

**RADIO AMATEUR EXAM**  
**GENERAL CLASS**

By **4S7VJ**

**CHAPTER-7**      **MEASUREMENTS**

**7.1**      **TEST EQUIPMENT & MEASUREMENTS**

Correct operation of amateur radio equipment involves measurements to ensure optimum performance, to comply with the terms of the amateur transmitting licence and to avoid interference to other users. The purpose of these measurements is to give the operator information regarding the conditions under which his equipment is functioning. Basically, they are concerned with voltage, current and frequency.

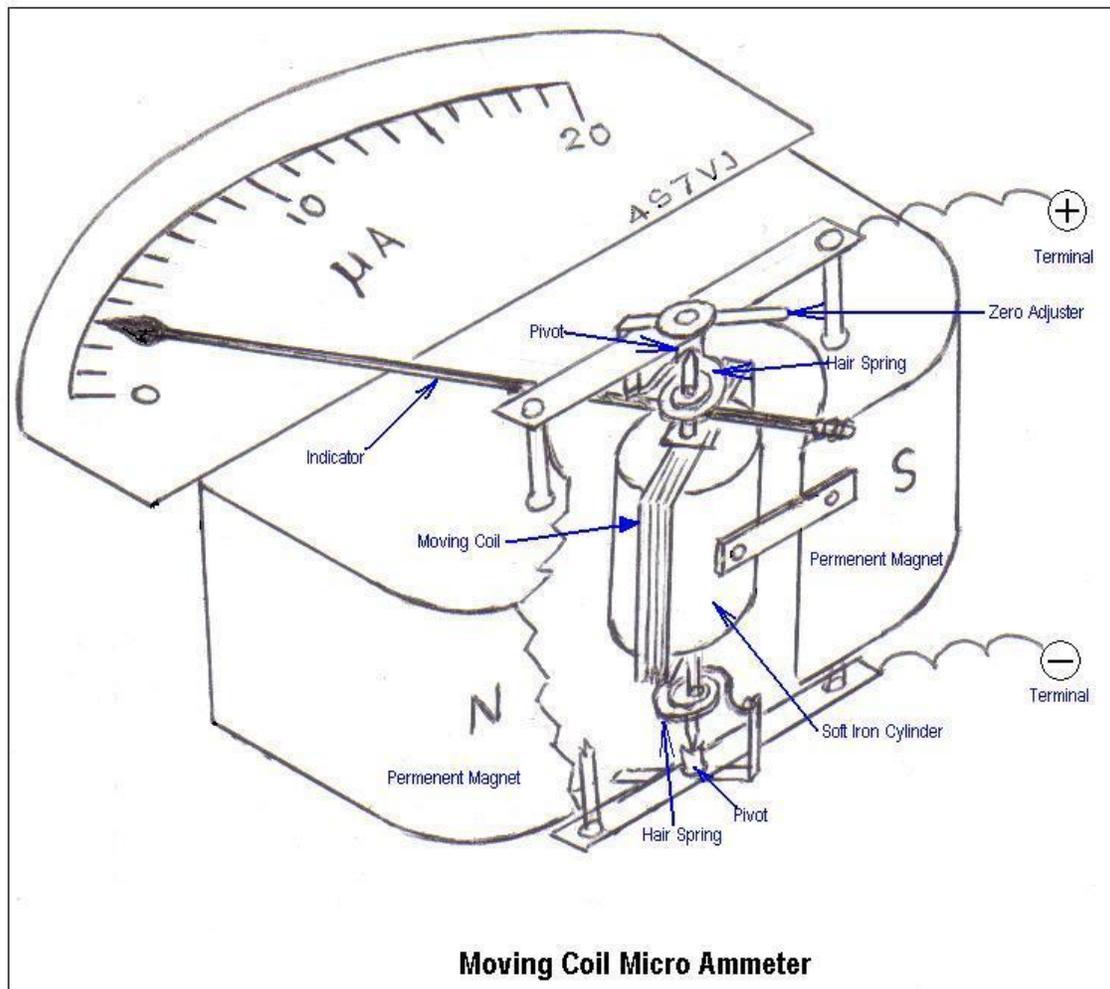


Fig 7.1

**7.1.1 Galvanometer**

The basis of most instruments for the measurement of voltage, current and resistance is the moving coil galvanometer, (Fig 7.1) calibrated for microampere ( $\mu\text{A}$ ) or milli-ampere (mA) or with an arbitrary scale. If it is calibrated for mA, it is called milliammeter. The heart of this is a coil with very thin wire generally wound on a rectangular former, is mounted on two pivots in the field of a permanent magnet. The coil experiences a torque proportional to the flow of current through it. Current is fed to the coil through two hairsprings mounted near to each end of the spindle. These springs also serve to return the pointer to the zero position when the current stops. Normally the scale is linear. This instrument can only be used on dc, but it can be adapted to measure ac with using a diode as a rectifier.

**7.1.2 Ammeter**

Milliammeters and microammeters are commonly manufactured with basic full-scale deflection (F.S.D.) of  $50\mu\text{A}$ ,  $100\mu\text{A}$ , 1mA. For higher current ratings, a shunt resistor with very low value, connected across the meter (Fig 7.2a). There are two methods for select the correct shunt resistor.

1. Compare with accurately calibrated ammeter and adjust the resistance of the shunt. (Fig 7.2b)
2. Calculate the resistance of the shunt with using Ohm's law. The following formula is derived with using this method. (Fig 7.2c)

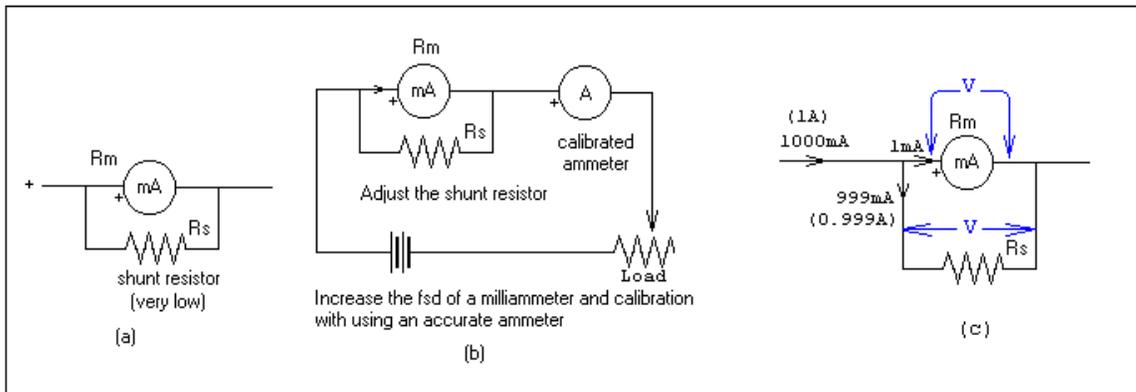


Fig 7.2

$$R_s = R_m / (n - 1)$$

Where,  $R_s$  is the resistance of the shunt.  $R_m$  is the internal resistance of the milliammeter.  $n$  is the scale multiplying factor.

$$n = \text{FSD of the ammeter} / \text{FSD of the milliammeter}$$

**Example:-**

Internal resistance of a milliammeter is  $10\Omega$  and FSD is  $1\text{mA}$ . What is the shunt resistor for converting it to an ammeter with  $1\text{A}$  of FSD?

**1<sup>st</sup> Method: (with using the above formula)**

$$R_m = 10\Omega, n = 1\text{A}/1\text{mA} = 1000\text{mA}/1\text{mA} = 1000$$

$$R_s = R_m / (n - 1) = 10 / (1000 - 1) = 10 / 999 = 0.01001\Omega \text{ or } 10.01\text{m}\Omega \text{ (approximately } 10\text{m}\Omega)$$

**2<sup>nd</sup> Method: (with using Ohm's law)**

We can solve this problem without use any formula other than Ohm's law.

As shown fig 7.2(c) when it is  $1\text{A}$  FSD, the input current to the system is  $1\text{A}$  and it is divided into two portions;  $1\text{mA}$  flow through the milliammeter and the balance  $999\text{mA}$  is passing through the shunt resistor ' $R_s$ '. Now apply Ohm's law ( **$V = I R$** ) to the milliammeter

$$V = 0.001 \times 10 \text{ because } I = 1\text{mA} = 0.001\text{A}, R = 10\Omega \\ = 0.01 \text{ volt}$$

Now apply Ohm's law for the shunt resistor,  $R_s$

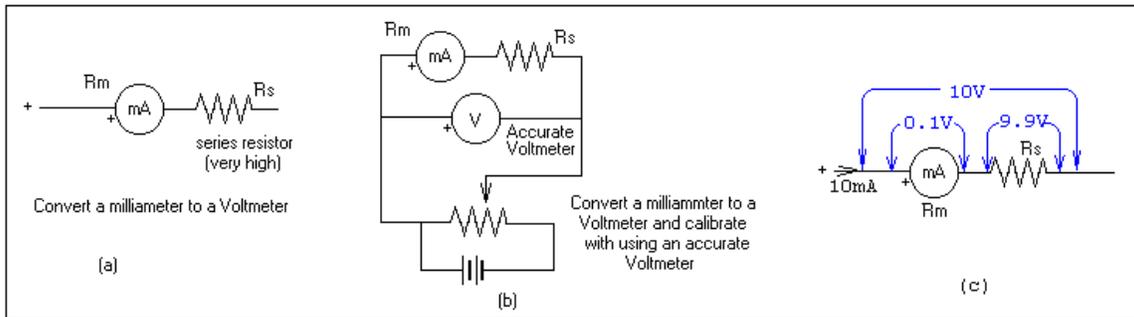
$$0.01 = 0.999 \times R_s$$

Because  $V=0.01$  (voltage across the milliammeter and shunt resistor are same),  $I = 0.999\text{A}$

$$\text{Therefore } R_s = 0.01 / 0.999 \\ = 0.01001\Omega \text{ (} 10.01\text{m}\Omega) \\ = 10\text{m}\Omega \text{ (Approximately)}$$

For this shunt resistor you can use a piece of copper wire. If you use  $20\text{swg}$  copper wire, about  $30\text{cm}$  is suitable.

**7.1.3 Volt meter**



**Fig 7.3**

A milliammeter may be used to read small dc voltages; few milli volts. For example, if the FSD 0.5mA and the internal resistance  $100\Omega$ , by using Ohm's law, the voltage between the terminals of the meter is  $0.5 \times 100$  or 50mV. That means it can be used as a mV meter with 50mV FSD. We can calibrate the scale accordingly.

It is possible to extend the scale or use to read higher voltages by connecting a large resistor (multiplier) in series with it (Fig 7.3a). The value of this resistor depends on the FSD of the meter (original FSD and extended FSD) and may be calculated from Ohm's law. The following formula can be used for the calculation:

$$R_s = R_m \times (n-1)$$

Where  $n = \text{FSD of voltmeter} / \text{FSD of mV-meter}$

If  $n$  is a large value (100 or more),  $n$  and  $n-1$  approximately equal, then

$$R_s = R_m \times n$$

Where  $R_s$  is the value of the series resistor and  $R_m$  is the internal resistance of the meter and  $n$  is the scale multiplying factor;

**Example :-**

Internal resistance of a milliammeter is  $10\Omega$  and FSD is  $10\text{mA}$ . What is the series resistor for converts it into a voltmeter with  $10\text{V}$  of FSD?

**1<sup>st</sup> methode:-** (using the formula)

Apply Ohm's low for the milliammeter, then

$$\begin{aligned} \text{FSD voltage} &= 10\text{mA} \times 10\Omega \\ &= 0.01\text{A} \times 10\Omega \\ &= 0.1\text{V} \\ n &= 10\text{V}/0.1\text{V} \\ &= 100 \\ R_m &= 10\Omega \\ R_s &= R_m \times (n-1) \\ &= 10 \times (100-1) \\ &= \underline{990\Omega} \quad (\text{approximately } 1\text{k}\Omega) \end{aligned}$$

**2<sup>nd</sup> Methode:-** With using Ohm's law (without formula)

Apply Ohm's law for the milliammeter

$$V = IR$$

$$I = 10\text{mA} = 0.01\text{A}, R = R_m = 10\Omega$$

$$\begin{aligned} \text{Therefore } V &= 0.01 \times 10 \\ &= 0.1 \text{ volt} \end{aligned}$$

Now apply the Ohm's law for the series resistor- $R_s$

$$V = 10 - 0.1 = 9.9 \text{ volt}, I = 10\text{mA} = 0.01\text{A}$$

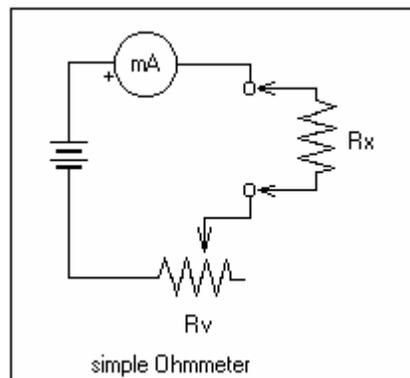
$$V = IR$$

$$\text{Therefore } 9.9 = 0.01 \times R_s$$

$$R_s = 9.9/0.01$$

$$= \underline{990 \Omega} \quad (\text{approximatly } 1\text{k}\Omega)$$

#### 7.1.4 Ohm meter



**Fig 7.4**

The measurement of resistance is based on Ohm's law, simple arrangement being shown in Fig 7.4. It will be seen that the circuit comprises a battery in series with a milliammeter, a variable resistor,  $R_v$  and an unknown resistor  $R_x$ . In practice, the terminals across which  $R_x$  is connected are first, short circuited and  $R_v$  adjusted until the meter reads full scale. The zero is in the right hand end or the FSD point and left-hand corner marked as infinity and the scale is not linear. Connecting a number of resistors of known value across the terminals in turn marking the scale accordingly can therefore carry out calibration.

### **7.1.5 Multimeter**

A number of shunts and multipliers selected by a switch can be used in association with a single basic meter to form a multi-range meter or multimeter measuring current, voltage, (ac and dc) and resistance. This is very useful basic instrument for radio amateurs.

#### **7.1.5.1 Digital Multimeter**

This is an advanced version of the Multi meter, having digital display for the reading.

Most of digital multimeters have some more facilities as follows:-

1. Capacitance meter
2. Inductance meter
3. Frequency meter
4. Transistor checker

#### **7.1.6 Frequency Counter**

This instrument can use for measure the exact frequency with high accuracy for AF or RF, which is indicating a digital display.

#### **7.1.7 Dip meter (GDO)**

This is also a frequency measuring instrument. This is really nothing more than a calibrated oscillator, which can be tuned over wide range of frequencies (1.5 to 250MHz) and which has a moving coil meter indicating the grid current (for valve type old version) or collector current (for solid state modern version). The valve type old version named as "**Grid Dip Oscillator**" (GDO)

Since the Dip Meter provides it's own RF energy it does not require the circuit being checked to be energized. It is therefore useful for checking the resonant frequency of tuned circuits or antenna systems.

The Dip Meter is also useful as an absorption wavemeter or simple signal generator.



Fig 7.5 (Dip meter)

### 7.1.8 Oscilloscope

The oscilloscope is one of the most versatile instruments an amateur can possess and permits the visual display of AF and RF signals. It is particularly useful for monitoring the wave-form, measure the frequency and voltage.

Fig 7.6 shows an Oscilloscope with the wave-form of a sin-wave signal. If two sin-wave signals input as the horizontal and vertical deflections, the result will be special kind of a curve called as "Lissajous" curve. The shape of this curve depends on the ratio of two frequencies and the phase difference.

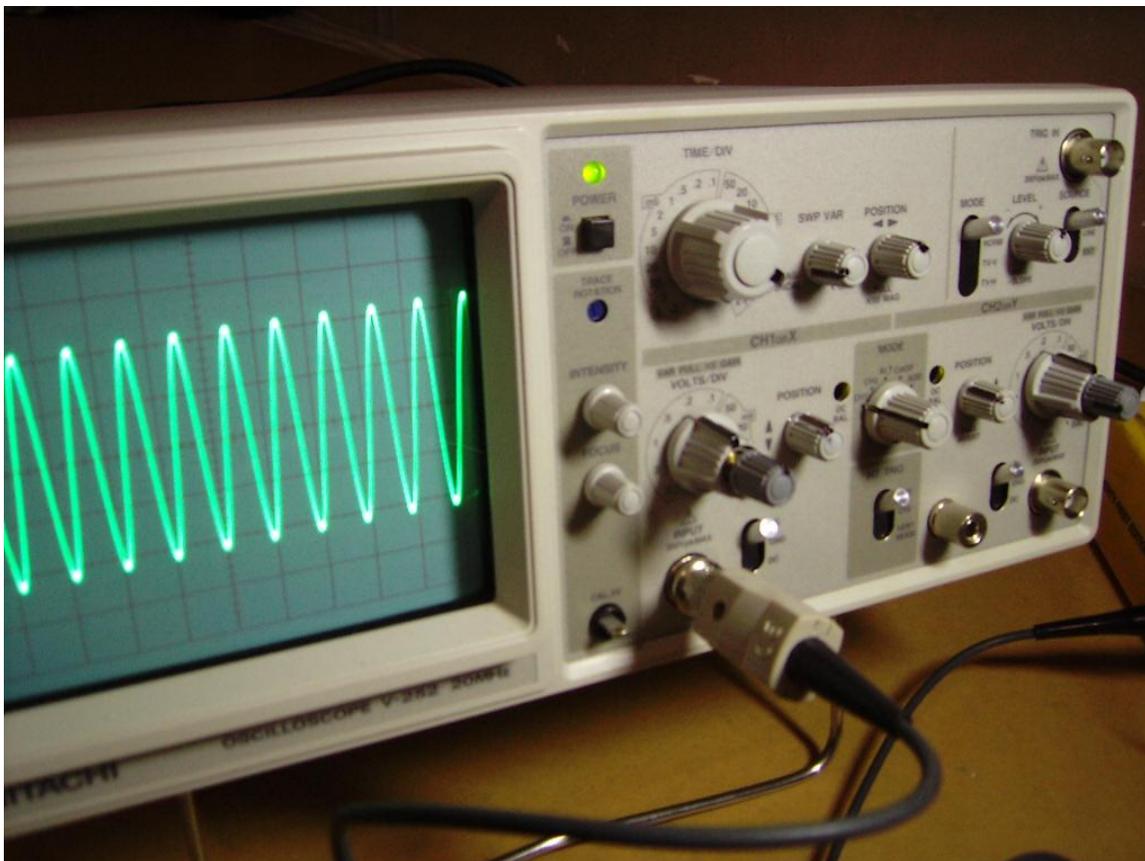


Fig 7.6 (Oscilloscope)

### 7.1.9 RF milliammeter

Measuring RF current and voltages, there is a special type of a milliammeter, using with a thermocouple. The measuring current is passing through a resistance wire, therefore it is getting heated. Junction of a thermocouple is connected to the middle portion of this wire and two terminals of the thermocouple are connected to an ordinary galvanometer. While heating the junction of the thermocouple small dc voltage is generating and it is measured by the galvanometer. The meter should be calibrated for RF voltage or current accordingly.

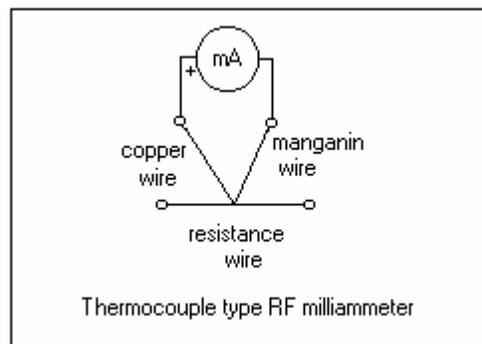


Fig 7.7

## 7.2 POWER MEASUREMENTS

Power in dc circuit is determined by measuring the current and voltage. When these are known, the power is equal to the voltage multiply by the current. If the voltage in Volts and current in Amperes, then the power will be in Watts. (  $W = VI$  )

Multiplication of the RF current and the voltage of a TX is the RF power output. If it is properly matched to the transmission line, it can be calculate with using the RF current and the characteristic impedance of the transmission line. (  $W = I^2Z$ ,  $W = V^2 / Z$  )

More convenient way is to measure the dc input power of the RF amplifier. For valve amplifiers this power is proportional to the anode current or cathode current of the final valve because the anode voltage is a constant, known value.

For solid state amplifiers it is proportional to the collector current of the final power transistors.

### 7.2.1 SWR and Power meter

SWR and power meter is very essential equipment for any Amateur Radio shack (see Fig-7.8A and Fig-7.8B). This is very simple instrument, explained in chapter-6 (Fig 6.4) for HF use. You can calibrate the meter dial for SWR and relative power levels.

For get the reading of SWR first keep the steady power output and adjust the middle knob of the SWR meter until the power meter (forward power) indicator shows "SET" position, then SWR meter (reflected power) shows the correct SWR.

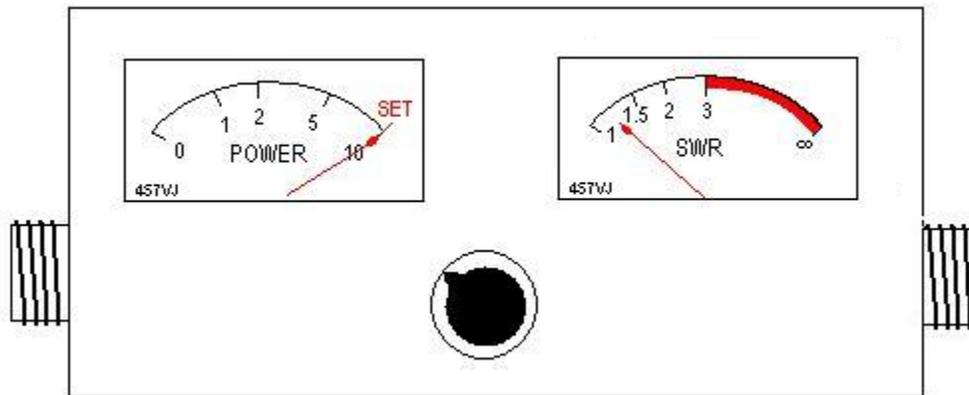


Fig-7.8A



Fig 7.8B

Fig 7.9 shows the correct calibration. The FSD of this meter is 10 units ( mA or  $\mu$ A or any unit) according to the middle scale. Lower scale calibrated for SWR and upper scale for power, if the output power is 100 watts then the meter should be adjusted for FSD at 100w. Then FSD-10 is equivalent to FSD of 100 watts.

If you use a cheaper quality meter, ( like record level indicator meter) the scale may not a linear scale. So you can use the mA or mV scale as the scale reading.

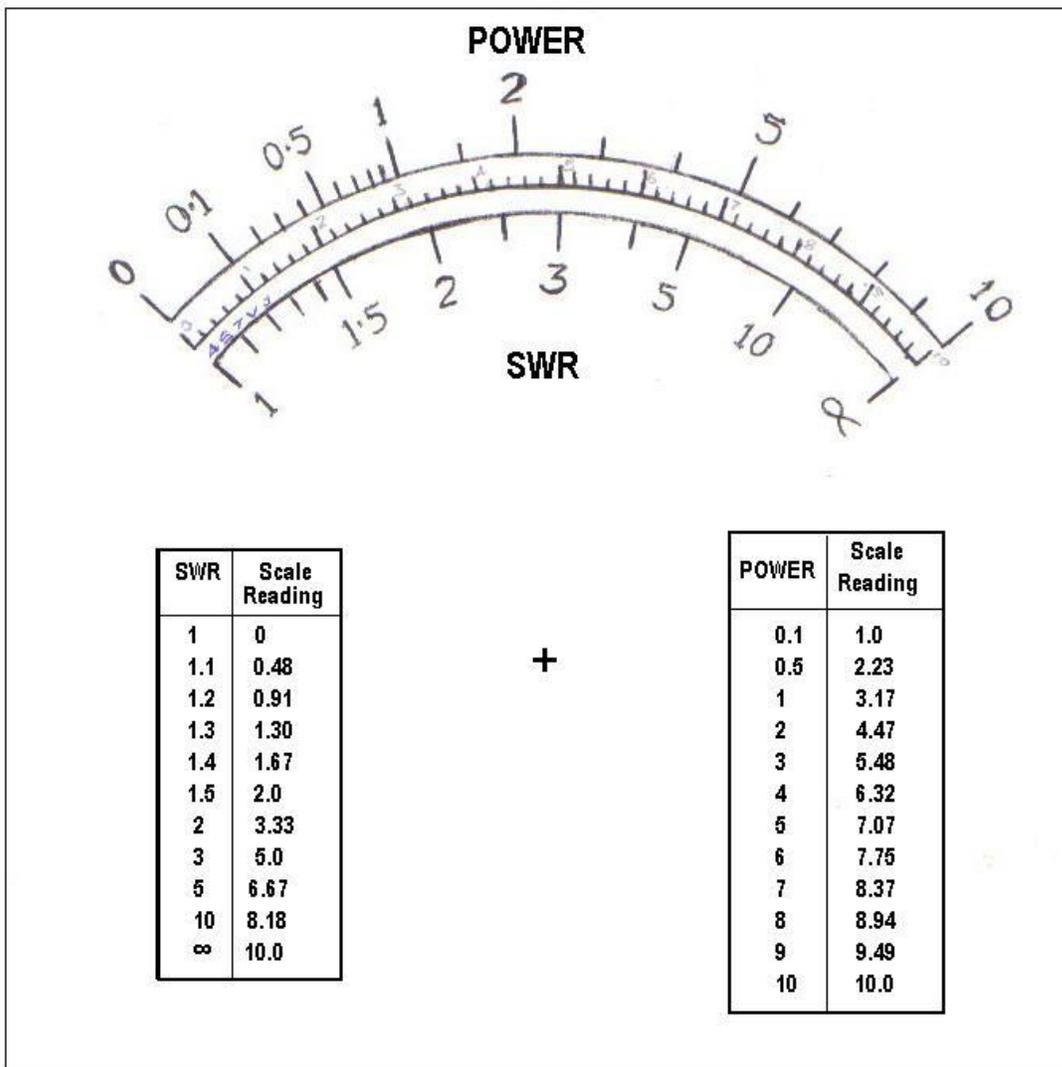


Fig-7.9

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**EXERCISES**

7.1 FSD of a moving coil meter is  $500 \mu\text{A}$  and the internal resistance is  $200\Omega$ . If it is converted to an Ammeter with  $10\text{A}$  of FSD what is the value of shunt resistor?

(Ans:-  $10 \text{ m}\Omega$ )

7.2 FSD for voltage and current of a moving coil instrument are  $10\text{mV}$  and  $0.2\text{mA}$  If it is converted to:

- (a) Ammeter having  $10\text{A}$ , FSD
- (b) DC Voltmeter having FSD of  $150\text{V}$
- (c) AC Voltmeter having FSD of  $300\text{V}$

How do you connect a shunt or series resistor and draw a circuit diagram.

- Ans:-
- (a)  $1\text{m}\Omega$  parallel with meter
  - (b)  $749950 \Omega$  or approximately  $750\text{k}\Omega$  resistor with series
  - (c)  $750\text{k}\Omega$  resistor and diode in series