Unit - IV

4.2 Electrical Instruments and Measurements

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HTC's Vive XR Elite is a lightweight mixed-reality headset

Lightyear 2 is a solar-powered car

Syllabus

UNIT – IV **11 Periods**

Measurements and Sensors: Introduction to measuring devices /sensors and transducers related to electrical signals - Elementary methods for the measurement of electrical quantities, impedance, power and energy in DC and AC systems and their practical application.

Electrical Wiring and Safety: Basic layout of distribution system - Types of Wiring System &Wiring Accessories –Electrical Safety - Necessity of earthing - Types of earthing.

Introduction

- **Measurement:**

  It is the act or result of quantitative comparison between a predefined standard and an unknown quantity.

- **Instrument:**

  It is a device or mechanism used to determine the present value of a quantity under observation.

Principle of operation

1. *Magnetic effect*	.....	Moving-iron instruments
2. *Electrodynamic effect*	.....	(*i*) Permanent-magnet moving coil
		(*ii*) Dynamometer type
3. *Electromagnetic-induction*	.....	Induction type instruments
4. *Thermal effect*	.....	Hot-wire instruments
5. *Chemical effect*	.....	Electrolytic instruments
6. *Electrostatic effect*	.....	Electrostatic instruments

Continued…

- **Various instruments used in practice:**

➢ Following instruments used in day to day life in order to measure different quantity.

Sr. No.	Name of the instruments	Quantity measured
1.	Voltmeter	AC or DC voltage
2.	Ammeter	AC or DC current
3.	Wattmeter	AC power (Watt)
4.	Energy meter	Energy (Watt hour)

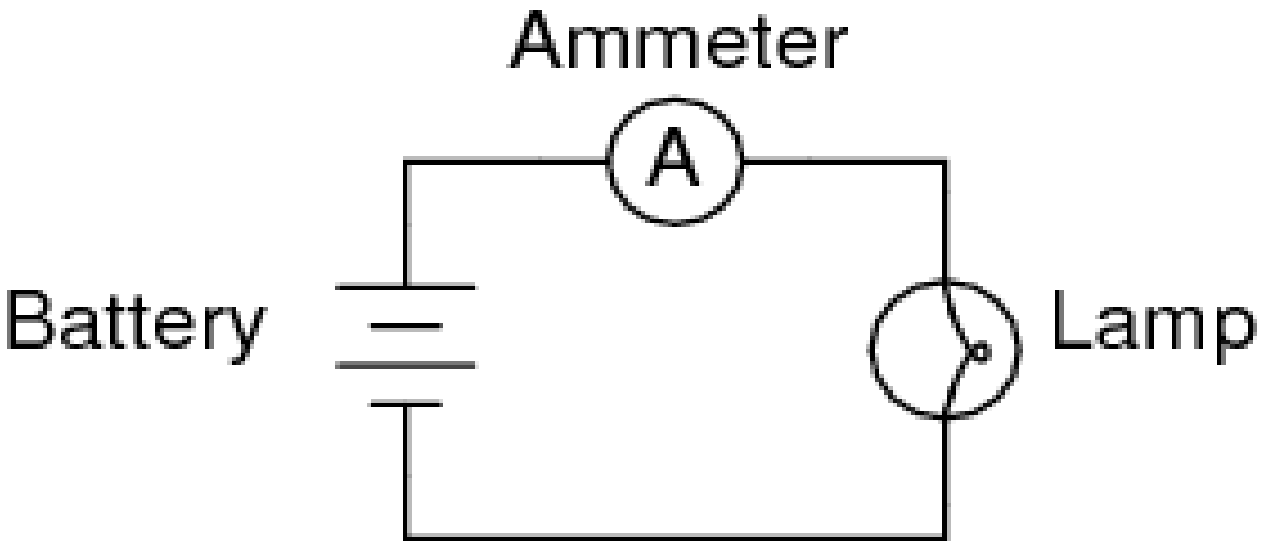
Connection Diagrams

- **Connection diagram of an Ammeter:**

➢ Ammeter is used for the measurement of current.

➢ An ammeter is always connected in series with the load, the current through which is to be measured as shown in fig.(1).

➢ Since the resistance offered by an ammeter is very small, its introduction in series with load does not alter the circuit conditions.



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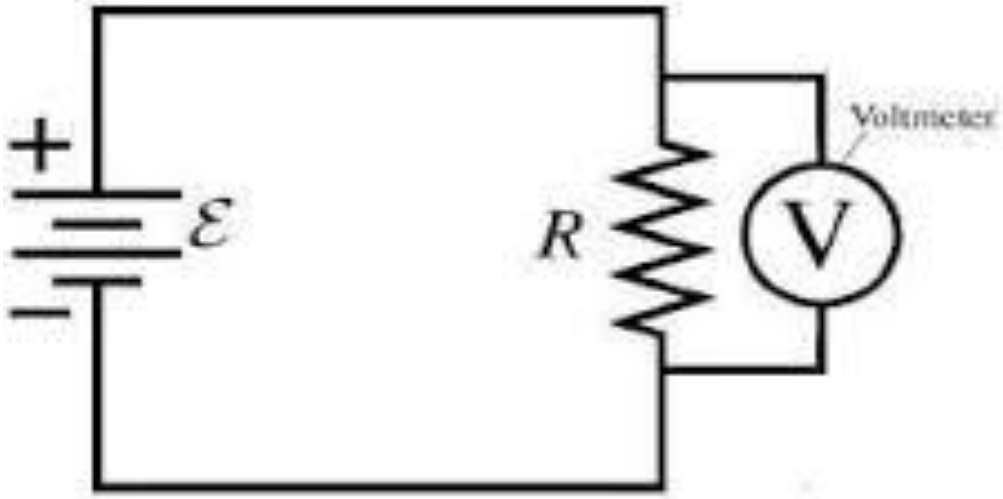
- **Connection diagram of a voltmeter:**

➢ A voltmeter is used for the measurement of voltage (potential difference).

➢ So it is connected across the points between which the potential difference is to be measured.

➢ A voltmeter has a high resistance, so it draws very small current. The connection of a voltmeter is as shown in fig.(2).



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- **Types of instruments used for Voltmeter and Ammeters:**

➢ The practically used ammeters and voltmeters can be of the following two types:

1. Permanent ,magnet moving coil (PMMC) type
2. Moving iron (MI) type
3. Hot wire type
4. Induction type

Operation of Indicating Instruments

- For satisfactory operation of any indicating instrument, following three torques must act together appropriately:

1. Deflecting torque
2. Controlling torque
3. Damping torque

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1. **Deflecting Torque:**

- It causes the moving system of the instrument to move from its position of rest.
- Deflecting torque is produced by using any one of the following effects of electric current:
  i. Magnetic effect
  ii. Electromagnetic induction effect
  iii. Heating effect
  iv. Electrostatic effect

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2. Controlling Torque:

- It limits the movement of moving systems. It also ensures that magnitude of deflection is always the same for the given value of input quantity under measurement.
- Controlling torque acts in the opposite direction to that of the deflecting torque.
- At steady state,

  Deflecting torque = Controlling torque

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3. Damping Torque:

- Due to deflecting torque, pointer moves in one direction while due to controlling torque pointer moves in opposite direction.
- Due to these opposite torques, the pointer may oscillate in the forward and backward direction if the damping torque is not present.
- Damping torque brings the moving system to rest quickly in its final position.
- Damping torque acts only when the moving system is actually moving. If moving system is at rest, damping torque is zero.

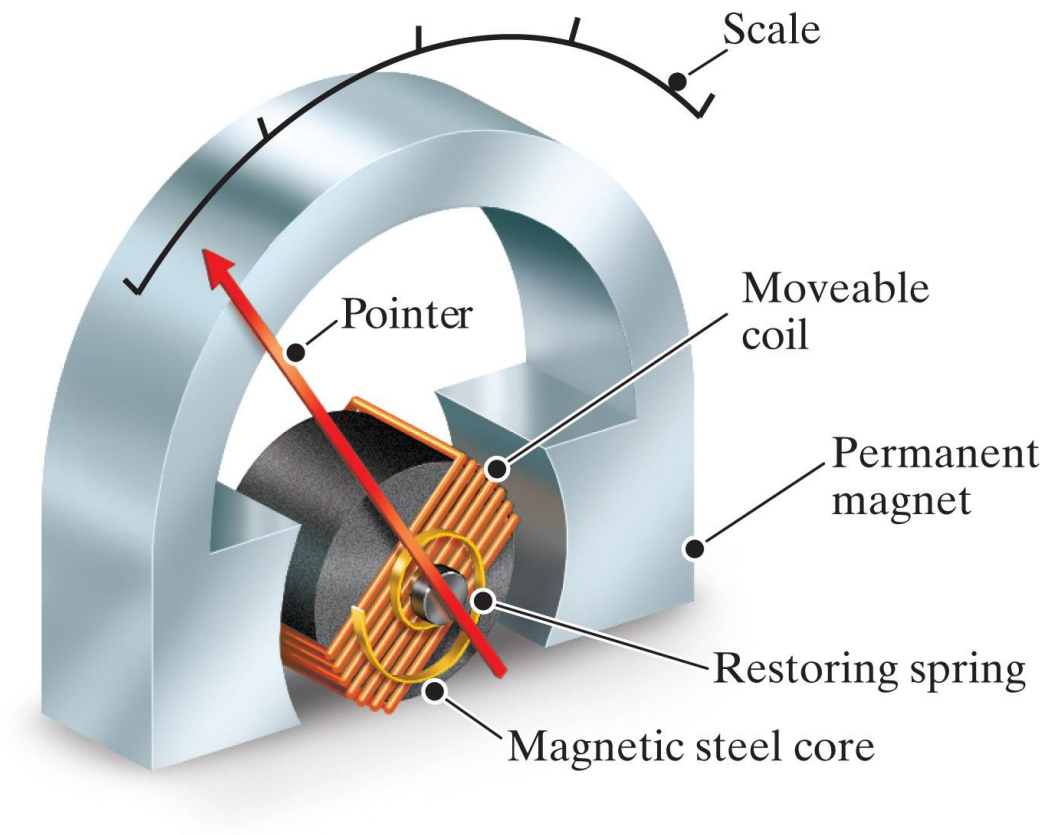
Permanent-Magnet Moving Coil (PMMC) Instruments

D’Arsonval Movement

DC Meters

Measuring Voltage and Current

- d'Arsenval analog meter movement



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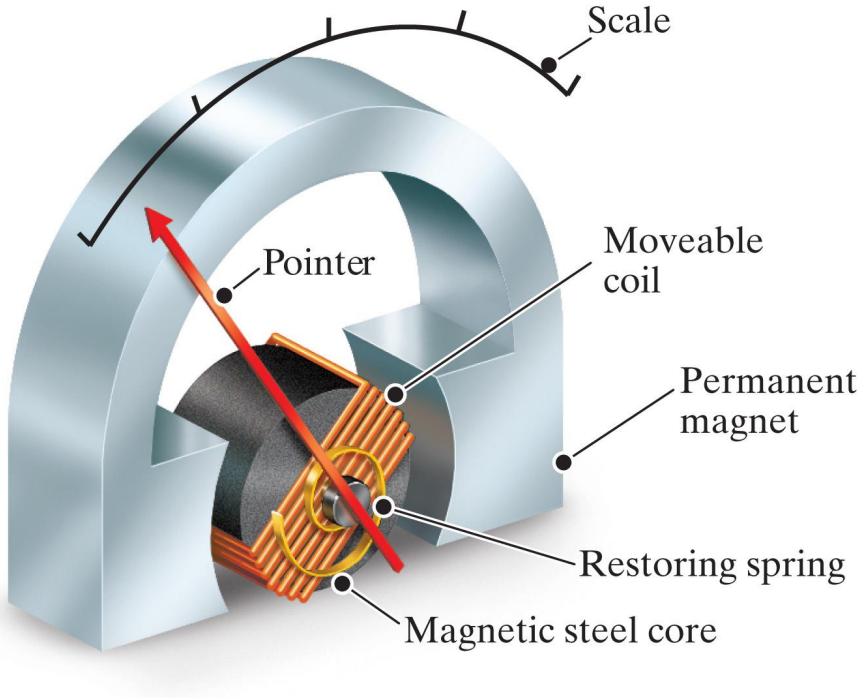

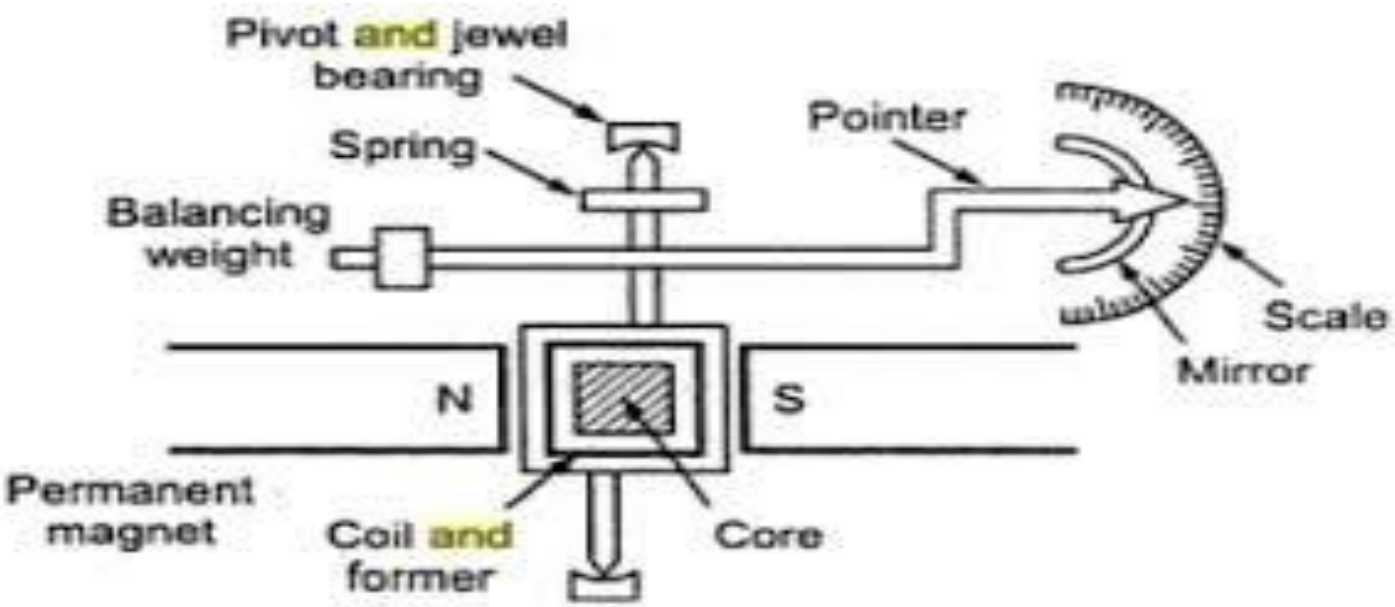

Fig.(1): construction of PMMC instrument

Moving Coil Instruments

- Moving coil instruments (ammeter and voltmeter) are of two types:

1. Permanent magnet moving coil type (PMMC) used only for D.C.
2. Dynamometer type can be used for AC as well DC.

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- **Working principle:**

➢ When a current carrying conductor is placed in a magnetic field, it experiences a force. It is given by expression,

$$F = BIL$$

Where F = Force in Newton,

B = Flux density is tesla,

I = Current is ampere,

L = Length of conductor in meter.

➢ The current I which is to be measured is passed through the moving coil and experiences a force which is directly proportional to this current.

➢ Due to this force the coil moves and the pointer attached to it will also move.

➢ The angle through which the pointer moves is proportional to current I.

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- **Construction of PMMC instrument:**

➢ A coil of thin wire is mounted on an aluminum frame (spindle) positioned between the poles of a U shaped permanent magnet which is made up of magnetic alloys like alnico.

➢ The coil is pivoted on the jewelled bearing and thus the coil is free to rotate. The current is fed to the coil through spiral springs which are two in numbers.

➢ The coil which carries a current, which is to be measured, moves in a strong magnetic field produced by a permanent magnet and a pointer is attached to the spindle which shows the measured value.

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- **Advantages of PMMC Instruments:**

1. The PMMC consumes less power and has great accuracy.
2. It has uniformly divided scale and can cover arc of 270 degree.
3. The PMMC has a high torque to weight ratio.
4. It can be modified as ammeter or voltmeter with suitable resistance.
5. It has efficient damping characteristics and is not affected by stray magnetic field.
6. It produces no losses due to hysteresis.

- **Disadvantages of PMMC Instruments:**

1. The moving coil instrument can only be used on D.C supply as the reversal of current produces reversal of torque on the coil.
2. It's very delicate and sometimes uses ac circuit with a rectifier.
3. It's costly as compared to moving coil iron instruments.
4. It may show error due to loss of magnetism of permanent magnet.

Moving-Iron Instruments

AC & DC Meters

Types

- **Attraction** type in which a single soft-iron vane (or moving iron) is mounted on the spindle and is attracted towards the coil when operating current flows through it.
- **Repulsion** type *in which two soft-iron vanes are used; one fixed and attached to the* stationary coil while the other is movable (*i.e. moving iron) and mounted on the spindle of the*instrument.

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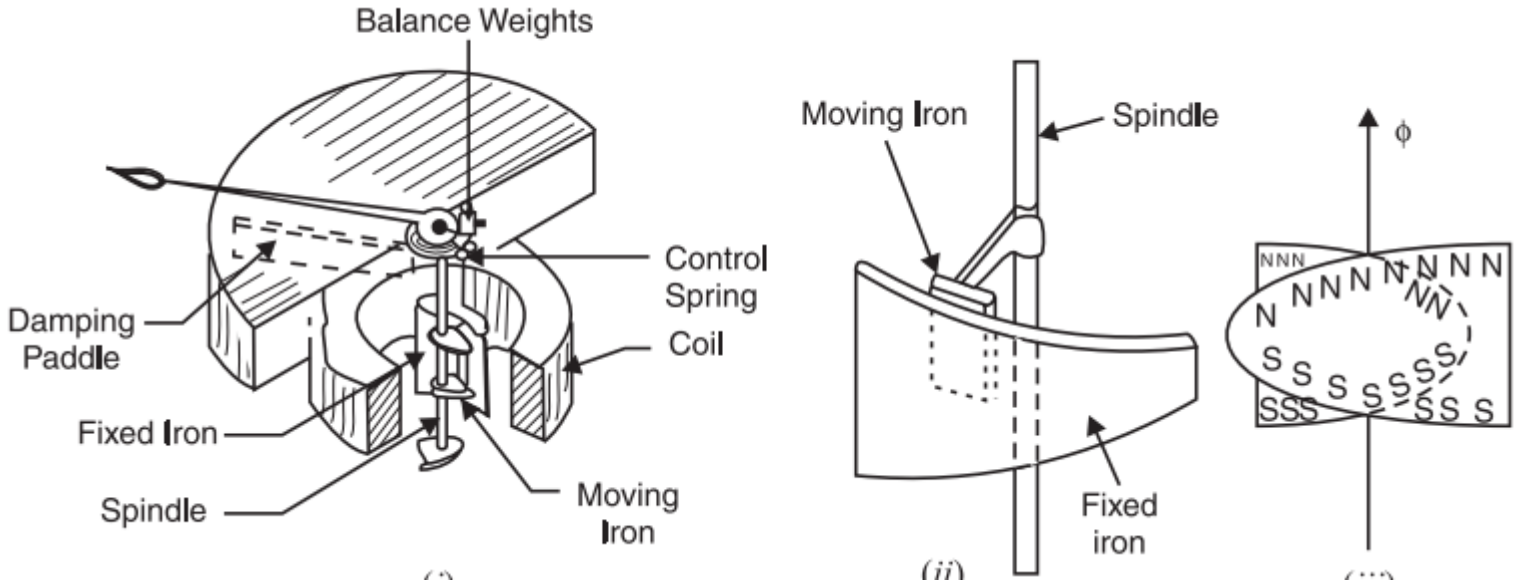

Fig.(1): attraction type moving instrument

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1. Attraction type moving iron instrument:

- Construction of the attraction type moving iron instrument is as shown in the given figure (1).
- The moving iron, i.e. the disc of soft iron, is eccentrically mounted. Coil is situated around the disc. When the coil is excited it produces magnetic field.
- Due to magnetic field the moving iron moves from the weaker field outside the coil to the stronger field inside the coil. Thus moving iron gets attracted inwards and thus the name attraction type.
- The controlling torque is provided by the balance weights attached to the moving iron. Spring also can be used to provide controlling torque.
- Damping is provided by air friction in which aluminum piston is attached to the moving system and moves in a closed air damping chamber.

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2. Repulsion type moving iron instrument:

- In these type of instruments there two vanes present inside the coil in which one is fixed while other is movable. These both vanes gets similarly magnetized when coil is excited. Thus there is a force of repulsion between both vanes causing movement in movable vane. There are further two different designs of repulsion type moving iron instruments.
  i. Radial vane type:
- In radial vane type radial strips of iron are used as moving vanes. The fixed vane is attached to the coil and moving is attached to the moving spindle.

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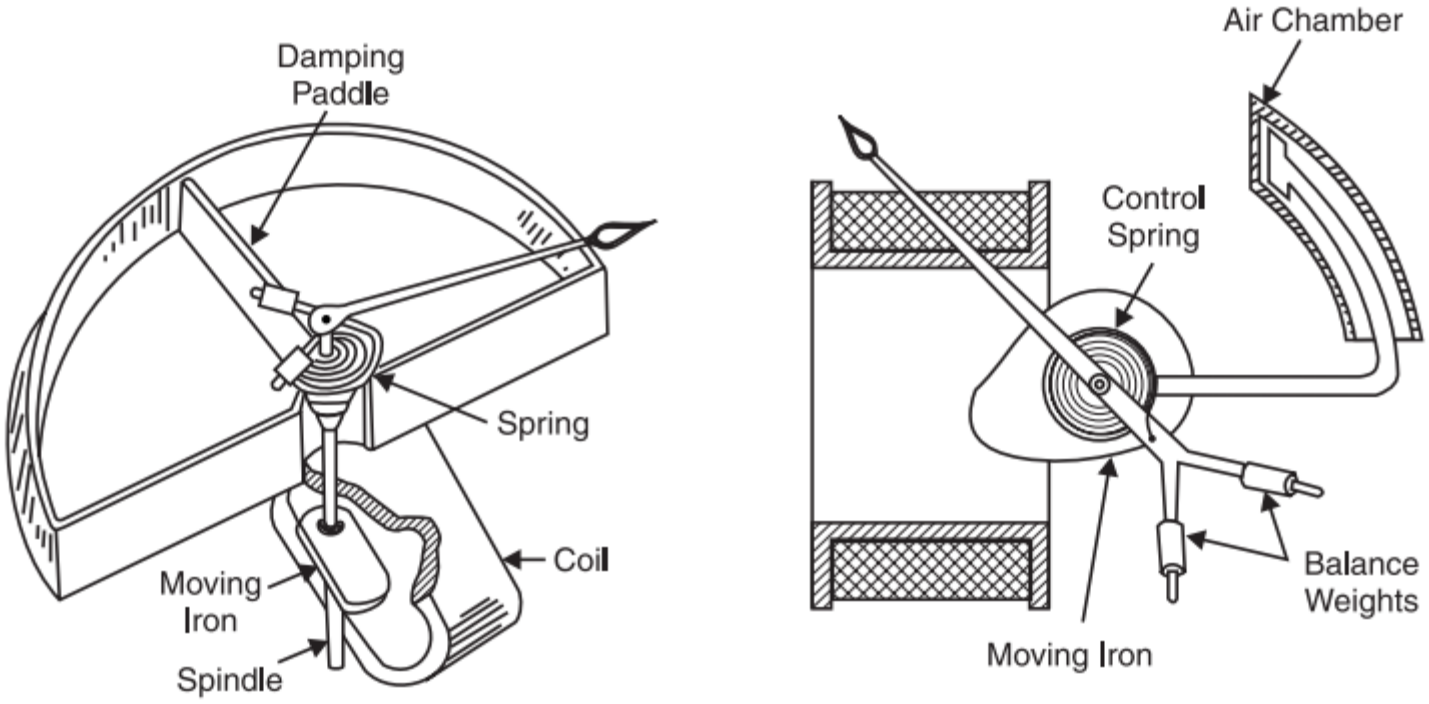

Fig.(2):Repulsion type Moving Iron Instrument

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ii. Coaxial vane type:

- In coaxial vane type the fixed as well as moving vanes are the sections of coaxial cylinders as shown in above figure.

  The controlling torque is provided by the springs or balancing weights (in vertically mounted instrument). The damping is provided by air friction damping same as in attraction type moving iron instruments.

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- Advantages of Moving iron Instruments:

1. Suitable of a.c. as well as d.c. measurements.
2. Good accuracy.
3. Cheaper in cost as compared to permanents magnet moving coil instruments.
4. The instrument has high torque to weight ratio.
5. The instrument can be used for low frequency measurement also.

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- Disadvantages of Moving iron instruments:

1. Power consumed by the instrument is high as compared to that of the permanent magnet moving coil instrument.
2. The scale is non-uniform.
3. Due to the presence of iron part in the operating system, error due to the hysteresis effect is introduced. To reduce this effect nickel iron alloys are used.

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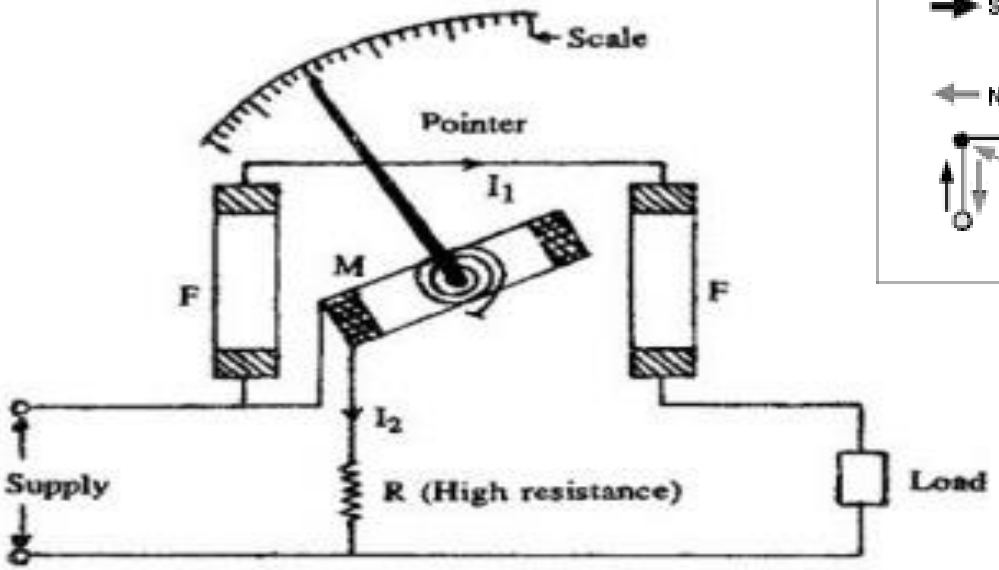

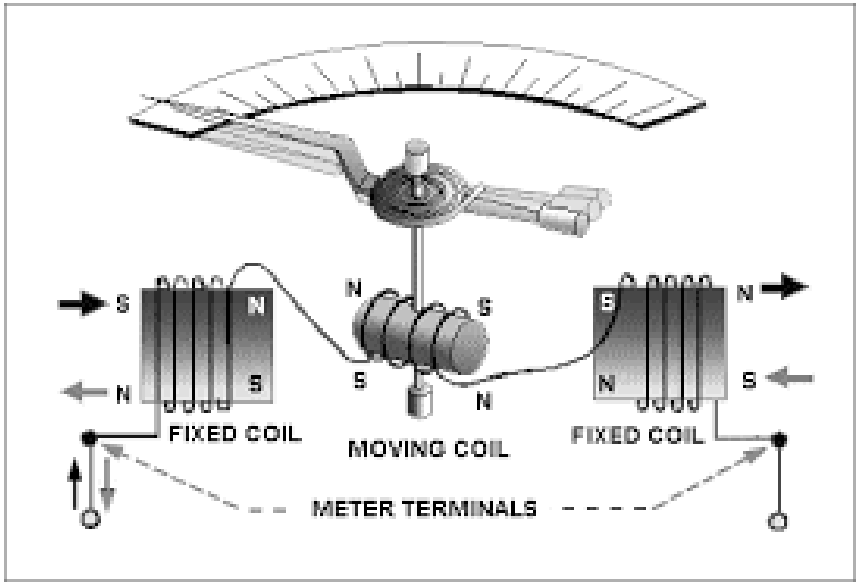

Fig.(1): electrodynamic wattmeter

Electro-dynamic Wattmeter

- The basic action of this instrument depends upon the electromagnetic force exerted between fixed and moving coils carrying current.
- Fig.(1) shows fixed coil FF and moving coil M carried by spindle.
- Controlling torque is provided by two spiral springs mounted on the spindle which act as the leads of coil M.
- The deflecting torque is proportional to the product of the current in the current coil and voltage across pressure coil. So Td is proportional to power.
- The scale of this instrument is uniform.
- It is used for power measurement in ac and dc circuits.

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- **Advantages:**

1. It can be used for a.c. as well as d.c. measurement.
2. It is easy in construction.
3. The instrument is free from hysteresis errors.
4. Uniform scale.
5. Light weight.
6. Consume less power.

- **Disadvantages:**

1. High cost.
2. Errors can occur due to friction, changes in temperature etc.
3. Large errors at low power factor.
4. It gets affected by the external stray magnetic fields. So shielding is essential.

Energy Meter

- The two exciting coils act as current coil and voltage coil and the disc acts as a time counting device.
- The disc is kept free to rotate continuously. Speed of the disc depends on the power supplied to the load. More the load, higher is the disc speed.
- In this instrument a gear train is provided to count the revolution of the disc. Number of revolution of the disc are directly recorded in terms of the energy consumed.

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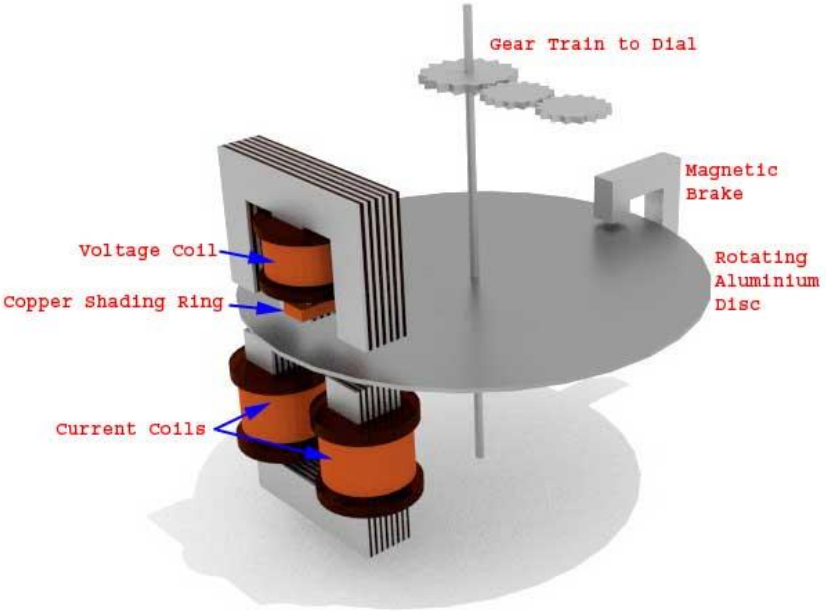

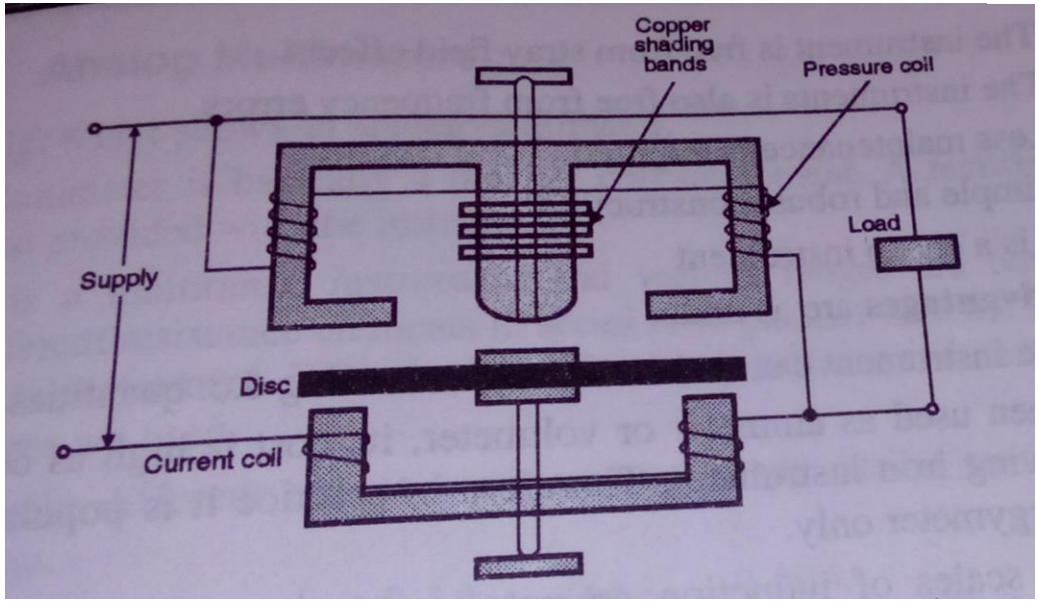

Fig.(1): construction of energy meter

Power vs. Energy

- Distribution companies doesn't sell you power. It sells energy.
- Energy is power times time, so a kilowatt-hour (what you buy from your energy company) is an amount of energy.

How much energy is a kilowatt hour (kWh)?

$$(1\ \text{kW})(1\ \text{h}) = (1000\ \text{W})(3600\ \text{s})$$

$$= \left(1000\ \frac{\text{J}}{\text{s}}\right)(3600\ \text{s})$$

$$= 3.6\times10^{6}\ \text{J}$$

Calculating the units of electricity

The amount of electrical energy (i.e. the amount of electricity) used by an appliance depends on its power and how long the electricity is used for.

electrical energy = power x time

Power is measured in kilowatts (kW) and the time is measured in hours (h), so what are the units of electricity measured in?

1 unit of electricity = 1 unit of electrical energy = 1 kilowatt hour (kWh)

Example: How many units of electricity is 17.6 kWh? **17.6 units**

How is electricity paid for?

- Electricity costs money, which is why every home has an **electricity meter**.
- The meter records how much electricity is used in a house in units of electrical energy.
- The units of electrical energy are called **kilowatt hours** (**kWh**).
- The cost of an electricity bill is calculated from the number of units used.

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How much does electricity cost?

- The cost of electricity is the number of units of electrical energy multiplied by the cost per unit.

cost = number of units x cost per unit

Example:

How much would 10 units of electricity cost at a price of 5 rupees per unit?

cost = 10 units x 5 rupees/unit

= 50 rupees

Tariff Rates

TANGEDCO Tariff rates can be found here :
https://www.tangedco.gov.in/linkpdf/ONE_PAGE_STATEMENT.pdf

II - Low Tension Supply

Tariff	Category of Consumers & slabs		Energy Charges (Rs/unit)	Fixed Charges for two months (Rs)	Energy Charges after Govt's subsidy (Rs/unit)	Fixed Charges for two months after Govt's subsidy (Rs)
#I-A	Domestic Handloom, Old age homes, Consulting rooms, Nutritious Meals Centres etc.					
	Consumption upto 100 units bi-monthly					
	(100 units free scheme)	0-100 units	2.50	30/service	0	0
	Consumption above 100 units and upto 200 units bi-monthly					
	(100 units free scheme)	0-100 units	2.50	30/service	0	20/service
		101-200 units			1.50	
	Consumption above 200 units and upto 500 units bi-monthly					
	(100 units free scheme)	0-100 units	2.50	40/service	0	30/service
		101-200 units			2.00	
		201 to 500 units	3.00		3.00	
	Consumption above 500 units bi-monthly					
	(100 units free scheme)	0-100 units	2.50	50/service	0	50/service
		101-200 units	3.50		3.50	
		201 to 500 units	4.60		4.60	
		above 500 units	6.60		6.60	
	For Handlooms in residence, 0 to 200 units bimonthly is free. (Above 200 units bi-monthly, the corresponding slab in the domestic tariff is applicable)					
*I-B	Huts in village panchayats,TAHDCO:- Till installation of meters (Fully subsidised by the Govt.)		0	290/service	0	0
	On installation of meters (Fully subsided by the Govt.)		4.95	0	0	0
I-C	L.T. Bulk supply to residential Colonies of Railway, Defence , Police quarters etc.		4.60	120/service	4.60	120/service
II-A	Public lighting by Govt./Local bodies, Public water supply, Sewerage etc.,		6.35	120/kW	6.35	120/kW
II-B(1)	Govt and Govt. aided Educational Institutions, Govt. Hospitals and Research labs, etc		5.75	120/kW	5.75	120/kW
II-B(2)	Private Educational Institutions & Hostels		7.50	120/kW	7.50	120/kW

Summary

- Measuring Instruments
- Types
- Energy Calculations