

Module 10

Measuring Instruments

Lesson 42

Study of DC-AC Measuring Instruments

Objectives

- To understand the basic construction of a permanent magnet moving coil (PMMC) instrument and its operation.
- Sketch and explain circuit diagrams for electromechanical dc ammeters and voltmeters.
- To understand how a single instrument may be used for multi-range ammeters and voltmeters.
- To study the advantage and limitation of PMMC instruments.
- To understand the basic construction of Moving-iron Instrument and its principle operation.
- To study the advantage and errors involved in moving-iron instruments.

L.42.1 Introduction

Measuring instruments are classified according to both the quantity measured by the instrument and the principle of operation. Three general principles of operation are available: (i) electromagnetic, which utilizes the magnetic effects of electric currents; (ii) electrostatic, which utilizes the forces between electrically-charged conductors; (iii) electro-thermic, which utilizes the heating effect.

Electric measuring instruments and meters are used to indicate directly the value of current, voltage, power or energy. In this lesson, we will consider an electromechanical meter (input is as an electrical signal results mechanical force or torque as an output) that can be connected with additional suitable components in order to act as an ammeter and a voltmeter. The most common analogue instrument or meter is the permanent magnet moving coil instrument and it is used for measuring a dc current or voltage of a electric circuit. On the other hand, the indications of alternating current ammeters and voltmeters must represent the RMS values of the current, or voltage, respectively, applied to the instrument.

L.42.1.1 Various forces/torques required in measuring instruments

- Deflecting torque/force: The deflection of any instrument is determined by the combined effect of the deflecting torque/force, control torque/force and damping torque/force. The value of deflecting torque must depend on the electrical signal to be measured; this torque/force causes the instrument movement to rotate from its zero position.
- Controlling torque/force: This torque/force must act in the opposite sense to the deflecting torque/force, and the movement will take up an equilibrium or definite position when the deflecting and controlling torque are equal in magnitude. Spiral springs or gravity usually provides the controlling torque.
- Damping torque/force: A damping force is required to act in a direction opposite to the movement of the moving system. This brings the moving system to rest at the deflected position reasonably quickly without any oscillation or very small oscillation. This is provided by i) air friction ii) fluid friction iii) eddy current. It should be pointed out that any damping force shall not influence the steady state deflection produced by a given deflecting force or torque. Damping force

increases with the angular velocity of the moving system, so that its effect is greatest when the rotation is rapid and zero when the system rotation is zero. Details of mathematical expressions for the above torques are considered in the description of various types of instruments.

L.42.2 General Theory Permanent Magnet Moving Coil (PMMC) Instruments

The general theory of moving-coil instruments may be dealt with considering a rectangular coil of N turns, free to rotate about a vertical axis.

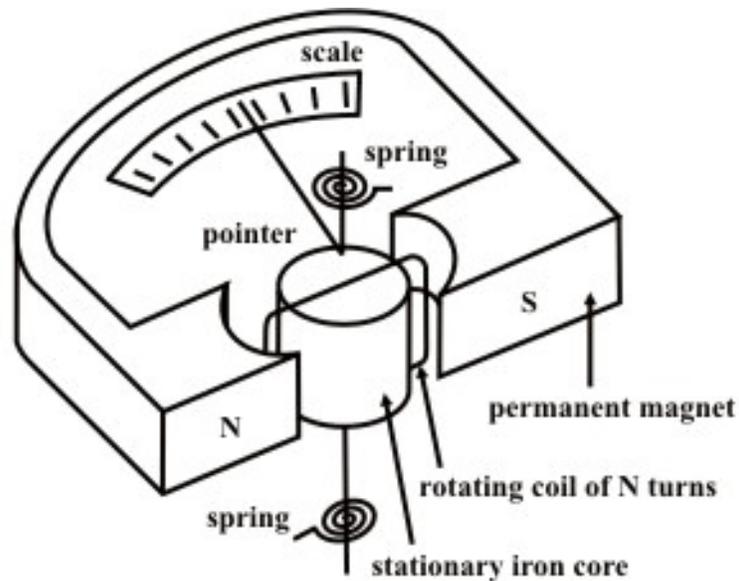


Fig. 42.1(a): Permanent Magnet Moving Coil Instrument.

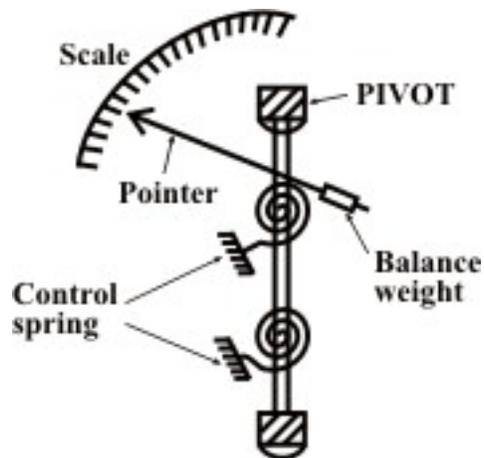


Fig. 42.1(b)

Fig. 42.1(a) shows the basic construction of a PMMC instrument. A moving coil instrument consists basically of a permanent magnet to provide a magnetic field and a small lightweight coil is wound on a rectangular soft iron core that is free to rotate around

its vertical axis. When a current is passed through the coil windings, a torque is developed on the coil by the interaction of the magnetic field and the field set up by the current in the coil. The aluminum pointer attached to rotating coil and the pointer moves around the calibrated scale indicates the deflection of the coil. To reduce parallax error a mirror is usually placed along with the scale. A balance weight is also attached to the pointer to counteract its weight (see Fig. 42.1(b)). To use PMMC device as a meter, two problems must be solved. First, a way must be found to return the coil to its original position when there is no current through the coil. Second, a method is needed to indicate the amount of coil movement. The first problem is solved by the use of hairsprings attached to each end of the coil as shown in Fig. 42.1(a). These hairsprings are not only supplying a restoring torque but also provide an electric connection to the rotating coil. With the use of hairsprings, the coil will return to its initial position when no current is flowing through the coil. The springs will also resist the movement of coil when there is current through coil. When the developing force between the magnetic fields (from permanent magnet and electro magnet) is exactly equal to the force of the springs, the coil rotation will stop. The coil set up is supported on jeweled bearings in order to achieve free movement. Two other features are considered to increase the accuracy and efficiency of this meter movement. First, an iron core is placed inside the coil to concentrate the magnetic fields. Second, the curved pole faces ensure the turning force on the coil increases as the current increases.

It is assumed that the coil sides are situated in a uniform radial magnetic field of flux density $B \text{ wb/m}^2$, let the length of a coil side (within the magnetic field) be l (meter), and the distance from each coil side to the axis be r (meter).

Principle of operation

It has been mentioned that the interaction between the induced field and the field produced by the permanent magnet causes a deflecting torque, which results in rotation of the coil. The deflecting torque produced is described below in mathematical form:

Deflecting Torque: If the coil is carrying a current of $i \text{ amp.}$, the force on a coil side = $BilN$ (newton, N). (42.1)

$$\therefore \text{Torque due to both coil sides} = (2r)(BilN) \text{ (Nm)} \\ = Gi \text{ (Nm)} \quad (42.2)$$

where G is the Galvanometer constant and it is expressed as $G = 2rBIN$ (Nm/amp.) = NBA (Nm/amp.). (note $A = 2rl = \text{area of the coil.}$)

N = no. of turns of the coil.

B = flux density in Wb/m^2 Wb/m^2 .

l = length of the vertical side of the coil, m.

$2r$ = breadth of the coil, m

i = current in ampere.

$A = 2rl = \text{area, m}^2$

Truly speaking, the equation (42.2) is valid while the iron core is cylindrical and the air gap between the coil and pole faces of the permanent magnet is uniform. This result the

flux density B is constant and the torque is proportional to the coil current and instrument scale is linear.

Controlling Torque: The value of control torque depends on the mechanical design of the control device. For spiral springs and strip suspensions, the controlling torque is directly proportional to the angle of deflection of the coil.

$$\text{i.e., Control torque} = C\theta \quad (42.3)$$

where, θ = deflection angle in radians and C = spring constant Nm/rad .

Damping Torque: It is provided by the induced currents in a metal former or core on which the coil is wound or in the circuit of the coil itself. As the coil moves in the field of the permanent magnet, eddy currents are set up in the metal former or core. The magnetic field produced by the eddy currents opposes the motion of the coil. The pointer will therefore swing more slowly to its proper position and come to rest quickly with very little oscillation. Electromagnetic damping is caused by the induced effects in the moving coil as it rotates in magnetic field, provided the coil forms part of closed electric circuit.

Let the velocity of the coil is $\omega(t) = \frac{d\theta}{dt} \text{ rad./sec.}$, and let the resistance of the coil circuit with N turns be $R\Omega$. Then the velocity of a coil side $v(t) = r \frac{d\theta}{dt} \text{ (m/sec.)}$

\therefore E.m.f induced in each turn of the coil = $2Blv = 2Blr \frac{d\theta}{dt} \text{ volt.}$ (note both the sides of the coil having same e.m.fs but they are additive in nature).

\therefore Induced current across N turns of coil = $\frac{2BlN r \frac{d\theta}{dt}}{R} = \frac{G}{R} \frac{d\theta}{dt} \text{ amps.}$ (R = resistance of coil)

By Lenz's Law, torque produced = $Gi = G \frac{G}{R} \frac{d\theta}{dt} = \frac{G^2}{R} \frac{d\theta}{dt} = D \frac{d\theta}{dt} \text{ (Nm)}$ = opposing

torque. Note, $D = \frac{G^2}{R}$ is the damping constant for the induced currents in the coil due to

its motion. This damping torque is active when the coil poses a change in deflection. A metal former or core may be considered as a single-turn coil and if its dimensions are l_1 and r_1 and its resistance R_1 . Similarly, damping torque for the former or core can be computed as

Damping torque (for the core or former) = $D_1 \frac{d\theta}{dt} \text{ (Nm)}$ where D_1 = damping constant

due to induced currents in the core or former. In addition to the induced current damping, there will be a small damping torque due to air friction. Air damping torque ($D_2 \frac{d\theta}{dt}$) may be assumed to be proportional to the angular velocity of the coil.

Equation of motion: The resulting torque in a coil or motion of a coil in a magnetic field is due to the combined effect of deflecting torque (T_d), controlling torque ($C\theta$), damping torque ($D\frac{d\theta}{dt}$) and it is expressed mathematically as

$$J \frac{d^2\theta}{dt^2} = Gi - C\theta - D \frac{d\theta}{dt} \Rightarrow J \frac{d^2\theta}{dt^2} + D \frac{d\theta}{dt} + C\theta = Gi$$

where J is the moment of inertia of the moving parts. One can easily study the dynamic behavior of the above second order system by solving the differential equation.

Remarks: When the moving system reached at steady state i.e. at final deflected position, the controlling torque becomes equal and opposite to the deflecting torque. The deflecting angle is directly proportional to the current in the movable coil (see eq. 42.2). For this reason, the scale of the moving coil instrument is calibrated linearly.

L.42.3 A multi-range ammeters and voltmeters

An ammeter is required to measure the current in a circuit and it therefore connected in series with the components carrying the current. If the ammeter resistance is not very much smaller than the load resistance, the load current can be substantially altered by the inclusion of the ammeter in the circuit. To operate a moving coil instrument around a current level 50ma is impractical owing to the bulk and weight of the coil that would be required. So, it is necessary to extend the meter-range shunts (in case of ammeters) and multipliers (in case of volt meters) are used in the following manner.

For higher range ammeters a low resistance made up of manganin (low temperature coefficient of resistance) is connected in parallel to the moving coil (see Fig.42.2 (a)) and instrument may be calibrated to read directly to the total current.

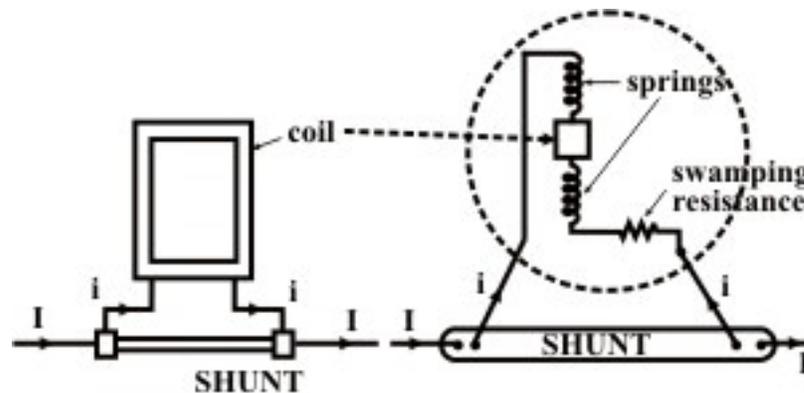


Fig. 42.2(a)

They are called shunts. The movement of PMMC instrument is not inherently insensitive to temperature, but it may be temperature-compensated by the appropriate use of series and shunt resistors of copper and manganin. Both the magnetic field strength and spring-tension decrease with an increase in temperature. On other side, the coil resistance

increases with an increase in temperature. These changes lead to make the pointer read low for a given current with respect to magnetic field strength and coil resistance. Use of manganin resistance (known as swamping resistance which has a temperature coefficient practically zero) in series with the coil resistance can reduce the error due to the variation of resistance of the moving coil. The swamping resistance (r) is usually three times that of coil thereby reducing a possible error of, say, 4% to 1%. A multirange ammeter can be constructed simple by employing several values of shunt resistances, with a rotary switch to select the desired range. Fig. 42.2(b) shows the circuit arrangement.

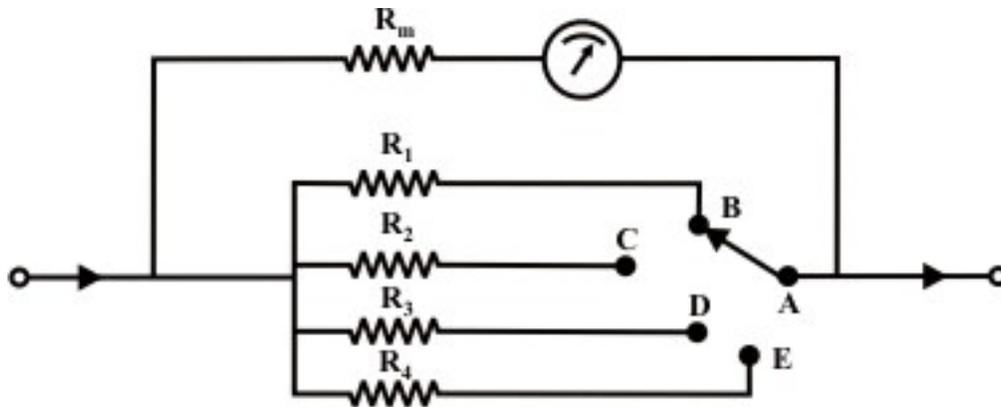


Fig. 42.2(b): Multi-range ammeter circuit

When an instrument is used in this fashion, care must be taken to ensure shunt does not become open-circuited, even for a very short instant. When the switch is moved from position 'B' to 'C' or moved to any positions, the shunt resistance will remain open-circuited for a fraction of time, resulting a very large current may flow through the ammeter and damage the instrument. To avoid such situation, one may use the make-before-break switch as shown in Fig.42.(c).

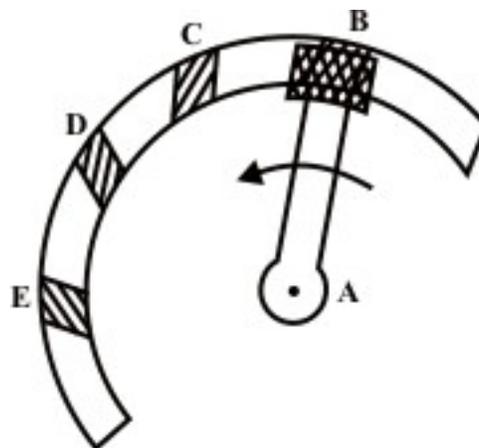


Fig. 42.2(c): Make-before break

The wide-ended moving contact connected to the next terminal to which it is being moved before it loses contact with the previous terminals. Thus, during the switching

time there are two resistances are parallel with the instrument and finally the required shunt only will come in parallel to the instrument.

Example- L42.1 A PMMC instrument has a coil resistance of 100Ω and gives a full-scale deflection (FSD) for a current of $500\mu A$. Determine the value of shunt resistance required if the instrument is to be employed as an ammeter with a FSD of $5A$.

Solution: Let current flowing through the shunt is I_s . From the circuit shown in Fig.42.3, one can the following expression using the parallel divided rule.

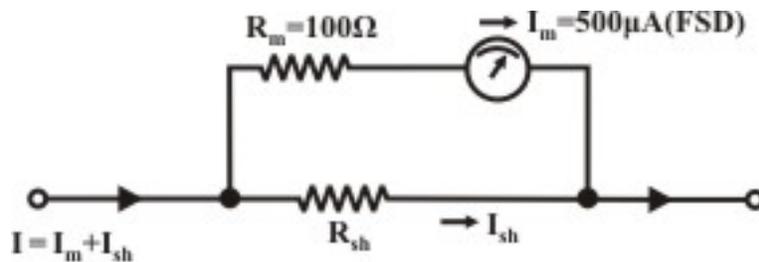


Fig. 42.3

$$I_m = \frac{R_{sh}}{R_{sh} + R_m} I \quad (42.4)$$

where R_{sh} = shunt resistance, R_m = ammeter resistance = 100Ω , I_m = ammeter full scale deflection current = $500\mu A$ and I = desired range of ammeter = $5A$. From the above expression (42.4) we get,

$$500 \times 10^{-6} = \frac{R_{sh}}{R_{sh} + 100} \times 5 \Rightarrow R_{sh} = 0.01\Omega$$

Multi-range voltmeter: A dc voltmeter is constructed by a connecting a resistor in series with a PMMC instrument. Unlike an ammeter, a voltmeter should have a very high resistance R_{se} and it is normally connected in parallel with the circuit where the voltage is to be measured (see Fig.42.4). To minimize voltmeter loading, the voltmeter operating current should be very small i.e., the resistance connected in series with the coil should be high.

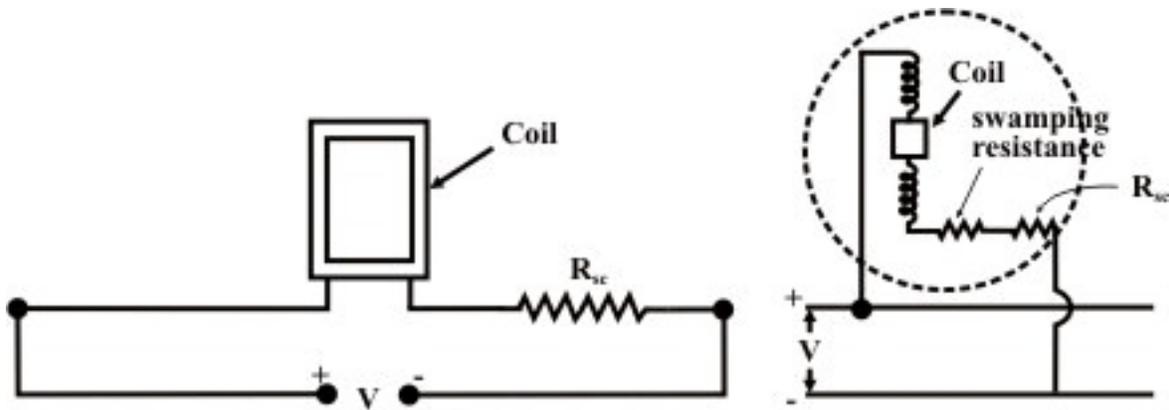


Fig. 42.4

The moving coil instruments can be suitably modified to act either as an ammeter or as a voltmeter. For multi-range voltmeters the arrangement is as follows: In Fig.42.5 any one of several multiplier resistors is selected by means of a rotary switch. Unlike the case of the ammeter, the rotary switch used with the voltmeter should be a break-before make type, that is, moving contact should disconnect from one terminal before connecting to the next terminal.

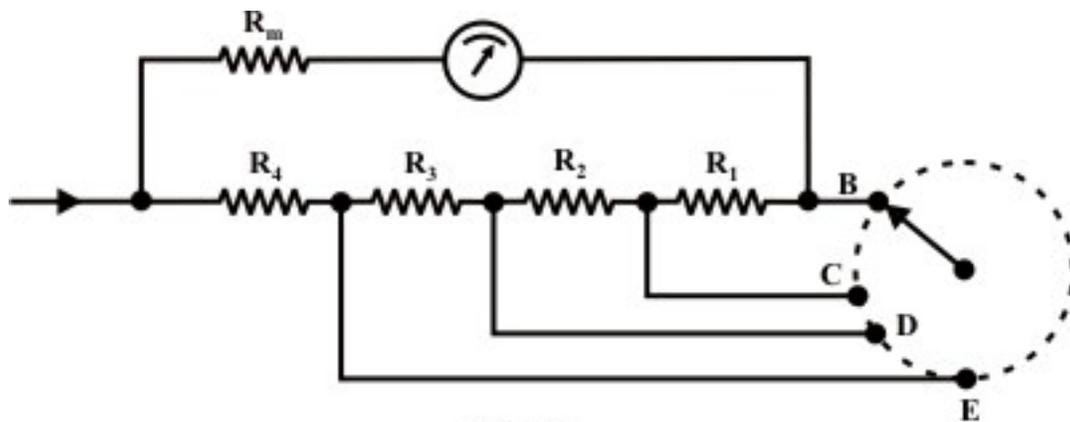


Fig. 42.5

Example-42.2 A PMMC meter with a coil resistance 100Ω and a full scale deflection current of $100\mu A$ is to be used in the voltmeter circuit as shown in Fig.42.6. The voltmeter ranges are to be $50V$, $100V$, and $150V$. Determine the required value of resistances for each range.

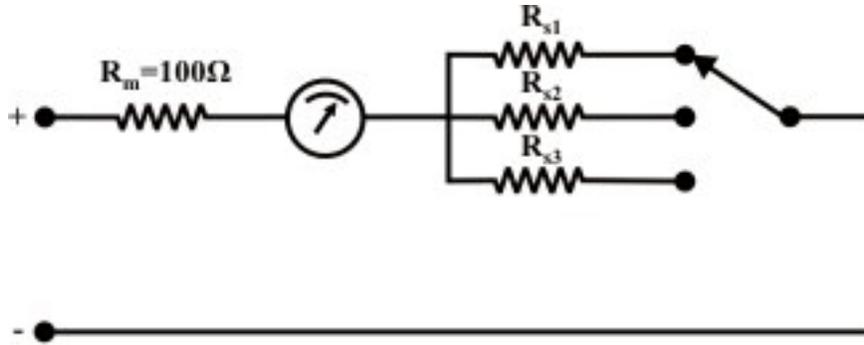


Fig. 42.6: Multirange voltmeter.

Solution: From the circuit shown in Fig.42.6, one can write the expression for the 50V range as

$$I = \frac{V}{R_m + R_s} \Rightarrow R_s = \frac{V}{I} - R_m \quad (42.5)$$

Now for (i) $V = 50V$, $I = 100\mu A = 100 \times 10^{-6} A$, and $R_m = 100\Omega$, the value of series resistance (R_{s1}) = $0.4999 M \Omega$.

(ii) $V = 100V$, $I = 100\mu A = 100 \times 10^{-6} A$, and $R_m = 100\Omega$, the required value of resistance (R_{s2}) = $0.9999 M \Omega$

(iii) $V = 150V$, $I = 100\mu A = 100 \times 10^{-6} A$, and $R_m = 100\Omega$, the required series resistance (R_{s3}) = $1.4999 M \Omega$.

L.42.4 Advantages, Limitations and sources of errors

Advantages:

- The scale is uniformly divided (see at steady state, $\theta = \frac{G}{C} I_s$).
- The power consumption can be made very low ($25 \mu W$ to $200 \mu W$).
- The torque-weight ratio can be made high with a view to achieve high accuracy.
- A single instrument can be used for multi range ammeters and voltmeters.
- Error due to stray magnetic field is very small.

Limitations:

- They are suitable for direct current only.
- The instrument cost is high.
- Variation of magnet strength with time.

The Errors are due to:

- Frictional error,
- Magnetic decay,
- Thermo electric error,
- Temperature error.

Errors can be reduced by following the steps given below:

- Proper pivoting and balancing weight may reduce the frictional error.
- Suitable aging can reduce the magnetic decay.
- Use of manganin resistance in series (swamping resistance) can nullify the effect of variation of resistance of the instrument circuit due to temperature variation.
- The stiffness of spring, permeability of magnetic core (Magnetic core is the core of electromagnet or inductor which is typically made by winding a coil of wire around a ferromagnetic material) decreases with increases in temperature.

Ammeter Sensitivity:

Ammeter sensitivity is determined by the amount of current required by the meter coil to produce full-scale deflection of the pointer. The smaller the amount of current required producing this deflection, the greater the sensitivity of the meter. A meter movement that requires only 100 microamperes for full- scale deflection has a greater sensitivity than a meter movement that requires 1 mA for the same deflection.

Voltmeter Sensitivity:

The sensitivity of a voltmeter is given in ohms per volt. It is determined by dividing the sum of the resistance of the meter (R_m), plus the series resistance (R_s), by the full-scale reading in volts. In equation form, sensitivity is expressed as follows:

$$Sensitivity = \frac{R_m + R_s}{E}$$

This is the same as saying the sensitivity is equal to the reciprocal of the full-scale deflection current. In equation form, this is expressed as follows:

$$sensitivity = \frac{ohms}{volt} = \frac{1}{\text{volt}/ohms} = \frac{1}{ampere}$$

Therefore, the sensitivity of a 100-microampere movement is the reciprocal of 0.0001 ampere, or 10,000 ohms per volt.

$$sensitivity = \frac{1}{ampere} = \frac{1}{0.0001} = 10,000 \text{ ohms per volt}$$

L.42.5 Construction and Basic principle operation of Moving-iron Instruments

We have mentioned earlier that the instruments are classified according to the principles of operation. Furthermore, each class may be subdivided according to the nature of the movable system and method by which the operating torque is produced. Specifically, the electromagnetic instruments are sub-classes as (i) moving-iron instruments (ii) electro-dynamic or dynamometer instruments, (iii) induction instruments. In this section, we will discuss briefly the basic principle of moving-iron instruments that are generally used to measure alternating voltages and currents. In moving –iron instruments the movable system consists of one or more pieces of specially-shaped soft iron, which are so pivoted as to be acted upon by the magnetic field produced by the current in coil. There are two general types of moving-iron instruments namely (i)

Repulsion (or double iron) type (ii) Attraction (or single-iron) type. The brief description of different components of a moving-iron instrument is given below.

- **Moving element:** a small piece of soft iron in the form of a vane or rod
- **Coil:** to produce the magnetic field due to current flowing through it and also to magnetize the iron pieces.
- **In repulsion type,** a **fixed** vane or rod is also used and magnetized with the same polarity.
- **Control torque** is provided by spring or weight (gravity)
- **Damping torque** is normally pneumatic, the damping device consisting of an air chamber and a moving vane attached to the instrument spindle.
- **Deflecting torque** produces a movement on an aluminum pointer over a graduated scale.

L.42.5.1 Construction of Moving-iron Instruments

The deflecting torque in any moving-iron instrument is due to forces on a small piece of magnetically 'soft' iron that is magnetized by a coil carrying the operating current. In repulsion (Fig.42.7) type moving-iron instrument consists of two cylindrical soft iron vanes mounted within a fixed current-carrying coil. One iron vane is held fixed to the coil frame and other is free to rotate, carrying with it the pointer shaft. Two irons lie in the magnetic field produced by the coil that consists of only few turns if the instrument is an ammeter or of many turns if the instrument is a voltmeter. Current in the coil induces both vanes to become magnetized and repulsion between the similarly magnetized vanes produces a proportional rotation. The deflecting torque is proportional to the square of the current in the coil, making the instrument reading is a true 'RMS' quantity. Rotation is opposed by a hairspring that produces the restoring torque. Only the fixed coil carries load current, and it is constructed so as to withstand high transient current. Moving iron instruments having scales that are nonlinear and somewhat crowded in the lower range of calibration. Another type of instrument that is usually classed with the attractive types of instrument is shown in Fig.42.8.

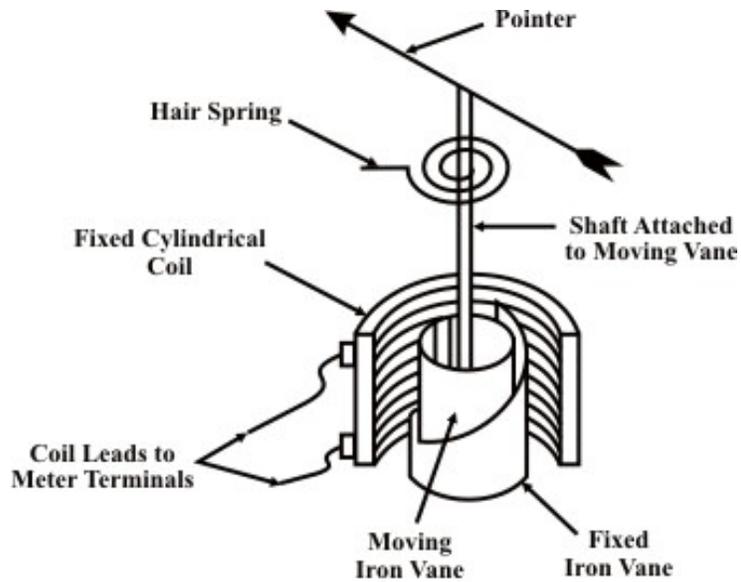


Fig. 42.7: Repulsion type.

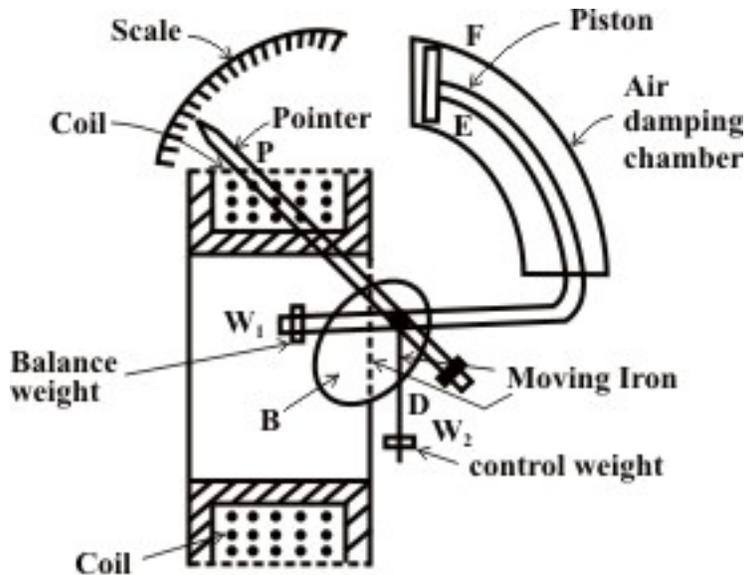


Fig. 42.8: Attraction type

This instrument consists of a few soft iron discs (B) that are fixed to the spindle (D), pivoted in jeweled bearings. The spindle (D) also carries a pointer (P), a balance weight (W_1), a controlling weight (W_2) and a damping piston (E), which moves in a curved fixed cylinder (F). The special shape of the moving-iron discs is for obtaining a scale of suitable form.

Remark: Moving-iron vanes instruments may be used for DC current and voltage measurements and they are subject to minor frequency errors only. The instruments may

be effectively shielded from the influence of external magnetic fields by enclosing the working parts, except the pointer, in a laminated iron cylinder with laminated iron end covers.

Torque Expressions: Torque expression may be obtained in terms of the inductance of the instrument. Suppose the initial current is I , the instrument inductance L and the deflection θ . Then let I change to $I + dI$, dI being a small change of current; as a result let θ changes to $(\theta + d\theta)$, and L to $(L + dL)$. In order to get an incremental change in current dI there must be an increase in the applied voltage across the coil.

$$\text{Applied voltage } v = \frac{d(LI)}{dt} = I \frac{dL}{dt} + L \frac{dI}{dt} \quad (42.6)$$

The electric energy supplied to the coil in dt is

$$v I dt = I^2 dL + IL dI \quad (42.7)$$

$$\begin{aligned} \text{Increase in energy stored in the magnetic field} &= \frac{1}{2}(I + dI)^2 (L + dL) - \frac{1}{2}I^2 L \\ &\approx IL dI + \frac{1}{2}I^2 dL \end{aligned}$$

(neglecting second and higher terms in small quantities)

If T is the value of the control torque corresponding to deflection θ , the extra energy stored in the control due to the change $d\theta$ is $T d\theta$. Then, the stored increase in stored

$$\text{energy} \approx IL dI + \frac{1}{2}I^2 dL + T d\theta \quad (42.8)$$

From principle of the conservation of energy, one can write the following expression

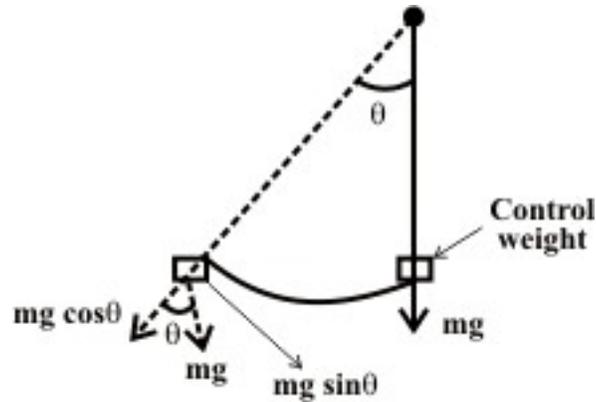
Electric energy drawn from the supply = increase in stored energy + mechanical work done

$$I^2 dL + IL dI = IL dI + \frac{1}{2}I^2 dL + T d\theta$$

$$T (\text{torque}) = \frac{1}{2}I^2 \frac{dL}{d\theta} \quad (Nm) \quad (42.9)$$

Controlling torque:

- i Spring control: $T_s = K_s \theta$ where K_s is the spring constant.
- ii Gravity control: $T_g = K_g \sin \theta$. Where $K_g = mgl$



At equilibrium i.e. for steady deflection, Deflecting torque = Controlling torque. If the instrument is gravity controlled

$$T_D = T_C$$

$$KI = K_g \sin \theta \Rightarrow \theta = \sin^{-1} \left(\frac{K}{K_g} I \right) \quad (42.10)$$

L.42.5.2 Ranges of Ammeters and Voltmeters

For a given moving-iron instrument the ampere-turns necessary to produce full-scale deflection are constant. One can alter the range of ammeters by providing a shunt coil with the moving coil.

L.42.5.2.1 Shunts and Multipliers for MI instruments

For moving-iron ammeters: For the circuit shown in Fig.42.9, let R_m and L_m are respectively the resistance and inductance of the coil and R_{sh} and L_{sh} the corresponding values for shunt.

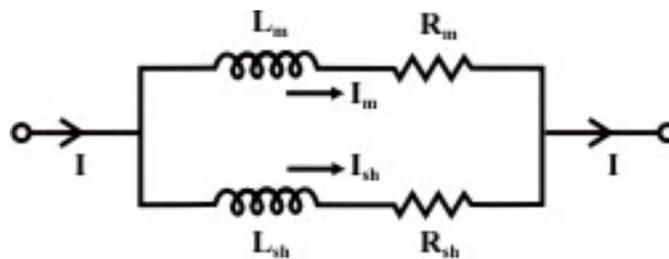


Fig. 42.9

The ratio of currents in two parallel branches is

$$\frac{I_{sh}}{I_m} = \frac{\sqrt{R_m^2 + (\omega L_m)^2}}{\sqrt{R_{sh}^2 + (\omega L_{sh})^2}} = \frac{R_m \sqrt{1 + \left(\frac{\omega L_m}{R_m}\right)^2}}{R_{sh} \sqrt{1 + \left(\frac{\omega L_{sh}}{R_{sh}}\right)^2}}$$

The above ratio will be independent of frequency ω provided that the time constants of the two parallel branches are same i.e. $\frac{L_m}{R_m} = \frac{L_{sh}}{R_{sh}}$

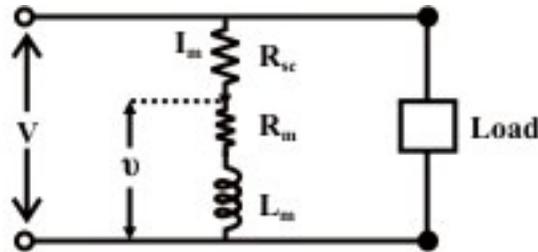
In other words, $\frac{I_{sh}}{I_m} = \frac{R_m}{R_{sh}}$ if $\frac{L_{sh}}{R_{sh}} = \frac{L_m}{R_m}$

Now,

$$I = I_{sh} + I_m = I_m \frac{R_m}{R_{sh}} + I_m = I_m \left(1 + \frac{R_m}{R_{sh}}\right)$$

Multipliers for the shunt = $\left(1 + \frac{R_m}{R_{sh}}\right)$. It is difficult to design a shunt with the appropriate inductance, and shunts are rarely incorporated in moving iron ammeters. Thus the multiple ranges can effectively be obtained by winding the instrument coil in sections which may be connected in series, parallel or series-parallel combination which in turn changing the total ampere-turns in the magnetizing coil.

For moving-iron voltmeters: Voltmeter range may be altered connecting a resistance in series with the coil. Hence the same coil winding specification may be employed for a number of ranges. Let us consider a high resistance R_{se} is connected in series with the moving coil and it is shown below.



R_{sc} is almost purely non inductive resistance of large value

$$v = I_m \sqrt{R_m^2 + (\omega L_m)^2}$$

$$V = I_m \sqrt{(R_{se} + R_m)^2 + (\omega L_m)^2}$$

$$\text{Multiplier} = m = \frac{V}{v} = \frac{\sqrt{(R_{se} + R_m)^2 + (\omega L_m)^2}}{\sqrt{R_m^2 + (\omega L_m)^2}} \quad (42.11)$$

Note: An ordinary arrangement with a non-inductive resistance in series with the fixed coil – results in error that increases as the frequency increases. The change of impedance

of the instrument with change of frequency introduces error in signal measurements. In order to compensate the frequency error, the multiplier may be easily shunted by the capacitor.



Fig.42.10: Connection for method of compensating frequency error in moving-iron voltmeter.

Advantages:

- The instruments are suitable for use in a.c and d.c circuits.
- The instruments are robust, owing to the simple construction of the moving parts.
- The stationary parts of the instruments are also simple.
- Instrument is low cost compared to moving coil instrument.
- Torque/weight ration is high, thus less frictional error.

Errors:

- i. Errors due to temperature variation.
- ii. Errors due to friction is quite small as torque-weight ratio is high in moving-iron instruments.
- iii. Stray fields cause relatively low values of magnetizing force produced by the coil. Efficient magnetic screening is essential to reduce this effect.
- iv. Error due to variation of frequency causes change of reactance of the coil and also changes the eddy currents induced in neighboring metal.
- v. Deflecting torque is not exactly proportional to the square of the current due to non-linear characteristics of iron material.

L.42.6 Test your understanding

(Marks: 40)

T.42.1 Sketch the circuit of an electro-mechanical ammeter, and briefly explain its operation. Comment on the resistance of an ammeter. [10]

T.42.2 Fig.42.11 shows a PMMC instrument has a coil resistance of 200Ω and gives a FSD (full-scale deflection) for a current $200\mu A$. Calculate the value of shunt resistance required to convert the instrument into a $500mA$ ammeter. [5]

(Ans. 0.08Ω)

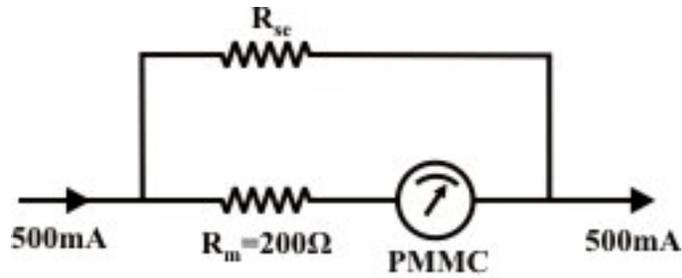


Fig. 42.11

T.42.3 A PMMC instrument has a resistance of 100Ω and FSD for a current of $400\mu A$. A shunt arrangement is shown in Fig.42.12 in order to have an multi-range ammeters. Determine the various ranges to which the ammeter may be switch. (Assume $R_1 = R_2 = R_3 = R_4 = 0.001\Omega$)

(Ans. 10 A, 13.32 A, 20 A, and 40 A)

[9]

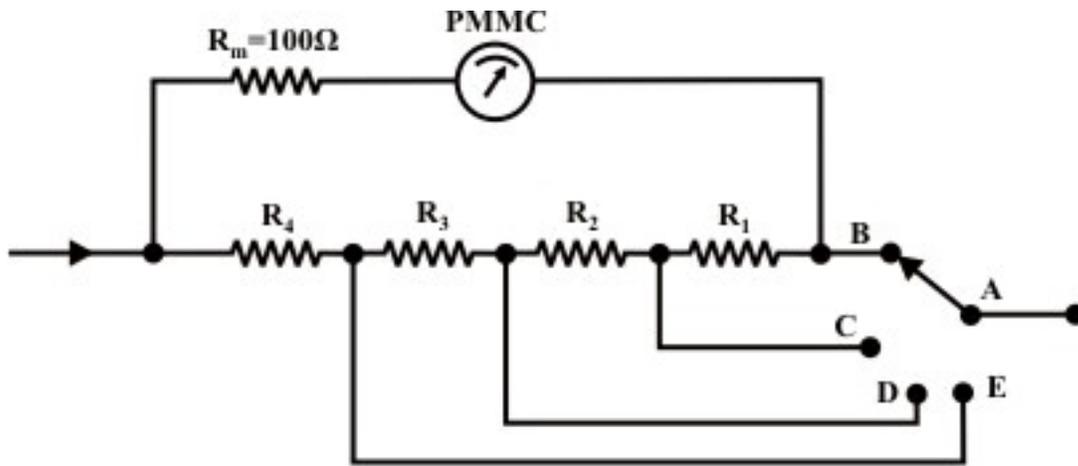


Fig. 42.12: An Ayrton shunt has several services connected shunts in parallel with PMMC.

T.42.4 Fig.42.13 shows a PMMC instrument with a resistance of 75Ω and FSD current of $100\mu A$ is to be used as a voltmeter with 200V, 300V, and 500V ranges. Determine the required value of multiplier resistor of each range.

(Ans. $2.0M\Omega$, $3.0M\Omega$, and $5.0M\Omega$)

[8]

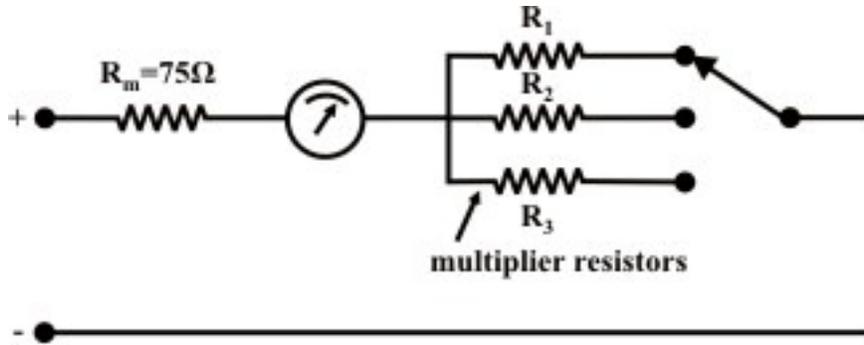


Fig. 42.13

T.42.5 Two resistors are connected in series across a 200V dc supply. The resistor values are $R_1 = 300k\Omega$ and $R_2 = 200k\Omega$. The voltmeter FSD is 250V and its sensitivity is $10k\Omega/V$. Determine the voltage across the resistance R_2 : (i) without voltmeter in the circuit. (ii) with voltmeter connected.

$$\text{(Voltmeter sensitivity} = \frac{\text{Meter resistance} + \text{resistance of multiplier}}{\text{Range of voltmeter}})$$

(Ans. 80V, 76.33V)

[8]

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