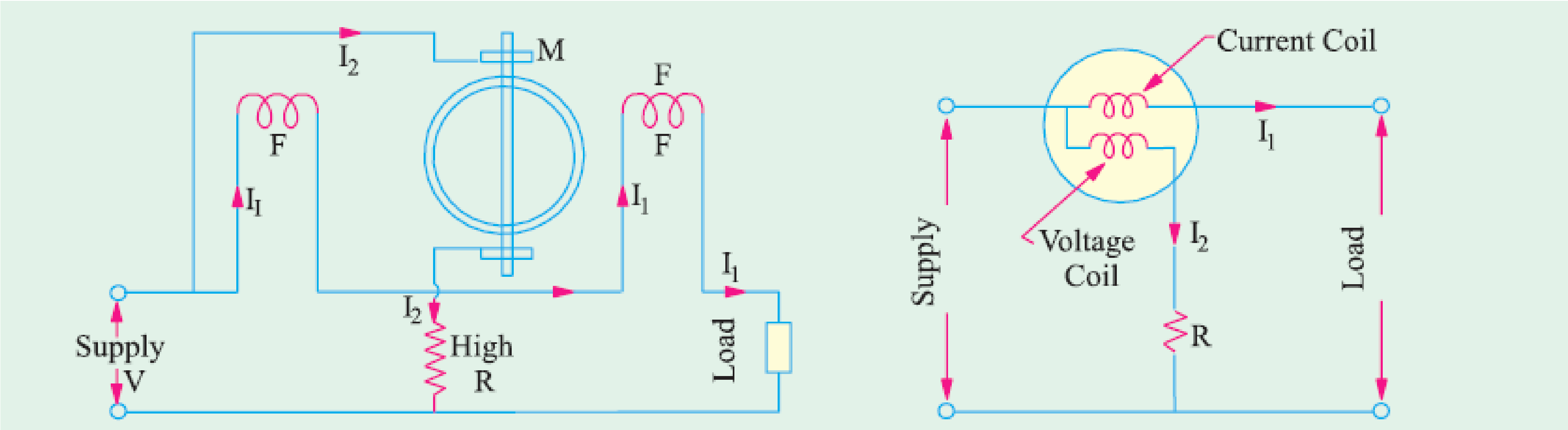
IoT 4211: Sensor Technology

Power Measurement

Electrodynamometer Type Wattmeter



Deflecting Torque

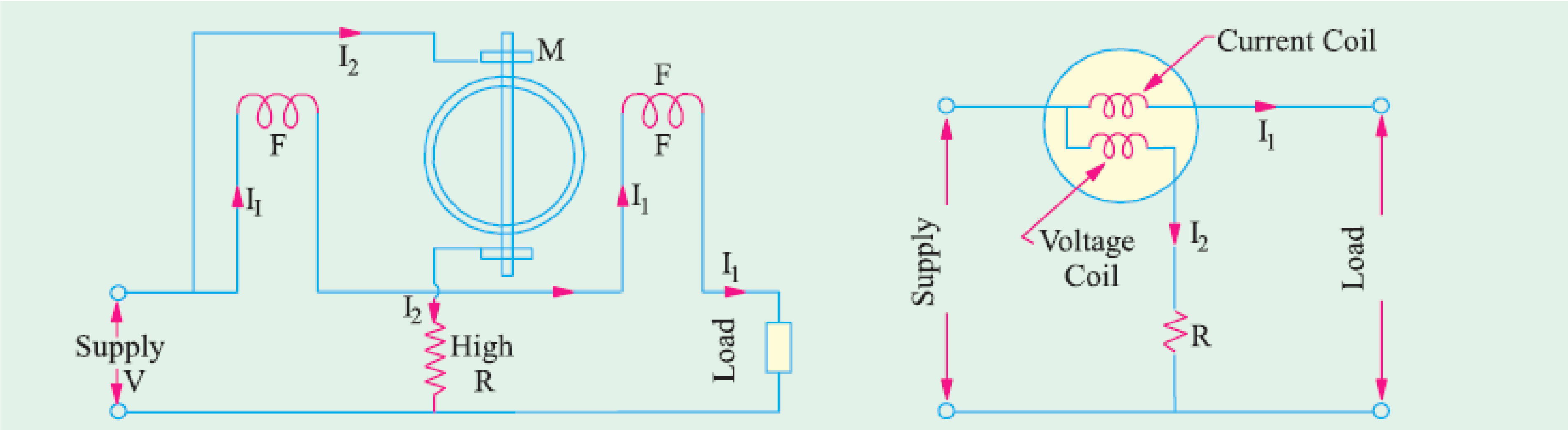
Since coils are air-cored, the flux density produced is directly proportional to the current I_1.

$\therefore$ $B \propto I_1$ or $B = K_1 I_1$; current $I_2 \propto V$ or $I_2 = K_2 V$

Now $T_d \propto B I_2 \propto I_1 V$ $\therefore$ $T_d = KV\,I_1 = K \times$ power

In d.c. circuits, power is given by the product of voltage and current in amperes, hence torque is directly proportional to the power.

Electrodynamometer Type Wattmeter



For a.c. supply, the value of instantaneous torque is given by $T_{inst} \propto vi = K\, vi$

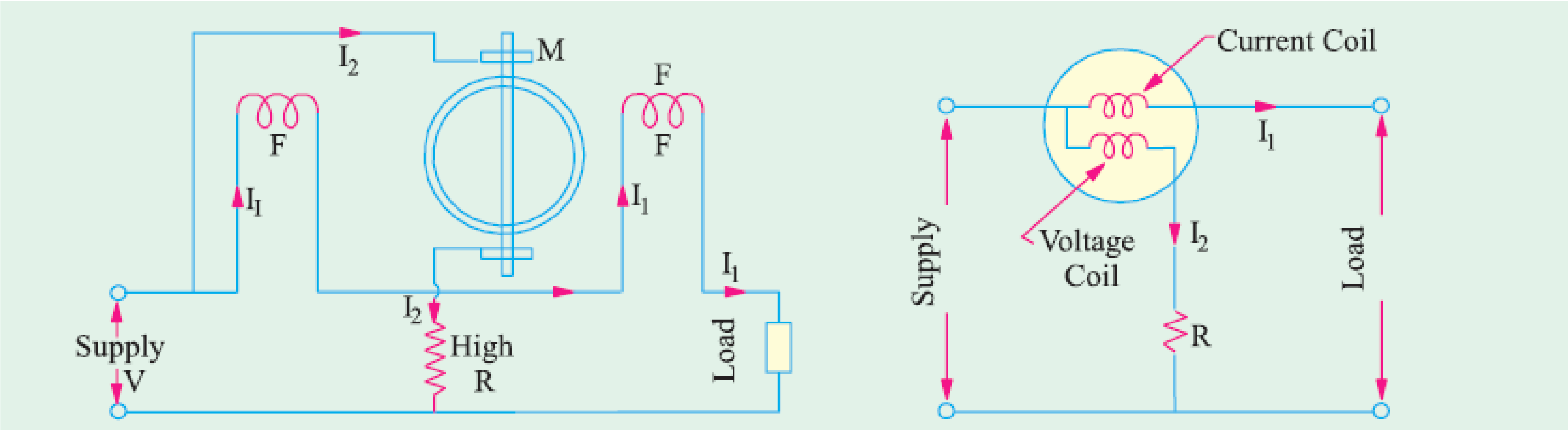
where v = instantaneous value of voltage across the moving coil

i = instantaneous value of current through the *fixed* coils.

However, owing to the large inertia of the moving system, the instrument indicates the mean or average power.

$\therefore$ Mean deflecting torque $T_m \propto$ average value of $v\, i$

Electrodynamometer Type Wattmeter

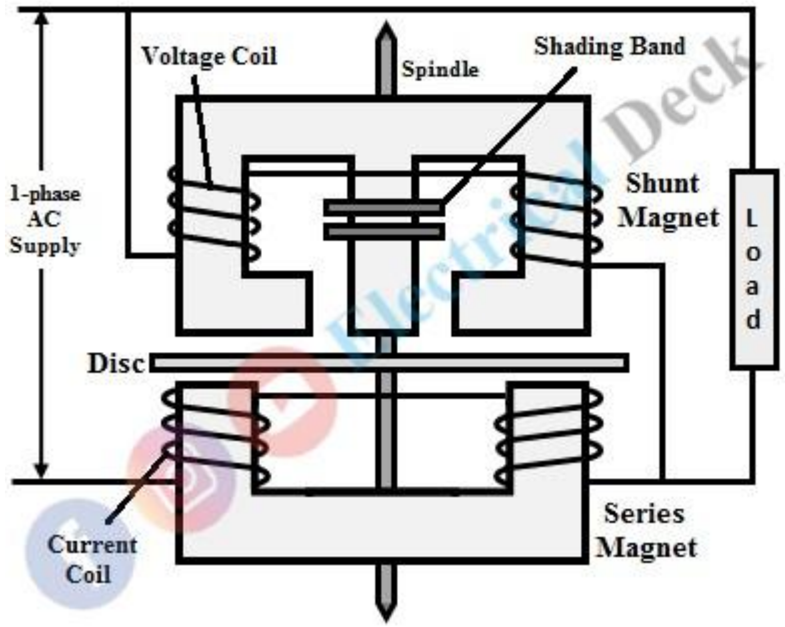


Let $v = V_{max} \sin\theta$ and $i = I_{max} \sin(\theta - \phi)$ $\therefore$ $T_m \propto \frac{1}{2\pi}\int_0^{2\pi} V_{max} \sin\theta \times I_{max} \sin(\theta - \phi)\, d\theta$

$$\propto \frac{V_{max}}{\sqrt{2}} \cdot \frac{I_{max}}{\sqrt{2}} \cdot \cos\phi \propto V\, I \cos\phi$$

where V and I are the r.m.s. values. $\therefore$ $T_m \propto VI \cos\phi \propto$ true power.

Induction Type Wattmeter



Voltage Coil (Potential Coil)

Winding Material: Fine wire with a high number of turns to increase inductance.

Location: Mounted on the voltage magnetic core.

Connection: Connected in parallel with the load. Includes a series resistor to limit the current through the coil.

Purpose: Produces a magnetic field proportional to the voltage across the load.

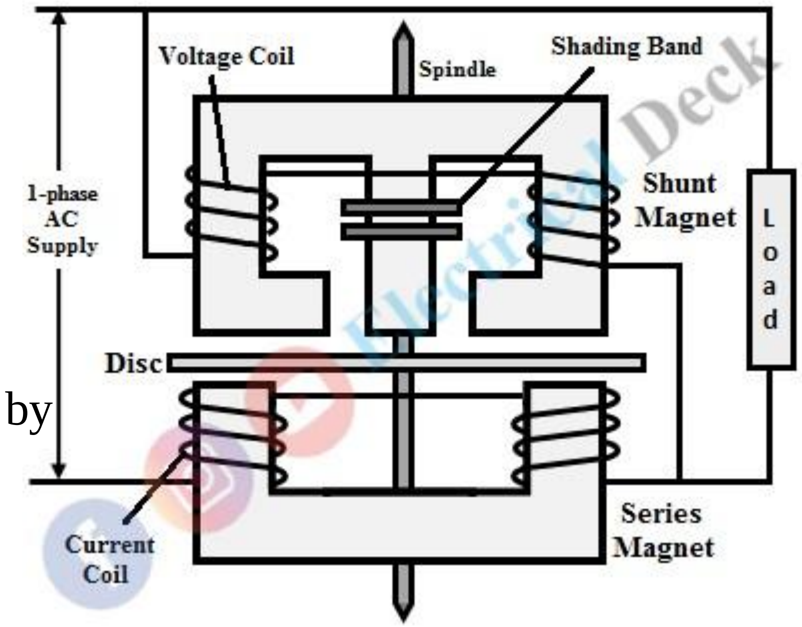
Current Coil

- **Winding Material**: Thick wire with fewer turns to handle high current.
- **Location**: Mounted on the current magnetic core.
- **Connection**:
  - Connected in series with the load.
- **Purpose**: Produces a magnetic field proportional to the current flowing through the load

Aluminum Disc

- **Material**: A lightweight, non-magnetic aluminum alloy.
- **Shape**: Circular and thin, mounted on a spindle.
- **Placement**: Suspended in the air gap between the voltage and current magnetic fields.
- **Function**:
  - The interaction of the magnetic fields induces eddy currents in the disc.
  - These eddy currents interact with the magnetic fields to produce a deflecting torque that rotates the disc.
  - The speed of rotation is proportional to the power being measured.

Induction Type Wattmeter



Moving System

•**Components**:

- **Aluminum Disc**: Mounted on a vertical spindle.
- **Pointer**: Connected to the spindle to display the power on a calibrated scale.

•**Function**:

- The moving system rotates under the influence of the deflecting torque produced by the interaction of eddy currents and magnetic fields.
- The deflection of the pointer over the scale represents the measured power.

Controlling Mechanism

•**Type**: Spiral springs (also called control springs).

•**Function**:

- Provides a controlling torque to counteract the deflecting torque.
- Ensures that the system reaches an equilibrium position where the reading is proportional to the power.

Damping Mechanism

•**Type**: Eddy current damping.

•**Construction**:

- A permanent magnet is placed near the edge of the rotating aluminum disc.

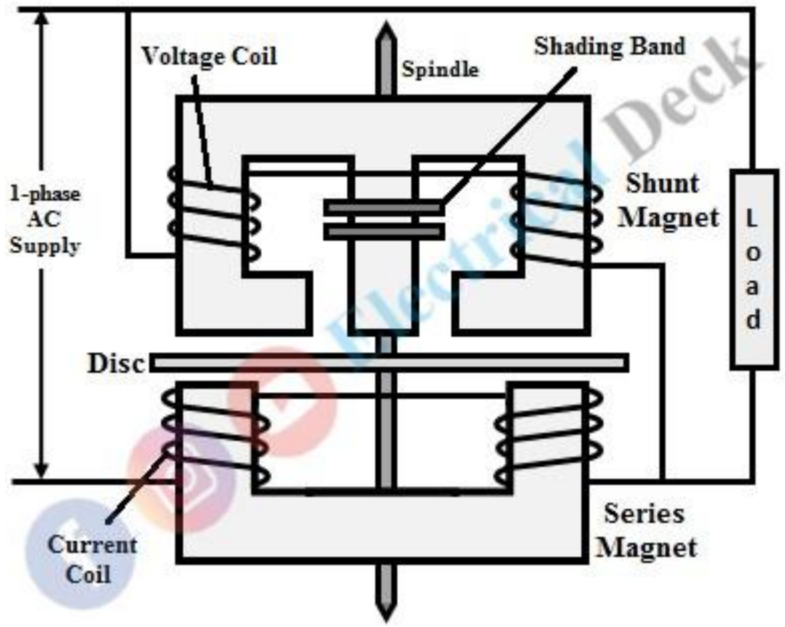
•**Function**:

- The motion of the disc in the magnetic field of the damping magnet induces eddy currents.
- These currents oppose the motion of the disc, providing a damping effect.
- Prevents oscillations and stabilizes the pointer for an accurate reading.

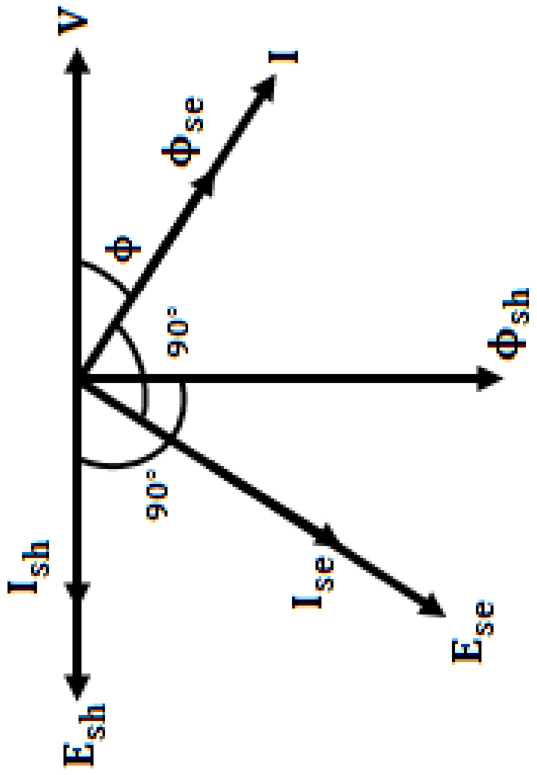
Induction Type Wattmeter

Scale

•**Type**: Graduated scale calibrated to display power (in watts, kilowatts, etc.).
•**Construction**: Marked with fine divisions for precise readings.
•**Range**: Depends on the wattmeter's design and application.



Torque Equation



Let,
V = Voltage to be measured
I = Current to be measured
φ = Phase angle between current and voltage
φse = Flux produced by series magnet
φsh = Flux produced by shunt magnet
Esh = Emf induced in the disc by the shunt magnet flux
Ish = Eddy current in the disc caused by emf Esh
Ese = Emf induced in the disc by the series magnet flux
Ise = Eddy current in the disc caused by emf Ese

Assuming the disc is fully resistive. The eddy current I_{se} induced by the emf E_{se} will be in phase with it. So, we can see that eddy current I_{se} lags behind the current I by 90°. Thus there will be a phase difference of 90° between I_{se} and φ_{se}.

The flux φ_{sh} induces an emf E_{sh} in the disc, which lags behind the φ_{sh} by 90°. Since the disc is resistive, the eddy current I_{sh} caused by E_{sh} will be in phase with it. Thus there will be a phase difference of 90° between I_{sh} and φ_{sh}.

Torque Equation

The torque produced by the interaction of current I_{se} and flux ϕ_{sh} is, $T_1 = K\, I_{se}\phi_{sh}\cos\phi$

The torque produced by the interaction of current I_{sh} and flux ϕ_{se} is, $T_2 = K\, I_{sh}\phi_{se}\cos(180° - \phi)$

Therefore, the resultant torque produced is,

$$= K\, I_{se}\phi_{sh}\cos\phi - K\, I_{sh}\phi_{se}\cos(180° - \phi)$$

$$= K[I_{se}\phi_{sh}\cos\phi + \ I_{sh}\phi_{se}\cos\phi]$$

$$= K[K_1 VI\cos\phi + \ K_2 VI\cos\phi]$$

$$= K\, VI\cos\phi\,[K_1 + K_2]$$

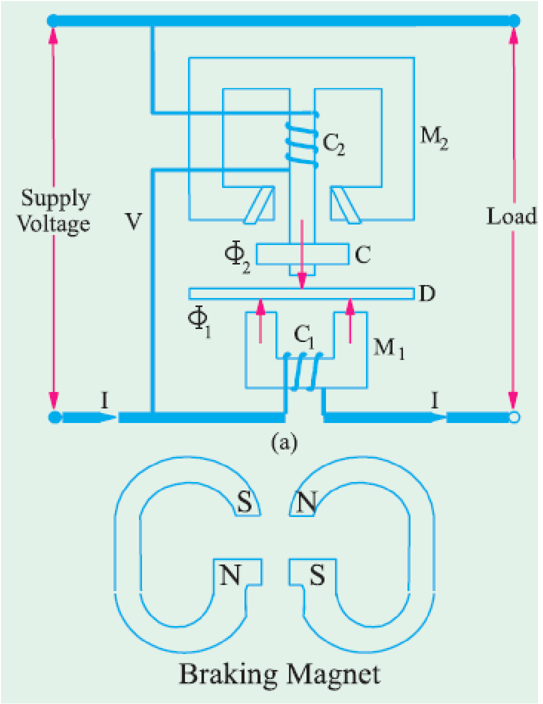
$$\therefore\ T_d \propto VI\cos\phi$$

Hence the deflecting torque produced is proportional to the ac power to be measured in the circuit.

Applications

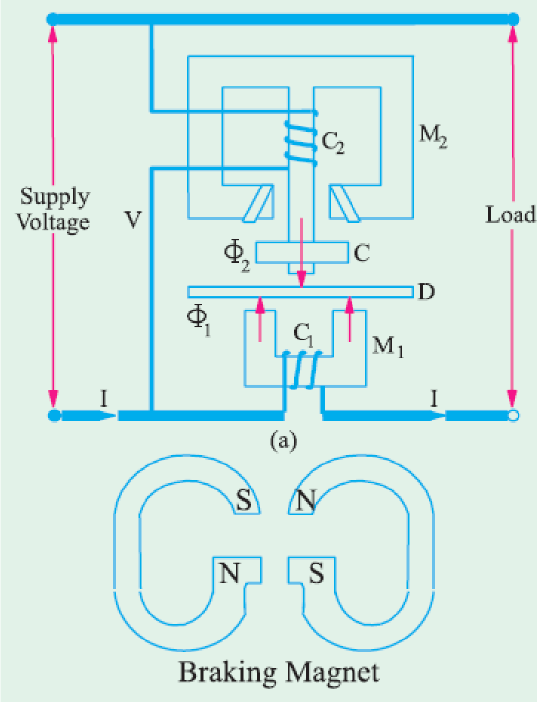
- Measurement of power in industrial and household AC circuits.
- Used in laboratories for educational and testing purposes.

Induction Type Single-phase Watt Hour meter



- Construction is similar to Induction Type Wattmeter.
- Spring is replaced by brake magnet.
- Pointer is replaced by a spindle.

Induction Type Single-phase Watt Hour meter



$T_B \propto \Phi_i$ $\quad i = e/R \quad e \propto \Phi n$

The braking torque $T_B \propto \Phi^2 N/R$

N is the speed of the rotating disk.

For constant magnetic flux and resistance:

$T_B \propto N.$

$T_d = T_B \quad \therefore\ N \propto \text{power } W$

Hence, in a given period of time, the total number of revolution $\int_0^t N.dt$ is proportional to $\int_0^t W.dt$ *i.e.*, the electric energy consumed.