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FACULTY OF SCIENCES

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GENERAL INFORMATION

1. You are expected to carry out all the experiments only. Only ten (10) experiments will be assessed.
2. It is expected that you plan your practical work before carrying out the experiment.
3. The experiments may be carried out individually or in groups.
4. In the event of being absent in any of the fixed practical period, try as much as possible to have another period fixed for you by the instructor.
5. You should ensure that the result generated at the end of the experiment is endorsed by the instructor before leaving the laboratory.
6. The practical work when completed should be submitted to the instructor within the number of days given to you by the instructor. Failure to submit your report at the appropriate day as required by the instructor attracts some loss of marks.
7. Practical work report not submitted at all should be awarded zero (0) mark.

GUIDELINES FOR ASSESSING THE EXPERIMENTS

The areas of the practical work report to be assessed are as follows

1. Procedure or Method: This should be assessed based on observing the student carryout the actual practical as well as the description of the method in the practical work.
2. Observation and Measurements: This should be assessed based on the followings
 - a. Relevant observation without assistance.
 - b. Readings recorded to reasonable accuracy.
 - c. Have good distribution of readings.
 - d. Present derived data to appropriate significant figures.
 - e. Form composite table with correct symbols and units correctly.
3. Processing and Analysis of Data: This should include
 - a. Choosing suitable graph for the data.
 - b. Choosing suitable scales on the graph for the data.
 - c. Plotting points correctly.
 - d. Drawing the best line of fit.
 - e. Calculate the slope correctly.
 - f. Stating the calculated slope with correct significant figure as well as the units.
 - g. Reading intercept on the graph correctly.
 - h. Make correct deduction from the graph.
4. Results: This should be assessed under the following.
 - a. Obtain the physical relations of the results from the slope or intercept calculated.
 - b. Draw the conclusions consistent with the analyzed data.
 - c. State appropriate precautionary measures taken during the experiment.
 - d. State appropriate sources of errors.

- e. State useful comments.
5. General Comments
- a. Completion and submission of the practical work report on time.
 - b. Done the required number of experiments by the instructor.
 - c. Used good language in reporting the experiments.
 - d. Shown good moral behavior.

The marks awarded to each of the above vital assessment areas is left at the discretion of the course lecturer.

EXPERIMENT 1

- (a) Determination of magnification produced by a convex lens through the variation of the distance of the image from the lens (b). Determination of the focal length of the lens graphically

Aim: (a) To determine the magnification produced by a convex lens through the variation of the distance of the image from the lens. (b) To determine the focal length of a lens graphically

Apparatus: Convex lens and holder: illuminated object consisting of three vertical slits, 10mm, 15mm and 20mm in length, cut in stiff cardboard and illuminated by an electric light bulb placed close behind image screen of stiff white cardboard.

Method First find the appropriate focal length of the lens by the usual method of focusing the image of the window panes on a sheet of paper.
Put the lens at rather more than its focal distance from the illuminated object.
Adjust the position of the image screen until the images of the three object slits for the image of the illuminated scale appear most clearly in focus. Selecting the image whose size can be most conventionally and accurately measured (dividers are useful here) measure the size of the image.
Record the corresponding size of the object. Measure also the image and object distances from the lens.
Gradually increase the distance of the object from the lens and take further sets of readings

Remember that in the experiment, as in nearly all other graphical problems in optics, one set of readings is in reality *two* sets, yielding two different points on the graph. Thus, v, u, m , represent the image distance, the object distance and the magnification, then $u, v, \frac{1}{m}$ are also values of image distance, object distance and magnification respectively. It is for this reason that a space for u has been allotted in the table of results

Tabulate the readings as shown in the table below:

Distance of image from lens v/cm	Distance of object from lens u/cm	Size of image h/cm	Size of object h_0/cm	Magnification $\frac{h}{h_0} = m$

Plot a graph with values of m on the vertical axis v on the horizontal axis.

Theory

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\therefore \frac{v}{u} + 1 = \frac{v}{f}$$

Putting $\frac{v}{u} = m$ we then have $m = \frac{v}{f} - 1$ 1

Thus, the graph of m against v is a straight line whose slope, obtained from two well-separated points on the graph, is numerically equal to $\frac{1}{f}$

It is interesting to note that this method of measuring f does not depend on the accuracy of any measurement involving the optical centre of the lens.

By writing $v + \varepsilon$ (where ε is an error in measurements, supposed constant) for, equation (1) above becomes

$$m = \frac{v + \varepsilon}{u} - 1$$

$$\text{i.e.} \quad m = \frac{v}{u} - \left(1 - \frac{\varepsilon}{f}\right)$$

which still yields a straight line slope $\frac{1}{f}/cm$

Alternative methods of deducing the focal length from the graph are:

- (a) To read off the value of v corresponding to $m = 1$. Half of this is the numerical value of f .
This follows from the fact that $m = 1$ when $v = u = 2f$.
- (b) To measure the intercept made by the straight line graph on the v axis. When $m = 0$, $v = f$.
Hence, this intercept is numerically equal to f .

It should be clear that both of these methods depend for their deduction of f on a particular value of v and they have not the advantage of calculation of f from the slope of the graph.

Errors and accuracy

Besides the usual errors in reading the scale positions of object, image and lens, and also in judging the position of maximum sharpness of the image on the screen, there are also the errors measuring the lengths of the small object and its image.

From the graph estimate the likely error in f from the difference between the slope of the chosen best straight line and the slopes of other possible straight lines drawn through the points.

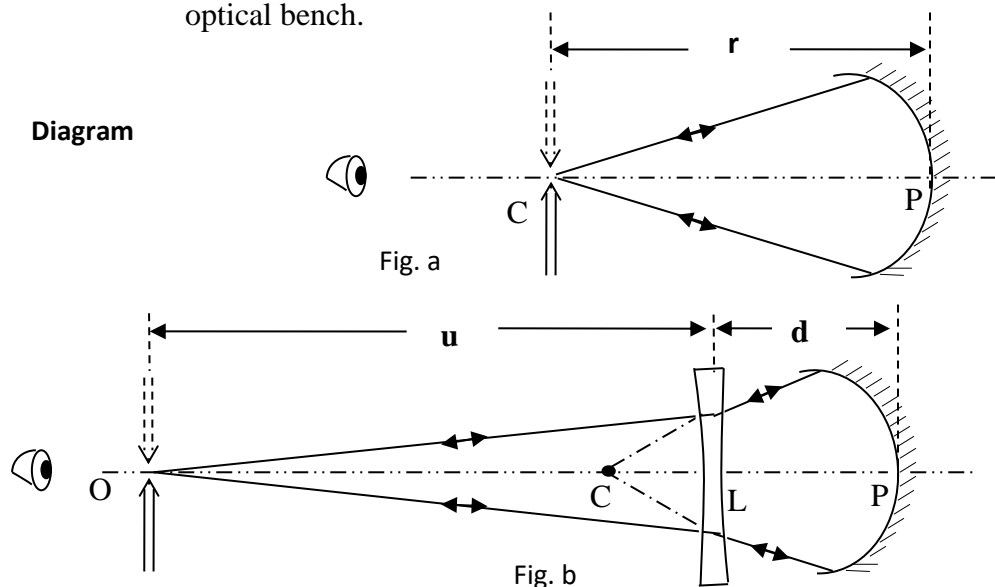
EXPERIMENT 2

Determination of the focal length of a concave lens using a concave mirror

Aim: To determine the focal length of a concave lens using a concave mirror

Apparatus Concave lens and holder, concave mirror and holder, mounted pin, metre rule or optical bench.

Diagram



Method

Find the radius of curvature r of the concave mirror by the simple method of finding the position of the mounted pin so that it coincides with its own image in the mirror as in fig. a above.

Measure the distance CP of the pin from the mirror. Repeat the observations and obtain a mean value for r the first column in the table of results.

Insert the concave lens between the pin and the mirror and quite close to the pin. Move the pin farther away from the lens until it again coincides with its own image as in fig. b above.

Measure the distance u of the pin from the lens and the distance d between the lens and the mirror.

Calculate the focal length f from the equation $\frac{1}{f} = \frac{1}{u} - \frac{1}{r-d}$

Moving the lens towards the mirror by about 2 cm each time, obtain several sets of readings of u and d .

Tabulate the readings:

CP/cm	u/cm	d/cm	$(r - d)/cm$	f/cm from
Mean (r/cm)				Mean (f/cm)

Experimental details

When the lens L is increased between C and P, it is no use inserting it in such a position that its distance CL from C is greater than its focal length. Any difficulty in locating the position O where object and image coincide will probably be due to the fact that this distance CL is too great, hence the advisability of starting with the lens quite near C .

Theory and calculation

Referring to the fig. b, if rays from O finally return to O , then, after leaving the lens, they must strike the mirror normally. That is, the virtual image formed by the lens must be at the centre of curvature C of the mirror.

For the concave lens and with the usual notation,

$$\frac{1}{u} + \frac{1}{v} - \frac{1}{f}$$

But $r = -(r - d)$ since the image at C is virtual

Hence,

$$\frac{1}{u} - \frac{1}{r-d} = \frac{1}{f}$$

From which f may be calculated.

Errors and accuracy

Errors occur in reading the scale positions of the mirror, lens and pin and in judging the position of no parallax.

From the variation in the values obtained for f in the final column of the table estimate the likely error in f and state your result accordingly.

EXPERIMENT 3

Determination of the focal length of a concave lens using a convex lens

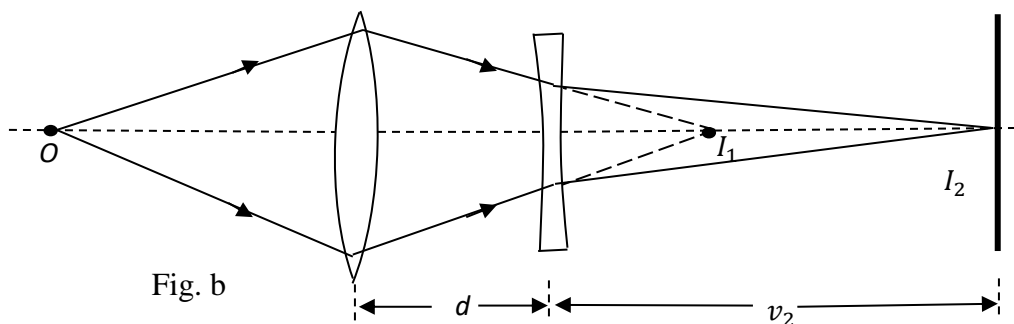
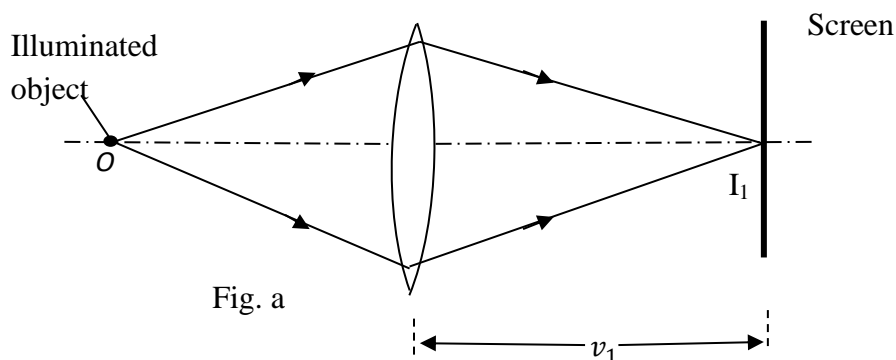
Aim: The focal length of a concave lens using a convex lens

Apparatus: Concave lens and holder, convex lens and holder, plane mirror, two mounted pins, metre rule or optical bench, illuminated object and screen.

Part A: This method can only be used if the convex lens is stronger than the concave lens. Find the focal length f_1 of the convex lens by the plane mirror method of experiment 1. Combine the two lenses together by placing them in the same lens holder and find the focal length of the convex combination by the same method. Deduce the focal length f_2 of the concave lens from

$$\frac{1}{F} + \frac{1}{f_1} = \frac{1}{f_2}$$

Part B: Although this experiment may be performed using a mounted pin as the object and another to locate the image, it is much quicker to employ an illuminated object and screen.



Place the screen about 40cm from the convex lens and adjust the position of the illuminated object O until a sharply focused image I_1 is seen on the screen (fig. a). Measure the image distance v_1 from screen to lens.

Insert the concave lens between the convex lens and the screen and fairly near the screen. Move the screen farther away (fig. b) until the image I_2 is again sharply focused on the screen. Measure the distance v_2 of the new image from the concave lens and also the distance d between the lenses.

Moving the illuminated object to a slightly different position each time obtain several further sets of readings for v_1 , v_2 and d .

Tabulate the readings:

v_1/cm	v_2/cm	d/cm	$(v_1 - d)/cm$	Focal length of concave lens f/cm from $\frac{1}{f} = \frac{1}{v_2} - \frac{1}{v_1 - d}$
				Mean

Experimental details

1. The second real image I_2 (i.e. after the insertion of the concave lens) will only be formed if the distance between the concave lens and the first position of the image I_1 , is less than the focal length of the concave lens. If, therefore, the second real image I_2 cannot be located, the concave lens must be moved nearer to the first position of the image pin I_1
2. Adjust the distance d so that I_2 is sufficiently removed from I_1 , to give reliable readings.

Theory and calculation

For the concave lens and with usual notation

$$\frac{1}{f} = \frac{1}{u} - \frac{1}{v}$$

Now I_2 is the real image of the virtual object I_1 $\therefore u = -(v_1 - d)$

and $v = v_2$

$$\therefore \frac{1}{f} = \frac{1}{-(v_1 - d)} + \frac{1}{v_2} \text{ or } \frac{1}{f} = \frac{1}{v_2} + \frac{1}{v_1 - d}$$

Errors and accuracy

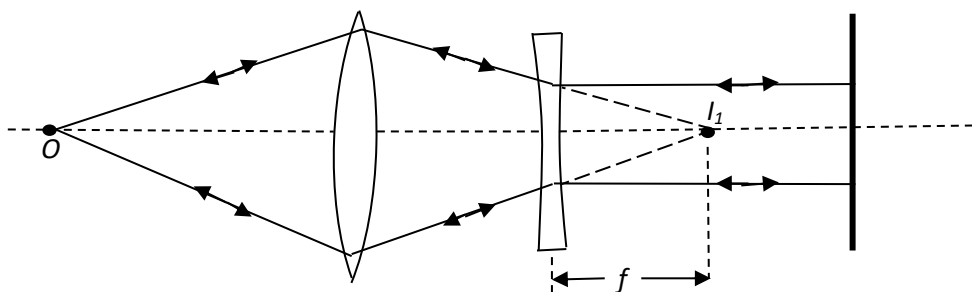
Errors are due to reading the positions of the lenses and the screen and in judging the position of maximum sharpness of the image on the screen.

From the variations in the values obtained for f in the final column of the table estimate the likely error in f and state your result accordingly.

Part C

Part B may be adapted to measure the focal length of the concave lens (diverging lens) directly.

If the concave lens (diverging lens) is placed at a distance from I_1 equal to its focal length, the rays of light after leaving the lens will be parallel to the principal axis. If, therefore, they fall normally on to a plane mirror they will be turned back and, after re-traversing their original paths, they will combine to form a real image coincident with the object at O .



When this is obtained the distance of the first image I_1 from the concave lens must be the focal length of the concave lens.

Moving the illuminated object to a slightly different position each time, obtain several measurements for f and take the mean.

Experimental details

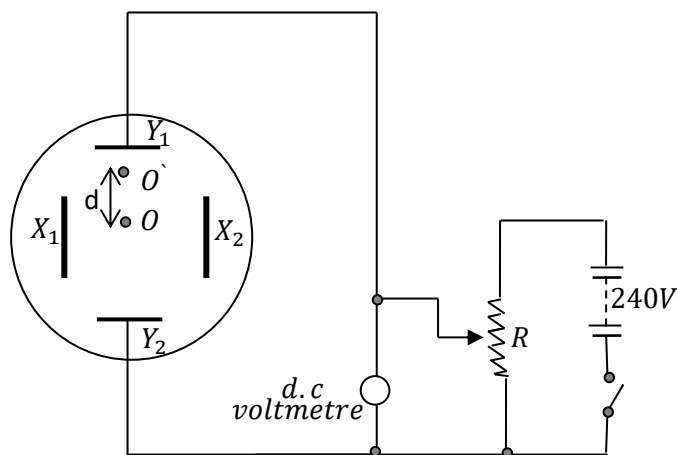
The plane mirror in the diagram is placed at a fairly large distance (exceeding f) from the concave lens so that the diagram may show clearly what is happening. In the actual experiment, the plane mirror may be placed immediately behind the concave lens and the two moved about together.

EXPERIMENT 4

Measurement of d.c. voltages

Aim: To measure the d.c voltage using cathode ray oscilloscope

Diagram:



Method: Switch off cathode ray oscilloscope (C.R.O.) time-base to obtain a stationary spot of light on the screen. In this and all experiments where deflection of the C.R.O. spot is measured, turn down the brightness control until the actual movement of the measurement has arrived. Then turn the brightness up, make measurement and reduce the brightness.

For a given setting of the Y sensitivity control (the Y-amplifier) apply suitable d.c. voltage to the Y-plates by means of the above circuit (R being 20 - 50k Ω) and measure the corresponding deflection of the spot of light. Plot a graph with values of d/mm on the vertical axis against the corresponding values of applied voltage on the horizontal axis. The straight line observed confirms that the deflection is proportional to the p.d. applied. Calculate the slope of the graph. What is the physical significance of the slope in mm per volt (mmV⁻¹)

Additional experiment

Check the Y-sensitivity control indications by using small input voltages, a voltmeter of smaller range and the next highest Y-sensitivity setting.

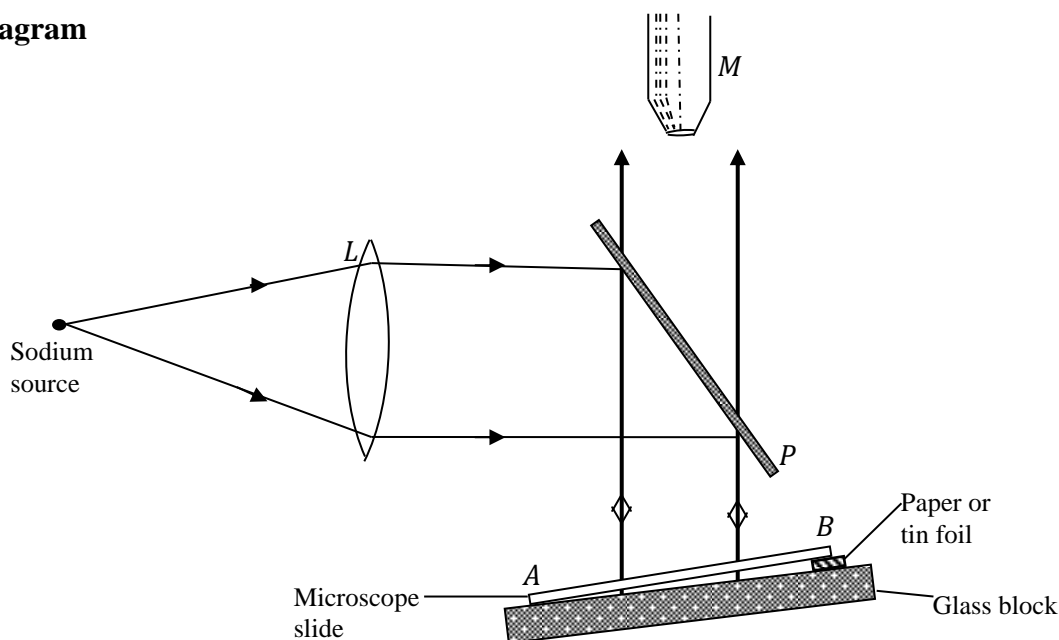
EXPERIMENT 5

Measurement of the thickness of paper or tinfoil by means of interference fringes in an air wedge.

Aim: To measure the thickness of paper or tinfoil by means of interference fringes in an air wedge

Apparatus: Glass block, microscope slide, thin glass plate, sodium burner or flame, travelling microscope, stand and clamp, convex lens and holder, methylated spirit and clean rag.

Diagram



Method

First clean the glass block and microscope slide with methylated spirit and a clean rag. Make an air wedge as shown in the diagram by inserting the piece of paper or tinfoil under one end B of the microscope slide the other end A resting on the glass block.

By means of the glass plate P held in a clamp at 45° to the horizontal shine a parallel beam of monochromatic light, obtained by placing the sodium source at the focus of the convex lens L , vertically down on to air sedge.

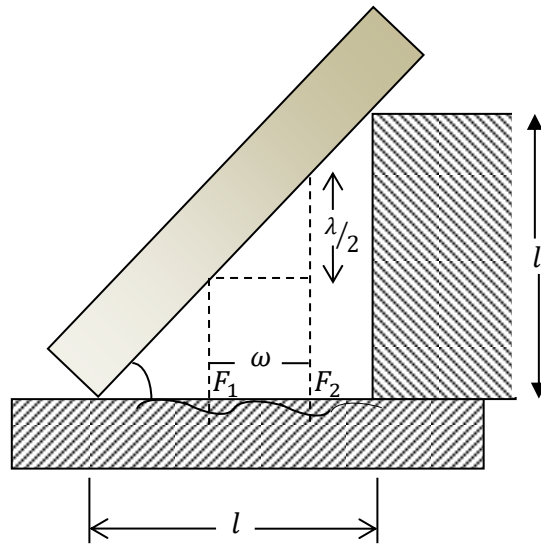
Put the microscope, M immediately above the reflecting plate and focus it on the air wedge when interference fringe should be seen. These should be straight fringes parallel to the line of contact between the slide and the glass block, and the position and tilt of the reflecting plate P should be adjusted until the fringes appear as bright and clear as possible.

Using the horizontal traverse of the microscope adjust the microscope so that its cross-hairs coincides with the centre of a bright (or dark) fringe near A. Read and record the vernier reading d_1 .

Traverse the microscope across a counted number of fringes N and again read and record the vernier reading d_2 . The fringe separation ω is thus $\frac{d_2 - d_1}{N}$

Still using the microscope measure the length L of the air film from the common line of contact A to the inner edge of the paper or foil.

Theory and calculation



The generally exaggerated diagram above shows two adjacent fringes F_2 and F_1 separated by a distance, ω . As the microscope moves from one fringe to the next, the thickness of the air film must increase by $\frac{1}{2}\lambda$ in order that the path difference (twice the thickness of the air film) between reinforcing (or interfering) coherent rays increase by λ .

From the geometry of the diagram

$$\tan \alpha = \frac{\frac{1}{2}\lambda}{\omega} = \frac{t}{l}$$

where t is the thickness of the paper or tin foil.

Hence,

$$t = \frac{\lambda l}{2\omega} = \frac{\lambda l N}{2(d_2 - d_1)}$$

Convert the microscope readings for l and $d_2 - d_1$ to metres

take $\lambda_{\text{sodium}} = 5.89 \times 10^{-7} \text{m}$

Hence t in metres.

Further, if the image α of the air wedge is required, since α is small

$$\therefore \tan \alpha = \alpha = \frac{\frac{1}{2}\lambda}{\omega} = \frac{\lambda l N}{2(d_2 - d_1)}$$

Errors and accuracy

The errors involved are those of setting the cross-hairs on the centre of a bright (or dark) fringe and on the extreme ends of the distance L and in reading the vernier. The error may be estimated by setting the vernier on the same fringe (or end of l) several times and reading the vernier each time. Estimate this likely error ε . The error in both l and $d_2 - d_1$ is 2ε as both are different measurements.

From (1) % error in t = %error in l + % error in $d_2 - d_1$

Evaluate this and state your result for t accordingly.

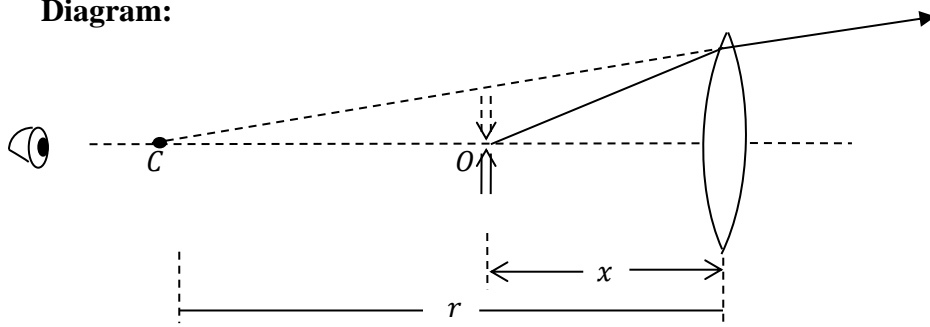
EXPERIMENT 6

Boys' method for the radii of curvature of the surfaces of a convex lens and hence the refractive index of the lens

Aim: To determine the radii of curvature of the surfaces of a convex lens and hence the refractive index of the lens using Boy's method.

Apparatus: Convex lens and holder, mounted pin and plane mirror.

Diagram:



Method

First find the focal length f of the lens by the plane mirror method of experiment 1.

Now place the lens in front of a dark background and the mounted object pin O in front of the lens.

Look from the object side of the lens towards the lens and, especially if the pin is moved backwards and forwards across the field of view, you will be able to discern two faint images. One of these, the stronger one will be erect and behind the lens. It is formed by reflection in the surface of the lens which is acting as a convex mirror. The other image, which may be either inverted or erect, is formed by light which has been internally reflected from the back surface of the lens acting as a concave mirror.

Move the object pin about until it coincides with its images by reflection in the second surface. In this position the image will be real, inverted and of the same size as the object.

Measure the distance x of the object pin from the lens.

Displacing the object pin each time take three or four determinations of x and calculate the mean value.

Calculate the radius of curvature r of this surface from the equation.

$$\frac{1}{x} + \frac{1}{r} = \frac{1}{f}$$

Turn the lens round and repeat to find the radius of curvatures of the other surface.

$$\frac{1}{f} = (n - 1) \left(\frac{1}{r} + \frac{1}{x} \right)$$

Experimental details

When the experiment is first performed it is often difficult to locate the required image formed by reflection in the back surface of the lens, so the following hints might prove useful.

1. First guess the approximate radius of curvature of the back surface and place the object pin nearer to the lens than this.
2. A paper flag on the object pin is often seen by reflection much more clearly than the pin itself. When the required image has been discerned, the final adjustment to coincidence may be made with the flag removed.
3. Whitening the object pin with chalk is also useful.

Note: Floating the lens on a horizontal mercury surface greatly improves the reflecting power of the second surface of the lens and the image required is consequently much more easily found. On the other hand, vertical distances are more difficult to measure than horizontal ones and the method is not recommended.

Theoretical calculation

Let O be position of the object pin when it coincides with its own image by reflection in the back surface. Rays of light, originally starting from O, must be striking normally, for some of this light is reflected back to form an image coincident with the object. A lot of this light pass out through the lens and C, the centre of the back surface, is therefore the virtual image of the object O.

Hence in the lens equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$$u = x \text{ (real and positive)}$$

$$v = r \text{ (virtual and negative)}$$

Since f and u are known $v(r)$ may now be calculated.

Errors and accuracy

Errors occur in measuring the distance x and the focal length f and in judging the position of parallax between object and image.

Estimate the % error δf in f .

The % error in r is unlikely to be less than the sum of these % errors in x and f .

Since n depends on r , x and f , the % error in n is unlikely to be less than the sum of the % errors in r , s and f .

EXPERIMENT 7

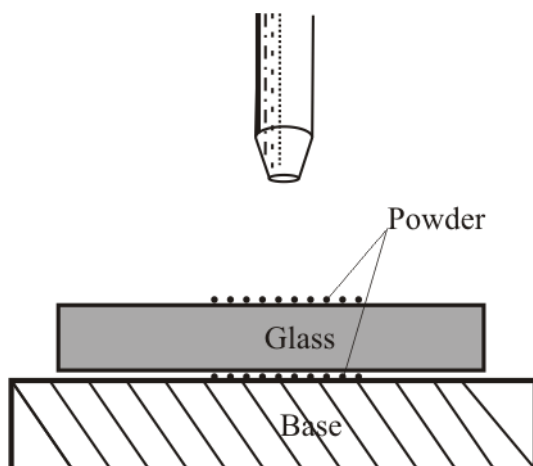
Determination of the refractive index of a glass and liquid by real and apparent depth method using a travelling microscope.

Aim: To determine the refractive index of a glass and liquid by real and apparent depth method using a travelling microscope.

Apparatus: Travelling microscope, two slabs of glass, lycopodium powder, liquid (e.g. water) vessel with a plane base to hold the liquid and some fine sand.

Part A: To measure the refractive index of glass

Diagram



Method: Place one of the glass slabs on the bench to serve as a base and sprinkle some lycopodium on its upper surface

Adjust the cross-hairs of the microscope so that they can be clearly seen without strain. Place the microscope vertically above the lycopodium powder and adjust the length of the instrument until the grains are in sharp focus with no parallax between their image and the cross-hairs. Read the vertical vernier scale of the microscope (d_1).

Place the second glass slab on top of the first one without removing the powder and raise the microscope slowly until the grains are again in focus. Read vernier (d_2).

Sprinkle some lycopodium on the upper surface of the second slab and raise the microscope again until these grains are clearly focused. Read the vernier (d_3).

Turn the upper glass slab on its side and repeat the measurement to obtain a second set of readings:

	Microscope readings			Real depth $d_3 - d_1/\text{mm}$	Apparent depth $d_3 - d_1/\text{mm}$	$\frac{\text{Real depth}}{\text{Apparent depth}}$
	d_1/mm	d_2/mm	d_3/mm			
1st set						
2nd set						
						Mean.....

Part B: To measure the refractive index of water

Method:

Sprinkle some grains of fine sand on the bottom of flat-bottomed vessel and focus the microscope on them. Read vernier scale (d_1)

Pour some water to a depth of about 10mm into the vessel. Raise the microscope until the grains of sand are again in focus. Read vernier scale (d_2)

Sprinkle lycopodium on the water surface. Raise microscope farther still until the lycopodium on the surface is in focus. Read vernier scale (d_3).

Continue the experiment with increasing depths of water and tabulate the readings:

Microscope readings		Real depth $d_3 - d_1/\text{mm}$	Apparent depth $d_3 - d_1/\text{mm}$	$\frac{\text{Real depth}}{\text{Apparent depth}} = n$
d_2/mm	d_3/mm			
				Mean

Experimental details

1. For those who are unfamiliar with the use of the microscope it is suggested that the instrument is first focused on the printed page of an open book placed approximately at the height of the grains of lycopodium which are presently to be focused. By this means the observer becomes familiar with the very small range of travel of the instrument over which the object being focused can be seen

2. When a travelling microscope is used, or any instrument which is moved by means of screw, the last movement of the screw should always be in the direction which moves the instrument forward through the nut of the screw.

3. It will be obvious that the underneath glass slab is merely a rigid base on which to rest the slab whose refractive index is being measured.
4. The actual thickness of the upper slab is measured by the difference between the two vertical positions of the microscope. This method is superior to the use of calipers or micrometer guage as it renders all necessary lengths difference measurements.
5. If the microscope is not provided with an eyepiece with which to read the vernier, use a short-focus convex lens.
6. Finally ground chalk can be used if lycopodium is not available.

Error and accuracy

Any microscope reading is subject to error due to focusing and to error in reading the scale and vernier. The error may be estimated by focusing on the same object several times and reading the vernier each time.

Estimate this likely error ϵ .

Both the real and apparent depths are different measurements and the total error in each is therefore 2ϵ . Express both errors as percentage

$$\left(\frac{2\epsilon}{\text{real depth}} \times \text{and} \frac{2\epsilon}{\text{real depth}} \right)$$

The % error in n is the sum of these % errors.

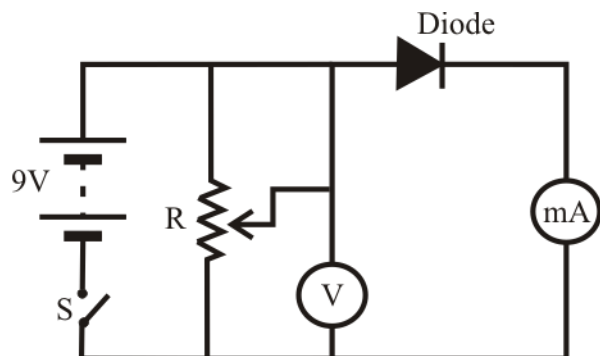
EXPERIMENT 8

Determination of the characteristic of a junction diode

Aim: To determine the forward and reverse bias characteristic of a junction diode

Apparatus: Junction diode (e.g. Mullard OA70 or Mullard AAZ15), 9V dry battery, $2k\Omega$ rheostat R , milliammeter 0-10 mA, circuit key.

Diagram:



Method:

Connect up the circuit as shown in the diagram. Set the slider of the rheostat R so as to give minimum reading on the voltmeter, close S and proceed to measure the circuit in the circuit for increasing applied voltage.

When the current has reached 10mA, reduce the voltage applied to the diode circuit to zero by means of the rheostat and open S . Reverse the connections to the diode. Close S and take further observations as the reversed voltage is increased.

Tabulate the readings:

Forward Bias	Applied voltage V/V						
	Current I/mA						
Reverse Bias	Applied voltage V/V						
	Current I/mA						

Using the same graph plot a graph of values of current on the vertical axis and the corresponding values of applied voltage on the horizontal axis.

Discussions

It will be found that very little current flows until the applied voltage rises above 0.2V after which the current increases rapidly. For reverse applied voltages the current remains at zero. However, if very large reverse voltage are applied (of the order 20-100V) breakdown in the

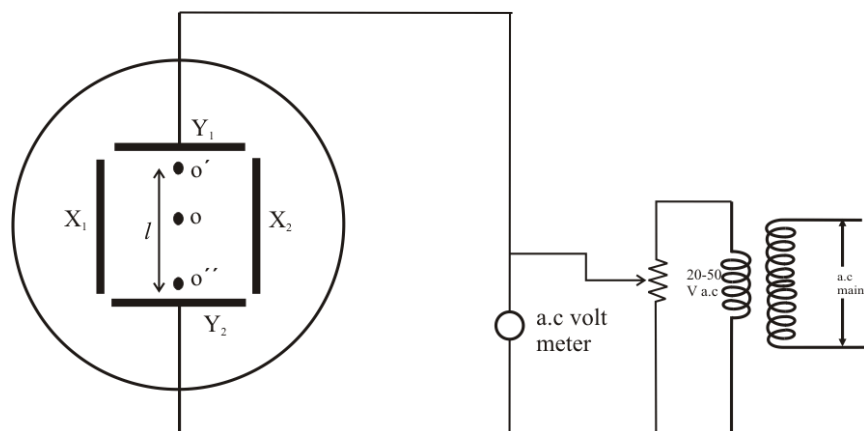
diode occurs and a small reverse current which increases sharply in value occurs (the Zener or avalanche effect). Identify the part of the graph that is forward bias and reverse bias respectively.

EXPERIMENT 9: Measurement of a.c. voltages

Aim: To measure a.c. voltages using Cathode Ray Oscilloscope.

Apparatus: Cathode Ray Oscilloscope (CRO), stepdown transformer, a.c. voltmeter, variable resistor.

Switch off the CRO time-base to obtain a stationary spot of light on the screen.



For a given setting of the Y-sensitivity control apply suitable ac voltages to the Y-plates by means of the above circuit (R being $2.5\text{k}\Omega$) and measure the length l of the vertical line $O'O''$ which is traced out by the spot of light.

Plot a graph with values of $l(\text{mm})$ on the vertical axis against the corresponding values of applied voltages on the horizontal.

Two points to note

1. The deflection OO' or OO'' corresponds to the peak value of the applied voltage, whereas
2. The a.c. voltmeter measures the rms value of the applied voltage

From the graph calculate the deflection sensitivity as the slope in mm per rms volt, which provided the ac supply is truly sinusoidal should be $2\sqrt{2}$ times the result obtained in the previous experiment with dc voltages.

EXPERIMENT 10

Demonstration of the action of a junction diode as (1) a half-wave rectifier (2) a full-wave rectifier.

Aim: To demonstrate the action of a junction diode as (1) a half-wave rectifier (2) a full-wave rectifier.

Apparatus: Four junction diodes, signal generator, dc milliammeter A, $1k\Omega$ rheostat R, cathode ray oscilloscope CRO, three circuit keys.

Diagram:

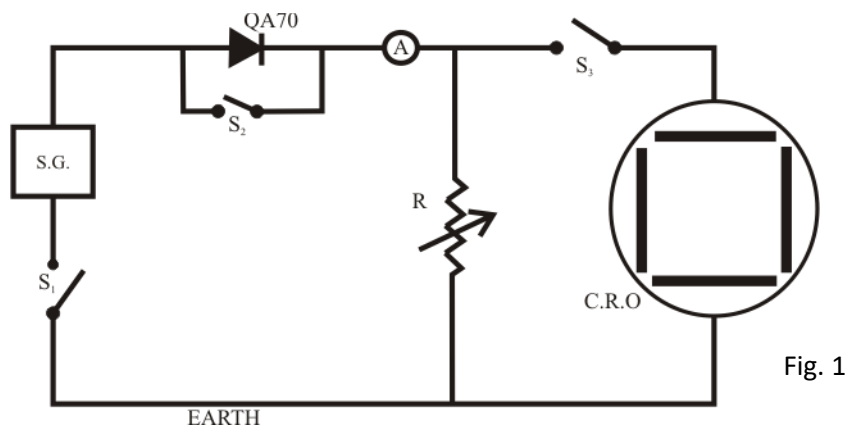


Fig. 1

Part A: Demonstration of half-wave rectification

Connect up one junction diode into the circuit as shown in the figure above.

Set the signal generator to give an output voltage of about 1 V at a frequency of 100 Hz. With S_2 and S_3 open, close S_1 and observe that though the milliammeter A is vibrating (at the frequency of the ac input, 100Hz) it nevertheless indicates that a small steady direct current is passing through the circuit and that rectification has been effected. This is because the junction diode being a one-way device, only allows current to pass through it for a half of each cycle.

Close S_2 thus enabling current to by-pass the diode in either direction. The milliammeter shows no steady deflection, merely a 100Hz vibration of the tip of the pointer about the zero of the scale.

Part B: Demonstration of the rectifying action with the CRO.

1. Select a low speed for the CRO time-base suitable for viewing 100Hz oscillations. With S_1 , S_2 and S_3 all closed, observe the form of the alternating current in the circuit as demonstrated by the waveform of the voltage developed across R (which can of course be varied) fig. 2(a).

2. Now open S2 and examine the new form of the voltage across R and hence the new form of the current in the circuit fig.2 (ii). This is half-wave rectification.
3. Keeping S2 open, connect in turn capacitances of 1, 2, 4 and $8\mu\text{F}$ in parallel with R and examine the effect on the shape of the CRO trace. It will be found that this capacitor C, called a reservoir capacitor, exerts a profound effect on the voltage across R, converting it from the half-wave unidirectional pulsations of fig.2(ii) to the pattern of fig. 2(iii). This is because when the capacitor has been charged during the half-cycle when the diode is conducting. Its charge and therefore its pd only slowly decay at a rate dependent upon the time-constant CR. Before much charge has leaked away the diode is once again allowing current through and the charge on the capacitor is thus replenished.

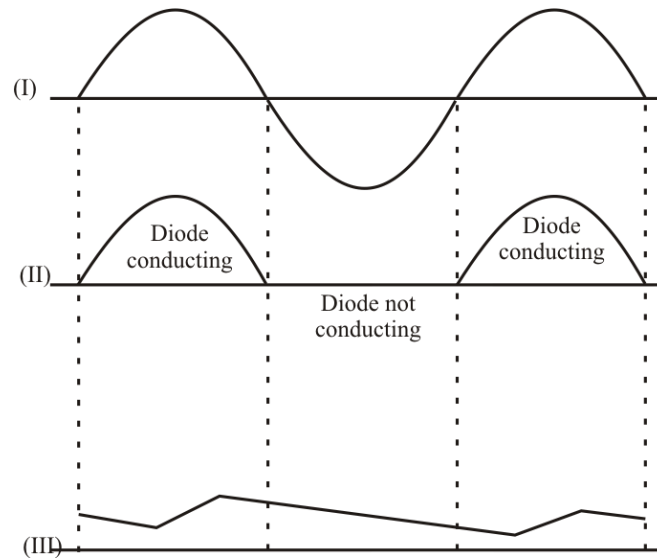


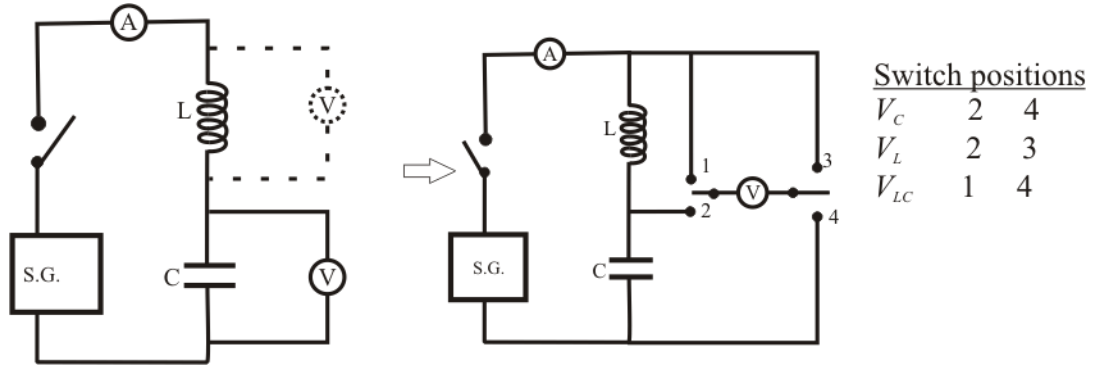
Fig. 2

EXPERIMENT 11: Investigation of the properties of a series resonance circuit.

Aim: To investigate the properties of a series resonance circuit.

Apparatus: Signal generator, high resistance a.c. voltmeter of 0-100V, a.c. ammeter (0-0.1A), a $1\mu\text{F}$ capacitor, an inductor of about 30mH.

Diagram



Method: Connect up the circuit as shown in the diagram. Before switching on the signal generator adjust its output to 2V and do not alter this setting throughout the experiment. Select the lowest available frequency, f , switch on the record the values of the current I in the circuit and the voltage V_C across the capacitor, C .

Transfer the voltmeter to the dotted position shown in the circuit diagram so that the voltage, V_L across the inductance, L is measured. Finally connect the voltmeter across the points marked X and Y in the diagram so that the voltage V_{LC} across L and C in series is measured.

Increase the frequency and measure the values of I , V_C , V_L and V_{LC} through a suitable frequency range of 100-5000Hz. Calculate the value of Z_{LC} in each case using $Z_{LC} = \frac{V_{LC}}{I}$

Tabulate your readings. Plot of I , V_C , V_L , V_{LC} and Z_{LC} against frequency in each case. Determine the resonant frequencies in each case.

Experimental details:

1. A slight modification to the circuit employing two single-pole two-way switches will enable the voltages V_C , V_L and V_{LC} to be obtained without the necessity of changing the connections of the voltmeter leads.
2. It will be found that each graph exhibits a pronounced maximum or minimum value which occurs either at or very near to an important frequency f , called the resonance frequency. In the order to determine this resonance frequency as accurately as possible

many readings of I , V_C , V_L and V_{LC} should be taken in the neighbourhood of the resonance frequency once the first graph of I against f has indicated the approximate value of f_r .

3. The maximum values of V_C , and V_L which will be found to be nearly equal, will be in excess of the applied voltage. This is unexpected and a remarkable feature of the series resonance circuit. It should be remembered and allowed for in selecting the appropriate voltage range for the voltmeter when approaching the resonance frequency.

Theory

The resonance frequency f_r is given by $f_r = \frac{1}{2\pi\sqrt{LC}}$ and should be tested by inserting the values for L and C in the above formula and comparing the calculated value for f_r with the experimentally obtained value.

The ratio $\frac{V_{Cmax.}}{applied\ voltage}$ (or $\frac{V_{Lmax.}}{applied\ voltage}$) is called the circuit magnification, Q .

Although V_C and V_L are in antiphase with each other at any frequency (V_C lagging on the current I by 90° , V_L leading the current by 90°), it is only at the resonance frequency that they are equal as well as in antiphase. It is this fact that explains the shape of the curves showing the variation of V_{LC} and Z_{LC} with frequency. The reason that the minimum value of V_{LC} is not zero is accounted for by the fact that the coil inevitably has some resistance and cannot be considered to be a pure inductance.

By inserting series resistance of (i) 100Ω (ii) 200Ω into the circuit, investigate the effect on the resonance curves in the above experiment.

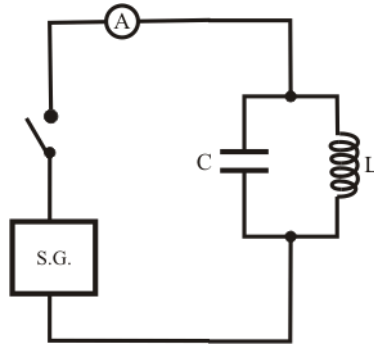
EXPERIMENT 12

Investigation of the properties of a parallel resonance circuit

Aim: To Investigate the properties of a parallel resonance circuit

Apparatus: Signal generator, a.c. ammetre 0-0.1A, and inductor of about 30mH, a $1\mu\text{F}$ capacitor.

Diagram



Method:

Connect up the circuit as shown in the diagram above. Before switching on the signal generator adjust its output voltage to 5V and do not alter the setting throughout the experiment.

Select a frequency of 100Hz, switch on and record the value I of the currents in the circuit. Increase the frequency in suitable steps up to 5 kHz, keeping the output voltage of the signal generator constant, and record the values of I . Tabulate your readings. Plot of a graph I on the vertical axis and frequency on the horizontal axis.

Theory

The graph is found to show the exact opposite of what is obtained for the series resonance circuit whereas the current in the series circuit exhibited a maximum at the resonance frequency, the current in a parallel resonance circuit passes through a minimum value at a particular frequency, f_r of the parallel resonance also known as the resonance frequency. To a close approximation, the resonance frequency f_r of the parallel resonance circuit is given by the same equation as for a series resonance circuit, namely $f_r = \frac{1}{2\pi\sqrt{LC}}$. This relationship should be tested by inserting the

values for L and C in the above equation and comparing the calculated value for f_r with the value obtained from the graph. The exact equation for the resonance frequency of a parallel

resonance circuit is $f_r = \frac{1}{2\pi} \sqrt{\left(\frac{1}{LC} - \frac{R^2}{L^2}\right)}$ where R is the resistance of the coil whose inductance is

L . In practice R is usually so small that the term $\frac{R^2}{L^2}$ can be neglected in comparison with the term $\frac{1}{LC}$ and the simple formula $f_r = \frac{1}{2\pi\sqrt{LC}}$ gives the resonance frequency to a high degree of approximation.

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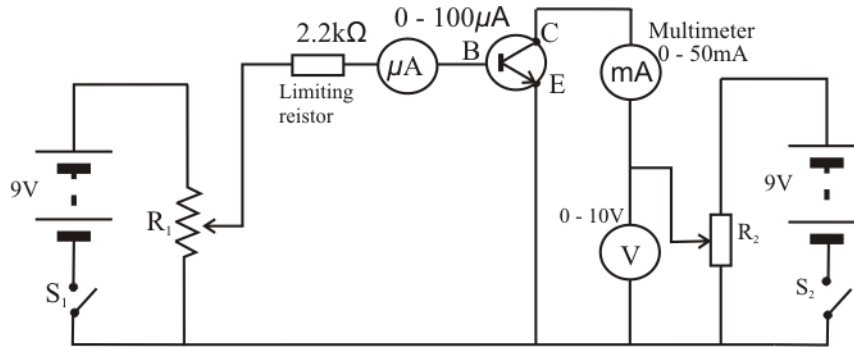
EXPERIMENT 13

Determination of the characteristics of an npn transistor in a common-emitter configuration.

Aim: To determine the characteristics of an npn transistor in a common-emitter configuration.

Apparatus: npn transistor(BC 108 or equivalent), two rheostats of range 0 – 10k Ω , two 9V dry batteries, fixed resistor of 2.2k Ω , multimeter or milliammeter of range 0 – 50mA, microammeter of 0 – 100 μ A, high resistance voltmeter of 0 – 10V and two keys.

Diagram



Method: Connect up the circuit as shown above in the diagram.

Part A: Collector characteristics

Close S_1 and by means of the rheostat R_1 adjust the value of I_b to a low value of about 20 μ A and keep it constant. Close S_2 and by means of the second rheostat R_2 reduce the V_{ce} to zero. Observe and record the values of I_c as V_{ce} is increased from zero up to 1V in steps of 0.1 V (it is in the early stages of the experiment when I_c is increasing very rapidly that a multimeter serves better than a milliammeter) and then by steps of 1 V up to a maximum value taking care to ensure that I_b remains constant throughout at 20 μ A.

Repeat the procedure and measurements for $I_b = 40, 60, 80$ and 100 μ A.

Tabulate your readings as shown below:

$I_b = 20\mu A$	V_{ce}/V						
	I_c/mA						
$I_b = 40\mu A$	V_{ce}/V						
	I_c/mA						
$I_b = . . .$	V_{ce}/V						
	I_c/mA						

Plot graphs of I_c against V_{ce} labeling each curve with the appropriate constant base current.

Calculation: Draw a line through the characteristics for a particular value of V_{ce} say at 5 V and calculate the ratio

$$\frac{\text{change in collector current, } \Delta I_c}{\text{change in base current, } \Delta I_b} = \text{current gain}$$

The current gain of the transistor describes how a small change in the base current produces a much larger change in collector current at a particular value of collector-emitter potential difference. A newer term for the current gain (β) is the small signal forward current transfer ratio for which the symbol is h_{fe} in which the subscript f denotes ‘forward’ and e a common-emitter circuit.

Calculate also for a particular curve beyond the knee, the ratio

$$\frac{\text{change in collector voltage, } \Delta V_{ce}}{\text{change in collector current, } \Delta I_c} = \text{output resistance for a particular base current}$$

Part B: Transfer Characteristics

The transfer characteristics exhibits the variation of collector current I_c with base current I_b while the collector voltage is kept constant. It can be plotted quite easily from the collector characteristics but much better to plot it from the data gained from a separate experiment. Select a suitable collector voltage beyond the knee of the collector curves, say 5 V and keep it constant by means of R_2 . By suitable adjustment of R_1 increase the base current I_b in suitable steps from zero to about $100\mu\text{A}$ and take the corresponding readings from the collector current, I_c .

Tabulate your readings as below.

$V_{ce} = \dots \text{ V}$	$I_b/\mu\text{A}$				
	$I_c \text{ mA}$				

Calculation: Calculate the ratio

$$\frac{\text{change in collector current, } \Delta I_c}{\text{change in base current, } \Delta I_b}$$

The ratio h_{fe} is the small signal forward current transfer ratio or current gain.

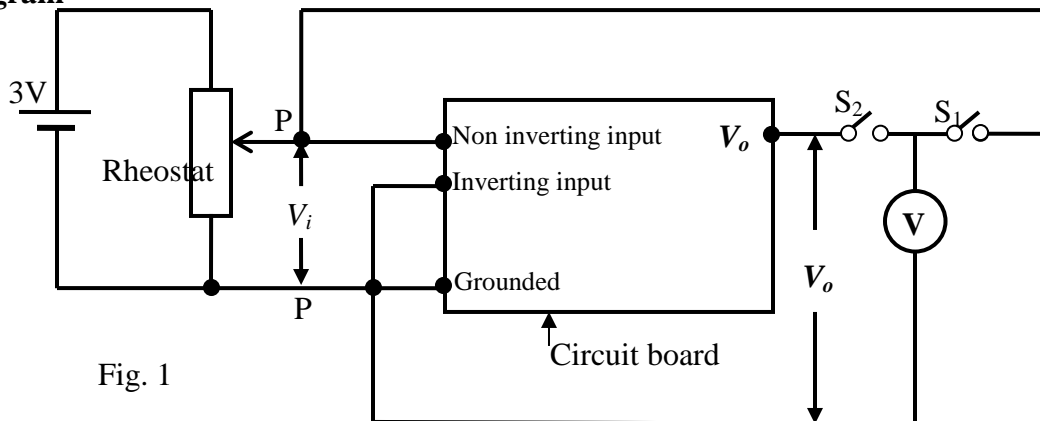
EXPERIMENT 14

Determination of the characteristics of an operational amplifier (OP-AMP) by measuring the voltage gains and bandwidths.

Aim: To determine the characteristics of an operational amplifier by measuring the voltage gains and bandwidths.

Apparatus: OP-AMP 741 IC with socket, signal generator, circuit board, rheostat, 2.2k Ω resistor, 22k Ω resistor, 3 V (two 1.5V) dry cell battery, connecting wires.

Diagram



Method

Part A: (a) Set up the circuit as shown in the diagram. (b) Close S_1 and open S_2 . Adjust rheostat until digital multimeter reads $V_i = 0.1$ V. Record V_i . Open S_1 and close S_2 . Record digital multimeter reading V_o . (c) Repeat step (b) with V_i increasing in steps until $V_i = 1.2$ V. (d) Tabulate the readings. Plot a graph of V_o against V_i . Calculate the voltage gain from the graph.

Part B: (a) Remove the rheostat and 3 V battery from terminal PQ and replace it with a signal generator. (b) Set the digital multimeter knob to alternating current. Adjust the frequency f of the signal generator to 1 kHz. (c) Open S_2 and close S_1 . Adjust input voltage V_i of signal generator so that the digital multimeter reads between 0.10 V and 0.15 V. Record V_i and f . (d) Open S_1 and close S_2 . Record the output voltage V_o . (e) Repeat steps (b), (c) and (d) by increasing the frequency f of the generator in steps until 30kHz. Tabulate the readings as f , V_i , V_o and $A = V_o / V_i$. Plot a graph of A and f . From the graph estimate the gain and bandwidth of frequency response of the inverting amplifier.

Theory: OP-AMP is used to detect the difference in the potential of two signals connected respectively to the two inputs, i.e. $(V_2 - V_1)$, which is multiplied by a factor A and will produce a voltage $A(V_2 - V_1)$ as the output. Ideally, OP-AMPs has very high gain, very

high input impedance and very low output impedance. OP-AMP is represented as in fig. 2a.

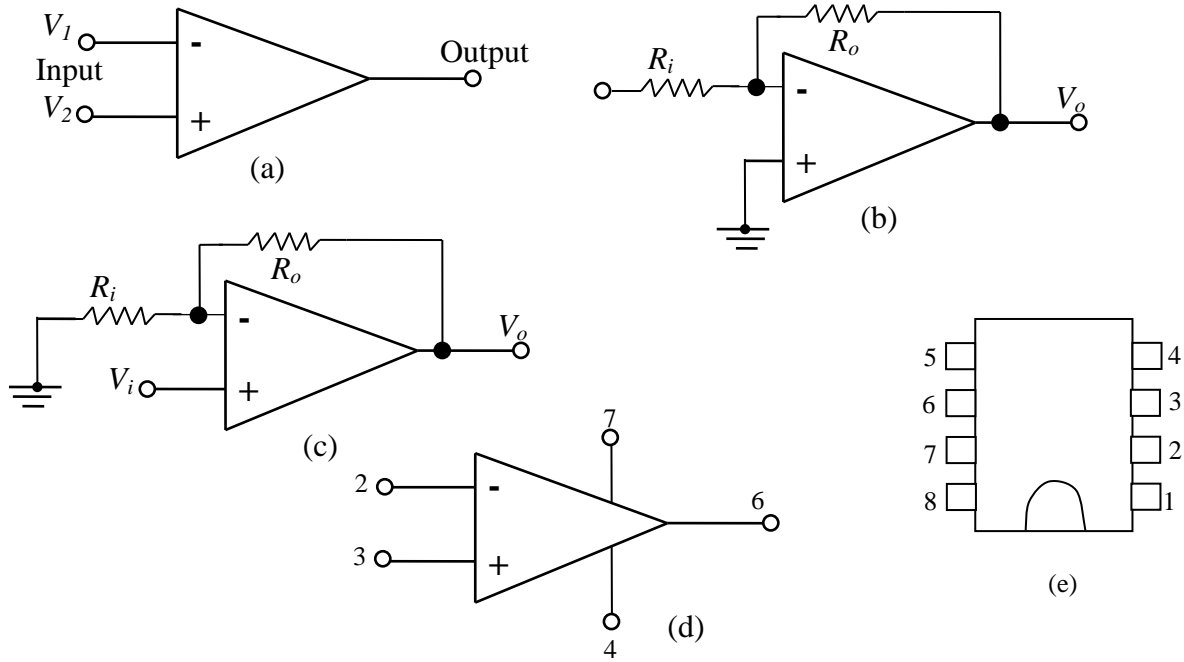


Fig. 2: OP-AMP circuit symbol and pins

The symbol (+) stands for non-inverting input while (-) represents the inverting input. Inverting input implies that the output will be negative if the potential at the inverting input is greater than the potential at the non-inverting input and vice versa. Thus sign (+) and (-) does not mean that (+) input is more positive than (-) input.

Normally OP-AMP is used with the negative feedback. There are two kinds of amplifiers with negative feedback, i. e. inverting amplifier and non-inverting amplifier. In the case of inverting amplifier (Fig. 2b), the non-inverting input is grounded and output voltage is given by $V_o = -\left(\frac{R_o}{R_i}\right)V_i$. Note that the resistor, R_o joins the output to the inverting input and this setup is called negative feedback. The equation relating to the gain is given by

$$\text{Gain } A = \frac{V_o}{V_i} = \frac{R_o}{R_i}$$

In the non-inverting amplifier (fig. 2c) the output voltage is given by

$$V_o = \left(1 + \frac{R_o}{R_i}\right)V_i \text{ and the gain } A \text{ as } 1 + \frac{R_o}{R_i}$$

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