22

Electronic Instruments

INTRODUCTION

In recent years, the rapid strides and remarkable advances in the field of electronics is partly due to modern electronic instruments. By using these instruments, we can gather much information regarding the performance of specific electronic circuit. Electronic instruments are also used for trouble shooting since they permit readings to be taken so that circuit faults can be located by ascertaining which component values do not coincide with the pre-established values indicated by the manufacturer. In fact, electronic instruments are playing a vital role in the fast developing field of electronics. It is with this view that they have been treated in a separate chapter.

22.1 Electronic Instruments

Those instruments which employ electronic devices for measuring various electrical quantities (*e.g.* *voltage, current, resistance etc.*) *are known as* **electronic instruments**.

There are a large number of electronic instruments available for completion of various tests and measurements. However, in this chapter, we shall confine our attention to the following electronic instruments :

(*i*) Multimeter

(*ii*) Electronic Voltmeters

(*iii*) Cathode ray oscilloscope

The knowledge of the manner in which each instrument is used plus an understanding of the applications and limitations of each instrument will enable the reader to utilise such instruments successfully.

22.2 Multimeter

A *multimeter* is an electronic instrument which can measure resistances, currents and voltages. It is an indispensable instrument and can be used for measuring d.c. as well as a.c. voltages and currents. Multimeter is the most inexpensive equipment and can make various electrical measurements with reasonable accuracy.

Construction. A multimeter consists of an ordinary pivoted type of moving coil galvanometer. This galvanometer consists of a coil pivoted on jeweled bearings between the poles of a permanent magnet. The indicating needle is fastened to the coil. When electric current is passed through the coil, mechanical force acts and the pointer moves over the scale.

Functions. A multimeter can measure voltages, currents and resistances. To achieve this objective, proper circuits are incorporated with the galvanometer. The galvanometer in a multimeter is always of *left zero type* *i.e.* normally its needle rests in extreme left position as compared to centre zero position of ordinary galvanometers.

(*i*) Multimeter as voltmeter. When a high resistance is connected in series with a galvanometer, it becomes a voltmeter. Fig. 22.1 (*i*) shows a high resistance R connected in series with the galvanometer of resistance G. If I_g is the *full scale deflection current*, then the galvanometer becomes a voltmeter of range $0 - V$ volts. The required value of series resistance R is given by :

$$V = I_g R + I_g G$$

or $$V/I_g = R + G$$

or $$R = V/I_g - G$$

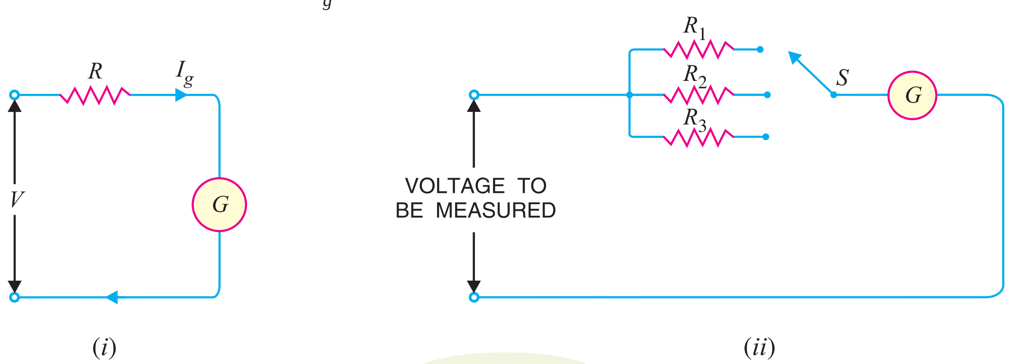

Fig. 22.1

For maximum accuracy, a multimeter is always provided with a number of voltage ranges. This is achieved by providing a number of high resistances in the multimeter as shown in Fig. 22.1 (*ii*). Each resistance corresponds to one voltage range. With the help of selector switch S, we can put any resistance (R_1, R_2 and R_3) in series with the galvanometer. When d.c. voltages are to be measured, the multimeter switch is turned on to d.c. position. This puts the circuit shown in Fig. 22.1 (*ii*) in action. By throwing the range selector switch S to a suitable position, the given d.c. voltage can be measured.

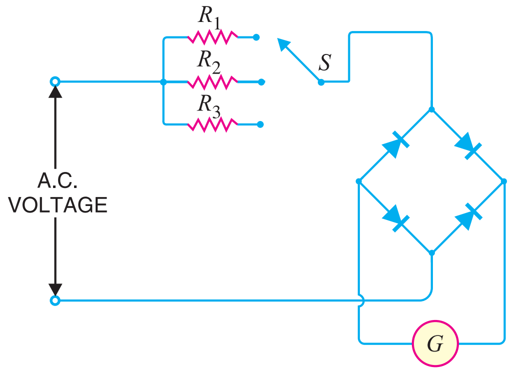

Fig. 22.2

The multimeter can also measure a.c. voltages. To permit it to perform this function, a full-wave rectifier is used as shown in Fig. 22.2. The rectifier converts a.c. into d.c. for application to the galvanometer. The desired a.c. voltage range can be selected by the switch S. When a.c. voltage is to be measured, the multimeter switch is thrown to a.c. position. This puts the circuit shown in Fig. 22.2 in action. By throwing the range selector switch S to a suitable position, the given a.c. voltage can be measured. It may be mentioned here that a.c. voltage scale is calibrated in r.m.s. values. Therefore, the meter will give the r.m.s. value of the a.c. voltage under measurement.

(*ii*) Multimeter as ammeter. When low resistance is connected in parallel with a galvanometer, it becomes an ammeter. Fig. 22.3 (*i*) shows a low resistance S (generally called *shunt*) connected in parallel with the galvanometer of resistance G. If I_g is the full scale deflection current, then the galvanometer becomes an ammeter of range $0 - I$ amperes. The required value of shunt resistance S is given by :

$$I_s S = I_g G$$

or $$I_s/I_g = G/S \quad \text{or} \quad \frac{I_s}{I_g} + 1 = \frac{G}{S} + 1$$

or $$\frac{I_s + I_g}{I_g} = \frac{G + S}{S} \quad \text{or} \quad \frac{I}{I_g} = \frac{G + S}{S}$$

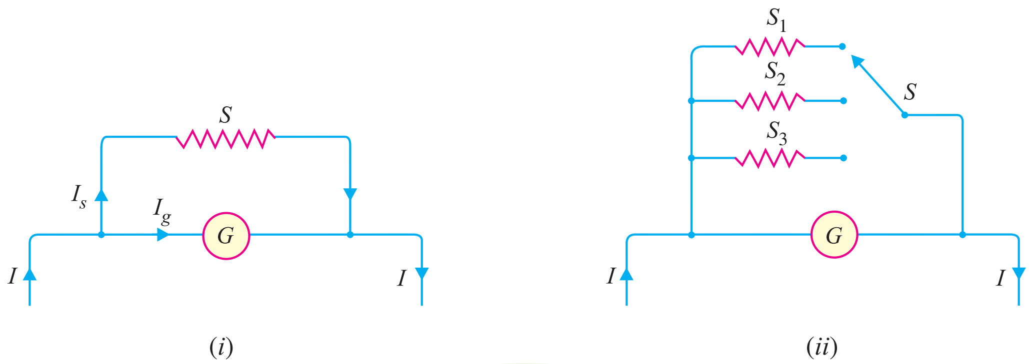

Fig. 22.3

In practice, a number of low resistances are connected in parallel with the galvanometer to provide a number of current ranges as shown in Fig. 22.3 (*ii*). With the help of range selector switch S, any shunt can be put in parallel with the galvanometer. When d.c. current is to be measured, the multimeter switch is turned on to d.c. position. This puts the circuit shown in Fig. 22.3 (*ii*) in action. By throwing the range selector switch S to a suitable position, the desired d.c. current can be measured.

The multimeter can also be used to measure alternating current. For this purpose, a full - wave rectifier is used as shown in Fig. 22.4. The rectifier converts a.c. into d.c. for application to the galvanometer. The desired current range can be selected by switch *S*. By throwing the range selector switch *S* to a suitable position, the given a.c. current can be measured. Again, the a.c. current scale is calibrated in r.m.s. values so that the instrument will give r.m.s. value of alternating current under measurement.

(*iii*) Multimeter as ohmmeter. Fig. 22.5 (*i*) shows the circuit of ohmmeter. The multimeter employs the internal battery. A fixed resistance *R* and a variable resistance *r* are connected in series with the battery and galvanometer. The fixed resistance *R* limits the current within the range desired and variable resistance *r* is for zero-adjustment reading. The resistance to be measured is connected between terminals *A* and *B*. The current flowing through the circuit will depend upon the value of resistor connected across the terminals. The ohmmeter scale is calibrated in terms of ohms. The ohmmeter is generally made multirange instrument by using different values of *R* as shown in Fig. 22.5 (*ii*).

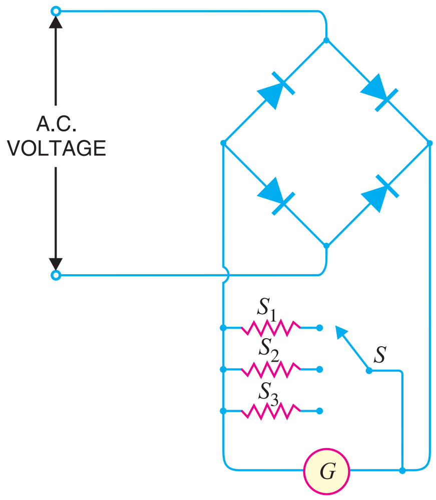

Fig. 22.4

To use ohmmeter, terminals *A* and *B* are shorted and resistance *r* is adjusted to give full scale deflection of the galvanometer. Under this condition, the resistance under measurement is zero. Because the needle deflects to full scale, the ohmmeter scale must then indicate *full scale deflection as zero ohm.* Then probes *A* and *B* are connected across the resistance to be measured. If the resistance to be measured is high, lower current flows through the circuit and the meter will indicate lower reading. It may be mentioned here that each time the ohmmeter is used, it is first shorted across *AB* and *r* is adjusted to zero the meter. This calibrates the meter and accommodates any decrease in the terminal voltage of the battery with age.

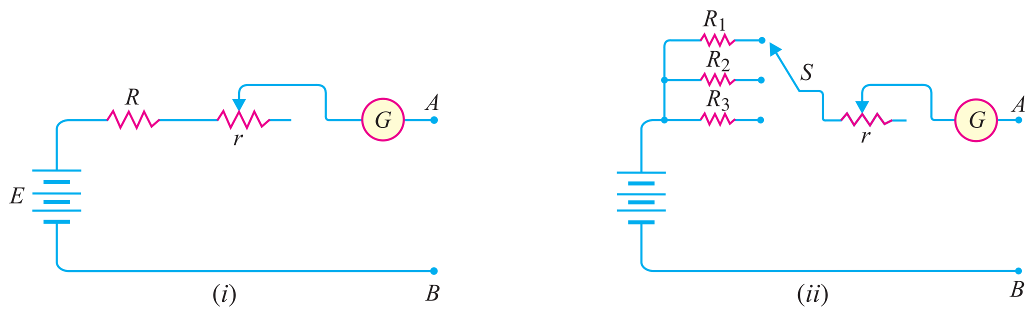

Fig. 22.5

Typical multimeter circuit. Fig 22.6 shows a typical multimeter circuit incorporating three voltage and current ranges.

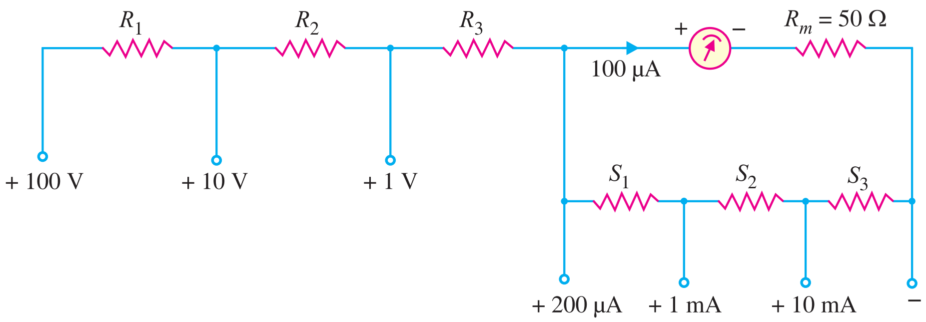

Fig. 22.6

Here the full-scale deflection (*f.s.d.*) current of the meter is 100 μA and meter resistance is 50 Ω. The design of this multimeter means finding the values of various resistances.

22.3 Applications of Multimeter

A multimeter is an extremely important electronic instrument and is extensively used for carrying out various tests and measurements in electronic circuits. It is used :

(*i*) For checking the circuit continuity. When the multimeter is employed as continuity-checking device, the ohmmeter scale is utilised and the equipment to be checked is shut off or disconnected from the power mains.

(*ii*) For measuring d.c. current flowing through the cathode, plate, screen and other vacuum tube circuits.

(*iii*) For measuring d.c. voltages across various resistors in electronic circuits.

Checking the circuit continuity by multimeter

(*iv*) For measuring a.c. voltages across power supply transformers.

(*v*) For ascertaining whether or not open or short circuit exists in the circuit under study.

22.4 Sensitivity of Multimeter

The resistance offered per volt of full scale deflection by the multimeter is known as **multimeter sensitivity.**

Multimeter sensitivity indicates the internal resistance of the multimeter. For example, if the total resistance of the meter is 5000 ohms and the meter is to read 5 volts full scale, then internal resistance of the meter is 1000 Ω per volt *i.e.* meter sensitivity is 1000 Ω per volt. Conversely, if the meter sensitivity is 400 Ω per volt which reads from 0 to 100 V, then meter resistance is 40,000 ohms. If the meter is to read V volts and I_g is the full scale deflection current, then,

$$\text{Meter resistance} = \frac{V}{I_g}$$

$$\text{Meter sensitivity} = \text{Resistance per volt full scale deflection}$$

$$= \frac{V}{I_g}\Big/ V = \frac{1}{I_g}$$

Sensitivity is the most important characteristic of a multimeter. If the sensitivity of a multimeter is high, it means that it has high internal resistance. When such a meter is connected in the circuit to read voltage, it will draw a very small current. Consequently, there will be no change in the circuit current due to the introduction of the meter. Hence, it will measure the voltage correctly. On the other hand, if the sensitivity of multimeter is low, it would cause serious error in voltage measurement. The sensitivity of multimeters available in the market range from 5 kΩ per volt to 20 kΩ per volt.

22.5 Merits and Demerits of Multimeter

Although multimeter is widely used for manufacturing and servicing of electronics equipment, it has its own merits and demerits.

Merits

(*i*) It is a single meter that performs several measuring functions.

(*ii*) It has a small size and is easily portable.

(*iii*) It can make measurements with reasonable accuracy.

Demerits

(*i*) It is a costly instrument. The cost of a multimeter having sensitivity of 20 kΩ per volt is about Rs. 1000.

(*ii*) It cannot make precise and accurate measurements due to the loading effect.

(*iii*) Technical skill is required to handle it.

22.6 Meter Protection

It is important to provide protection for the meter in the event of an accidental overload. This is achieved by connecting a diode in parallel with the voltmeter as shown in Fig. 22.7.

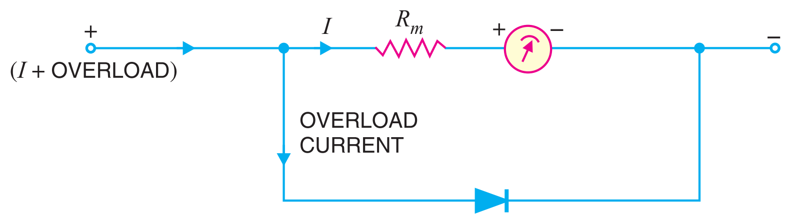

Fig. 22.7

Let us see how diode across the meter enables it to withstand overload without destroying the expensive movement. If I is the normal *f.s.d.* current, a potential difference of IR_m is developed across the diode. The circuit is so designed that IR_m does not turn on the diode. In the event of an accidental overload (say 5 I), the voltage across diode becomes 5 times greater and it is immediately turned on. Consequently, diode diverts most of the overload current in the same manner as a shunt. Thus protection of the meter against overload is ensured. Silicon diodes are perhaps the best to use in such circuits.

Example 22.1. *A multimeter has full scale deflection current of 1 mA. Determine its sensitivity.*

Solution. Full scale deflection current, $I_g = 1 \text{ mA} = 10^{-3}$ A

∴ Multimeter sensitivity $= 1/I_g = 1/10^{-3} =$ **1000 Ω per volt**

Example 22.2. *A multimeter has a sensitivity of 1000 Ω per volt and reads 50 V full scale. If the meter is to be used to measure the voltage across 50000 Ω resistor, will it read correctly ?*

Solution. Meter sensitivity = 1000 Ω per volt

Full scale volts = 50 V

∴ Meter resistance $= 50 \times 1000 = 50{,}000\ \Omega$

When the meter is used to measure the voltage across the resistance as shown in Fig. 22.8, the total resistance of the circuit is a parallel combination of two 50,000 Ω resistors. Therefore, the circuit resistance would be reduced to 25000 Ω and double the amount of current would be drawn than would otherwise be the case.

∴ *Meter will give highly incorrect reading.*

Comments. This example shows the limitation of multimeter. The multimeter will read correctly only if its resistance is very high as compared to the resistance across which voltage is to be measured.

As a rule, the resistance of the multimeter should be atleast 100 times the resistance across which voltage is to be measured.

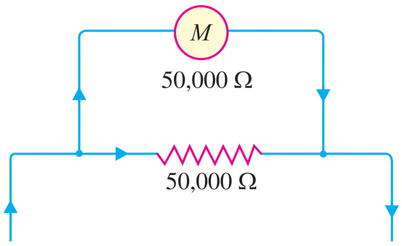

Fig. 22.8

Example 22.3. *In the circuit shown in Fig. 22.9 (i), it is desired to measure the voltage across 10 kΩ resistance. If a multimeter of sensitivity 4 kΩ/volt and range 0-10 V is used for the purpose, what will be the reading ?*

Solution. In the circuit shown in Fig. 22.9 (*i*), the circuit current by Ohm's law is 1 mA. Therefore, voltage across 10 kΩ resistance is 10 V. Let us see whether the given multimeter reads this value. Fig. 22.9 (*ii*) shows the multimeter connected across 10 kΩ resistance. The introduction of multimeter will change the circuit resistance and hence circuit current.

$$\text{Resistance of meter} = 4 \text{ k}\Omega \times 10 = 40 \text{ k}\Omega$$

$$\text{Total circuit resistance} = 40 \text{ k}\Omega \,||\, 10 \text{ k}\Omega + 10 \text{ k}\Omega$$

$$= \frac{40 \times 10}{40 + 10} + 10 = 8 + 10 = 18 \text{ k}\Omega$$

$$\therefore \quad \text{Circuit current} = \frac{20\,V}{18 \text{ k}\Omega} = 1.11 \text{ mA}$$

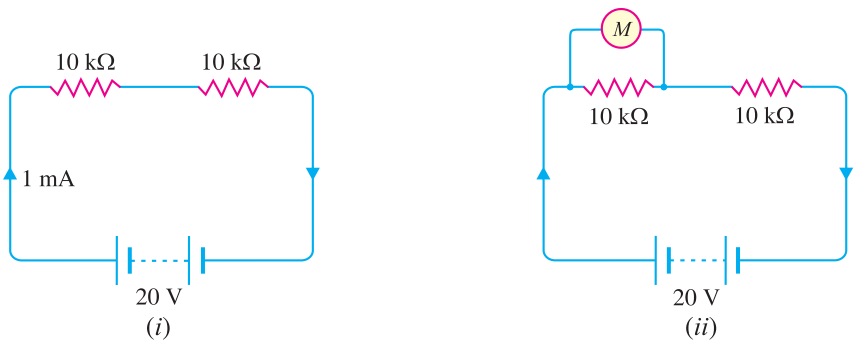

Fig. 22.9

$$\text{Voltage read by multimeter} = 8 \text{ k}\Omega \times 1.11 \text{ mA} = \mathbf{8.88\ V}$$

Example 22.4. *If in the above example, a multimeter of sensitivity 20 kΩ per volt is used, what will be the reading ?*

Solution.

$$\text{Meter resistance} = 20 \text{ k}\Omega \times 10 = 200 \text{ k}\Omega$$

$$\text{Total circuit resistance} = 200 \text{ k}\Omega \,||\, 10 \text{ k}\Omega + 10 \text{ k}\Omega$$

$$= \frac{200 \times 10}{200 + 10} + 10 = 9.5 + 10 = 19.5 \text{ k}\Omega$$

$$\text{Circuit current} = \frac{20\,V}{19.5 \text{ k}\Omega} = 1.04 \text{ mA}$$

$$\therefore \quad \text{Voltage read by multimeter} = 9.5 \text{ k}\Omega \times 1.04 \text{ mA} = \mathbf{9.88\ V}$$

A comparison of examples 22.3 and 22.4 shows that a multimeter with higher sensitivity gives more correct reading.

Example 22.5. *In the circuit shown in Fig. 22.10, find the voltage at points A, B, C and D (i) before the meter is connected and (ii) after the meter is connected. Explain why the meter readings differ from those without the meter connected.*

Solution. (*i*) **When meter is not connected.** When meter is not connected in the circuit, the circuit is a simple series circuit consisting of resistances 20 kΩ, 20 kΩ, 30 kΩ and 30 kΩ.

$$\text{Total circuit resistance} = 20 + 20 + 30 + 30 = 100 \text{ k}\Omega$$

$$\therefore \quad \text{Circuit current} = \frac{100\,V}{100 \text{ k}\Omega} = 1 \text{ mA}$$

$$\text{Voltage at point } A = \mathbf{100\ V}$$

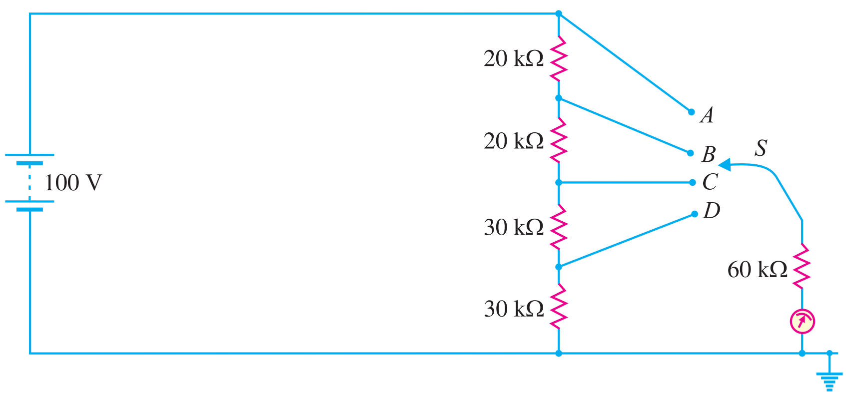

Fig. 22.10

$$\text{Voltage at point } B = 100 - 1 \text{ mA} \times 20 \text{ k}\Omega = \mathbf{80\ V}$$

$$\text{Voltage at point } C = 100 - 1 \text{ mA} \times 40 \text{ k}\Omega = \mathbf{60V}$$

$$\text{Voltage at point } D = 100 - 1 \text{ mA} \times 70 \text{ k}\Omega = \mathbf{30V}$$

(***ii***) **When meter is connected.** When meter is connected in the circuit, the circuit becomes a series-parallel circuit. The total circuit resistance would depend upon the position of switch *S*.

(*a*) *When switch is at position A*

The voltage at point *A* is 100 V because point *A* is directly connected to the voltage source.

$$\therefore \quad \text{Voltage at point } A = \mathbf{100\ V}$$

(*b*) *When switch is at position B*

$$\text{Total circuit resistance} = 20 + \frac{80 \times 60}{80 + 60} = 20 + 34.28 = 54.28 \text{ k}\Omega$$

$$\therefore \quad \text{Circuit current} = \frac{100\,V}{54.28 \text{ k}\Omega}$$

$$\therefore \quad \text{Voltage at point } B = \frac{100 \text{ V}}{54.28 \text{ k}\Omega} \times 34.28 \text{ k}\Omega = \mathbf{63\ V}$$

(*c*) *When switch is at point C*

$$\text{Total circuit resistance} = 40 + \frac{60 \times 60}{60 + 60} = 40 + 30 = 70 \text{ k}\Omega$$

$$\therefore \quad \text{Circuit current} = \frac{100 \text{ V}}{70 \text{ k}\Omega}$$

$$\therefore \qquad \text{Voltage at point } C = \frac{100\text{ V}}{70\text{ k}\Omega} \times 30\text{ k}\Omega = \mathbf{42.8\text{ V}}$$

(*d*) *When switch is at point D*

$$\text{Total circuit resistance} = 70 + \frac{30 \times 60}{30 + 60} = 70 + 20 = 90\text{ k}\Omega$$

$$\therefore \qquad \text{Circuit current} = \frac{100\text{ V}}{90\text{ k}\Omega}$$

$$\therefore \qquad \text{Voltage at point } D = \frac{100\text{ V}}{90\text{ k}\Omega} \times 20\text{ k}\Omega = \mathbf{22.2\text{ V}}$$

Comments. Note that potential measurements are being made in a high-impedance circuit; the circuit resistance is comparable to meter resistance. As a rule, the resistance of the voltmeter should be 100 times the resistance across which voltage is to be measured. Since such a condition is not realised in this problem, the meter readings differ appreciably from those without the meter connected.

22.7 Electronic Voltmeters

The electromagnetic and electrostatic voltmeters have two main drawbacks. First, the input resistance/impedance of these instruments is not very high so that there is a considerable *loading effect of the instrument. Secondly, considerable power is drawn from the circuit under measurement. Both these drawbacks are overcome in electronic voltmeters. The electronic devices (*e.g.* vacuum tubes, transistors etc.) have very high input resistance/impedance and possess the property of amplification. The latter property permits the input signal to be amplified so that the power to operate the indicating mechanism comes from a source other than the measured circuit. There are a large number of electronic voltmeters. However, we shall discuss the following three types of electronic voltmeters :

(*i*) Vacuum Tube Voltmeter (*VTVM*)

(*ii*) Transistor Voltmeter

(*iii*) Bridge Rectifier Voltmeter

22.8 Vacuum Tube Voltmeter (VTVM)

A vacuum tube voltmeter consists of any ordinary voltmeter and electron tubes. It is extensively used for measuring both a.c. and d.c. voltages. The vacuum tube voltmeter has high internal resistance ($> 10\text{ M}\Omega$) and draws extremely small current from the circuit across which it is connected. In other words, the loading effect of this instrument is very small. Therefore, a *VTVM* measures the exact voltage even across a high resistance. In fact, the ability of *VTVM* to measure the voltages accurately has made this instrument the most popular with technicians for trouble shooting radio and television receivers as well as for laboratory work involving research and design.

(*i*) Simple VTVM circuit. Fig. 22.11 shows the simple circuit of a vacuum tube voltmeter. It consists of a triode having meter *M* connected in the plate circuit. The meter is calibrated in volts. R_1 is the grid leak resistor. The voltage to be measured is applied at the grid of triode in such a way that grid is always negative *w.r.t.* cathode. This voltage at the grid is transformed by the triode into corresponding plate current. The meter *M* connected in the plate circuit directly gives the value of the voltage under measurement. It may be seen that as grid draws extremely small current ($< 1\ \mu$A), therefore, internal resistance of *VTVM* is very large. This circuit has the disadvantage that if the applied voltages change (especially filament voltage), the plate current will also change. Consequently, the meter will give wrong reading.

* When a voltmeter is connected across a resistance *R* to measure voltage, the measured voltage will be less than the actual value. It is because the resistance *R* is shunted by the voltmeter. This is called loading effect of the meter. The greater the input resistance of voltmeter, the smaller will be the loading effect and more accurate is the reading.

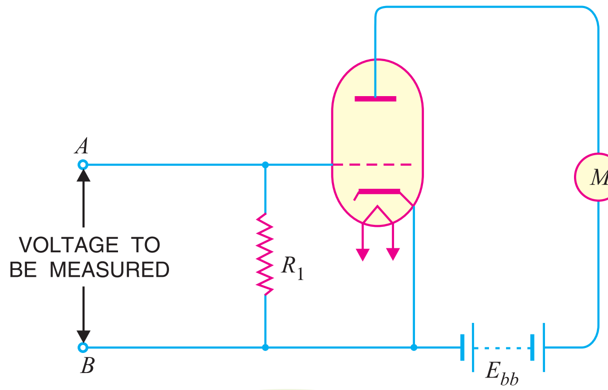

Fig. 22.11

(*ii*) **Balanced bridge Type VTVM.** The disadvantage of above circuit is overcome in the balanced bridge type *VTVM* shown in Fig. 22.12. Here, two similar triodes V_1 and V_2 are used. The meter *M* is connected between the plates of triodes and indicates the voltage to be measured. The variable resistance *r* in the plate circuit of V_2 is for zero adjustment of the meter. The voltage to be measured is applied at the grid of triode V_1 in such a way that grid is always negative with respect to cathode.

Operation. When no voltage is applied at the input terminals *AB*, the plate currents flowing in both valves are equal as the triodes are similar. Therefore, plates of both valves are at the same potential. Consequently, the current through the meter *M* is zero and the meter reads zero volt. However, in actual practice, there are always some constructional differences in plates, grids and cathodes of the two valves. The result is that two plate currents differ slightly and the meter may give some reading. In such a case, the meter needle is brought to zero by changing resistance *r*.

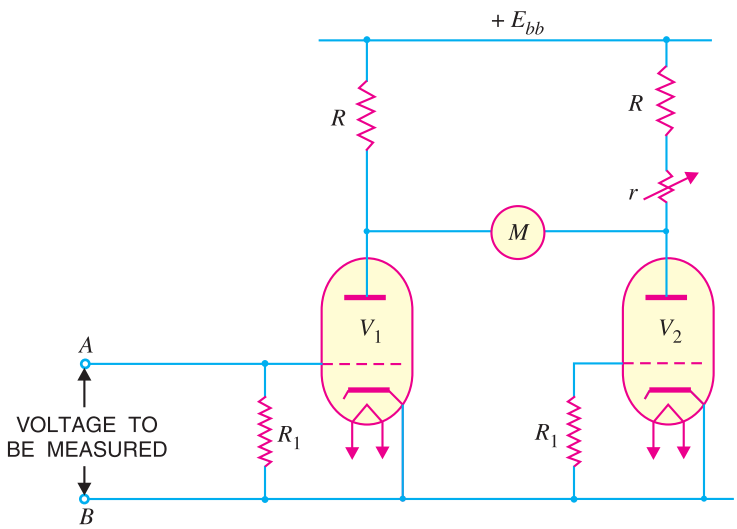

Fig. 22.12

The voltage to be measured is applied at the grid of triode V_1, making the grid negative *w.r.t.* cathode. This changes the plate current of triode V_1 and the plates of two valves no longer remain at the same potential. Therefore, a small current flows through the meter *M* which directly gives the value of the voltage being measured. It may be noted that actually triode V_1 is used for voltage measurement, the purpose of V_2 is simply to prevent zero drift. By using two similar tubes, any change in plate current due to supply fluctuations will equally affect the two plate currents. Therefore, net change in potential drop across voltmeter is zero.

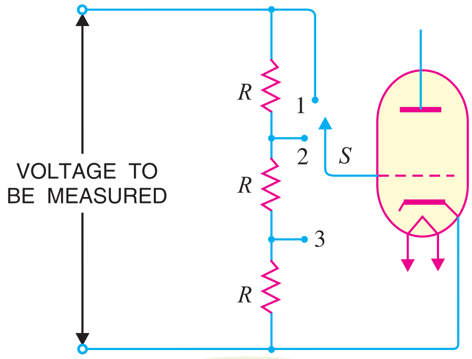

Fig. 22.13

VTVM

Range selection. In practice, a *VTVM* is made a multirange instrument by employing a potentiometer at the input circuit as shown in Fig. 22.13. By throwing the range selector switch *S* to a suitable position, the desired voltage range can be obtained. Thus when the range selector switch *S* is thrown to position 1, the voltage applied to the grid is three times as compared to position 3. Although only three voltage ranges have been considered, a commercial *VTVM* may have more ranges.

22.9 Applications of VTVM

A *VTVM* is far superior to a multimeter and performs a number of measuring functions. A few important applications of *VTVM* are discussed below :

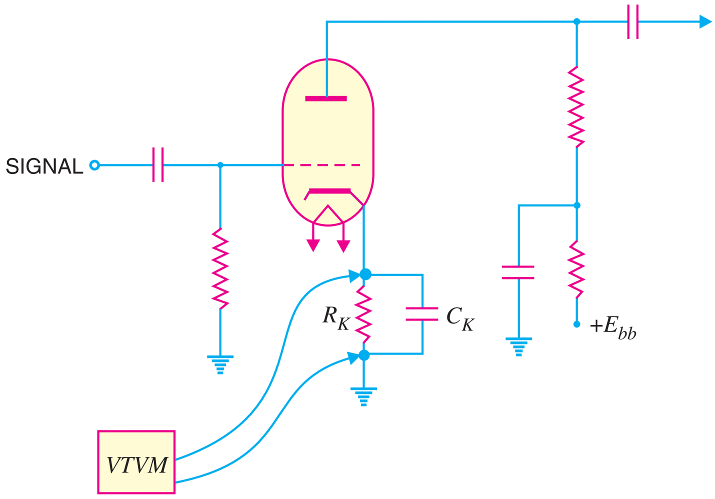

Fig. 22.14

(*i*) d.c. voltage measurements. A *VTVM* can accurately measure the d.c. voltages in an electronic circuit. The d.c. voltage to be measured is applied at the input (*i.e.* grid of V_1) terminals in such a way that grid of the input valve V_1 is always negative. Fig. 22.14 shows the circuit of an amplifier stage and measurement of d.c. voltage across cathode resistor R_K.

(*ii*) d.c. current measurements. A conventional *VTVM* does not incorporate a current scale. However, current values can be found indirectly. For instance, in Fig. 22.14, the d.c. current through R_K can be found by noting the voltage across R_K and dividing it by the resistance R_K.

(*iii*) a.c. voltage measurements. For measuring a.c. voltage, a rectifier is used in conjunction with a *VTVM*. The rectifier converts a.c. into d.c. for application to the grid of valve V_1. In fact, rectifier circuit is a part of *VTVM*. Fig. 22.15 shows the transistor power amplifier stage and measurement of a.c. voltage across the speaker.

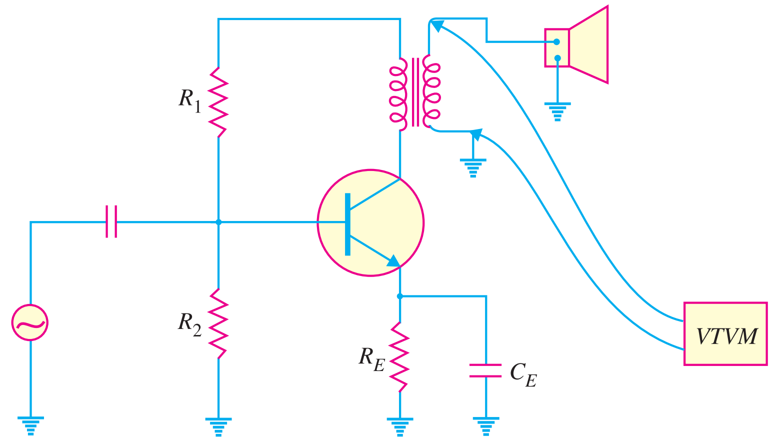

Fig. 22.15

(*iv*) Resistance measurements. A *VTVM* can be used to measure resistances and has the ability to measure resistances upto 1000 megaohms whereas the ordinary ohmmeter will measure only upto about 10 megaohms. Fig. 22.16 shows the circuit of *VTVM* ohmmeter. By throwing the selector switch *S* to any suitable position, the desired resistance range can be obtained. The unknown resistor whose value is to be measured is connected between points *A* and *B*. If the unknown resistance has high value, a higher negative bias will be applied to triode V_1. Reverse will happen if the unknown

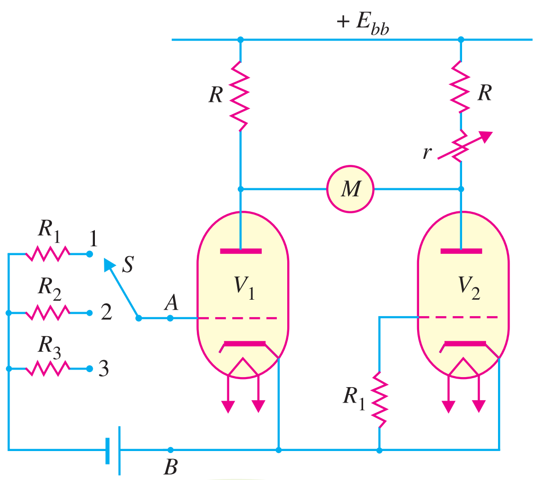

Fig. 22.16

resistance has low value. The imbalance in the plate currents of the two valves will cause a current through the meter *M* which will directly give the value over the resistance scale of the meter.

22.10 Merits and Demerits of VTVM

A *VTVM* is an extremely important electronic equipment and is widely used for making different measurements in electronic circuits.

Merits

(*i*) A *VTVM* draws extremely small current from the measuring circuit. Therefore, it gives accurate readings.

(*ii*) There is little effect of temperature variations.

(*iii*) Because a *VTVM* uses triodes, the voltage to be measured is amplified. This permits the use of less sensitive meter.

(*iv*) It has a wide frequency response.

Demerits

(*i*) It cannot make current measurements directly.

(*ii*) Accurate readings can be obtained only for sine waves.

22.11 Transistor Voltmeter Circuit

Since vacuum tubes have become obsolete, these have been replaced by transistors and other semiconductor devices. Fig. 22.17 shows the circuit of an emitter-follower voltmeter. The voltage *E* to be measured is applied between base and emitter. A permanent-magnet moving coil (PMMC) instrument and a multiplier resistor R_S are connected in series with the transistor emitter. The circuit measures the voltage quite accurately because the emitter follower offers high input resistance to the voltage being measured and provides a low output resistance to drive current through the coil of PMMC meter.

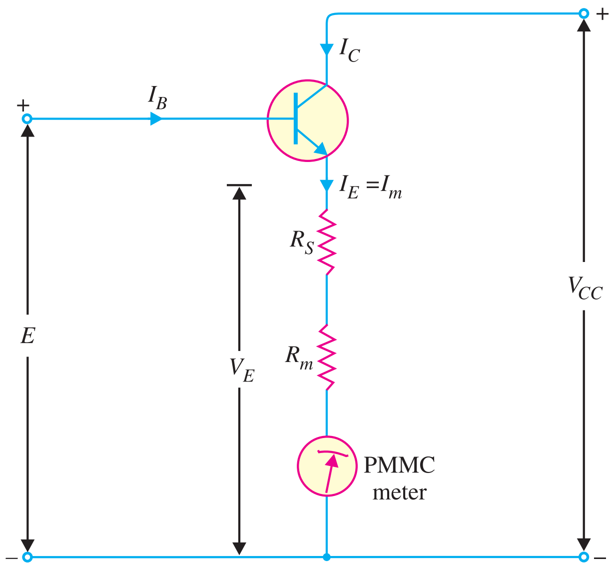

Fig. 22.17

Operation. The voltage *E* to be measured is applied between base and emitter of the transistor and causes a base current I_B to flow through the base circuit. Therefore, collector current $I_C = \beta I_B$ where β is the current amplification factor of the transistor. Since $I_E \simeq I_C$ and the meter is connected in the emitter, the meter current $I_m = I_E = \beta I_B$. Now the meter current I_m depends upon the input voltage to be measured. Therefore, the PMMC meter can be calibrated to read the input voltage directly.

$$\text{Emitter voltage, } V_E = E - V_{BE}$$

$$\text{Meter current, } I_m = \frac{V_E}{R_S + R_m}$$

Here R_S = multiplier resistor ; R_m = meter resistance

$$\text{Input resistance of voltmeter, } R_i = \frac{E}{I_B}$$

Example 22.6. *The emitter follower circuit shown in Fig. 22.17 has V_{CC} = 12 V ; R_m = 1kΩ and a 2 mA meter. If transistor β = 80, calculate (i) the suitable resistance for R_S to give full -scale deflection when E = 5V (ii) the voltmeter input resistance.*

Solution.

$$\text{Meter resistance, } R_m = 1 \text{ k}\Omega$$

$$\text{F.S.D. current of meter, } I_{m\,(f.s.d.)} = 2 \text{ mA} = 2 \times 10^{-3} \text{A}$$

(i) $$\text{Emitter voltage, } V_E = E - V_{BE} = 5 \text{ V} - 0.7 \text{ V} = 4.3 \text{ V}$$

$$\therefore \quad I_{m\,(f.s.d.)} = \frac{V_E}{R_S + R_m}$$

or $$2 \times 10^{-3} = \frac{4.3\text{V}}{1000\Omega + R_S} \qquad \therefore \; R_S = \mathbf{1150\ \Omega}$$

(ii) $$\text{Base current, } I_B = \frac{I_{m\,(f.s.d.)}}{\beta} = \frac{2 \text{ mA}}{80} = 0.025 \text{ mA}$$

$$\therefore \quad \text{Input resistance of voltmeter, } R_i = \frac{E}{I_B} = \frac{5\text{V}}{0.025 \text{ mA}} = \mathbf{200\ k\Omega}$$

Example 22.7. *The emitter-follower voltmeter circuit in Fig. 22.17 has V_{CC} = 20 V, $R_S + R_m$ = 9.3 kΩ, I_m = 1 mA and transistor β = 100.*

(i) *Calculate the meter current when E = 10V.*

(ii) *Determine the voltmeter input resistance with and without the transistor.*

Solution.

(i) $$\text{Emitter voltage, } V_E = E - V_{BE} = 10\text{V} - 0.7 \text{ V} = 9.3 \text{ V}$$

$$\therefore \quad \text{Meter current, } I_m = \frac{V_E}{R_S + R_m} = \frac{9.3 \text{ V}}{9.3 \text{ k}\Omega} = \mathbf{1\ mA}$$

(ii) $$\text{Base current, } I_B = \frac{I_m}{\beta} = \frac{1 \text{ mA}}{100} = 0.01 \text{ mA}$$

$$\text{With transistor, } R_i = \frac{E}{I_B} = \frac{10 \text{ V}}{0.01 \text{ mA}} = 1000 \text{ k}\Omega = \mathbf{1\ M\Omega}$$

$$\text{Without transistor, } R_i = R_S + R_m = \mathbf{9.3\ k\Omega}$$

Note that without transistor, the voltmeter input resistance = $R_S + R_m$ = 9.3 kΩ. However, with transistor, the voltmeter input resistance = 1 MΩ = 1000 kΩ. The obvious advantage of the electronic voltmeter is that its loading effect in voltage measurement will be very small.

Example 22.8. *In the above example, if E = 5V, all other values remaining the same, what will be the value of meter current? Comment on the result.*

Solution.

$$\text{Meter current, } I_m = \frac{E - V_{BE}}{R_S + R_m} = \frac{5\text{V} - 0.7\text{V}}{9.3 \text{ k}\Omega} = \frac{4.3\text{V}}{9.3 \text{ k}\Omega} = \mathbf{0.46\ mA}$$

With $E = 5$V, the meter should read half of full-scale reading *i.e.* 0.5 mA. However, the meter current is actually 0.46 mA. This error is due to V_{BE} and can be eliminated by the modification of the circuit.

22.12 Bridge Rectifier Voltmeter

A permanent-magnet moving coil (PMMC) instrument responds to *average* or d.c. value of current through the moving coil. If alternating current is passed through the moving coil, the driving torque would be *zero. It is because the average value of a sine wave over one cycle is zero. Therefore, a PMMC instrument connected directly to measure a.c. indicates zero reading. In order to measure a.c. with a PMMC instrument, the given a.c. is converted into d.c. by using a bridge rectifier. The instrument is then called rectifier type instrument.

Circuit details. Fig. 22.18 shows bridge rectifier voltmeter for the measurement of a.c. voltages. A multiplier resistor R_S is connected in **series with the PMMC instrument having resistance R_m. When a.c. voltage to be measured is applied to the circuit, full-wave rectification will be obtained as shown in Fig. 22.19. The meter deflection will be proportional to the †average current. Since there is a definite relationship between the average value and r.m.s. value of a sine-wave (r.m.s. value = 1.11 × average value), the meter scale can be calibrated to read the r.m.s. value directly.

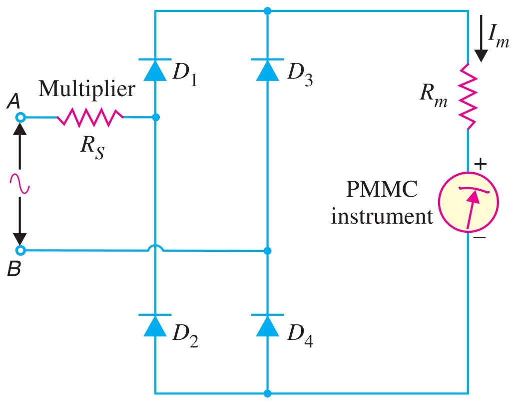

Fig. 22.18

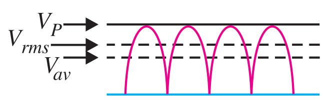

Fig. 22.19

Operation. When a.c. voltage to be measured is applied to the circuit, it passes the positive half-cycles of the input and inverts the negative half-cycles.

(i) During the positive half-cycle of the a.c. input voltage, point *A* is positive w.r.t. point *B*. Therefore, diodes D_1 and D_4 are forward biased while diodes D_2 and D_3 are reverse biased. As a result, diodes D_1 and D_4 conduct and the current follows the path $R_S - D_1$ – PMMC meter – D_4 – back to point *B*. Note that multiplier resistor R_S and the meter are in series.

(ii) During the negative half-cycle of the a.c. input voltage, diodes D_2 and D_3 are forward biased while diodes D_1 and D_4 are reverse biased. As a result, diodes D_2 and D_3 conduct and the current follows path D_3 – PMMC meter – $D_2 - R_S$ back to point *A*. Note that current through the meter is in the same direction as for the positive half-cycle. Consequently, full-wave rectification results.

* The driving torque would be in one direction for the positive half-cycle and in the other direction for the negative half-cycle. The inertia of the coil is so great that at supply frequency (50 Hz),the pointer cannot follow the rapid reversals of the driving torque. Therefore, pointer of the meter remians stationary at zero mark.

** If you see carefully, the four diodes (D_1, D_2, D_3 and D_4) form the bridge. Note that the same current flows through the R_s and R_m.

† Note that a voltmeter is a current-operated device.

The scale of the PMMC meter is calibrated to read directly the r.m.s. value of a.c. voltage being measured. It may be noted that rectifier voltmeter can be used only to measure pure sine-wave voltages. When other than pure sine-waves are applied, the meter will *not* indicate the r.m.s. voltage.

Example 22.9. *A PMMC instrument with a full-scale deflection (f.s.d.) current of 100 μA and R_m = 1 kΩ is to be used as a voltmeter of range 0 – 100 V (r.m.s.). The diodes used in the bridge rectifier circuit are of silicon. Calculate the value of multiplier resistor R_S required.*

Solution. Note that 100 μA is the average current.

$$\text{F.S.D. current of meter, } I_{m\,(f.s.d.)} = 100\ \mu A = 100 \times 10^{-6}\ A = 10^{-4}\ A$$

$$\text{Total circuit resistance, } R_T = R_S + R_m = (R_S + 1000)\ \Omega$$

$$\text{Peak value of applied voltage, } V_m = \sqrt{2}\ V_{r.m.s.} = \sqrt{2} \times 100\ V = 141.4V$$

$$^*\text{Total rectifier drop} = 2\ V_F = 2 \times 0.7 = 1.4V$$

$$\text{Peak f.s.d. current of meter} = \frac{\text{Peak applied voltage} - \text{Rectifier Drop}}{\text{Total circuit resistance}}$$

or
$$\frac{10^{-4}}{0.637} = \frac{141.4 - 1.4}{R_S + 1000} \qquad \left(\because I_{peak} = \frac{I_{av.}}{0.637}\right)$$

∴
$$R_S = \mathbf{890.7\ k\Omega}$$

Example 22.10. *An a.c. voltmeter uses a bridge rectifier with silicon diodes and a PMMC instrument with f.s.d. current of 75 μA. If meter coil resistance is 900Ω and the multiplier resistor is 708 kΩ, calculate the applied r.m.s. voltage when the meter reads f.s.d.*

Solution. The PMMC meter reads average value.

$$\therefore \quad \text{Peak f.s.d. meter current} = \frac{75 \times 10^{-6}}{0.637}\ A \qquad \left(\because I_{peak} = \frac{I_{av.}}{0.637}\right)$$

$$\text{Now Peak f.s.d. meter current} = \frac{\text{Peak applied voltage} - \text{Rectifier drop}}{\text{Total circuit resistance}}$$

or
$$\frac{75 \times 10^{-6}}{0.637} = \frac{\sqrt{2}\ V_{r.m.s.} - 2 \times 0.7}{R_S + R_m}$$

or
$$117.74 \times 10^{-6} = \frac{1.414\ V_{r.m.s} - 1.4}{708 \times 10^3 + 900}$$

∴
$$V_{r.m.s.} = \frac{(117.74 \times 10^{-6})(708 \times 10^3 + 900) + 1.4}{1.414} = \mathbf{60V}$$

22.13 Cathode Ray Oscilloscope

The cathode ray oscilloscope (commonly abbreviated as *CRO*) is an electronic device which is capable of giving a visual indication of a signal waveform. No other instrument used in the electronic industry is as versatile as the cathode ray oscilloscope. It is widely used for trouble shooting radio and television receivers as well as for laboratory work involving research and design. With an oscilloscope, the wave-shape of a signal can be studied with respect to amplitude distortion and deviation from the normal. In addition, the oscilloscope can also be used for measuring voltage, frequency and phase shift.

In an oscilloscope, the electrons are emitted from a cathode accelerated to a high velocity and brought to focus on a fluorescent screen. The screen produces a visible spot where the electron beam strikes. By deflecting the electron beam over the screen in response to the electrical signal, the electrons can be made to act as an *electrical pencil of light* which produces a spot of light wherever it

* During positive or negative half-cycle of input a.c. voltage, two diodes (D_1 and D_4 or D_2 and D_3) are in series.

strikes. An oscilloscope obtains its remarkable properties as a measuring instrument from the fact that it uses as an indicating needle a beam of electrons. As electrons have negligible mass, therefore, they respond almost instantaneously when acted upon by an electrical signal and can trace almost any electrical variation no matter how rapid. A cathode ray oscilloscope contains a *cathode ray tube* and necessary power equipment to make it operate.

22.14 Cathode Ray Tube

A cathode ray tube (commonly abbreviated as *CRT*) is the heart of the oscilloscope. It is a vacuum tube of special geometrical shape and converts an electrical signal into visual one. A cathode ray tube makes available plenty of electrons. These electrons are accelerated to high velocity and are brought to focus on a fluorescent screen. The electron beam produces a spot of light wherever it strikes. The electron beam is deflected on its journey in response to the electrical signal under study. The result is that electrical signal waveform is displayed visually. Fig. 22.20 shows the various parts of cathode ray tube.

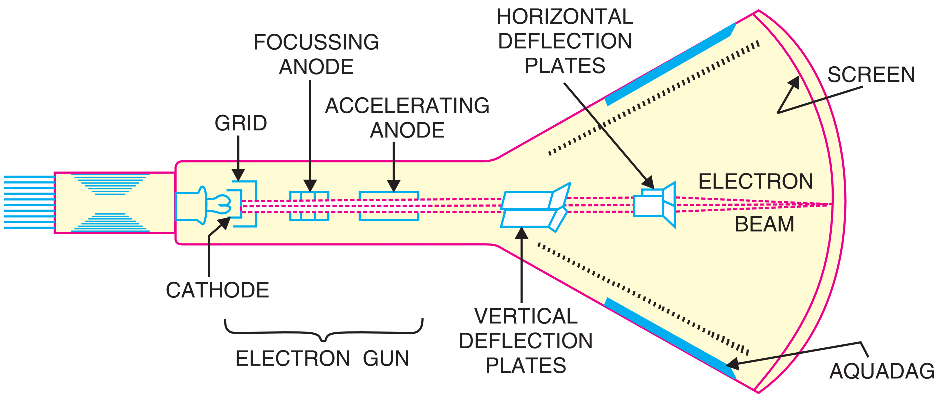

Fig. 22.20

(*i*) Glass envelope. It is conical highly evacuated glass housing and maintains vacuum inside and supports the various electrodes. The inner walls of *CRT* between neck and screen are usually coated with a conducting material, called *aquadag*. This coating is electrically connected to the accelerating anode so that electrons which accidentally strike the walls are returned to the anode. This prevents the walls of the tube from charging to a high negative potential.

(*ii*) Electron gun assembly. The arrangement of electrodes which produce a focussed beam of electrons is called the *electron gun.* It essentially consists of an indirectly heated *cathode*, a *control grid*, a *focussing anode* and an *accelerating anode*. The control grid is held at negative potential *w.r.t.* cathode whereas the two anodes are maintained at high positive potential *w.r.t.* cathode.

The cathode consists of a nickel cylinder coated with oxide coating and provides plenty of electrons. The control grid encloses the cathode and consists of a metal cylinder with a tiny circular opening to keep the electron beam small in size. The focussing anode focuses the electron beam into a sharp pin-point by controlling the positive potential on it. The positive potential (about 10,000 V) on the accelerating anode is much higher than on the focusing anode. For this reason, this anode accelerates the narrow beam to a high velocity. Therefore, the electron gun assembly forms a narrow, accelerated beam of electrons which produces a spot of light when it strikes the screen.

(*iii*) Deflection plate assembly. The deflection of the beam is accomplished by two sets of deflecting plates placed within the tube beyond the accelerating anode as shown in Fig. 22.20. One set is the *vertical deflection plates* and the other set is the *horizontal deflection plates*.

The vertical deflection plates are mounted horizontally in the tube. By applying proper potential to these plates, the electron beam can be made to move up and down vertically on the fluorescent screen. The horizontal deflection plates are mounted in the vertical plane. An appropriate potential on these plates can cause the electron beam to move right and left horizontally on the screen.

(*iv*) Screen. The screen is the inside face of the tube and is coated with some fluorescent material such as zinc orthosilicate, zinc oxide etc. When high velocity electron beam strikes the screen, a spot of light is produced at the point of impact. The colour of the spot depends upon the nature of fluorescent material. If zinc orthosilicate is used as the fluorescent material, green light spot is produced.

Action of CRT. When the cathode is heated, it emits plenty of electrons. These electrons pass through control grid on their way to screen. The control grid influences the amount of current flow as in standard vacuum tubes. If negative potential on the control grid is high, fewer electrons will pass through it and the electron beam on striking the screen will produce a dim spot of light. Reverse will happen if the negative potential on the control grid is reduced. Thus, the intensity of light spot on the screen can be changed by changing the negative potential on the control grid. As the electron beam leaves the control grid, it comes under the influence of focussing and accelerating anodes. As the two anodes are maintained at high positive potential, therefore, they produce a field which acts as an *electrostatic lens* to converge the electron beam at a point on the screen.

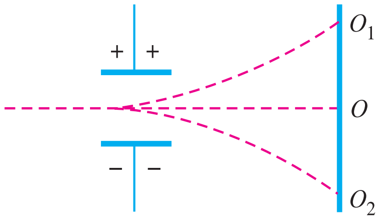

Fig. 22.21

As the electron beam leaves the accelerating anode, it comes under the influence of vertical and horizontal deflection plates. If no voltage is applied to the deflection plates, the electron beam will produce spot of light at the centre (point O in Fig. 22.21) of the screen. If the voltage is applied to vertical plates *only* as shown in Fig. 22.21, the electron beam and hence the spot of light will be deflected upwards (point O_1). The spot of light will be deflected downwards (point O_2) if the potential on the plates is reversed. Similarly, the spot of light can be moved horizontally by applying voltage across the horizontal plates.

22.15 Deflection Sensitivity of CRT

The shift of the spot of light on the screen per unit change in voltage across the deflection plates is known as *deflection sensitivity* of *CRT*. For instance, if a voltage of 100 V applied to the vertical plates produces a vertical shift of 3 mm in the spot, then deflection sensitivity is 0.03 mm/V. In general,

$$\text{Spot deflection} = \text{Deflection sensitivity} \times \text{Applied voltage}$$

The deflection sensitivity depends not only on the design of the tube but also on the voltage applied to the accelerating anode. The deflection sensitivity is low at high accelerating voltages and vice-versa.

Example 22.11. *The deflection sensitivity of a CRT is 0.01 mm/V. Find the shift produced in the spot when 400 V are applied to the vertical plates.*

Solution. As voltage is applied to the vertical plates only, therefore, the spot will be shifted vertically.

$$\begin{aligned} \text{Spot shift} &= \text{deflection sensitivity} \times \text{applied voltage} \\ &= 0.01 \times 400 = \mathbf{4\ mm} \end{aligned}$$

Example 22.12. *The deflection sensitivity of a CRT is 0.03 mm/V. If an unknown voltage is applied to the horizontal plates, the spot shifts 3 mm horizontally. Find the value of unknown voltage.*

Solution.

$$\begin{aligned} \text{Deflection sensitivity} &= 0.03 \text{ mm/V} \\ \text{Spot shift} &= 3 \text{ mm} \\ \text{Now, spot shift} &= \text{deflection sensitivity} \times \text{applied voltage} \end{aligned}$$

$$\therefore \qquad \text{Applied voltage} = \frac{\text{spot shift}}{\text{deflection sensitivity}} = \frac{3 \text{ mm}}{0.03 \text{ mm/V}} = \textbf{100 V}$$

22.16 Applying Signal Across Vertical Plates

If a sinusoidal voltage is applied to the vertical deflection plates, it will make the plates alternately positive and negative. Thus, in the positive half of the signal, upper plate will be positive and lower plate negative while in the negative half-cycle, the plate polarities will be reversed.

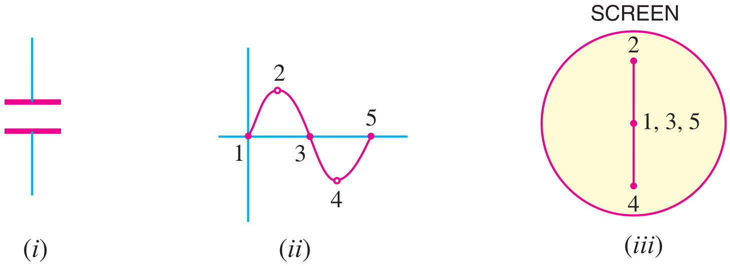

Fig. 22.22

The result is that the spot moves up and down at the same rate as the frequency of the applied voltage. As the frequency of applied voltage is 50 Hz, therefore, due to persistence of vision, we will see a continuous vertical line 2 - 1 - 4 on the screen as shown in Fig. 22.22 (*iii*). The line gives no indication of the manner in which the voltage is alternating since it does not reveal the waveform.

22.17 Display of Signal Waveform on CRO

One interesting application of *CRO* is to present the wave shape of the signal on the screen. As discussed before, if sinusoidal signal is applied to the vertical deflection plates, we get a vertical line. However, it is desired to see the signal voltage variations with time on the screen. This is possible only if we could also move the beam horizontally from left to right at a uniform speed while it is moving up and down. Further, as soon as a full cycle of the signal is traced, the beam should return quickly to the left hand side of the screen so that it can start tracing the second cycle.

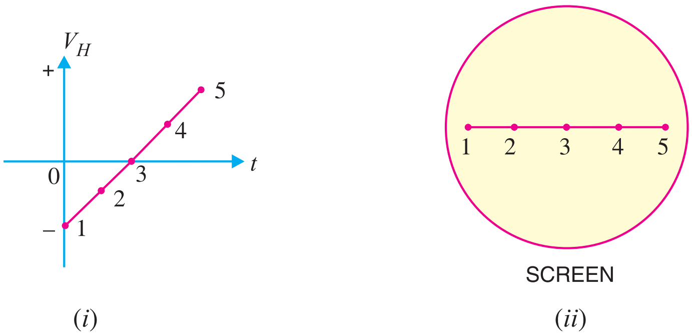

Fig. 22.23

In order that the beam moves from left to right at a uniform rate, a voltage that varies linearly with time should be applied to the horizontal plates. This condition is exactly met in the saw tooth wave shown in Fig. 22.23 (*i*).

When time $t = 0$, the negative voltage on the horizontal plates keep the beam to the extreme left on the screen as shown in Fig. 22.23 (*ii*). As the time progresses, the negative voltage decreases linearly with time and the beam moves towards right forming a horizontal line. In this way, the saw-tooth wave applied to horizontal plates moves the beam from left to right at a uniform rate.

22.18 Signal Pattern on Screen

If the signal voltage is applied to the vertical plates and saw-tooth wave to the horizontal plates, we get the exact pattern of the signal as shown in Fig. 22.24. When the signal is at the instant 1, its amplitude is zero. But at this instant, maximum negative voltage is applied to horizontal plates. The result is that the beam is at the extreme left on the screen as shown. When the signal is at the instant 2, its amplitude is maximum. However, the negative voltage on the horizontal plates is decreased. Therefore, the beam is deflected upwards by the signal and towards the right by the saw tooth wave. The result is that the beam now strikes the screen at point 2. On similar reasoning, the beam strikes the screen at points 3, 4 and 5. In this way, we have the exact signal pattern on the screen.

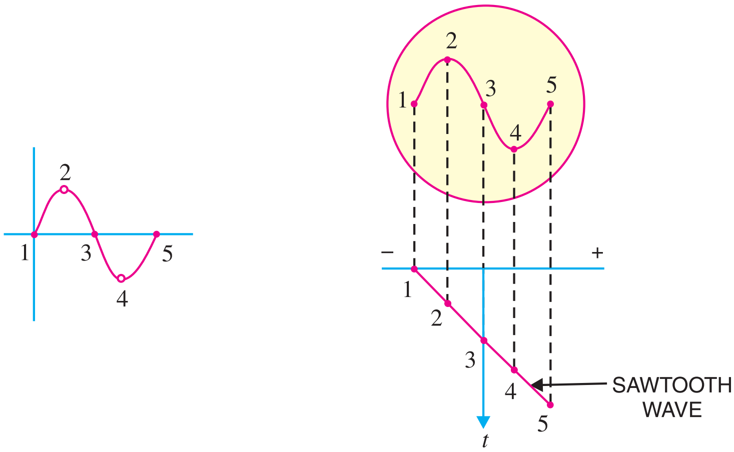

Fig. 22.24

22.19 Various Controls of CRO

In order to facilitate the proper functioning of *CRO*, various controls are provided on the face of *CRO*. A few of them are given below:

(*i*) *Intensity control.* The knob of intensity control regulates the bias on the control grid and affects the electron beam intensity. If the negative bias on the grid is increased, the intensity of electron beam is decreased, thus reducing the brightness of the spot.

(*ii*) *Focus control.* The knob of focus control regulates the positive potential on the focussing anode. If the positive potential on this anode is increased, the electron beam becomes quite narrow and the spot on the screen is a pin-point.

(*iii*) *Horizontal position control.* The knob of horizontal position control regulates the amplitude of d.c. potential which is applied to the horizontal deflection plates, in addition to the usual saw-tooth wave. By adjusting this control, the spot can be moved to right or left as required.

(*iv*) *Vertical position control.* The knob of vertical position control regulates the amplitude of d.c. potential which is applied to the vertical deflection plates in addition to the signal. By adjusting this control, the image can be moved up or down as required.

22.20 Applications of CRO

The modern cathode ray oscilloscope provides a powerful tool for solving problems in electrical measurements. Some important applications of *CRO* are :

1. Examination of waveforms
2. Voltage measurement
3. Frequency measurement

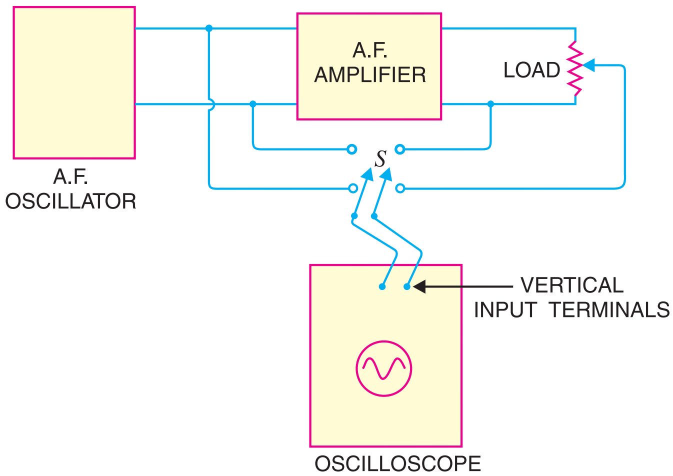

Fig. 22.25

1. Examination of waveform. One of the important uses of *CRO* is to observe the wave shapes of voltages in various types of electronic circuits. For this purpose, the signal under study is applied to vertical input (*i.e.*, vertical deflection plates) terminals of the oscilloscope. The sweep circuit is set to internal so that sawtooth wave is applied to the horizontal input *i.e.* horizontal deflection plates. Then various controls are adjusted to obtain sharp and well defined signal waveform on the screen.

Fig. 22.25 shows the circuit for studying the performance of an audio amplifier. With the help of switch *S*, the output and input of amplifier is applied in turn to the vertical input terminals. If the waveforms are identical in shape, the fidelity of the amplifier is excellent.

2. Voltage measurement. As discussed before, if the signal is applied to the vertical deflection plates only, a vertical line appears on the screen. The height of the line is proportional to peak-to-peak voltage of the applied signal. The following procedure is adopted for measuring voltages with *CRO*.

(*i*) Shut off the internal horizontal sweep generator.

(*ii*) Attach a transparent plastic screen to the face of oscilloscope. Mark off the screen with vertical and horizontal lines in the form of graph.

(*iii*) Now, calibrate the oscilloscope against a known voltage. Apply the known voltage, say 10 V, to the vertical input terminals of the oscilloscope. Since the sweep circuit is shut off, you will get a vertical line. Adjust the vertical gain till a good deflection is obtained. Let the deflection sensitivity be *V* volts/mm.

(*iv*) Keeping the vertical gain unchanged, apply the unknown voltage to be measured to the vertical input terminals of *CRO*.

(*v*) Measure the length of the vertical line obtained. Let it be *l* mm.

Then, Unknown voltage $= l \times V$ volts

3. Frequency measurement. The unknown frequency can be accurately determined with the help of a *CRO*. The steps of the procedure are as under :

(*i*) A known frequency is applied to horizontal input and unknown frequency to the vertical input.

(*ii*) The various controls are adjusted.

(*iii*) A pattern with loops is obtained.

(*iv*) The number of loops cut by the horizontal line gives the frequency on the vertical plates (f_v) and the number of loops cut by the vertical line gives the frequency on the horizontal plates (f_H).

$$\therefore \quad \frac{f_v}{f_H} = \frac{\text{No. of loops cut by horizontal line}}{\text{No. of loops cut by vertical line}}$$

For instance, suppose during the frequency measurement test, a pattern shown in Fig. 22.26 is obtained. Let us further assume that frequency applied to horizontal plates is 2000 Hz. If we draw horizontal and vertical lines, we find that one loop is cut by the horizontal line and two loops by the vertical line. Therefore,

$$\frac{f_v}{f_H} = \frac{\text{No. of loops cut by horizontal line}}{\text{No. of loops cut by vertical line}}$$

or $$\frac{f_v}{2000} = \frac{1}{2}$$

or $$f_v = 2000 \times 1/2 = 1000 \text{ Hz}$$

i.e. Unknown frequency is 1000 Hz.

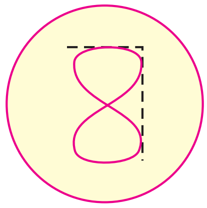

Fig. 22.26

Example 22.13. *In an oscilloscope, 200 V, 50 Hz signal produces a deflection of 2 cm corresponding to a certain setting of vertical gain control. If another voltage produces 3 cm deflection, what is the value of this voltage ?*

Solution. Deflection sensitivity = 200 V/2 cm = 100 V/cm

Unknown voltage = D. S. × deflection = 100 × 3 = **300 V**

Example 22.14. *When signals of different frequencies were applied to the vertical input terminals of oscilloscope, the patterns shown in Fig. 22.27 were obtained. If the frequency applied to horizontal plates in each case is 1000Hz, determine the unknown frequency.*

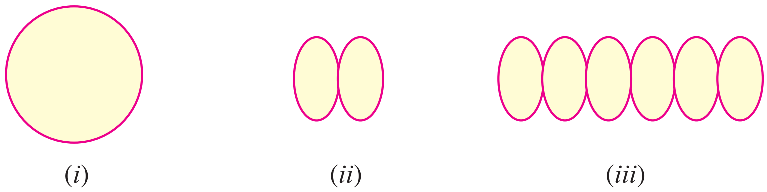

Fig. 22.27

Solution.

(*i*) The number of loops cut by horizontal and vertical line is one.

$$\therefore \quad \frac{f_v}{f_H} = \frac{1}{1} \quad \text{or} \quad f_v = f_H = \mathbf{1000 \text{ Hz}}$$

(*ii*) The number of loops cut by horizontal line is 2 and the number of loops cut by vertical line is 1.

$$\therefore \quad \frac{f_v}{f_H} = \frac{2}{1} \quad \text{or} \quad f_v = 2 \times f_H = 2 \times 1000 = \mathbf{2000 \text{ Hz}}$$

(*iii*) The number of loops cut by the horizontal line is 6 and that by vertical line is 1.

$$\therefore \quad \frac{f_v}{f_H} = \frac{6}{1}$$

or $$f_v = 6\, f_H = 6 \times 1000 = \mathbf{6000 \text{ Hz}}$$

MULTIPLE-CHOICE QUESTIONS

1. An ammeter is connected in .... with the circuit element whose current we wish to measure.
   (i) series
   (ii) parallel
   (iii) series or parallel
   (iv) none of the above
2. A galvanometer in series with a high resistance is called ....
   (i) an ammeter (ii) a voltmeter
   (iii) a wattmeter (iv) none of the above
3. An ammeter should have .... resistance.
   (i) infinite (ii) very large
   (iii) very low (iv) none of the above
4. A voltmeter is connected in .... with the circuit component across which potential difference is to be measured.
   (i) parallel
   (ii) series
   (iii) series or parallel
   (iv) none of the above
5. A voltmeter should have .... resistance.
   (i) zero (ii) very high
   (iii) very low (iv) none of the above
6. The sensitivity of a multimeter is given in ....
   (i) Ω (ii) amperes
   (iii) kΩ/V (iv) none of the above
7. If the full-scale deflection current of a multimeter is 50 μA, its sensitivity is ....
   (i) 10 kΩ/V (ii) 100 kΩ/V
   (iii) 50 kΩ/V (iv) 20 kΩ/V
8. If a multimeter has a sensitivity of 1000 Ω per volt and reads 50 V full scale, its internal resistance is...............
   (i) 20 kΩ (ii) 50 kΩ
   (iii) 10 kΩ (iv) none of the above
9. A *VTVM* has .... input resistance than that of a multimeter.
   (i) more (ii) less
   (iii) same (iv) none of the above
10. The input resistance of a *VTVM* is about ....
   (i) 1000 Ω (ii) 10 kΩ
   (iii) 20 kΩ (iv) 10 MΩ
11. If the negative potential on the control grid of *CRT* is increased, the intensity of spot ....
   (i) is increased
   (ii) is decreased
   (iii) remains the same
   (iv) none of the above
12. For display of signal pattern .... voltage is applied to the horizontal plates of a *CRO*.
   (i) sinusoidal (ii) rectangular
   (iii) sawtooth (iv) none of the above
13. Two multimeters *A* and *B* have sensitivities of 10 kΩ/V and 30 kΩ/V respectively. Then ....
   (i) multimeter *A* is more sensitive
   (ii) multimeter *B* is more sensitive
   (iii) both are equally sensitive
   (iv) none of the above
14. A galvanometer of resistance *G* is shunted by a very small resistance *S*. The resistance of the resulting ammeter is ....
   (i) $\frac{GS}{G+S}$ (ii) $G + S$
   (iii) $G - S$ (iv) none of the above
15. A *VTVM* is never used to measure ....
   (i) voltage (ii) current
   (iii) resistance (iv) none of the above
16. The sensitivity of a voltmeter which uses a 100 μA meter movement is ....
   (i) 1 kΩ/V (ii) 10 kΩ/V
   (iii) 5 kΩ/V (iv) data insufficient
17. What is the total resistance of a voltmeter on the 10 V range when the meter movement is rated for 50 μA of full-scale current ?
   (i) 10 kΩ (ii) 20 kΩ
   (iii) 200 kΩ (iv) none of the above
18. The material used to coat inside face of *CRT*

is ....

(i) carbon (ii) sulphur

(iii) silicon (iv) phosphorus

19. When an ammeter is inserted in the circuit, the circuit current will ....

(i) increase

(ii) decrease

(iii) remain the same

(iv) none of the above

20. A series ohmmeter circuit uses a 3 V battery and a 1 mA meter movement. What is the half-scale resistance for this movement ?

(i) 3 kΩ (ii) 1.5 kΩ

(iii) 4.5 kΩ (iv) 6 kΩ

21. The most accurate device for measuring voltage is ....

(i) voltmeter (ii) multimeter

(iii) *CRO* (iv) *VTVM*

22. The horizontal plates of a *CRO* are supplied with .... to observe the waveform of a signal.

(i) sinusoidal wave

(ii) cosine wave

(iii) sawtooth wave

(iv) none of the above

23. A *CRO* is used to measure ....

(i) voltage (ii) frequency

(iii) phase (iv) all of above

24. If 2 % of the main current is to be passed through a galvanometer of resistance *G*, then resistance of the shunt required is ....

(i) $G/50$ (ii) $G/49$

(iii) $49\ G$ (iv) $50\ G$

25. Which of the following is likely to have the largest resistance ?

(i) voltmeter of range 10 V

(ii) moving coil galvanometer

(iii) ammeter of range 1 A

(iv) a copper wire of length 1 m and diameter 3 mm

26. An ideal ammeter has .... resistance.

(i) low (ii) infinite

(iii) zero (iv) high

27. The resistance of an ideal voltmeter is ....

(i) low (ii) infinite

(iii) zero (iv) high

28. To send 10% of the main current through a moving coil galvanometer of resistance 99 Ω, the shunt required is ....

(i) 11 Ω (ii) 9.9 Ω

(iii) 100 Ω (iv) 9 Ω

29. A voltmeter has a resistance of *G* ohms and range *V* volts. The value of resistance required in series to convert it into voltmeter of range *nV* is ....

(i) nG (ii) $\frac{G}{n}$

(iii) $\frac{G}{n-1}$ (iv) $(n-1)\,G$

30. An ammeter has a resistance of *G* ohms and range of *I* amperes. The value of resistance required in parallel to convert it into an ammeter of range *nI* is ....

(i) nG (ii) $(n-1)\,G$

(iii) $\frac{G}{n-1}$ (iv) $\frac{G}{n}$

Answers to Multiple-Choice Questions

1. (i)	2. (ii)	3. (iii)	4. (i)	5. (ii)
6. (iii)	7. (iv)	8. (ii)	9. (i)	10. (iv)
11. (ii)	12. (iii)	13. (ii)	14. (i)	15. (ii)
16. (ii)	17. (iii)	18. (iv)	19. (ii)	20. (i)
21. (iii)	22. (iii)	23. (iv)	24. (ii)	25. (i)
26. (iii)	27. (ii)	28. (i)	29. (iv)	30. (iii)

Chapter Review Topics

1. What is a multimeter ? How does it work ?
2. What type of measurements can be made with a multimeter ? Explain with suitable diagrams.
3. Briefly explain the advantages of 20 kΩ/volt multimeter as compared to a 10 kΩ/volt multimeter.
4. What are the applications of a multimeter ?
5. Discuss the advantages and disadvantages of a multimeter.
6. What is a *VTVM* ? Explain balanced bridge Type *VTVM* with a neat circuit diagram.
7. What are the applications of *VTVM* ?
8. Discuss the advantages and disadvantages of *VTVM*.
9. Briefly explain the differences between a *VTVM* and a multimeter.
10. Explain the construction and working of a cathode ray tube.
11. How will you make the following measurements with a *CRO* :
    (*i*) voltage (*ii*) frequency ?
12. Write short notes on the following :
    (*i*) Limitations of multimeter
    (*ii*) Advantages of oscilloscope
    (*iii*) Vacuum tube voltmeter
    (*iv*) Oscilloscope controls

Problems

1. A voltmeter is used to measure voltage across 20 kΩ resistor as shown in Fig. 22.28. What will be the voltage value if (*i*) voltmeter has infinite resistance (*ii*) voltmeter has a sensitivity of 1000 Ω per volt and reads 100 V full scale ? **[(*i*) 50 V (*ii*) 45 V]**

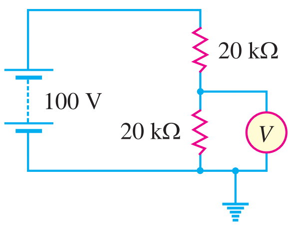

Fig. 22.28

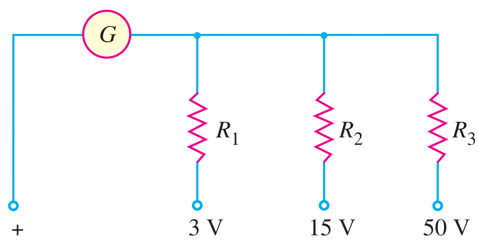

Fig. 22.29

2. The three range voltmeter is arranged as shown in Fig. 22.29. The ranges are 0 to 3 V, 0 to 15 V and 0 to 50 V as marked. If the full scale deflection current is 10 mA, what should be the values of R_1, R_2 and R_3 ? The resistance of the meter is 5 Ω. **[305 Ω, 1505 Ω, 5005 Ω]**
3. If the sensitivity of voltmeter in Fig. 22.28 is 500 Ω/volt (Full-scale reading being 100 V), what will be the reading of the voltmeter ? **[41.7 V]**
4. What is the lowest full-scale voltage that could be displayed with a 100 μA meter movement with an internal resistance of 150 Ω ? What would be the sensitivity of this meter in ohms per volt ? **[15 mV, 10,000 Ω/V]**
5. If a 20,000 Ω/V meter with 5 kΩ internal resistance is used in an ohmmeter with a 3-V-battery, what internal resistance is required in the meter to produce proper zeroing? **[60 kΩ]**
6. A PMMC instrument with f.s.d. = 100 μA and R_m = 1 kΩ is to be used as an a.c. voltmeter with f.s.d. = 100 V (r.m.s.) as shown in Fig. 22.18. Silicon diodes are used in the bridge rectifier circuit. Calculate the pointer indications for the voltmeter when the r.m.s. input voltage is (*i*) 75 V (*ii*) 50V. **[0.75 f.s.d. ; 0.5 f.s.d.]**
7. In the above example, calculate the voltmeter sensitivity. **[9 kΩ/V]**

Discussion Questions

1. Why is sensitivity of best multimeter not more than 20 kΩ per volt ?
2. Why do we generally prefer *VTVM* to multimeter for measurements in electronic circuits ?
3. Why does oscilloscope give more accurate measurements than a *VTVM* ?
4. What is the basic difference between vacuum tubes and cathode ray tube ?
5. How can a multimeter be used for continuity checking ?
6. Which would usually have more linear scales, dc or ac meters ?
7. Which is more sensitive, a 0 – 59 μA or a 0 – 1 mA meter ?
8. On a multirange ohmmeter, where is 0 Ω mark ?
9. What component prevents meter damage in a *VTVM*?
10. Could a 0 – 1 mA-movement 100 – V voltmeter and a 0 – 50 μA – movement 100 – V voltmeter be used in series across 125 V ?

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