University of Global Village

Department of Electrical & Electronics Engineering

OBE Curriculum

MEASUREMENT & INSTRUMENTATION

Code: EEE 0713-2207
Core Course
Exam Hours: 03

Credits: 03
CIE Marks: 90
SEE Marks: 60

MEASUREMENT & INSTRUMENTATION

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RATIONALE OF THE COURSE

The course aims to provide students with a fundamental understanding of the principles and applications of electrical instruments and measurements. It prepares them to analyze and design systems for measuring electrical quantities, ensuring accuracy and precision in engineering solutions. The knowledge gained is vital for addressing real-world challenges in electrical and electronic systems.

OBJECTIVES

1. To understand the theory and operation of electrical measuring instruments, including analog and digital systems.
2. To analyze the working principles of sensors and transducers.
3. To gain practical knowledge in measuring various electrical quantities, resistance, and AC/DC parameters.
4. To explore error analysis and calibration techniques in measurement systems.

COURSE LEARNING OUTCOMES (CLO):

01 *Demonstrate knowledge of the working principles of electrical instruments and measuring systems*

02 *Analyze and evaluatethe performance of sensors, transducers, and measurement devices*

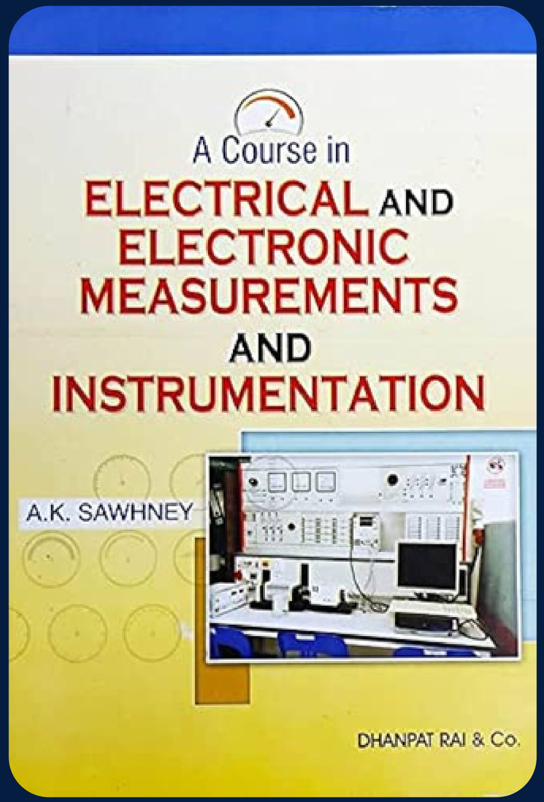
03 *Design and implement measurement setups for electrical quantities with accuracy*

04 *Identify and minimize measurement errors in practical systems*

Content of Course	Hours	CLOS
Introduction to Measurement & Instrumentation	6	CLO 1
Instruments andMeasurement Systems	5	CLO 1, CLO 2
Important Terms Associated with Measurement	5	CLO 1, CLO 4
Error Analysis and Calibration	5	CLO 4
Measurement of Resistance (Low, Medium, High)	5	CLO 3

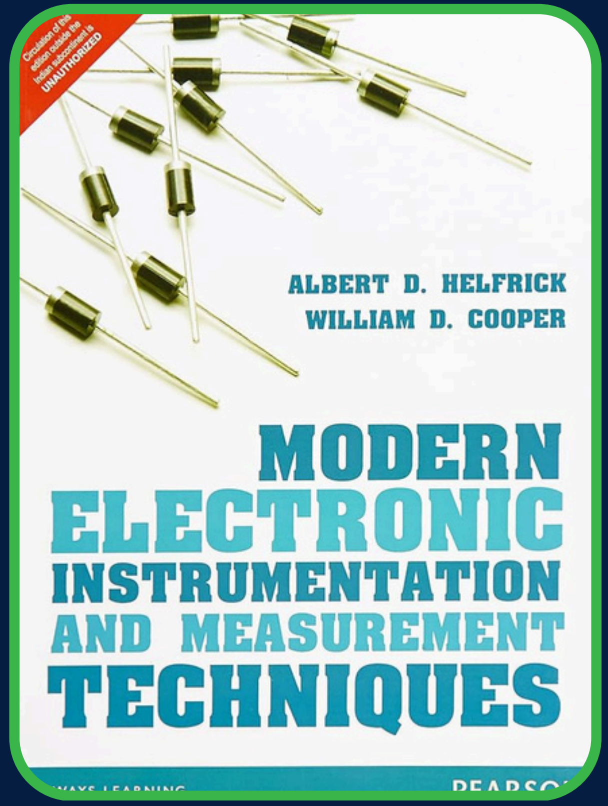
Content of Course	Hours	CLOS
AC BridgeTechniques	5	CLO 2, CLO 3
Magnetic and Electronic Measurements	5	CLO 1, CLO 3
Transducers and Sensors	5	CLO 2, CLO 3, CLO 4

REFERENCE BOOKS



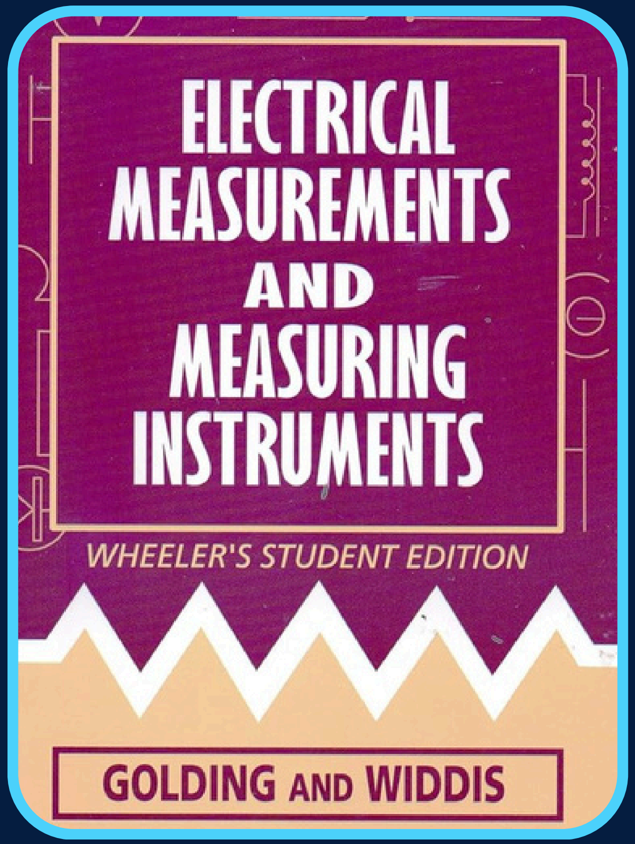
ELECTRICAL & ELECTRONICS MEASUREMENT & INSTRUMENTATION

A. K Sawhney



MODERN ELECTRONIC INSTRUMENTATION AND MEASUREMENT TECHNIQUES:

Helfrick & Cooper



ELECTRICAL MEASUREMENT AND MEASURING INSTRUMENTS

Golding & Widdis

ASSESSMENT PLAN

CIE- Continuous Internal Evaluation (90 Marks)

Bloom's Category Marks (out of 90)	Exam (45)	Assignments/ Viva/ Presentation (15)	Quiz (15)	External Participation in Curricular/Co-Curricular Activities (15)
Remember	10		8	Bloom's Affective Domain: (Attitude or will) Attendance: 15 Copy or attempt to copy: -10 Late Assignment: -10
Understand	8		7	
Apply	13			
Analyze	7			
Evaluate	4			
Create	3			

ASSESSMENT PLAN

SEE- Semester End Examination (60 Marks)	
Bloom's Category	Tests
Remember	15
Understand	13
Apply	12
Analyze	10
Evaluate	5
Create	5

Course plan specifying content, CLOs, teaching learning and assessment strategy mapped with CLOs

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
1 (1 & 2)	Definition, Importance of Measurement & Instrumentation, Methods of measurement, measurement system	-To have a formal interaction with the students and know about the proceedings of the subjectmatter. -Course outline will be discussedin detail -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Animation, Simulation, Link) -Group discussion	Quiz, Written exam -Collect feedback by questioning and answering -Collect feedback from group discussion	CLO1

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
2 (1& 2)	Definition, classification of Instrument, functions of Instrument	Recap main points -Forward Plan -Discussion aboutthe subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Animation, Simulation, Link) -To be supplied Lessonmaterials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO1

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
3 (1 & 2)	Accuracy, precision, sensitivity, resolution,	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Animation, Simulation, Link) -To be supplied Lesson materials notes, Hard copy, Audiovideo materials/Link -Group discussion	Quiz, Written exam,Collect feedback by questioning and answering from group discussion -Collect feedback from Midterm and ClassTest 1 -Assessment of LOs	CLO1, CLO2

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
4 (1 & 2)	Definition, Types, gross error, systematic error, random error, how to eliminate error, Ammeter, Voltmeter.	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO2

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
5 (1 & 2)	Classification of resistance, Method of measurement of medium resistance, Ammeter- voltmeter method, Substitution method, Wheatstone Bridge, theorem to Wheatstone	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO2, CLO4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
6 (1 & 2)	Defects of Wheatstone Bridge, Limitation of Wheatstone Bridge, Measurement of Low Resistance: Kelvin Bridge method Kelvin double Bridge method,	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO2, CLO4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
7 (1 & 2)	Measurement of High Resistance: Loss of charge method, Megohm Bridge method, Localization of Cable faults, Bridge sensitivity, , Bridge resistance, Voltage sensitivity, Bridge sensitivity for a Wheatstone bridge having the Bridge resistance,	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO2, CLO4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
8 (1 & 2)	Types of measurement, Inductance comparison bridge, Maxwell's Inductance-Capacitance bridge, Advantage, Disadvantage.	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO1, CLO2, CLO4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
9 (1 & 2)	Operation of Hay's Bridge, Advantage, Disadvantage, Circuitdiagram of De Sauty's Bridge.	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO1, CLO2

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
10 (1 & 2)	Types of Instruments, Permanent magnet moving coil (PMMC): Derivation, advantage, disadvantage, Electrostatic Instrument: Derivation, advantage, disadvantage	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO1, CLO3

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
11 (1 & 2)	Rectifier Type Instrument, Types of Wattmeters: Electrodynamometer type wattmeter.	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 1, CLO 3, CLO 4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
12 (1 & 2)	Measurement of power by using three Ammeter, Types of Frequency Meter.	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 1, CLO 3, CLO 4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
13 (1 & 2)	D'Arsonval Galvanometer, Flux Meter, Fluxmeter with shunt, Measurement of flux density in ringspecimens, Power measurement in D.C circuits, Dynamometer wattmeter,	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 1, CLO 3, CLO 4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
14 (1 & 2)	Single phase energy meter, Working of a single-phase induction type energy meters	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 1, CLO 4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
15 (1 & 2)	Phasor diagramof a single-phase induction type energy meter, Single phase electro dynamotype power factormeter, Electrical resonance frequency meter	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 3, CLO 4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
16 (1 & 2)	Probe, Key attributes of ideal probe, Probe Constructions, Attenuator probe.	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 2, CLO 4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
17 (1 & 2)	Compensating the Probe, Basic Block Diagram of Oscilloscope, Dual Trace Oscilloscope, Chop Display.	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 2

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
18 (1 & 2)	Lissajous Pattern,Determination of angle of phase shift	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 1, CLO 4

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
19 (1 & 2)	Measurement of non-electrical quantities, Displacement transducer, Construction of Non wire potentiometer, Merits & demerits	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 3, CLO 2

Week & Class No	Task Details	Teaching Learning strategy(s)	Assessment strategy(s)	Alignment to CLOs
20 (1 & 2)	Linear variable differential transformer (LVDT), Dc output from LVDT,Voltage output, Merits of LVDT, Very small displacement, Strain gauge, Capacitive transducer, Inductive transducer, Speaker as inverted transducer	-Recap main points -Forward Plan -Discussion about the subject content with the students -Interactive discussion -Lecture with aid of multimedia (Using Document, Slide, PDF, Video, Link Animation, Simulation) -To be supplied Lesson materials notes, Hard copy,Audio video materials/Link -Group discussion	Quiz, Written exam Collect feedback by questioning and answering -Collect feedback from group discussion -Collect feedback from Midterm and Class Test 1 -Assessment of LOs	CLO 4

STUDENT SUPPORT DOCUMENTS

WEEK 1
CLASS 1

MEASUREMENT & INSTRUMENTATION

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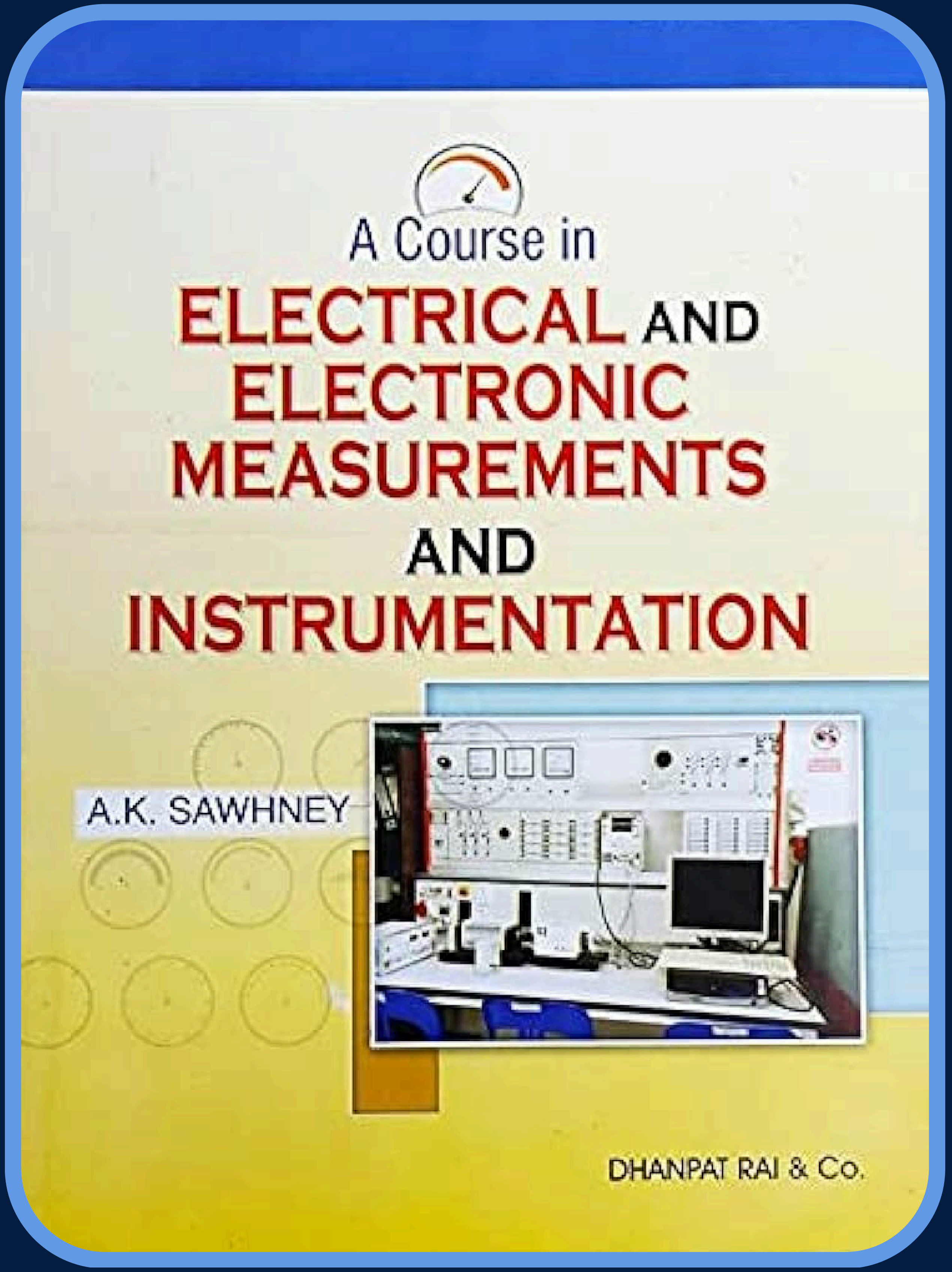
Course outline:

- Introduction (measurement, error,...)
- R, L, C measurement
- Magnetic measurement
- Measuring instruments
- Electronic Measuring Instruments
- Instrumentation
- Sensors – Measurement of Non-electrical quantities



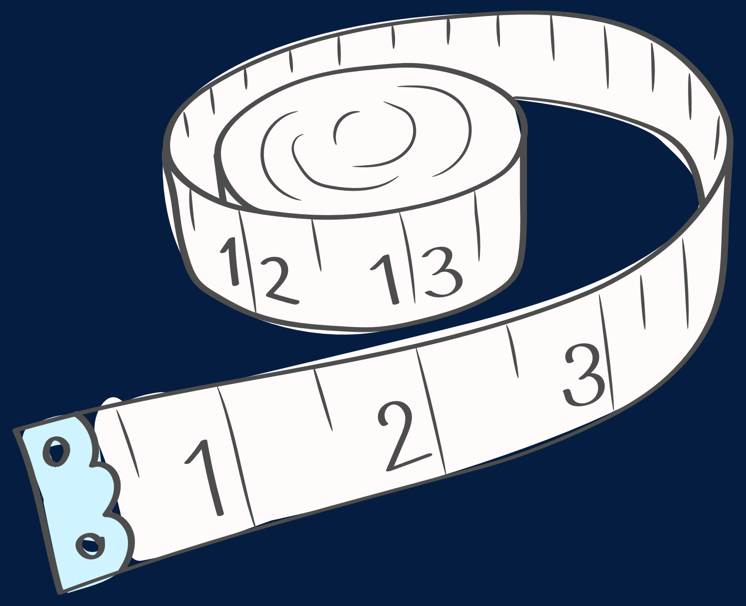
REFERENCE BOOK

Electrical & Electronics
Measurement & Instrumentation
by A K Sawhney

What is measurements & measurement system?

It is a process of converting physical parameters in meaningful numerical numbers.

Your friend is suffering from fever. Now you ask "How is your fever?" He replies "Very high". This does not involve any measurement. But if he replies "My temperature is 102 degree " then it is a meaningful number and it gives more clear idea of his fever.



Methods of Measurement

Direct Method

In these methods, the unknown quantity is directly compared against a standard. e.g. length, mass and time etc.

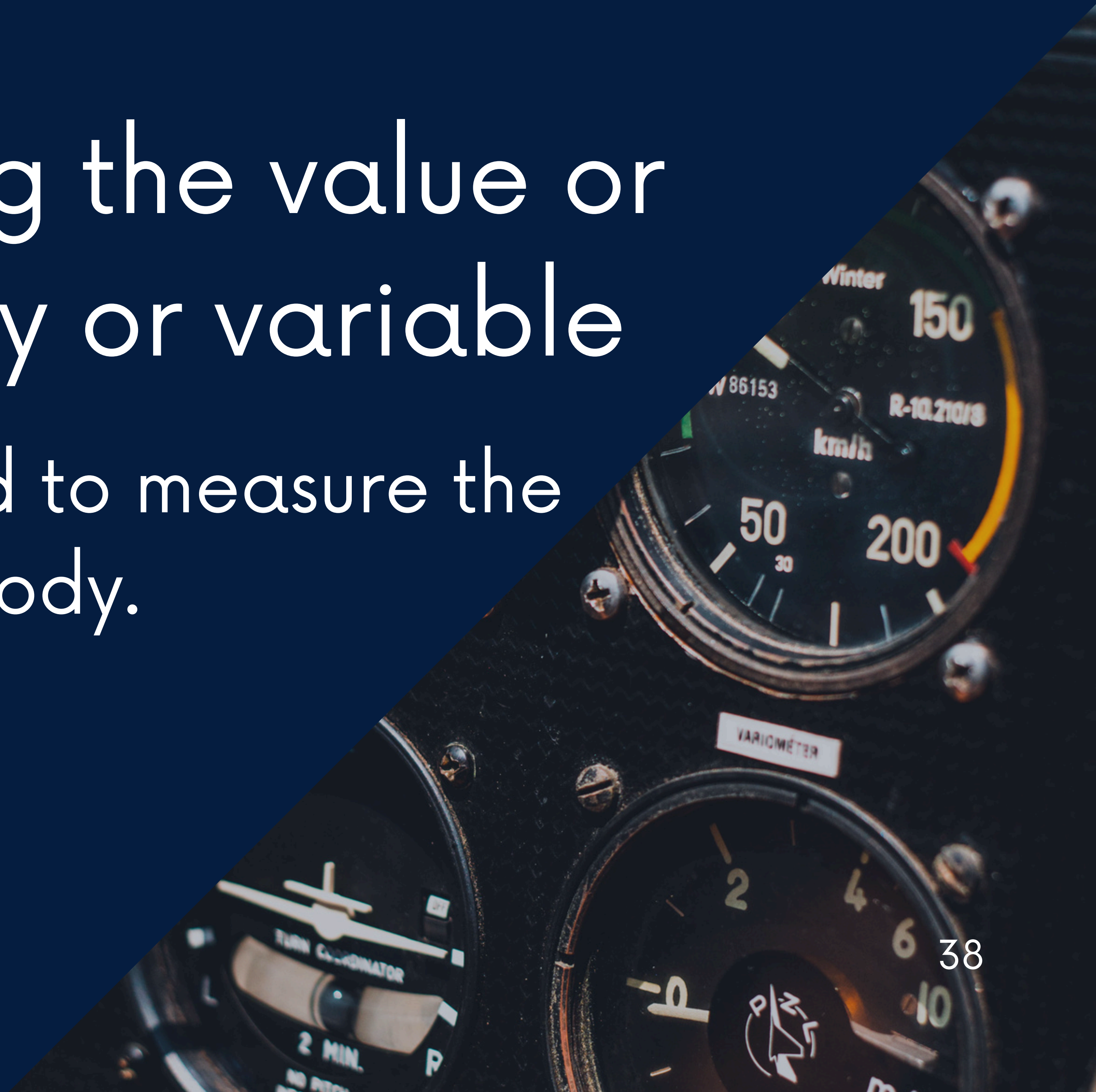
Indirect Method

Measurement of direct methods are not always possible, feasible and practicable. So we need of indirect methods of measurement.

What is Instruments?

a device for determining the value or magnitude of a quantity or variable

For example, a thermometer is required to measure the temperature of a human body.



Phases of Instruments:

Mechanical Instruments

these are very reliable for static and stable conditions but unable to respond rapidly to measurement of dynamic and transient condition.

Electrical Instruments

these are very reliable for static and stable conditions and respond rapidly to measurement of dynamic and transient condition. e.g. galvanometer

Electronic Instruments

These instruments require use of semiconductor devices. The only movementinvolved is thatof electrons, the response time is extremely small. e.g. CRO

Classification of Instrument

Absolute Instruments

These instruments give the magnitude of the quantity under measurement in terms of physical constants of the instrument. E.g: tangent galvanometer.

Secondary Instruments

These are so constructed that the quantity being measuredcan only be measured by observing the output indicating by the instruments. E.g: voltmeter, thermometer

Function of instruments and measurement system

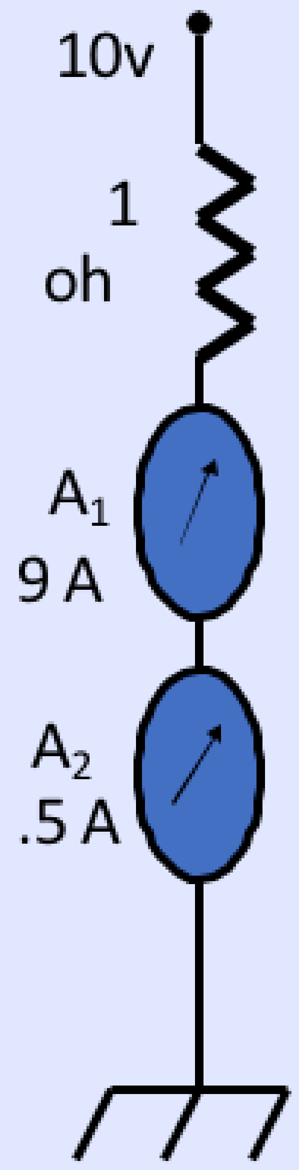
- Indicating function
- Recording function
- Controlling function

WEEK 1
CLASS 2

Accuracy

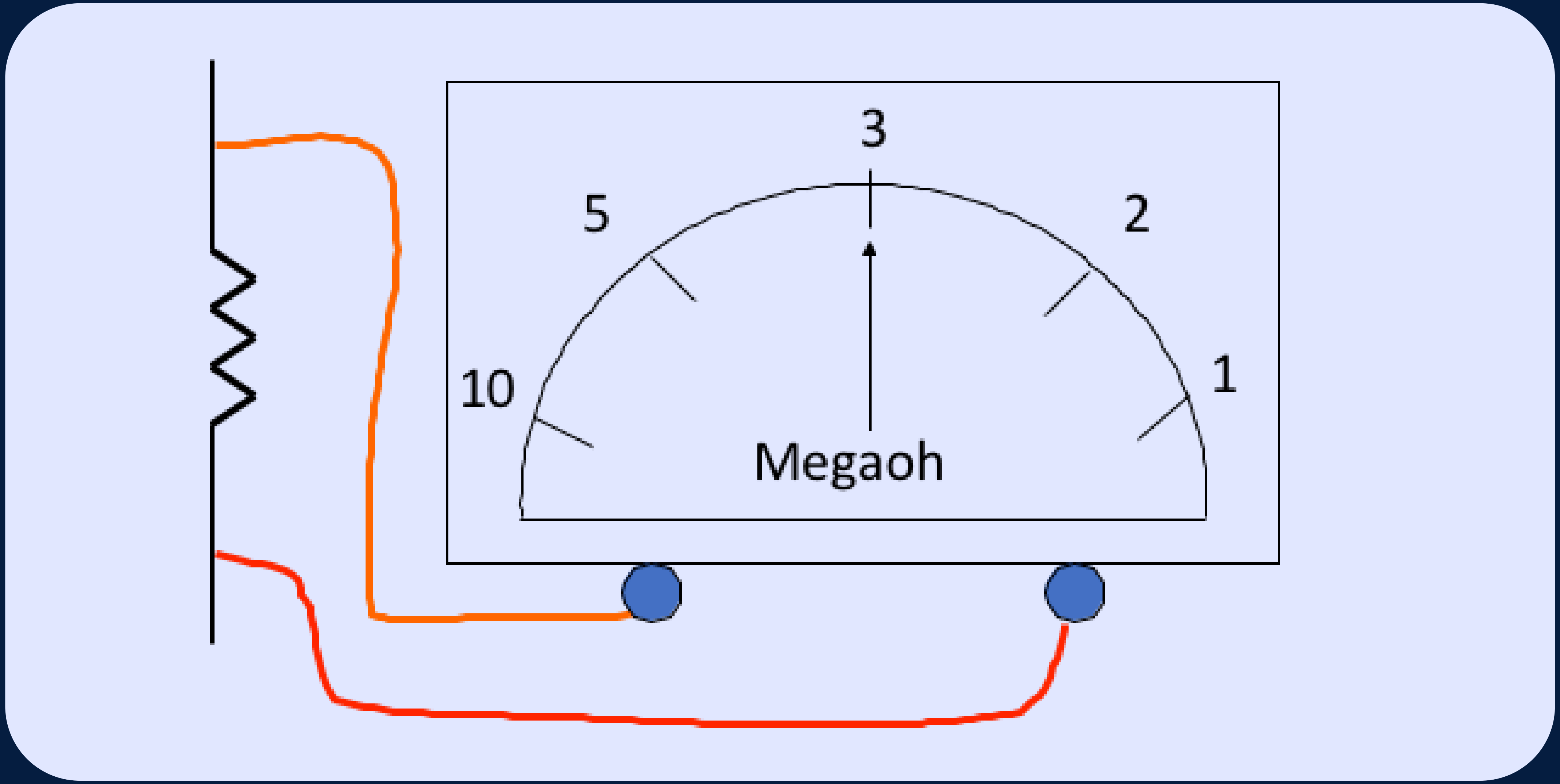
The term accuracy means how the instrument reading is close to the actual quantity.

Example : Suppose you want to find the weight of a chick purchased from market. The shopkeeper takes the weight b "Daripalla" to be 1kg and 100 gram. But if you take the we with a balance in your Laboratory, you may find it to be 1.1 kg, which is more closer to the actual quantity.



Precision

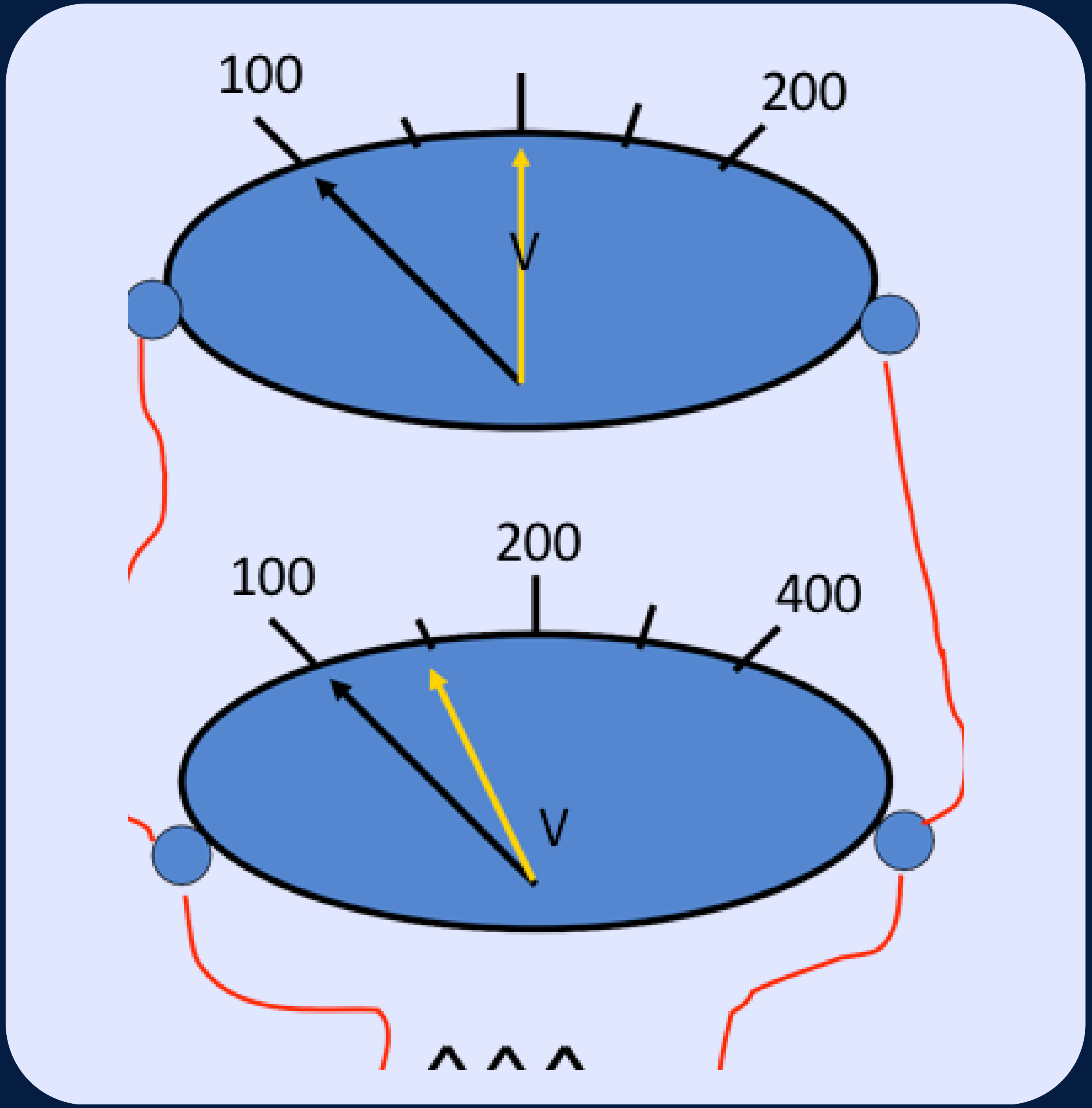
It is the degree to which successive measurements differ from each other.



Sensitivity

It is the ratio of the response of the instrument to a change of the input signal

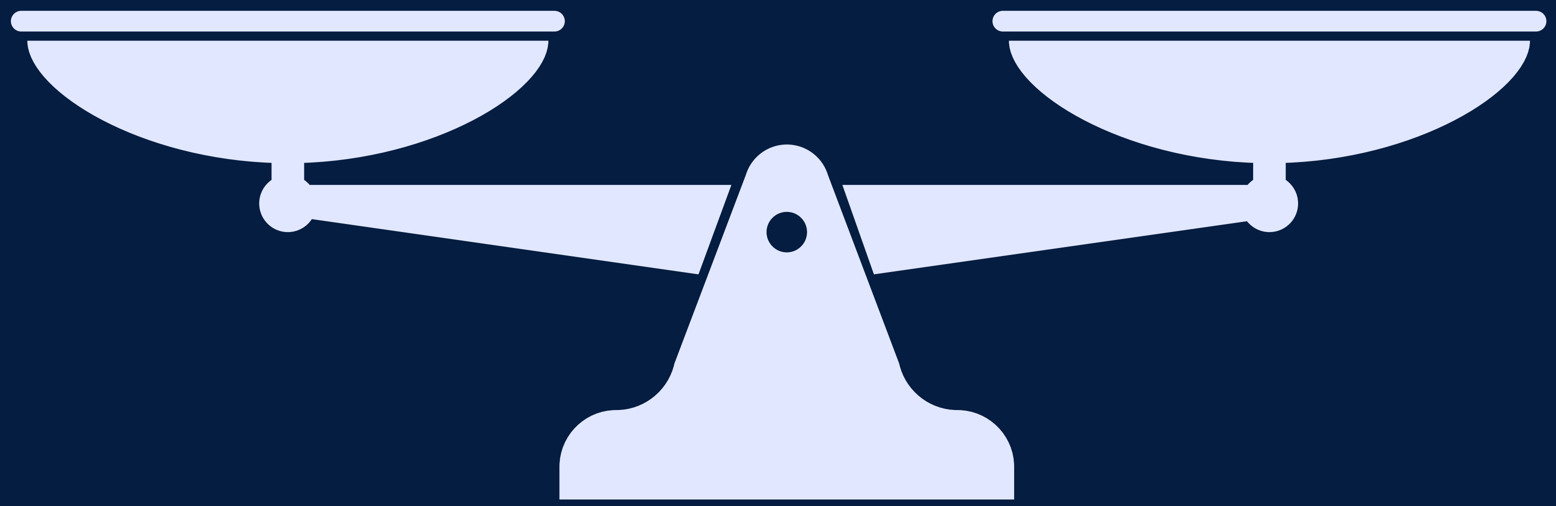
Suppose two voltmeters are used to measure the voltage of the same circuit. Now the circuit is slightly changed so that the voltage is also changed by a small quantity. The pointer of one meter moves by small distance, whereas the pointer of the other meter moves by a larger distance. Therefore the second meter is more sensitive.



Resolution

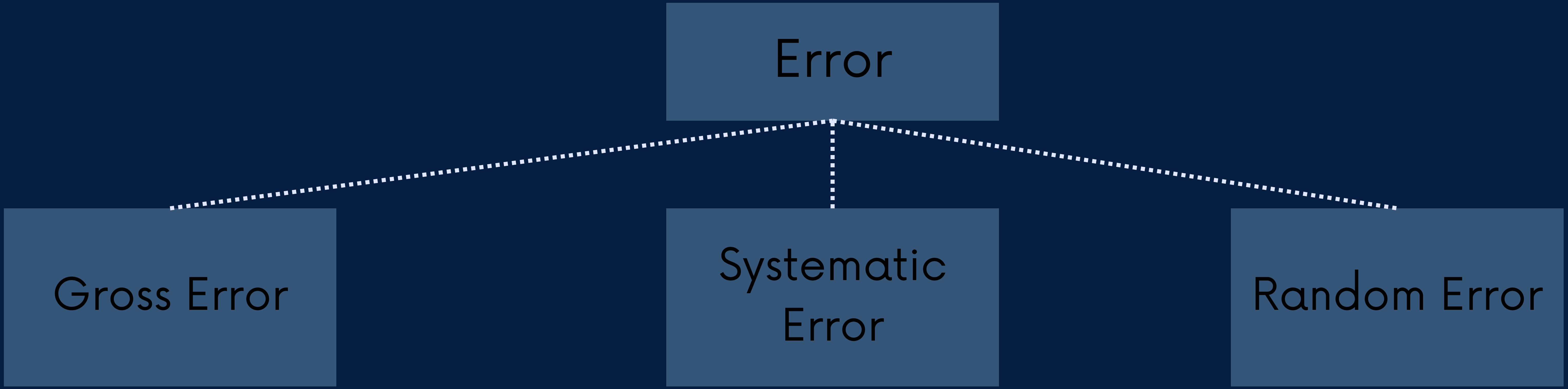
Resolution means the smallest change in the instrument reading to which it can respond.

Suppose you purchase a fish. The fisherman has a “Daripalla” and “Butkhara”, the minimum size of the butkhara which he has is 100 gm. So the weight of your fish will be either 800gm or 900gm or 1000gm etc.



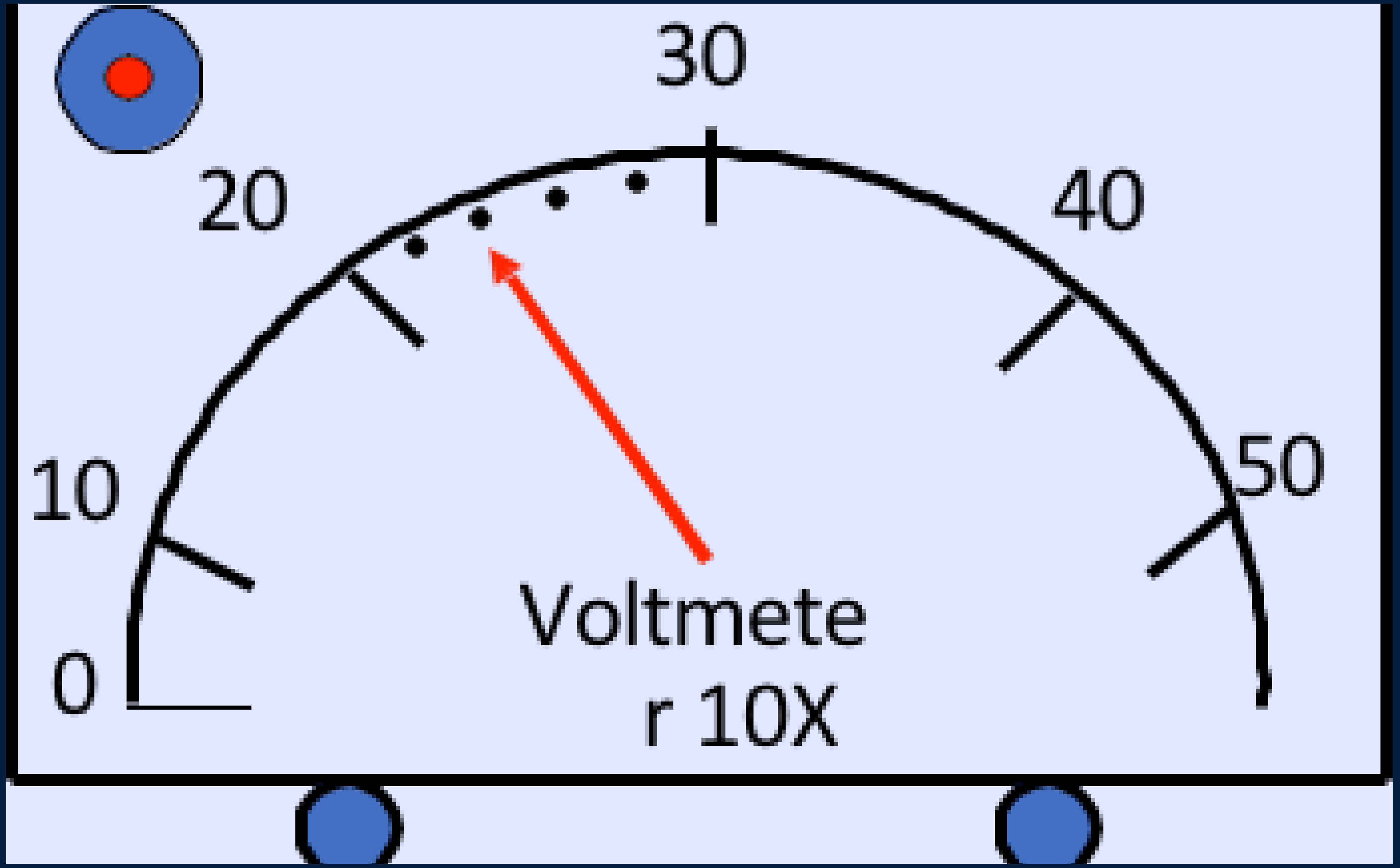
Error

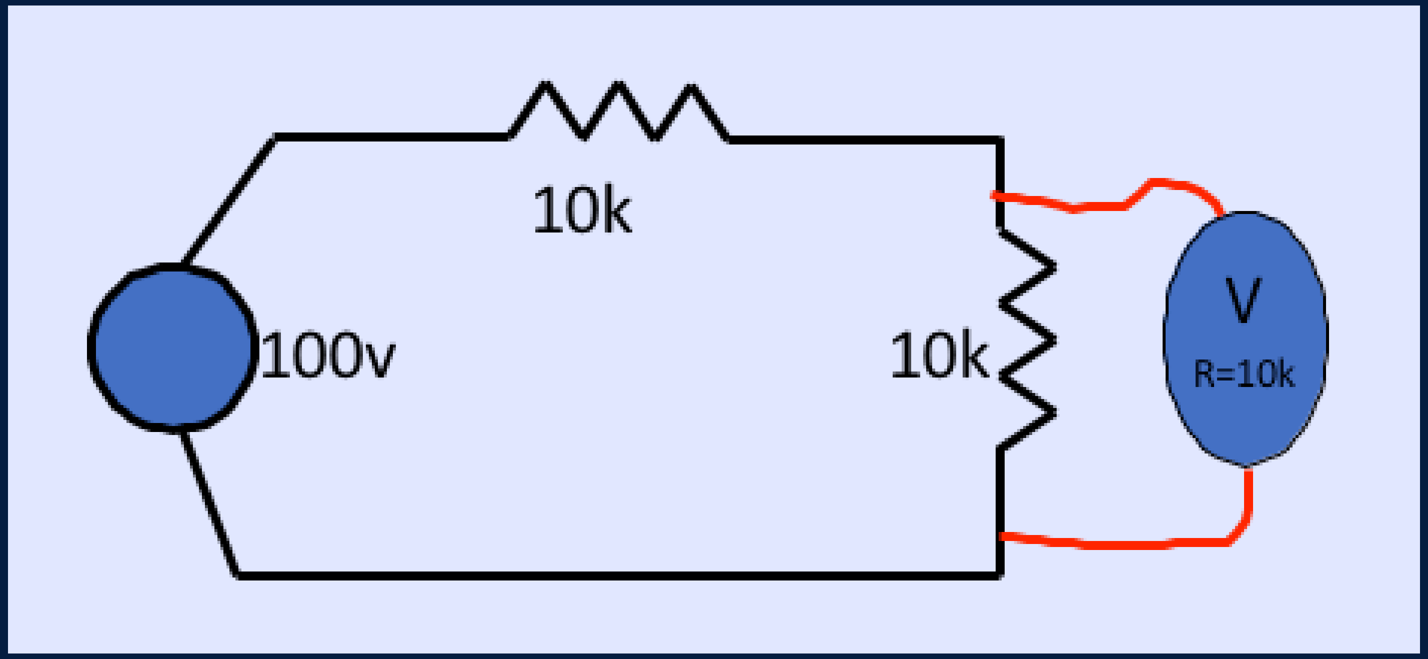
Error can be defineas the deviation from the true value of the quantity measured.



List of gross error

I. Human error
II. Misreading of Instrument
III. Incorrect adjustment
IV. Improper application
V. Computational mistakes





What are the systematic error?

Instrumental error

- Frictional loss
- Irregular spring tension
- Overloading
- Permanent Stress

Environmental error

- Dusty environment
- Temperature change
- Humidity

Electromagnetic field

What is random error?

The random error is the error due to unknowncauses even all precautions and preventive measures are observed.

Suppose a voltmeter is used to monitor the voltage of a circuit at an interval of 1 hour.Sometimes it is observed that the meter reading includes small amount of deviations in each reading, even if all cautions are taken.

Eliminating error

Errors can not be eliminated totally.However it can be minimized by observing proper corrective steps.

Minimization of Systematic error:

•Take care of your measuring Instrument.
•Ensure proper environment.

Minimization of Gross error:

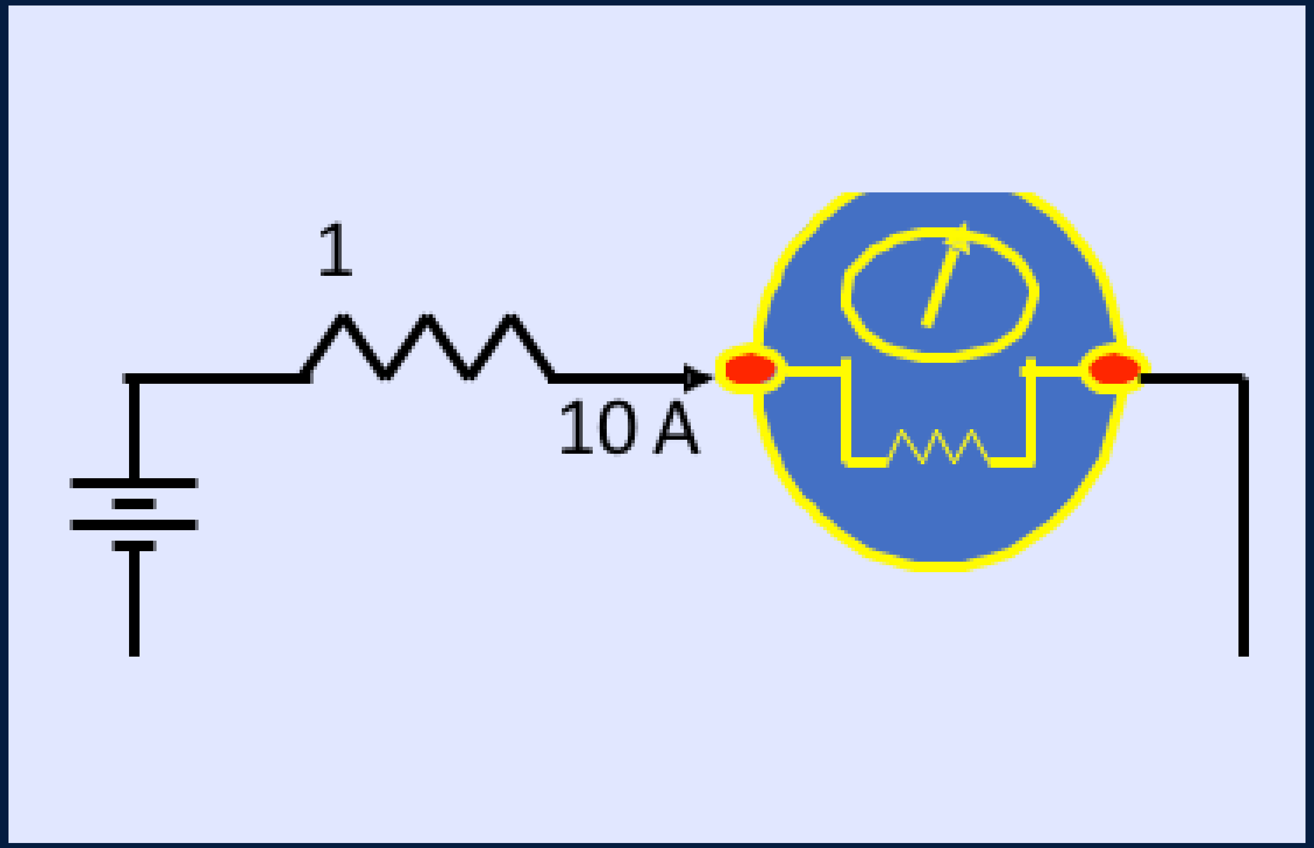
Be more careful while taking reading.

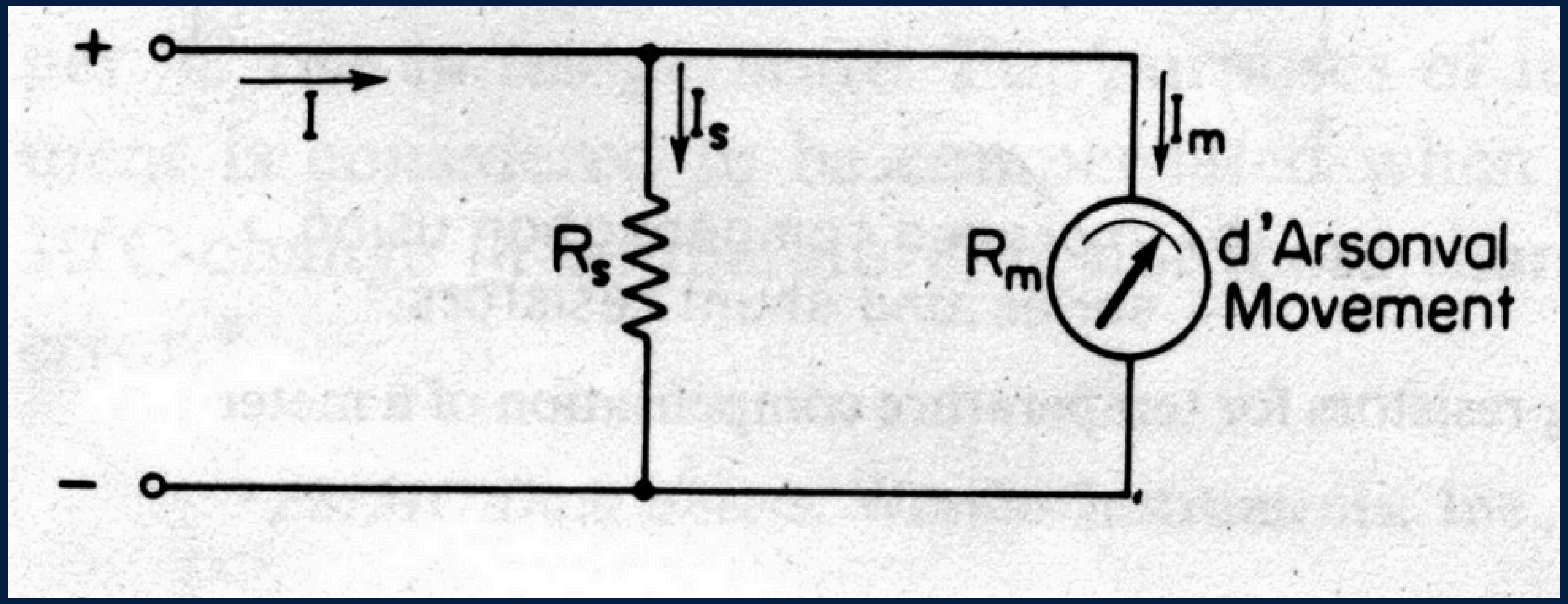
Minimization of Random error:

Increase the number of reading and apply statistical analysis.

WEEK 2
CLASS 1

Ammeter

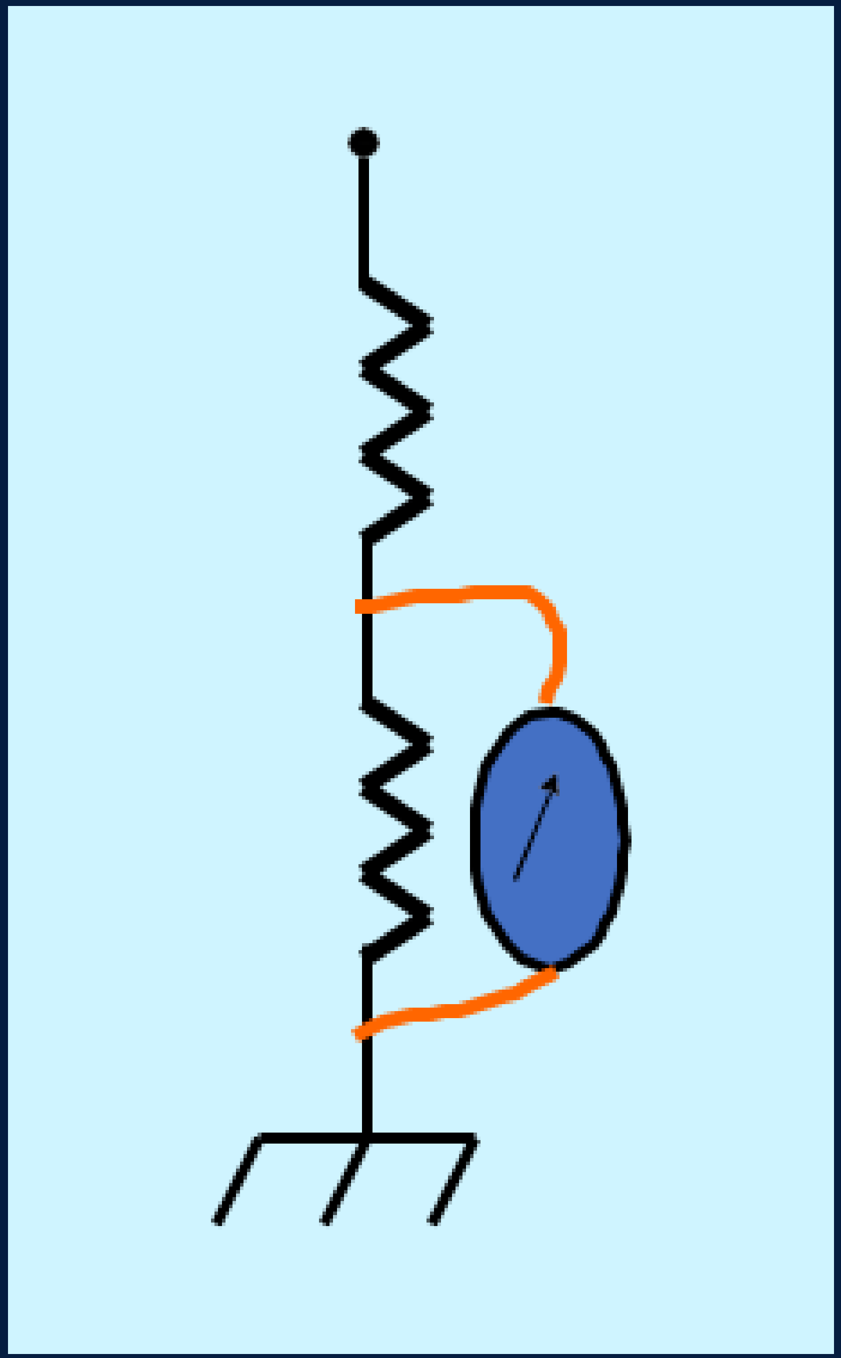


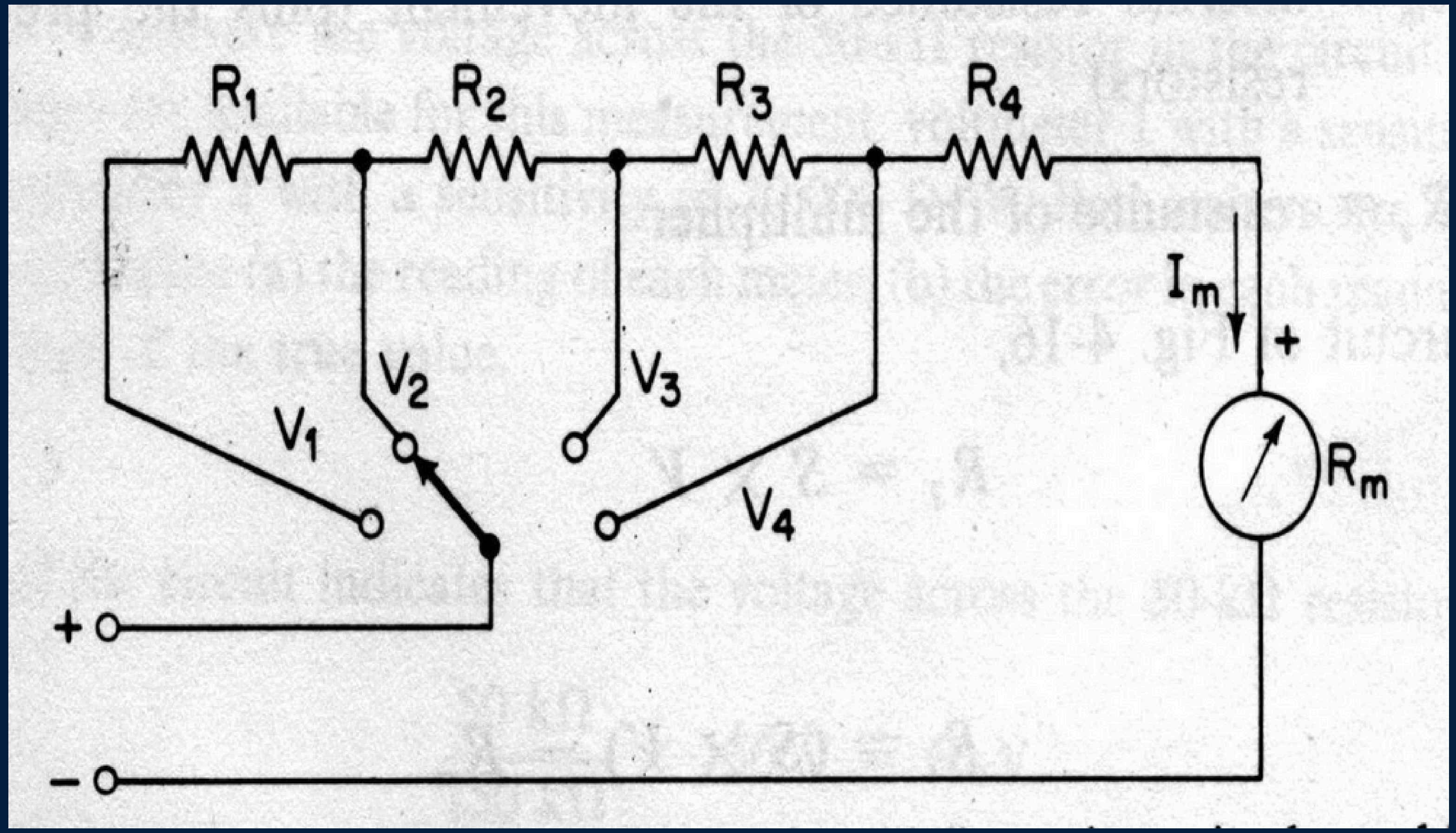


$$I_s = I - I_m$$

$$R_s = I_m R_m / I_s$$

Voltmeter





Measurement of Resistance

Classifications of resistance

1. Low resistance

All resistances of the order of 1W and under may be classified as low resistance ($R<1\Omega$).

2. Medium resistance

This class includes resistances from 1W upwards to about 0.1MW or 100kW ($1\Omega<R<100k\Omega$).

3. High resistance

Resistances of the order of 100kW and upwards are classified as high resistances. ($R>100k\Omega$).

Measurement of Resistance

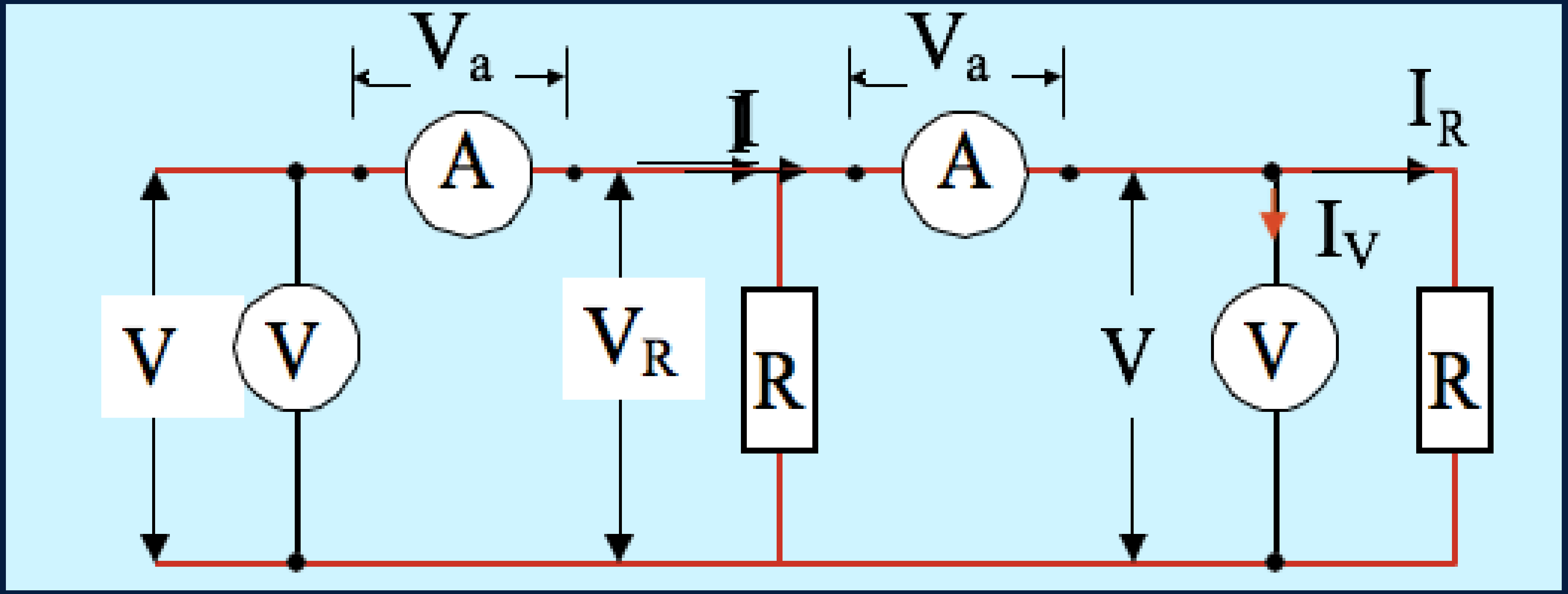
Method of measurement of medium resistance

-Ammeter-Voltmeter method
-Substitution method
-Wheatstone bridge method
-Ohmmeter method

Measurement of Medium Resistance

Ammeter-voltmeter method

This method is very popular since the instruments required for this test are usually available in the laboratory.



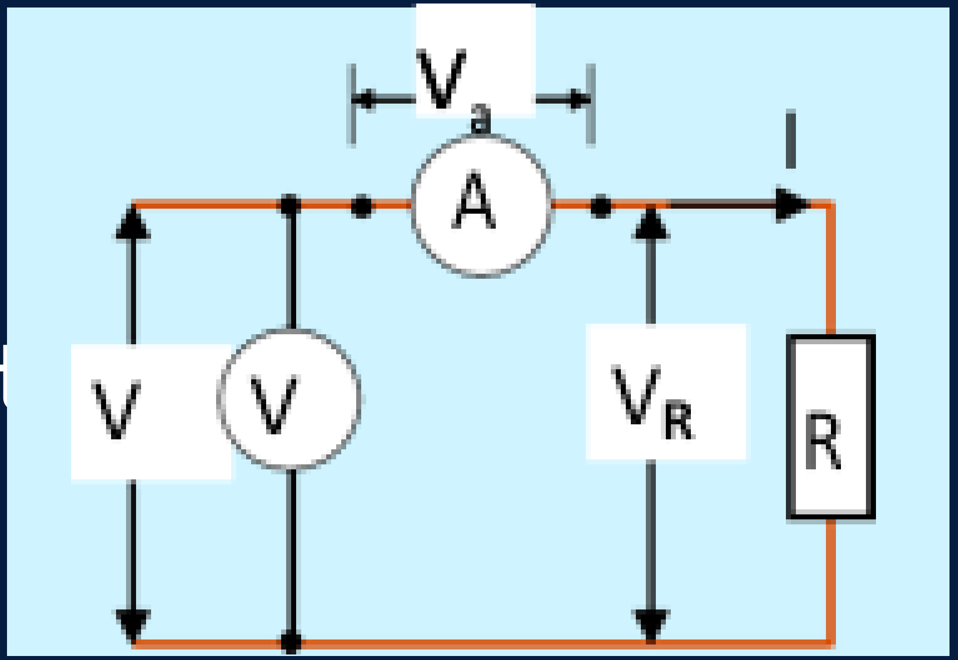
In both cases, if the readings of ammeter and voltmeter are taken, then the
measured value of resistance is given by

$$R_m = \frac{Voltmeterreading}{Ammeterreadin} = \frac{V}{I}$$

WEEK 2
CLASS 2

Measurement of Medium Resistance

Ammeter-voltmeter method



Case 1: If the ammeter measures the true value of the current through the resistance but the voltmeter does not measure the true voltage across the resistance.

The voltmeter indicates the sum of the voltages across the ammeter and the measured resistance.

Let, Ra is the resistance of the ammeter, so voltage across the ammeter, Va= IRa

Now the measured value of resistance, $R_{m1} = \frac{V}{I} = \frac{V_R + V_a}{I} = \frac{IR + IR_a}{I} = R + R_a$

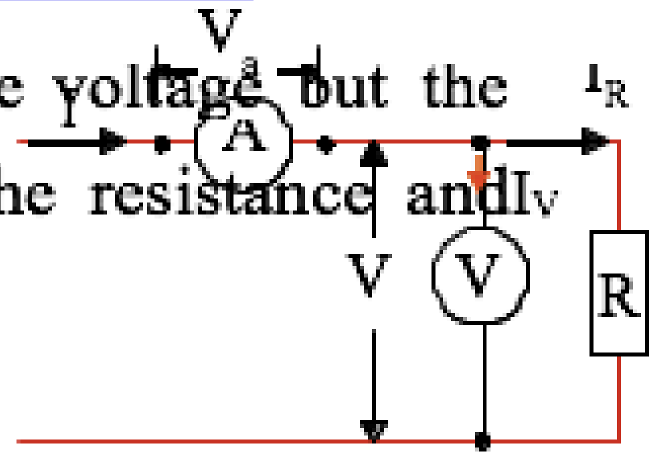
True value of resistance, R = Rm1 – Ra [Rm1>Ra if Ra=0 then R=Rm1]

Relative error, $\varepsilon_r = \frac{R_{m1} - R}{R} = \frac{R_a}{R}$

Measurement of Medium Resistance

Ammeter-voltmeter method

Case 2: If the voltmeter measures the true value of the voltage but the ammeter measures the sum of current through the resistance and the voltmeter.



Let, R_v is the resistance of the ammeter,

∴ Current through the voltmeter, $I_v = V/R_v$

Measured value of resistance,

$$R_{m2} = \frac{V}{I} = \frac{V}{I_R + I_v} = \frac{V}{V/R + V/R_v} = \frac{\quad}{1+}$$

True value of resistance,

$$R = \frac{R_{m2}R_v}{R_v - R_{m2}} = R_{m2}\left(\frac{1}{1 - R_{m2}/R_v}\right)$$

If $R_v >> R_{m2}$ then R_{m2}/R_v is very small

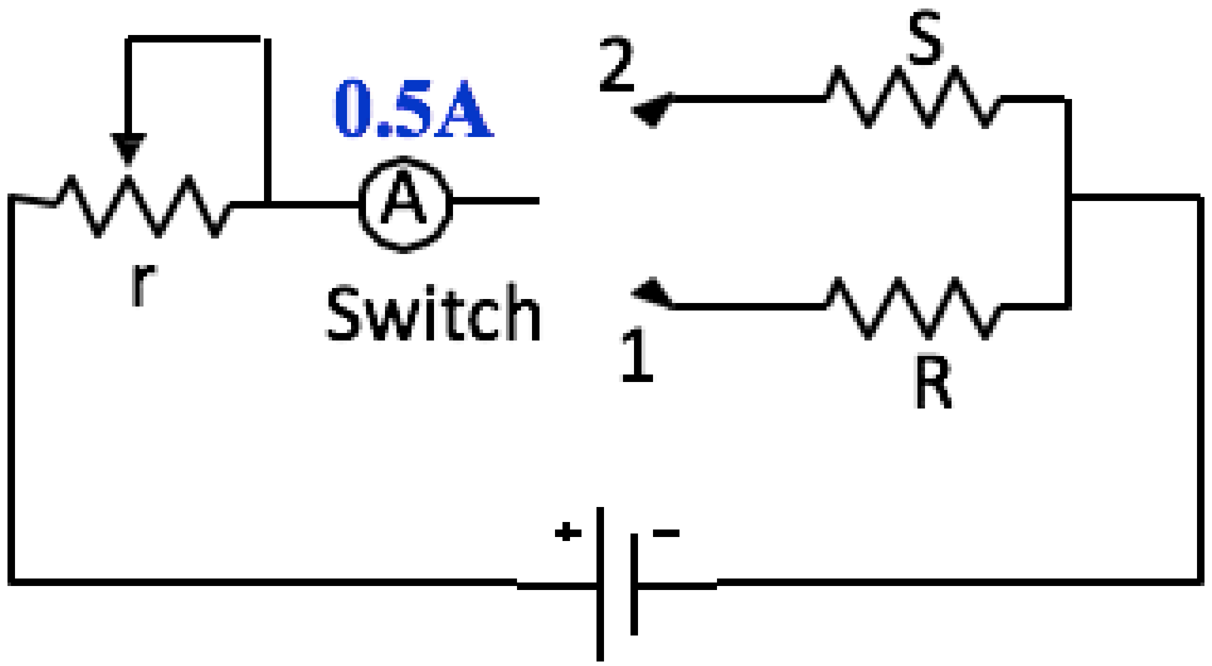
So, $R_{m2} < R$

t the error in measurement would be small if ce under measurement is very small as ce of voltmeter

$$\varepsilon = \frac{R_{m2} - R}{\quad} = \frac{R_{m2} - \frac{R_{m2}R_v}{R_v - R_{m2}}}{\quad} = -$$

Measurement of Medium Resistance

Substitution method



R is the unknown resistance

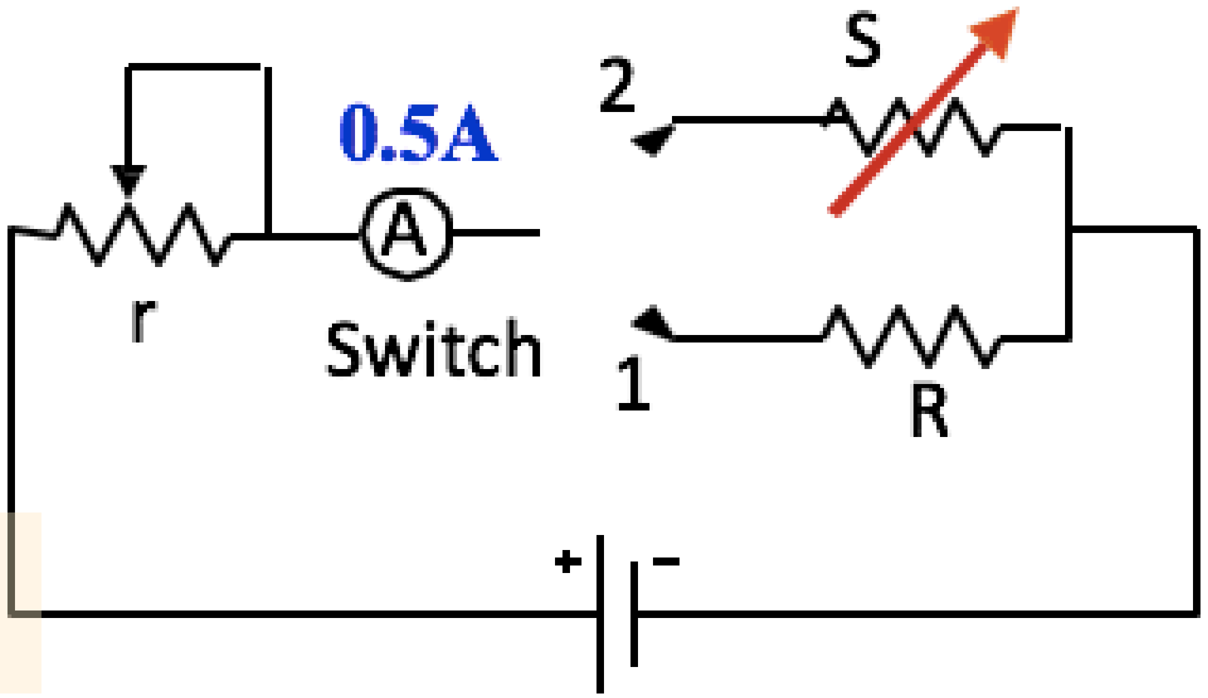
S is a standard variable resistance

A is an ammeter, and

r is a regulating resistance

SW at 1: The 'r' is adjusted till the ammeter pointer is at a chosen scale mark.

SW at '2': The value of 'S' is varied till the same deflection – as was obtained with 'R' in the circuit – is obtained. The settings of the dial of 'S' are read.



This is a more accurate method than the Ammeter-voltmeter method

Measurement of Medium Resistance

Wheatstone Bridge

Main features

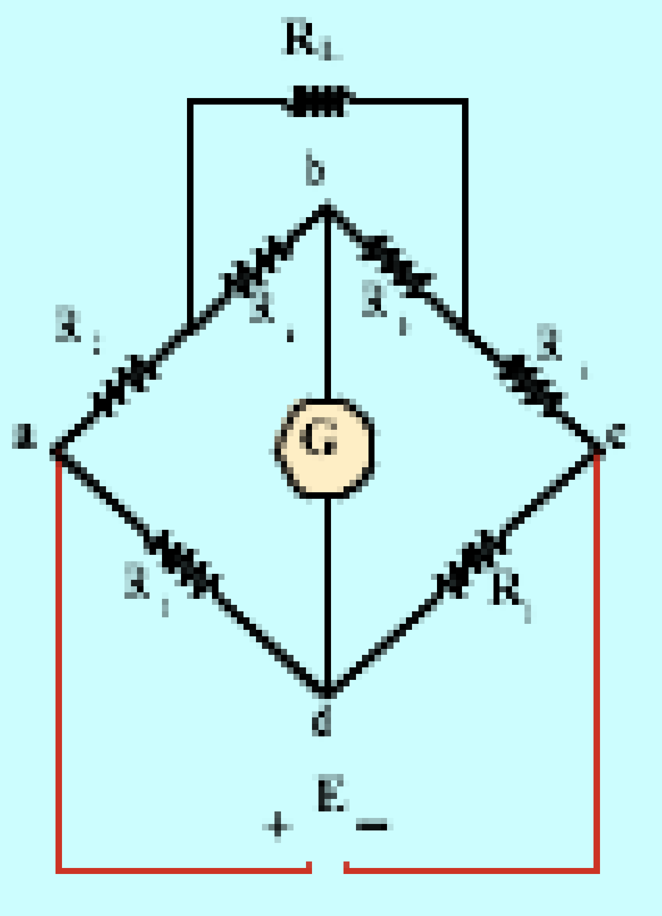
- Wheatstone bridge is an important device used in the measurement of medium resistance.
-]It is still an accurate and reliable instrument and is extensively used in industry.
- It has been in use longer than almost any electrical measuring instrument.
- It is an instrument for making comparison measurements and operates upon a null indication principle.

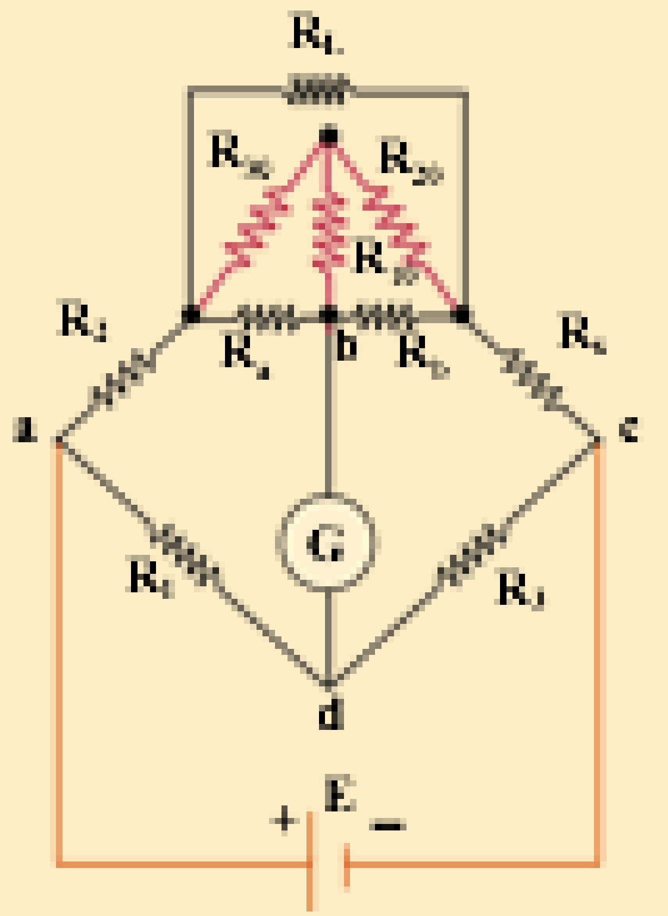
The indication of Wheatstone bridge is independent of the calibration of the null indicating instrument or any of its characteristics. So, it has very high degree of accuracy.

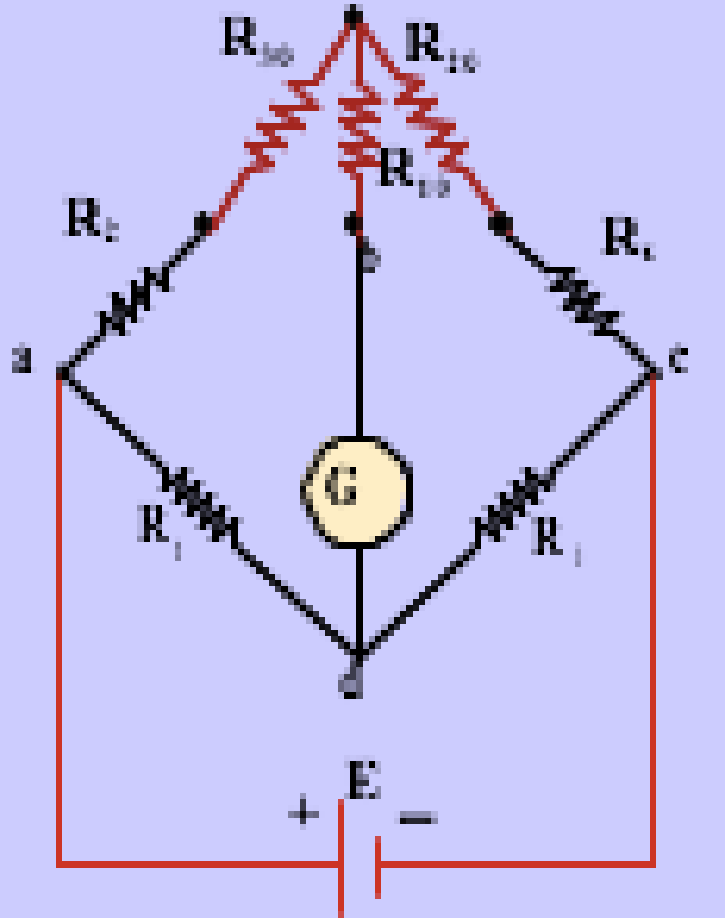
WEEK 3
CLASS 1

Measurement of Medium Resistance

Modified Wheatstone Bridge





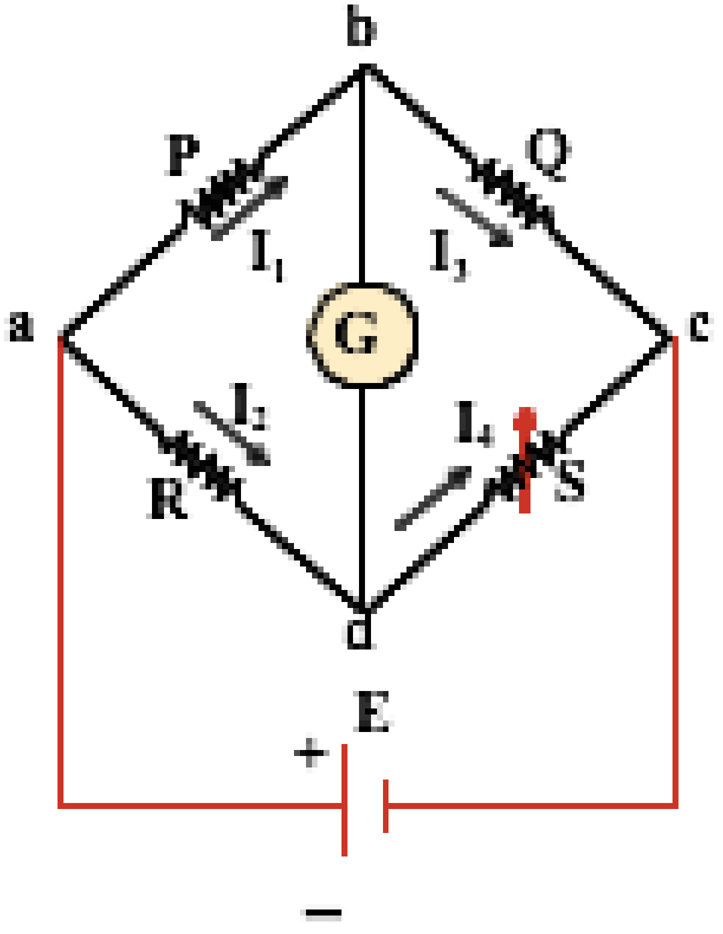


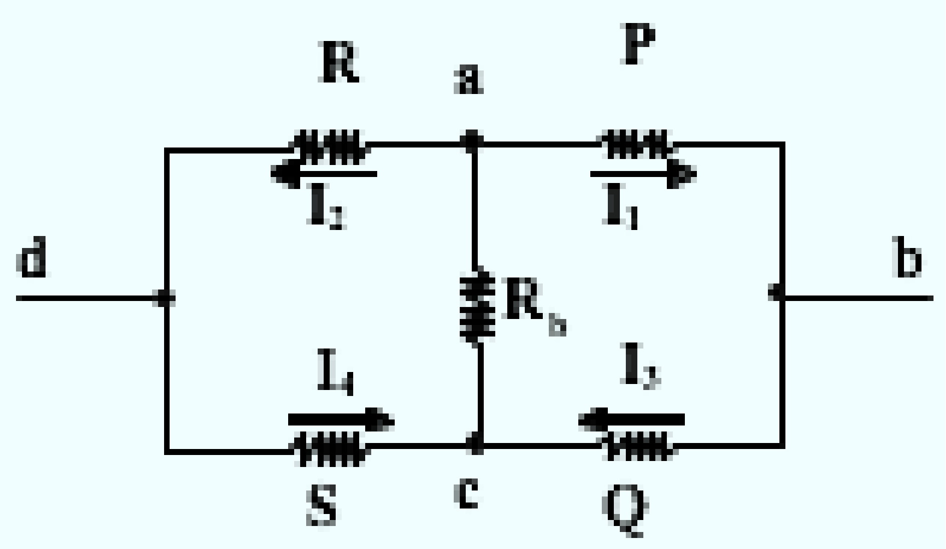
$$R_{10} = \frac{R_a R_b}{R_a + R_b + R_L}, \quad R_{20} = \frac{R_b R_L}{R_a + R_b + R_L}, \quad and \quad R_{30} = \frac{R_a R_L}{R_a + R_b + R_L}$$

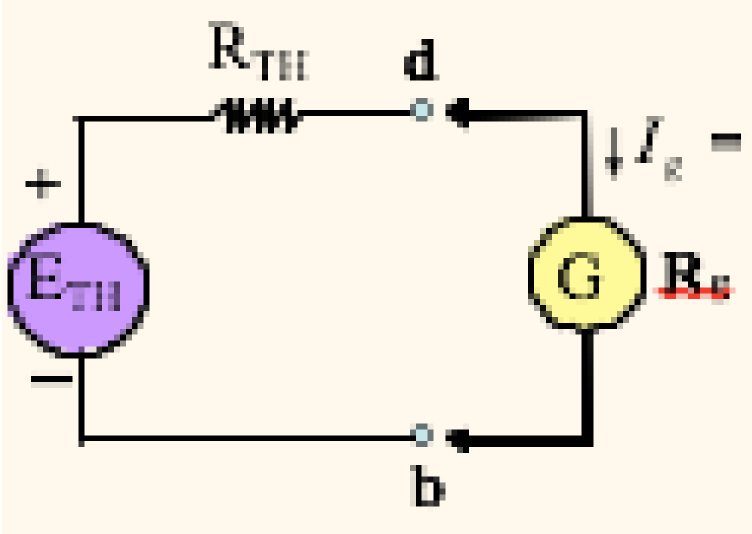
For balance, $\frac{R_2 + R_{30}}{R_1} = \frac{R_x + R_{20}}{R_3}$ $\quad \therefore \; R_x = \frac{(R_2 + R_{30})R_3}{R_1} - R_{20}$

Measurement of Medium Resistance

Application of Thévenin's theorem to Wheatstone Bridge





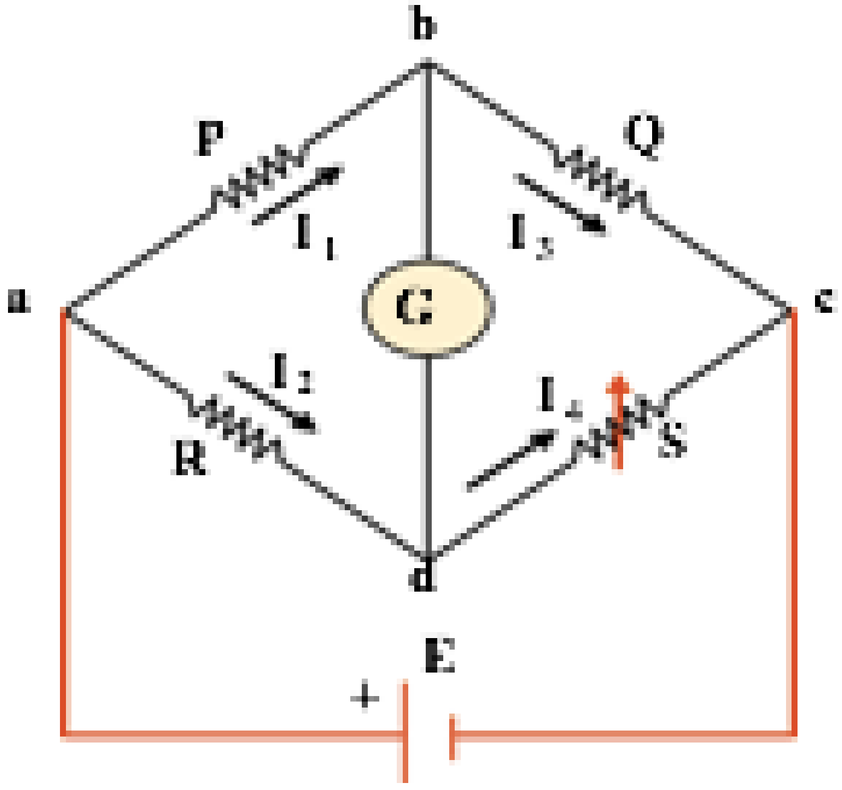


$$I_g = \frac{E_{TH}}{R_{TH} + R_g}$$

$$R_{TH} = \frac{RS}{R+S} + \frac{PQ}{P+Q}$$

Measurement of Medium Resistance

Wheatstone Bridge



It has four resistive arms, consisting of resistances P,Q,R, and S together with a source of emf (a battery) and a null detector, usually a galvanometer.

The current in G depends on the potential between c and d.

The bridge is balanced when there is no current through the Galvanometer or when the potential difference across the Galvanometer is zero.

For balanced conditions, $I_1 P = I_2 R$

For G current to be Zero, the following conditions exist

$$I_1 = I_3 = \frac{E}{P+Q} \quad \text{and,} \quad I_2 = I_4 = \frac{E}{S+R}$$

Combining these equations

$$\frac{P}{P+Q} = \frac{R}{R+S}$$

$$\Rightarrow R = S\frac{P}{Q}$$

Where R is unknown resistance, S is called the 'standard arm' of the bridge and P and Q are called the 'ratio arms'

Measurement of Medium Resistance

<u>Defects of Wheatstone Bridge</u>

- Ø The actual value of the resistances P, Q and S are different from the mark value.
- Ø Insufficient sensitivity of the galvanometer.
- Ø Contact resistances of the arms comes errors.

Resistance changes due to the heat produce by the I^2R losses.

Limitation of Wheatstone Bridge

Ø The Wheatstone bridge can be measured high resistance by increasing applied emf, but in this case has to be taken to avoid overheating of any arm of the bridge. Inaccuracy may also be introduced on account of leakage over insulation of the bridge arms.

Ø During measurement of lower resistance, the error caused by leads may be corrected fairly well, but contact resistance presents a source of uncertainty that is difficult to overcome.

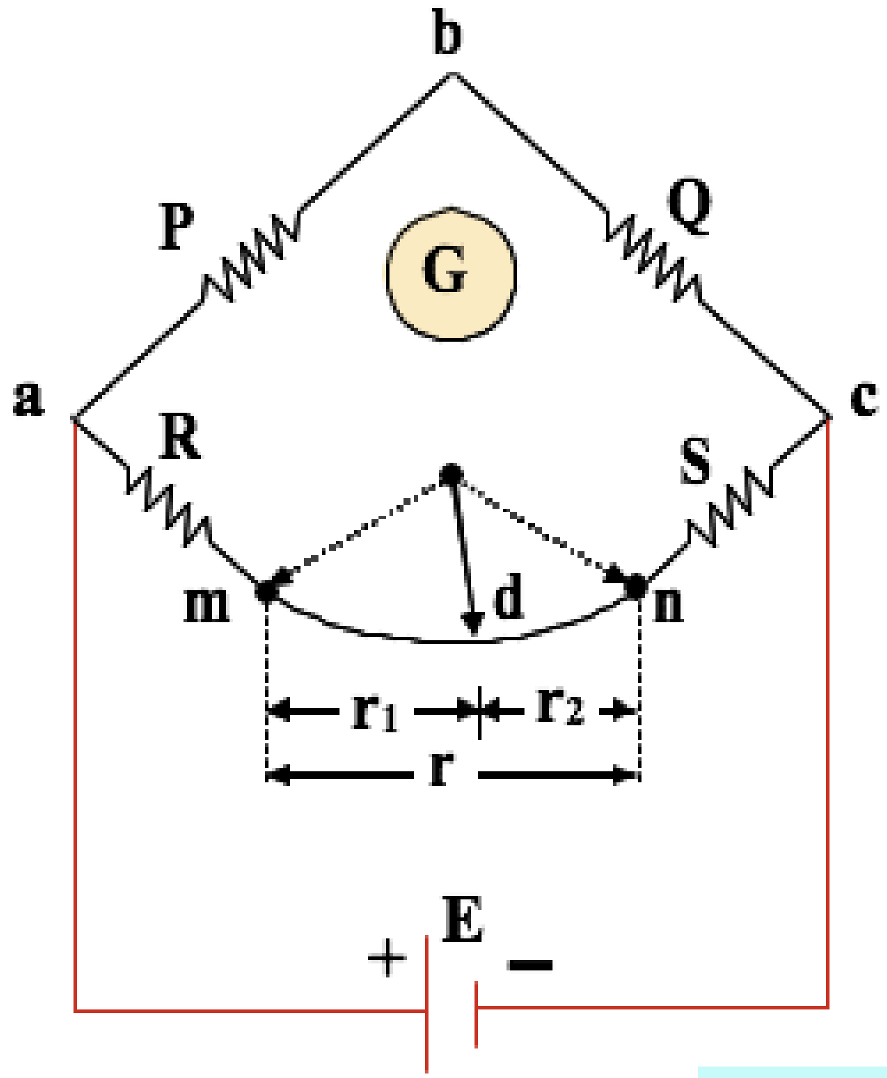
WEEK 3
CLASS 2

Measurement of Low Resistance

- Ammeter voltmeter method
- Kelvin Double bridge method
- Potentiometer method
- Shunt ohmmeter method

Measurement of Low Resistance

Kelvin Bridge method



- When n, r is added to R.
- When m, r is added to S.

If G is connected to a point 'd', in such a way that the

$$\frac{r_1}{r_2} = \frac{P}{Q} - - - - -(1)$$

For balance condition

$$R + r_1 = \frac{P}{Q}(S + r_2) - - - - -(2)$$

$$\frac{r_1}{r_1 + r_2} = \frac{P}{P+Q} \Rightarrow r_1 = \frac{P}{P+Q}r \text{ and} \Rightarrow r_2 = \frac{Q}{P+Q}r$$

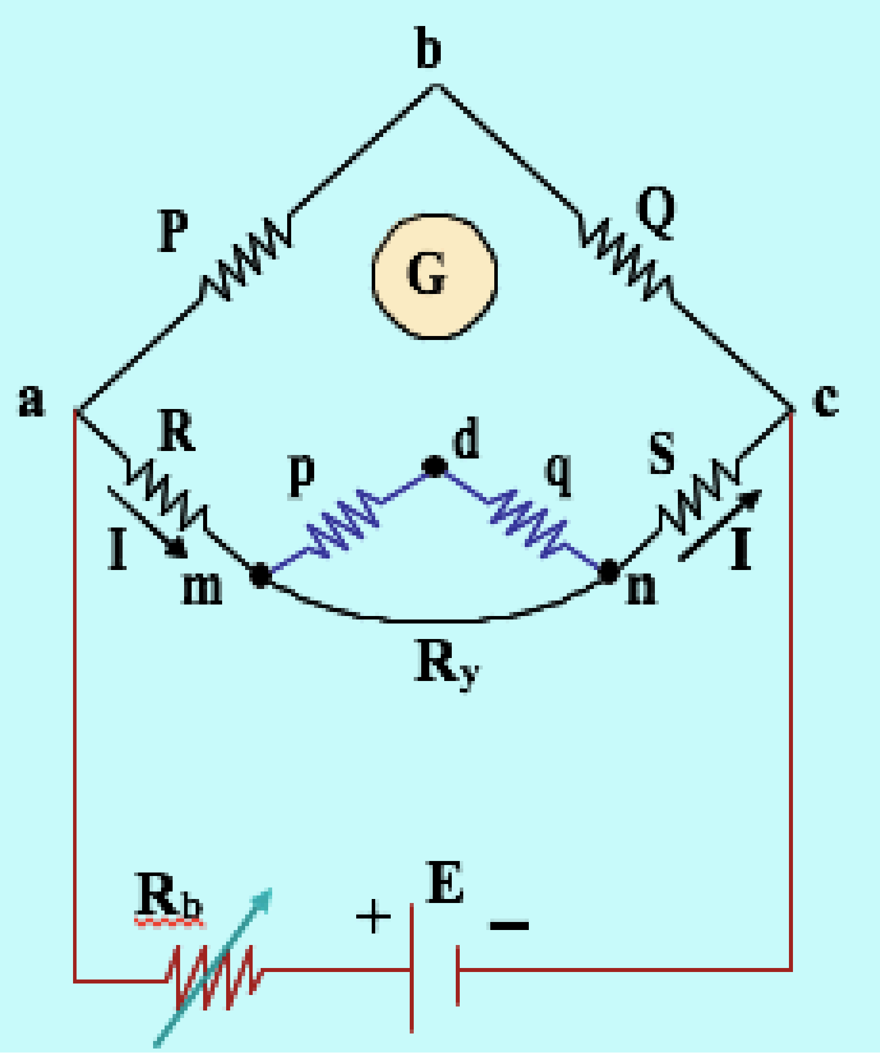
Now from equation (2)

$$R + \left(\frac{P}{P+Q}\right)r = \frac{P}{Q}\left(S + \left(\frac{Q}{P+Q}\right)r\right)$$

$$\Rightarrow R = \frac{P}{Q}S$$

Measurement of Low Resistance

Kelvin double Bridge method



Now, $E_{ab} = \frac{P}{P+Q} E_{ac}$ and, $E_{ac} = I\left[R + S + \frac{(p+q)r}{p+q+r}\right]$

and $E_{amd} = I\left[R + \frac{p}{p+q}\left[\frac{(p+q)r}{p+q+r}\right]\right] = I\left[R + \frac{pr}{p+q+r}\right]$

For zero galvanometer deflection, $E_{ab} = E_{amd}$

$$\frac{P}{P+Q} I\left[R + S + \frac{(p+q)r}{p+q+r}\right] = I\left[R + \frac{pr}{p+q+r}\right]$$

$$\Rightarrow R = \frac{P}{Q} \cdot S + \frac{qr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]$$

Now, if P/Q = p/q then it becomes $R = \frac{P}{Q} \cdot S$

WEEK 4
CLASS 1

Measurement of High Resistance

- Loss of charge method
- Direct deflection method
- Mega ohm bridgemethod
- Megger

Loss of charge method

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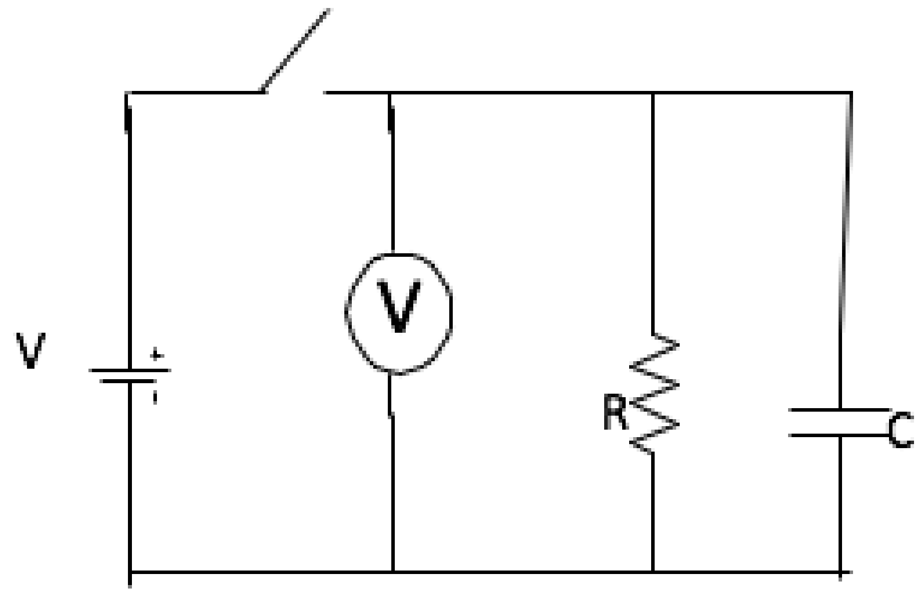


Insulation resistance should be connected in parallel with a capacitor and electrostatic voltmeter

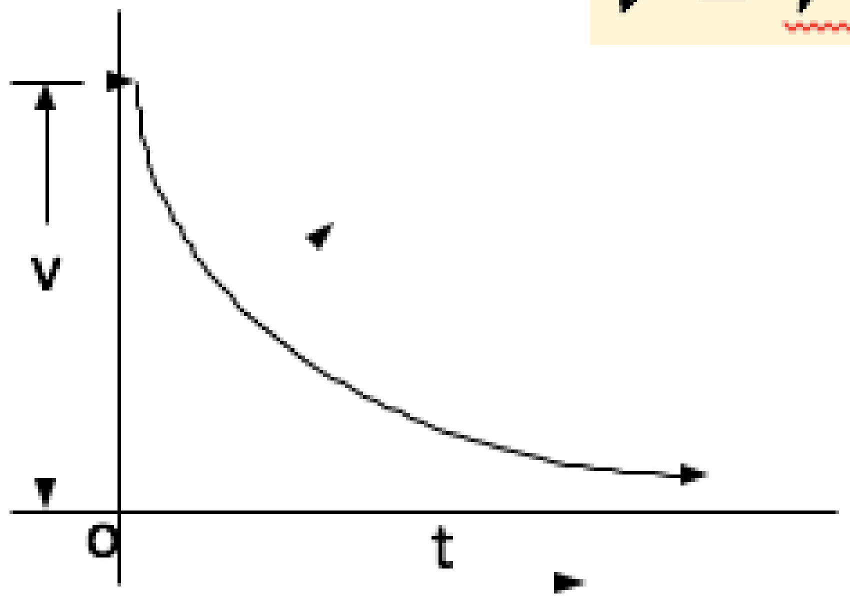
$$i = -\frac{dQ}{dt} = C\frac{dV}{dt}$$

But $i = V/R$ then

$$\frac{V}{R} = -C\frac{dV}{dt} \quad \Rightarrow \frac{V}{R} + C\frac{dV}{dt} = 0$$

$$v = Ve^{-\frac{t}{RC}}$$

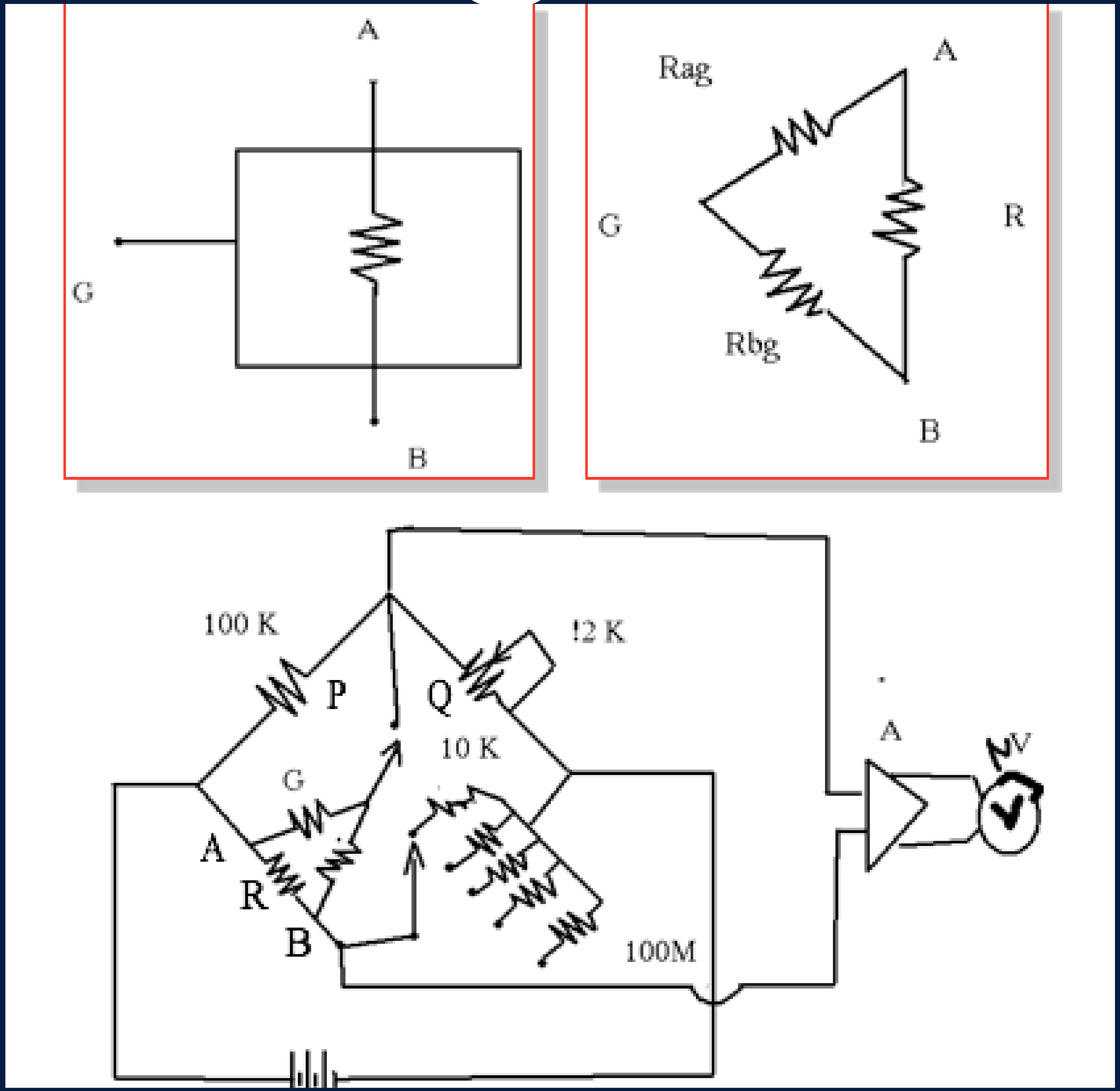
$$\log_e v = \log_e V - \frac{t}{RC}$$



Insulation Resistance:

$$R = \frac{0.4343t}{C\log_{10}\frac{V}{v}}$$

Megohm Bridge Method



- A high resistance
- Guard terminal to insulator

R= PS/Q

Localization of Cable faults

Ground fault: The insulation of the cable may breakdown causing a flow of current from core of the cable to the lead sheath or the earth. This is called Ground fault.

Short circuit fault: If the insulation between two conductors is faulty, a current flows
between them. This is called Short circuit Fault.

The advantages of these tests is that their set-up is such that the resistance is connected in the battery circuit and therefore doest not effect the result

Bridge Sensitivity

The bridge sensitivity of a Wheatstone is define as the ratio of deflection in galvanometer to per unit fractional change in the unknown resistance.

Bridge resistance,

$$S_B = \frac{\theta}{\frac{\Delta R}{R}}$$

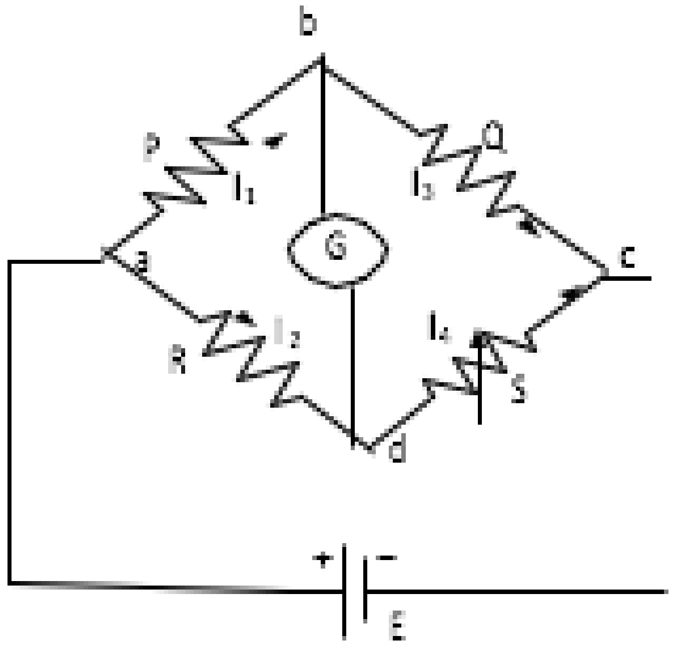
Voltage sensitivity

Voltage sensitivity is define as the ratio of deflection in galvanometer and emf across the galvanometer, i.e

Voltage sensitivity, $$S_V = \frac{\theta}{e}$$

WEEK 4
CLASS 2

Bridge sensitivity for a Wheatstone bridge having the equal arms:



Resistance R is changed to R+ ΔR to create unbalance and emf e will appear across the G branch.

$$E_{ab} = I_1 P = \frac{EP}{P+Q}, \quad E_{ad} = I_2 (R+\Delta R) = \frac{E(R+\Delta R)}{R+\Delta R+S}$$

Voltage difference between points d and b is:

$$e = E_{ad} - E_{ab} = E\left[\frac{R+\Delta R}{R+\Delta R+S} - \frac{P}{P+R}\right]$$

But,

$$\frac{P}{P+Q} = \frac{R}{R+S}$$

$$e = E\,\frac{ES\Delta R}{(R+S)^2 + \Delta R(R+S)} = \frac{ES\Delta R}{(R+S)^2}$$

Deflection of galvanometer is:

$$\theta = S_v e = S_v \frac{ES\Delta R}{(R+S)^2}$$

Bridge sensitivity,

$$S_B = \frac{\theta}{\frac{\Delta R}{R}} = \frac{S_v ESR}{(R+S)^2} = \frac{S_v E}{\frac{P}{Q} + \frac{Q}{P} + 2}$$

For, P = Q = R = S

$$S_B = \frac{S_v E}{4}$$

Problem: A Kelvin bridge has the following specification- standard resistance=100.03Ω, outer ratio arms 100.24Ω and 200Ω, inner ratio arms 100.31Ω and 200Ω. Resistance of link connecting the standard and unknown resistance is 700µΩ. Calculate the unknown resistance.

$$R = \frac{P}{Q}S + \frac{qr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]$$

Problem: A length of cable is tested for insulation resistance by the loss of charge method. An electrostatic voltmeter of infinite resistance is connected between the cable conduct and earth forming there with a joint capacitance of 600pF. It is observed that after charging the voltage falls from 250V to 92V in 1 minute. Calculate the insulation resistance of the cable.

Insulation Resistance:

$$R = \frac{0.4343t}{C \log_{10} \frac{V}{v}}$$

Types of Instruments

The main types of instruments used as ammeters and voltmeters are:

(i) Permanent magnet movingcoil (PMMC)
(ii) Moving iron
(iii) Electrodynamometer
(iv) Electrostatic
(v) Induction
(vi) Rectifier
(vii) Thermocouple

WEEK 5
CLASS 1

Permanent magnetmoving coil (PMMC)

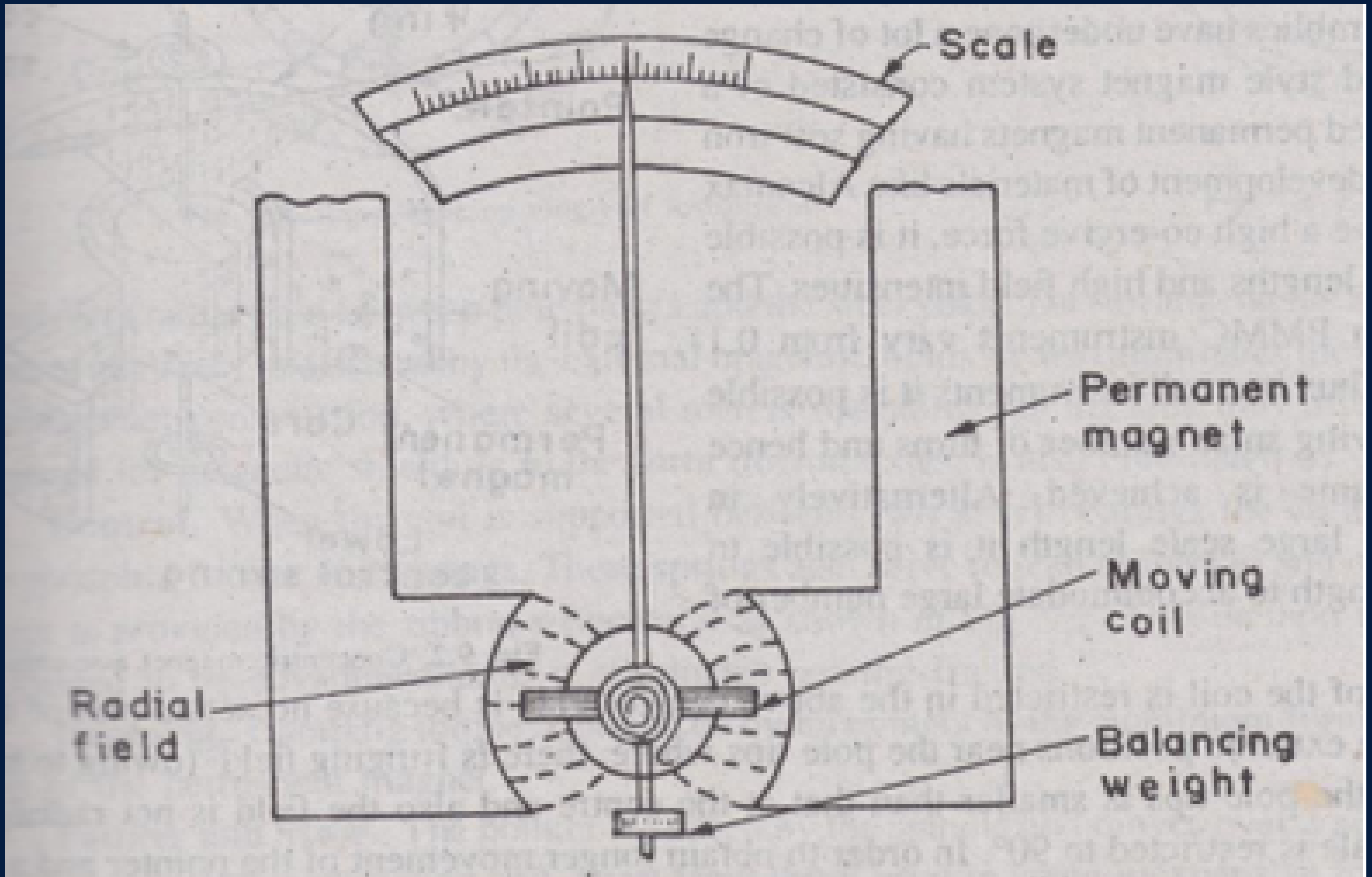


Fig. 9.1. Permanent magnet moving coil instrument.

Permanent magnet moving coil (PMMC)

Deflectiontorque:

When current, I passes through the coil then the force in each side of the coil is:

$$F = BIl$$

For N numbers of turns-

$$F = NBIl$$

T_d = Force· Perpendicular distance

$= NBIl \cdot b$

$= NBIA$

Controling torque,

$T_C = K\theta$

At balance condition, $F = BIl$

$T_C = T_d$

$K\theta = NABI$

$\therefore \theta \propto I$

Advantages:

(i)The accuracy is high.

(ii) Power consumption is very low.

(iii) The scale is linearlydivided.

(iv) One instrument may be usedfor different ranges of voltage and current.

Disadvantages:

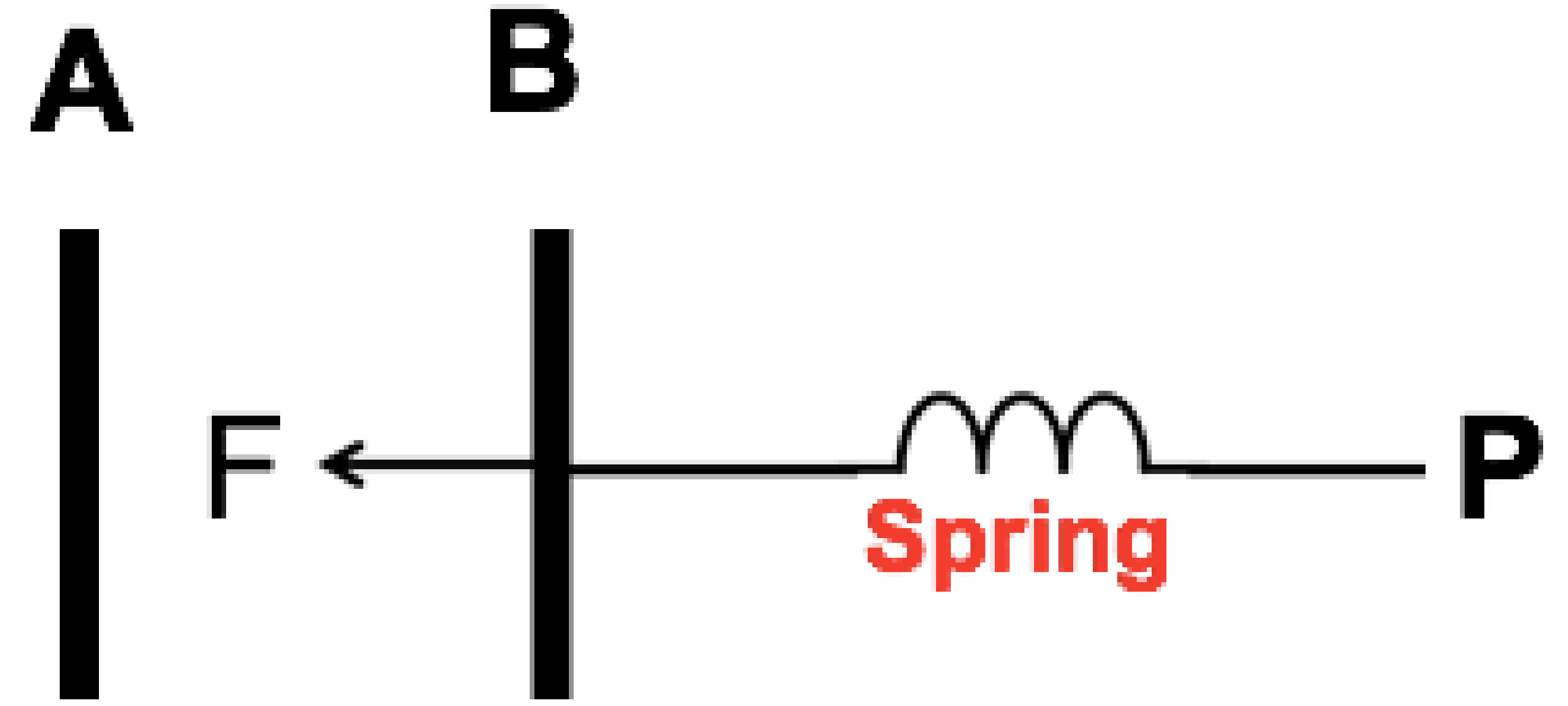
(i)It is only for DC.

(ii)Thecost of PMMC is higher than that of other instrument.

(iii)Thefriction and heatingerrors are present.

WEEK 5
CLASS 2

Electrostatic Instrument



If C is the capacitance between the plates then, store energy $= \frac{1}{2} CV^2$

When applied voltage is increased the capacitance current is,

$$i = \frac{dq}{dt} = \frac{d(CV)}{dt} = C\frac{dV}{dt} + V\frac{dC}{dt}$$

$$\text{Input energy} = Vi\,dt = V\left(C\frac{dV}{dt} + V\frac{dC}{dt}\right)dt$$

$$= CV\,dV + V^2 dC$$

The change in the store energy,

$$= \frac{1}{2}(C + dC)(V + dV)^2 - \frac{1}{2}CV^2$$

$$= \frac{1}{2}V^2 dC + CV\,dV$$

From the principle of the conversion of energy

Input energy = Change in store energy+

Mechanical work done

$$\Rightarrow CVdV + V^2dC = \frac{1}{2}V^2dC + CVdV + F.dx$$

$$\Rightarrow F = \frac{1}{2}\frac{V^2dC}{dx}$$

Torque, $T = F \cdot dx = \frac{1}{2}V^2dC$

But Controlling torque,

$$T_C = K\theta$$

At balance conditions,

$$K\theta = \frac{1}{2} V^2 dC$$

$$\therefore \theta \propto V^2$$

Advantages:

(i) It can be used for both AC and DC.

(ii) Power consumption is low.

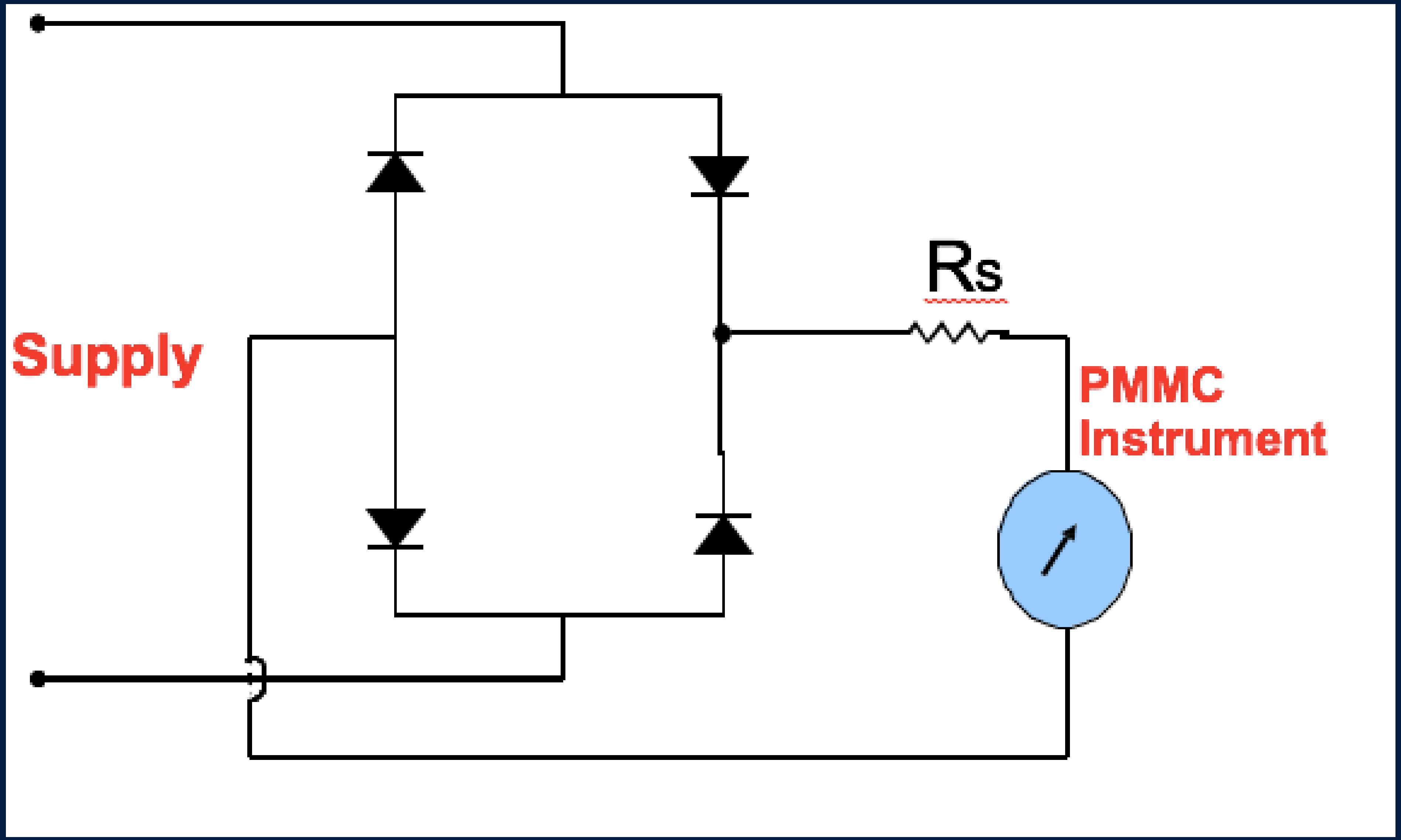
(iii) It is free from hysteresis and eddy current loss.

Disadvantages:

(i) They are suitable only for low voltages.

WEEK 6
CLASS 1

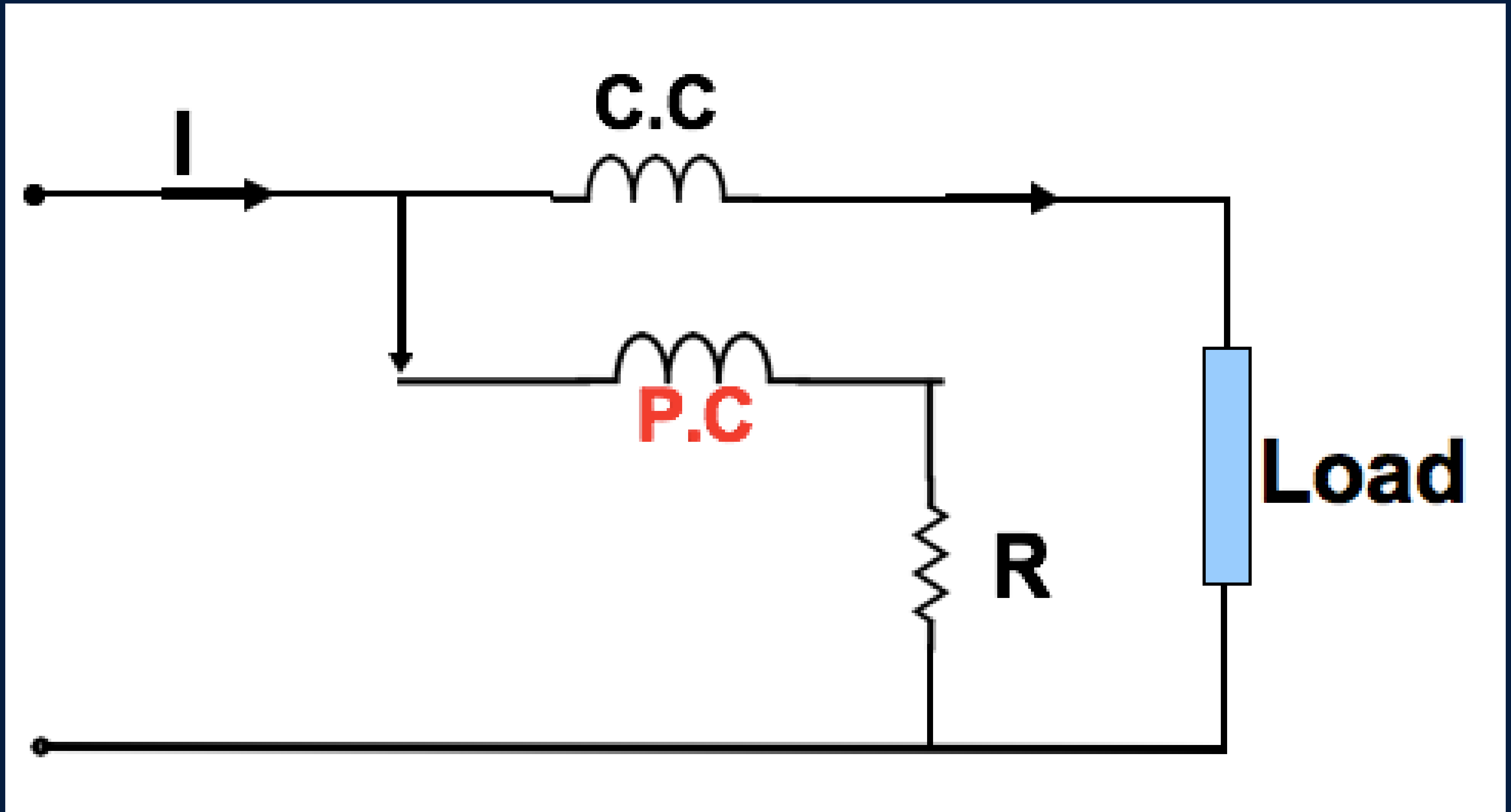
Rectifier Type Instrument



Types of Wattmeter

(i) Electrodynamometertype wattmeter
(ii) Induction typewattmeter
(iii) Electrostatic wattmeter

Electrodynamometer type wattmeter



Electrodynamometer type wattmeter

Operation:

An instantaneous torque is given by-

$$T_i = i_1 i_2 \frac{dM}{d\theta}$$

Let V and I be the r.m.s values of the voltage and current being measured. So the instantaneous voltage across the

pressure coils, $v = \sqrt{2}\, V \sin wt$

Instantaneous current in P.C

$$i_p = \frac{v}{R_P} = \frac{\sqrt{2}V \sin wt}{R_P} = \sqrt{2}I_P \sin wt$$

$$(\text{where } I_P = \frac{V}{R_P})$$

If the current in C.C lags the voltage by an angle φ, then the instantaneous current in C.C,

$$i_C = \sqrt{2}I \sin(wt - \varphi)$$

∴ The instantaneous torque,

$$T_i = I_P I[\cos\varphi - \cos(2wt - \varphi)] \frac{dM}{d\theta}$$

Average deflectingtorque -

$$T_a = \frac{1}{T}\int_0^T T_i\, d(wt)$$

$$= \frac{P}{R_P}\frac{dM}{d\theta}$$

But, $T_C = K\theta$

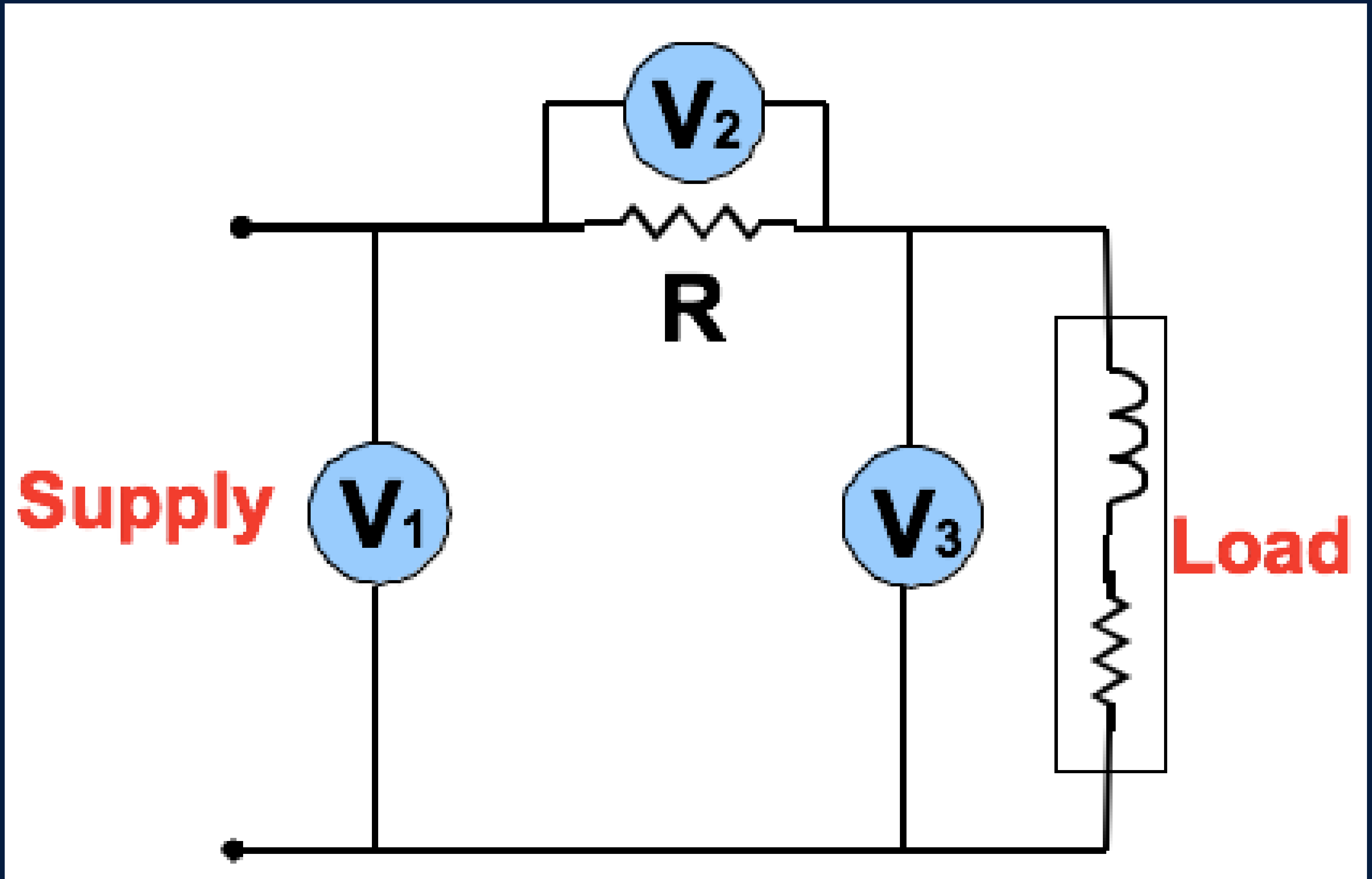
At balance condition,

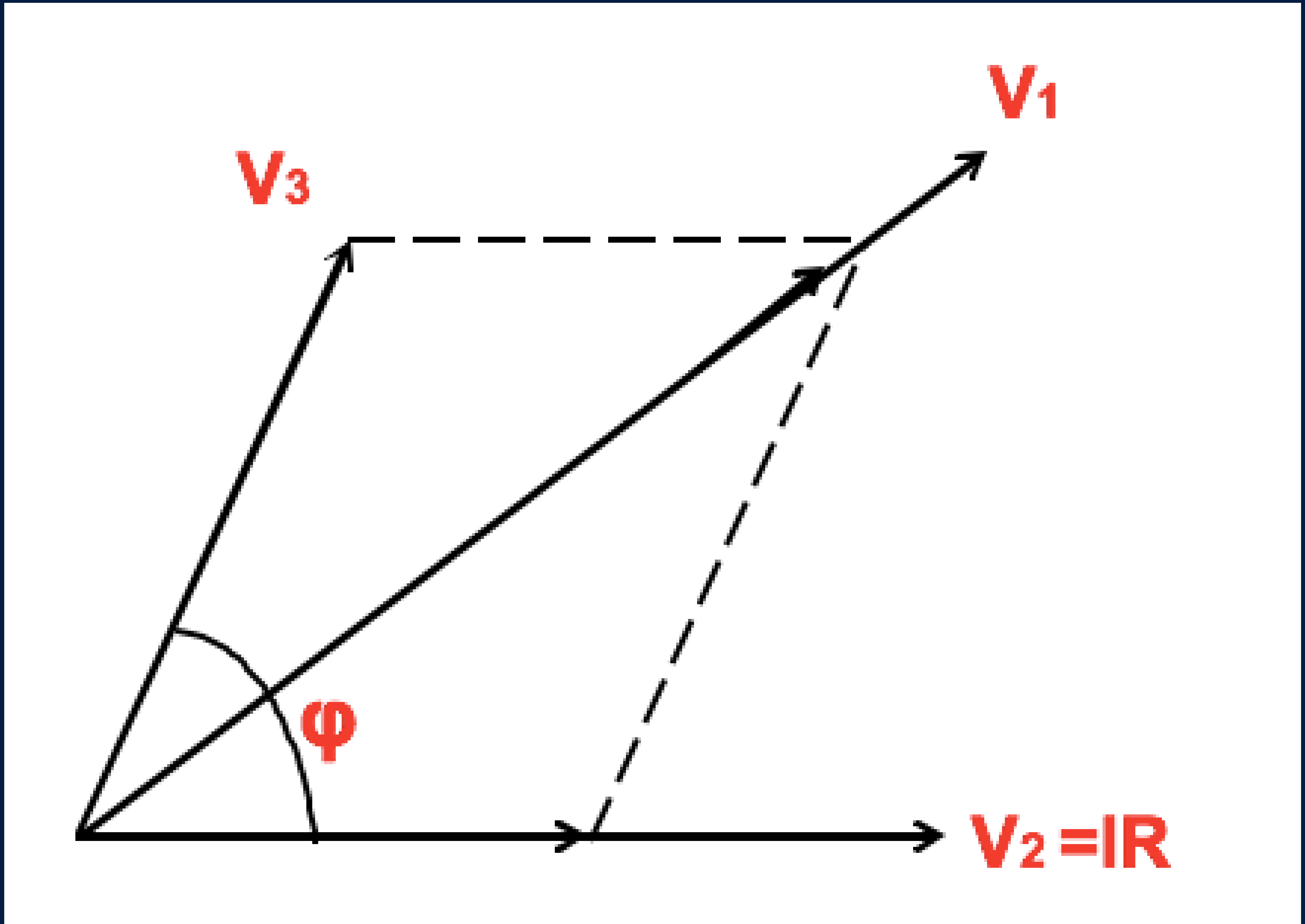
$T_C = T_d$

$\Rightarrow \theta \propto P$

WEEK 6
CLASS 2

Measurement of power by using three Voltmeter




V3
V1
φ
V2 =IR

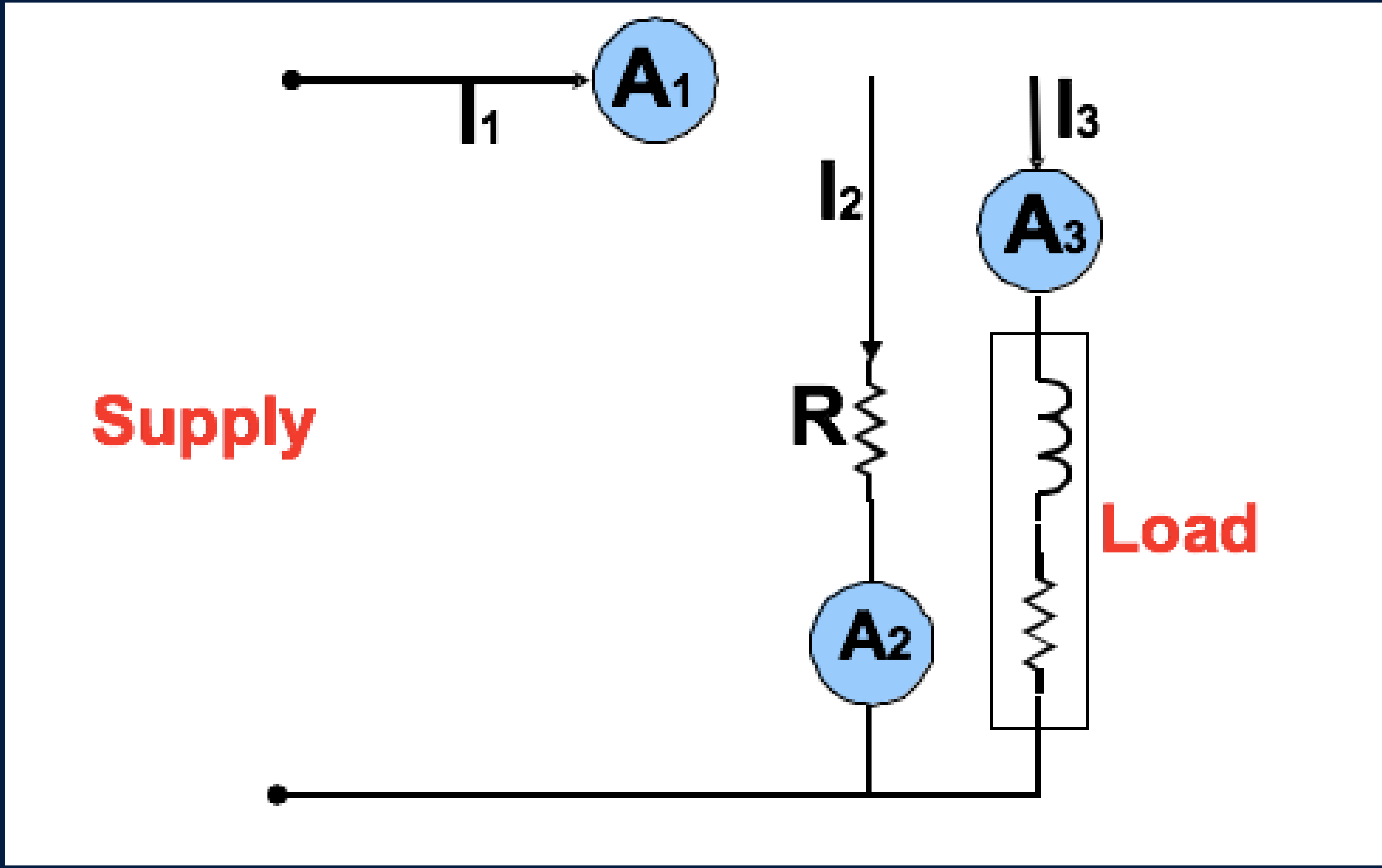
$$V_1^2 = V_2^2 + V_3^2 + 2V_2V_3\cos\Phi$$

$$= V_2^2 + V_3^2 + 2IRV_3\cos\Phi$$

$$= V_2^2 + V_3^2 + 2RP \ (\text{where}, P = V_3 I \cos\Phi)$$

$$P = \frac{V_1^2 - V_2^2 - V_3^2}{2R}$$

Measurement of power by using three Ammeter



Measurement of power by using three Ammete

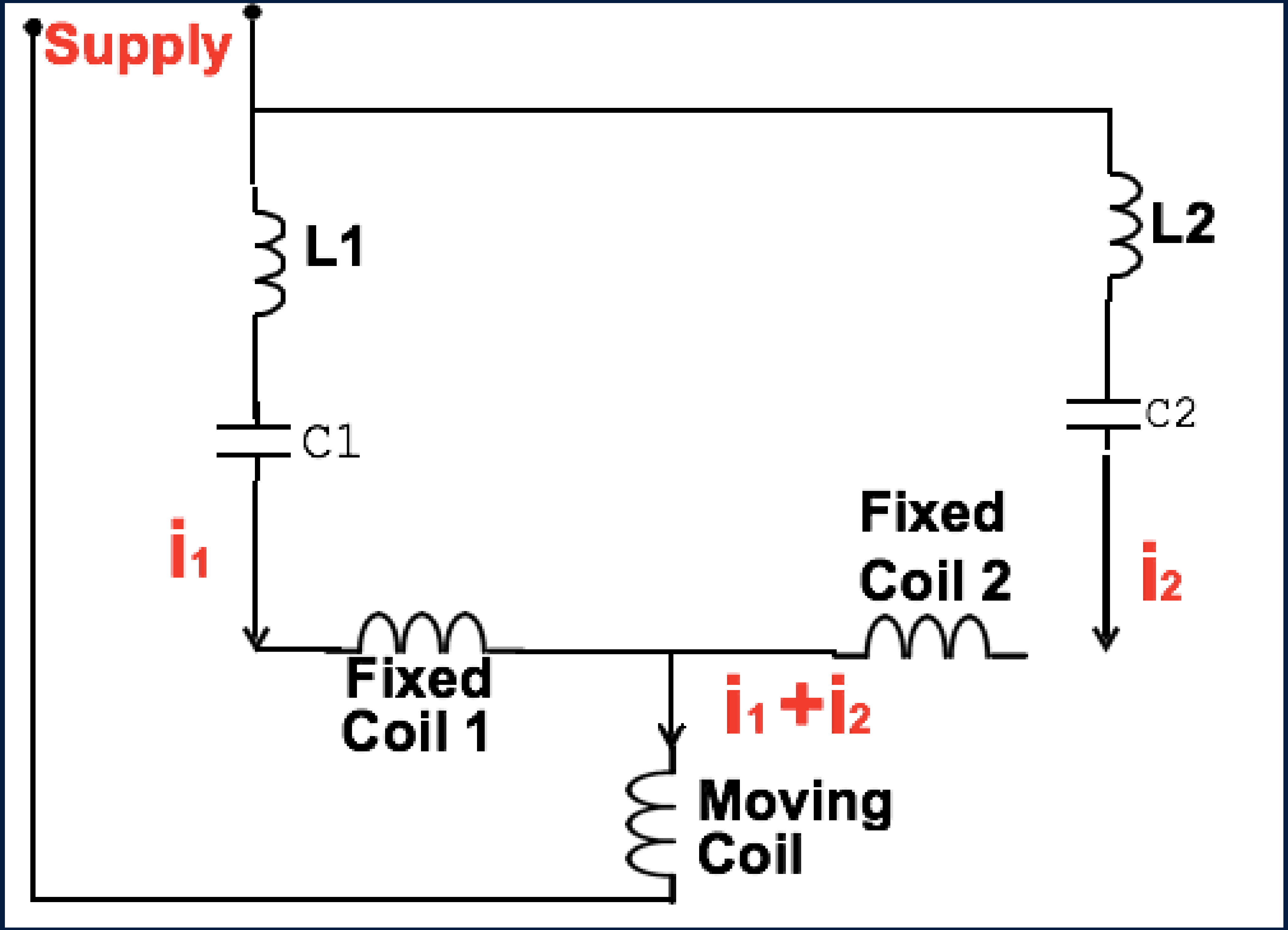
$$P = \frac{(I_1^2 - I_2^2 - I_3^2)R}{2}$$

WEEK 7
CLASS 1

Types of Frequency Meter:

- Mechanical resonance type
- Electrical resonance type
- Electrodynamomometer type
- Weston type
- Ratiometer type
- Saturable core type

Electrodynamometer type Frequency Meter



Electrodynamometer type Frequency Meter

$$X_{L1} > X_{C1}$$

$$X_{C2} > X_{L2}$$

D’ Arsonval Galvanometer

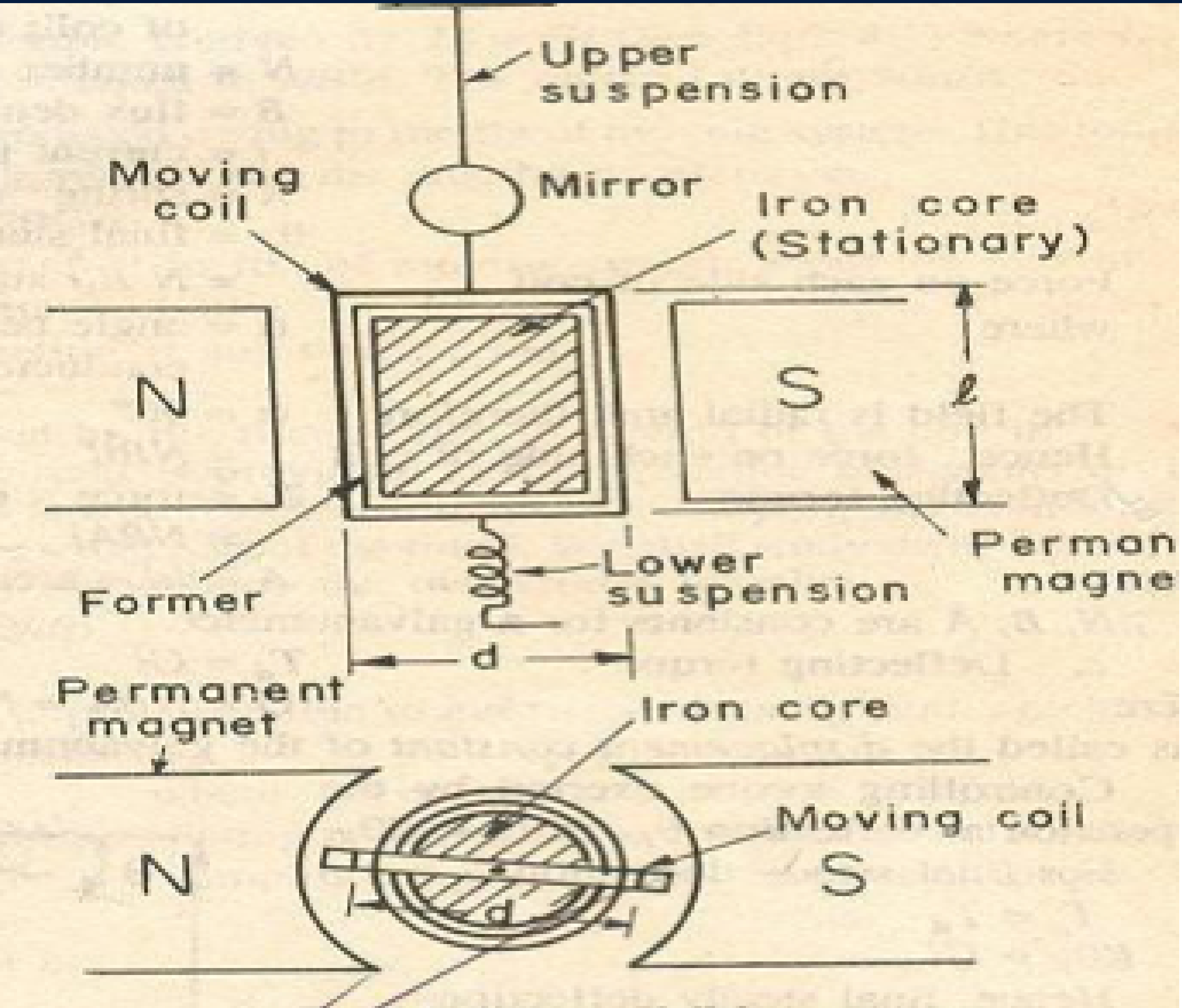


Fig. 8.1. d'Arsonval Galvanometer.

WEEK 7
CLASS 2

Flux Meter

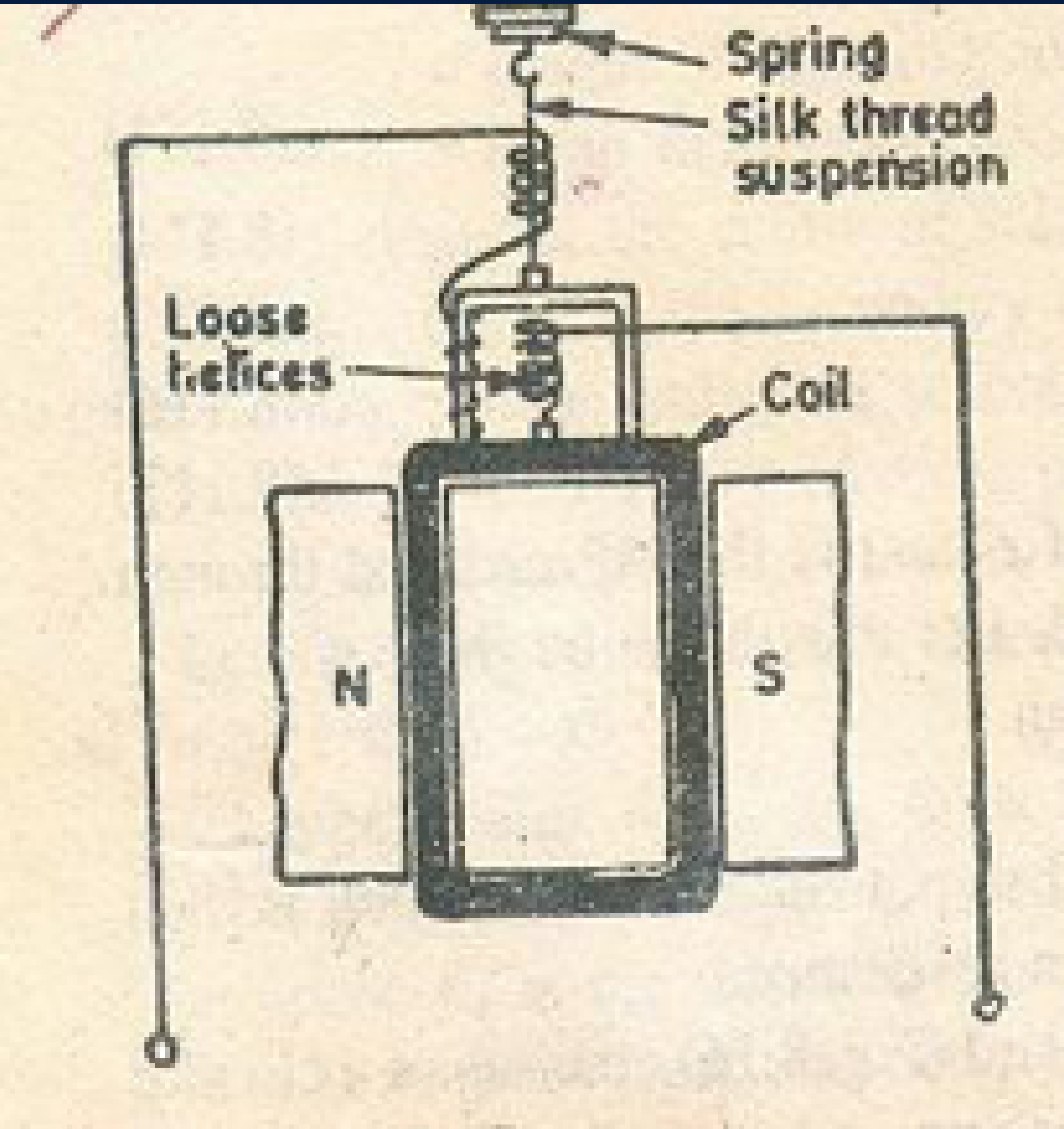


Fig. 8.17. Flux meter.

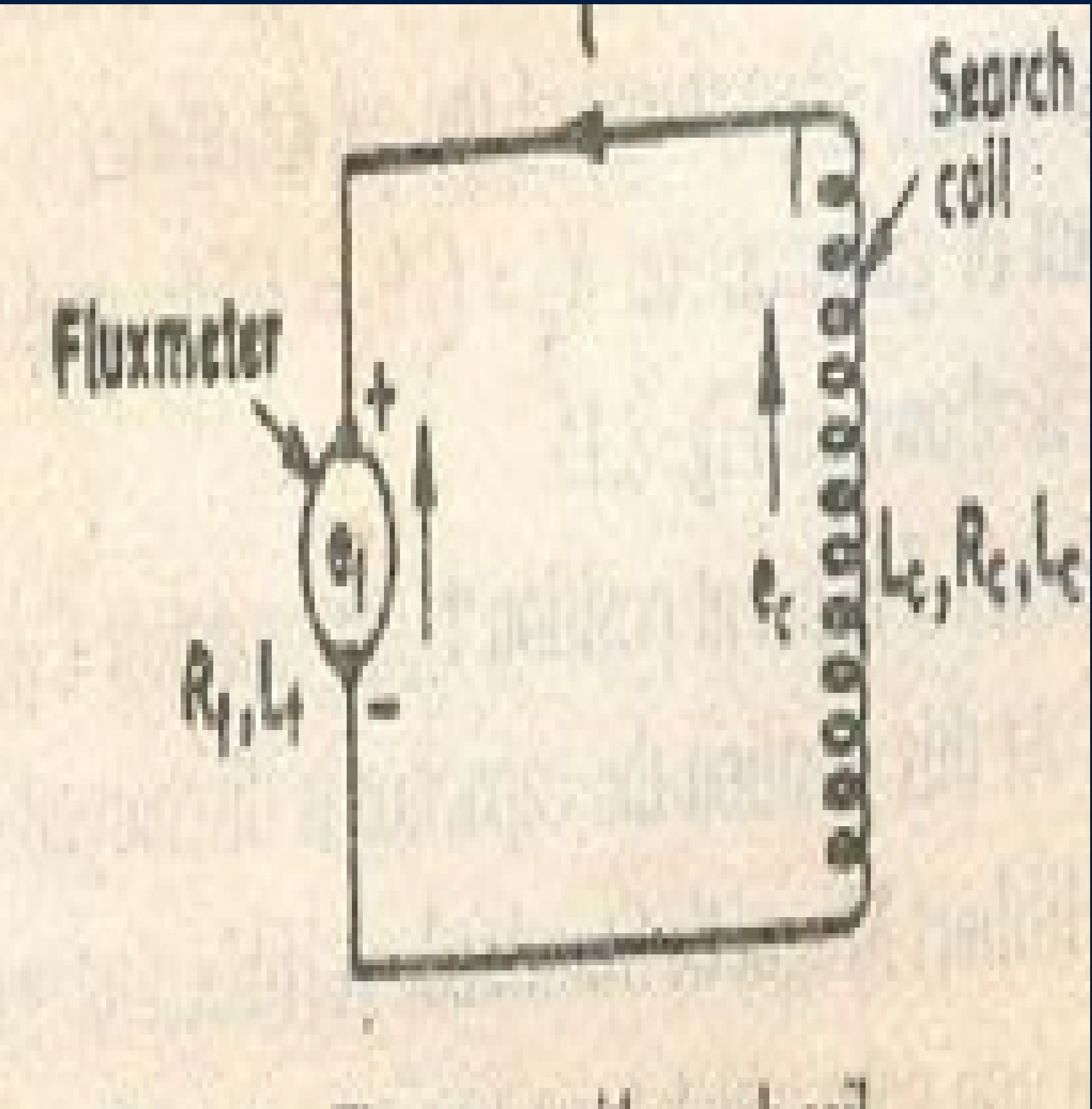


Fig. 8.18. Flux meter with search coil.

Flux meter with shunt

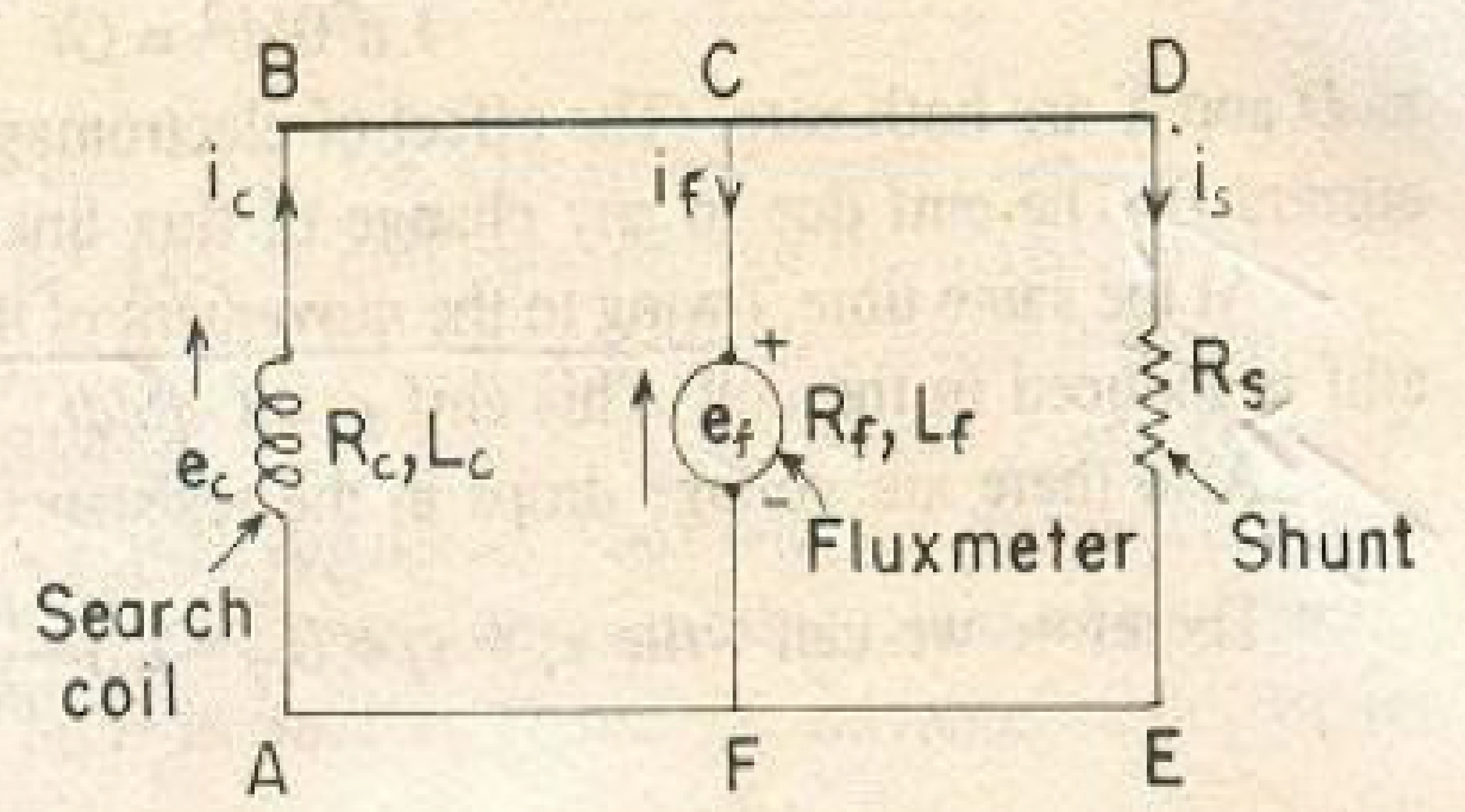


Fig. 8.19. Fluxmeter with shunt.

Measurement of flux densityin ring specimens

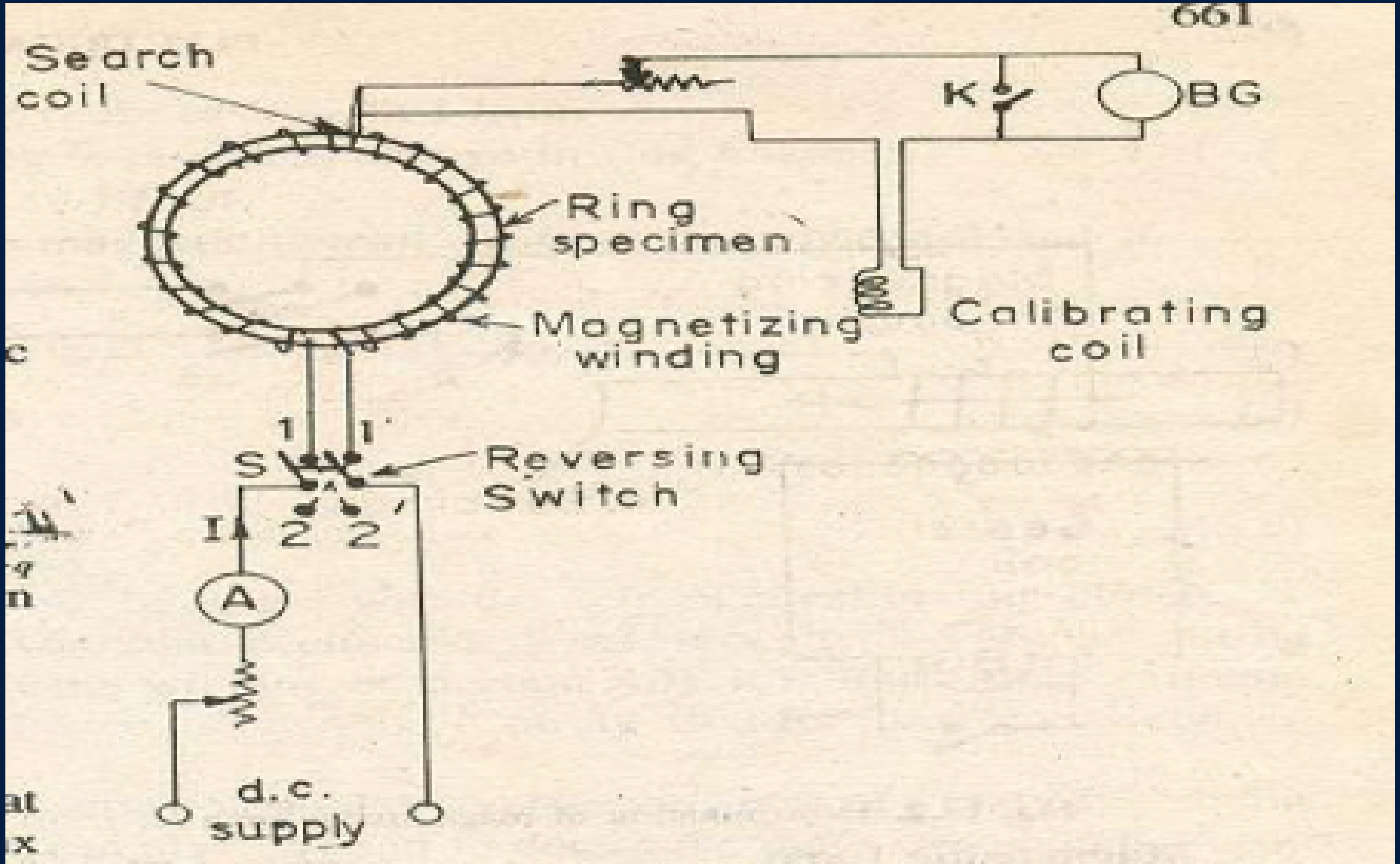


Fig. 18.1 Measurement of flux density in ring specimens.

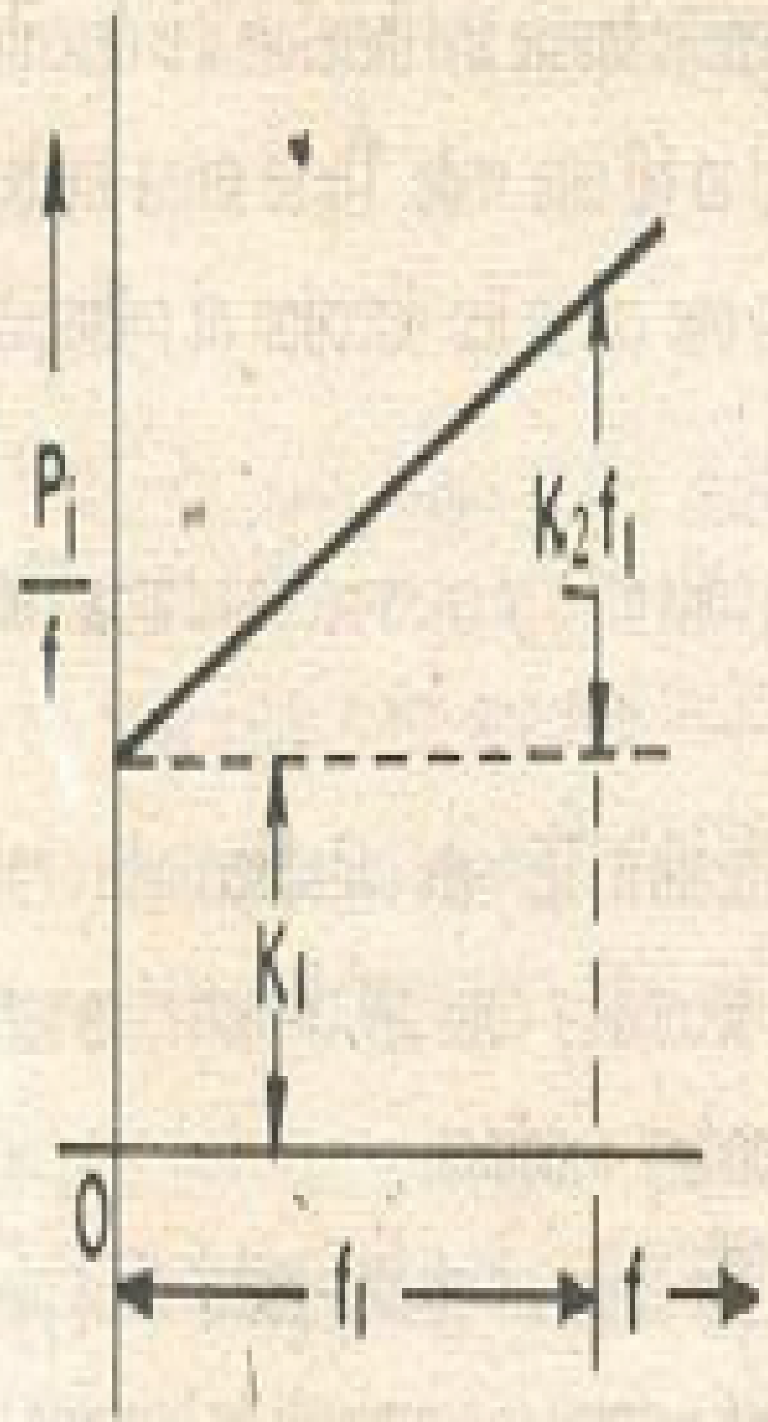


Fig. 18.17. Variation of iron loss with frequency.

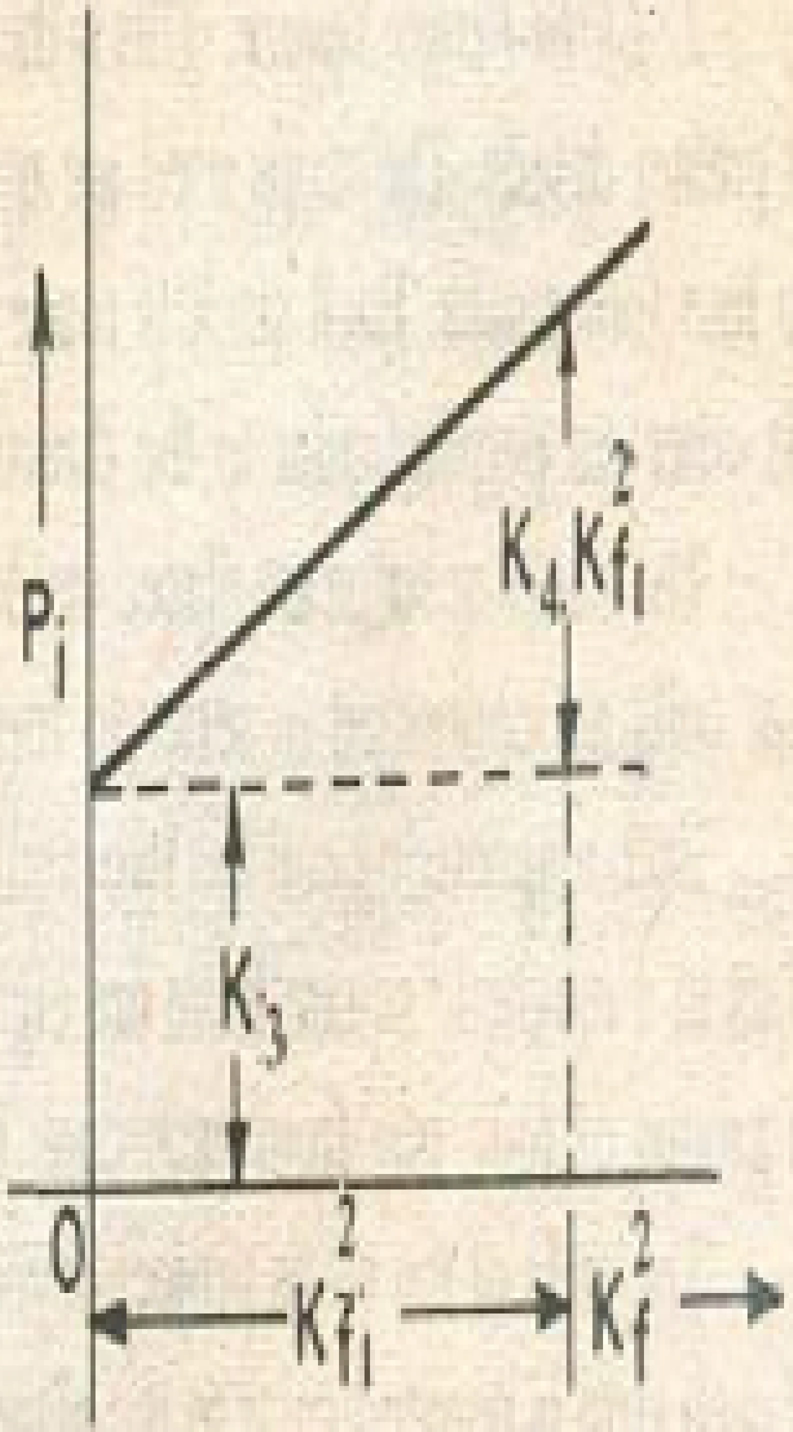


Fig. 18.18. Variation of iron loss with K_f^2.

WEEK 8
CLASS 1

Power measurement in D.C circuits

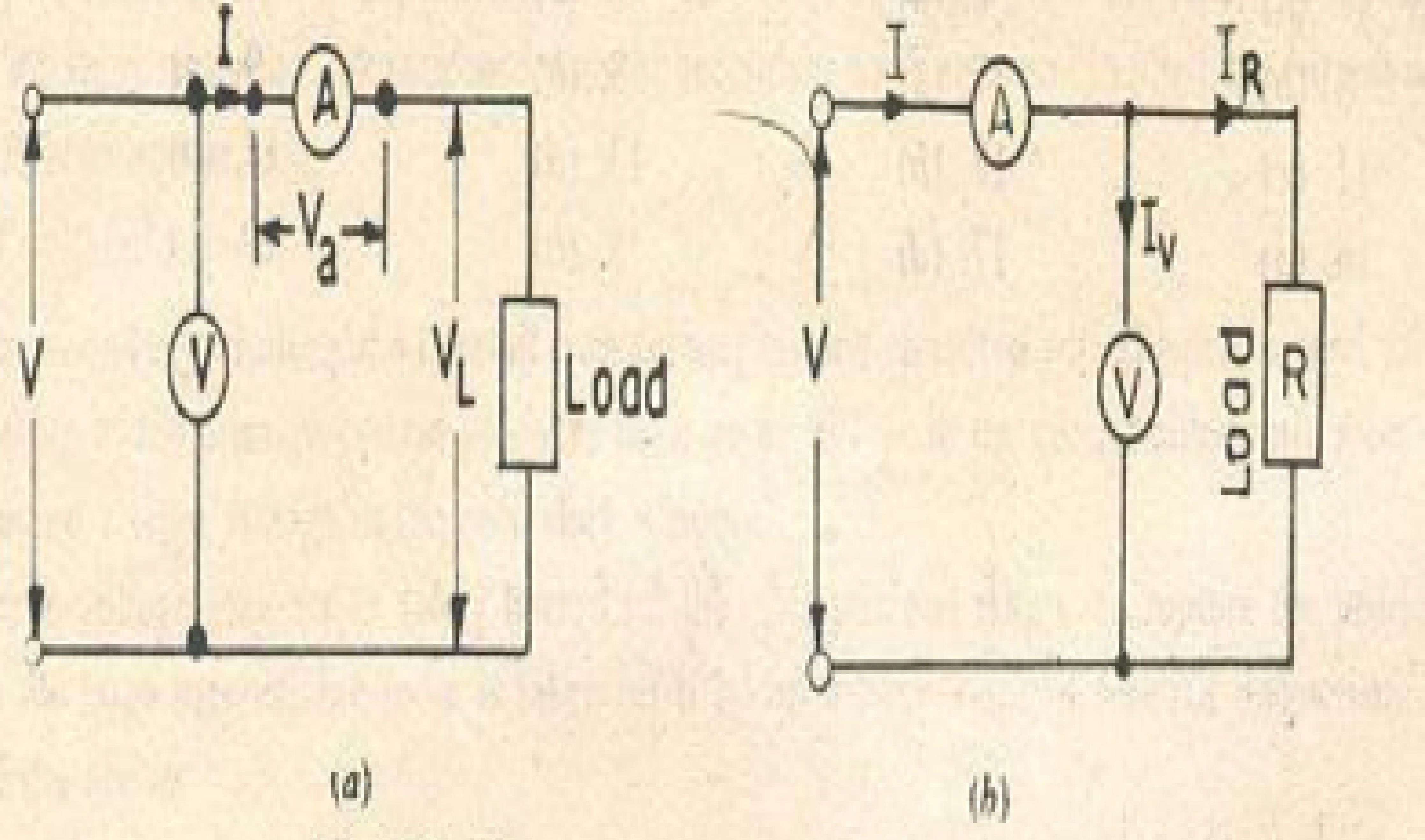


Fig. 11.1. Power measurements in D.C. circuits.

Dynamometer wattmeter

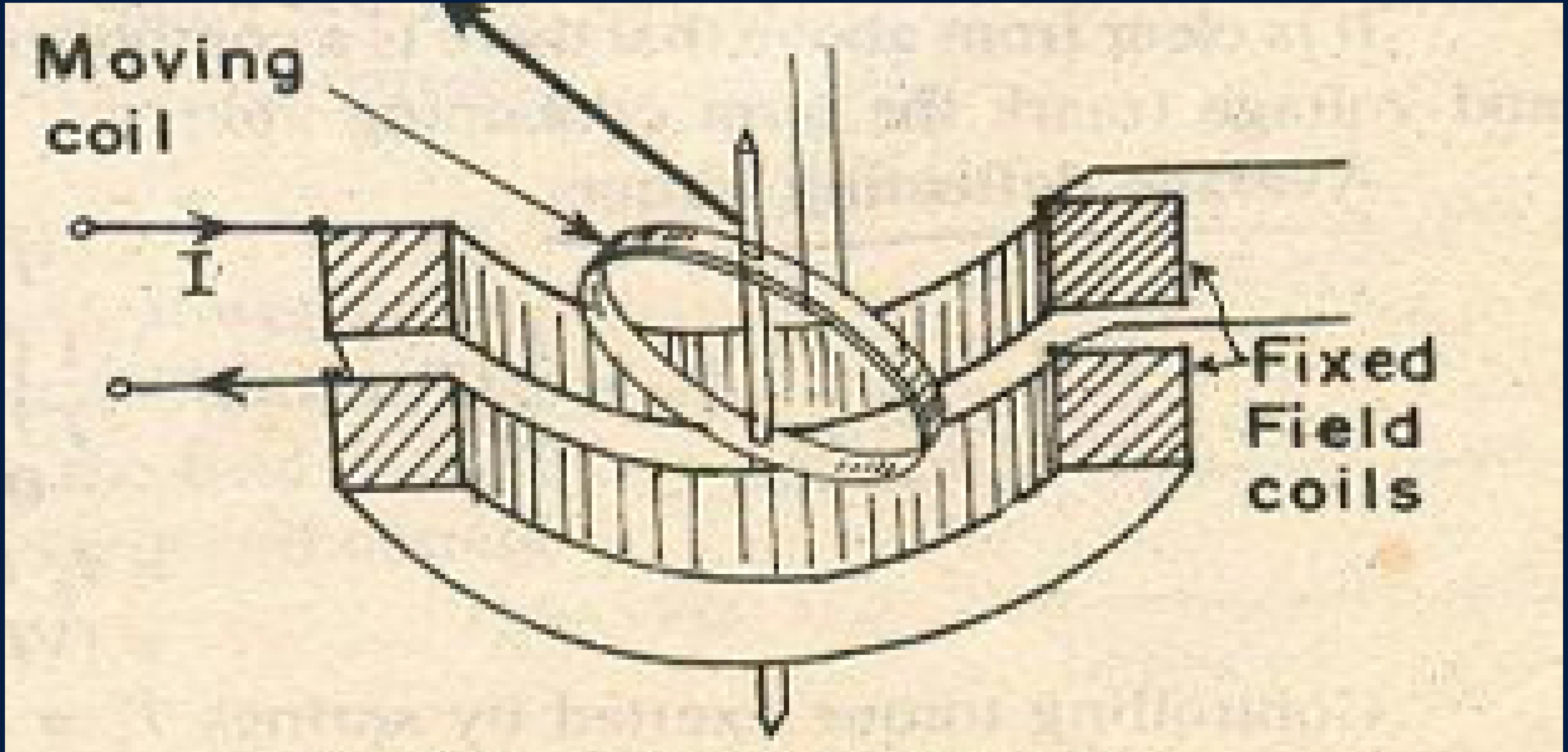


Fig. 11.2. Dynamometer wattmeter.

Electrodynamometer wattmeter

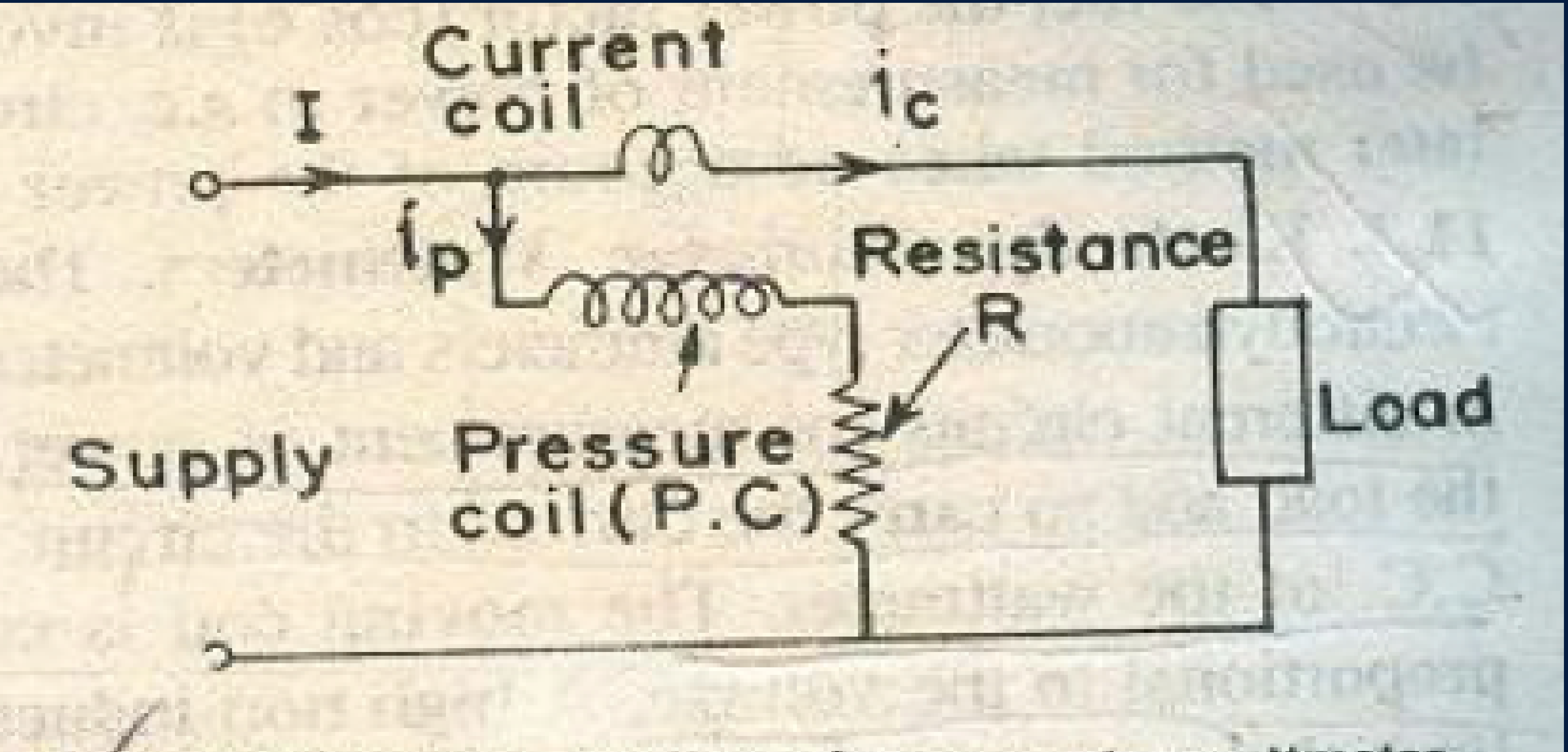


Fig. 11.3. Circuit of electrodynamometer wattmeter.

Single phase energy meter

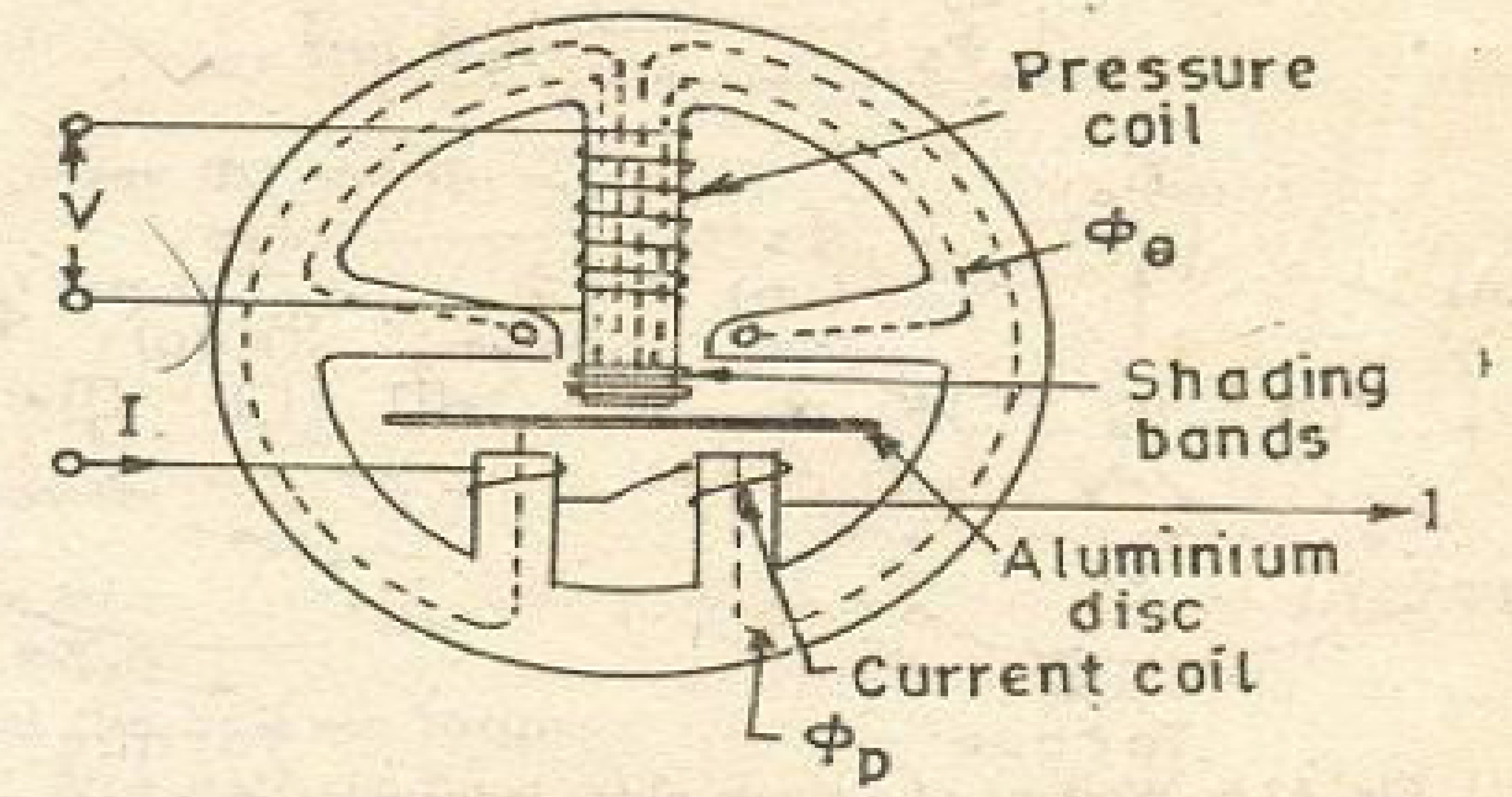


Fig. 12.3 Single phase energy meter.

Working of a singlephase induction type energy meter

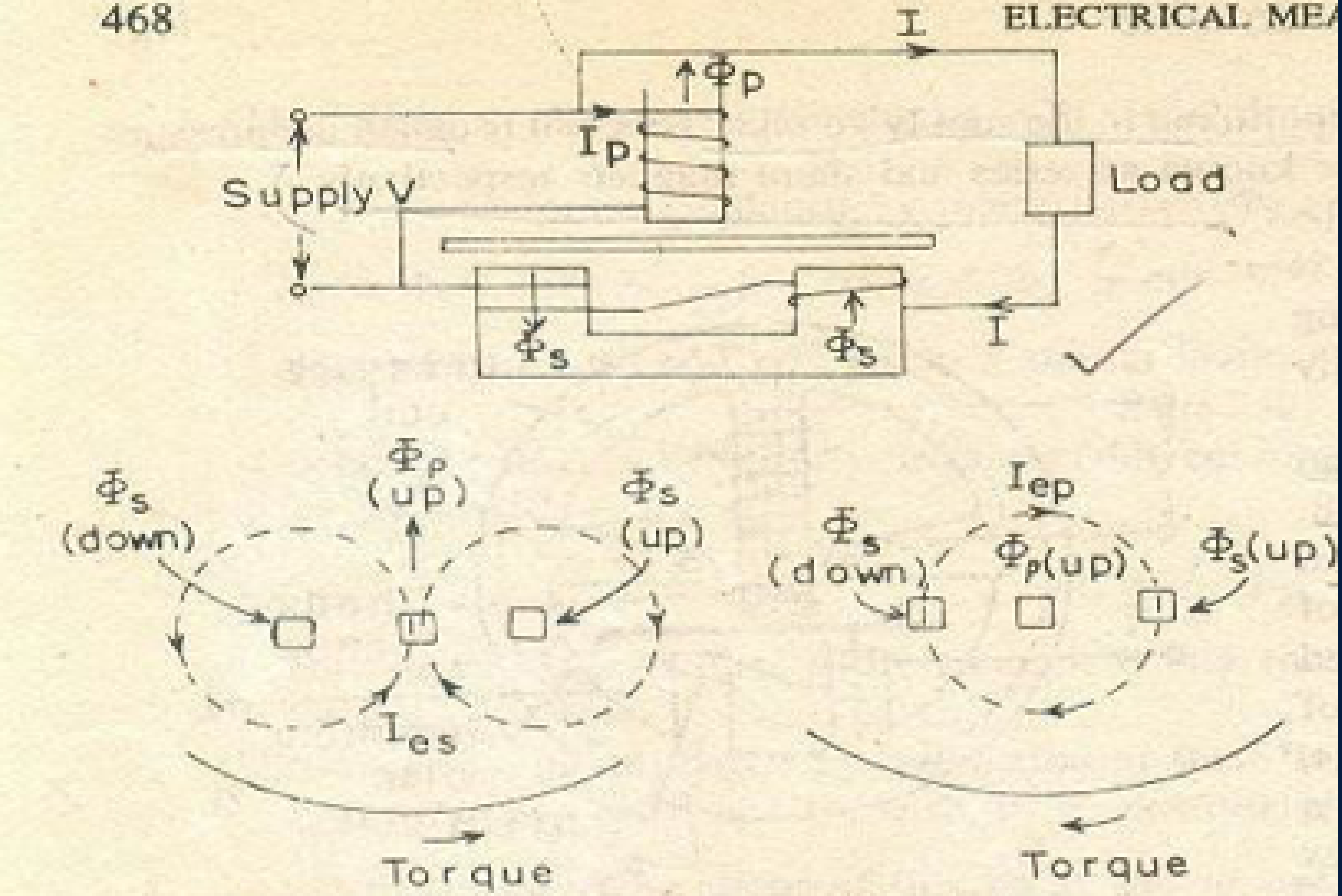
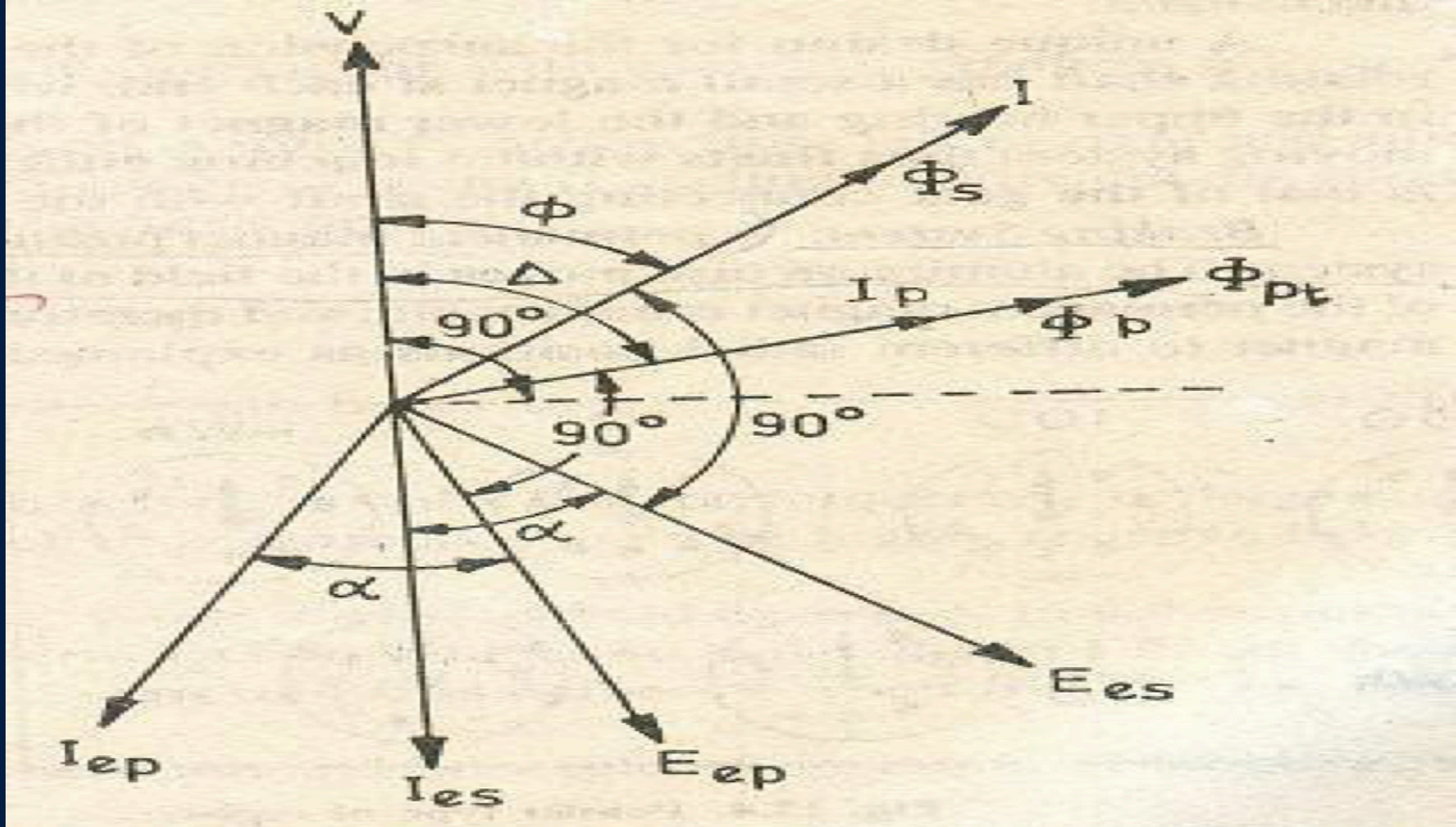


Fig. 12.6. Working of a single phase induction type energy meter.

Phasor diagramof a single phase induction type energy meter



ig. 12.7. Phasor diagram of single phase induction type energy meter.

Single phase electro dynamotype power factor meter

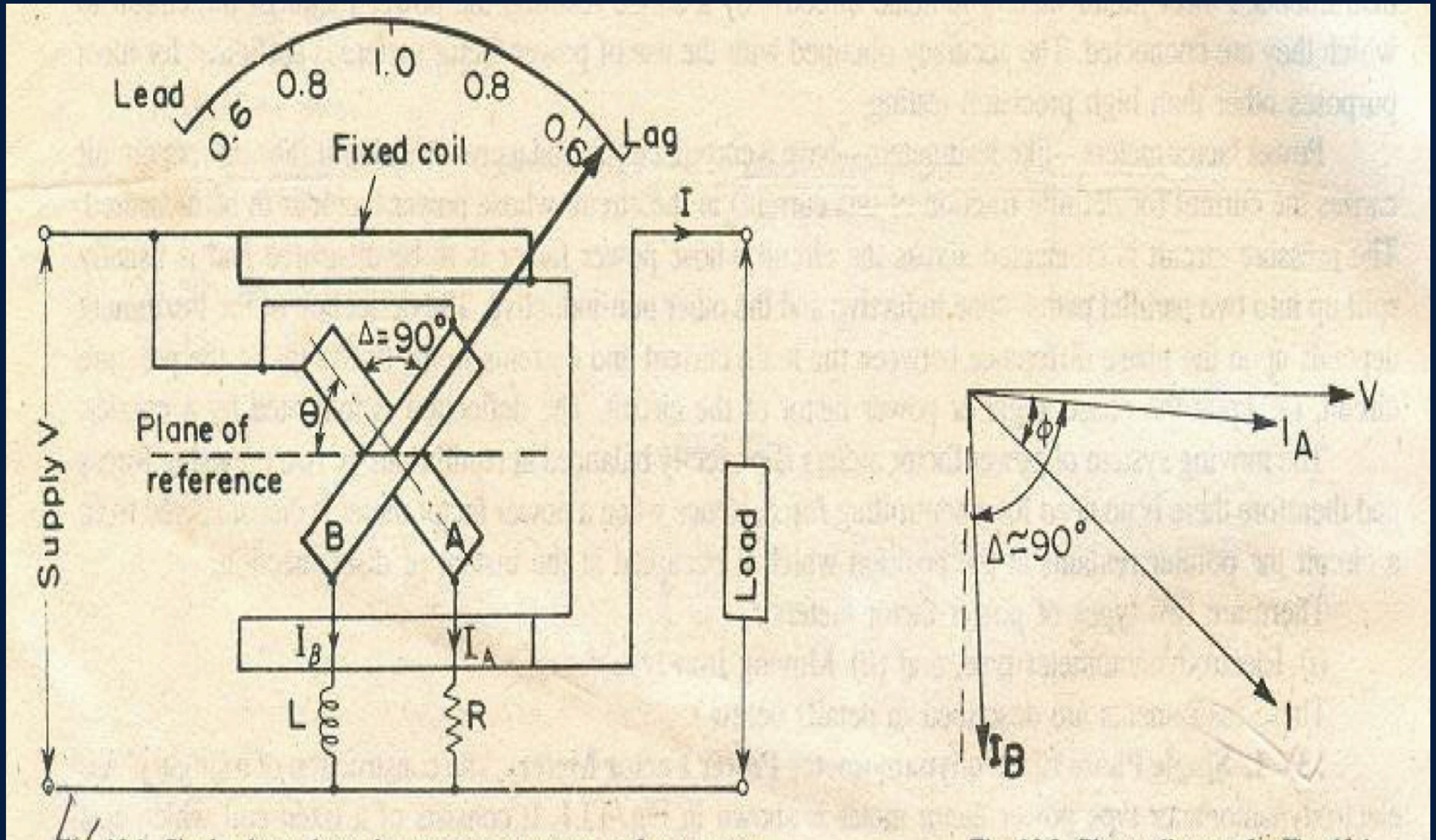


Fig. 13.1. Single phase electrodynamometer type power factor meter.

Fig. 13.2. Phasor diagram for Fig. 13.1.

WEEK 8
CLASS 2

Electrical resonance frequency meter

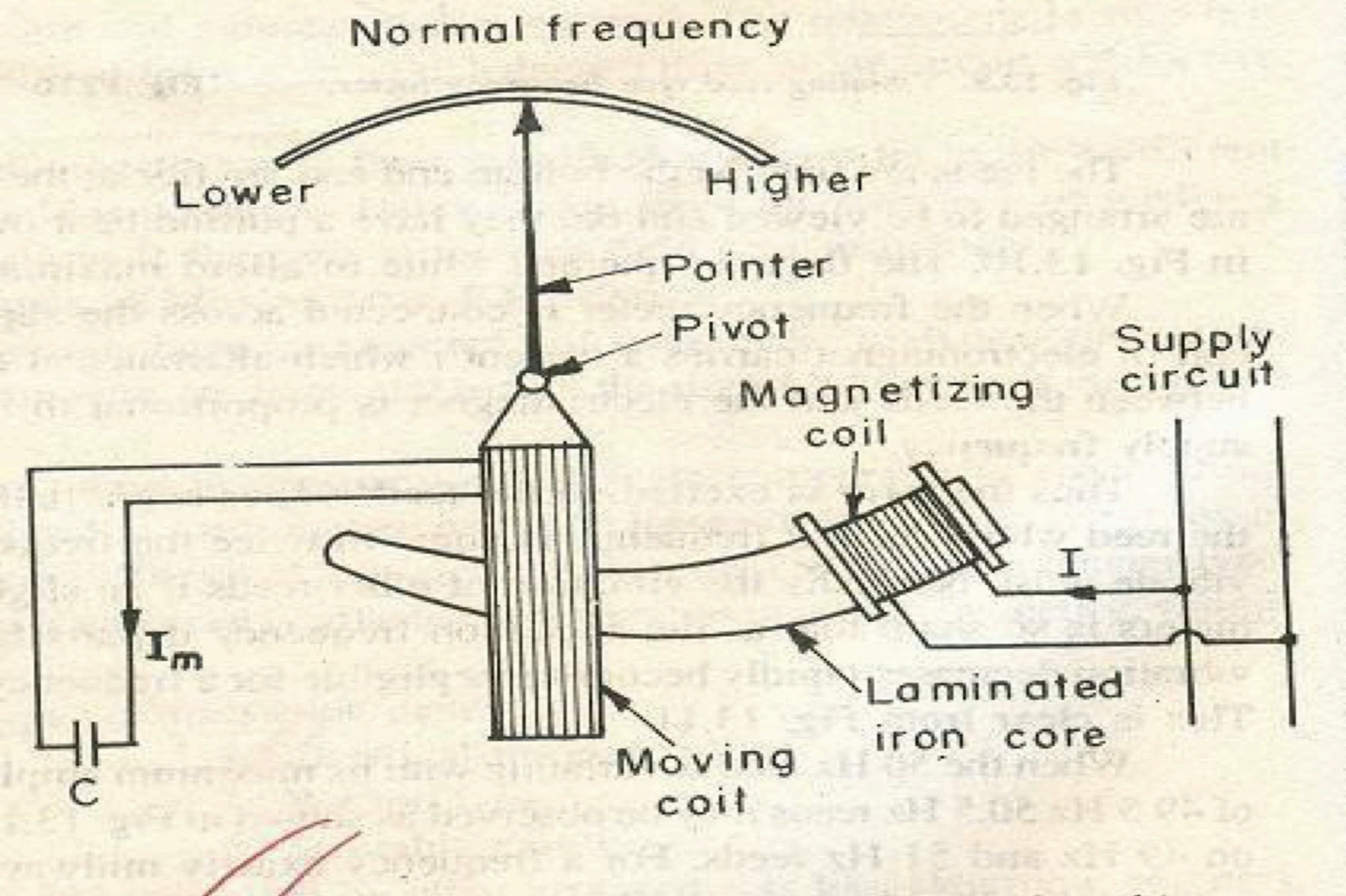


Fig. 13.13. Electrical resonance frequency meter (Ferro-dynamic).

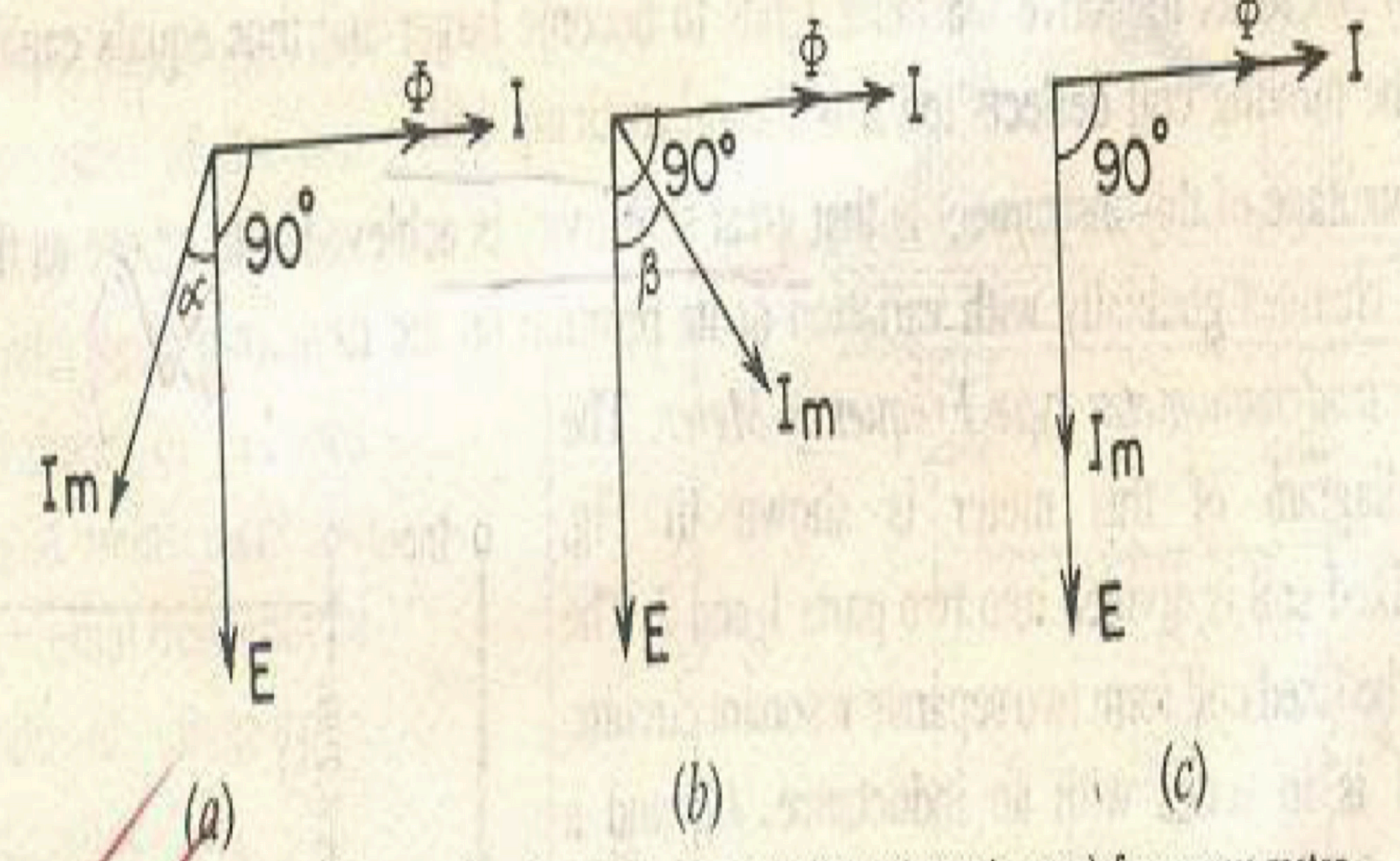
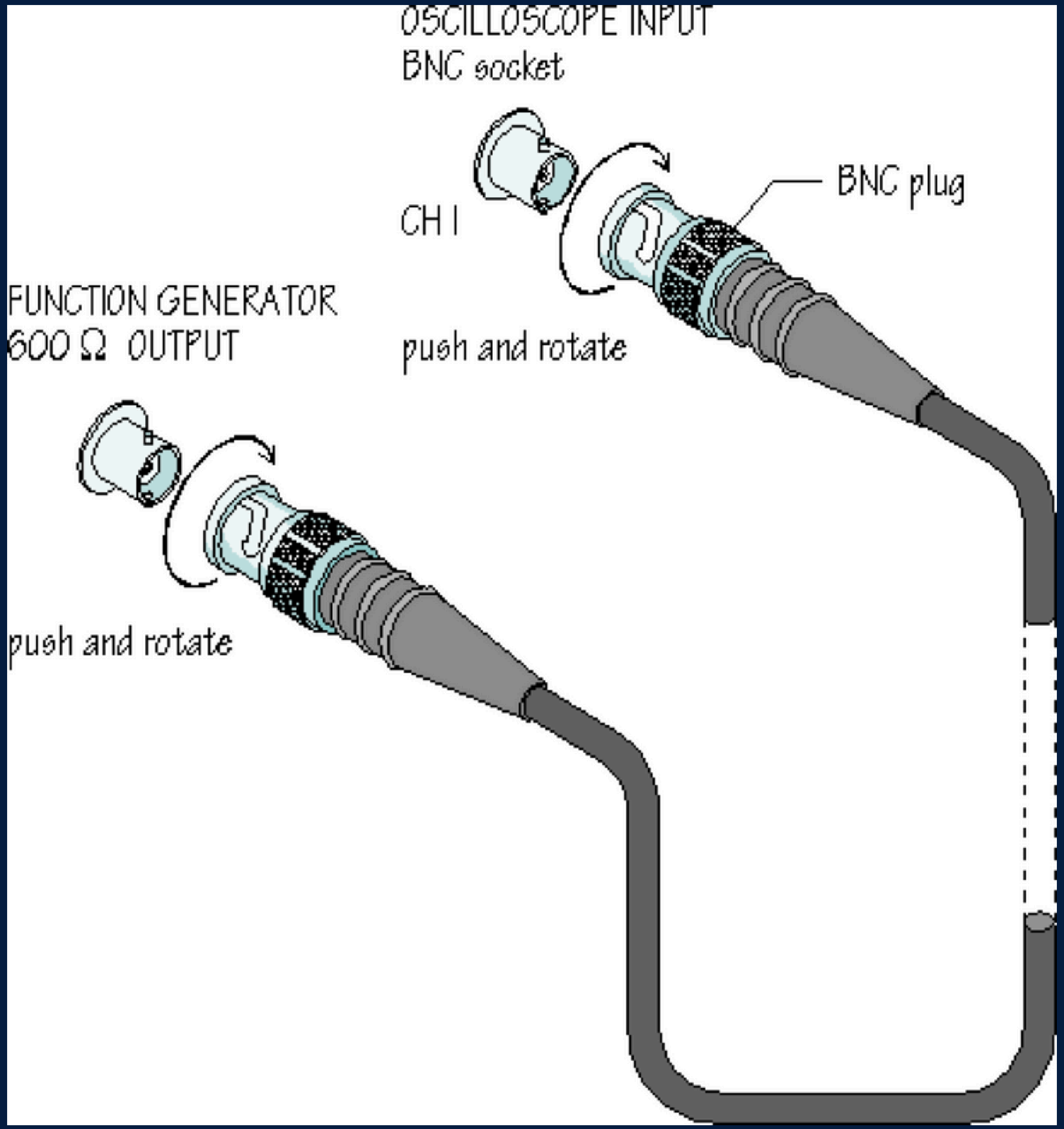


Fig. 13.14. Phasor diagrams for electrical resonance (ferrodynamic type) frequency meter.

PROBE

What is probe?

Probe is the connecting cable betweeninput of the oscilloscope and the point where the voltage is to be measured.



The input signals to an oscilloscope are usually connected via coaxial cables with probes on one end. Each probe has two connections an input and a ground.

A probe can be any conductor used to establish a connection between the circuit under test and the measuring instrument.
This conductor could be a piece of bare wire, a multi-meter lead, etc.

These simple probes, however, do not fulfill the essential purpose of a probe, that is, to extract minimal energy from the circuit under test and transfer it to a measuring instrument with maximum fidelity.

The bare wire can load the input amplifier with its high capacitance and inductance or even cause a short circuit.

Multimeter leads are unshielded and are often susceptible to stray pickup.

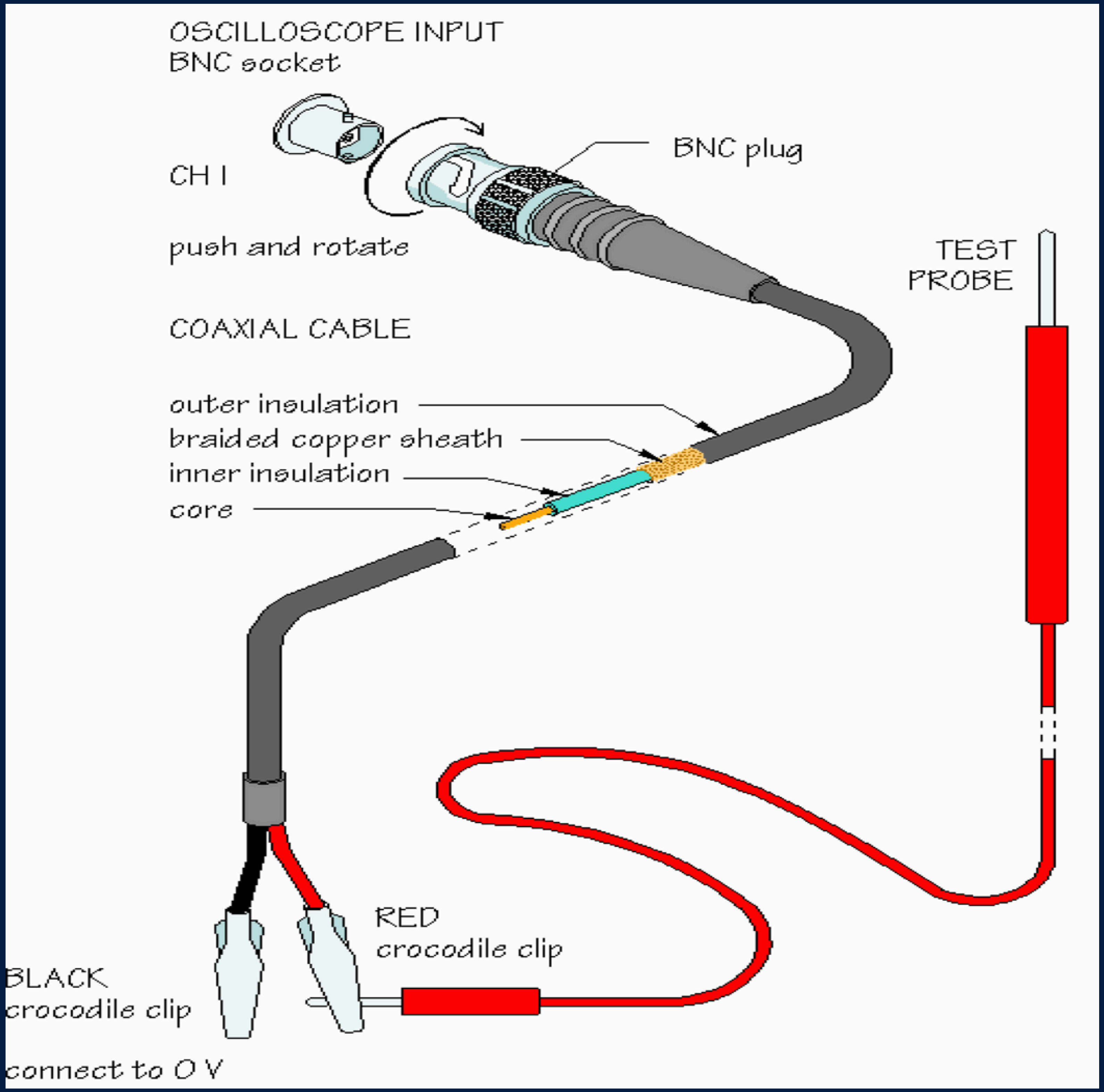
WEEK 9
CLASS 1

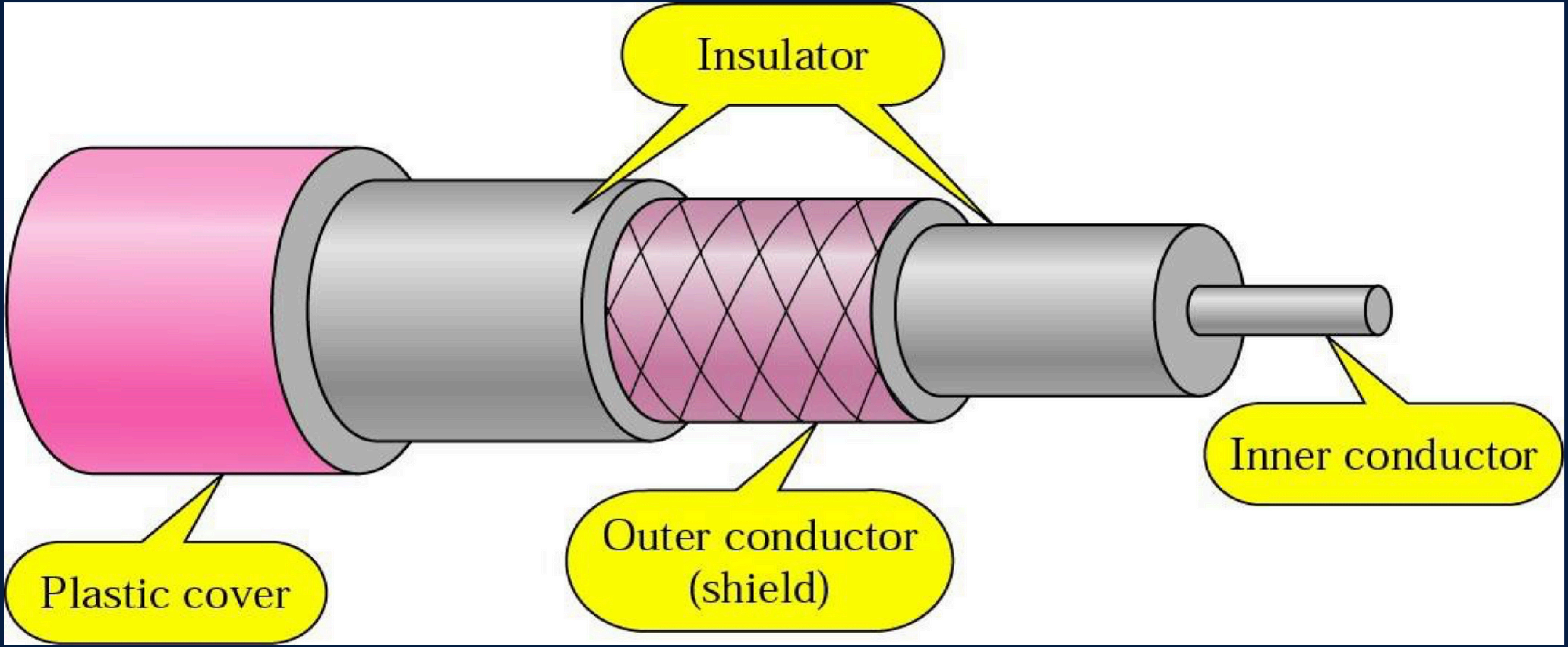
probe

Key attributes of ideal probe:

1. Ease of connection
2. Absolute signalfidelity
3. Zero signalsource loading
4. Complete noiseimmunity

Probe Constructions





Insulator
Plastic cover
Outer conductor
(shield)
Inner conductor

The central conductor carries the input signal. The circular conductor is grounded so that it acts like a screen to help prevent unwanted signals being picked up by the oscilloscope input.

1:1 Probe

It does not contain attenuate the input signal resistors

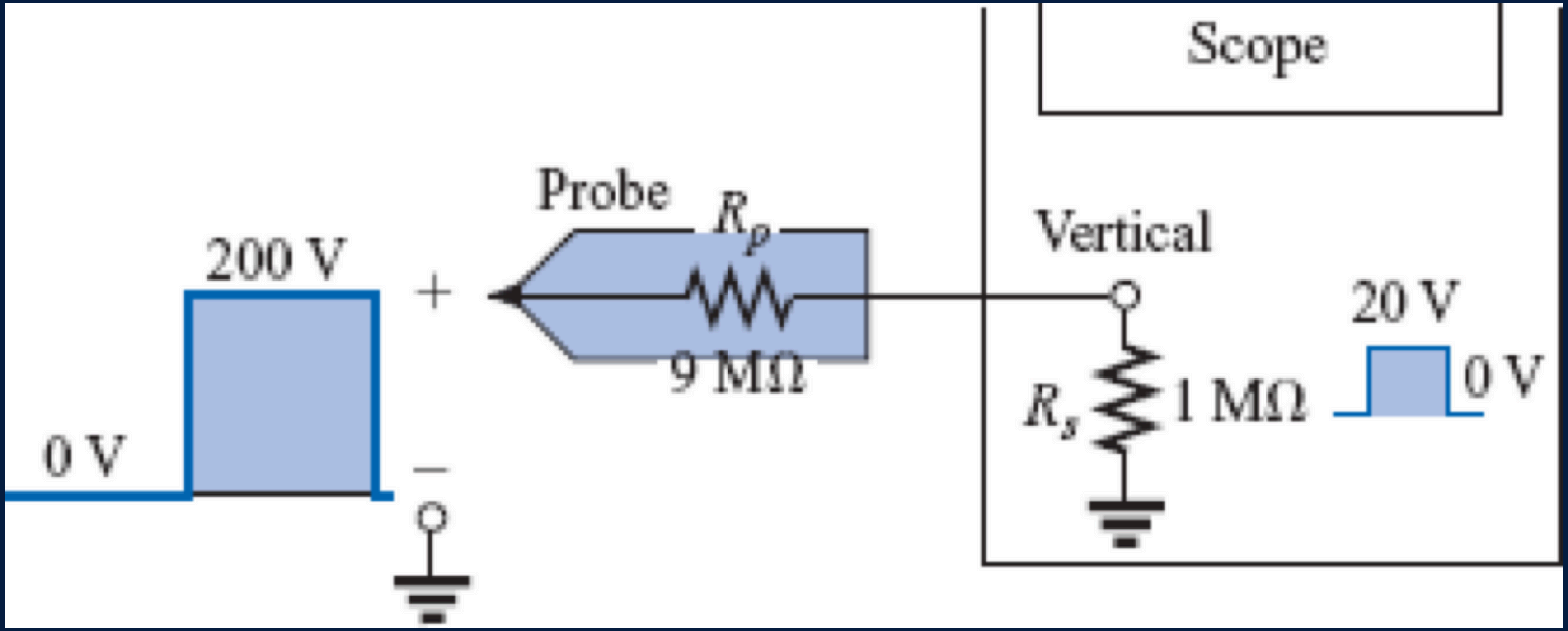
10:1 Probe (Attenuator Probe)

Attenuates the input signal. Usually by a factor 10. Also normally offer a much larger input impedance than a 1:1 probe, thereby minimizing loading effects on the circuit.

WEEK 9
CLASS 2

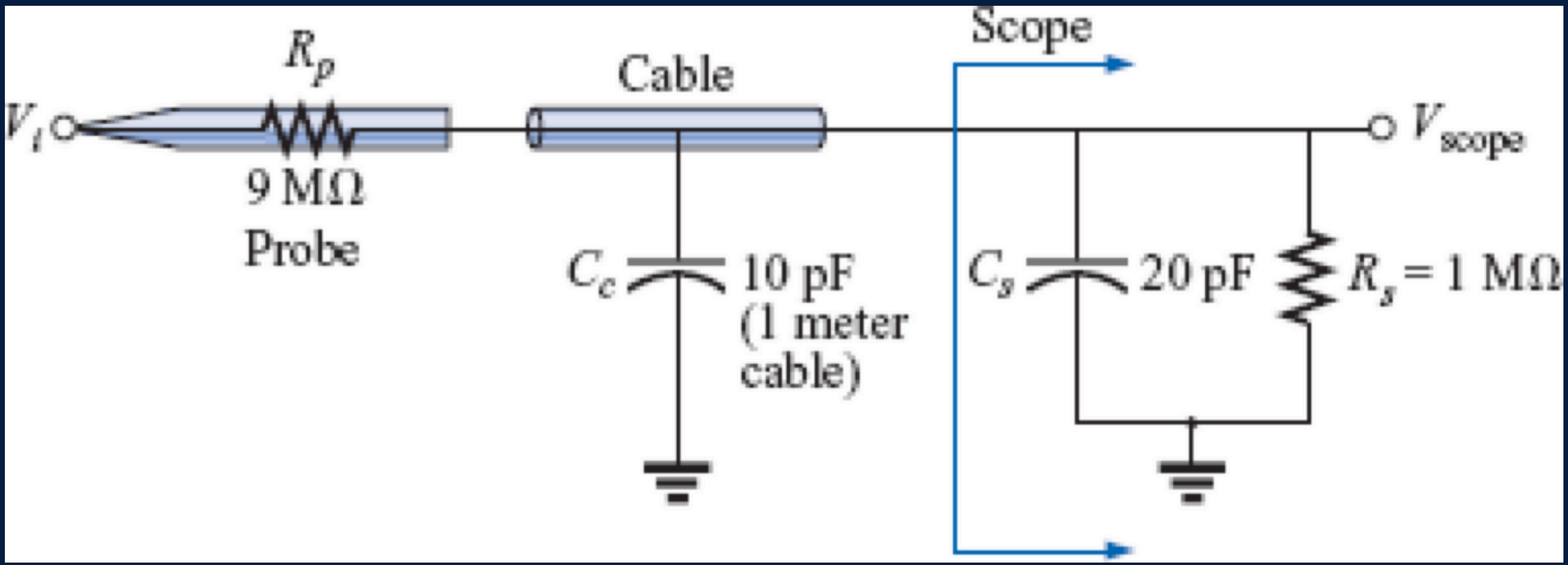
PROBE

$$V_{scope} = \frac{(1\ \text{M}\Omega)(V_i)}{1\ \text{M}\Omega + 9\ \text{M}\Omega} = \frac{1}{10}V_i$$



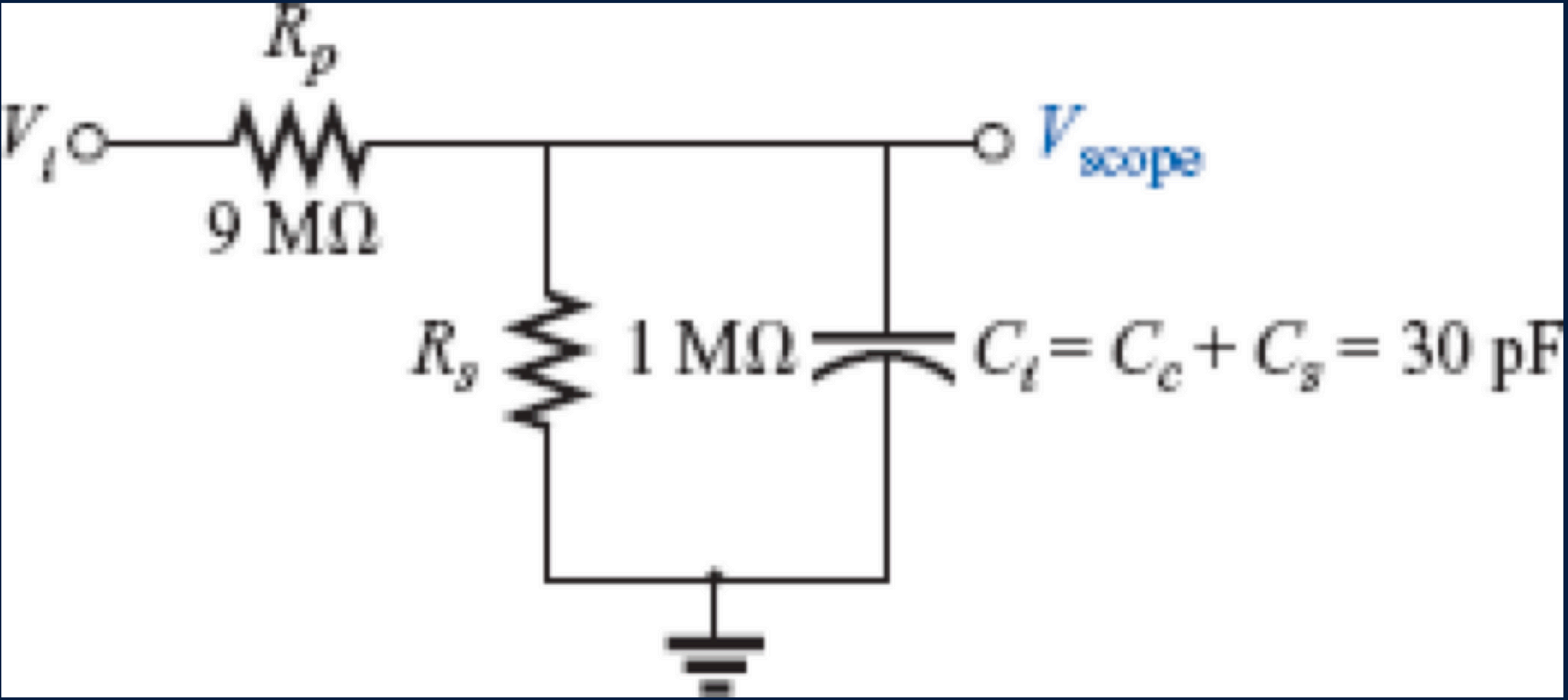
X10 probe

PROBE



Scope
R_p
Cable
V_i
V_{scope}
9 MΩ
Probe
C_c
10 pF
(1 meter
cable)
C_s
20 pF
R_s = 1 MΩ

PROBE

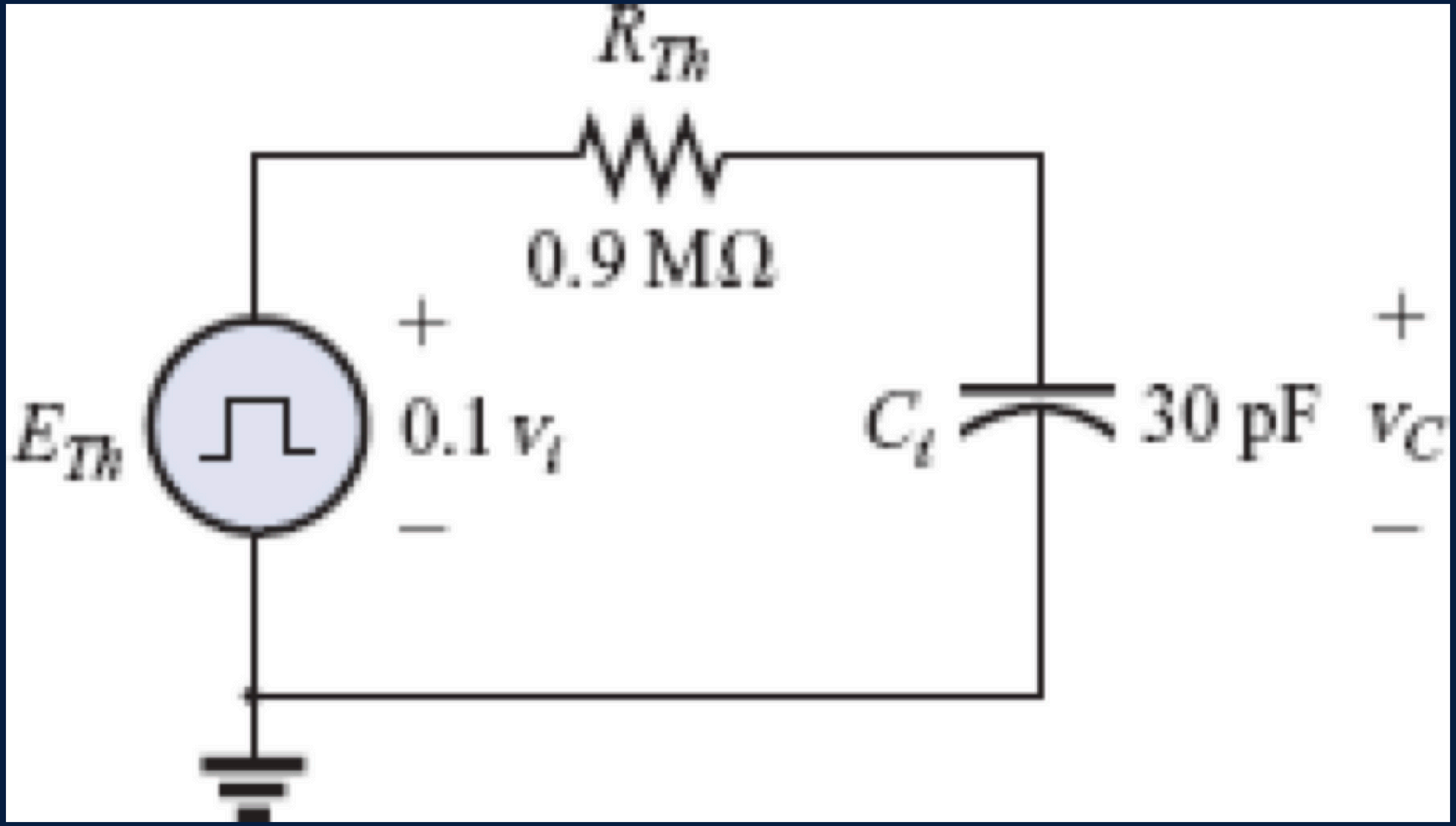


PROBE

Thevenin equivalent for the capacitor Ci

$$E_{Th} = \frac{(1\ \text{M}\Omega)(V_i)}{1\ \text{M}\Omega + 9\ \text{M}\Omega} = \frac{1}{10}V_i$$

$$R_{Th} = 9\ \text{M}\Omega \parallel 1\ \text{M}\Omega = 0.9\ \text{M}\Omega$$



PROBE

or v_i = 200 V (peak),

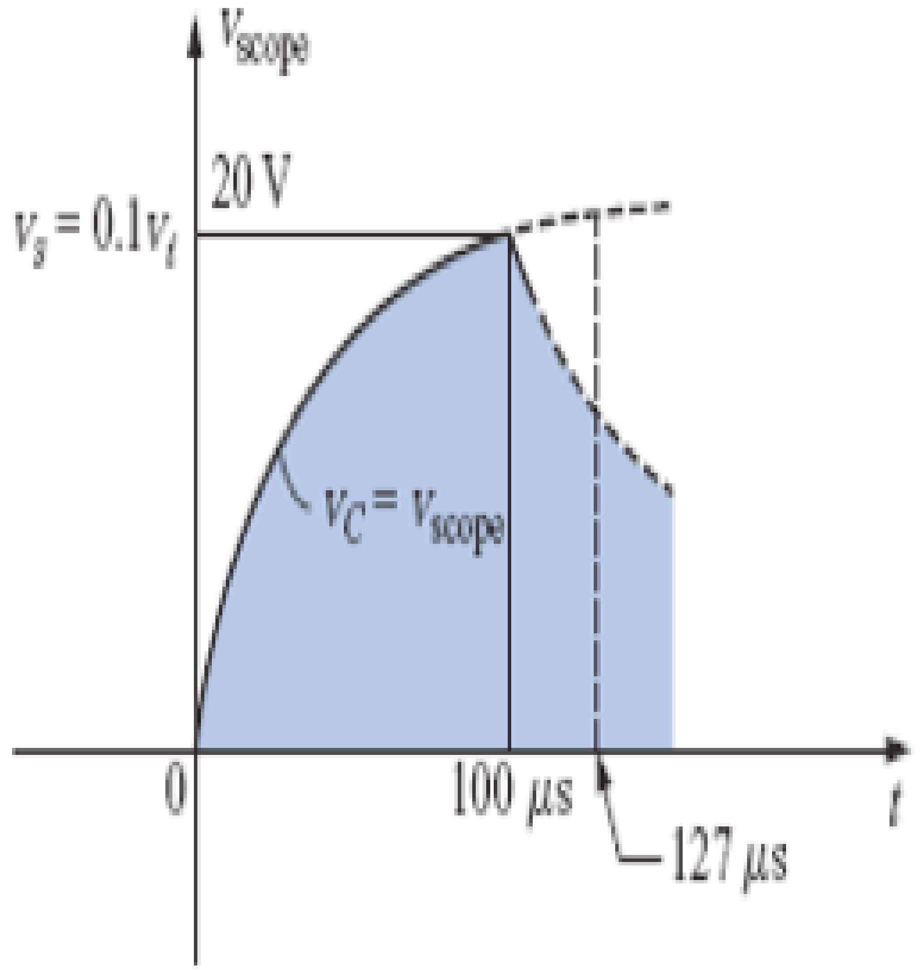
$$E_{Th} = 0.1v_i = 20\,\text{V (peak)}$$

for v_C, V_f = 20 V and V_i = 0 V, with

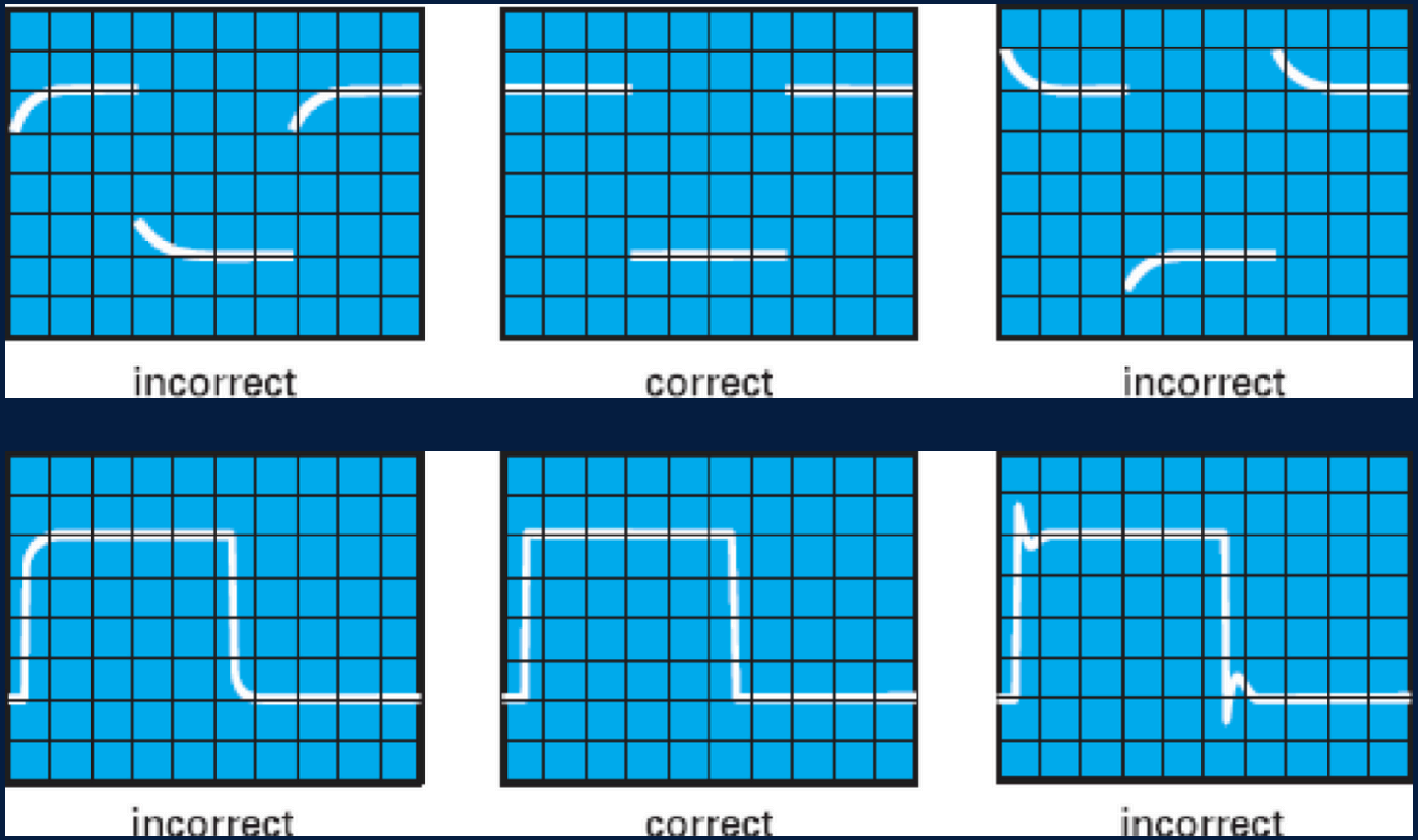
$$\tau = RC = (0.9 \times 10^6\,\Omega)(30 \times 10^{-12}\,\text{F}) = 27\,\mu\text{s}$$

r an applied frequency of 5 kHz,

$$T = \frac{1}{f} = 0.2\,\text{ms} \quad \text{and} \quad \frac{T}{2} = 0.1\,\text{ms} = 100\,\mu\text{s}$$



PROBE



(a) Under compensated (b) Correctly compensated (c) over compensated

WEEK 10
CLASS 1

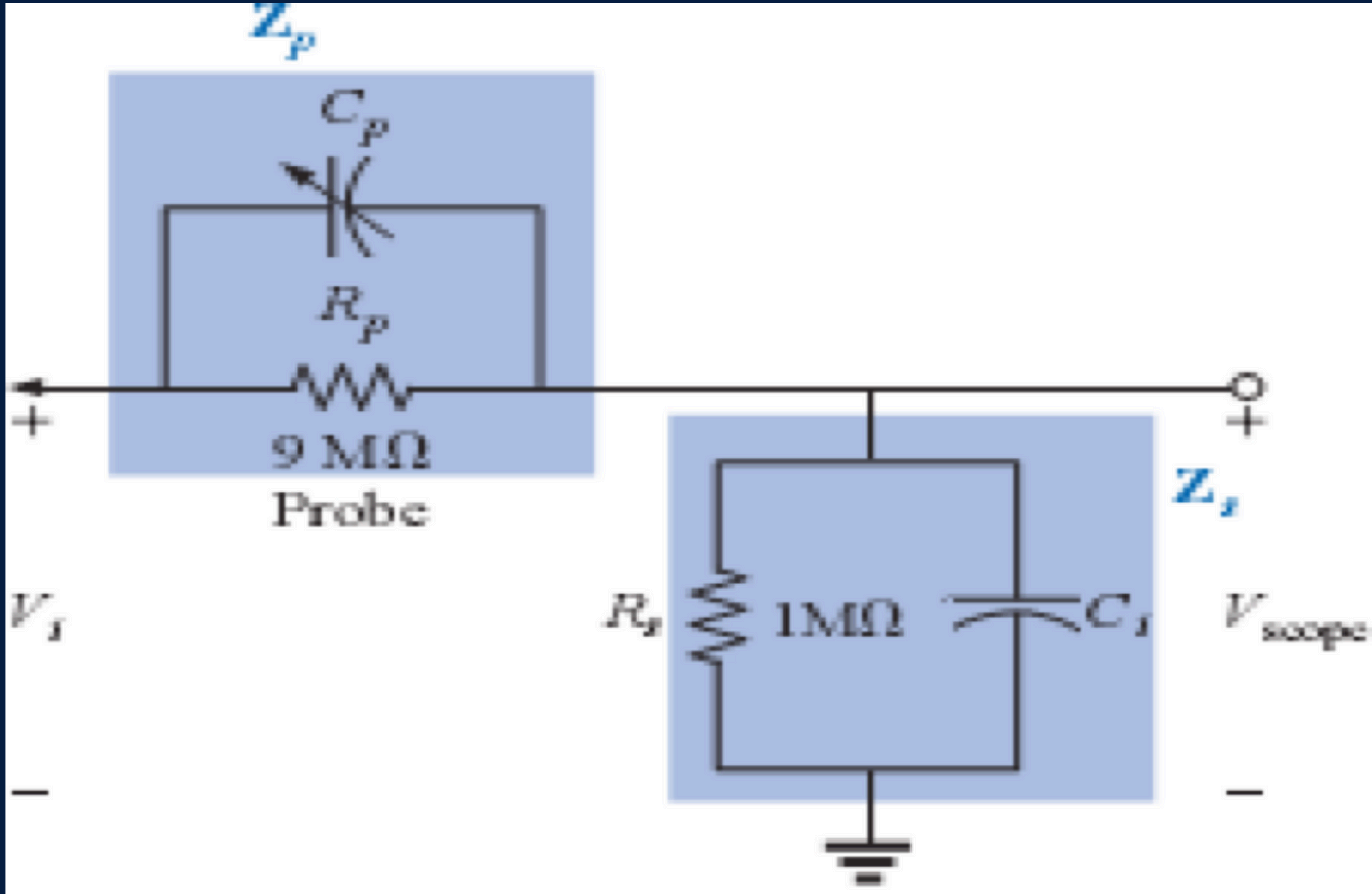


FIG. 24.42

Compensated attenuator and input impedance to a scope, including the cable capacitance.

Attenuator probe

- To improve matters, a variable capacitor is often added in parallel with the resistance of the attenuator, resulting in a compensated attenuator probe

$$\mathbf{V}_{\text{scope}} = \frac{\mathbf{Z}_s \mathbf{V}_i}{\mathbf{Z}_s + \mathbf{Z}_p} \tag{24.8}$$

If the parameters are chosen or adjusted such that

$$R_p C_p = R_s C_s \tag{24.9}$$

the phase angle of $\mathbf{Z}_s$ and $\mathbf{Z}_p$ will be the same, and Equation (24.8) will reduce to

$$\mathbf{V}_{\text{scope}} = \frac{R_s \mathbf{V}_i}{R_s + R_p} \tag{24.10}$$

which is insensitive to frequency since the capacitive elements have dropped out of the relationship.

Compensating

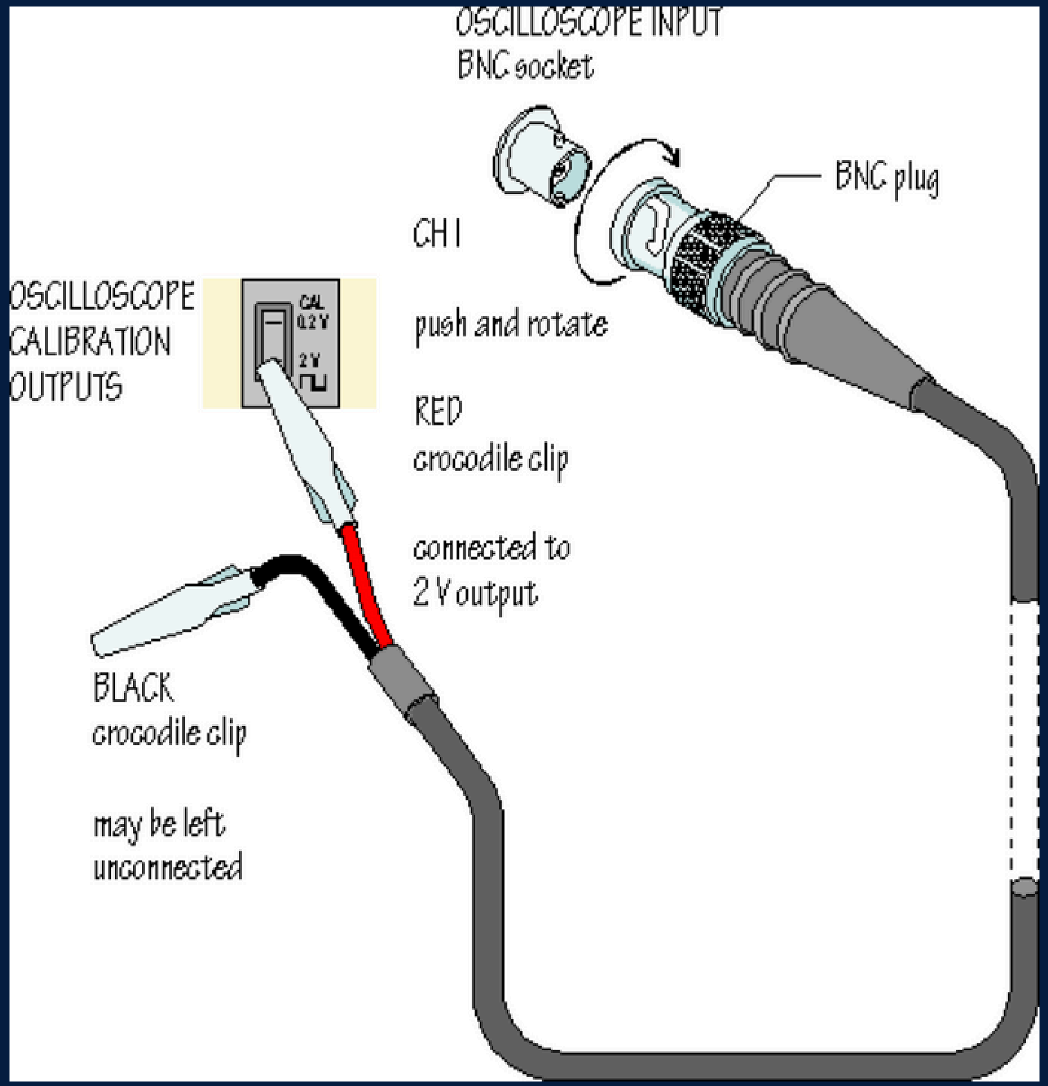
In the laboratory, simply adjust the probe capacitance using a standard or known square-wave signal until the desired sharp corners of the square wave are obtained. Too much capacitance will result in an overshoot effect, whereas to little will continue to show the rounding effect.

WEEK 10 CLASS 2

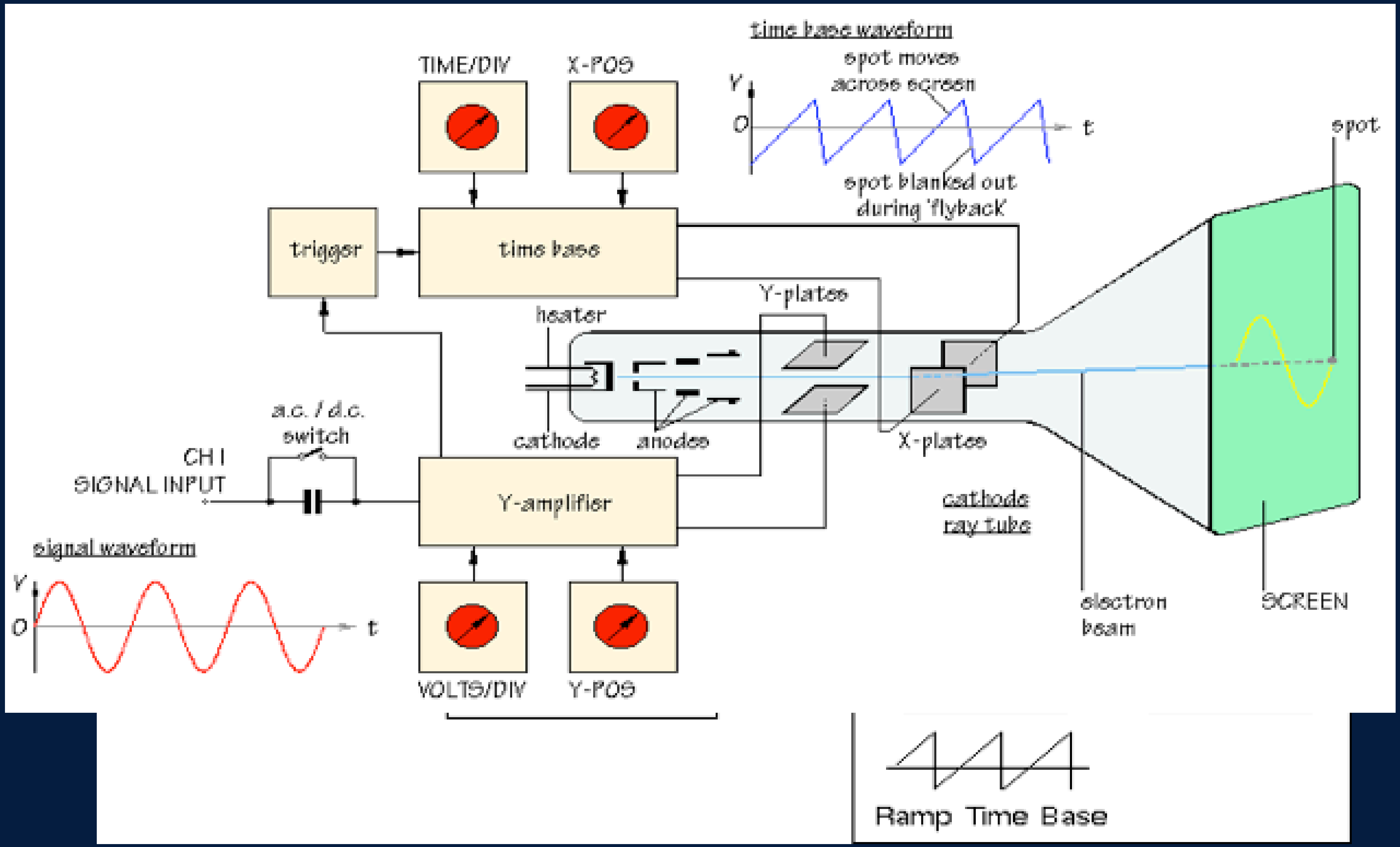
Compensating the Probe

Before using a probe, it should be compensated - to balance its electrical properties to a particular oscilloscope

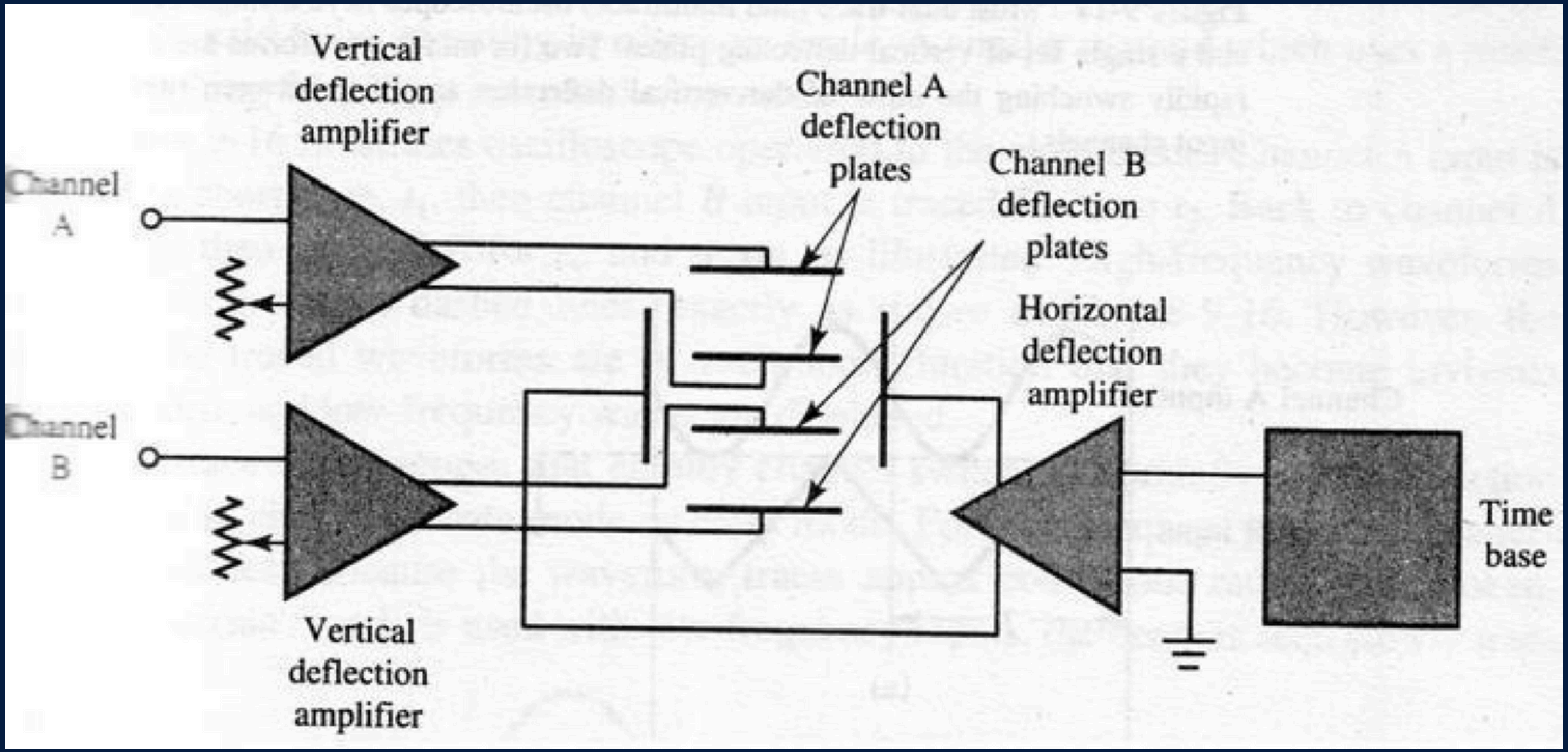
Attaching the ground clip of the probe to ground
*Viewing the square wave reference signal
*Making the proper adjustments on the probe so thatthe corners of the square wave are square
*Attachingthe probe to an input connector



Basic Block Diagramof Oscilloscope



Dual Trace Oscilloscope



Deflection system for dual-beam dual trace oscilloscope

Dual Trace Oscilloscope

Most oscilloscopes can display two waveforms rather than just one.

This allows waveforms to be compared in terms of amplitude and phase or time.

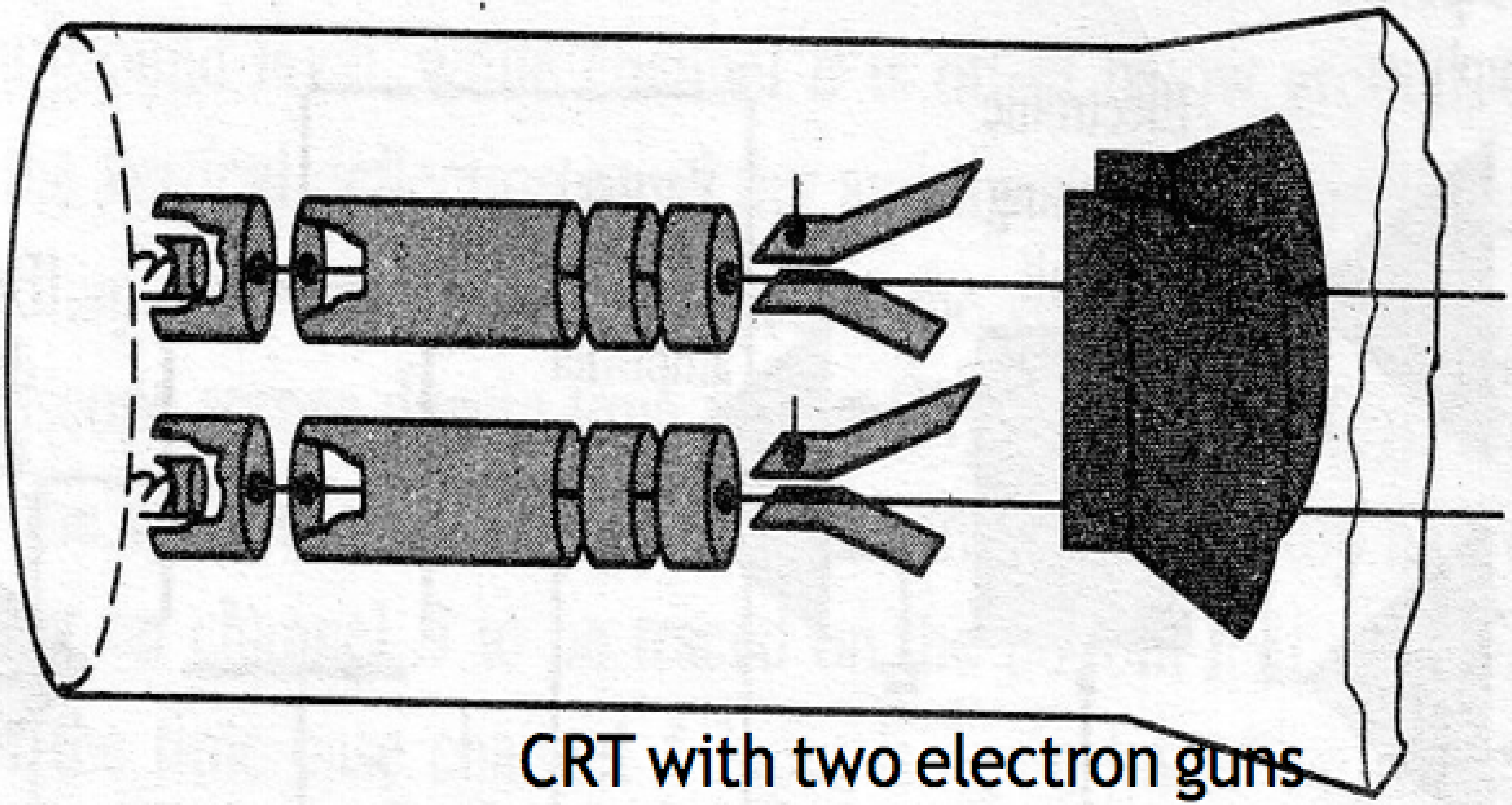
Usually two input terminals and two sets of controls are provided, identified as channel A and channel B

WEEK 11
CLASS 1

Dual Trace Oscilloscope

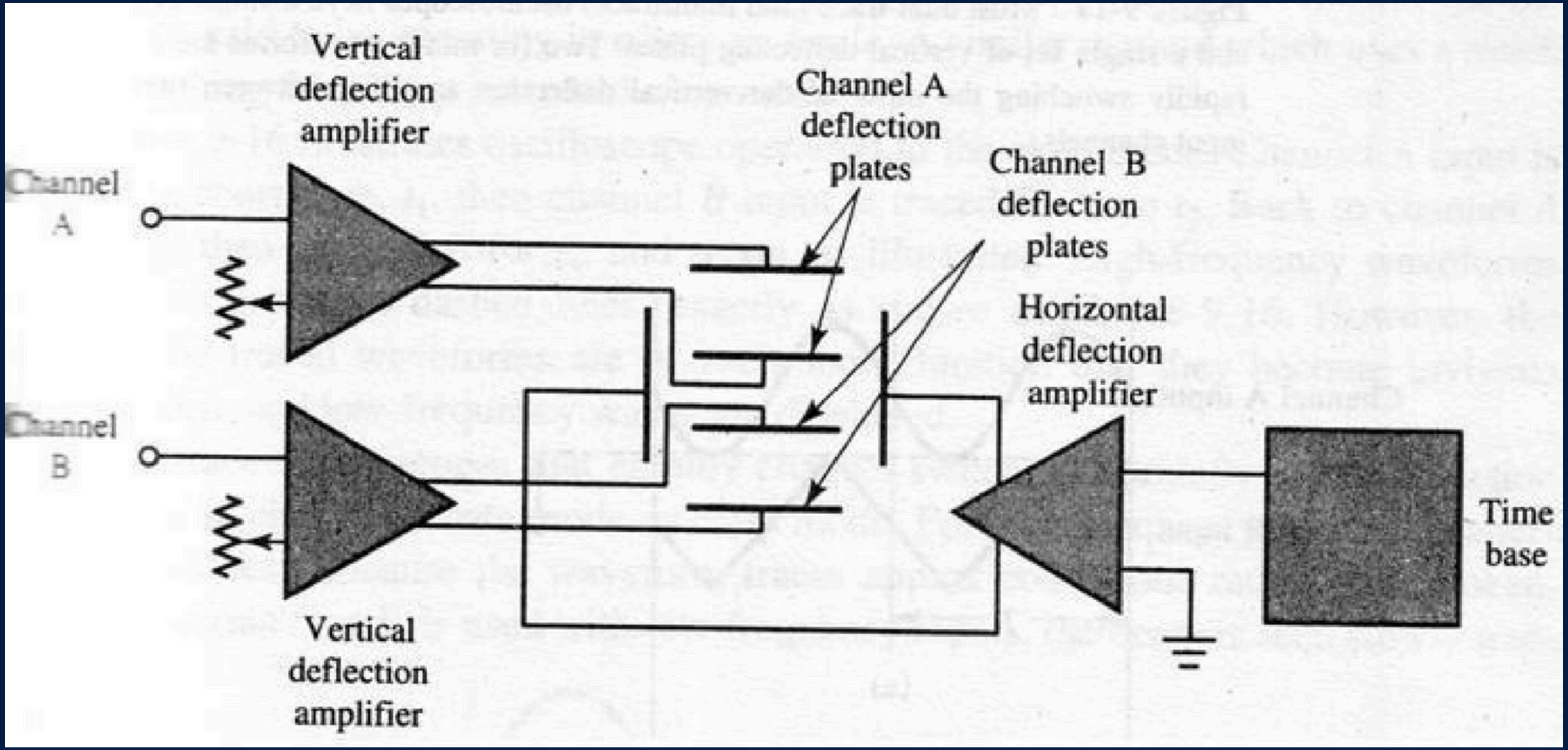
Dual Beam Oscilloscope

Single Beam Oscilloscope



CRT with two electron guns

Dual Trace Oscilloscope



Deflection system for dual-beam dual trace oscillos

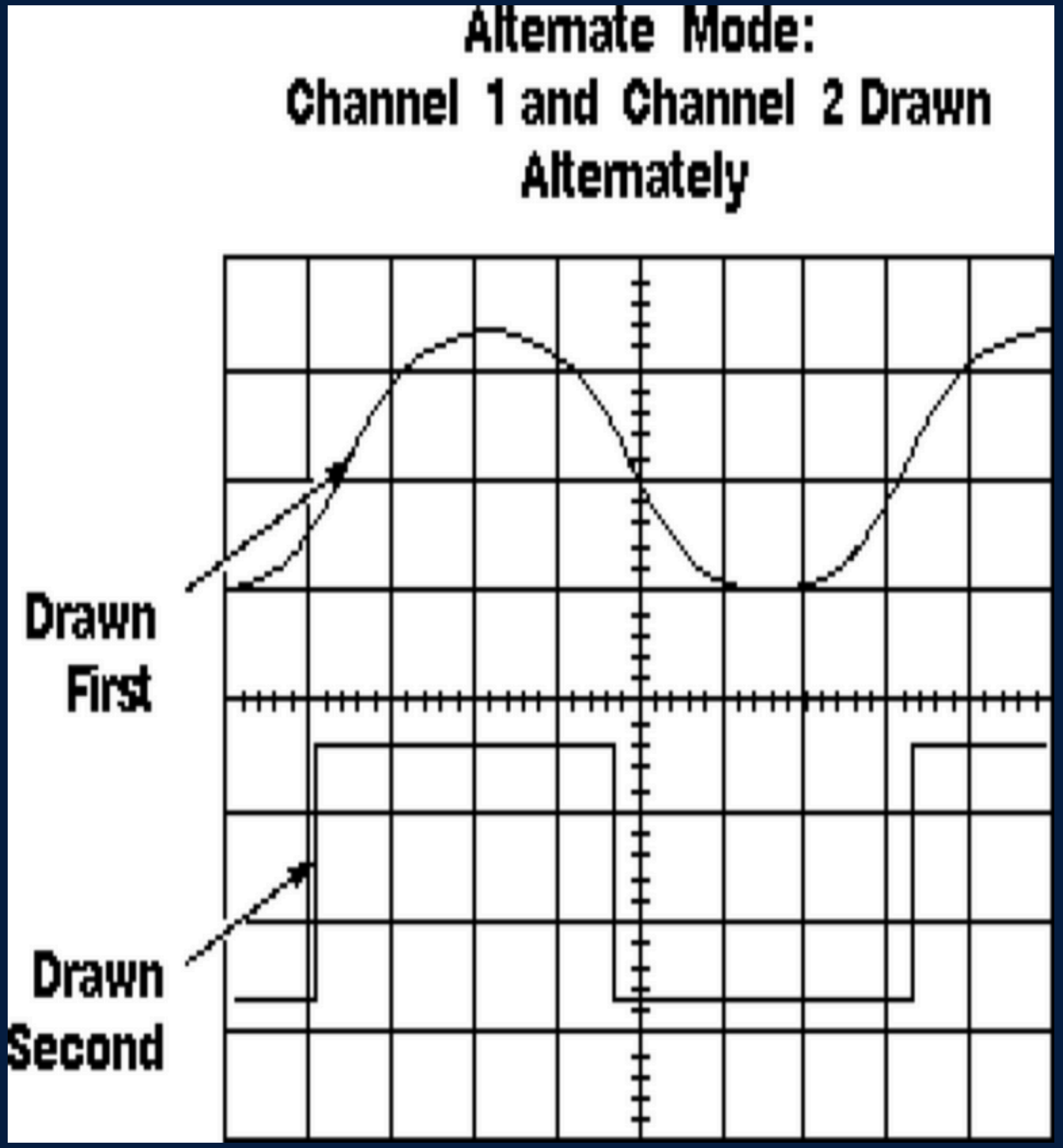
Multiple wither mode

channels are displayed using ALT (alternate) or the CHOP Digitizing oscilloscopes can present multiple channels simultaneously without the need for chop or alternate modes.

WEEK 11/12 CLASS 2

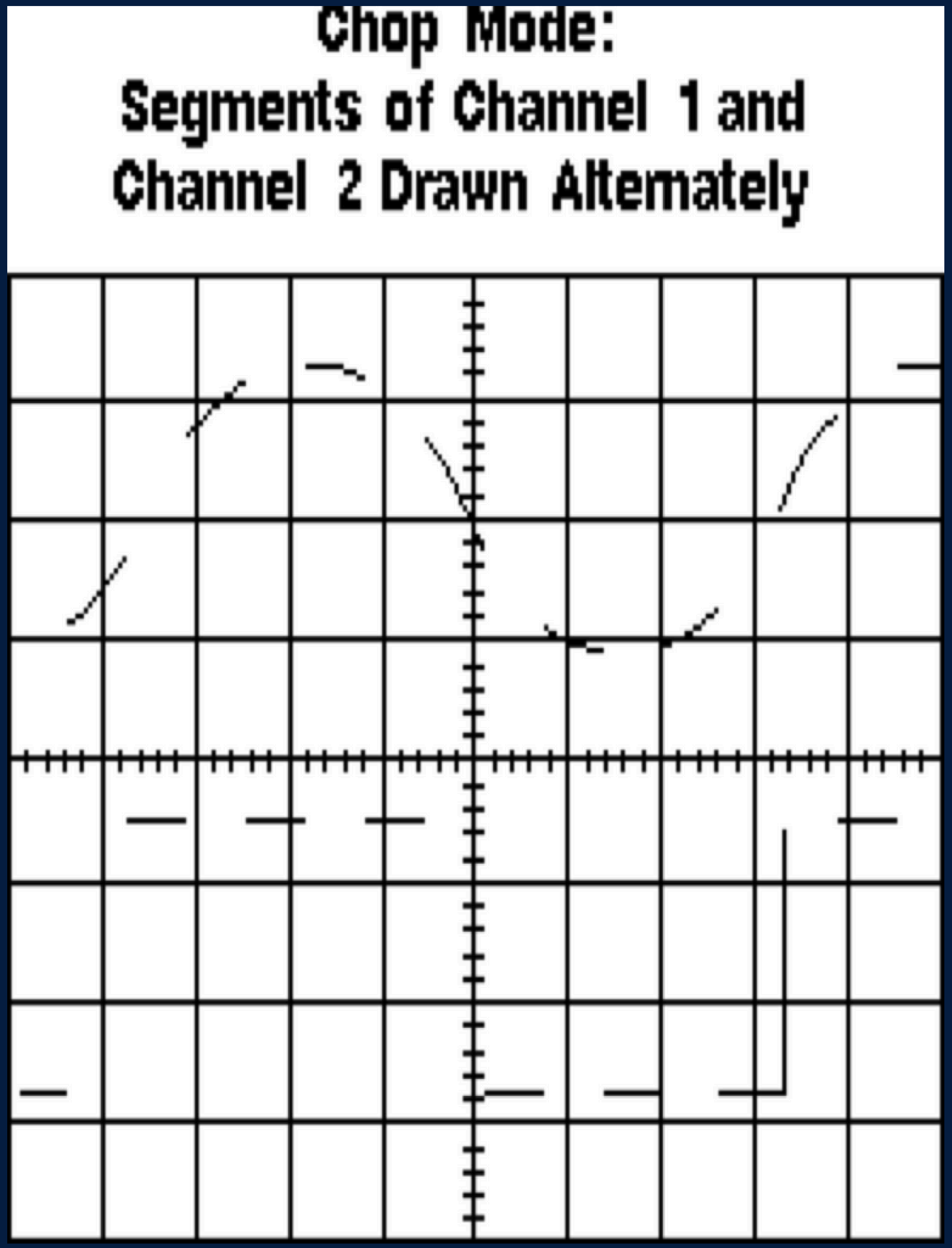
Alternate Display

On analog scope, multiple channels are displayed using an alternate mode. (Digital oscilloscopes do not normally use chop or alternate mode.) Alternate mode draws each channel alternately - the oscilloscope completes one sweep on channel 1, then one sweep on channel 2, a second sweep on channel 1, and so on.

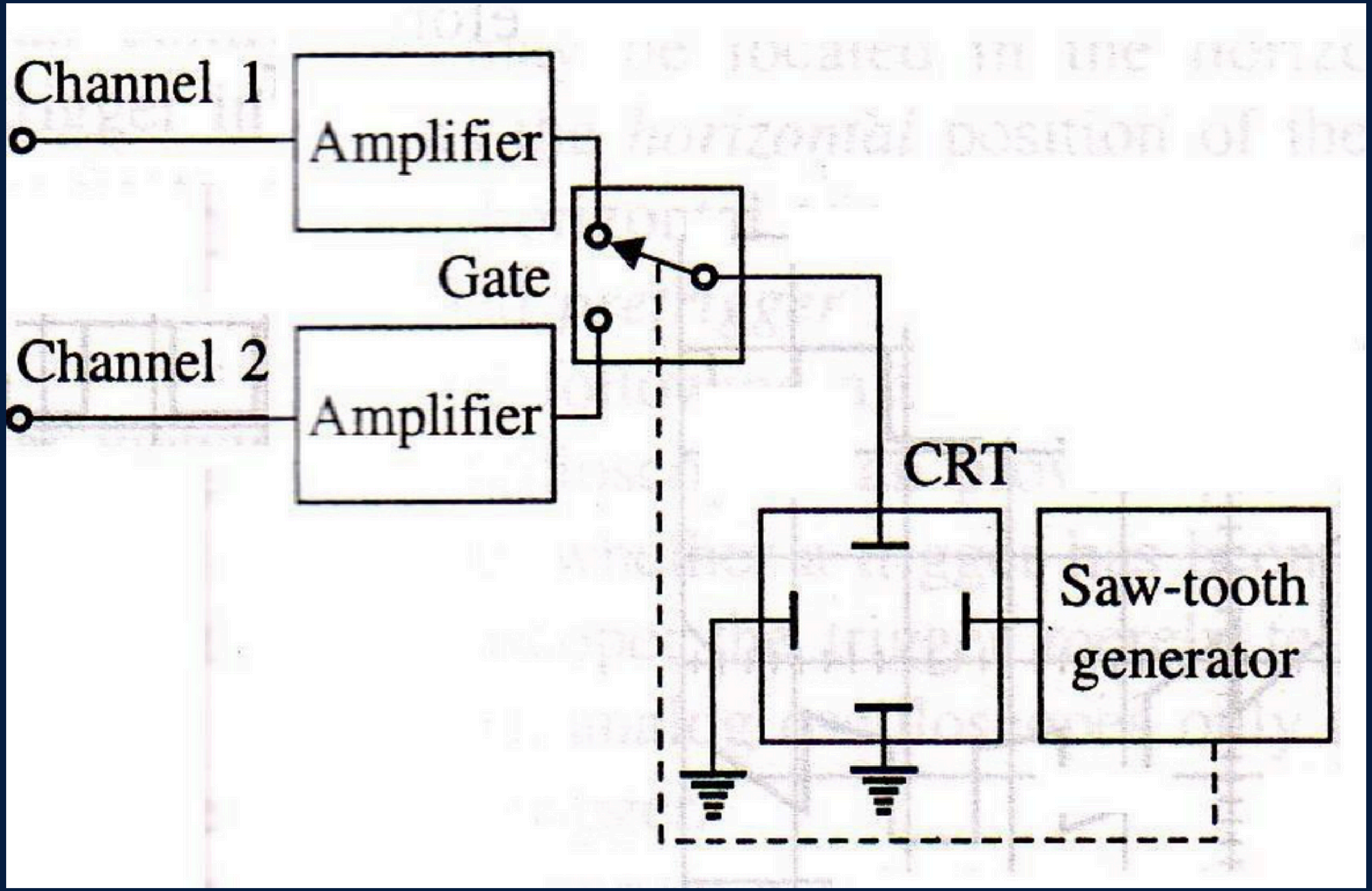


Chop Display

Chop mode causes the oscilloscope to draw small parts of each signal by switching back and forth between them.



Dual Trace Oscilloscope



Alternate mode internal arrangement

Lissajous Pattern:

The patterns that appear on the screen of a CRT when the sinusoidal voltage are simultaneously applied to horizontal and vertical plates, these patterns are called ‘Lissajous Pattern ’.

Two sinusodial waveforms of same frequency produce a Lissajous pattern, which may be a straight line, a circle or an ellipse depending on the magnitude of voltages.

A straight line results when the two voltages are equal and are either in phase with each other or 180° out of phase with each other. The angle formed with the horizontal is 45° when the magnitudes of voltages are equal . An increase in the vertical deflection voltage causes the line to have an angle greater than 45° with the horizontal. On the other hand a greater horizontal voltages makes the angle less than 45° with the horizontal.

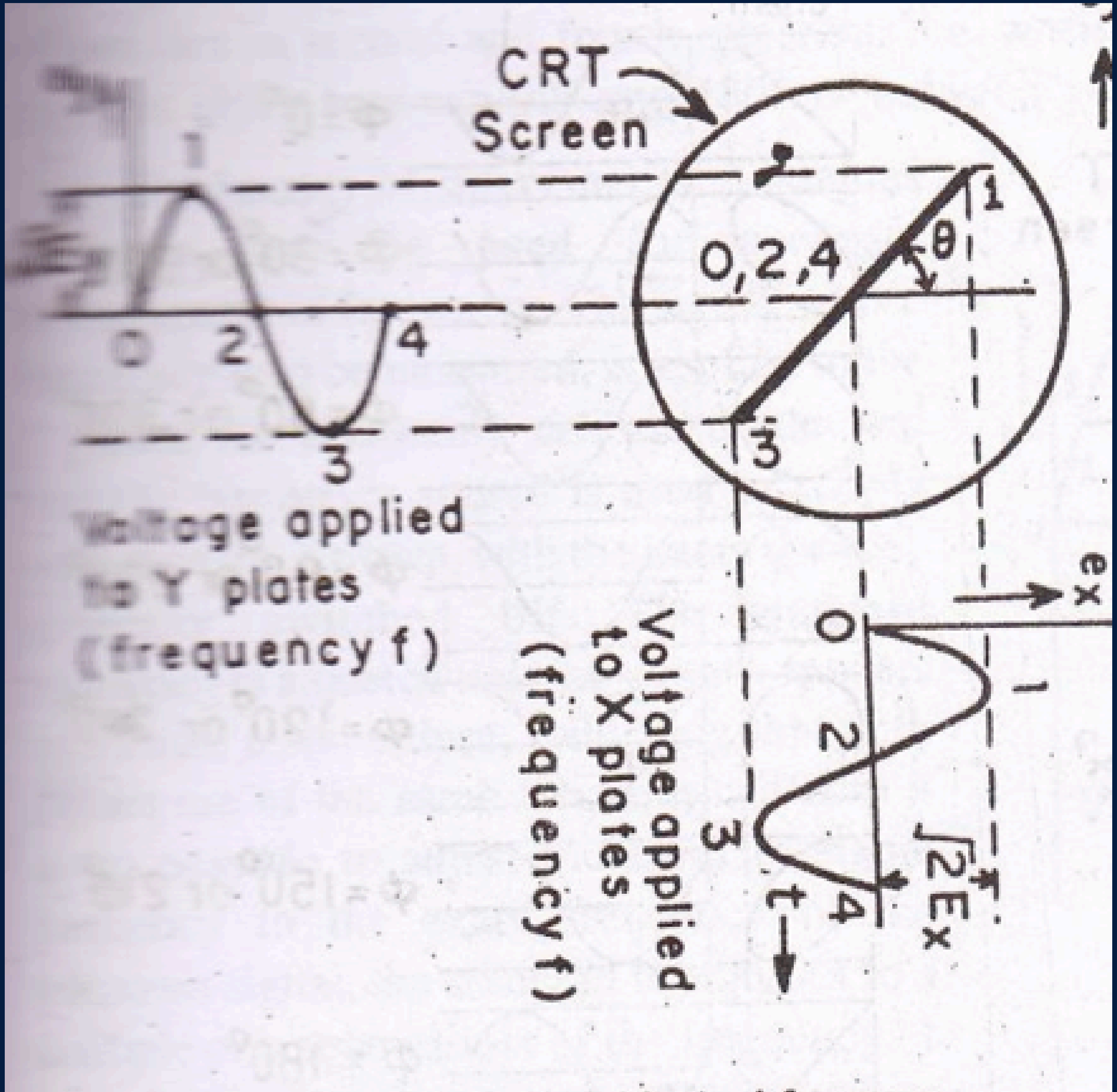
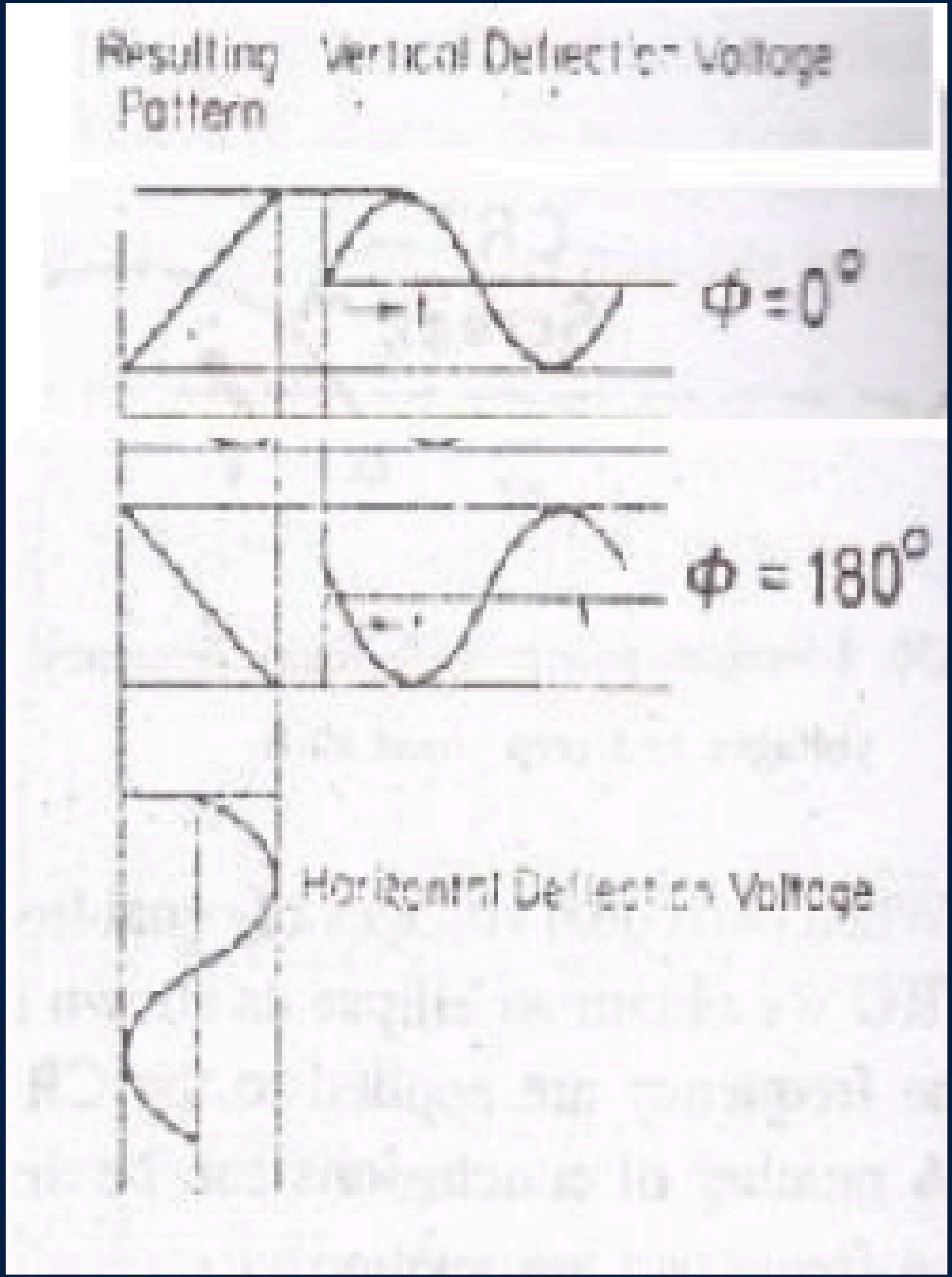


Fig. 21.30. Lissajous pattern with equal frequency voltages and zero phase shift.



A circle can be formed only when the magnitude of the two signal are equal and the phase difference between them either 90° or 270

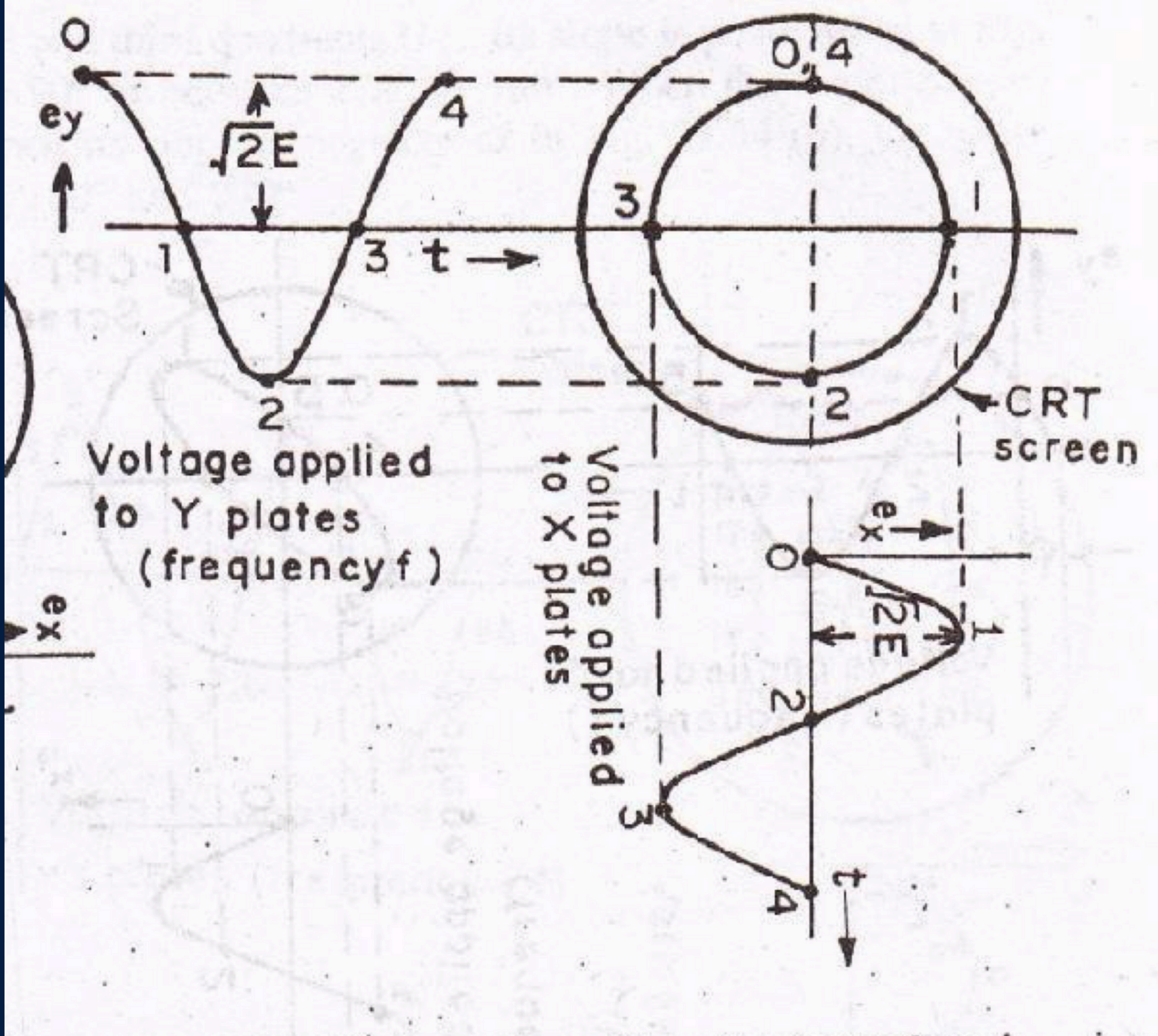
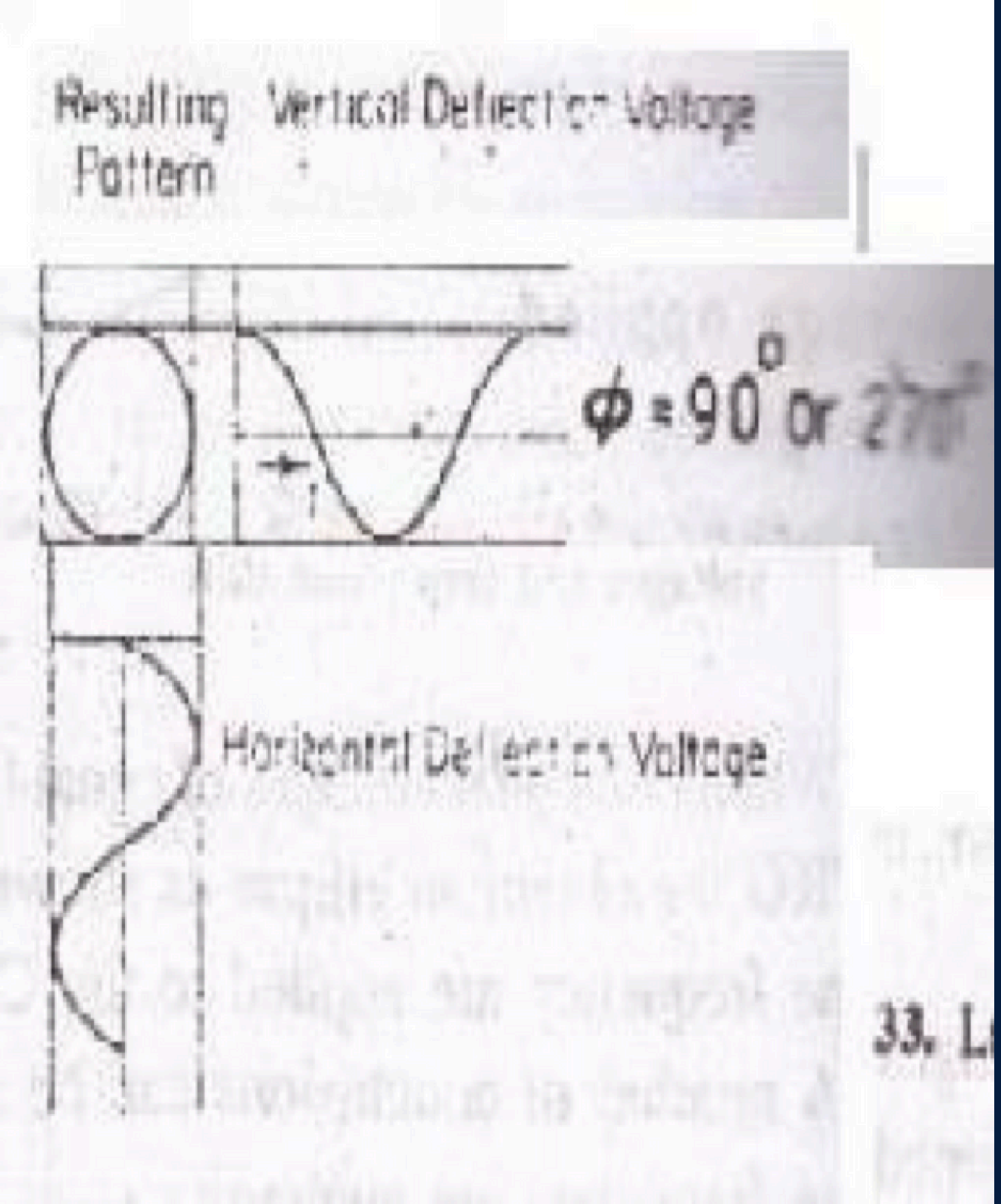


Fig. 21.31. Lissajous pattern with equal voltages of equal frequency and a phase shift of 90°.



When two equal voltage is of equal frequency but with a phase shift φ (not equal 0 ° or 90° or 270 °) are applied to a CRO we obtain an ellipse as shown in fig. An ellipse also obtained when unequal voltages of same frequency are applied to CRO.

If the Y voltages is larger , an ellipse with vertical major axis is formed, while if the plate X plate voltages has a greater magnitude, the major axis of the ellipse lies along horizontal axis.

WEEK 13/14 CLASS 2

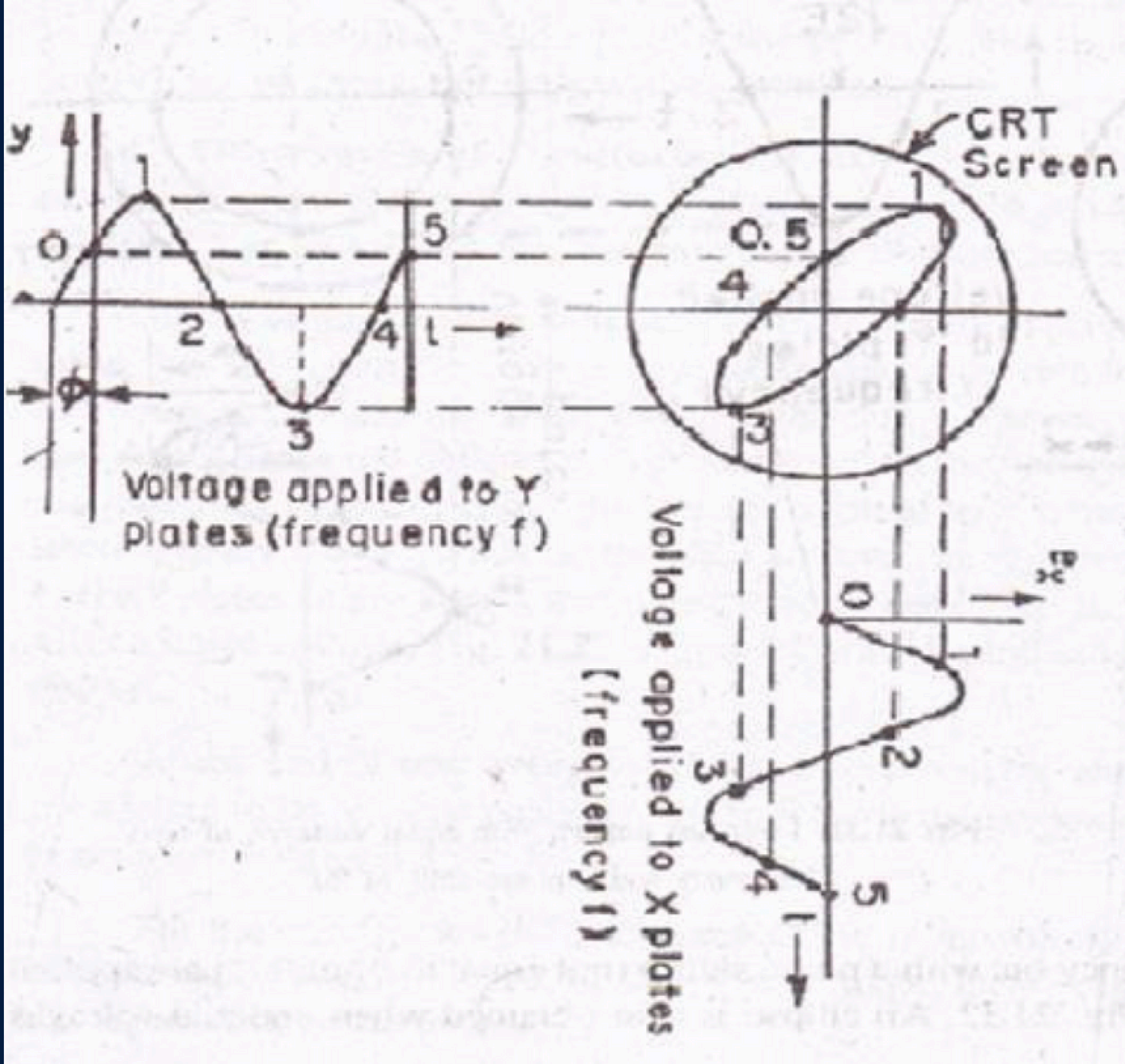


Fig. 21.32. Lissajous pattern with two equal voltages of same frequency and phase shift of φ.

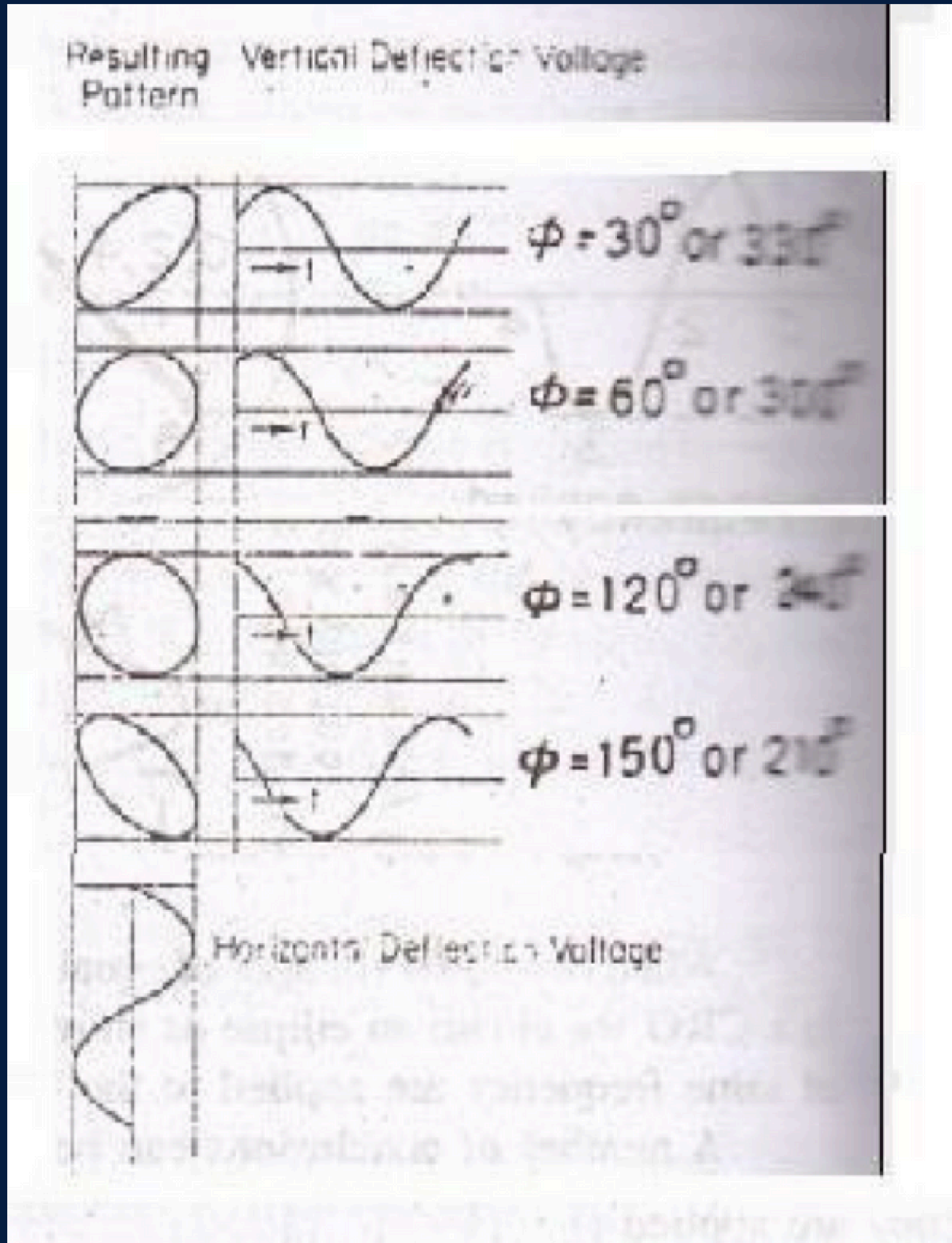


Fig. 21.33. Lissajous patterns with different phase shifts

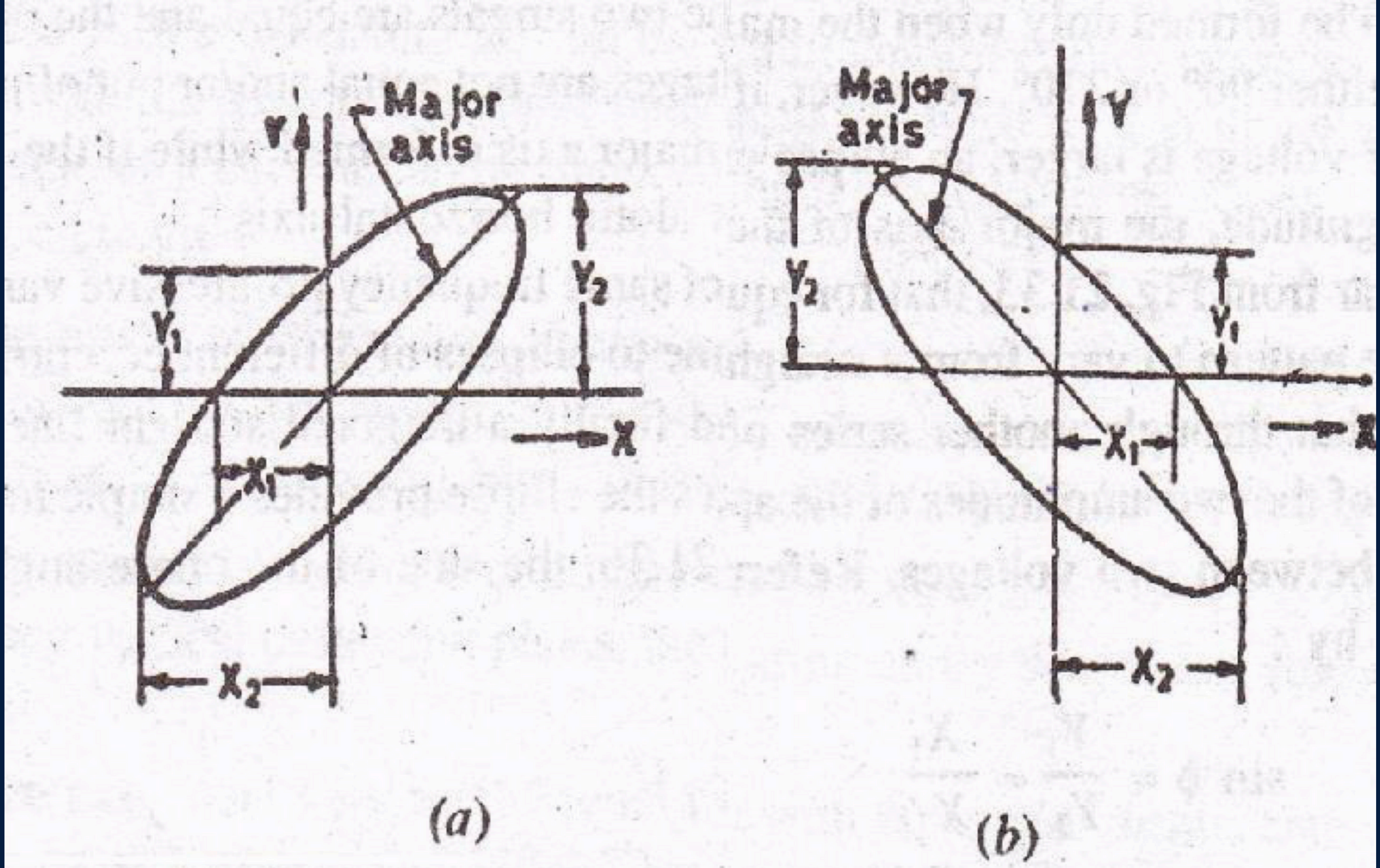


Fig. 21.34. Determination of angle of phase shift.

Regardless of the two amplitudes of the applied voltages the ellipse provides a simple means of finding the phase difference between two voltages. Refering to the figurethe sine of the phase angle between the voltages is given by:

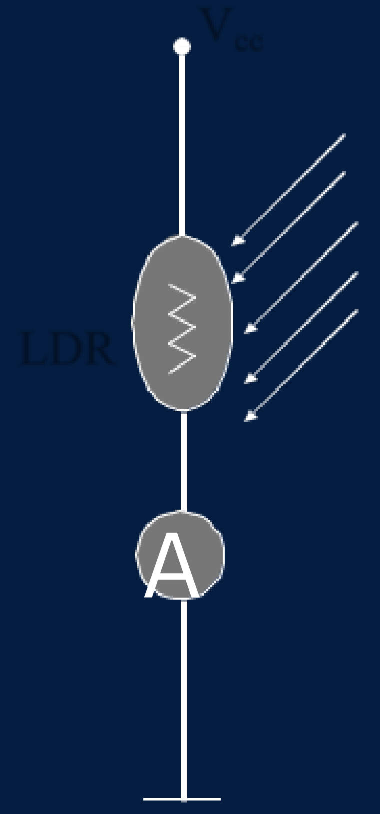
$$sin\varphi = \frac{Y1}{Y2} = \frac{X1}{X2}$$

If the major axis of the ellipse lies in the first and third quardants (i.e it's slope is positive) as shown in figure (a), the phase angle is either between 0° to 90° or between 270° to 360°. When the major axis of ellipse lies in second and fourth quardants i.e when its slope is negative as in fig (b) the phase angle is either between 90° and 180° or between 180° to 270°

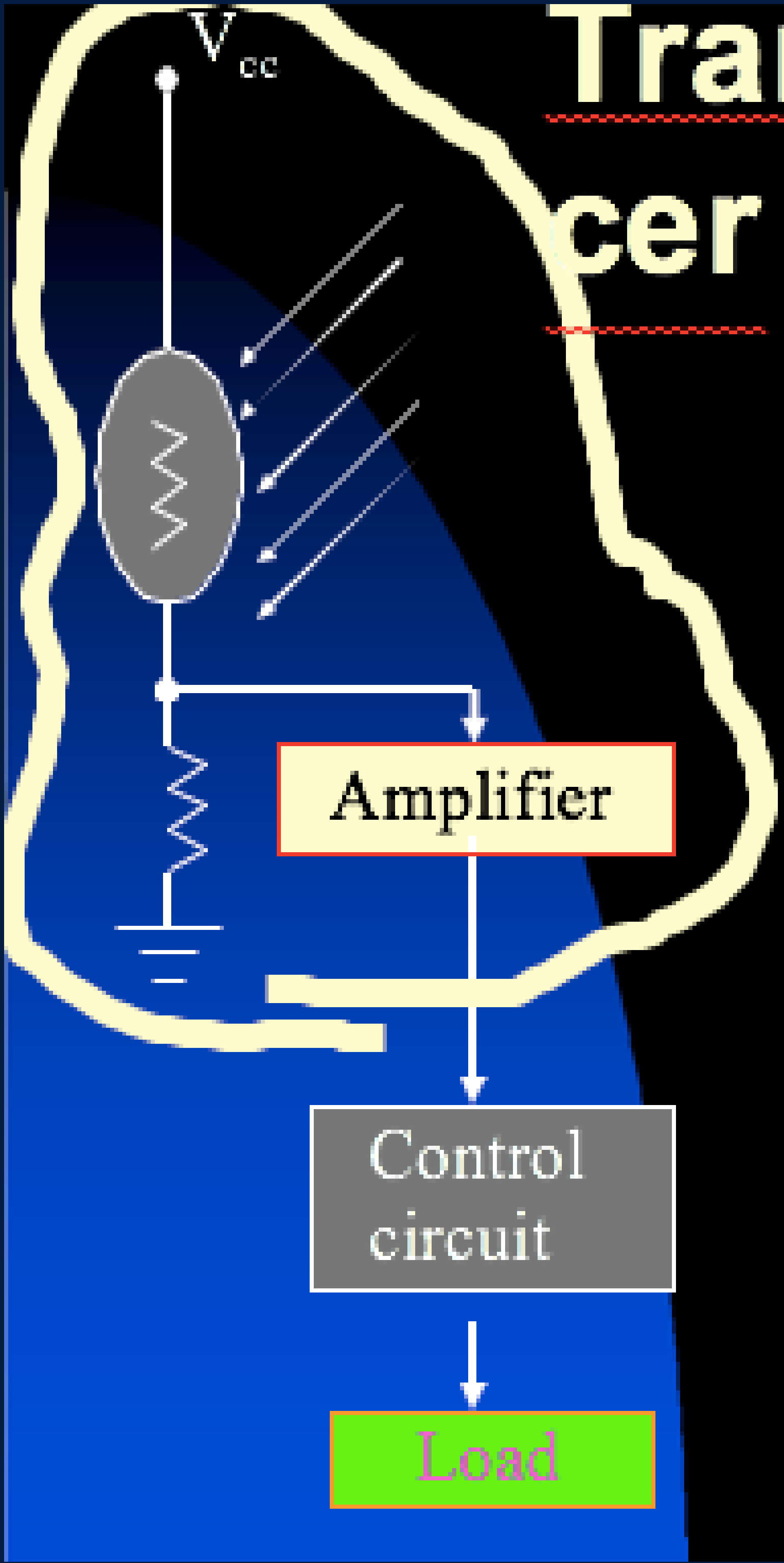
Measurement of non electrical quantities

Sensor: It is a device used to generate an equivalent electrical signal, either in the form of voltage or current, if a non- electrical physical quantity is applied to it.

Example : A light dependentResistor or LDR is a sensor in which the resistance changes if the intensity of light is changed. If the LDR is connected with a voltage source, the current will also change. The change of current will be in accordance with the change of light intensity.



Transducer



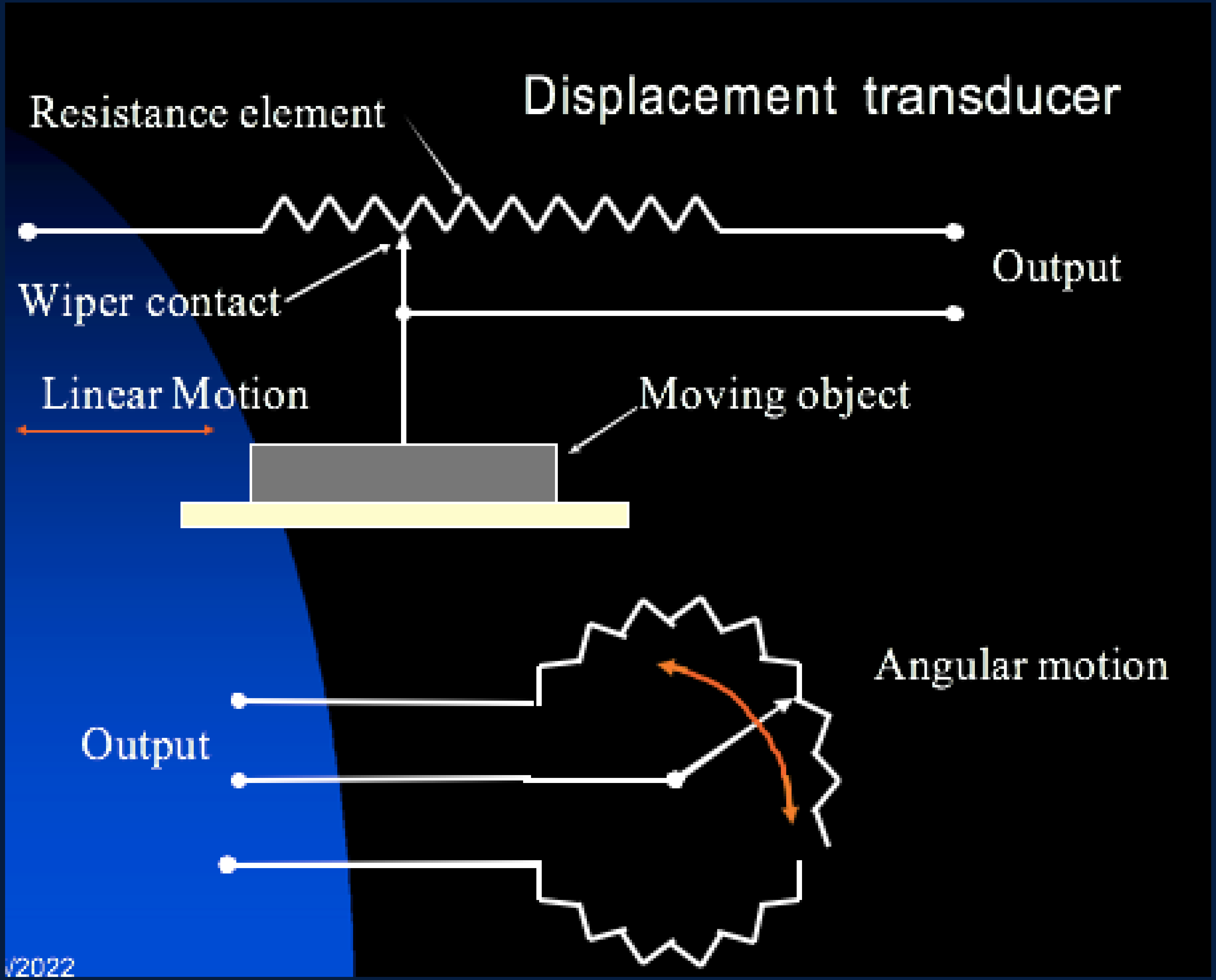
Usually the electrical signal extracted by a sensor is too weak to be used further. In such cases an amplifier is used at the first step, to make the signal strong, so that it can be now connected to other circuit. A **transducer** is a device which include a sensor and other circuits if necessary, to produce a suitable electrical signal, which can be connected directly to other circuits, for control or further processing.

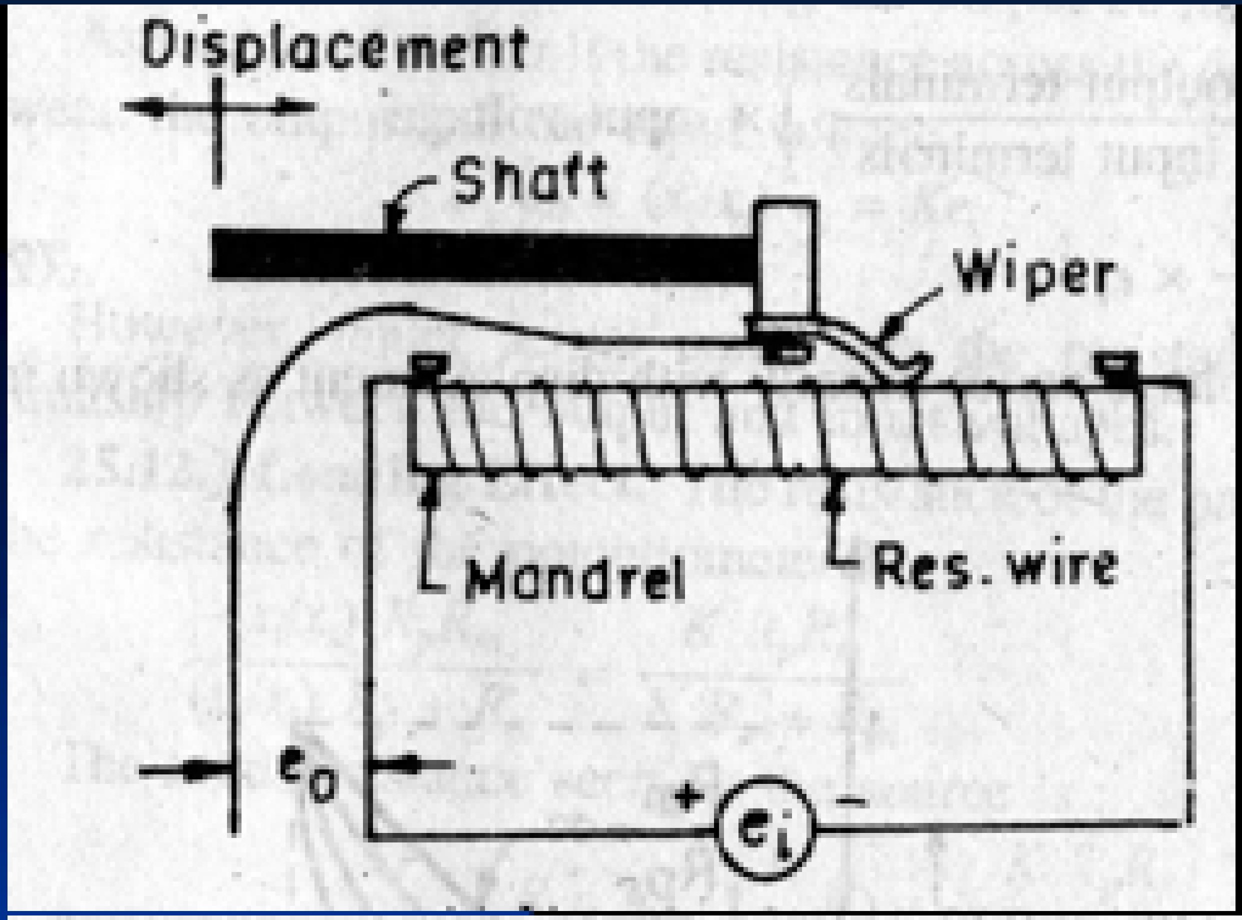
In In the broadest sense, a transducer is any device that receives energy from one system and retransmits it, usually in another form, to a system. The word sensor is more restrictive, it refers to that part of a transducer that responds to the quantity being measured.

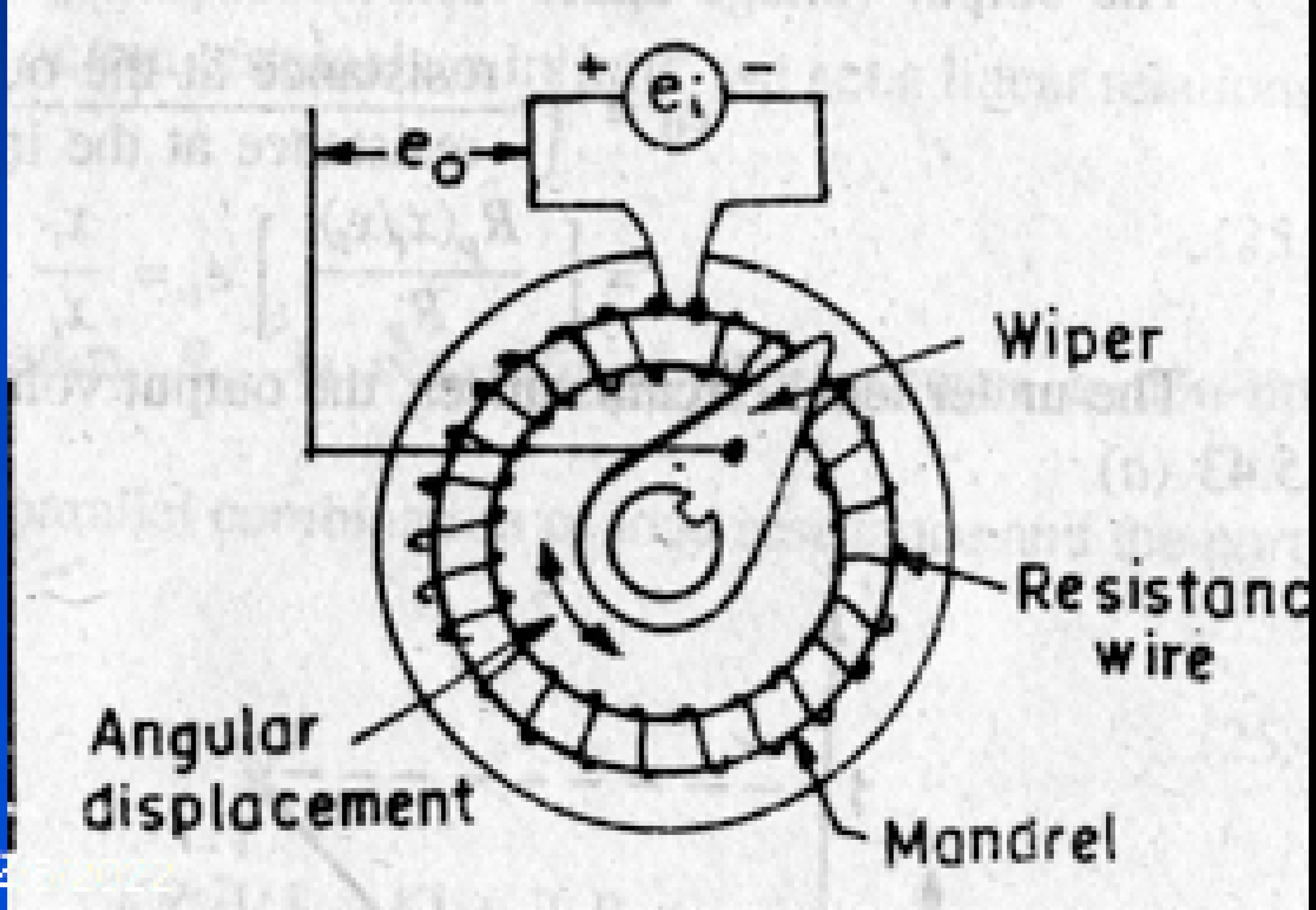
Major non-electrical quantities

-Position and displacement
-Rotation
-Pressure
-Temperature
-Lightintensity
-FluidFlow

WEEK 15/16 CLASS 4


Displacement transducer
Resistance element
Output
Wiper contact
Linear Motion
Moving object
Angular motion
Output
/2022



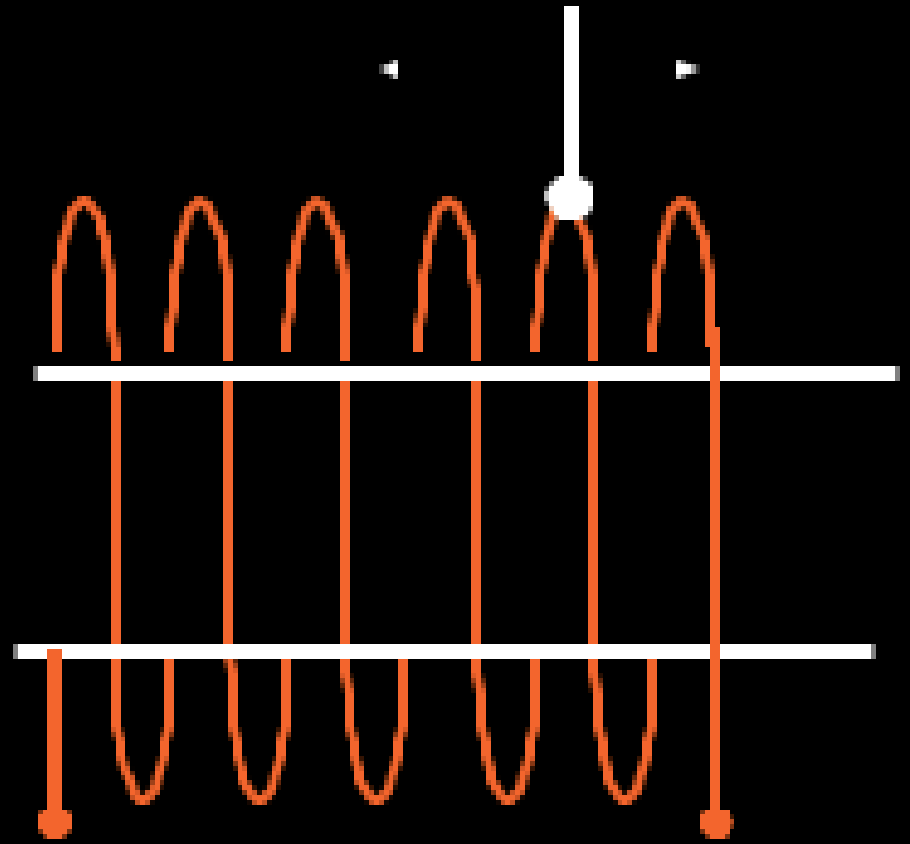


Total resistance = 1000 ohm

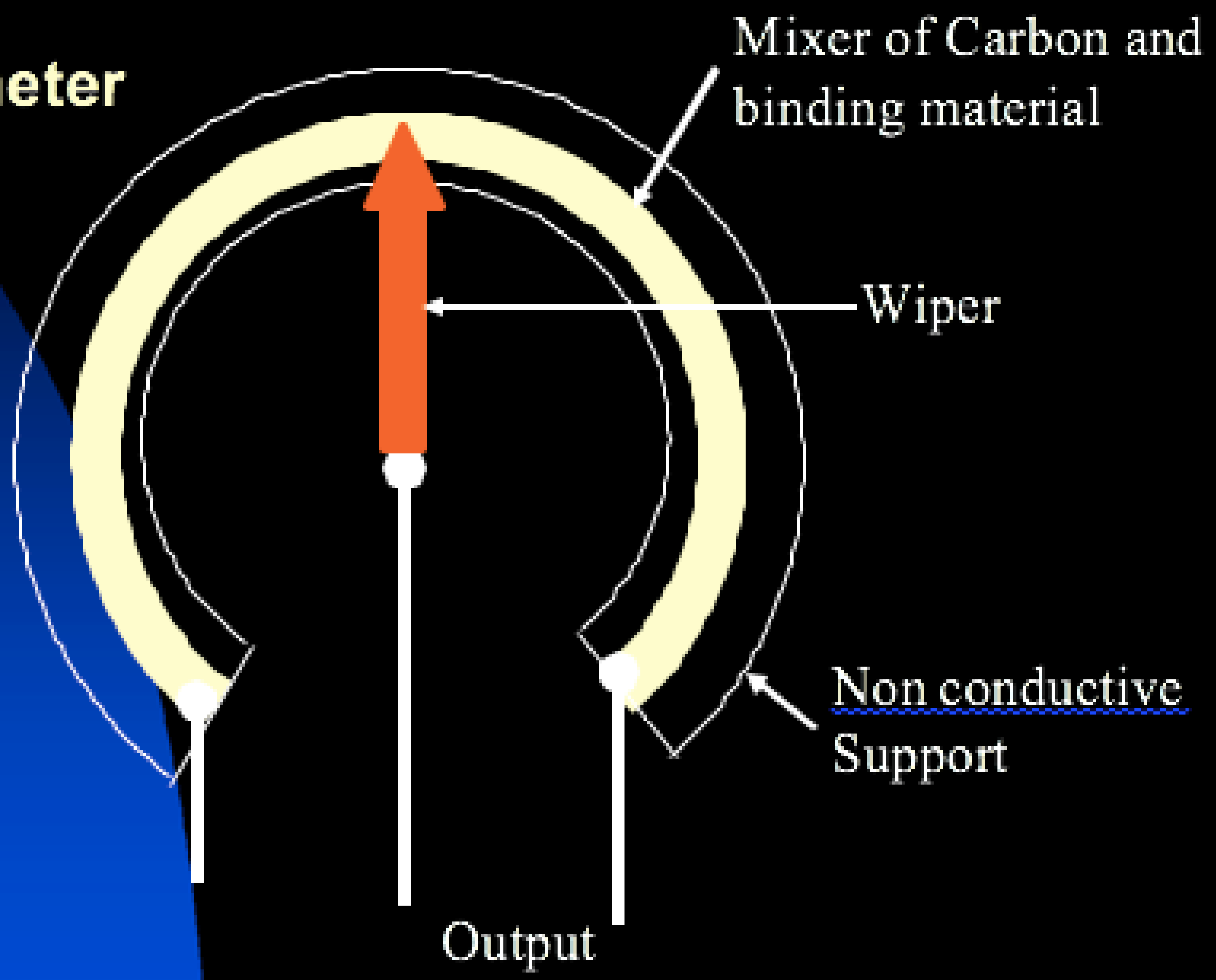
No. of turns = 100

Resistance per turn = 10 ohm

Therefore resolution = 10 ohm



Construction of Non wire potentiometer



Merits and Demerits of Potentiometer transducer

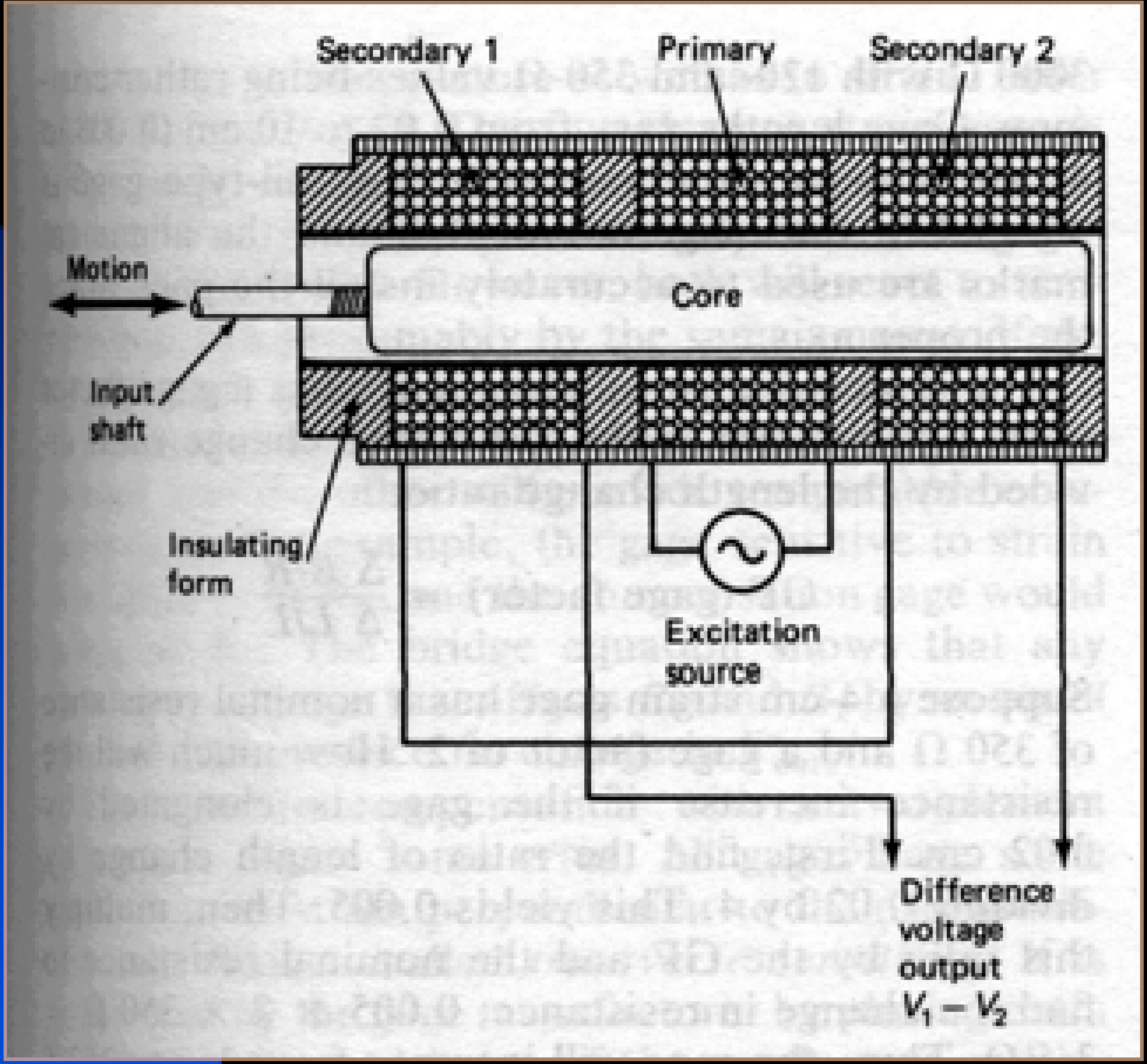
Merits :

1. Inexpensive.
2. Simple operation
3. Useful for large displacement
4. Strong output signal

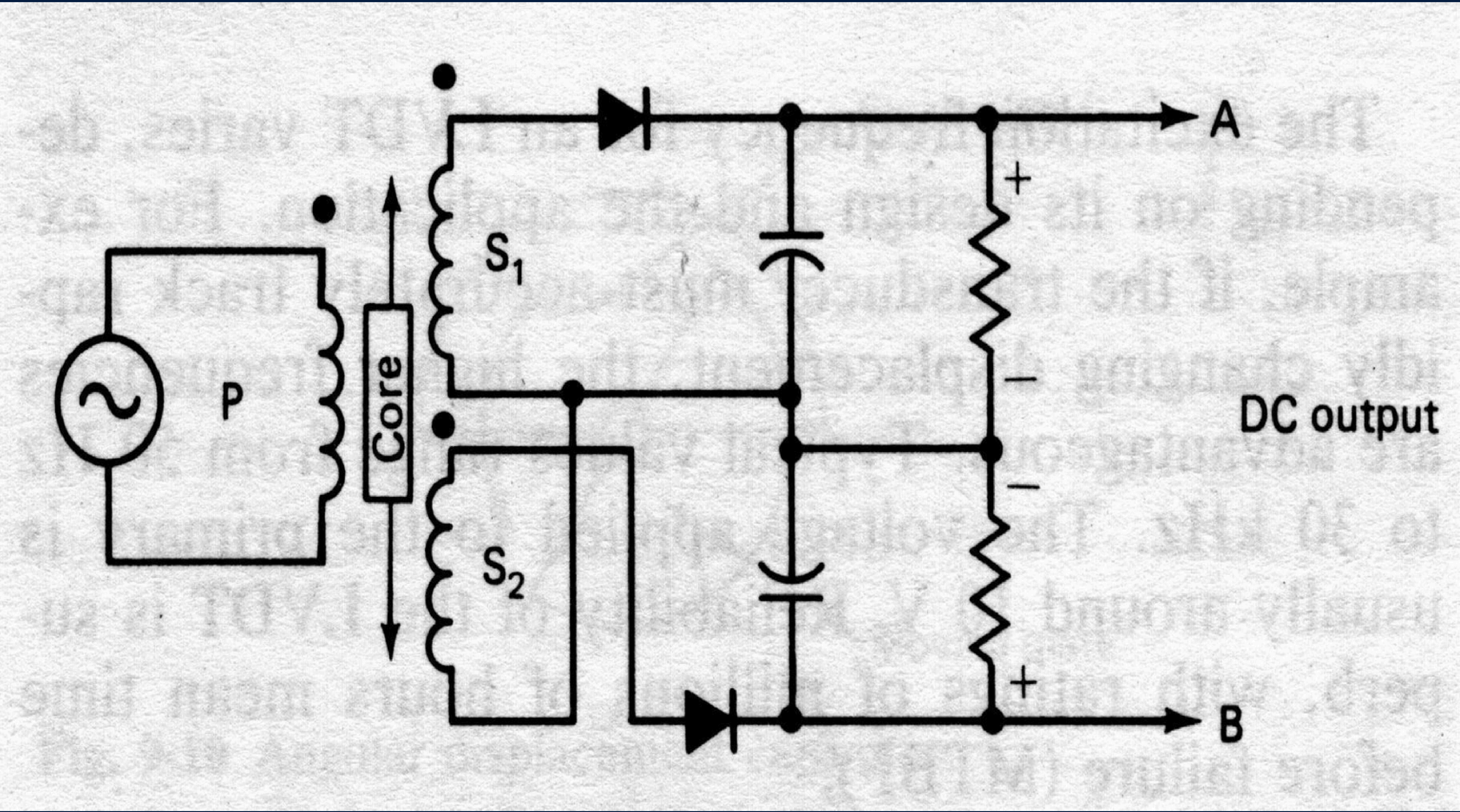
Demerits :

1. Large force is required.
2. Contamination
3. Non linearity
4. Low resolution
5. Wear and tear
6. Noise

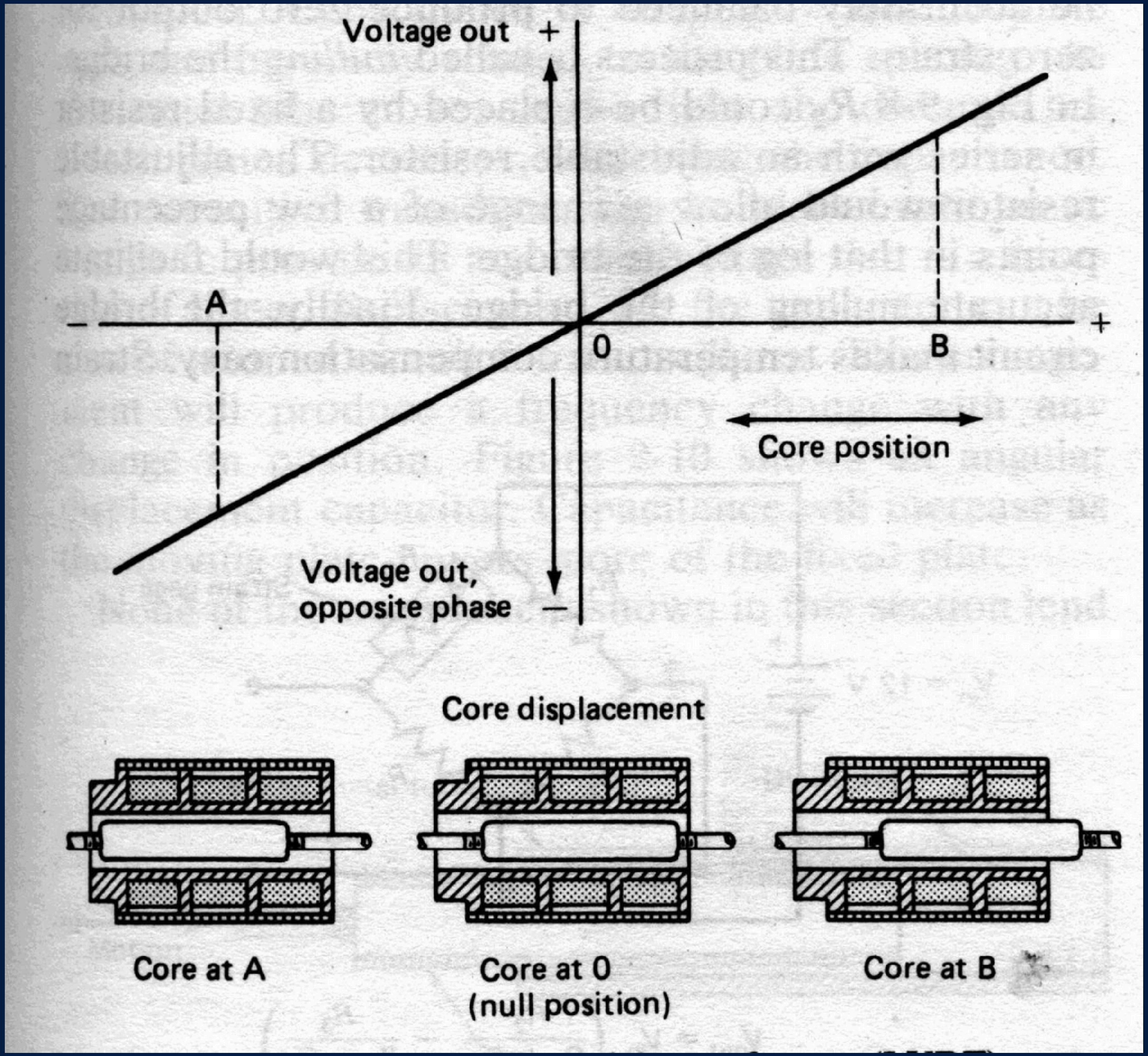
Linear variable differential transfo



Dc output from LVDT



Voltage output



Merits of LVDT:

- Sensitive to vibration
- Essentially linear
- High resolution
- No wear and tear
- Less aging effect

Very small displacement

Strain gaug

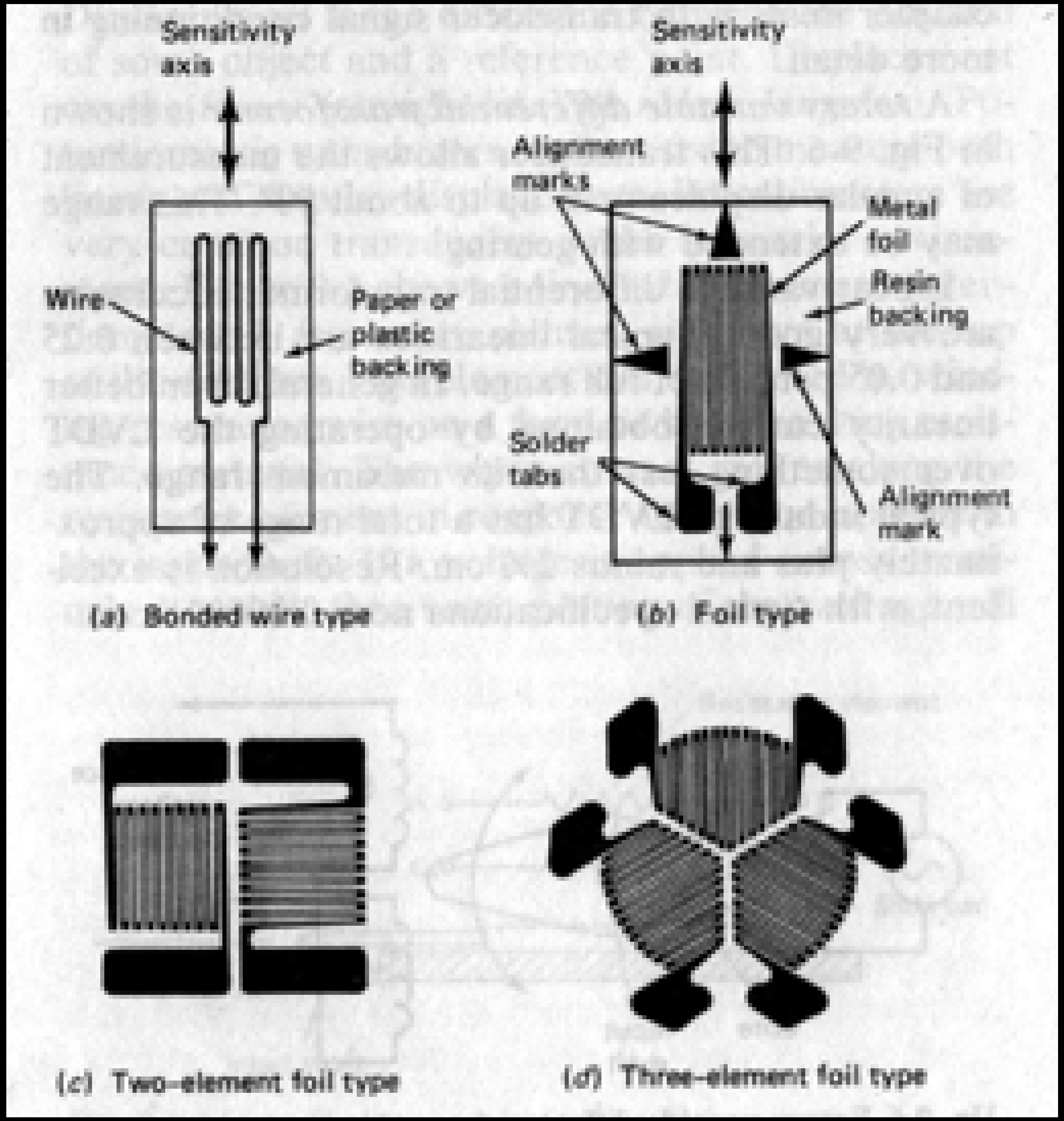
Resistance

Length

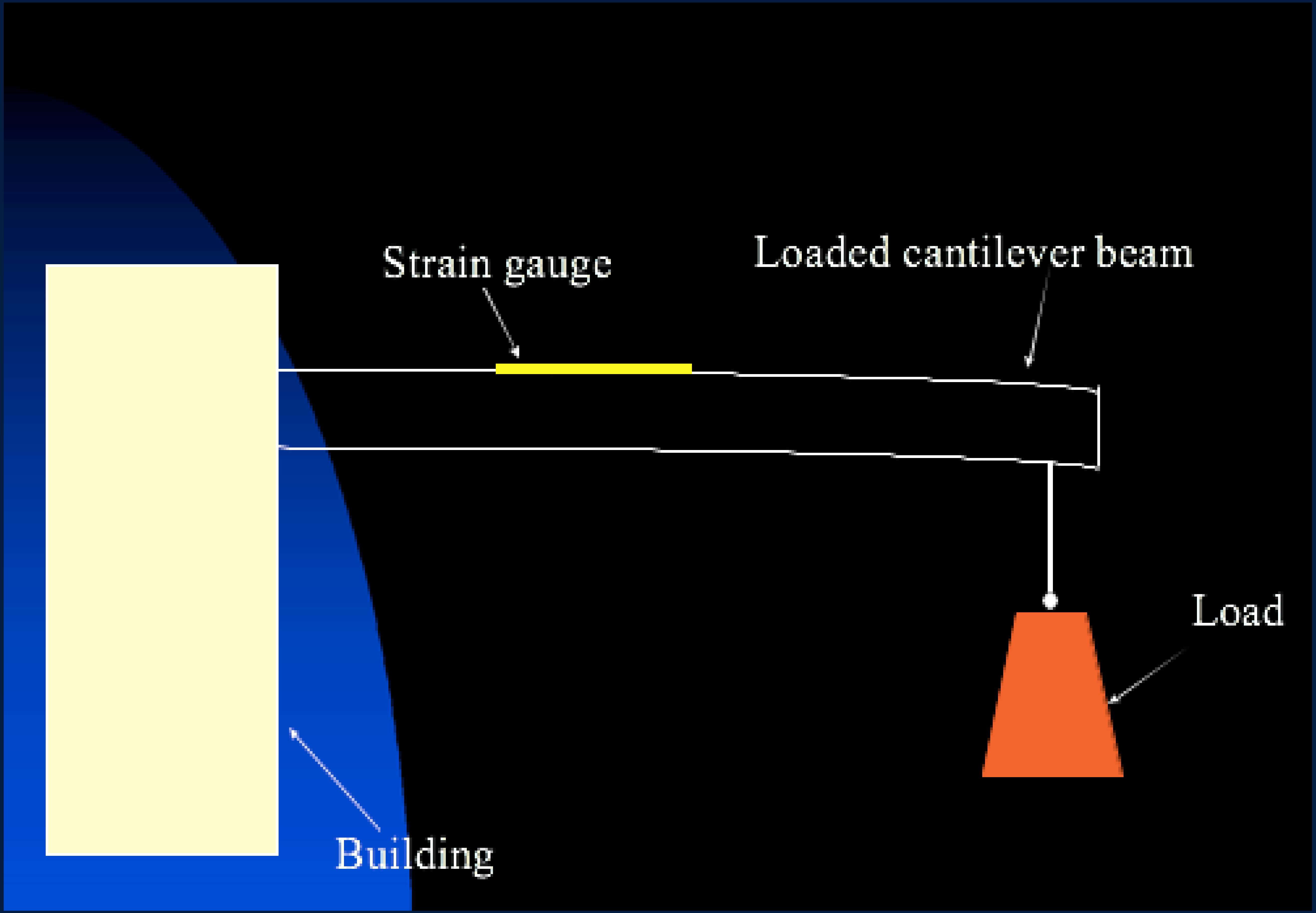
$$R = \rho L / A$$

Resistivity

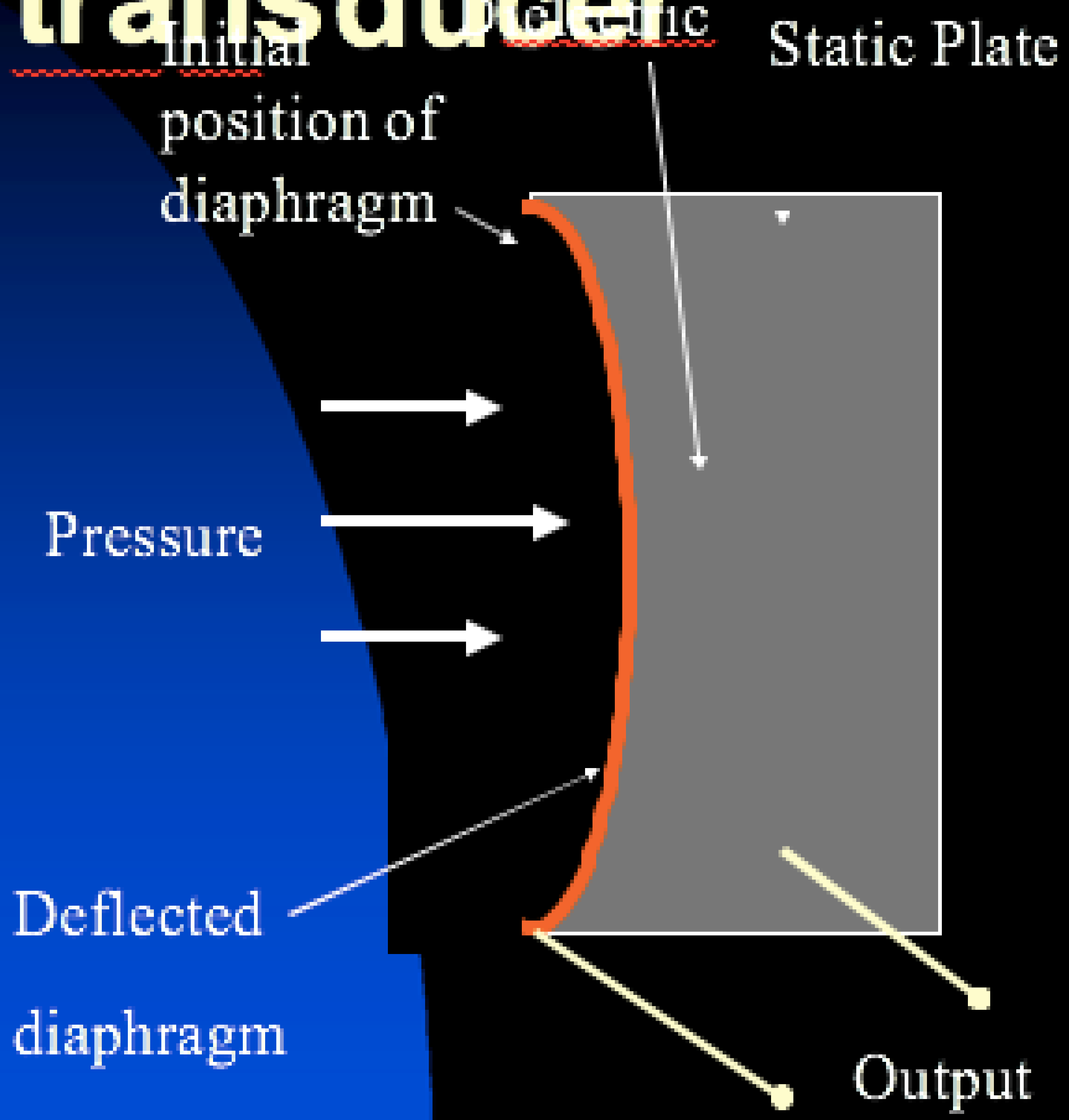
Area of cross section



Nichrome, Constantan , Nickel, Platinum etc.


Strain gauge
Loaded cantilever beam
Load
Building

Capacitive transducer



Capacitance,

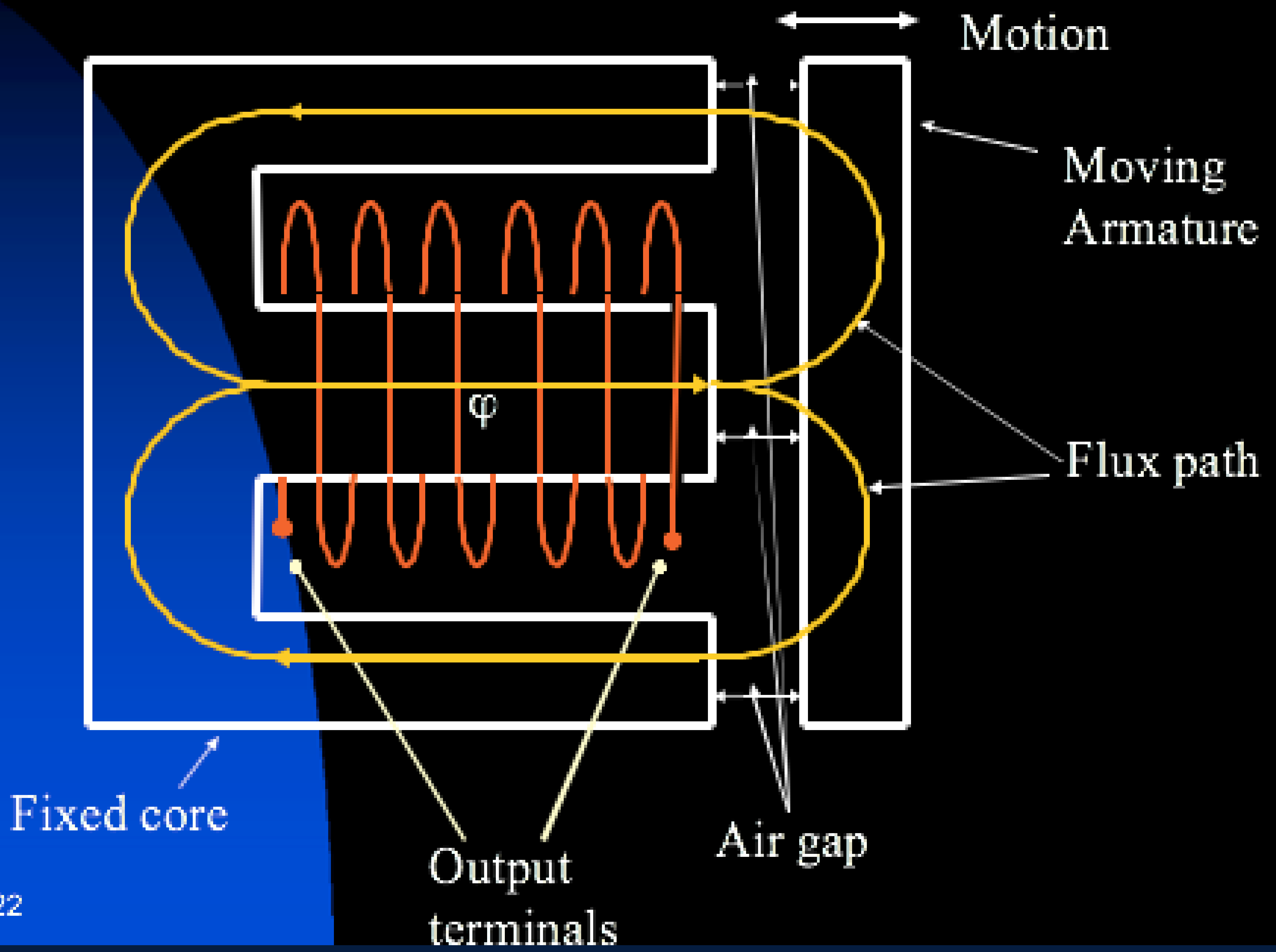
C = k .A / d

Where k is a constant

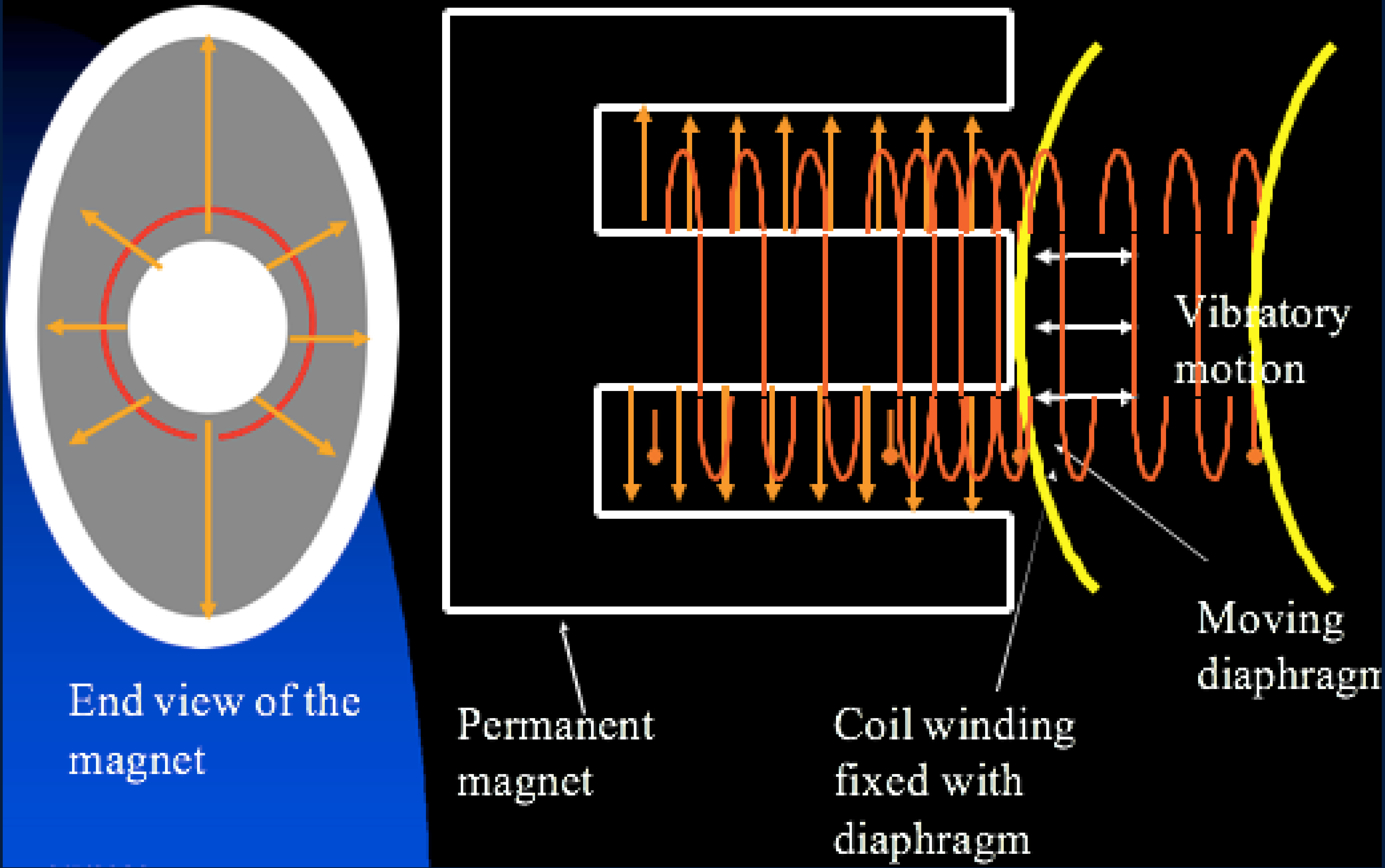
A is plate area

D is plate spacing

Inductive transducer

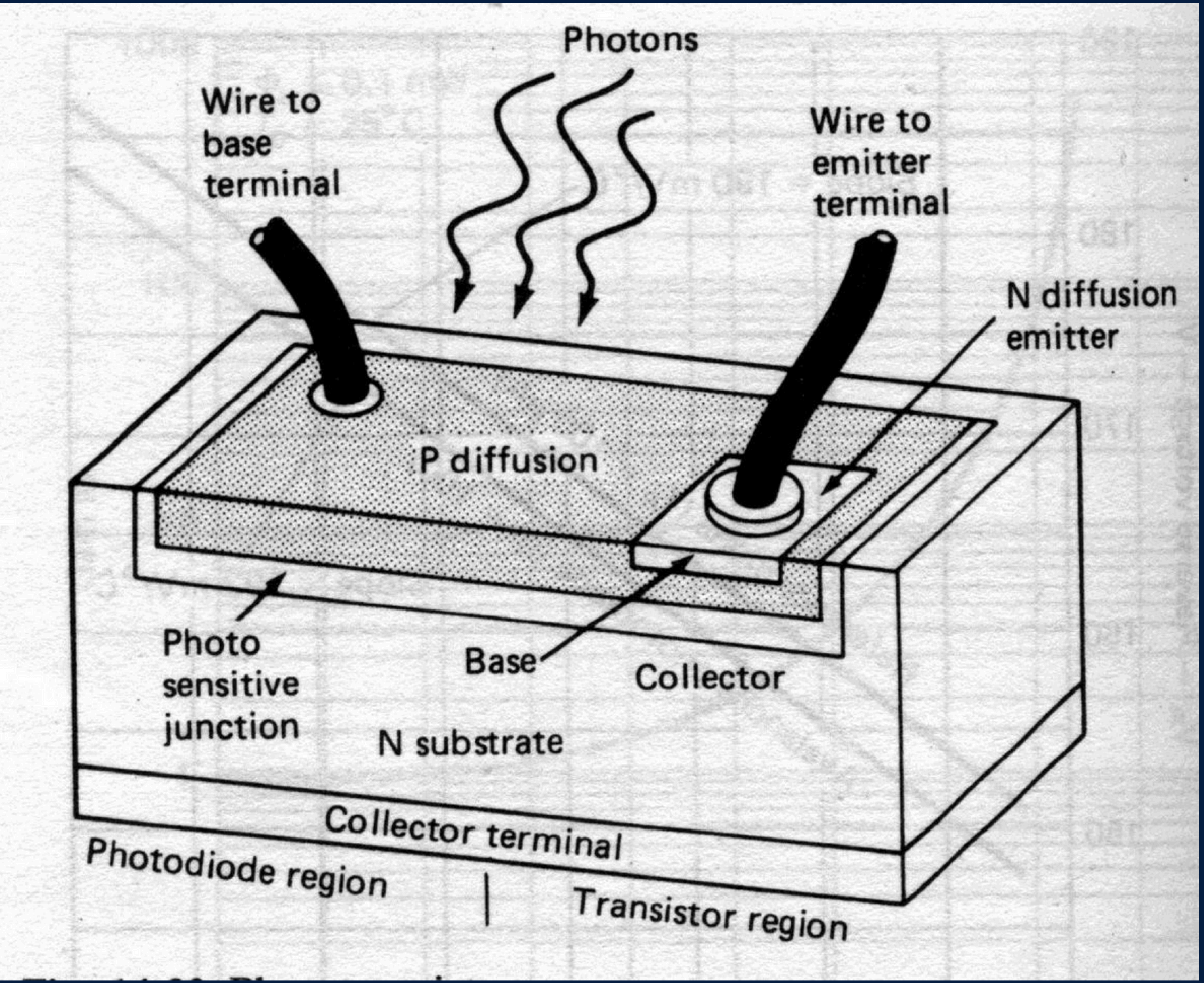


Speaker as inverted transducer

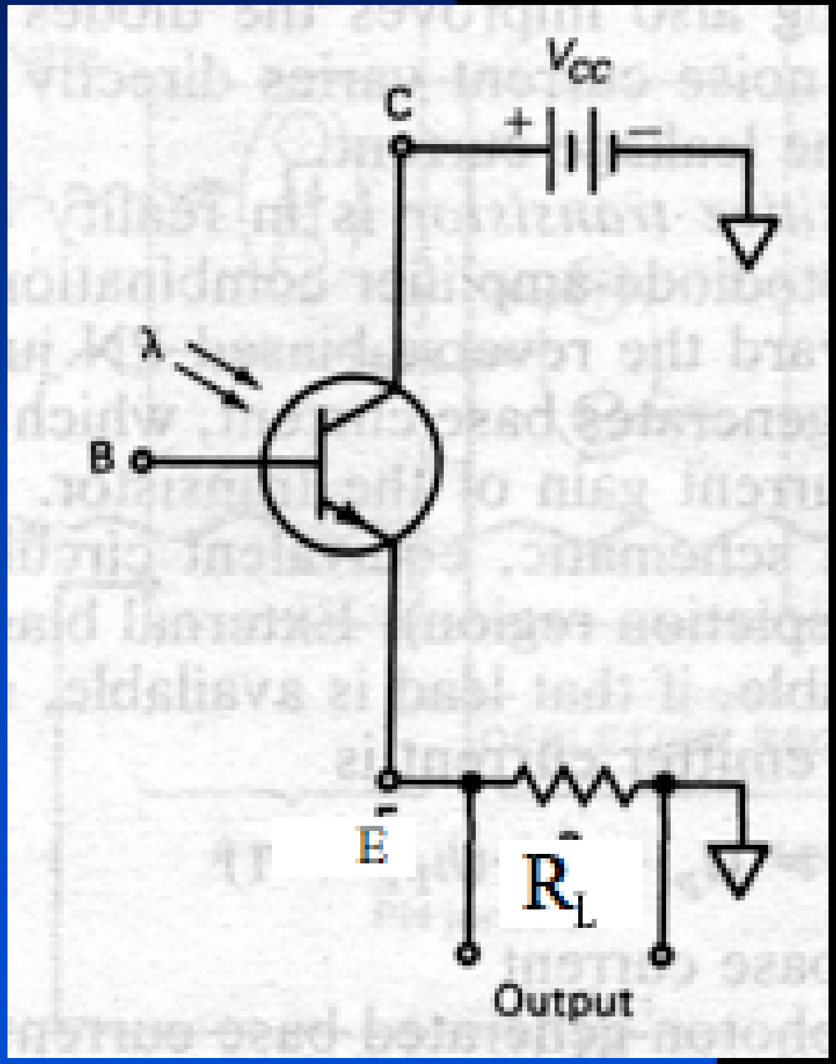


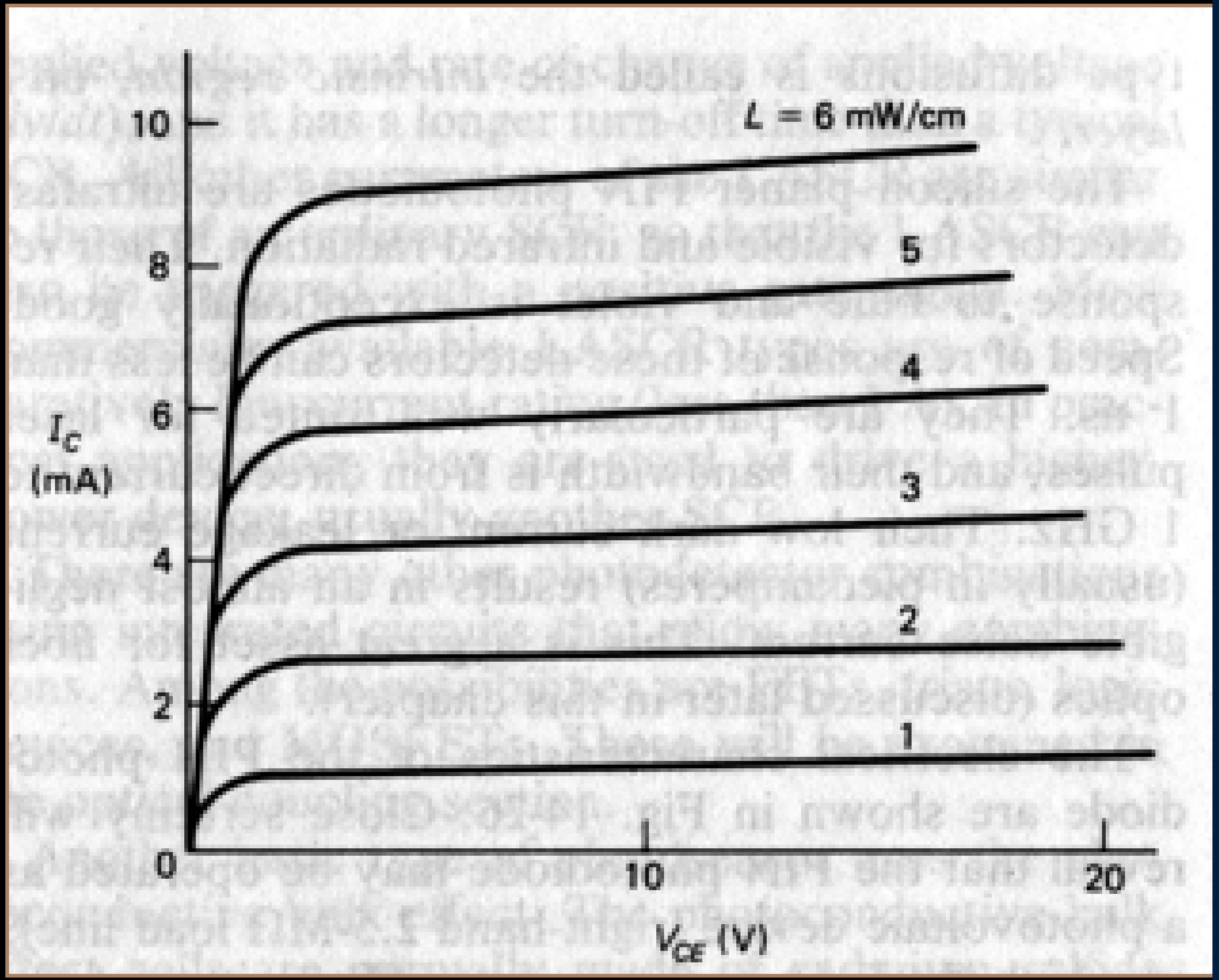
WEEK 17/18
CLASS 4

Semiconductor photosensitive devices Phototransistor



Phototransistor transducer

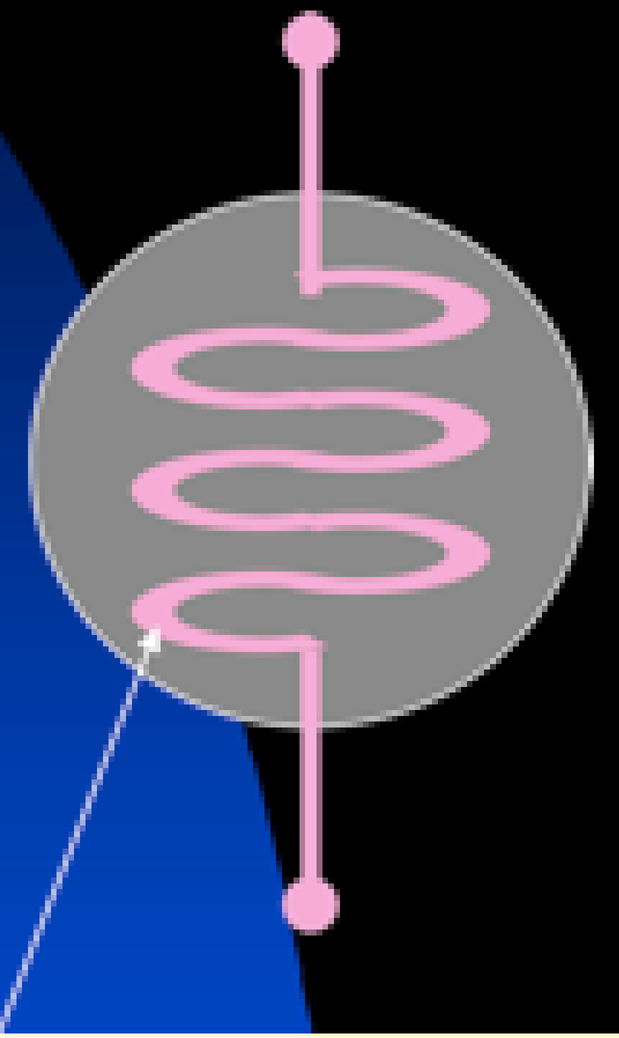




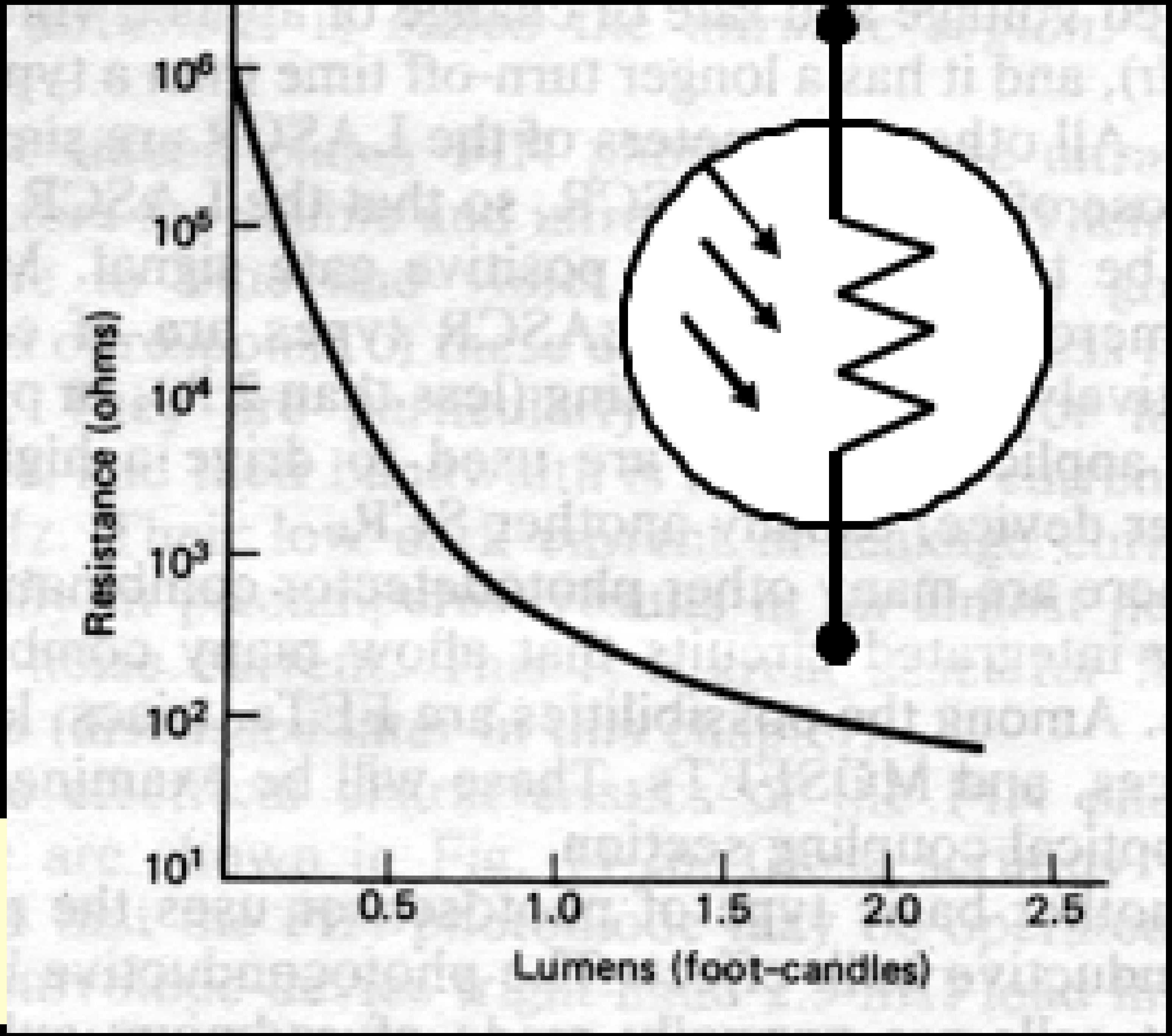
Volt-Amp characteristics of phototransistor

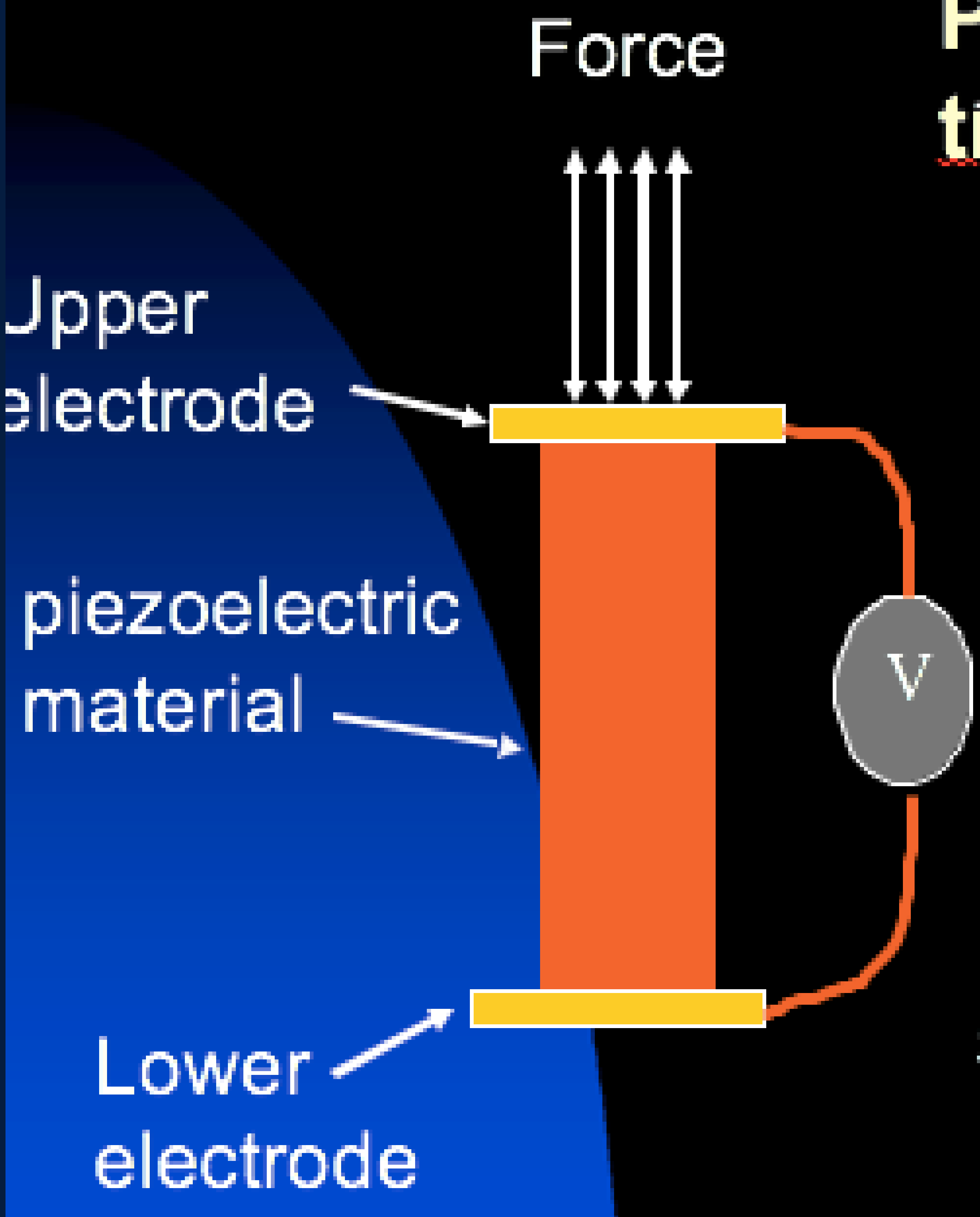
Photoconductive cell

It is also known as Light sensitive resistor (LDR)



Cadmium sulfide or Cadmium selenide





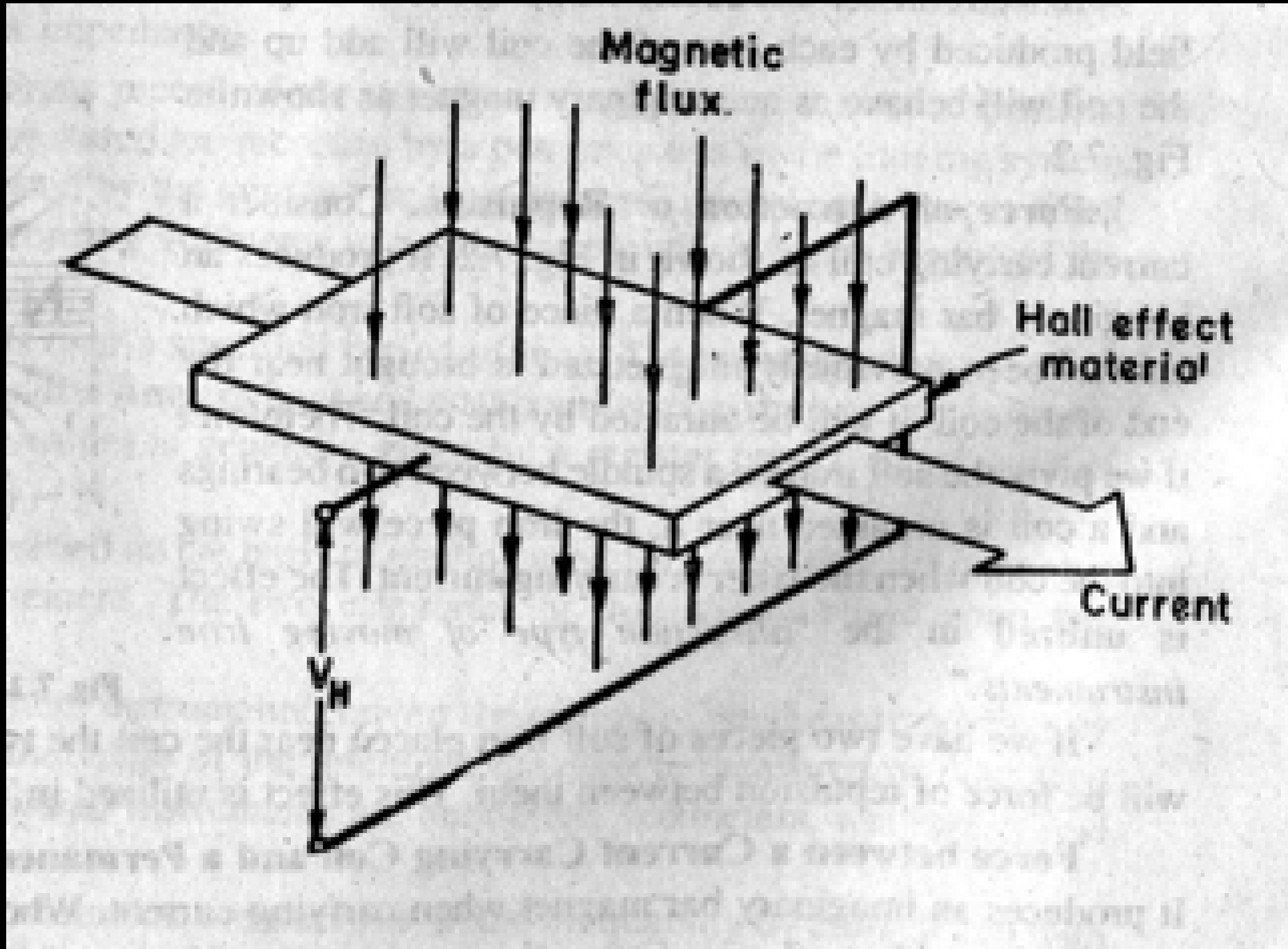
Piezoelectric transducer

There are some special type of materials in which an electric potential appears across certain surfaces of some crystals if the dimensions of the crystal are changed by application of an oscillatory mechanical force. The effect is reversible, that is, if a varying potential is applied, the dimension will change. The effect known as piezoelectric effect.

Some piezoelectric materials are, Rochelle salt, lithium sulphate, dipotassium tartarate etc.

Hall effect

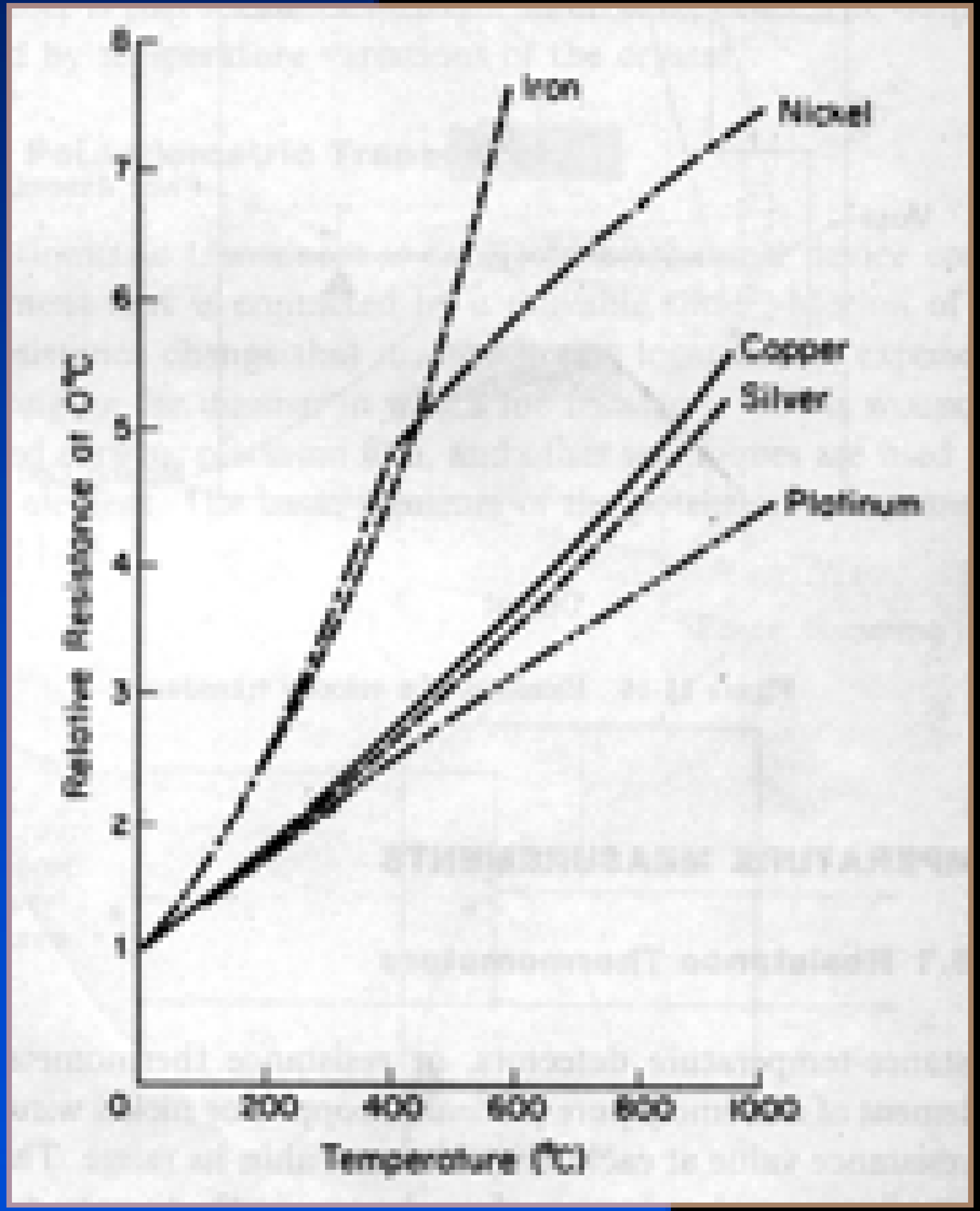
If a strip of conductive material carries current in the presence of a transverse magnetic field, an emf is produced between two edges of the conductor. The effect is known as Hall effect. The magnitude of the voltage developed depends on the current, flux density and a property of the material called Hall effect co-efficient.



2/5/2022

Temperature sensing transducer

Resistance Temperature detector (RTD)



Resistance at t° C

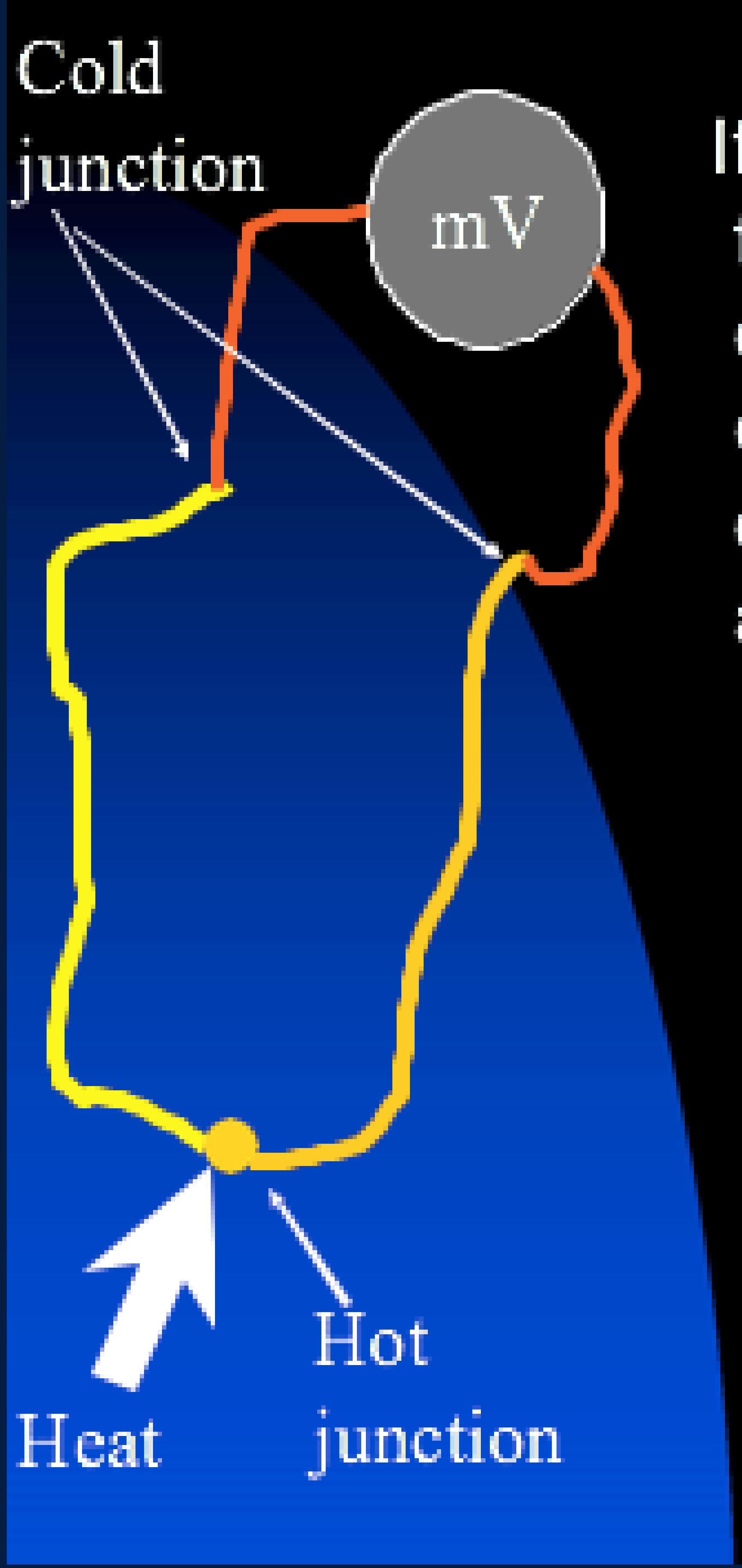
Temperature co-efficient

$$R_t = R_{ref} (1+ \alpha.\Delta t)$$

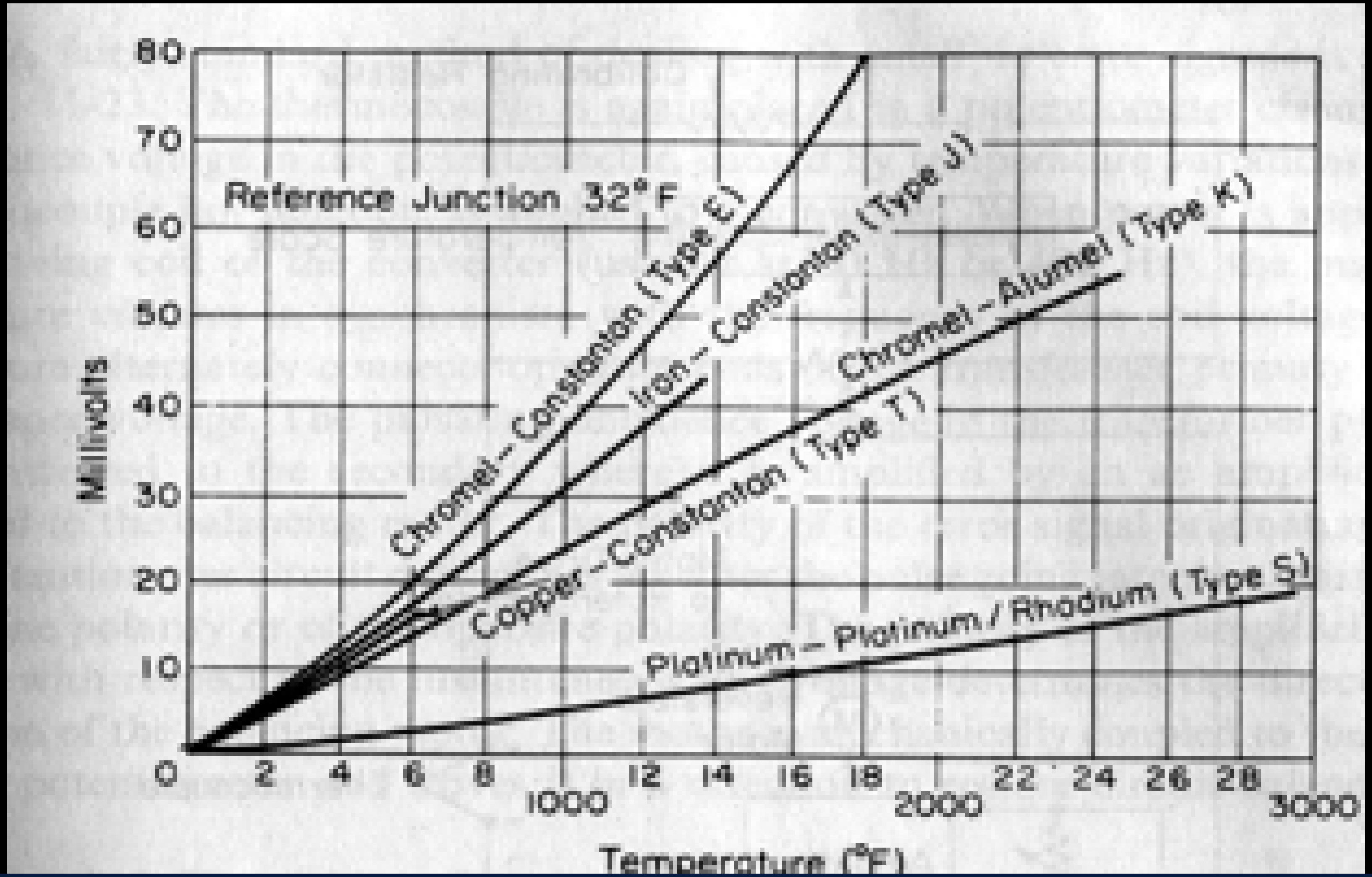
Resistance at reference temperature

Difference between operating and reference temperature

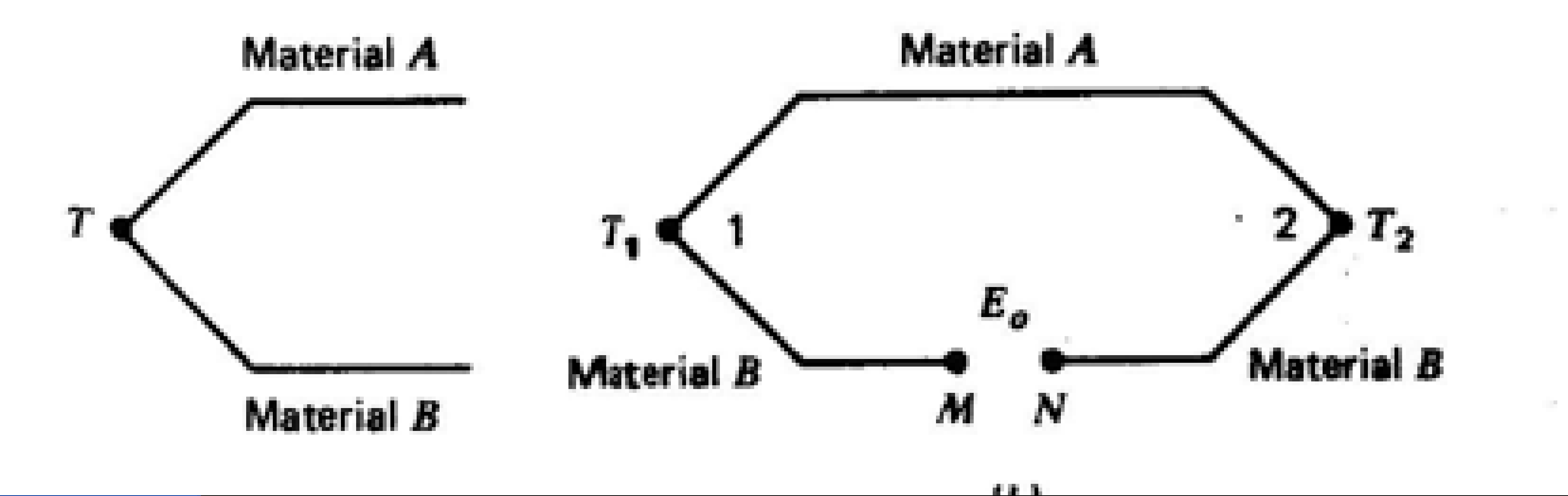
Thermocouple



If a pair of dissimilar metal wires joined together and subjected to heat, a potential different is observed between the cold ends. The voltage thus produced is dependent on the property of the materials and the temperature difference.



THERMOCOUPLE



$$E_o = C_1(T_1 - T_2) + C_2(T_1^2 - T_2^2)$$

C_1 and C_2 are thermoelectric constants that depend on the mater
used to form the junctions.

T_1 and T_2 are junction temperatures.

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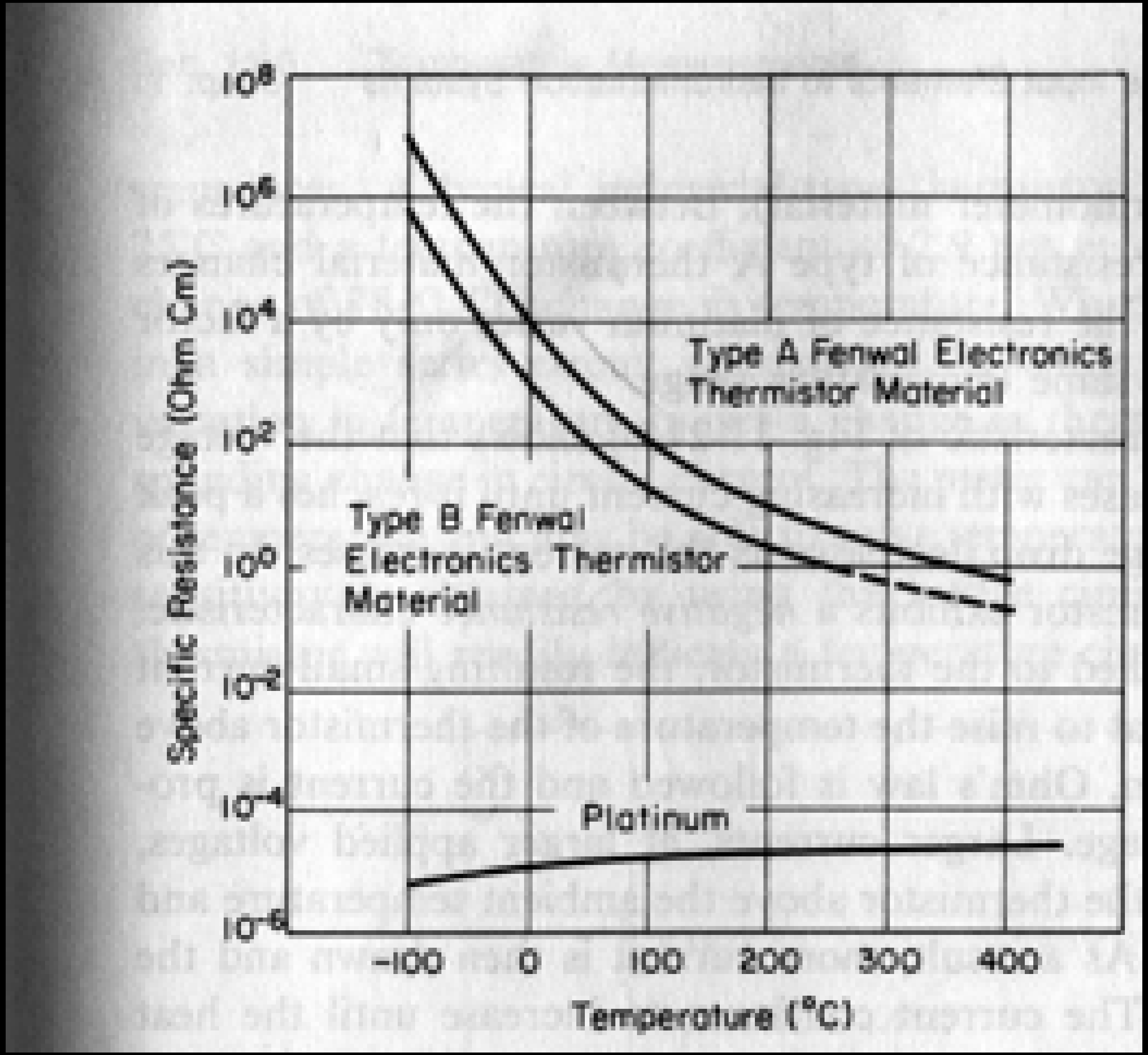
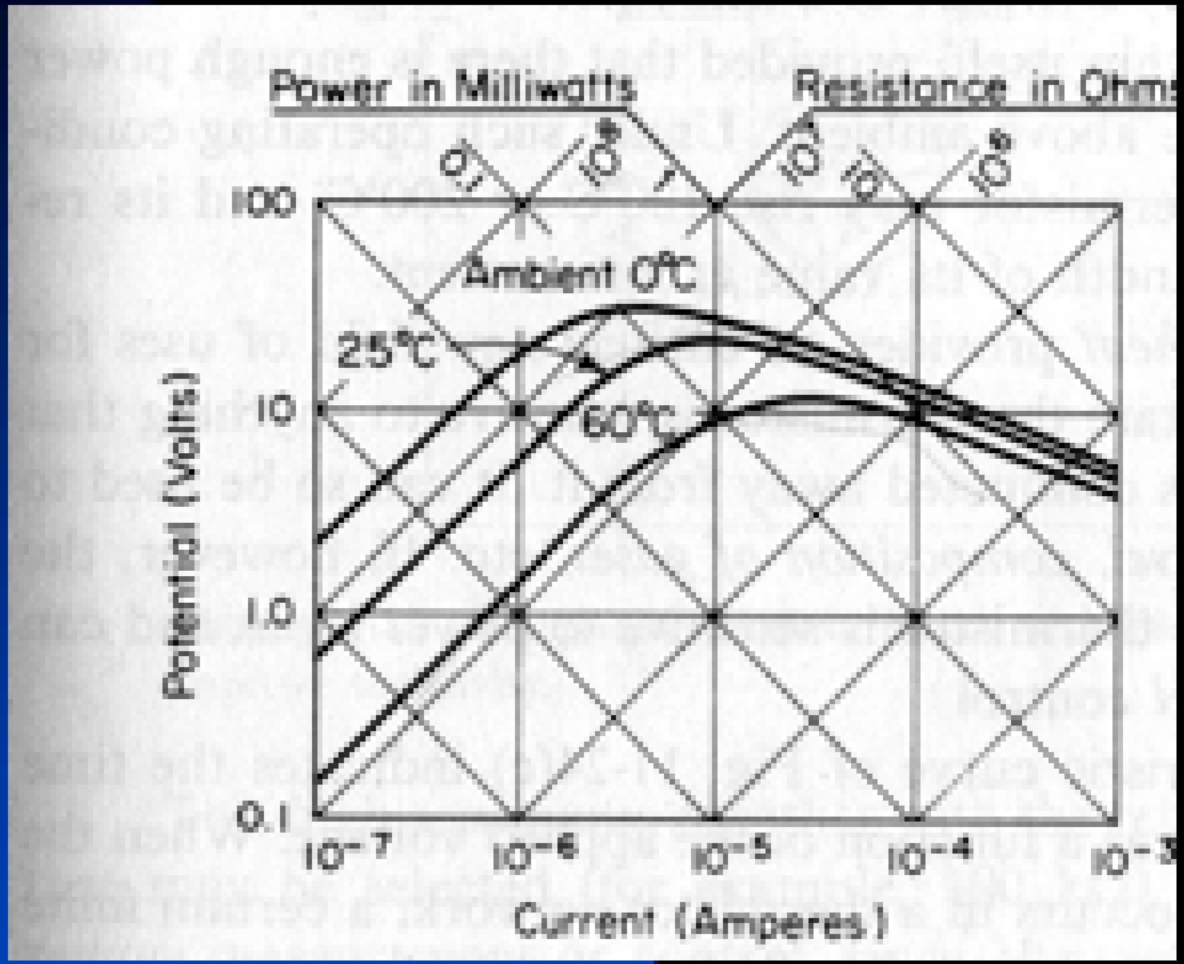
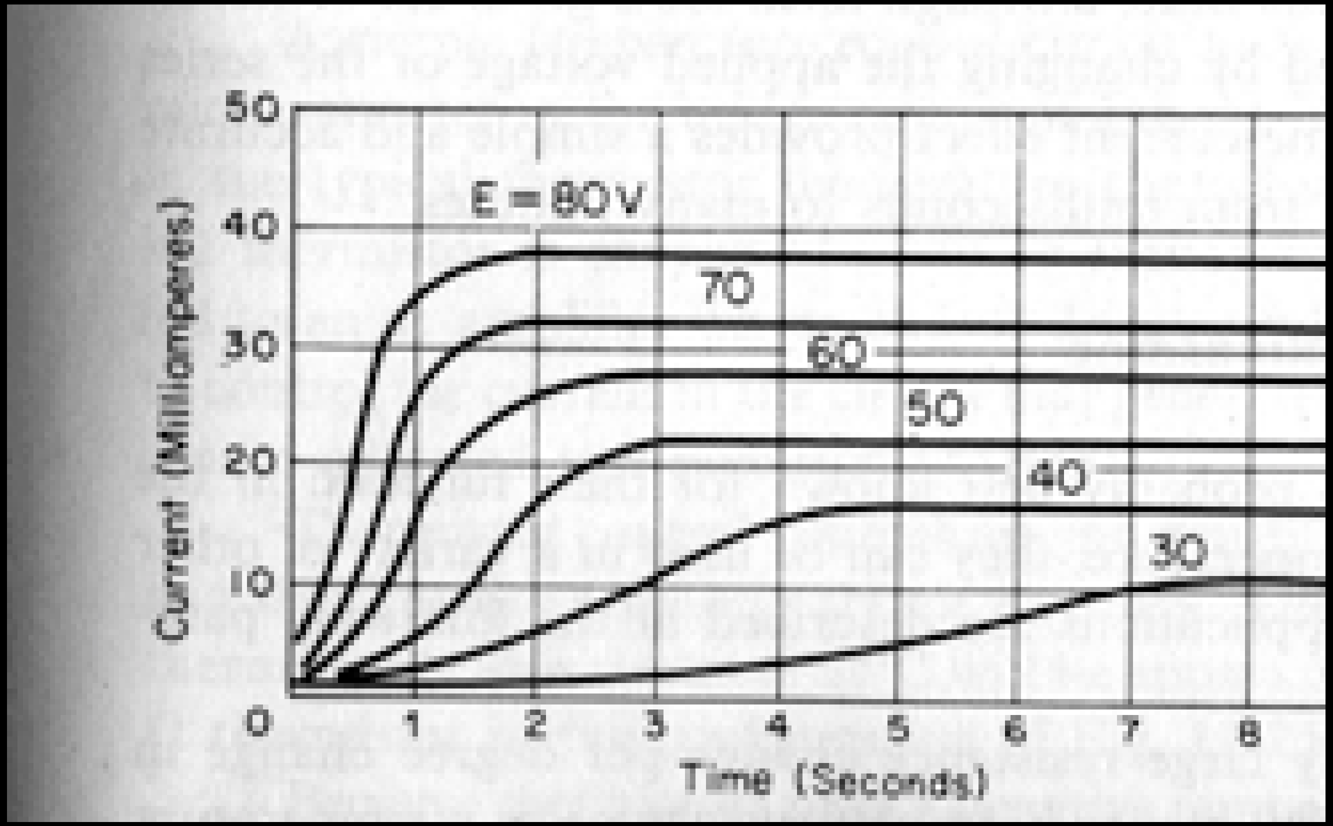
Thermistor

There are some semiconductor materials in which the resistance decreases with the increase of temperature. It is highly sensitive and useful for wide range of temperature as minus 100°C to +300°C.



Thermistor characteristics





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