$	$\delta_1=$	mean
			X	Y	X~X$_1$	Y~Y$_1$	$\delta_m = \dfrac{\delta_1 + \delta_2}{2}$
		A^0	degree	degree	degree	degree	degree
1.	Yellow I	5790					
2.	Yellow II	5769					
3.	Green	5461					
4.	Blue	4358					

Direct reading : X$_1$ = ...   Y$_1$ = ...

Formula :

$$\mu = \frac{\sin\left(\dfrac{\alpha + \delta_m}{2}\right)}{\sin\left(\dfrac{\alpha}{2}\right)} \ , \qquad \alpha = 60^0$$

(8)

Table 2 :

Obs. No.	Colour	Wavelength	δ_m	μ
		A^0	degree	
1.	Yellow I	5790		
2.	Yellow II	5769		
3.	Green	5461		
4.	Blue	4358		

Table 3 : To find a :

Obs. no.	Slit	Left reading	Right reading	Difference	mean $a = \dfrac{a_1 + a_2}{2}$
		cm	cm	cm	cm
1.	Closing			$a_1 =\ldots\ldots\ldots$	
2.	Opening			$a_2 =\ldots\ldots\ldots$	

1. Calculation of Cauchy constant B :

$$\mu = A + \frac{B}{\lambda^2}$$

since $\mu_1 = A + \dfrac{B}{\lambda_1^2}$ and $\mu_2 = A + \dfrac{B}{\lambda_2^2}$

therefore , $\mu_2 - \mu_1 = B\left[\dfrac{1}{\lambda_2^2} - \dfrac{1}{\lambda_1^2} \right]$

choose : yellow 1 and green to obtain B_1

            yellow 2 and blue to obtain B_2

then, $B = \dfrac{B_1 + B_2}{2}$

(9)

2. Calculation of $\left|\dfrac{d\mu}{d\lambda}\right|$:

$$\left|\frac{d\mu}{d\lambda}\right| = \frac{2\,B}{\lambda^3}$$ λ : mean wavelength of two yellow lines

3. Calculation of w :

The width **w** of the base of the prism resolving the yellow lines can be calculated using the formula :

$$w = \frac{2a\,\sin(\alpha/2)}{\cos\left(\dfrac{\alpha + \delta_m}{2}\right)}$$

δ_m : mean value of the angle of minimum deviation for the two yellow lines

4. Calculation of R. P. of the effective prism :

$$R.P. = w\left(\frac{d\mu}{d\lambda}\right)$$

Result : 1) R. P. of prism (theoretical) $\dfrac{\lambda}{d\lambda}$ = ...

         2) R. P. of prism (experimental)   = ...

Goniometer

Aim : To determine the focal length of a lens system and to determine the cardinal points of a lens system using Searle's Goniometer.

Apparatus : Searle's Goniometer, lens system, half meter scale, lamp, index pin, plane mirror etc.

Formula : focal length of the lens system is given by

$$f = \left(\frac{h}{h'}\right) \times \ell$$

     h : shift in string loop on meter scale

     h' : shift in goniometer scale reading

     ℓ : length of the goniometer arm

Procedure :

1. The vertical wire is adjusted in the focal plane of the goniometer lens by auto collimation method. This is done by keeping the plane mirror behind the goniometer lens and removing parallax between the vertical wire and its image. Illuminate the wire while doing this. Fix the wire by tightening the screws of the adjustable frame.

2. Keep distance between two lenses of the lens system, **d** at some fixed values.

3. Tie a loop of thin string to the half meter scale at reading **A₀** and illuminate it. Keep the lens system between the meter scale and the goniometer such that the string lies along the axis of the lens system and is with the goniometer axis. Keep horizontal wire of the goniometer scale at reading **B₀**.

4. Move the lens system towards or away from the object (string loop) and remove parallax between the image of the loop and the vertical wire.

5. Measure the distance **x** between the meter scale and the lens nearer to it.

6. Move the loop through a small distance, say, 0.2 cm to a reading **A**. Turn the goniometer arm so that the image again falls on the vertical wire. If earlier parallax had been properly removed then there will be no parallax in the new position. Note the new reading **B** on the goniometer scale.

7. Repeat for different positions of the loop (at least 3) on both the sides of **A₀**.

8. Turn the lens system through 180^0 and repeat 4 to 7, for another set.

9. Plot graph of **h'** (i. e. B – B₀) against **h** (i. e. A - A₀) and determine the focal length **f** using the values of slopes in the formula:

$$f = \ell \times \left(\frac{h}{h'}\right) = \ell \times \left(\frac{1}{slope}\right)$$

for the above two sets of observation. Find mean focal length **f**.

10. With the values of **x, d, f**, draw a diagram (to the scale) of the lens system and show the cardinal points.

11. Use auto collimation method and find the focal lengths f'_1 and f'_2 of each lens separately.

12. Calculate the focal length f' of the lens system using the formula.

$$\frac{1}{f'} = \frac{1}{f'_1} + \frac{1}{f'_2} - \frac{d}{f'_1 f'_2}$$

Observation :

1. Length of goniometer arm　　: ℓ = ...cm

2. focal length of individual lenses : f'_1 = ...cm, f'_2 = ...cm

3. Distance between two lenses　: d = ...cm

Set – I

Distance between meter scale and lens nearer to it = x = ...cm

Obs. No.	Meter scale Reading	Goniometer Reading	$h = A - A_0$	$h' = B - B_0$	focal length of system $f_1 = \dfrac{\|h\|}{\|h'\|}\ell$
	cm	cm	cm	cm	cm
1	A_0	B_0			
2	A_1	B_1			
3	A_2	B_2			
4	.	.			
5	.	.			
6	.	.			
7	.	.			

mean f_1 = ...cm

Set – II

After turning lens system through 180^0

Distance between meter scale and lens nearer to it = x' = ...cm

Obs. No.	Meter scale Reading	Goniometer Reading	$h = A - A_0$	$h' = B - B_0$	focal length of system $f_2 = \dfrac{\|h\|}{\|h'\|}\ell$
	cm	cm	cm	cm	cm
1	A_0	B_0			
2	A_1	B_1			
3	A_2	B_2			
4	.	.			
5	.	.			
6	.	.			
7	.	.			

mean f_2 = ...cm

[12]

Diagram showing cardinal points of lens system
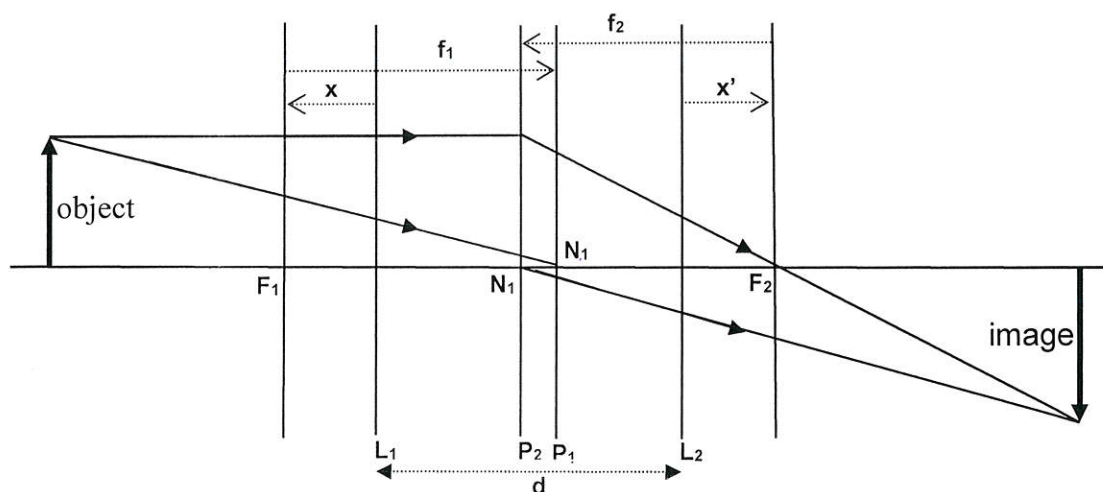
Result :

focal length of the lens system

1. $f' = (f' \pm \Delta f')$ = ... cm.

2. f (expt.)   = ...cm.

3. f (graph) = f $\pm$ Δf = ...cm.

Refractive Index of Liquid using Laser

Aim   : To find the refractive index of liquid using LASER.

Apparatus   : Laser beam, container tray, ruler, mirror.

Ray Diagram :
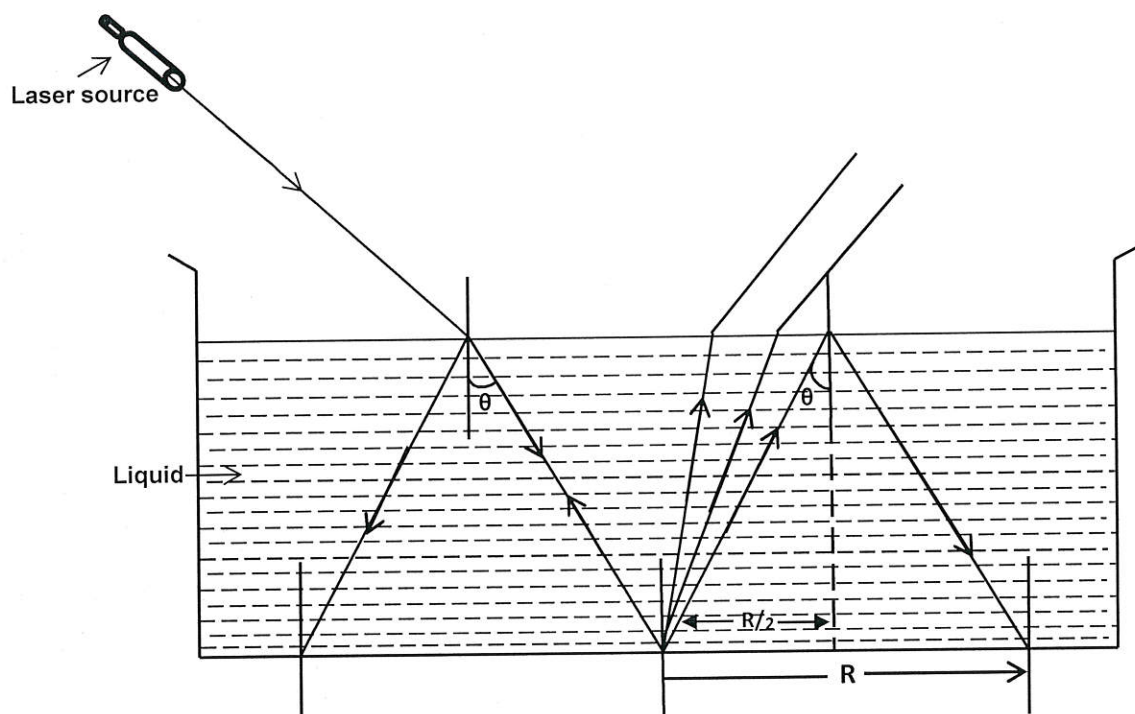
θ is slightly greater than θc

Theory :

When a light ray travels from rarer to denser medium, the ray bends towards the normal.

When a light ray travels from denser to rarer medium the ray bends away from the normal. As the angle of incidence increases, the angle of refraction goes on increasing. For a particular angle of incidence, the ray will travel along the surface separating the two media. This angle of incidence is known as critical angle and is denoted by θc. For angle of incidence greater than θc the ray is totally reflected back.
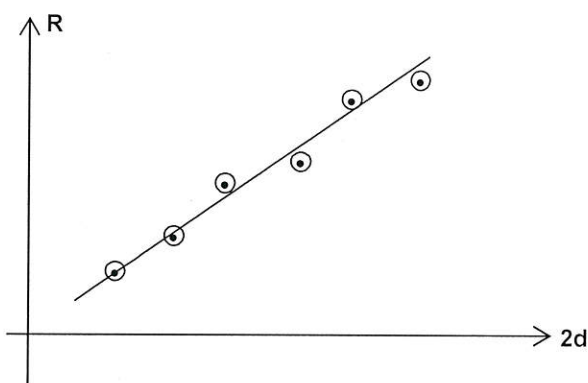
$$\mu = \frac{1}{\sin \theta_c}$$

θc = critical angle,

μ = refractive index of the liquid.

[14]

Procedure :

1. Fill the container with the given liquid.

2. Place a graph paper at the bottom of this container with liquid.

3. Adjust the inclination of the laser source so as to get total internal reflection. This leads to the formation of a circular ring pattern.

4. Measure the radius **R** of the ring pattern formed on the graph paper.

5. Measure the depth **d** of the liquid in the container using scale.

6. Calculate the critical angle θ_c and hence find the refractive index of the liquid **μ**.

7. Repeat the above for different depths **d** of the liquid.

8. Plot a graph of **R** against **2d**.

9. Calculate **μ** from the slope.

Observations:

Obs. no.	Depth of liquid d	2d	Diameter of ring D	Radius of ring R	$\theta = \tan^{-1}(\dfrac{R}{2d})$	$\mu = \dfrac{1}{\sin \theta_c}$
	cm	cm	cm	cm		

mean of **μ** = ...

Graph :

slope = ...

Calculations: $\theta_c = \tan^{-1}$ (slope)

$$\mu = \frac{1}{\sin \theta_c}$$

Result : Refractive index of the liquid μ (cal.)   =   ---------

          Refractive index of the liquid μ (graph) =   ---------

Energy Band Gap of a Germanium Semiconductor

Aim   : To determine the energy band gap of a germanium semi-conductor.

Apparatus : Germanium semiconductor (collector base junction of an NPN transistor), DC Power supply (0-5 V), microammeter(0-200 μA), Digital voltmeter(0-5 V), thermometer, burner.

Circuit Diagram :
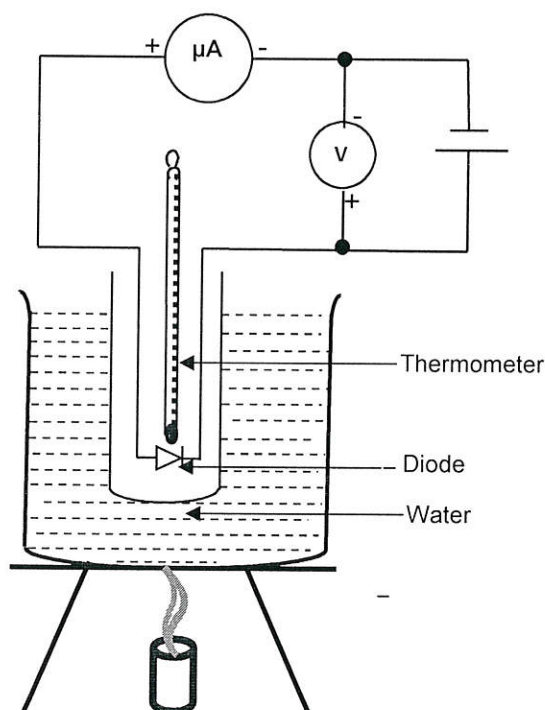
Formula : $I_s = AT^2 exp(\frac{-E_g}{kT})$

I_s : reverse saturation current
T : absolute temperature of diode
k : Boltzmann constant = 8.62×10^{-5} eV / K
A : constant

taking log on both sides, we get,

$log(\frac{I_s}{T^2}) = -\frac{E_g}{2.303k}(\frac{1}{T})$ + constant

comparing with y = mx +c and if we plot a graph of $log(\frac{I_s}{T^2})$ against $(\frac{1}{T})$, the slope will be $-\frac{E_g}{2.303k}$.

Therefore, E_g = 2.303 k | slope |

Procedure:

1) Connect the circuit as shown in the diagram.

2) Initially keep the water bath at room temperature. Increase the reverse voltage V_R from 0 V to 1.0 V in steps of 0.2 V and then in steps of 1 V from 1.0 V to 4.0 V. Note the corresponding reverse currents I_R in the micrometer.

3) Increase the temperature of the water bath and at various steady temperatures of the diode such as 35 °C, 40 °C, 45 °C, 50 °C and 55 °C repeat step 2.
   Note: Take readings in quick succession so that the temperature of the diode remains steady.

4) Plot a graph of I_R against V_R.

   Note: Even though you have not recorded, both V_R and I_R are negative and the reverse characteristic curves lie in the III quadrant. If the current shows linear increase with voltage, the increase is due to surface leakage effect. This is because, impurities on the surface of the diode setup ohmic paths on the surface of the diode.

5) To eliminate the error due to surface leakage effect, we extrapolate the straight line backwards to intersect the current axis and use this value of intercept as I_s, the reverse saturation current.

6) Note I_s in a separate table for various temperatures **T**. Calculate and then plot a graph of $\log(\frac{I_s}{T^2})$ against $(\frac{1}{T})$. Find the slope of this straight line.
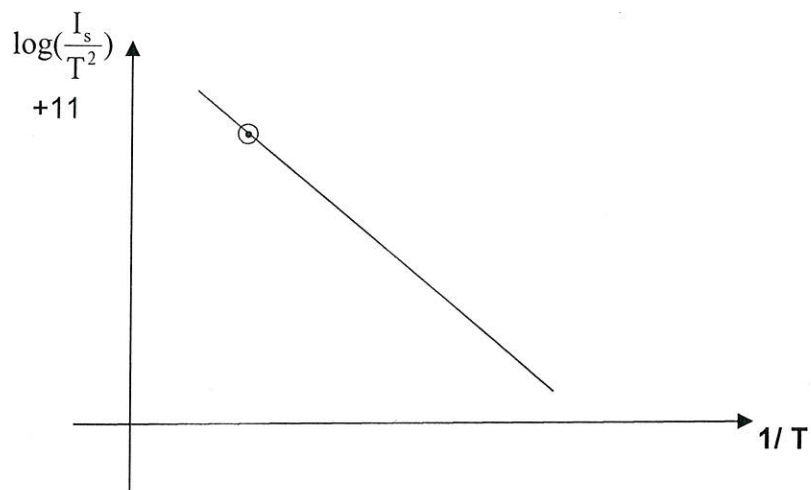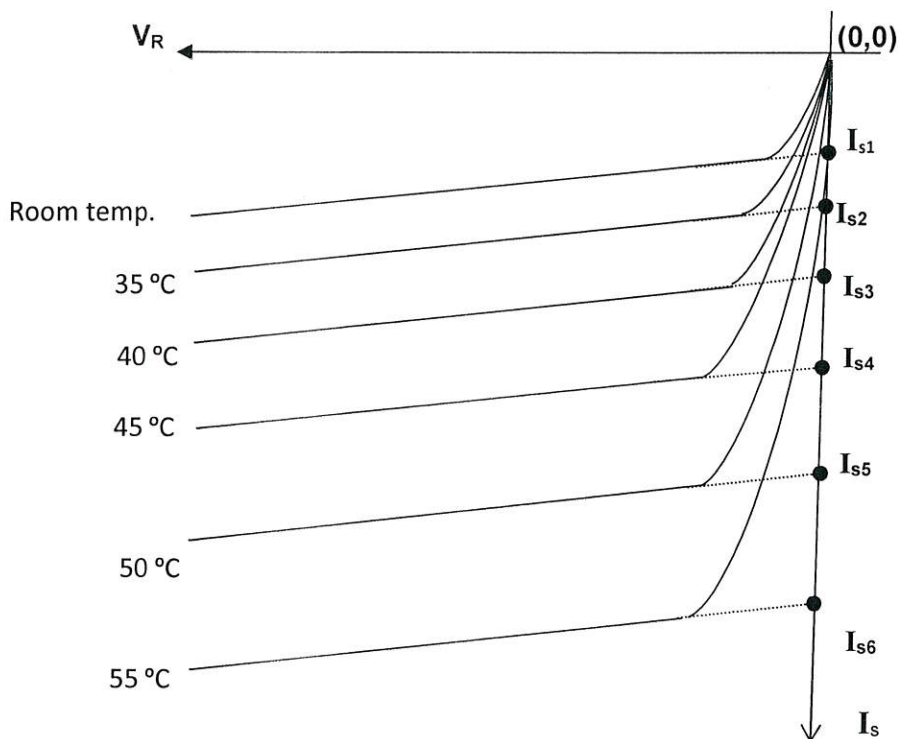
Observations:

Table : I

t = room temp.		t_1 = 35 °C		t_2 = 40 °C		t_3 = 45 °C		t_4 = 50 °C		t_5 = 55 °C	
V_R	I_R	V_R	I_R	V_R	I_R	V_R	I_R	V_R	I_R	V_R	I_R
V	µA	V	µA	V	µA	V	µA	V	µA	V	µA
0.1											
0.2											
.											
.											
.											
1.0											
2.0											
3.0											
4.0											

Table : II

Obs. No.	t	T = 273 + t	I_s	$\dfrac{I_s}{T^2}$	$\log(\dfrac{I_s}{T^2})$	$\log(\dfrac{I_s}{T^2}) + 11$	$\dfrac{1}{T}$
	°C	K	µA	A / K²			K⁻¹
1.	Room temp.						
2.	35						
3.	40						
4.	45						
5.	50						
6.	55						

Graph :

Calculations :

$$E_g = 2.303 \, k \, | \, \text{slope} \, | \, ,$$
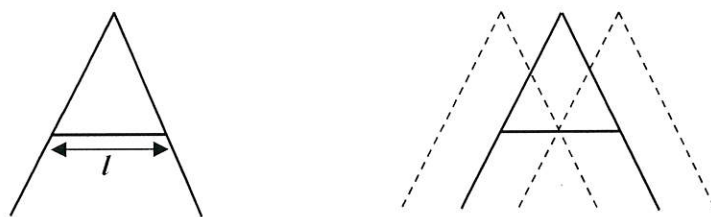
$$E_g = \ldots\ldots\ldots\ldots eV$$

Result :

The energy band gap of the given Germanium semiconductor is E_g = ……….. eV.

Edser's A Pattern

Aim   : To determine the wavelength of the given source of light using Edser's **A** pattern.

Apparatus : Edser's **A** pattern, sodium source, meter scale, wire gauze mounted on a frame, microscope, telescope.

Figure   :

Formula   : $\lambda = \dfrac{\ell\, d}{2\,D}$

λ : wavelength of the source

ℓ : length of the cross bar of **A**

d : distance of the wire gauze element

D : distance between **A** pattern and the wire gauze

Procedure :

1. Place the given **A** pattern in front of the source.

2. Mount the wire gauze of element **d** at some distance in front of the **A** pattern, parallel to the **A** pattern and with one set of wires vertical.

3. Place the telescope behind the wire gauze. Focus the telescope to get clear and direct image of the **A** pattern with few diffraction images.

4. Move the wire gauze such that the first order diffraction images of the **A** pattern intersect each other on the cross bar of **A** as shown in the figure. Note down the distance **D** between the wire gauze and the **A** pattern.

5. Find **d** of the wire gauze using microscope. Also find *l* of the **A** pattern. Hence calculate the wavelength **λ** of the source using the given formula.

6. With the same wire gauze, repeat the procedure for one more **A** pattern.

[19]

Observations :

1. Determination of cross bar length *l* :

A pattern	microscope reading		cross bar length
	Left R_1	Right R_2	$l = R_1 \sim R_2$
	cm	cm	cm
First			
Second			

.

2. Determination of the wire gauze element d :

Obs. No.	microscope readings	difference 5d	mean 5d
	cm	cm	cm
1	d_0 =		
2	d_5 =	$d_0 \sim d_5$ =	
3	d_{10} =	$d_5 \sim d_{10}$ =	
4	d_{15} =	$d_{10} \sim d_{15}$ =	
5	d_{20} =	$d_{15} \sim d_{20}$ =	
6	d_{25} =	$d_{20} \sim d_{25}$ =	

$\therefore$ **d** = ...cm

3. (i)   **D** for first **A** pattern   = ... cm.

   (ii) **D** for second **A** pattern = ... cm.

Calculations :

$$\lambda = \frac{\ell \, d}{2 \, D}$$

Result : Wavelength of the given monochromatic source λ = ...A⁰.

Rydberg's Constant

Aim   : **To determine the value of Rydberg's constant using Hydrogen source.**

Apparatus : Spectrometer, Prism, Mercury source, Hydrogen source, spirit level, etc.

Theory :

When electric discharge is produced in a hydrogen discharge tube, the hydrogen atoms will emit visible light due to excitation. This line spectra can be observed with the help of prism and spectrometer. The line spectra has 4 distinct lines H_α, H_β, H_γ and H_δ with the wavelength λ_α, λ_β, λ_γ and λ_δ. These wavelengths can be calculated using relation.

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

$$\frac{1}{\lambda} = R_H\left(\frac{1}{4} - \frac{1}{n^2}\right)$$

Or $R_H = (4n^2 - 4)/ \lambda(n^2-4)$

For λ_α , n= 3, λ_β,, n= 4, , λ_γ, n=5,& for λ_δ, n=6

Formula   : $R_H = (4n^2 - 4)/ \lambda(n^2-4)$

Procedure

1. Switch on the Mercury source.
2. Adjust the spectrometer for parallel light using Schuster's method.
3. Level the prism table.

Calibration of spectrometer.

4. adjust the position of telescope such that violet line is in minimum deviation position. note down the reading in any one spectrometer window. Next by using the tangent screw move the telescope and bring the vertical cross wire on the Blue line. Note down the reading. Next take the reading for bluish green, Green, Yellow 2, yellow1, Red respectively.
5. Plot a graph of θ against λ to get the calibration curve.

Determination of wavelengths of Hydrogen

6. without disturbing the position of prism table and telescope replace the Mercury source by Hydrogen discharge tube.
7. You will be able to see the line spectrum of hydrogen. Without disturbing the prism table move the telescope using tangent screw and bring the vertical cross wire on H_α, line. Take the reading in the spectrometer window. The reading should be taken in the same window as used in the previous part.
8. Using the tangent screw move the telescope and bring the vertical cross wire on H_β, H_γ and H_δ lines. Take the readings in the spectrometer window.

9. Calculate the wavelengths λ_α, λ_β, λ_γ and λ_δ using the calibration curve.

10. calculate R_H using the given formula.

Observations : Least count of spectrometer. ....

Calibration of spectrometer

Sr. No.	colour	Wavelength λ ^0A	θ^0
1	Red	6232	
2	Yellow1	5790.	
3	Yellow2	5769	
4	Green	5461	
5	Blue Green	4916	
6	Blue	4358	
7	Violet	4047	

Graph : θ
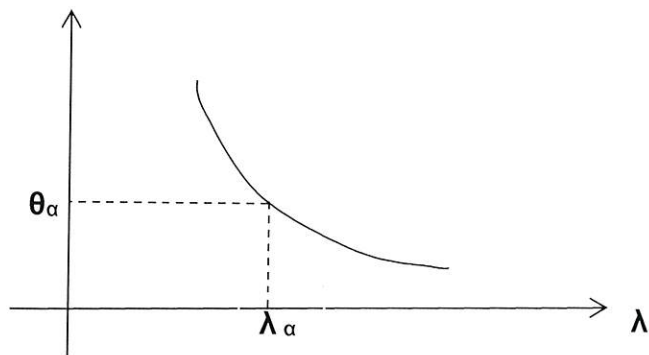
Hydrogen Spectrum Readings

| Value of n	Colour	θ^0	λ ^0A from graph	R_H /m
3	Red H_α			
4	Green H_β,			
5	Blue H_γ			
6	Violet H_δ			

Mean R_H = ... /m

Result : Value of Rydberg's constant R_H = _____ /m

[22]

Coefficient of Mutual Inductance

Aim   : To determine the coefficient of mutual inductance between two coils by a ballistic galvanometer.

Apparatus : An accumulator, two given coils, two commutator keys, a fractional resistance box, a resistance box (0-10,000 Ω), a sequence key, a ballistic galvanometer, wires etc.

Circuit Diagram:
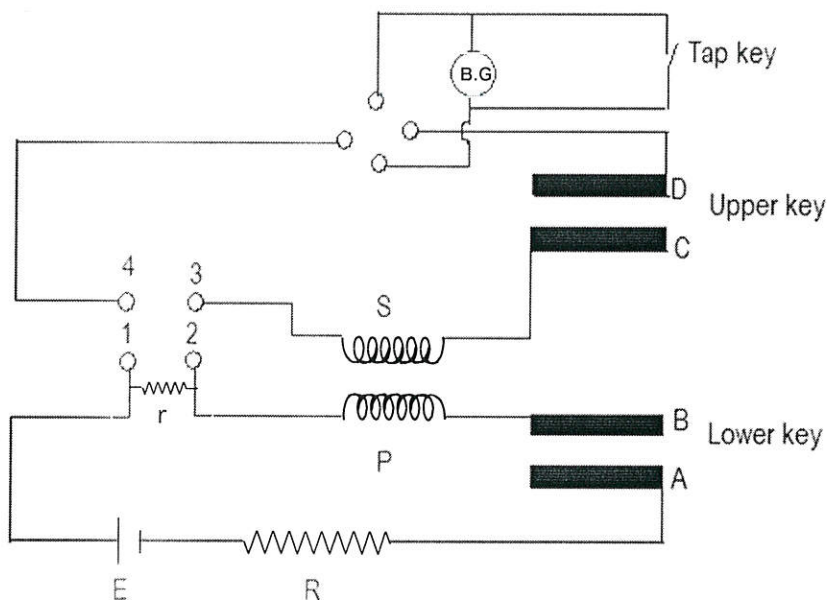
Procedure:

1. Connect the circuit as given in the circuit diagram.

2. In the four way key of the primary circuit, insert a plug between 1 and 2, and between 3 and 4 so that there is no d.c. path between primary and secondary coils. Keep **r** = 0 Ω and **R** = 1 kΩ. Press the Rayleigh key and observe the throw during the release of the key (which breaks the circuit). Adjust the resistance **R** to get a throw of about 8 to 10 cm.

3. Start the primary current by pressing the Rayleigh's key and during the release of the key, note θ_1 and θ_3, the two consecutive throws of the B.G. on the same side. Calculate the corrected throw θ_0 using relation :
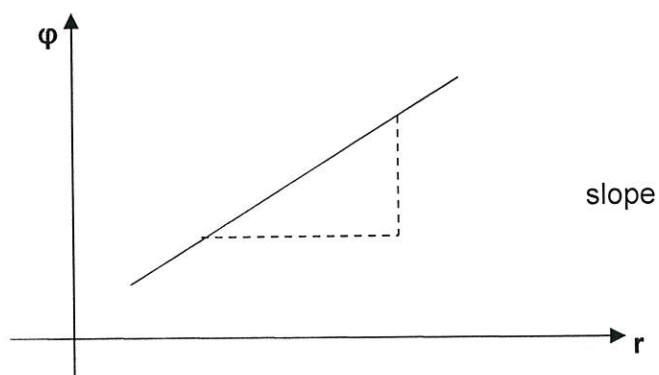
   $\theta_0 = \theta_1 (\theta_1 / \theta_3)^{1/4}$ Take a set of 10 observations.

4. Connect terminal 1 to 4 and 2 to 3 using plug keys. Keep **r** = 0.02 Ω, and resistance **R** (same as that chosen in step 2). Now press the Rayleigh's key till a steady deflection φ is observed. Repeat this for different values of **r**.(change **r** in steps of 0.02 Ω)

5. Determine periodic time **T** of the oscillation of the B.G., when it oscillates freely.

6. Plot a graph of φ against **r**.

7. Calculate **M** using the given formula.

PART-A

Observations:

To determine θ_0 :

Obs. No.	θ_1	θ_3	$\theta_0 = \theta_1 (\theta_1 / \theta_3)^{1/4}$	$(\theta_0 - \overline{\theta}_0)^2$
	cm	cm	cm	cm^2
1				
2				
.				
.				
10				

mean $\overline{\theta}_0$ = _____ cm $\Sigma (\theta_0 - \overline{\theta}_0)^2$ = _____ cm^2

PART-B

for steady deflection φ

Obs. No.	r	Steady deflection		mean φ
		Left φ	Right φ	
	Ω	cm	cm	cm
1				
2				
3				
4				
5				

Graph:

slope

Calculations:

$$M = \frac{T}{2\pi} \; \overline{\theta}_0 \; \left(\frac{1}{slope}\right)$$

M = _____ **H =** ....**mH.**

Error calculations :

$$\frac{dM}{M} = \frac{dT}{T} + \frac{d\left(\frac{\varphi}{r}\right)}{\frac{\varphi}{r}} + \frac{d\theta_0}{\overline{\theta}_0} \quad .... \; (i)$$

1) To measure dT / T, take T as the time for 10 oscillations and dT as the least count of the stop watch.

2) $\dfrac{d\left(\frac{\varphi}{r}\right)}{\frac{\varphi}{r}} = \dfrac{d(slope)}{slope}$

   d(slope) : difference in the maximum and minimum slopes drawn using error bars

   slope   : mean of the maximum and minimum slopes

3) Here $d\theta_0$ should be the standard error in $\overline{\theta}_0$ given by

$$d\theta_o = \sqrt{\frac{\Sigma \, (\theta_o - \overline{\theta}_o)^2}{n\,(n-1)}}$$

   n : the number of observations

   substituting the various values in equation (i), calculate dM.

   Express the result along with the possible error in appropriate significant figures.

   Note : *The experiment can be repeated by changing the primary current to a different value (i.e. for different value of R) but keeping the positions of primary and secondary coils unchanged.*

   Result : Mutual Inductance M ± dM =................ mH.

Hysteresis

Aim : To study the magnetization curve and hysteresis of the given ferromagnetic material in the form of a rod using a tangent magnetometer.

Apparatus : Solenoid(S), compensating coil(C), lamp board, d.c. supply, commutator, ammeter (1-3 A), magnetometer, specimen rod, solenoid connected to a transformer and switch for demagnetization of the specimen rod.
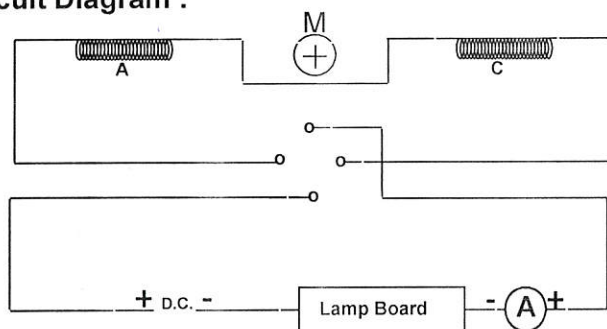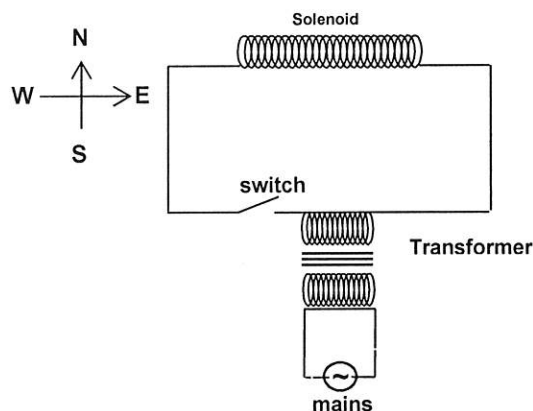
Circuit Diagram :

fig (i)   fig (ii)

Procedure :   *Part - A*

1. Measure the length **L** and the radius **r** of the specimen rod. The magnetic length of the rod is $2l = 5L / 6$.

2. Connect the components as shown in fig (i). The axes of the solenoid and the compensating coil C must be collinear and along the East-West direction. Keep the ammeter as far as away from the solenoid, since the ammeter has a permanent magnet in it.

3. Adjust the magnetometer to read 0-0. Introduce the specimen rod into S so that its centre is at the centre of the solenoid. Switch on all the lamps for maximum current. Adjust the distance of the solenoid from the magnetometer so that the reading is around 65°.

4. Remove the specimen rod and keep it far away from the set-up. Keeping the current maximum, adjust the distance between the compensating coil and magnetometer so that the reading is 0-0. If necessary, reverse the connections of the compensating coil to achieve this. **Now the setup is ready to perform the experiment, so do not disturb anything throughout the experiment.** Reduce the current to zero.

5. For demagnetizing the rod, connect the circuit as in fig (ii). Switch on the A.C. current and slowly introduce the specimen rod into the solenoid and withdraw it from the other end. Repeat this a number of times. Test if the rod is demagnetized by bringing its ends close to the magnetometer needle. No repulsion is observed if the rod is completely demagnetized.

Part - B

1) Introduce the rod into the solenoid S of fig(i) so that it is coaxial with its centre coinciding with that of the solenoid. Switch on the lamps one by one and each time note the current and the magnetometer readings till maximum current is reached. (section OA of the hysteresis curve).

2) Switch off the lamps one by one and read the ammeter and magnetometer readings till the current goes to zero. (section AB of the hysteresis curve)

3) Reverse the commutator key. Switch on the lamps one by one and read the ammeter and magnetometer readings till maximum current is reached.(section BD of the hysteresis curve).

4) Switch off the lamps one by one and read the ammeter and magnetometer readings till the current goes to zero. (section DE of the hysteresis curve)

5) Reverse the commutator key. Switch on the lamps one by one and read the ammeter and magnetometer readings till maximum current is reached.(section EA of the hysteresis curve). This completes one cycle magnetization cycle for the specimen.

6) Measure the distance between the centre of the specimen and the centre of the magnetic needle, **d**.

7) Calculate magnetization **M** and magnetizing field intensity **H** using the formula given below.

8) Plot a graph of **M** on y-axis and **H** on x-axis. Draw a tangent at the origin. Find the slope to obtain maximum susceptibility χ_m.

Formulae:

1) Magnetic field intensity H = n I

   n : number of turns per unit length

   I : current

2) Magnetic field produced by the specimen rod at the centre of the magnetic needle is

$$\frac{\mu_o \, 2 \, (\pi \, r^2 \, L \, M) \, d}{4 \pi \, (d^2 - l^2)^2} = B_H \, \tan \theta$$

   ℓ : length of the specimen rod

   r : radius of the specimen rod

   2ℓ : the magnetic length of the rod

   d : the distance between the centre of the specimen and the centre of the magnetic needle

   μ_o : permeability of free space

   M : magnetization of the specimen rod

Observations :

1) Length of the specimen rod L = ... cm = ... m

2) Diameter of the specimen rod $2r$ = ... cm = ... m

3) Half the magnetic length ℓ = 5 L / 12   = ... m

4) Number of turns of the solenoid N = ...

5) Length of the solenoid L_s = ... cm = ... m

6) Number of turns per unit length of the solenoid n = N / L_s = ... m^{-1}

7) Distance between the centre of the specimen
   and the centre of the magnetic needle d = ...cm =............ m

8) Given :

permeability of free space μ_o = 4 π x 10^{-7} Wb $A^{-1}m^{-1}$

Horizontal component of earth's magnetic field B_H = **3.6 x 10^{-5} Wb m^{-2}**

Obs. No.	Current	Deflection			tan θ	Magnetization	Magnetic field intensity
	I	θ_1	θ_2	mean θ		M	H
	A	degree	degree	degree		A m^{-1}	A m^{-1}
1							
2							
3							
4							
5							
6							

Graph :

Residual magnetization   : M_R = (OB + OE) / 2 = ... A m^{-1}

Coersive field   : H_c = (OF + OC) /2 = ... A m^{-1}

Magnetic susceptibility   : χ_m = slope of the tangent at the origin

                                        = ...

Result :   **The hysteresis curve for the given specimen rod is determined.**

Residual magnetization M_R = ... Am^{-1}

Coersive field H_c = ...Am^{-1}

Magnetic susceptibility χ_m = ...

Maxwell's Bridge

Aim   : To determine the self inductance **L** and quality factor **Q** of a coil.

Apparatus : Four resistance boxes, decade condenser box (variable C), inductance coil, D. C. power source, A. C. source (audio frequency oscillator 1 kHz), digital multimeter, 4-way key etc.

Circuit Diagram :
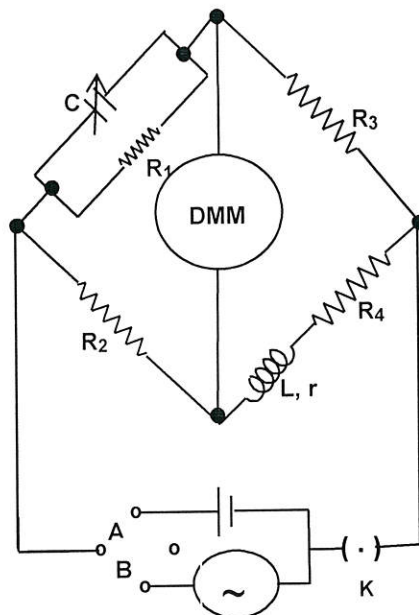
Condition for DC Balance :

$$\frac{R_1}{R_2} = \frac{R_3}{R_4 + r}$$

$$\frac{R_1}{R_2} = \frac{R_3}{R}$$

$$R = R_4 + r \; , \text{ where } \quad r : \text{resistance of inductance coil}$$

Condition for AC Balance :

$$L = C\, R_2\, R_3$$

Procedure :

1. Connect the circuit as shown in the figure.

2. Keep **R₄** = 50 Ω. **R₄** is kept constant throughout the experiment.

3. Choose a value of **R₁** and **R₃** from the observation table and take out some resistance from **R₂** (say 100 Ω). Keep the 4 way key on A (B open) so that DC power supply is connected in the circuit.

4. Keeping the multimeter on DC 20 V range, connect the key k and adjust the resistance R_2 so that the voltage is closest to zero (that means, if R_2 is increased or decreased by 1 Ω the sign of voltage should change). Change to 2 V range if needed, that is if voltage reading is zero (on 20 V range) for more than one value of R_2. Note down this R_2 and calculate **R** and **r**.

5. Bring both the knobs of the decade condenser box to zero and remove 4-way key from slot A and insert it in B. Now the AC power supply is connected in the circuit.

6. Keep the multimeter in 20 V AC range and increase the capacitance in steps of 0.1 μF to get minimum voltage.

7. Change the multimeter to AC 2 V range and then increase the capacitance in the steps of 0.01 μF to obtain minimum voltage. Note the total value of the capacitance **C** from step 6 and 7 and hence calculate **L**.

Observations :

$$R_4 = 50 \ \Omega$$

Obs. No.	R_1	R_3	(DC Balance) R_2	$R = \dfrac{R_2 \, R_3}{R_1}$	$r_i = R - R_4$	(AC Balance) C	$L_i = C \, R_2 \, R_3$	L_i
	Ω	Ω	Ω	Ω	Ω	F	H	mH
1.	50	100						
2.	100	50						
3.	100	100						
4.	100	150						
5.	150	100						
6.	150	200						
7.	200	150						
8.	100	200						
9.	200	100						
10.	150	150						

mean $\bar{r}$ = ... Ω   mean $\bar{L}$ = ...H $\bar{L}$ =.......mH

Calculation :

$$Q = \frac{\omega \bar{L}}{\bar{r}}, \quad where , \quad \omega = 2\pi f$$

$$\bar{L} = ... \, H$$
$$f = 1000 \ Hz$$

[31]

Error Calculation :   f = 1000 Hz $\overline{L}$ = ... H

Sr.No.	L_i	$L_i - \overline{L}$	$(L_i - \overline{L})^2$	r_i	$r_i - \overline{r}$	$(r_i - \overline{r})^2$
1.	mH	mH	(mH)²	Ω	Ω	Ω²
2.						
.						
.						
.						
.						
.						
.						
.						
10.						

$$\Sigma\left|L_i - \overline{L}\right|^2 = _____ (mH)^2 \qquad \Sigma\left|r_i - \overline{r}\right|^2 = _____ \Omega^2$$

Standard error in the mean :

$$\Delta L = \sqrt{\frac{\Sigma\left|L_i - \overline{L}\right|^2}{n(n-1)}} = ...mH \qquad \Delta r = \sqrt{\frac{\Sigma\left|r_i - \overline{r}\right|^2}{n(n-1)}} = ...\Omega$$

n : number of observations

Maximum possible error ΔL and Δr is rounded off to correct significant digits.

Result : Inductance of the coil $\overline{L} \pm \Delta L$ = _____ mH.

Resistance of the coil $\overline{r} \pm \Delta r$ = _____ Ω

Quality factor of the coil   Q   = _____

Note   : *The value of L and r written in the result should have decimal place only up to the decimal place of maximum possible error.*

[32]

Schmitt trigger using OP AMP

Aim : To study Schmitt trigger using OP AMP in the inverting mode.

Apparatus : Built up circuit, C.R.O., dual power supply(0 -10 V and 0 - 5 V), sine wave generator, connecting wires, etc.

PART- I
(d.c. input)

Circuit Diagram : $+V_{cc}= +10$ V
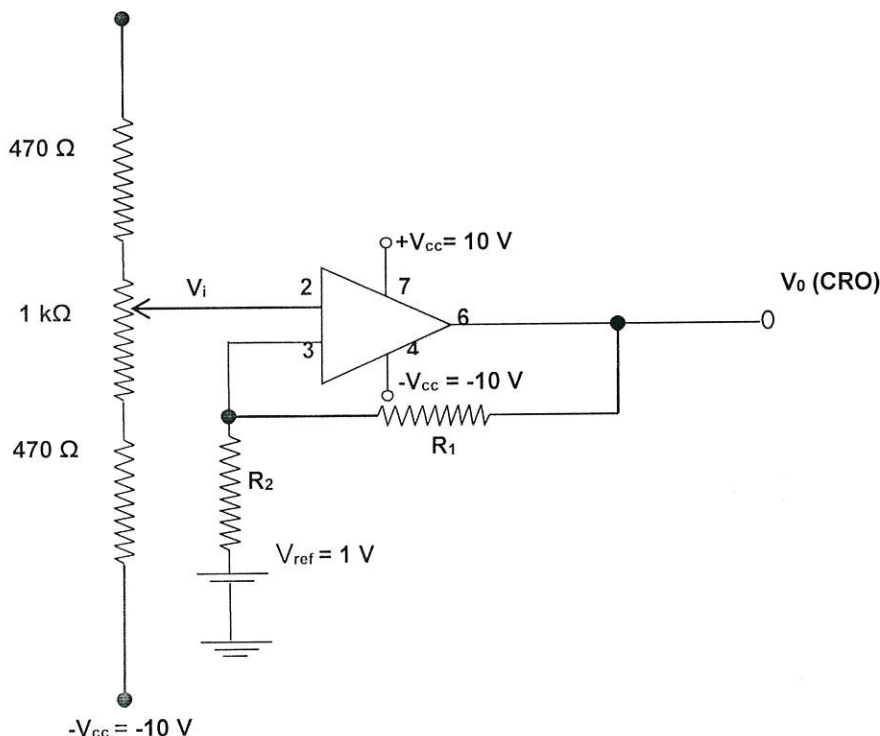
Formula :

$$V_{UTP} = \frac{V_H\,R_2}{R_1 + R_2} + \frac{V_{ref}\,R_1}{R_1 + R_2} \qquad\qquad V_{LTP} = \frac{V_L\,R_2}{R_1 + R_2} + \frac{V_{ref}\,R_1}{R_1 + R_2}$$

$$V_H = +V_{sat} \qquad\qquad V_L = -V_{sat}$$

Procedure :

1. Connect the circuit using the components as shown in the diagram.

2. For a given pair of R_1 and R_2 values (i.e. for a given value of positive feed back $\beta = \frac{R_2}{R_1 + R_2}$),

   increase the input voltage V_I from a minimum value (by varying the pot. meter) till the output switches from high voltage V_H to low voltage V_L as observed on the C.R.O. Note the d.c. input voltage which is equal to V_{UTP} using a digital voltmeter.

3. For the same combination of R_1 and R_2, decrease the input voltage from the maximum value (by varying the pot. meter), till the output voltage V_o switches from low voltage V_L to high voltage V_H as observed on the C.R.O. Note the d.c. input voltage which is equal to V_{LTP} using a digital voltmeter.

4. Note the values of V_H and V_L using a digital multimeter. Calculate V_{UTP} and V_{LTP} by using the formula given above and compare it with the measured values.

5. Repeat the above procedure for two two more combinations of R_1 and R_2.

6. Plot the Hysteresis curve for any one combination of R_1 and R_2.

Observation Table :

$V_H = +V_{sat}$ ....V, $V_L = -V_{sat}$ V

Obs. No.	R_1	R_2	V_{UTP} measured	V_{UTP} calculated	V_{LTP} measured	V_{LTP} calculated	Hysteresis = $V_{UTP} – V_{LTP}$ measured	Hysteresis = $V_{UTP} – V_{LTP}$ calculated
	Ω	Ω	V	V	V	V	V	V
	15 k	10 k						
	22 k	10 k						
	33 k	10 k						

Graph :

PART- II
(a.c. input)

Circuit Diagram :

(34)
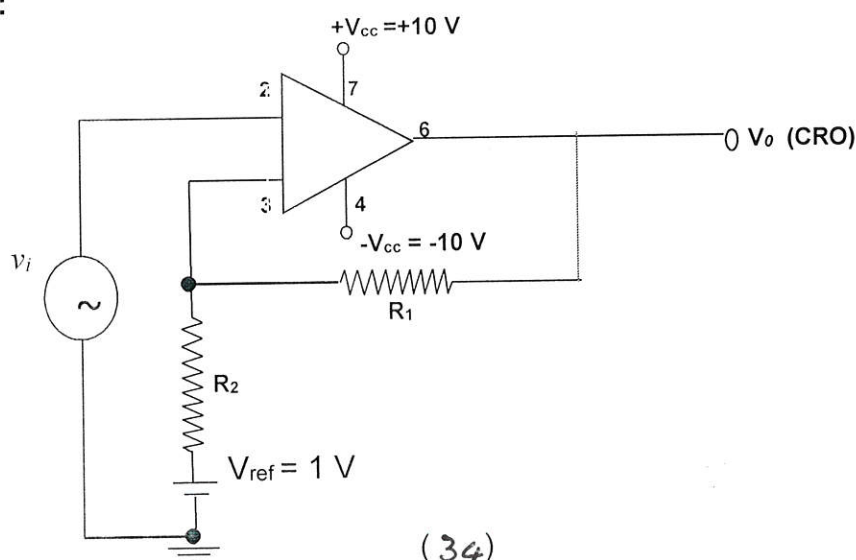
Procedure :

1. Connect the circuit as shown in the diagram (for any one value of R_1 and R_2 combination).

2. Apply a sine wave of frequency say 1 kHz. Vary the input voltage till you observe the squaring effect at the output on the CRO. Measure the input voltage (peak to peak) with the help of a C.R.O. Draw the input and output waveform. Determine V_{UTP} and V_{LTP} from the waveform and compare them with those obtained from d.c. measurements.

3. Measure the time period T_o of the output square wave and hence calculate the output frequency f_o. Compare it with the input sine wave frequency.

4. Repeat step 2 and 3 for one more value of input frequency where slew rate distortion is noticeable.

Observation :

Obs. No.	Input frequency f_i	Output time period T_o	Output frequency f_o	$V_{i(p-p)}$	$V_{0(p-p)}$	V_{UTP}	V_{LTP}
	Hz	s	Hz	V	V	V	V

Waveform :
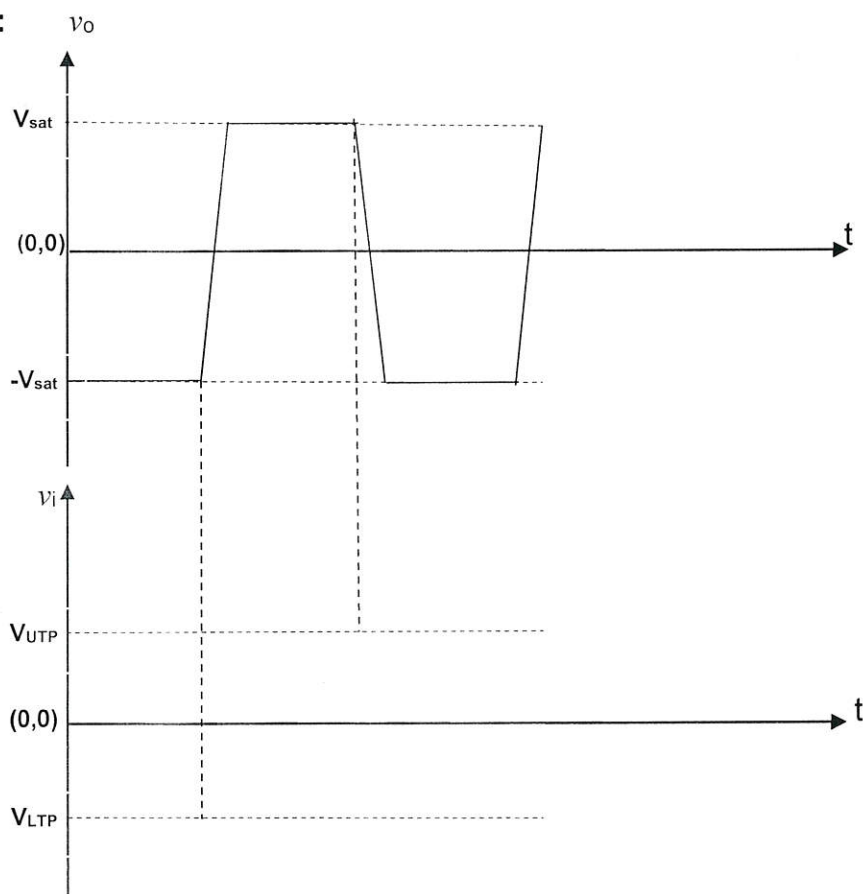
Result : Studied Schmitt trigger using OP AMP in the inverting mode.

| Active High Pass Filter |

Aim   : To study first order active high pass filter.

Apparatus   : OP AMP, dual power supply, signal generator, CRO, resistors, capacitance, etc.

Circuit Diagram :
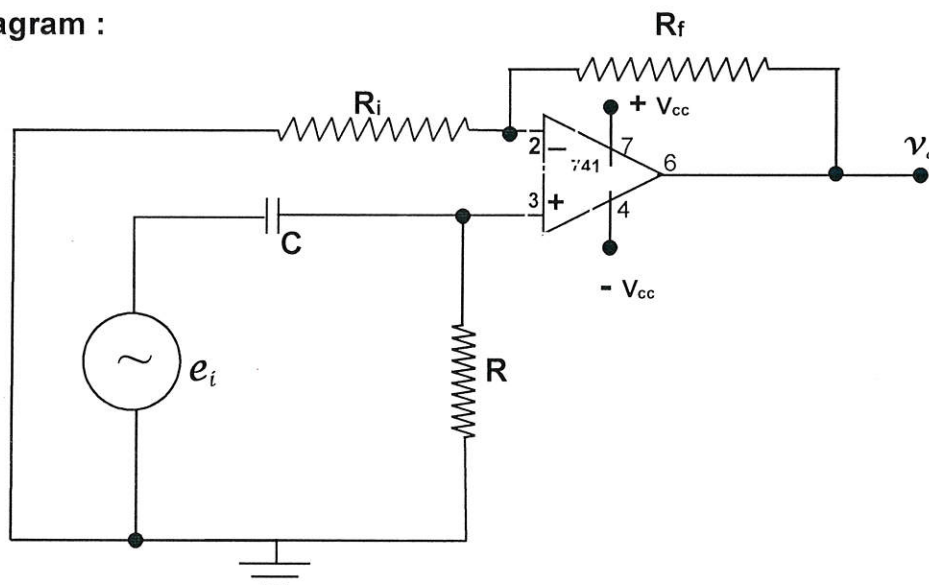
Theory : When e_i is connected, let the voltage at terminal no. 3 be v_i.

The gain of the OP AMP in the non-inverting mode is $A_v = \dfrac{v_o}{v_i} = 1 + \dfrac{R_f}{R_i}$

$$v_o = v_i \left(\frac{R_i + R_f}{R_i} \right) \quad \dots\dots\dots\dots\dots\dots(i)$$

To construct a first order active high pass filter using an OP AMP having a

closed Loop gain $A_{VCL} = \dfrac{v_o}{e_i} == 1.56$, let $R_i = 1\ k\Omega$ and $R_f = 560\ \Omega$
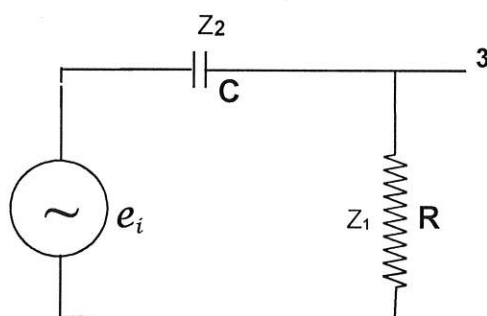
$$v_i = \frac{Z_1}{Z_1 + Z_2} e_i \quad ; \quad Z_1 = R \quad \text{and} \quad Z_2 = \frac{1}{j\omega C}$$

$$v_i = \left(\frac{1}{1 - \dfrac{j}{\omega C R}} \right) e_i \quad \dots\dots\dots\dots\dots(ii)$$

[36]

substituting (ii) in (i), we get ,

$$v_o = (\frac{R_i + R_f}{R_i}) (\frac{1}{1 - \dfrac{j}{\omega CR}}) e_i$$

$$A_{vcl} = \frac{v_o}{e_i} = (\frac{R_i + R_f}{R_i}) (\frac{1}{1 - \dfrac{j}{\omega CR}})$$

$$| A_{vcl} | = (\frac{R_i + R_f}{R_i}) (\frac{1}{\sqrt{1 + \dfrac{1}{\omega^2 C^2 R^2}}})$$

when, $\omega^2 C^2 R^2 = 1$ we get ,

$$| A_{vcl} | = \frac{R_i + R_f}{R_i} (\frac{1}{\sqrt{2}})$$

Then, ω_c is called the cut-off frequency.

$$\omega_c\, C\, R = 1 \quad\quad or, \;\; \omega_c = \frac{1}{R\,C} \quad\quad or, \;\; f_c = \frac{1}{2 \pi\, R\, C}$$

Procedure :

1) Calculate the cut-off frequency f_c of the filter for the given value of R and C.

2) Connect the circuit as shown in the circuit diagram and give a sinusoidal input wave from the signal generator.

3) Keeping e_i = 2.0 V, Change the frequency f_{in} from f_c / 10 to 10 f_c. and measure the corresponding output voltage v_o on the C.R.O. Take atleast 20 observations in this range. Measure e_i and v_o for each f_{in} simultaneously using dual trace C.R.O.

4) Plot a graph of v_o on y-axis and **log f_{in}** on x-axis.

5) Choose any frequency in the pass band (**f > f_c**) and determine the phase shift **θ** between v_o and e_i using the formula: $\theta_{measured} = (\frac{t}{T}) 360$.

6) Determine the phase shift for another frequency in the pass band and at the cut-off frequency.

Calculations:

R_i = ……… Ω, R_f = ………. Ω,   R = ………….Ω, C = 0.1 µF

$$f_c = \frac{1}{2 \pi\, R\, C} = …………… Hz,$$

Observations :

frequency response

$$e_i = 2.0 \text{ V}$$

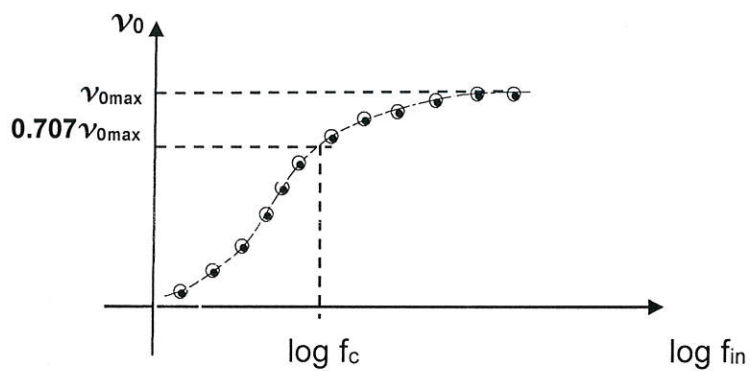| Obs. no.	f_{in}	log f_{in}	v_0
	Hz		V
1.			
2.			
.			
.			
.			
.			
.			
.			
.			
20.			

Phase Shift

Input Waveform

Output Waveform
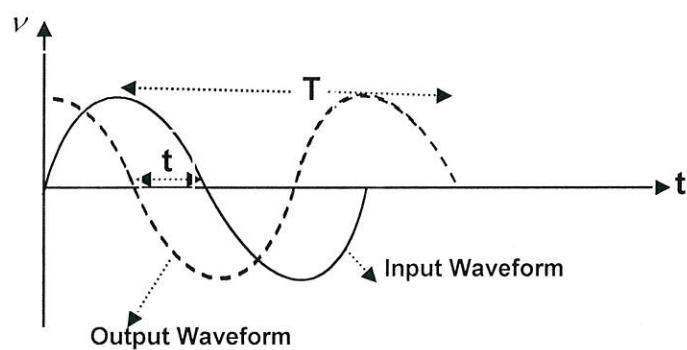
$$\theta_{calculation} = \tan^{-1}\left(\frac{f_c}{f}\right)$$

$$\theta_{measured} = \left(\frac{t}{T}\right) 360$$

Obs. no.	f_{in}	t	T	$\theta_{measured}$	$\theta_{calculated}$
	Hz	s	s	degree	degree
1.	f > f_c = 7 k				
2.	f > f_c = 5 k				
3.	f = f_c = 3 k				

[38]

Graph :

Result:

(1) f_c **(designed)**   = ………………..Hz.

(2) f_c **(graph)**   = …………………Hz.

(3)   **The angle by which the output voltage v_0 leads the input voltage e_i is the phase shift at f_c = ……….°.**

Wien Bridge Oscillator

Aim   : To study Wien bridge oscillator using OP AMP IC – 741.

Apparatus   : OP AMP IC- 741, dual power supply, bread board, oscilloscope, generator etc.

Circuit Diagram :
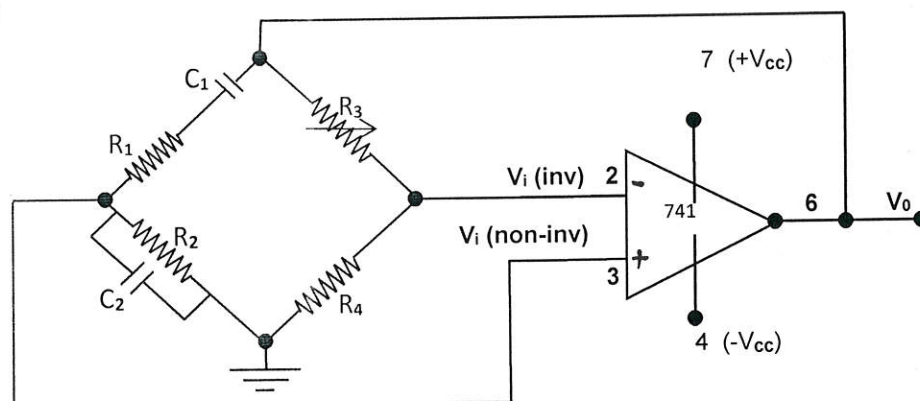
Procedure:

1) Trace the given circuit and write down the component values.

2) Make the necessary connections as shown in the circuit diagram and switch on the power supply.

3) Adjust the potentiometer R_3 to get a stable sinusoidal waveform at the Y input of the oscilloscope.

4) Determine the peak to peak signal voltage at-
   (i)   The non-inverting input terminal (no. 3),
   (ii)   Inverting input terminal (no. 2),
   (iii)   Output terminal (no. 6) of the OP AMP.

   Find the ratio of the output voltage to the non-inverting input voltage.

5) Determine the frequency of the oscillator using CRO time base.

6) Now feed another adjustable sinusoidal wave to the X input of the oscilloscope. Adjust the frequency of the sine wave to obtain different Lissajous figures and hence determine the frequency of the Wien bridge oscillator.

7) Compare the frequency with the expected value.

$$f_{expected} = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

$$f_{expected} = \frac{1}{2\pi RC} \qquad\qquad R_1 = R_2 = R \; ; C_1 = C_2 = C \; ;$$

8) Repeat the procedure to get a different frequency by changing the R-C combination.

[40]

Part- A

To determine the gain A_v :

$$R_1 = R_2 = R \qquad C_1 = C_2 = C$$

R	C	Frequency f	Output voltage V_o	Input voltage inverting V_{-i}	Non inverting V_{+i}	Gain $A_v = V_o / V_{+i}$
Ω	F	Hz	V	V	V	

Part-B

To determine the frequency by Lissajous figure :

frequency of the signal generator = f_x ;   frequency of Wien bridge oscillator = f_y

$$\frac{f_y}{f_x} = \frac{points \ of \ tangency \ on \ the \ x-axis}{points \ of \ tangency \ on \ the \ y-axis}$$

Obs. No.	Lissajous figure	f_y / f_x	f_x Hz	f_y Hz
1.	◯	1		
2.	◯◯	2		
3.	⊗	1 / 2		

mean f_y =...........Hz

Result : The Wien bridge oscillator using OP AMP is studied.

R	C	A_v	f_y (calculated)	f_y (observed)
Ω	F		Hz	Hz

[41]

Counter mod 2, 5, 10

Aim   : To study mod-2, mod-5 and mod-10 (decade) counters using IC 7490.

Apparatus   : IC 7490 mounted on a 14 – pin board, 5 V d.c. power supply, dual trace CRO, signal generator, wires etc.
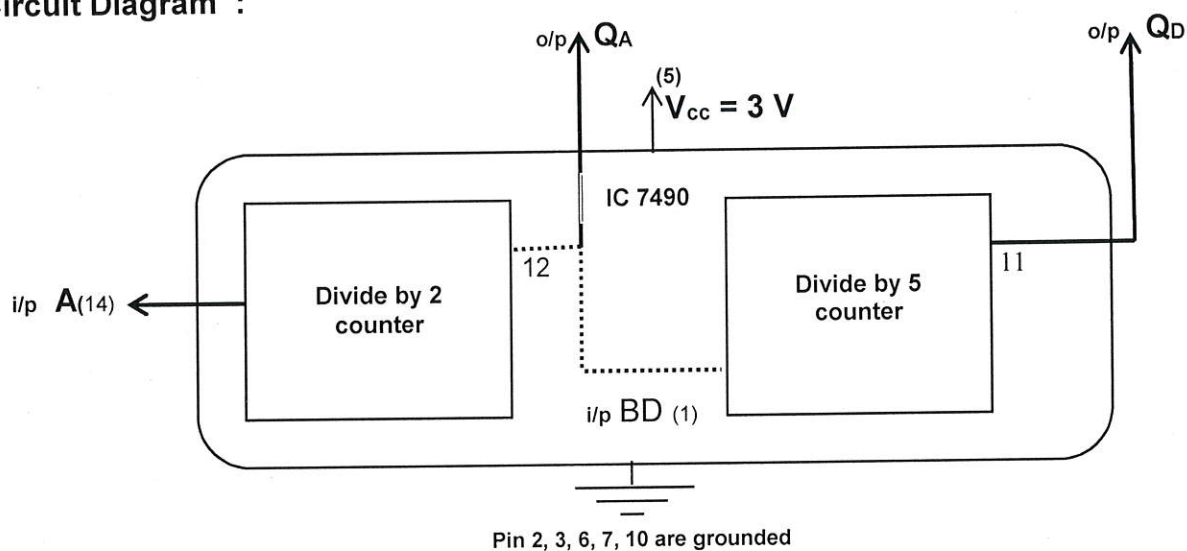
7490 logic Diagram
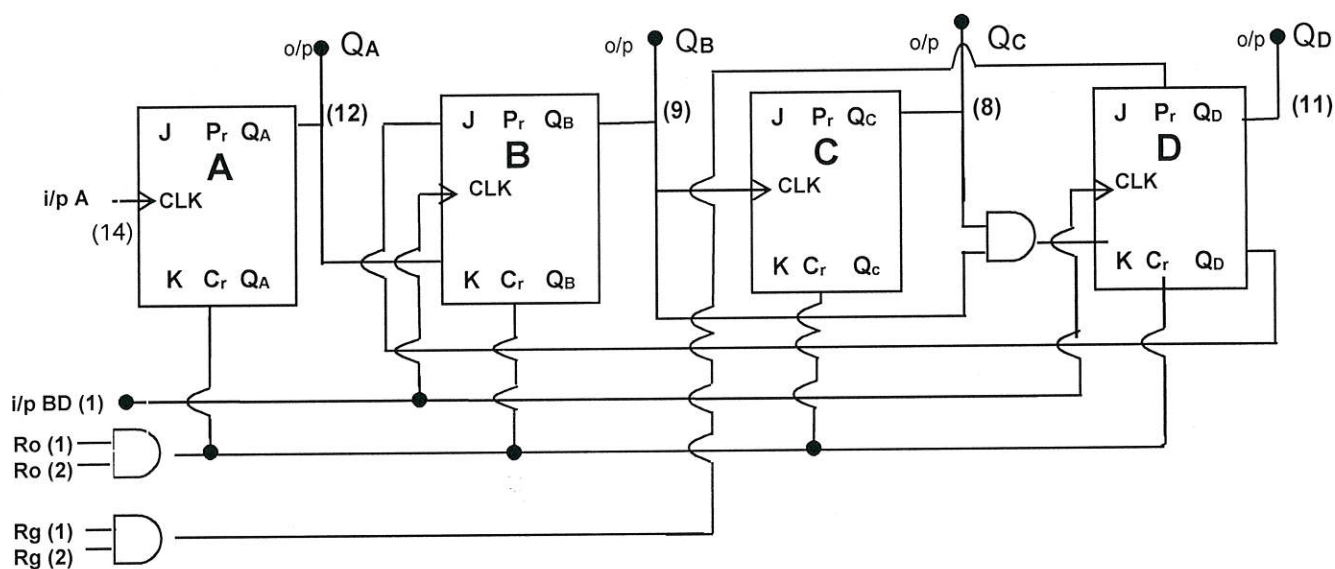
PIN OUT of IC 7490

i/p A	NC	QA	QD	GND	QB	QC
14	13	12	11	10	9	8
1	2	3	4	5	6	7
i/p BD	$R_{o(1)}$	$R_{o(2)}$	NC	V_{cc}	$R_{g(1)}$	$R_{g(2)}$

NC : no connection,   GND : ground

(42)

Circuit Diagram :

Pin 2, 3, 6, 7, 10 are grounded

Procedure :

Connect V_{cc} = +3 V to pin (5) and connect pin 2, 3, 6, 7 and 10 to the ground terminal.

Part-I

To use IC 7490 as mod-2 counter

1) Apply input square wave of frequency f_i = 10 kHz at the input A [pin (14)], and observe the output Q_A at pin (12) using a dual trace CRO.

2) Measure the time period T_o of the output waveform.

3) Calculate the output frequency f_o and the ratio f_i / f_o.

4) Repeat the above steps for 20 kHz.

5) Trace both input and output waveform for f_i = 10 kHz, keeping the same scale for both input and output.

Part-II

To use IC 7490 as mod-5 counter

1) Apply input square wave of frequency f_i = 10 kHz at the input BD pin (1), and observe the output Q_D at pin (11) using a dual trace CRO.

2) Measure the time period T_o of the output waveform.

3) Calculate the output frequency f_o and the ratio f_i / f_o.

4) Repeat the above steps for 20 kHz.

5) Trace both input and output waveform for f_i = 10 kHz, keeping the same scale for both input and output.

Part-III

To use IC 7490 as Mod-10 (decade counter 2 X 5)

1) Externally connect the output Q_A [pin (12)] to the input BD [pin (1)]. Now apply input square wave of frequency f_i = 10 kHz at the input A [pin (14)], and observe the output Q_D at pin (11) using a dual trace CRO.

2) Measure the time period T_o of the output waveform.

3) Calculate the output frequency f_o and the ratio f_i / f_o.

4) Repeat the above steps for 20 kHz.

5) Trace both input and output waveform for 10 kHz, keeping the same scale for both input and output.

Observations :

1. For mod – 2 counter :

Input frequency f_i	Output time period T_o	Output frequency $f_o = 1 / T_o$	f_i / f_o
Hz	s	Hz	
10 k			
20 k			

2. For mod – 5 counter :

Input frequency f_i	Output time period T_o	Output frequency $f_o = 1 / T_o$	f_i / f_o
Hz	s	Hz	
10 k			
20 k			

3. For mod – 10 counter :

Input frequency f_i	Output time period T_o	Output frequency $f_o = 1 / T_o$	f_i / f_o
Hz	s	Hz	
10 k			
20 k			

Waveforms :

MOD-2
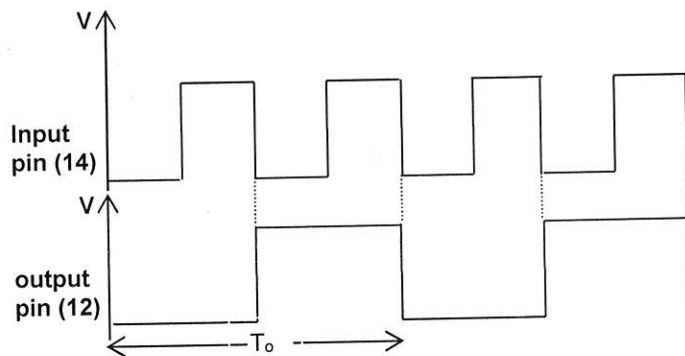
MOD-5
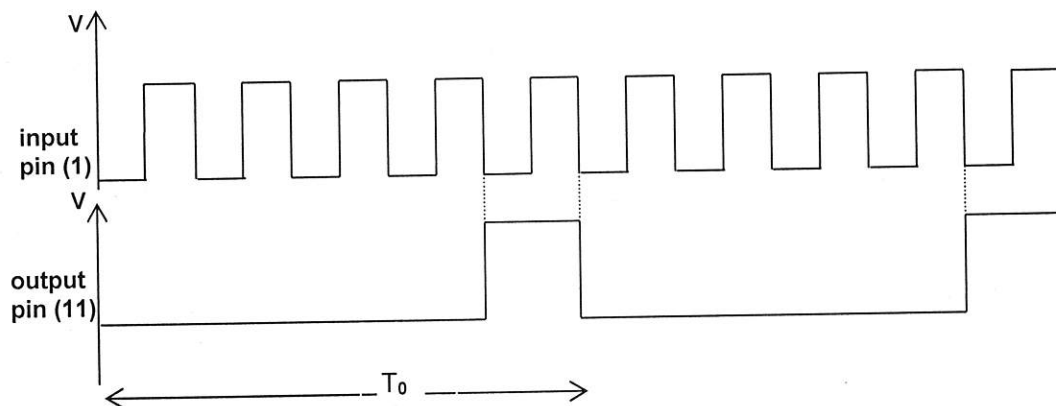
MOD-10
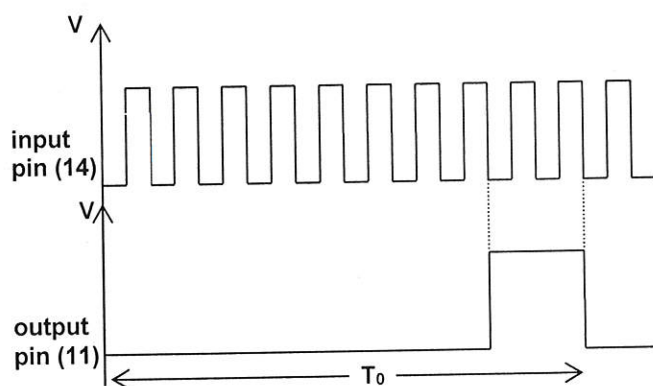
Result : Studied 7490 IC as divide by 2, 5, 10 counter.

(45)

| LM 317 Voltage Regulator |
|---|

Aim   : To study IC- LM 317 as a Voltage Regulator.

Apparatus : IC- LM 317, Bridge rectifier, resistance boxes (0 – 5000 Ω), milliammeter,
              Multimeter, C.R.O. etc.

Theory   : The LM 317 is a three-terminal positive voltage regulator that can supply
              1.5 A of load current over an adjustable output voltage range of 1.25 to 37 V.
              The fig. below shows an unregulated d.c. supply driving a LM 317 circuit.
              The output voltage is given as

$$V_o = V_{ref}\left(1 + \frac{R_2}{R_1}\right)$$

Circuit Diagram:
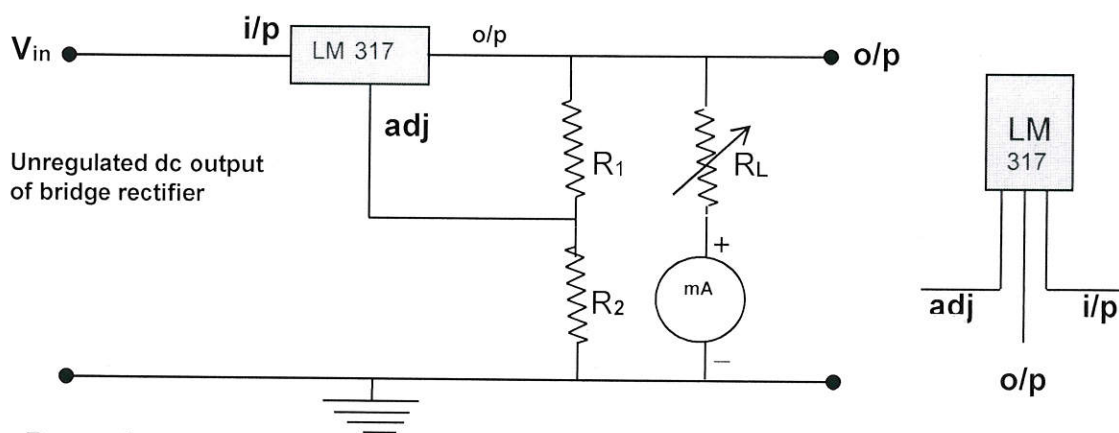
Procedure :

1. Switch ON the unregulated d.c. supply and measure its voltage. Note it as $V_{in} \approx 12$ V.
2. Connect the circuit as shown in the circuit diagram. Keeping the load resistance R_L at
   infinity, measure V_{ref} which is the voltage between the output terminal and the
   adjustable pin when the adjustable pin is grounded (i.e. keep $R_2 = 0$ Ω) . $V_{ref} \approx 1.25$ V.

3. $R_1 = \dfrac{V_{ref}}{I_{min}}$,   consider V_{ref} = 1.25 V and I_{min} = 50 x I_{adj} = 50 x 100 μA = 5 mA.

   Hence, **R_1 = 250 Ω. R_2** is a variable resistor connected between the adjustable pin and
   reference ground. *For further calculation, take V_{ref} as the measured value.*

4. Design a regulated voltage source using the equation $V_o = V_{ref}\left(1 + \dfrac{R_2}{R_1}\right)$ so that its output

   voltage V_o is less than V_{in} – 3 V say, from $V_{o(min)}$ = 4 .0 V to $V_{o(max)}$ = 7.0 V

$$\therefore R_{2(max)} = \frac{V_{0(max)} - V_{ref}}{I_{min}}   ;   R_{2(min)} = \frac{V_{0(min)} - V_{ref}}{I_{min}}$$

[46]

5. Keep R_L at infinity so that no current passes through the load resistance. Keep $R_2 = R_{2(min)}$ and measure the output voltage. Check whether it tallies with the designed value of $V_{o(min)}$. Keep $R_2 = R_{2(max)}$ and measure the output voltage. Check whether it tallies with the designed value of $V_{o(max)}$.

6. Now choose a value of $V_o = 5.5$ V, (between $V_{o(min)}$ and $V_{o(max)}$). Calculate R_2 , using

   the formula , $R_2 = \dfrac{V_o - V_{ref}}{I_{min}}$ or $V_o = V_{ref}\left(1+\dfrac{R_2}{R_1}\right)$

7. Determine the range of R_L, so that the load current I_L changes from $I_{L(min)} = 200$ mA to $I_{L(max)} = 300$ mA. Using the formula obtain $R_{L(max)}$ and $R_{L(min)}$

   $$R_{L(min)} = \frac{V_o}{I_{L(max)}} \qquad ; \qquad R_{L(max)} = \frac{V_o}{I_{L(min)}}$$

8. Keeping R_2 at the value obtained in step 6, change R_L from $R_{L(min)}$ to $R_{L(max)}$ in proper steps and note the corresponding value of load I_L and the output voltage V_L. Take at least six readings.

9. Plot a graph of V_L against I_L.

   The degree to which a power supply varies in output voltage under conditions of load variations is measured by the voltage regulation, which is usually expressed as a percentage. Determine the % load regulation, using the formula:

   $$\% \; load \; regulation = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

   V_{NL} : output voltage , keeping R_L at infinity *(when no load current passes through the load)*

   V_{FL} : output voltage , keeping R_L at $R_{L(min)}$ *(when full load current passes through the load)*

10. Measure peak to peak value of the input unregulated voltage $V_{ir(p-p)}$ using a C.R.O. at full load current i.e keeping R_L at $R_{L(min)}$.

11. Calculate the output ripple for an assumed ripple rejection of 90 dB , using the formula

   $$90 = 20 \log \frac{V_{ir(p-p)}}{V_{or(p-p)}}$$

Note : Do not trace the unregulated input.

Observations:

1) V_{in} = ... V

2) V_{ref} = ... V

3) Designed $V_{o(min)}$ =   4.0 V , $V_{o(max)}$ = 7.0 V

   Measured $V_{o(min)}$ = ...V , $V_{o(max)}$ = ... V

4) R_1 = 250 Ω and R_2 = ...Ω

5) Calculated $R_{L(min)}$ = ...Ω

   $R_{L(max)}$ = ...Ω

Obs. no.	R_L	I_L	V_L
	Ω	mA	V
1			
2			
3			
4			
5			
6			

Graph :
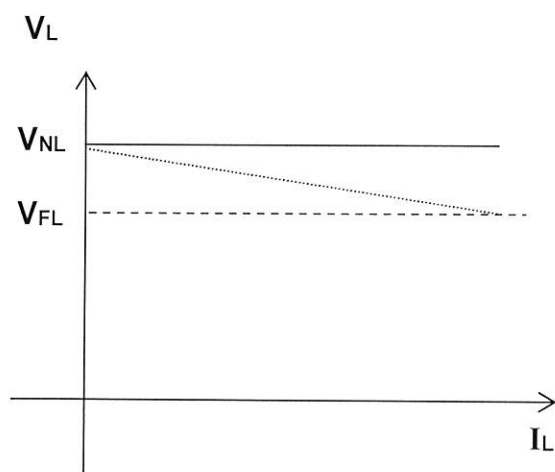
Result :   **Studied the use of LM 317 as a voltage regulator.**

% load regulation = ...%

LM 317 : Current Regulator

Aim   : To study LM 317 regulator as a variable current source.

Apparatus   : IC - LM 317, bridge rectifier, digital d.c. current meter (200 mA), resistance boxes etc.
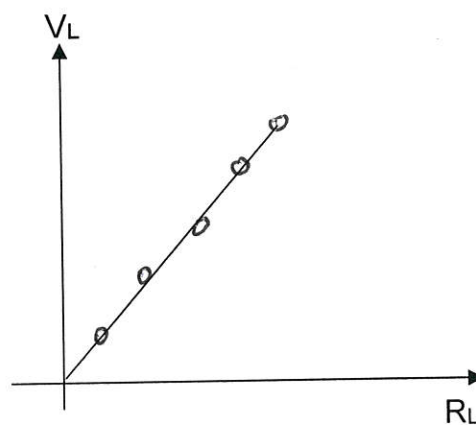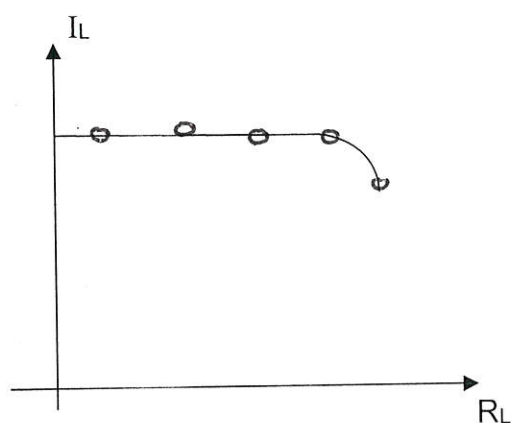
Circuit Diagram:
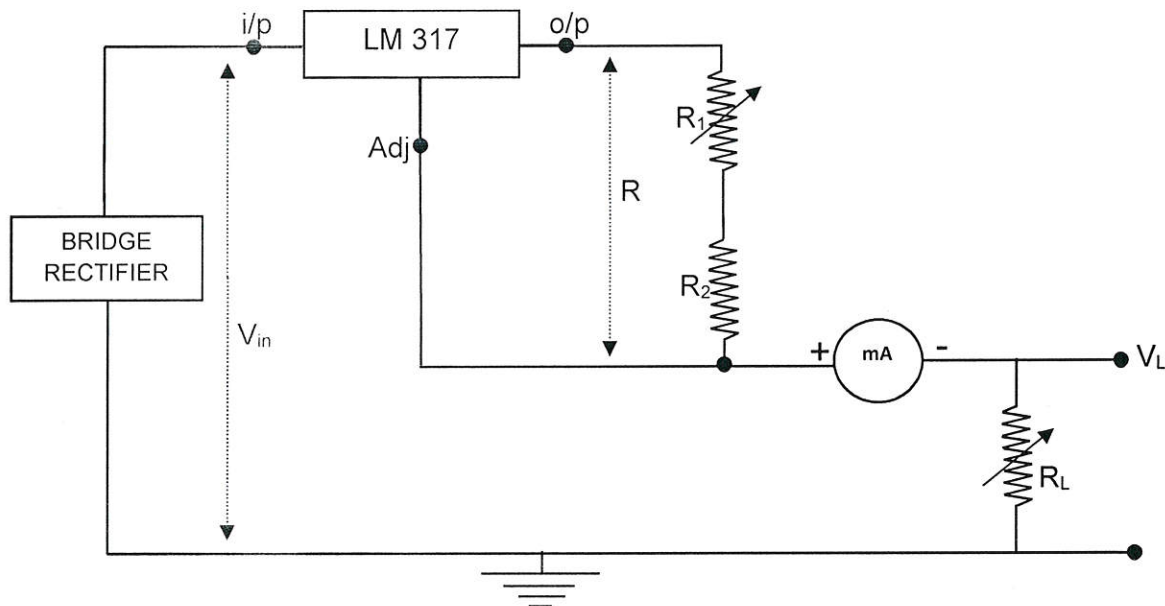
Procedure:

1. Connect the circuit as shown in the diagram.

2. Check the reference voltage, V_{ref} between the output (o/p) and adjust (Adj.) pin keeping $R_L = 0 \ \Omega$

3. Design a variable current source capable of sourcing a continuous current from , say, $(I_o)_{min} = 25$ mA to $(I_o)_{max} = 100$ mA. For this, use the equation $(I_o) = V_{ref} / R$ Thus calculate R_{max} and R_{min} for corresponding $(I_o)_{min}$ and $(I_o)_{max}$ respectively.   Note that **R** consists of resistance box R_1 with a fixed resistance R_2 in series.

4. Switch on the voltage source. Adjust the resistance values R_1 such that the current shows the designed minimum and maximum values. (Note: $R = R_1 + R_2$)

5. Select a suitable value of I_o (say, about 50 mA) by adjusting the value of R_1.

6. Increase R_L in suitable steps and record I_L and V_L for each R_L. Increase R_L till the current I_L reduces by a small amount (say, 0.5 mA)

7. Repeat step 6 for a different value of I_o (say, 75 mA)

8. Plot I_L against R_L and V_L against R_L graphs.

9. Hence determine the maximum value of R_L up to which the circuit functions as a constant current source.

Observations:

1. V_{in} = _____ V

2. R_2 = _____ Ω

3. V_{ref} = _____ V

4. $I_{L(min)}$ = _____ mA, $I_{L(max)}$ = _____ mA

5. $R_{(max)}$ = _____ Ω, $R_{(min)}$ = _____ Ω

6. For I_0 = _____ mA

Obs. No.	R_L	I_L	V_L
	Ω	mA	V

Graph:

Result : The given circuit works as a constant current source up to :

(i) R_L = _____ Ω for I_L = _____ mA

(ii) R_L = _____ Ω for I_L = _____ mA

| Thermistor Characteristics |

PART- A

ELECTRICAL CHARACTERISTICS

Aim   : To study the electrical characteristics of the given thermistor.

Apparatus   : Thermistor (470 Ω), d. c. power supply (0-30 V), resistor (47 Ω ,5 W),
                      digital voltmeter (0 – 20 V), digital milliammeter (0 – 200 mA), etc.

Circuit diagram :
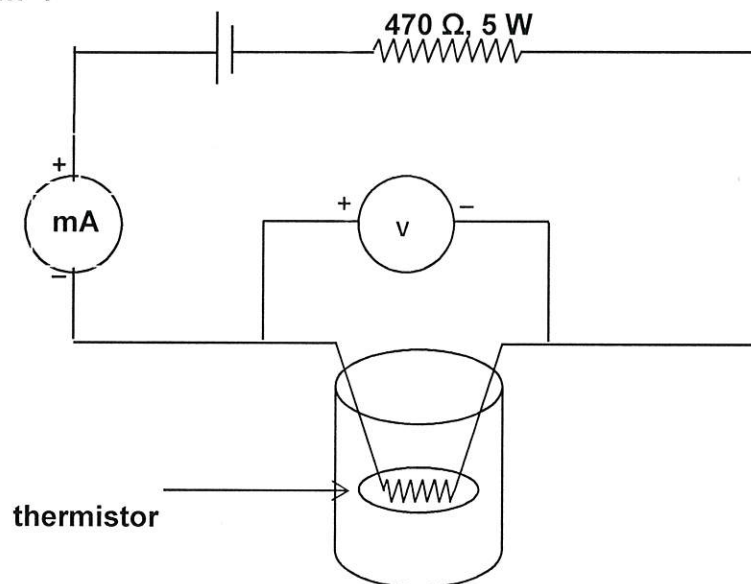
Procedure :

1. Connect the circuit as shown in the circuit diagram.

2. Place the thermistor in a dry test tube.

3. By adjusting the d. c. voltage source in quick succession, set circuit current **I** to 10 mA, 20 mA, 30 mA, 40 mA, 50 mA and 60 mA, and note down the thermistor voltage **V** for each value of current.

4. Without further increasing the source voltage, measure thermistor current **I** and voltage **V** until the steady state is reached (voltmeter and current reading becomes constant).

5. Plot a graph of **V** against **I**. Select any point in the negative resistance region and determine the resistance. Later from the thermal characteristics curve [fig(ii)], determine the temperature of the thermistor at that value of resistance .

Observations :

Current I	Voltage V
mA	V
10 mA	
20 mA	
.	
.	
60 mA	

Self heating mode

Graph :

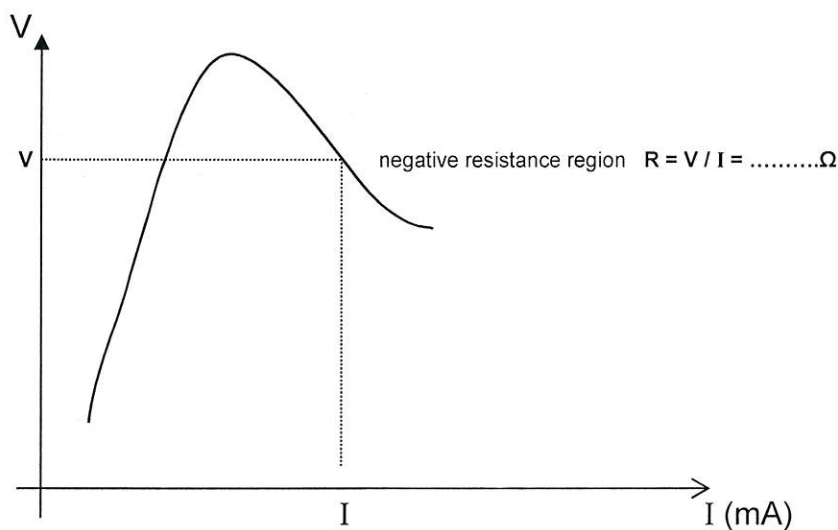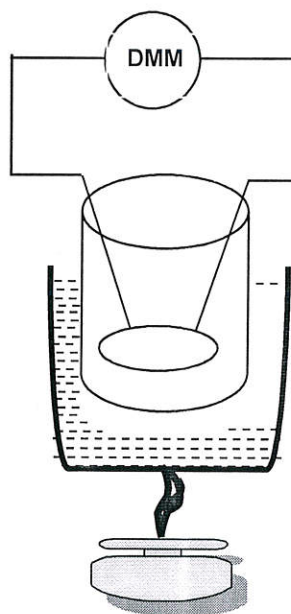negative resistance region   R = V / I = ...Ω

fig (i)

PART – B

THERMAL CHARACTERISTICS

Aim　　　　: To study the electrical characteristics of the given thermistor.

Apparatus : Digital ohmmeter, Thermistor, thermometer, test tube, beaker containing water, burner, etc.

Circuit diagram :

Formula :

$$\alpha = \frac{1}{R_T}\frac{dR_T}{dT} \quad and \quad R_T = R_0 e^{b\left[\frac{1}{T}-\frac{1}{T_0}\right]}$$

b : thermistor material constant

α : temperature coefficient of resistance

R_0 : resistance at 0 ^{0}C or 273 K

Procedure :

1. Arrange the set up as shown in the diagram. Tie the bulb of the thermometer to the thermistor and place it in a dry test tube. Connect a digital ohmmeter across the thermistor to measure its resistance R_T at room temperature.

2. Heat the thermistor in steps of 5 ^{0}C up to 60 ^{0}C and measure the corresponding resistance R_T.

3. Plot graph of resistance R_T against absolute temperature **T** of the thermistor.

4. Find the slope at temperature 315 K and using the formula, calculate α.

5. Plot also a graph of ln R_T against **1/T**. From the graph determine :
   a) the resistance R_0 (that is the resistance at 0 ^{0}C or 273 K)
   b) b (thermistor material constant)

Observations :

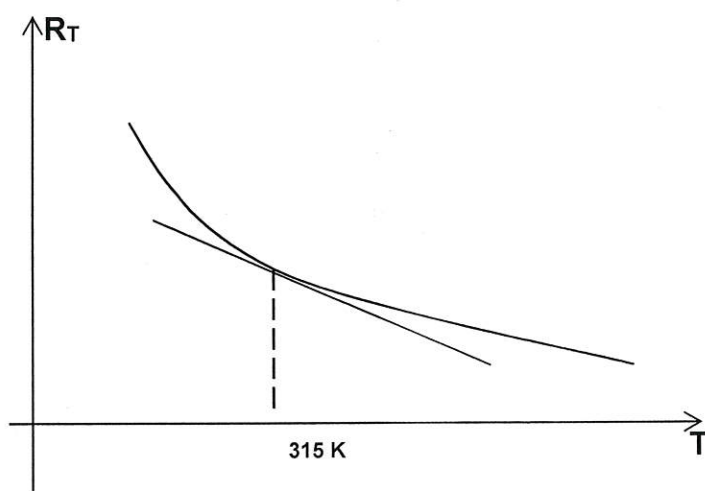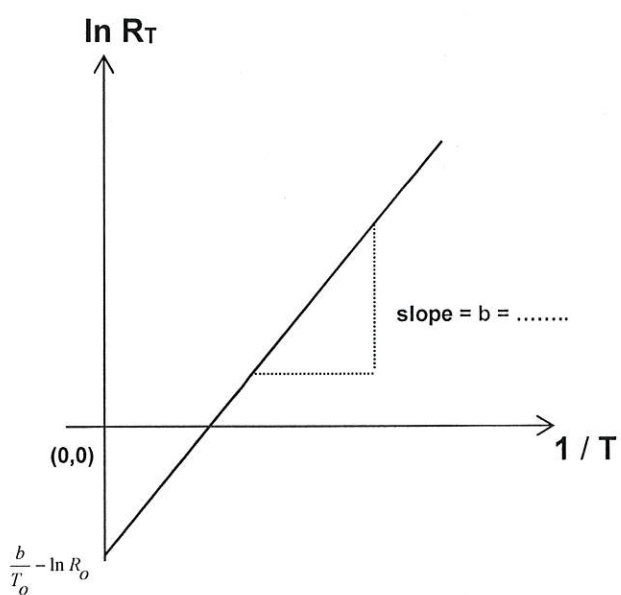| Temperature		Resistance	ln R_T	1 / T
θ	T	R_T		
^{0}C	K	Ω		K^{-1}

Graphs :

fig (ii)

fig (iii)

Calculations :

$$R_T = R_0 e^{b\left[\frac{1}{T} - \frac{1}{T_0}\right]}$$

Simplifying and rearranging, we get, $\ln R_T = b\left(\frac{1}{T}\right) - \left[\frac{b}{T_o} - \ln R_o\right]$

This equation is similar to the equation of a straight line : y = mx + c

Thus plotting a graph of $\ln R_T$ on y-axis and $\frac{1}{T}$ on the x-axis, will give a straight line

with slope = b and an intercept on the y –axis   as $\left[\frac{b}{T_o} - \ln R_o\right]$.

$| \text{intercept} | = \frac{b}{T_o} - \ln R_o$

On simplifying and rearranging, we get,

(i) R_0 = antiln ($\frac{slope}{T_0} - | \text{intercept} |$)

R_0 = ... Ω

(ii) $\alpha = \frac{1}{R_T} \frac{dR_T}{dT}$ and $R_T = R_0 e^{b\left[\frac{1}{T} - \frac{1}{T_0}\right]}$

Result :   1) Temperature of the thermistor at a point in the negative resistance region
T = ... K

2) Resistance of the thermistor at 273 K ,   **R₀** = ... Ω.

3) Thermistor material constant,   **b** = ...

4) Temperature coefficient of resistance   **α** = ... /°C

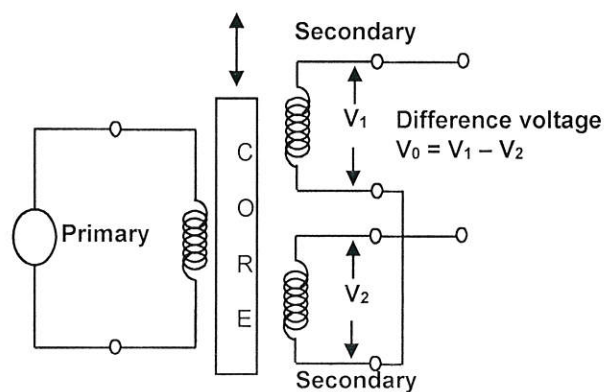## Linear Variable Differential Transducer

Aim   : To study a Linear Variable Differential Transducer (LVDT).

Apparatus : LVDT kit, patch cords, dual trace CRO

Diagram   :
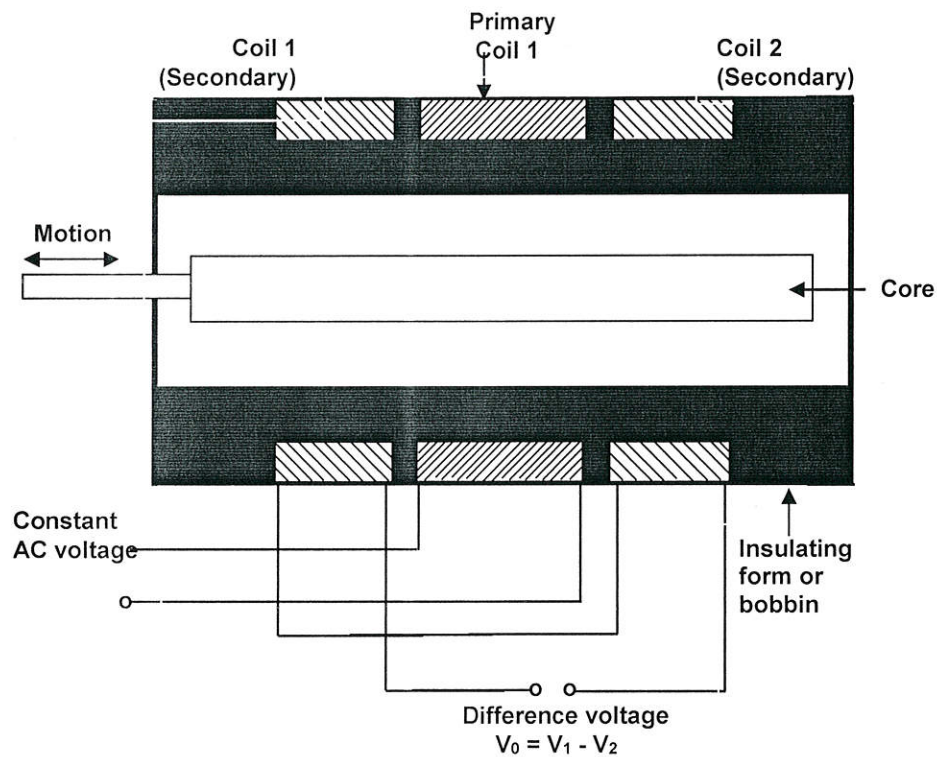
(a)
Sectional view

(b)
Circuit diagram

(56)

Procedure :

1. Connect the LVDT kit to the mains and switch it on.

2. Observe the output of the sine wave oscillator on the first channel of dual trace CRO and adjust the output so as to get maximum peak -to- peak voltage without distortion.
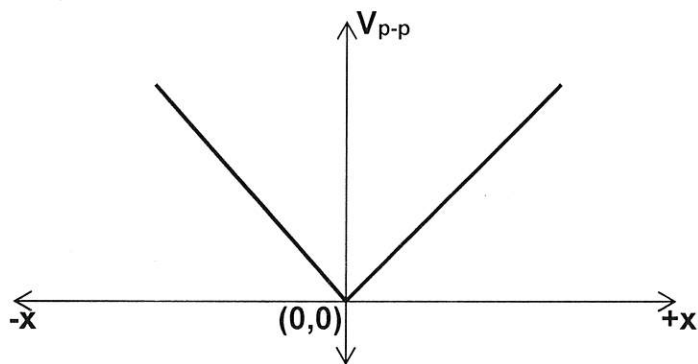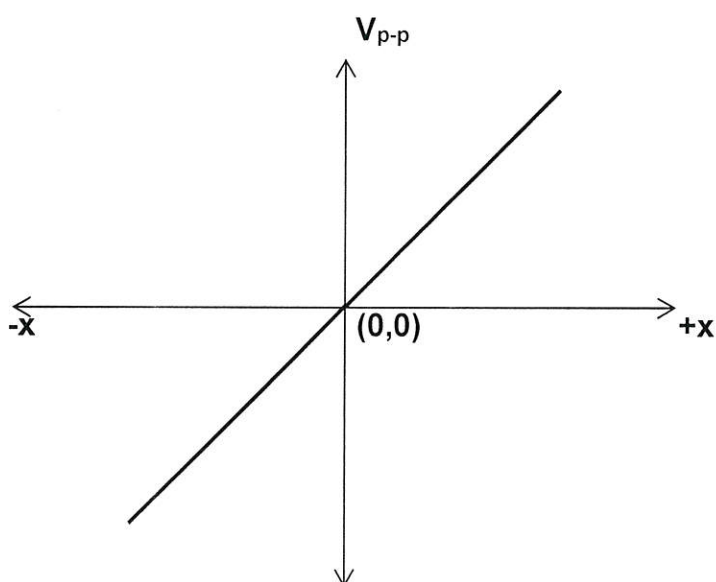
Part – A

AC characteristics

1. Connect the output signal to the input of the LVDT transducer primary and short the secondary terminals using the patch cords (as shown by the dotted lines on the kit).

2. Observe the output of LVDT (between terminals marked C and A on the kit). Bring the marker on the LVDT shaft on 10 mm position and measure the amplitude of the output waveform.

3. Take similar readings by shifting the marker by 1 mm from 10 mm to -10 mm. Notice the change of phase by 180^0 when marker crosses 0.

4. Plot a graph of peak -to- peak voltage V_{p-p} vs. the marker position x.

PART – B

DC characteristics

1. Keeping the connection in Part A intact, connect the output of the LVDT to the rectifier circuit (A to A, B to B and C to C on the kit).

2. Connect the output of the rectifier to the digital display. Bring the marker on the LVDT shaft on 10 mm position and adjust the knob on the rectifier circuit to show some suitable voltage (say 50) in millivolt.

3. Take the readings on the digital display by moving the marker by 1 mm from 10 mm to –10 mm.

4. Plot the graph of this DC voltage V_{dc} vs. the marker position x.

Observations :

Sr. No.	Marker position	AC	DC
		peak-to-peak voltage	reading on the display
	(mm)	V	mV
1.	10		
2.	9		
11.	0		
20.	-9		
21	-10		

Graph:

AC characteristics

DC characteristics

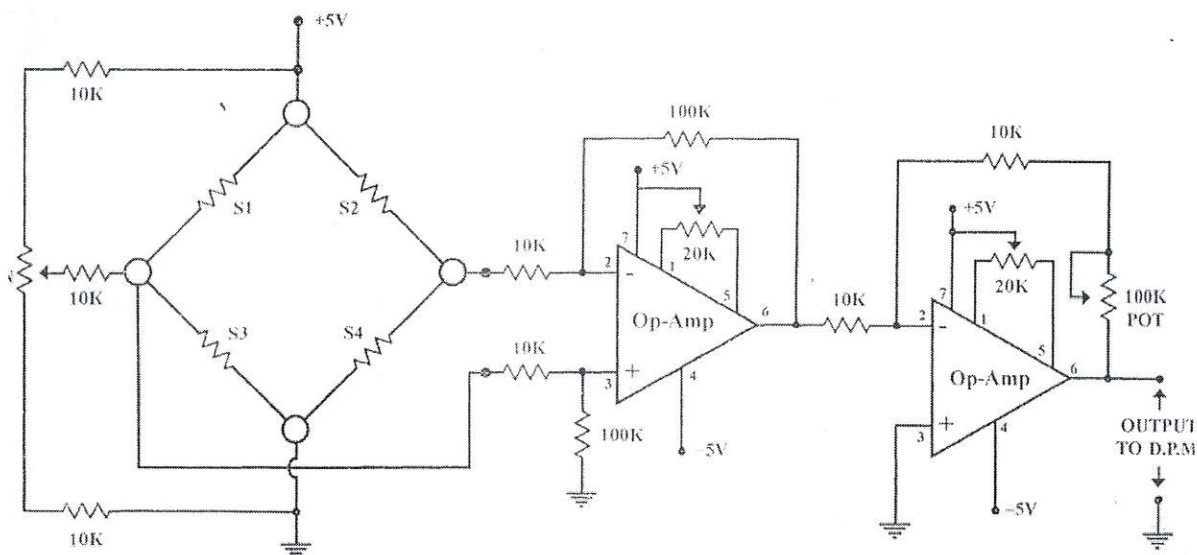**Result :** The AC and DC characteristics of LVDT were studied and its linearity was verified.

<div style="border:1px solid black; text-align:center;">

Study of Load Cell / Strain Gauge

</div>

Aim   : To study the characteristics of the strain gauge.

Apparatus   : Load cell kit, DMM, different weights.

Circuit diagram :

Theory :

A load cell transducer converts mechanical pressure into corresponding electrical signal. The electrical output of a load cell has very good linear response. A load cell comprises of 4 strain guages connected in a Wheatstone bridge . Two of these four strain guages are bonded to a cantilever type metallic stand (S1 and S2) and other two are for temperature compensation. The differential voltage generated (in microvolts) is then amplified and calibrated by two stages using Op-Amps.

Procedure:

1. Switch on the kit and connect the load cell to the socket marked for it.
2. Complete the bridge connection by connecting a wire at J1.
3. Connect the output of the bridge to the input of the first amplifier.
4. Connect the DMM in millivolts range at the output of the first Op-Amp.
5. Connect the output of the second amplifier to the digital display (DPM) on the panel.
6. Adjust the Zero Adj. potentiaometer to get zero indication on the D. P. M. of the panel.
7. Now put different weights and observe the output on the digital display of the panel.
8. Plot the graph of the output voltage vs load.

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Observation Table:

| Sr. No.	Load in Kg.	Output in millivolts	Reading on the display

Result : Studied the characteristics of the strain gauge.

Thermistor As a sensor in temperature to voltage convertor using OP AMP

PART- A

THERMAL CHARACTERISTICS

Aim   : To study thermistor as a temperature to voltage converter .

Apparatus : Thermistor (10 kΩ) , d. c. power supply (0-30 V), resistors, digital voltmeter, digital multimeter etc.
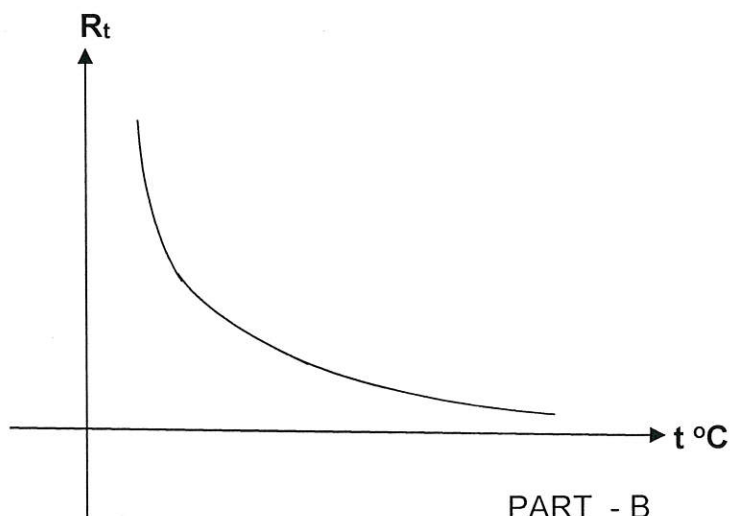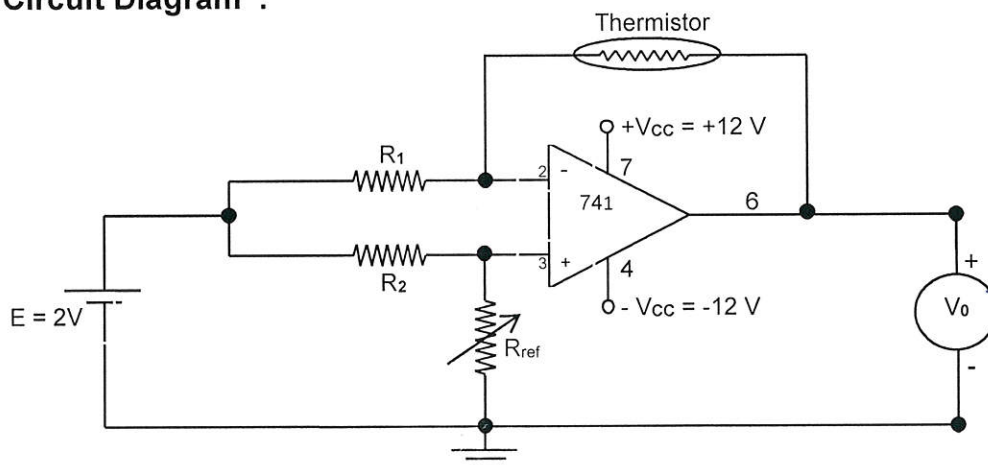
Circuit diagram :
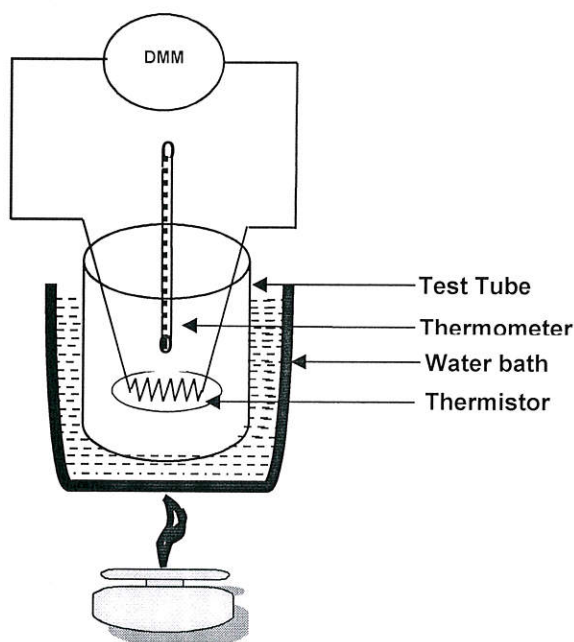
Procedure :

1. Arrange the set up as shown in the diagram. Tie the bulb of the thermometer to the thermistor and place it in a dry test tube. Connect a digital ohmmeter across the thermistor to measure its resistance R_t at room temperature.

2. Heat the thermistor in steps of 5 ^{0}C up to 60 ^{0}C and measure the corresponding resistance R_t.

3. Plot graph of resistance R_t against temperature **t** of the thermistor.

Observations :

Temperature t	Resistance R_t	ΔR_t
^{0}C	kΩ	kΩ
Room temp. 35	R_0	
40	R_1	$|R_1 - R_0|$
45	R_2	$|R_2 - R_0|$
50	R_3	$|R_3 - R_0|$
55	R_4	$|R_4 - R_0|$
	R_5	$|R_5 - R_0|$

Graph:

PART - B

Temperature to voltage convertor

Circuit Diagram :

Procedure:

1. Connect the circuit as shown in the figure.

2. Keep **E** = 2.0 V and **V_{cc}** = 12 V.

3. Keeping the thermistor at room temperature and adjust **R_{ref}** (pot.) to make the output voltage **V_o** equal to zero. Measure R_{ref} (by keeping R_{ref} open).

4. Raise the temperature of the thermistor in the same steps as in part (A) and record the output voltage in each case.
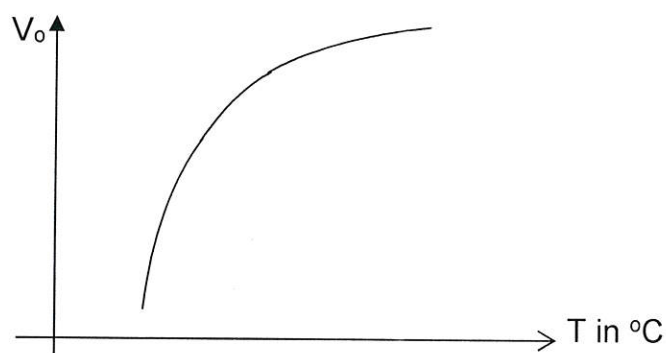
5. Compare the output voltage with calculated voltage.

$$V_{o(cal.)} = |\, I\, \Delta R\,| \qquad , \qquad I = \frac{E}{R_1 + R_{ref}}$$

6. Plot a graph of V_o against temperature t.

Observations :

$$E = 2.0 \text{ V}, \; R_{ref} = \; \ldots\ldots\ldots k\Omega, \; R_1 = \; \ldots\ldots\Omega$$

Temperature t	Output Voltage V_{o(measured)}	Output Voltage V_{o(calculation)}
°C	V	V
Room temp.= ….		
35		
40		
45		
50		
55		

Graph :

Result : The given thermistor was used as a sensor in temperature to voltage converter using OP AMP.
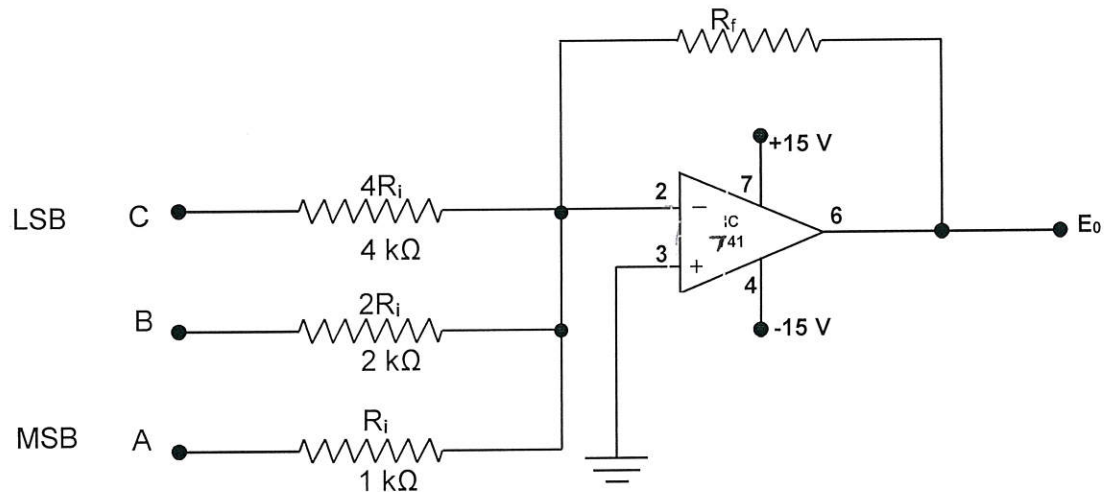
OP AMP as Digital to Analog converter
Binary Weighted Resistor network

Aim   : To study 3 bit digital input, digital to analog converter using OP AMP with binary weighted resistor network.

Apparatus : Breadboard, resistances, d. c. power supply (dual), d. c. power supply (0 – 5 V), IC 741, digital multimeter, connecting wires etc.

Circuit diagram :

LSB : Least significant bit   MSB : Most significant bit

Formula :

$$E_0 = -E \left(\frac{R_f}{R_i} \right) \sum_{i=1}^{3} \frac{b_i}{2^{i-1}}$$

b_i is 0 or 1, depending on various input

Calculations : To determine R_f :

To get, E_0 = -7 V, take all b_i = 1 and E = 5 V.

Procedure :

1. Using logic level 1 as 5.0 V and logic level 0 as 0 V, calculate the feedback resistor R_f required so as to limit the maximum output voltage (when all the input data bit are logical 1) to -7 V.

2. Construct the circuit on a breadboard.

3. Switch on the power supply and measure the output voltage for all possible input combinations ranging from 000 to 111.

4. Compare the output voltage with the expected ones.

(64)

Observations :

Digital Input			Decimal Conversion	Analog Output	
A	B	C		Measured V_0	Calculated V_0
				V	V
0	0	0	0		
0	0	1	1		
0	1	0	2		
0	1	1	3		
1	0	0	4		
1	0	1	5		
1	1	0	6		
1	1	1	7		

Result : Using binary weighted resistor and a 741 OP AMP, a 3-bit digital to analog converter has been studied.

Positive and Negative Clipper using OPAMP

Aim   : To study positive and negative cliper circuit using OP AMP.

Apparatus   : IC 741, diode, 10 kΩ resistance, signal generator, dual power
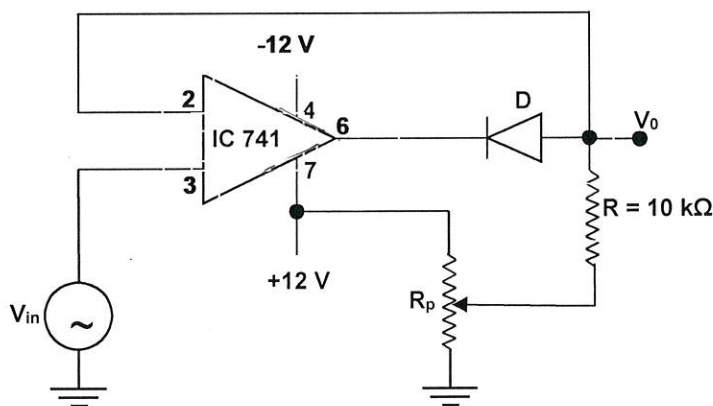supply (0 -10 V), C. R. O., bread board, wires, etc.
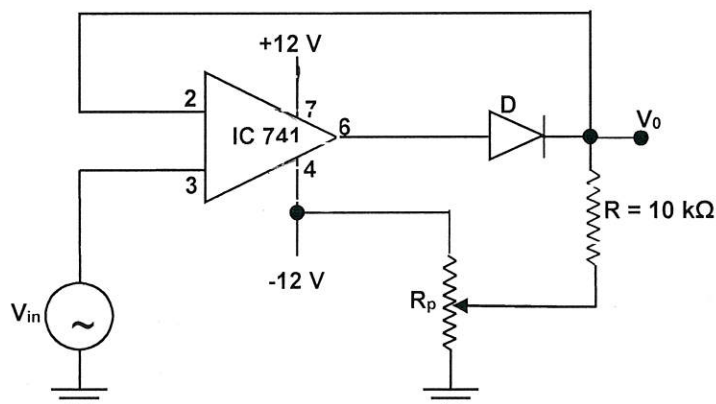
Circuit Diagram :

fig. (i)

fig. (i)

Procedure :

1. Connect the circuit of positive clipper as shown in fig(i) on the bread
Board. (use colour conventions of the wires)

2. Switch on the power supply and signal generator. Keep input
frequency of the sine wave as 5 kHz. Adjust the amplitude of the input
sine wave to get a perfect sinusoidal wave.

3. Observe both input and output waveforms on the C.R.O.

4. Adjust the pot R_p to get the output clipped to a certain V_{ref} voltage.

(66)

5. Trace both input and out waveforms.

6. Repeat step 3 for another V_{ref} voltage and trace only output waveform.

7. Now connect the circuit for negative clipper as shown in fig.(ii) and repeat step 2 to 6.

Waveforms :

Positive Clipper :
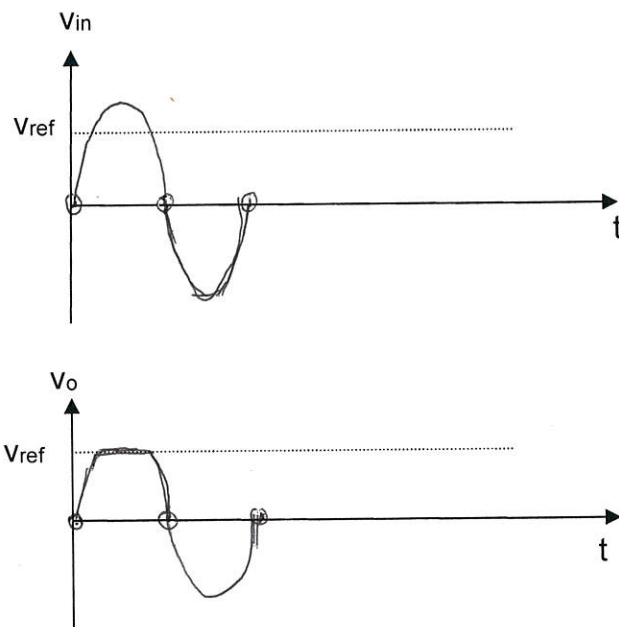
Negative Clipper:
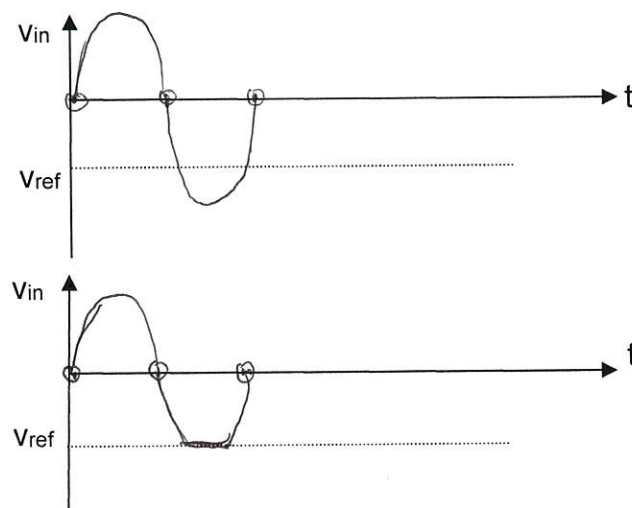
Result : Studied positive clipper and negative clipper circuits using OP AMP.

Active Notch Filter

Aim   : To study frequency response of an active notch filter circuit and hence determine the notch frequency.
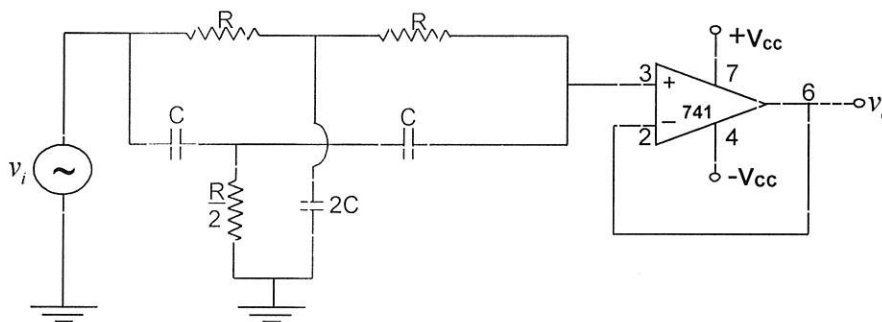
Apparatus : Bread board, IC 741, signal generator, 12 volt dual power supply, DMM, components of given value.

Formula   : Notch frequency

$$f_N = \frac{1}{2\pi\, RC}$$

(designed cut off frequency f_N = _____ Hz)

Circuit Diagram :

$$C = 0.01\ \mu F,\ 2C = 0.022\ \mu F,\ R = \ldots\ldots\ldots\ldots\Omega,\ R / 2 = \ldots\ldots\ldots\ldots\Omega$$

Procedure :

1. Design the filter circuit. Given the value of notch cut off frequency **f_N** and the capacitor C = 0.01 µF, Calculate the value of resistor **R**.

2. Build the above circuit, with suitable components on a bread board.

3. Switch on the power supply, signal generator and dual trace CRO.

4. Set the frequency of the sine wave input signal to **f_N / 10**.

5. Adjust the i/p voltage v_i = 2.0 V (AC) and measure the corresponding v_0.

6. Keeping the input signal voltage v_i at 2 V , change the frequency **f** of the input sine wave in suitable steps up to 10 f_N and note the corresponding output voltage, v_0 of the filter, using DMM.

7. Plot the graph of v_0 against **f**. Hence determine the notch frequency **f_N** and compare it with the expected values.

8. Connect channel I of the CRO to the input and channel II of the CRO to the output of the circuit. Keep the knob of the both channels at ground position. Make the two lines coincide with one another. Now change knobs from ground to a.c. Measure **t** and **T** as shown in the diagram, for f < f_N (f = f / 2), f = f_N and for f > f_N (i. e. f = 2 f_N).

9. Calculate the phase shift using the formula $\theta = \dfrac{t}{T} \times 360^0$.

10. Comment whether the o/p leads or lags behind the i/p.
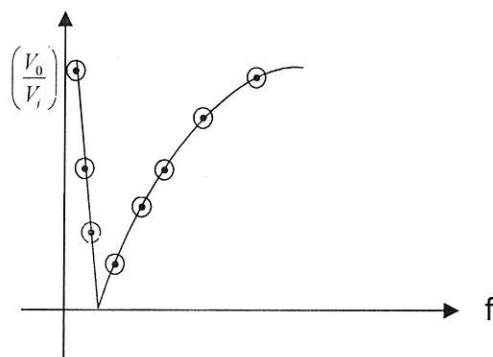
Phase Shift

Input Waveform

Output Waveform
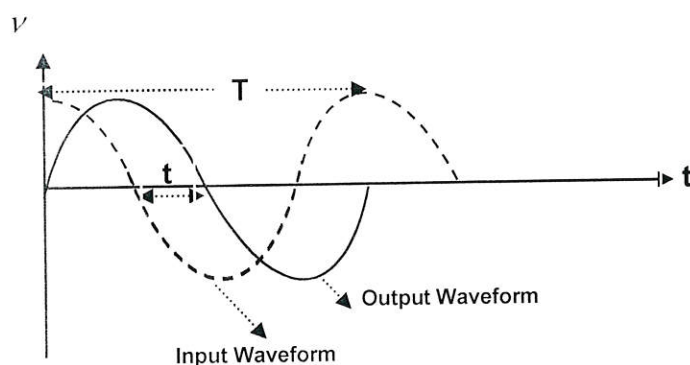
Observation Table : 1

v_i = 2.0 V

Frequency f	Output voltage v_0	$Gain = \left(\dfrac{v_0}{v_i} \right)$
Hz	V	

Observation Table : 2

f	t	T	θ
Hz	s	s	degree
f < f_N			
f = f_N			
f > f_N			

Graph :

Result : Notch filter is studied.

Notch frequency f_N (designed) = _____ Hz.
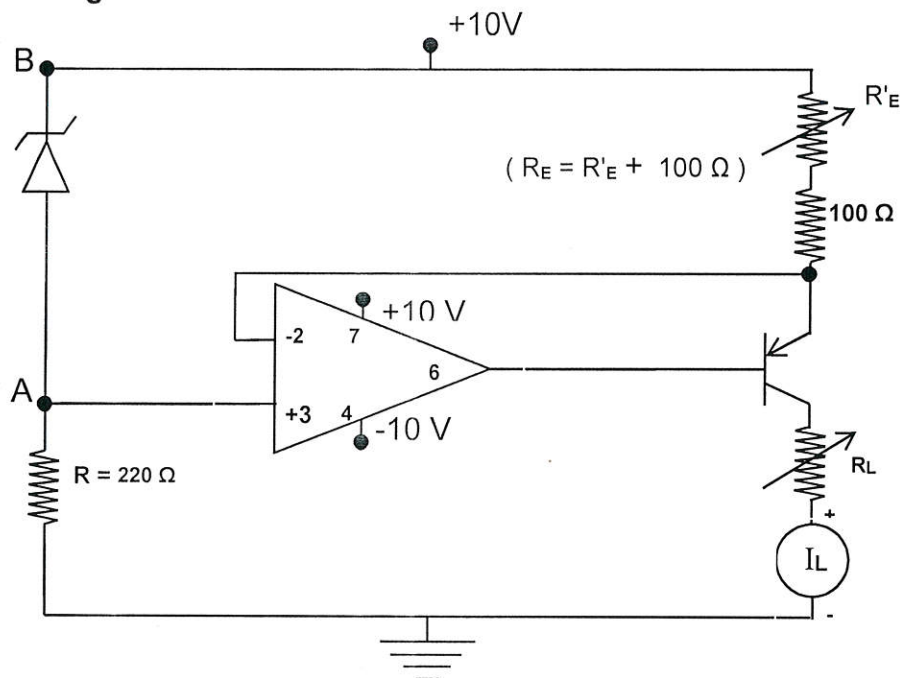
Notch frequency f_N (Graphical) = _____ Hz.

Constant current source using OP AMP and PNP transistor

Aim   : To study constant current source built using OP AMP and PNP transistor.

Apparatus   : OP AMP 741, zener diode (5.6 V), PNP transistor, DMM, dual supply (0 – 15 V), resistance boxes.
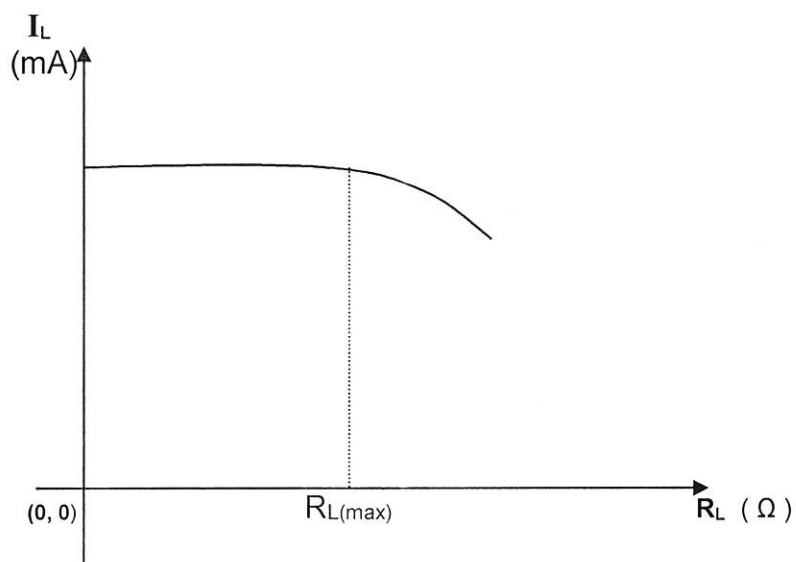
Circuit Diagram :
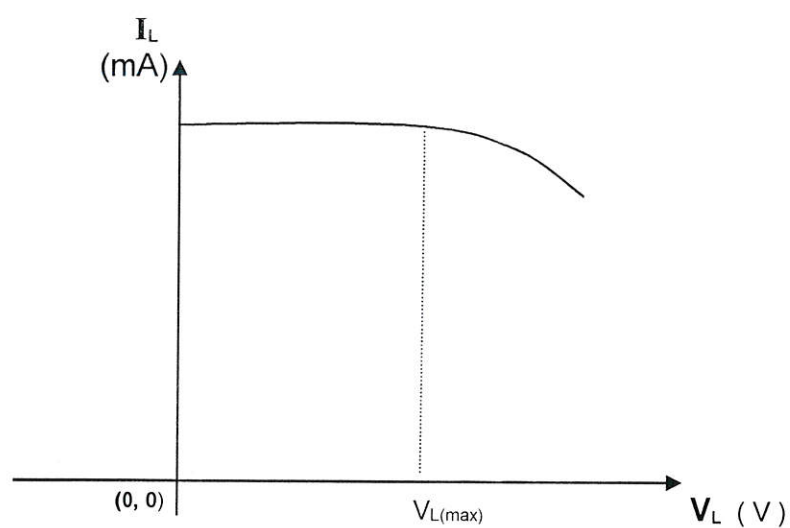

Procedure :

1. Trace the given circuit and make the required connections.

2. Switch ON the supply. Measure voltage (**Vz)** across the zener diode between A and B.

3. Using the formula $I_L = \dfrac{V_z}{R_E}$, calculate R_E to set I_L = 10 mA.

4. Introduce **R'$_E$** = ……….. Ω, such that   **R$_E$ = R'$_E$ + 100 Ω.**

5. Change **R$_L$** from zero upto a value for which current **I$_L$** decreases by 0.1 mA. Hence get the range of **R$_L$** (Load resistance) for which the current **I$_L$** remains constant.

6. For each **R$_L$** value also note the corresponding voltage **V$_L$** across **R$_L$** using DMM.

7. Plot a graph of **I$_L$** versus **R$_L$** and **I$_L$** versus **V$_L$**.

8. From the graph find the maximum voltage **V$_{L(max)}$** and maximum resistance **R$_{L(max)}$** upto which current remains constant.

9. Repeat step 3 to 8 for another value of **I$_L$** = 15 mA.

Observation Table :

$$V_z = ... V, \qquad I_L = ...mA$$

R_L	I_L	V_L
Ω	mA	V

Graph :

I_L
(mA)

(0, 0)

$V_{L(max)}$

V_L (V)

Result:

	I_L =……… mA	I_L =…….. mA
$V_{L\ (max)}$	………V	……….V
$R_{L\ (max)}$	……….Ω	……….Ω

Procedure :

1. Draw the circuit diagram of a second order active low pass filter.
2. Let $C_2 = C_3 = C = 0.001\mu f$ and $R_2 = R_3 = R = 17k\Omega$. Calculate the cutoff frequency (f_c) of the filter.
3. Design the circuit for voltage gain of $A_v = 1.586$ by taking $R_1 = 10 k\Omega$ and $R_f = 5.6 k\Omega$.
4. Connect the circuit on the bread board and study its frequency response over the frequency range of $f_c / 10$ to $10 f_c$. Take 20 readings by changing frequency in suitable steps, keeping input voltage constant ($V_i = 1.5$ volts).
5. Plot the graph of V_0 versus by log f_{in}. Determine the cutoff frequency from graph and compare it with expected value.
6. Using the dual trace CRO determine the time lag between V_0 and V_i at
   (i) $f_{in} << f_c$ (ii) $f_{in} = f_c$ and   (iii) $f_{in} >> f_c$
   Calculate the phase shift θ^0
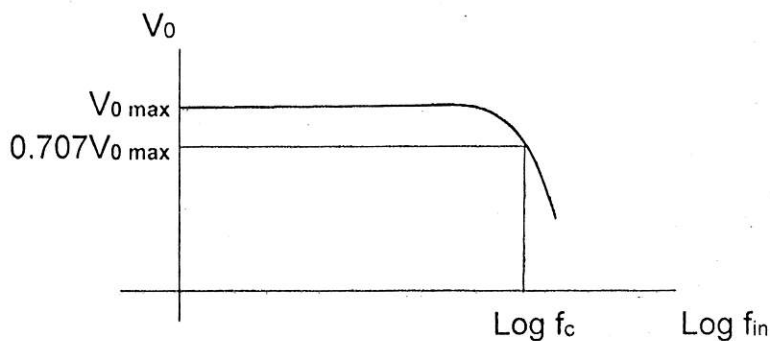
Observation Table:

$R_1 =$ _____ , $R_2 =$ _____ , $R_3 =$ _____ , $R_f =$ _____

$C_2 =$ _____ , $C_3 =$ _____ , $f_c =$ _____ , $V_1 =$ _____

Frequency response Table

Obs. No.	Frequency $F_{in}(H_z)$	Output Voltage V_0 (volts)	Log f_{in}
1			
.			
.			
.			
20			

Phase Lag Table

Obs. No.	Frequency $F_{in}(H_z)$	Time Lag $t(s)$	Phase shift θ^0
1			
2			
3			

Result : a) Cut-off frequency f_c (calculated) = _____ H_z

b) Cut-off frequency f_c (from graph) = _____ H_z

c) Phase shift at f_c, $\theta =$ _____ degrees.