GATE

2018

ELECTRICAL AND ELECTRONIC MEASUREMENT

ELECTRICAL ENGINEERING

ECG
Publications

ECG
Publications

A Unit of **ENGINEERS CAREER GROUP**

Head Office: S.C.O-80-81-82, 3rd floor, Sector-34/A, Chandigarh-160022

Website: www.engineerscareergroup.in **Toll Free:** 1800-270-4242

E-Mail: ecgpublications@gmail.com | info@engineerscareergroup.in

GATE-2018: Electrical and Electronic Measurement | Detailed theory with GATE & ESE previous year papers and detailed solutions.

First Edition: 2016

Price of Book: *INR 509/-*

CONTENTS

CHAPTER - 1

MEASUREMENTS AND MEASUREMENT SYSTEMS

1.1 MEASUREMENTS

Measurement of quantity is result of comparison of the quantity under measurement, also called as measurand, with perfect standard. The result is expressed in numerical values.
There are two methods to measure:

1. Direct Method

The measurement is compared directly with the standard.

Example. Measurement of length by tape.

2. Indirect Method

The measurand is measured by use of measuring instruments.

1.1.1 Measurement Instruments

1.Mechanical Instruments

They are good for static measurement i.e. measurand is not varying with time. Due to inertia, mechanical instruments are not suitable for dynamic measurement.

2. Electrical Instruments

They are better than mechanical instruments for dynamic measurements. However electrical systems use mechanical parts.

3. Electronic Instruments

Because the mass of electron is very less, the electronic systems are fastest.
In these, amplification of the signal can be done, hence very weak signals can also be measured.

1.1.2 Properties

1. Highest sensitivity
2. Power consumption is least
3. Most reliable
4. Fastest response
5. Low weight

1.1.3 Classification of Instruments

1. Absolute Instruments

The magnitude of measurand is measured in terms of the instruments constants. For eg: Tangent Galvanometer, rayleigh current balance. They are used for caliberating secondary instruments.

2. Secondary Instruments

They are caliberated with absolute instruments. The measurand is observed by output indication.

3. Deflection – Type Instruments

The measurand produces force or torque for deflection. Opposing torque to this deflection is produced externally. At the point of balance,
Deflection torque = controlling torque.

ESE OBJ QUESTIONS

1. A resistance of 108 Ω is specified using significant figures as indicated below:
1. 108 Ω
2. 108.0 Ω
3. 0.00108 Ω

[EE ESE - 2011]

Among these:
(a)1 represents greater precision than 2 and 3.
(b)2 represent greater precision but 1 and 3 represents same precision.
(c)2 and 3 represent greater precision than 1
(d)1, 2 and 3 represents same precision

2. A resistance of 105 ohms is specified using significant figures as indicated below:
1. 105 ohms
2. 105.0 ohms
3. 0.000105 MΩ

[EE ESE - 2010]

Among these
(a) 1 represents greater precision than 2 and 3.
(b) 2 and 3 represent greater precision than 1.
(c) 1, 2 and 3 represent same precision.
(d) 2 represents greater precision but 1 and 3 represent same precision.

3. What is the prefix tera equivalent to?

[EE ESE - 2008]

(a) 10^3 (b) 10^6
(c) 10^9 (d) 10^{12}

4. For defining the standard meter, wavelength of which material is considered?

[EE ESE - 2006]

(a) Neon (b) Krypton
(c) Helium (d) Xenon

5. Which one of the following is the most stable frequency primary atomic standard for frequency

[EC ESE - 2005]

(a) Caesium beam standard
(b) Hydrogen maser standard
(c) Rubidium vapour standard
(d) Quartz crystal standard

6. Match List-I (Accuracy) with List-II (Type of the standard) and select the correct answer:

List-I
A. Least accurate
B. More accurate
C. Much more accurate
D. Highest possible accurate

List-II
(i) Primary
(ii) Secondary
(iii) Working
(iv) International

[EE ESE - 2004]

Codes:
(a) A-iii, B-iv, C-i, D-ii
(b) A-i, B-iv, C-iii, D-ii
(c) A-iii, B-ii, C-i, D-iv
(d) A-i, B-ii, C-iii, D-iv

7. For time and frequency, the working standard is

[EE ESE - 2003]

(a) Microwave oscillator
(b) Crystal controlled oscillator
(c) Laser
(d) ARF oscillator

8. The most suitable primary standard for frequency is

[EC ESE - 2002]

(a) Rubudium vapour standard
(b) Quartz standard
(c) Hydrogen maser standard
(d) Ceasium beam standard

9. The modern standard of time

[EE ESE - 2001]

(a) A second defined as 1/86400 of a mean solar day.

(b) A second defined as time constant of an RC series circuit having R = 2 MΩ, C = 500 pF.

(c) A second which is duration of 9192631770 periods of radiation corresponding to the transition between the two hyperfine levels of the fundamental state of the atom cesium 133.

(d) A second defined as 1/31556925.9747 of the time required by the earth to orbit the sun in the year 1900.

10. The resistivity of the wire material can be expressed in terms of LMTl system of dimensional parameter as

[EC ESE - 2001]

(a) $ML^2T^{-2}I^{-2}$ (b) $ML^2T^{-3}I^{-2}$

(c) $ML^3T^{-3}I^{-2}$ (d) $ML^3T^{-2}I^{-2}$

11. "The current internationally recognized unit of time and frequency is based on the cesium clock, which gives an accuracy better 1μs per day ". This statement is related to

[EC ESE - 1999]

(a) Working standards
(b) International standards
(c) Primary standards
(d) Secondary standards

SOLUTIONS

Sol. 1. (b)

1. 108 Ω has 3 significant figures.
2. 108.0 Ω has 4 significant figures.
3. 0.000108 MΩ can be written has 108 Ω.

So, it has 3 significant figures.
The more the significant figures, the greater the precision of measurement.
Hence, option (b) is correct.

Sol. 2. (d)

Sol. 3. (d)

Sol. 4. (b)

Sol. 5. (b)

The hydrogen maser is the most stable frequency source currently known , having a frequency of 1420405751.73± 0.03Hz. However, due to its relatively large size, its use is limited to area where stability is critical, and size is not a consideration

Sol. 6. (c)

Sol. 7. (b)

Sol. 8. (d)

Sol. 9. (c)

Sol. 10. (c)

$$R = \frac{\rho l}{A} \Rightarrow \rho = \frac{RA}{l}$$

But $R = \frac{V}{i}$ where $V = \frac{W}{Q}$

So, $\rho = \frac{W}{Q} . \frac{1}{i} . \frac{A}{l}$

Where
W = work
Q = charge
I = current
A = area
l = length
Considering dimensions

$$\rho = \frac{ML^2T^2}{IT} . \frac{1}{l} . \frac{L^2}{L}$$

Or $\rho = ML^3T^{-3}l^{-2}$

So, the dimension of resistivity is $ML^3T^{-3}l^{-2}$

Sol. 11. (c)

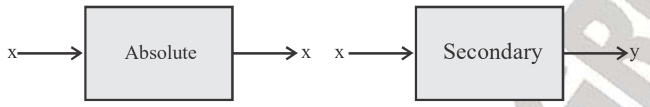
CHAPTER - 2

CHARACTERISTICS OF INSTRUMENTS AND MEASUREMENT SYSTEMS

2.1 STATIC CHARACTERISTICS

1. Calibration Curve

In this process, a known quantity is given as an input to instrument and output is seen. If output varies then instrument is adjusted accordingly using absolute instruments.



Adjust instrument so that output is x

2. Accuracy

Confirmity to truth, or true value. True value is impossible to calculate. However, most agreed value by experts may be considered as true value.

Measured in terms of its error.

Static error = Measured value – True value

$\delta A = A_m - A_t$

Absolute error/static error (δA) = $E_0 = A_m - A_t$

Relative error,

$$E_r = \frac{\delta A}{A_t}$$

(i) Accuracy is specified in three ways

(a) Point Accuracy

Only for a particular value the instrument is accurate to measure

(b) Accuracy as percentage of scale range i.e., x% of full scale deflection.

(c) Accuracy as percentage of true value i.e., x% of true value.

3. Static Correction

$\delta C = -(\delta A)$

Error is corrected in opposite to the error.

4. Scale Range

The range from minimum to maximum that instrument can measure.

5. Scale Span

$X_{max} - X_{min}$ = Scale Span

6. Reproducibility and Drift

The degree of closeness with which a given value can be measured repeatedly at different times in reproducibility.

If there is perfect reproducibility over time that is called No Drift.

GATE QUESTIONS

1. Two magnetically uncoupled inductive coils have Q factors q_1 and q_2 at the chosen operating frequency. Their respective resistances are R_1 and R_2. When connected in series. Their effective Q factor at the same operating frequency is

[GATE - 2013]

(a) $q_1 + q_2$
(b) $(1/q_1) + (1/q_2)$
(c) $(q_1R_1 + q_2R_2)/(R_1 + R_2)$
(d) $(q_1R_2 + q_2R_1)/(R_1 + R_2)$

SOLUTIONS

Sol. 1. (c)

The quality factor of the inductances are given by

$q_1 = \frac{\omega L_1}{R_1}$ and $q_2 = \frac{\omega L_2}{R_2}$

So, in series circuit, the effective quality factor is given by

$$Q = \frac{|X_{Leq}|}{R_{eq}} = \frac{\omega L_1 + \omega L_2}{R_1 + R_2}$$

$$= \frac{\frac{\omega L_1}{R_1R_2} + \frac{\omega L_2}{R_1R_2}}{\frac{1}{R_2} + \frac{1}{R_1}} = \frac{\frac{q_1}{R_2} + \frac{q_2}{R_2}}{\frac{1}{R_2} + \frac{1}{R_1}} = \frac{q_1R_1 + q_2R_2}{R_1 + R_2}$$

CHAPTER - 3

ERRORS IN MEASUREMENTS AND THEIR STATISTICAL ANALYSIS

3.1 INTRODUCTION

3.1.1 Limiting Errors/ Guarantee Errors

Limiting error is the deviation from nominal value guaranteed by manufacturer.

$A_a = A_s \pm \delta A$

Where A_a is Actual value

Relative limiting Error(E_r) = $\dfrac{\text{Actual Value} - \text{Nominal Value}}{\text{Nominal Value}} = \dfrac{\delta A}{As}$

Example A wattmeter has fsd 1000W and error ± 1% fsd. What will be the range of value if we measure 100W if error was specified as percentage of true value.

Solution.

Magnitude of limiting error at fsd = $\pm\dfrac{1}{100}\times 1000 = \pm 10\text{W}$

$\Rightarrow$ 100 ± 10W i.e., Between 90W to 110W

Percentage of E_r = $\pm\dfrac{10}{100}\times 100 = \pm 10\%$

If error given as percentage of true value

Magnitude = $\pm\dfrac{1}{100}\times 100 = \pm 1\text{W}$

Hence, meter will read from 99 to 101 W

Example A 0 – 150V voltmeter has guaranteed accuracy of 1% of fsd. At = 75V. what is the limiting error ?

Solution.

$\delta A = \dfrac{1}{100}\times 150 = 1.5$

A_t = 75V

Percentage of E_r = $\dfrac{1.5}{75}\times 100 = 2\%$

3.1.2 Limiting error of components/combination of quantities

1. Addition

$x = x_1 + x_2$

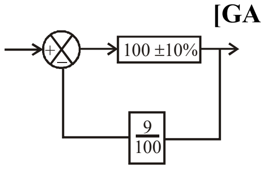
$$\frac{dx}{x} = \pm\frac{d(x_1 + x_2)}{x}$$

$$\frac{dx}{x} = \pm\left[\left(\frac{\partial x_1}{x_1}.\frac{x_1}{x}\right) + \left(\frac{\partial x_2}{x_2}.\frac{x_2}{x}\right)\right]$$

GATE QUESTIONS

1. As shown in the figure, a negative feedback system has an amplifier of gain 100 with + 10% tolerance in the forward path, and an attenuator of value 9/100 in the feedback path. The overall system gain is approximately

[GATE - 2010]



(a) 10 ± 1%
(b) 10 ± *2%*
(c) 10 ± 5%
(d) 10 ± 10%

2. A variable *w* is related to three other variables *x,y,z* as *w= xy/Z,* The variables are measured with meters of accuracy ±0.5% reading, ±1% of full scale value and ±1.5% reading. The actual readings of the three meters are 80, 20 and 50 with 100 being the full scale value for all three. The maximum uncertainty in the measurement of *w* will be

[GATE - 2006]

(a) ±0.5% rdg
(b) ±5.5% rdg
(c) ±6.7 rdg
(d) ±7.0 rdg

SOLUTIONS

Sol. 1. (a)

Overall gain of the system is

$$g = \frac{100}{1+100\left(\frac{9}{100}\right)} = 10(\text{zero error})$$

Gain with error

$$g = \frac{100+10\%}{1+(100+10\%)\left(\frac{9}{100}\right)}$$

$$= \frac{110}{1+\frac{110\times 9}{100}} = 10.091$$

error $\Delta g = 10.091 - 10 \sqcup 0.1$

Similarly

$$g = \frac{100-10\%}{1+(100-10\%)\frac{9}{100}} = \frac{90}{1+90\times\frac{9}{100}} = 9.89$$

Error $\Delta g = 9.89 - 10 \sqcup -0.1$

So gain g = 10 ± 0.1 = 10 ± 1%

Sol. 2. (d)

Given that $\omega = \frac{xy}{2}$

$\log\omega = \log x + \log y - \log z$

Maximum error in ω

$$\%\frac{d\omega}{\omega} = \pm\frac{dx}{x} \pm \frac{dy}{y} \pm \frac{dz}{z}$$

$$\frac{dx}{x} = \pm 0.5\%\ \text{readings}$$

$$\frac{dy}{y} = \pm 1\%\ \text{full scale} = \pm\frac{1}{100}\times 100 = \pm 1$$

$$\frac{dy}{y} = \pm\frac{1}{20}\times 100 = \pm 5\%\ \text{reading}$$

$$\frac{dz}{z} = 1.5\%\ \text{reading}$$

So $\%\frac{d\omega}{\omega} = \pm 0.5\% \pm 5\% \pm 1.5\% = \pm 7\%$

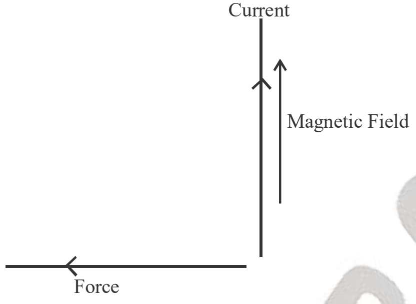
CHAPTER - 4

ANALOG INSTRUMENTS

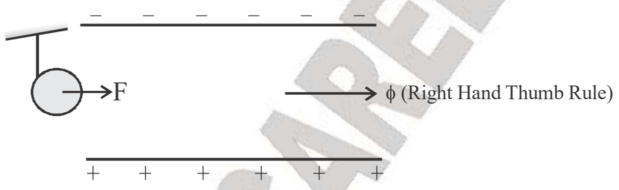
4.1 INTRODUCTION

4.1.1 Fleming's Left Hand Rule

This rule is used in Permanent Magnet Moving Coil (PMMC)



When an iron piece is placed near magnetic field then magnetic energy acts in such a way so as to reduce reluctance.



Reluctance = $\frac{\text{mmf}}{\text{flux}} = \frac{NI}{\phi}$

Where mmf is Magneto Motive Force
emf is Electro Motive Force

4.1.2 Ampere's Law

$\oint H.d\ell = I_{enclosed}$

where H is Magnetic Field Intensity
$\oint$ is magnetic path enclosed

$H \times \ell_m = NI$
Where ℓ_m is length of magnetic path

4.1.3 Right Hand Thumb Rule

Thumb is the direction of current and curl of fingers is the direction of flux.

GATE QUESTIONS

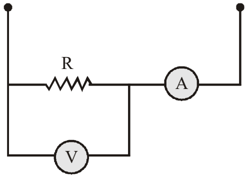
1. A current of $-8+6\sqrt{2}(\sin\omega t+30^\circ)$ A is passed through three meters. They are a centre zero PMMC meter, a true rms meter and a moving iron instrument. The respective reading (in A) will be

[GATE - 2006]

(a) 8, 6, 10
(b) 8, 6, 8
(c) –8,10,10
(d) –8, 2, 2

2. The set-up in the figure is used to measure resistance *R*. The ammeter and voltmeter resistances are 0.01Ω and 2000 Ω, respectively. Their readings are 2 A and 180 V, respectively, giving a measured resistances of 90 Ω The percentage error in the measurement is

[GATE - 2005]



(a) 2.25%
(b) 2.35%
(c) 4.5%
(d) 4.71%

3. A moving coil of a meter has 100 turns, and a length and depth of 10 mm and 20 mm respectively. It is positioned in a uniform radial flux density of 200 mT. The coil carries a current of 50 mA, The torque on the coil is

[GATE - 2004]

(a) 200 μNm
(b) 100 μNm
(c) 2 μNm
(d) 1 μNm

4. A dc A-h meter is rated for 15 A, 250 V. The meter constant is 1.4,4 A-sec/rev, The meter constant at rated voltage may be expressed as

[GATE - 2004]

(a) 3750 rev/kWh
(b) 3600 rev/kWh
(c) 1000 rev/kWh
(d) 960 rev/kWh

5. A moving iron ammeter produces a full scale torque of 240 μNm with a deflection of 120° at a current of 10 A. The rate of change of self induction (μH/radian) of the instrument at full scale is

[GATE - 2004]

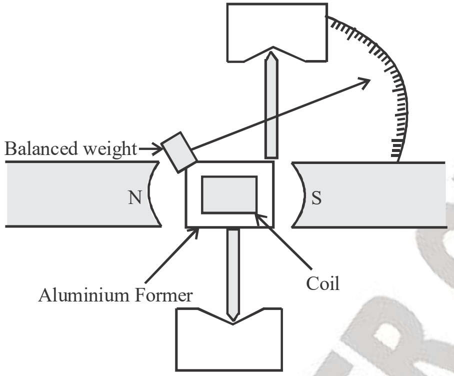
(a) 2.0 μH/radian
(b) 4,8 μH/radian
(c) 12.0 μH/radian
(d) 114.6 μH/radian

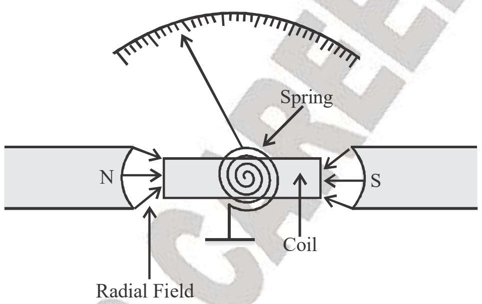
CHAPTER - 5

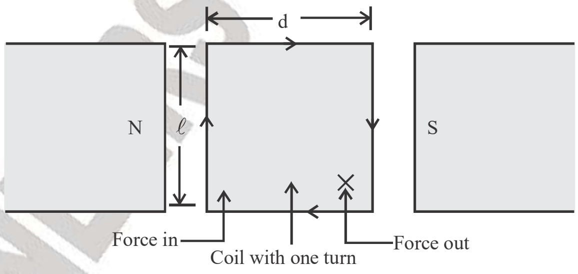
ANALOG AMMETER, VOLTMETER AND OHMETER

5.1 INTRODUCTION

5.1.1 Permanent Magnet Moving Coil (PMMC)







$F = NIBl \sin\theta$

For radial field; $\theta = 90^0$

$T_d = F.d$

$F = NIB\,ld$

$\because\ A = ld$

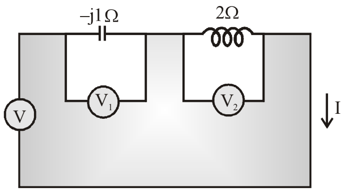
$F = NIBA$

$\because\ G = NBA$

GATE QUESTIONS

1. Three moving iron type voltmeter are connected as shown below. Voltmeter readings are V, V_1 and V_2 as indicated. The correct relation among the voltmeter readings is

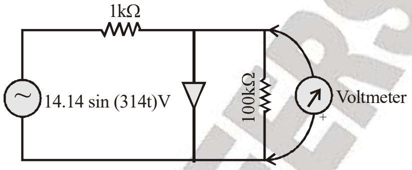
[GATE - 2013]



(a) $V = \frac{V_1}{\sqrt{2}} + \frac{V_2}{\sqrt{2}}$
(b) $V = V_1 + V_2$
(c) $V = V_1 V_2$
(d) $V = V_2 - V_1$

2. The input impedance of the permanent magnet moving coil (PMMC) voltmeter is infinite. Assuming that the diode shown in the figure below is ideal, the reading of the voltmeter in Volts is

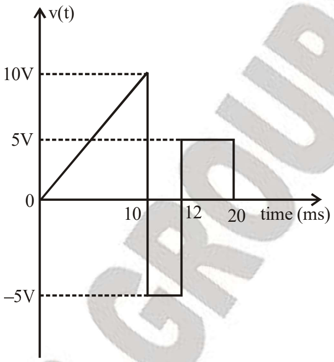
[GATE - 2013]



(a) 4.46	(b) 3.15
(c) 2.23	(d) 0

3. A periodic voltage waveform observed on an oscilloscope across a load is shown. A permanent magnet moving coil (PMMC) meter connected across the same load reads

[GATE - 2012]



(a) 4V	(b) 5V
(c) 8V	(d) 10V

4. An analog voltmeter uses external multiplier settings. With a multiplier setting of 20 kΩ, it reads 440V and with a multiplier setting of 80 kΩ, it reads 352V, For a multiplier setting of 40 kΩ, the voltmeter reads

[GATE - 2012]

(a) 371V	(b) 383V
(c) 394 V	(d) 406V

5. An ammeter has a current range of 0.5 A, and its internal resistance is 0.2 Ω. In order to change the range to 0-25 A, we need to add a resistance of

[GATE - 2010]

(a) 0.8 Ω in series with the meter
(b) 1.0 Ω in series with the meter
(c) 0.04 Ω in parallel with the meter
(d) 0.05 Ω in parallel with the meter

6. The Q-meter works on the principle of

[GATE - 2005]

(a)Mutual inductance	(b)Self inductance
(c)Series resonance	(d)Parallel resonance

7. A PMMC voltmeter is connected across a series combination of DC voltage source $V_1 = 2$ V and AC voltage source $V_2(t) = 3 \sin(4t)$ V, The meter reads

ESE OBJ QUESTIONS

1. A $3\frac{1}{2}$ digit digital voltmeter is accurate to ±0.5% of reading ±2 digits. What is the percentage error, when the voltmeter reads 0.10V on its 10V range?

[EC ESE - 2017]

(a) 0.025% (b) 0.25%
(c) 2.05% (d) 20.5%

2. A PMMC instrument if connected directly to measure alternating current, it indicates

[EC ESE - 2017]

(a) The actual value of the subject AC quantity
(b) Zero reading
(c) $\frac{1}{\sqrt{2}}$ of the scale value where the pointer rests
(d) $\frac{\sqrt{3}}{2}$ of the scale value where the pointer rests.

3. Consider the following statements:
Sphere gap method of voltage measurement is used
1. For measuring r.m.s. value of a high voltage
2. For measuring peak value of a high voltage
3. As the standard for calibration purposes
Which of the above statements are correct ?

[EC ESE - 2017]

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

4. A voltmeter having a sensitivity of 1000 Ω/V reads 100 V on its 150 V scale when connected across at resistor of unidentified specifications in series with a milliammeter. When the milliammeter reads 5 mA, the error due to the loading effect of the voltmeter will be nearly

[EC ESE - 2017]

(a) 13% (b) 18%
(c) 23% (d) 33%

5. Statement (I): Moving iron instruments are used in ac circuits only.
Statement (II): The deflecting torque in moving iron instruments depends on the square of the current.

[EE ESE - 2017]

(a) Both statement (I) and statement (II) are individually true and statement (II) is the correct explanation of statement (I).
(b) Both statement (I) and statement (II) are individually true but statement (II) is not the correct explanation of statement (I).
(c) Statement (I) is true but statement (II) is false.
(d) Statement (I) is false but statement (II) is true.

6. Statement (I): PMMC instruments are suitable in aircraft and air space applications.
Statement (II): PMMC instruments use a core magnet which possesses self– shielding property.

[EE ESE - 2017]

(a) Both statement (I) and statement (II) are individually true and statement (II) is the correct explanation of statement (I).
(b) Both statement (I) and statement (II) are individually true but statement (II) is not the correct explanation of statement (I).
(c) Statement (I) is true but statement (II) is false.
(d) Statement (I) is false but statement (II) is true.

7. Statement (I): An instrument manufacture as an ammeter should not be used as voltmeter
Statement (II): The high resistance winding of an ammeter will suffer serious damage if connected across a high voltage source.

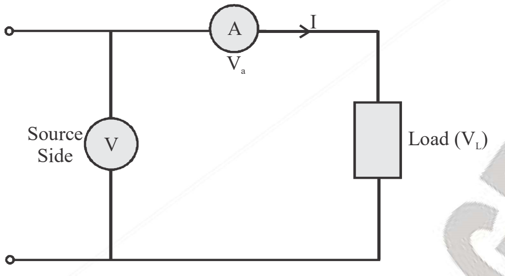
[EE ESE - 2017]

CHAPTER - 6

MEASUREMENT OF POWER

6.1 DC CIRCUITS

1. Voltmeter – Ammeter method

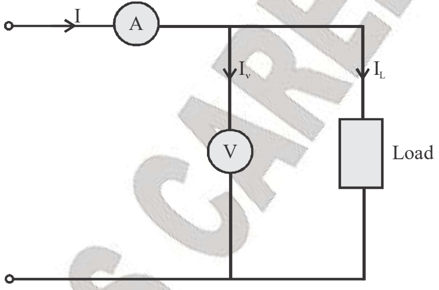


Power indicated by the instrument is = VI

$= (V_a + V_L).I = V_a.I + V_L.I$

$= V_L I + I^2 Ra$

2. Actual Power and Loss in Ammeter



$I = I_L + I_v$

$\Rightarrow (I_L + I_v)V$

$\Rightarrow VI_L + I_v V$

$\Rightarrow VI_L + VI_v$

Actual Power and Loss in voltmeter = $V \cdot I_L + \dfrac{V^2}{R_V}$

Power indicated by the instrument is actual power and loss in the instrument placed near load.

6.2 AC CIRCUITS

Here we use ED type Wattmeter

Fixed coils are connected in series so that they carry load current. Hence fixed coils are also called cc coils(current carrying coils). Moving coil depends on source on load and current carried by moving coils is proportional to voltage. They are also called potential coils or pressure coils.

GATE QUESTIONS

1. The bridge method commonly used for finding mutual inductance is

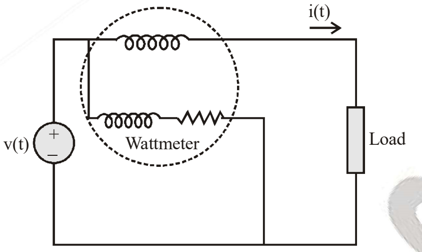
[GATE - 2012]

(a) Heaviside Campbell bridge
(b) Schering bridge
(c) De Sauty bridge
(d) Wien bridge

2. For the circuit shown in the figure, the voltage and current expressions are $V(t) = E_1 \sin(\omega t) + E_3 \sin(3\omega t)$ and $i(t) = I_1 \sin(\omega t - \phi_1) + I_3 \sin(3\omega t - \phi_3) + I_5 \sin(5\omega t)$

The average power measured by the wattmeter is

[GATE - 2012]



(a) $\frac{1}{2}E_1I_1\cos\phi_1$

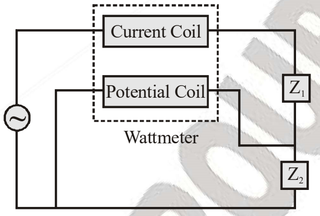
(b) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_1I_3\cos\phi_3 + E_1I_s]$

(c) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_3I_3\cos\phi_3)$

(d) $\frac{1}{2}[E_1I_1\cos\phi_1 + E_3I_1\cos\phi_1]$

3. A wattmeter is connected as shown in figure. The wattmeter reads.

[GATE - 2010]



(a) Zero always
(b) Total power consumed by Z_1 and Z_2
(c) Power consumed by Z_1
(d) Power consumed by Z_2

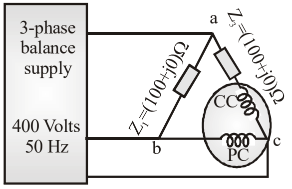
4. The pressure coil of dynamometer type wattmeter is

[GATE - 2009]

(a) Highly inductive
(b) Highly resistive
(c) Purely resistive
(d) Purely inductive

5. The figure shows a three-phase delta connected load, supplied from a 400V, 50 Hz, 3-phase balanced source. The pressure coil (PC) and current coil (CC) of a wattmeter are connected to the load as shown, with the coil polarities suitably selected to ensure a positive deflection. The wattmeter reading will be

[GATE - 2009]



(a) 0
(b) 1600 Watt
(c) 800 Watt
(d) 400 Watt

6. A sampling wattmeter (that computes power from simultaneously sampled values of voltage and current) is used to measure the average power of a load. The peak to peak voltage of the square wave is 10 V and the current is a triangular wave of 5 A p-p as shown in the figure. The period is 20 ms. The reading in W will be

CHAPTER - 7
MEASUREMENT OF RESISTANCE

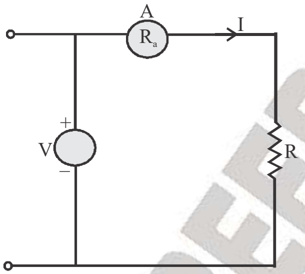
7.1 THREE CATEGORY FOR MEASUREMENT OF RESISTANCE

(i) Low R: of order of 1Ω or less
(ii) Medium R: of order of 1 Ω – 100 kΩ
(iii) High R: R > 100kΩ

7.2 METHOD TO CALCULATE RESISTANCE

Type-I. Ammeter Voltmeter Method

This method is suitable for measuring high resistance



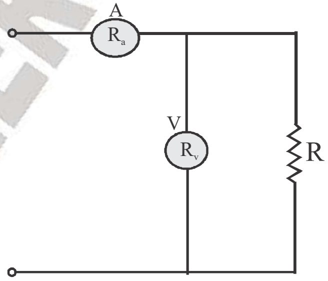
Measured value of $R_m = \frac{V}{I}$

If R_a then, $R_m = \frac{V}{I} = \frac{I_R + R_a}{I} = R + R_a$

Percentage error = $\frac{R_a}{R}$

Type-II.

This method is suitable for measuring low resistances.



$$R_m = \frac{V}{I} = \frac{V}{I_v + I_R}$$

$$I_v = \frac{V}{R_v} \text{ and } I_R = \frac{V}{R -}$$

CHAPTER - 8

AC BRIDGES

8.1 INTRODUCTION

AC bridges are used for measurement of inductance, capacities, quality factor of coils and dissipation factor of capacitances etc.

Source is an electronic oscillator with controllable frequencies.

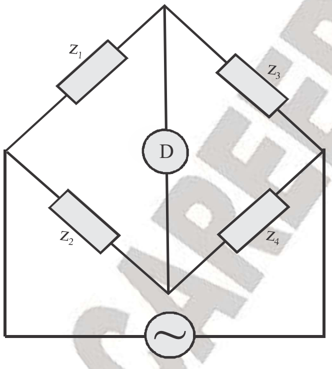
1. Detectors are

1. Headphones: 250Hz to 4 kHz
2. Vibration galvanometer: This is most sensitive for 5Hz to 200 Hz.
3. Wide frequency range, tunable amplifier: 100Hz to 10 kHz

At balance, $\overline{z}_1\overline{z}_4 = \overline{z}_2\overline{z}_3$

$$|z_1||z_4| = |z_2||z_3| \qquad \ldots(i)$$

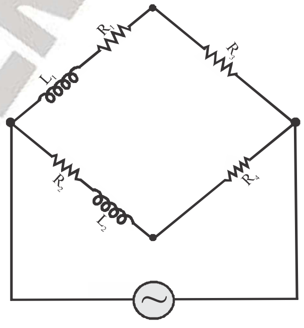
$\angle\theta_1 + \theta_4 = \angle\theta_4 + \theta_3$



Two equations: two unknown variable can be known in terms of known variable. For quick balance, the known variables shall not come in the equation.

$(R_1 + j\omega L_1)R_4 = (R_2 + j\omega L_2)R_3$

$R_1R_4 = R_2R_3$



And $L_1R_4 = L_2R_3$

$$R_1 = \frac{R_2R_3}{R_4}$$

GATE QUESTIONS

1. Consider the following statement

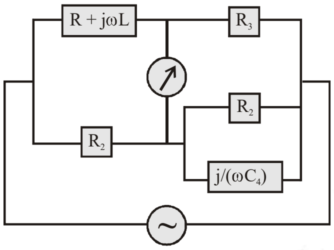
(1) The compensating coil of a low power factor wattmeter compensates the effect of the impedance of the current coil.

(2) The compensating coil of a low power factor wattmeter compensates the effect of the impedance of the voltage coil circuit.

[GATE - 2011]

(a) (1) is true but (2) is false
(b) (1) is false but (2) is true
(c) Both (1) and (2) are true
(d) Both (i) and (2) are false

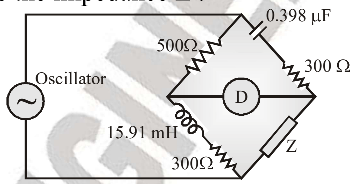
2. The Maxwell's bridge shown in the figure is at balance. The parameters of the inductive coil are.



[GATE - 2010]

(a) $R = R_2R_3/R_4$, $L = C_4R_2R_3$
(b) $L = R_2R_3/R_4$, $R = C_4R_2R_3$
(c) $R = R_4/R_2R_3$, $L = 1/(C_4R_2R_3)$
(d) $L = R_4/R_2R_3$, $R = 1/(C_4R_2R_3)$

3. The ac bridge shown in the figure *is* used to measure the impedance Z .



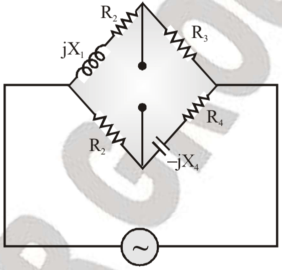
If the bridge is balanced for oscillator frequency f = 2 kHz, then the impedance *Z* will be

[GATE - 2008]

(a) (260 + J0)Ω
(b) (0 + j200)Ω
(c) (260 – j200)Ω
(d) (260 + j200) Ω

4. A bridge circuit is shown in the figure below. Which one of the sequence given below is most suitable for balancing the bridge ?

[GATE - 2007]



(a) First adjust
(b) First adjust
(c) First adjust
(d) First adjust

5. R_1 and R_4 are the opposite arms of a Wheatstone bridge as are R_2 and R_1. The source voltage is applied across R_1 and R_3. Under balanced conditions which one of the following is true

[GATE - 2006]

(a) $R_1 = R_3R_4/R_2$
(b) $R_1 = R_2R_3/R_4$
(c) $R_1 = R_2R_4/R_3$
(d) $R_1 = R_2 + R_3 + R_4$

6. The items in Group-I represent the various types of measurements to be made with a reasonable accuracy using a suitable bridge. The items in Group-II represent the various bridges available for this purpose. Select the correct choice of the item in Group-II for the corresponding item in Group-I from the following

List-I

A. Resistance in the milli-ohm range
B. Low values of Capacitance
C. Comparison of resistance which are nearly equal
D. Inductance of a coil with a large time-constant

SOLUTIONS

Sol. 1. (c)

The compensation coil compensation the effect of impedance of current coil.

Sol. 2. (a)

At balance condition

$$(R + j\omega L)\left(R_4 \parallel \frac{-j}{\omega C_4}\right) = R_2R_3$$

$$(R + j\omega L)\frac{\frac{-jR_4}{\omega C_4}}{\left(R_4 - \frac{j}{\omega C_4}\right)} = R_2R_3$$

$$\frac{-jRR_4}{\omega C_4} + \frac{\omega LR_4}{\omega C_4} = R_2R_3R_4 - \frac{jR_2R_3}{\omega C_4}$$

Comparing real & imaginary parts.

$$\frac{RR_4}{\omega C_4} = \frac{R_2R_3}{\omega C_4}$$

$$R = \frac{R_2R_3}{R_4}$$

Similarly, $\frac{LR_4}{C_4} = R_2R_3R_4$

$L = R_2R_3C_4$

Sol. 3. (a)

Impedance of different branches is given as

$Z_{AB} = 500\Omega$

$$Z_{BC} = \frac{1}{j \times 2\pi \times 2 \times 10^3 \times 0.398\mu F} + 300\Omega$$

⊔ (–200 J + 300) Ω

$Z_{AD} = j \times 2\pi \times 2 \times 10^3 \times 15.91$ mH + 300Ω

⊔ (200 j + 300)Ω

To balance the bridge

$Z_{AB}Z_{CD} = Z_{AD}Z_{BC}$

500Z = (200 j + 300) 9–200 j + 300)

500 Z = 130000

Z = (260 + j0)Ω

Sol. 4. (a)

To balance the bridge

$(R_1 + jX_1)(R_4 - jX_4) = R_2R_3$

$(R_1R_4 + X_1X_4) + j(X_1R_4 - R_1X_4) = R_2R_3$

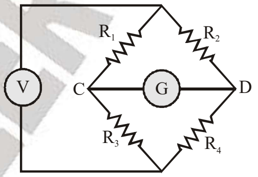
Comparing real and imaginary parts on both sides of equations

$R_1R_4 + X_1X_4 = R_2R_3$ … (i)

$X_1R_4 - R_1X_4 = 0 \Rightarrow \frac{X_1}{X_4} = \frac{R_1}{R_4}$ …(ii)

From eq(1) and (2) it is clear that for balancing the bridge first balance R_4 and then R_1.

Sol. 5. (b)



In balanced condition there is no current in CD arm so $V_C = V_D$

Writing node equation at C and D

$$\frac{V_C - V}{R_1} + \frac{V_C}{R_3} = 0 \Rightarrow V_C = V\left(\frac{R_3}{R_1 + R_3}\right)$$

$$\frac{V_0 - V}{R_2} + \frac{V_D}{R_4} = 0 \Rightarrow V_D = V\left(\frac{R_4}{R_2 + R_4}\right)$$

So $V\left(\frac{R_3}{R_1 + R_3}\right) = V\left(\frac{R_4}{R_2 + R_4}\right)$

$R_2R_3 + R_3R_4 = R_1R_4 + R_3R_4$

$R_1 = R_2R_3/R_4$

Sol. 6. (a)

Kelvin Double bridge is used for measuring low values of resistances. (P → 2)

Low values of capacitances is precisely measured by Schering bridge (Q → 3)

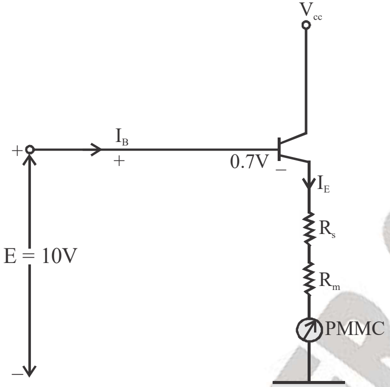
Inductance of a coil with large time constant or high quality factor is measured by hay's bridge (R → 5)

CHAPTER - 9

ELECTRONIC MEASUREMENTS

9.1 ELECTRONIC MEASUREMENT

Example Find I_m when E = 10V. Find input resistance with and without transistor.



$R_s + R_m = 9.3\ k\Omega$

$I_{fsd} = 1mA$

$\beta = 100$

Solution.

E = 10V = V

$I_m = ImA$

$10 - 0.7 = (9.3 \times 10^3)\ I_m$

$I_m = 1mA$

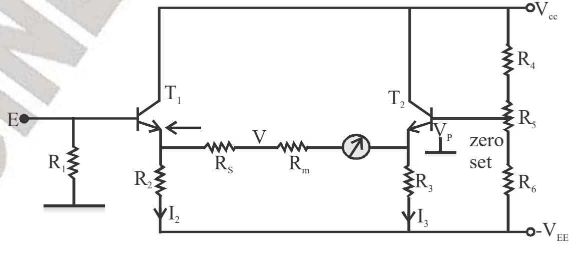
$Z_{in} = (h_{fe} + 1)Re.$

$$Z_{in} = \frac{E}{I_B} \Rightarrow Z_{in} = \frac{10}{0.1\mu A} = 100M\Omega$$

$$I_B \approx \frac{I_E}{B} = 0.1\mu A$$

$Z_{in} = R_s + R_m = R_E$

Input impedance should be high to avoid loading effect. Thus, to eliminate the error due to V_{BE}, we will make certain arrangements.



No two transistors can be same.

GATE QUESTIONS

1. An average-reading digital multi-meter reads 10 V when fed with a triangular wave, symmetric about the time-axis. For the same input an rms reading meter will read

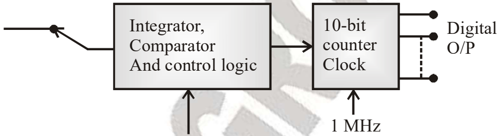
[GATE - 2009]

(a) $\frac{20}{\sqrt{3}}$ (b) $\frac{10}{\sqrt{3}}$

(c) $20\sqrt{3}$ (d) $10\sqrt{3}$

2. The simplified block diagram *of* a 10-bit A/D converter of dual slope Integrator type is shown In figure. The 10-bit counter at the output is clocked by a 1 MHz clock. Assuming negligible timing overhead for the control logic, the maximum frequency of the analog signal that can be converted using this A/D converter is approximately

[GATE - 2003]



(a) 2 kHz (b) 1 kHz

(c) 500 Hz (d) 250 Hz

SOLUTIONS

Sol. 1. (d)

Average value of a triangular wave

$$V_{av} = \frac{V_m}{3}$$

$$\text{rms value} V_{ms} = \frac{V_m}{\sqrt{3}}$$

Given that $V_{av} = \frac{V_m}{3} = 10V$

So $V_{rms} = \frac{V_m}{\sqrt{3}} = \sqrt{3}\, V_{av} = 10\sqrt{3}\, V$

Sol. 2. (b)

Maximum frequency of input in dual slope A/D converter is given as

$T_m = 2^n T_C$

Where $f_m = \frac{1}{T_m} \rightarrow$ maximum frequency of input

$f_C = \frac{1}{T_C} \rightarrow$ clock frequency

So $f_m = \frac{f_c}{2^{n'}}$ n = 10

$= \frac{10^6}{1024} = 1\text{kHz(approx)}$

CHAPTER - 10

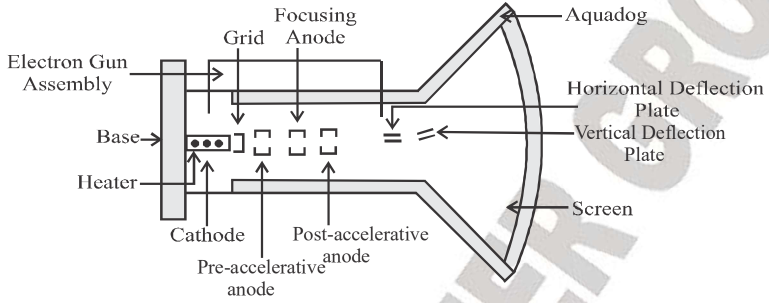
CATHODE RAY OSCILLOSCOPE (CRO)

10.1 INTRODUCTION

Cathode Ray Oscillator is basically a XY plotter, the CRO can measure frequency upto 1GHz. CRO is basically voltage meter.

10.1.1 Part of CRO

1. Cathode Ray Oscillator (CRT)



Electron gun assembly produces sharp beam of accelerated electrons.

(i) ***Cathode:*** It produces electrons when heated. A layer of stromdium oxide is placed over cathode to increase efficiency. Cathode is cylindrical with a hole in it.

(ii) ***Grid:*** The intensity/ brightness spots on screen depends on no. of electrons. This can be controlled by putting a negative bias on grid.

(iii) ***Pre – Accelerative Anode:*** By placing positive high voltage, speed of electron increases.

(iv) ***Focusing Anode:*** The scattered beam is focused by electrostatic focusing in CRO and by magnetic focusing in TV sets.

(v) ***Post –Accelerative Anode:*** It is required to accelerate the electrons.

(vi) ***Horizontal Deflection Plate :*** Its function is to move electrons beam horizontally on the screen.

(vii) ***Vertical Deflection Plate:*** Its function is to move electrons beam vertically on the screen.

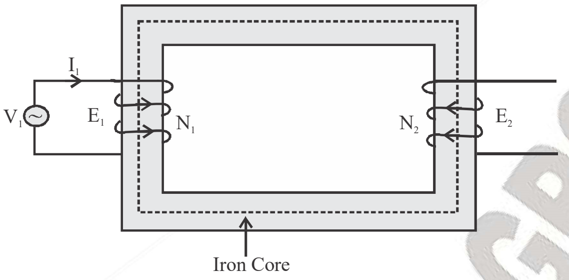
(viii) ***Screen:*** It is made of glass coated with phosphor. When electrons strike on phosphor, the energy is increased and it produces light that is called cathode luminance.

(ix) ***Gratiule:*** Horizontal and vertical divisions on screen for measurement.

(x) ***Aquadog:*** When electrons strike over screen, they cause emission of electrons from screw which is called secondary emission. Aquadog is aqueous summation of device which collect through secondary emitted electrons.

CHAPTER - 11
INSTRUMENT TRANSFORMERS

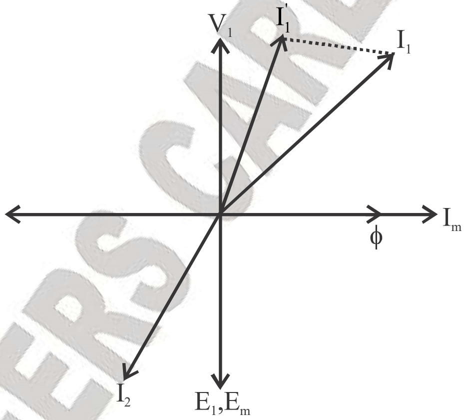
11.1 INTRODUCTION



$$E_1 = \frac{-N_1 d\phi}{dt}$$

$$E_2 = -N_2\frac{d\phi}{dt}$$

$$\Rightarrow \frac{E_1}{E_2} = \frac{N_1}{N_2}$$

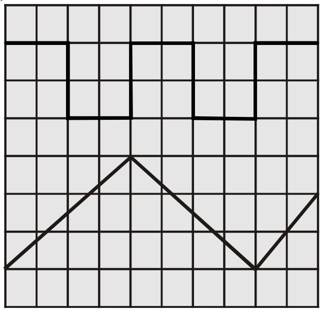


The above graph is phasor diagram of ideal transformer without any load.

If we put some load on transformer, and we get a path for current to flow. So the current produced will be to oppose the flux here,
$E_1 = 4.44\ \phi_m\ fN_1$
$E_2 = 4.44\ \phi_m\ fN_2$
$V_1 = -E_1 = 4.44\ \phi\ f\ N$
When V_1, f and N are not changing then even ϕ we cannot change.
I_2 causing ϕ decreases. But ϕ cannot on decreasing
Then transformer drives more current from supply to maintain the ϕ such that

GATE QUESTIONS

1. The time/div and voltage/div axes of an oscilloscope have been erased. A student connects a 1 kHz, 5 V p-p square wave calibration pulse to channel-1 of the scope and observes the screen to be as shown in the upper trace of the figure. An unknown signal is connected to channel-2 (lower trace) of the scope. It the time/ div and V/div on both channels are the same, the amplitude (p-p) and period of the unknown signal are respectively



[GATE - 2006]

(a) 5 V. 1 ms (b) 5 V, 2 ms
(c) 7,5 V, 2 ms (d) 10 V, 1 ms

2. 200/1 Current transformer (CT) is wound with 200 turns on the secondary on a toroidal core. When it carries a current of 160 A on the primary, the ratio and phase errors of the CT are found to be – 0.5% and 30 minutes respectively. If the number of secondary turns is reduced by 1 new ratio-error(%) and phase error(min) will be respectively

[GATE - 2006]

(a) 0.0, 30 (b) -0.5, 35
(c) -1.0, 30 (d) -1.0, 25

3. A 50 Hz, bar primary CT has a secondary with 500 turns. The secondary supplies 5 A current into a purely resistive burden of 1 Ω. The magnetizing ampere-turns is 200. The phase angle between the primary and second current is

[GATE - 2004]

(a) 4.6° (b) 85.4°
(c) 94.6° (d) 175.4°

CHAPTER-12

PRIMARY SENSING ELEMENTS AND TRANSDUCERS

12.1 INTRODUCTION

TYPE	OPERATION
Contacting spindle, pin or figure	displacement to displacement
Proving ring	Force to displacement
Bourdon tube	Pressure to displacement
Bellows	Pressure to displacement
Diaphragm	Pressure to displacement
Spring	Force to displacement
Siesmic mass	Forcing function to displacement
Pendulum scale	Force to displacement
Monometer	Pressure to displacement
Thermocouple	Temperature to electric current
Bi-metallic strip	Temperature to displacement
Temp – stick	Temperature to phase
Float	Fluid level to displacement
Hydrometer	Specific gravity to displacement
Quefis	Fluid velocity to pressure
Venturi tube	Fluid velocity to pressure
Pitot tube	Fluid velocity to pressure
Vanes	Fluid velocity to force

12.2 CLASSIFICATION OF TRANSDUCERS

1. Principle of Transduction used

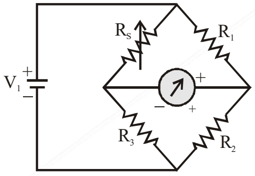
(i) Resistive Transducers

Transducer	Operation	Typical Use
(a) Potentiometer device	Positioning of slider changes	Measurement of displacement
	the resistance	and pressure
(b) Strain Gauge	Resistance of conductors and	Force, troque, displacement
	semi – conductor changes by	
	tensile or compressive stress.	
(c) Pirani Gauge	Resistance of heating element	Gas flow, gas pressure
	is changed by connection cooling	
(d) Thermometer	Resistance changes with	Temperature
	temperature with positive α.	
(e) Thermistor	Resistance changes with	Temperature, gas flow, water flow
	temperature with negative α.	
(f) Photoconductive Cell	Resistance changes by light	Photosensitive relay

(ii) Capacitive Transducers

GATE QUESTIONS

1. A strain gauge forms one arm of the bridge shown in the figure below and has a nominal resistance without any load as $R_s = 300\ \Omega$, Other bridge resistances are $R_1 = R_2 = R_3 = 300\ \Omega$. The maximum permissible current through the strain gauge is 20mA, During certain measurement when the bridge is excited by maximum permissible voltage and the strain gauge resistance is increased by 1% over the nominal value, the output voltage V_0 in mV is



[GATE - 2013]

(a) 56.02 (b) 40.83
(c) 29.85 (d) 10.02

2. A $4\frac{1}{2}$ digit DMM has the error specification as: 0.2% of reading + 10 counts. If a dc voltage of 100 V is read on its 200 V full scale, the maximum error that can be expected in the reading is

[GATE - 2011]

(a) ±0.1% (b) ±0.2%
(c) ±0.3% (d) ±0.4%

3. Two 8-bit ADCs, one *of* single slope integrating type and other of successive approximate type, take T_A and T_B times to convert 5V analog input signal to equivalent digital output. If the input analog signal is reduced to 2.5 V, the approximate time taken by the two ADCs will respectively, be

[GATE - 2008]

(a) T_A. T_B (b) $T_A/2$, T_B
(c) T_A, $T_B/2$ (d) $T_A/2$, $T_B/2$

4. A digital-to-analog converter with a full-scale output voltage of 3.5 V has a resolution close to 14 mV. Its bit size is

[GATE - 2005]

(a) 4 (b) 8
(c) 16 (d) 32