∴ precision does not guarantee accuracy.

Although,
accuracy requires precision.

6th Dec

(iii) Resolution

If an i/p to an instrument is slowly ↑ from an arbitrary i/p value, it will be observed that the o/p does not change until a certain increment is exceeded.
This increment is termed as resolution

Resolution is defined as minimum i/p which gives a detectable o/p.

In case of an analog instrument, it is the significance of smallest division on the scale whereas incase of
digital instrument it is the significance of least significant bit.

(iv) Senstivity

Sensitivity of an instrument or an instrumentation system is the ratio of magnitude of an o/p signal to the magnitude of i/p signal.

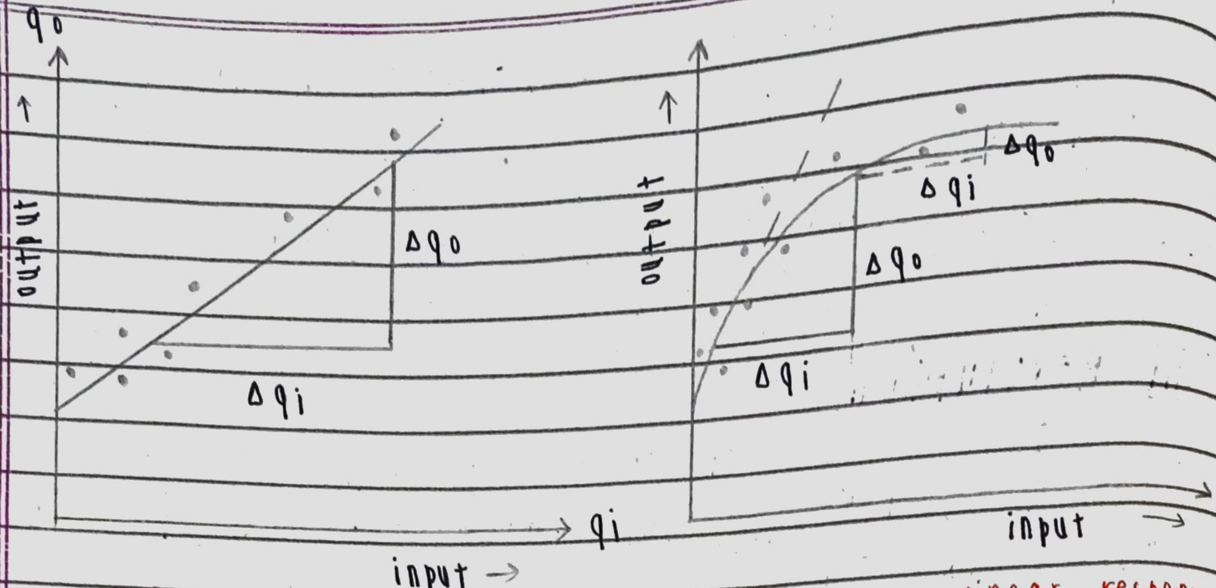

Fig (i): linear response

Fig (ii): Non-linear response

sensitivity = $\dfrac{\Delta q_o}{\Delta q_i}$

for both

When a calibration curve is linear as shown in fig (i), then the sensitivity of instrument is const. throughout the whole measurement range.

However, if the calibration of curve is non-linear then the sensitivity will vary w. the i/p as shown in fig (ii)

sensitivity is also defined as the ratio of smallest change in o/p to the smallest change in i/p.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

The value of unknown arm is found in terms of known value of other 3 arms.

- For measurement of
  - (i) Resistance ⟶ DC bridge is used
  - (ii) Inductance & capacitance ⟶ AC bridge is used.

• measurement of resistance

1000007

Resistance

1·10

- High (0·1 MΩ >)
  - Meggar
  - Direct deflection method
  - Loss of charge method
- medium (0·1 MΩ)
  - Ammeter, voltmeter
  - Wheatstone bridge
  - ohmmeter
  - substitution
- Low (1Ω)
  - Ammeter - voltmeter
  - Kelvin Double Bridge
  - potentiometer

Wheatstone bridge

Resistance can be measured w. the help of wheatstone bridge whose diagram is shown below.

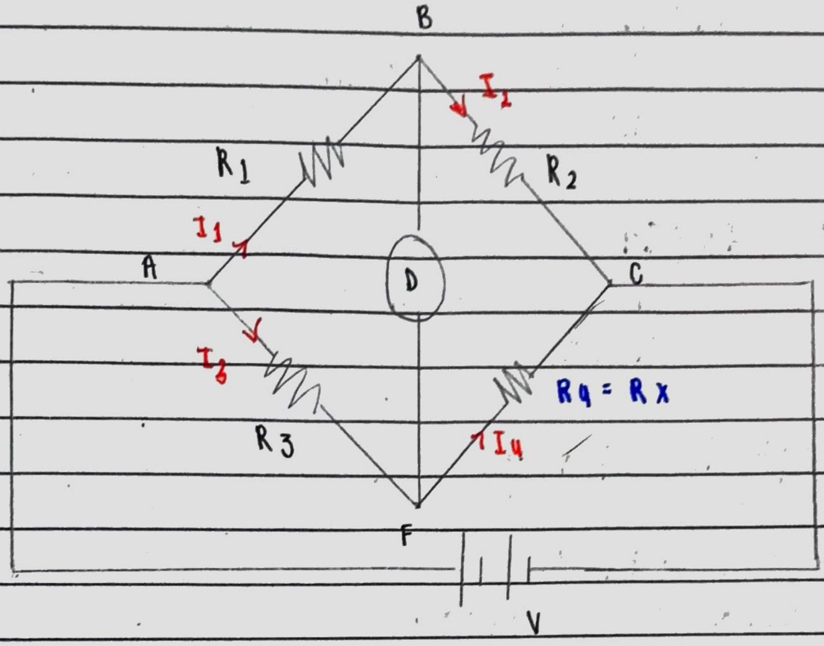

Fig: Wheatstone bridge

Bridge consists of 4 resitive arms together w. source of emf 'V' & a detector 'D'.

The bridge is said to be balanced when p.d. across the detector (galvanometer) is 0V

so,

that there is no current through the detector ($I_D = 0$)

∴ when bridge is balanced,

$V_{AB} = V_{AF}$

$$I_1 R_1 = I_3 R_3 \quad \text{(i)}$$

As no current is through detector (galvanometer)

$$I_1 = I_2 = \frac{V}{R_1 + R_2} \quad \text{(ii)}$$

$$I_3 = I_4 = \frac{V}{R_3 + R_4} \quad \text{(iii)}$$

From eq^n (i), (ii) & (iii)

$$\frac{V}{R_1 + R_2} * R_1 = \frac{V}{R_3 + R_4} * R_3$$

or, $R_1 R_3 + R_1 R_4 = R_1 R_3 + R_2 R_3$

$$\therefore R_1 R_4 = R_2 R_3 \quad \text{(iv)}$$

Eq^n (iv) gives necessary cond^n for wheatstone bridge to be balanced

i.e. when the bridge is balanced the product of resistance of any two opp. arms must be equal to that of other two arms.

Suppose an unknown resistance 'R_X' is placed in arm 4.

i.e. $R_4 = R_X$

then eqn (iv) becomes

$$R_X = \frac{R_2 R_3}{R_1} \rightarrow (v)$$

The arm containing:

- R_3 is called standard arm of bridge

&

- R_2 & R_1 is called ratio arm

Balanced condn for AC bridge

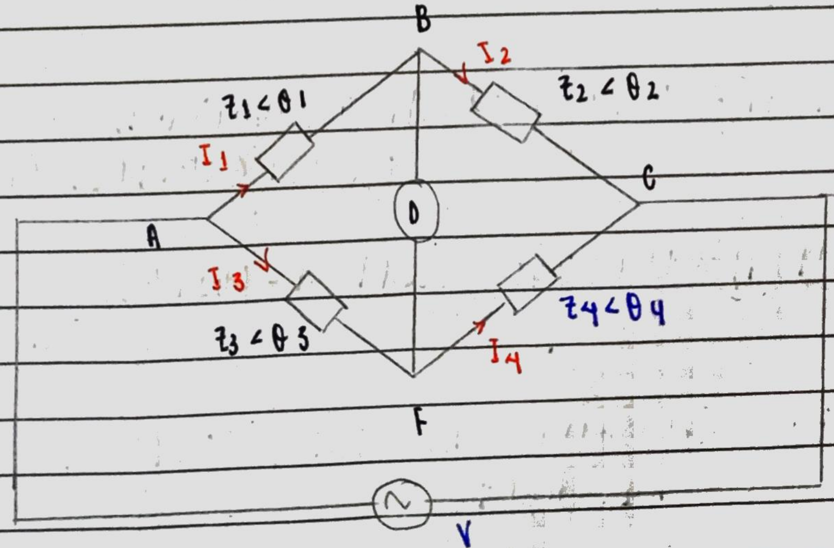

Fig: AC Bridge ckt

When bridge is balanced,

$$V_{AB} = V_{AF}$$

$$I_1 |Z_1| \angle \theta_1 = I_3 |Z_3| \angle \theta_3 \rightarrow \text{(i)}$$

As no current is flowing through detector

$$I_1 = I_2 = \frac{V}{|Z_1| \angle \theta_1 + |Z_2| \angle \theta_2} \rightarrow \text{(ii)}$$

$$I_3 = I_4 = \frac{V}{|Z_3| \angle \theta_3 + |Z_4| \angle \theta_4} \rightarrow \text{(iii)}$$

From eq^n (i), (ii) & (iii)

$$\frac{V}{|Z_1| \angle \theta_1 + |Z_2| \angle \theta_2} * |Z_1| \angle \theta_1 = \frac{V}{|Z_3| \angle \theta_3 + |Z_4| \angle \theta_4} * |Z_3| \angle \theta_3$$

or, $\cancel{|Z_1||Z_3| \angle (\theta_1 + \theta_3)} + |Z_1||Z_4| \angle (\theta_1 + \theta_4)$
$= \cancel{|Z_1||Z_3| \angle (\theta_1 + \theta_3)} + |Z_2||Z_3| \angle (\theta_2 + \theta_3)$

or, $|Z_1||Z_4| \angle (\theta_1 + \theta_4) = |Z_2||Z_3| \angle (\theta_2 + \theta_3)$ ↳ (iv)

Hence eq^n (iv) gives necessary cond^n for AC bridge to be balanced.

There two conditions:

① Product of mag. of any two opposite arms' impedance must be equal to that of other two

...urement of inductance

...can be done by using the following ...

...axwell bridge

measuring L of coil having ...

...ing L of coil having high quality factor

$Q = \frac{X_L}{R}$

For ↑ Q factor of coil

↳ $X_L >> R$ i.e. $R \to 0$

for ↑ Q factor coil

[$\theta \approx 90°$

lossless line]

a) Maxwell Bridge

↳ $(1 < Q < 10)$

↳ ckt arrangement for maxwell Bridge is shown in fig:

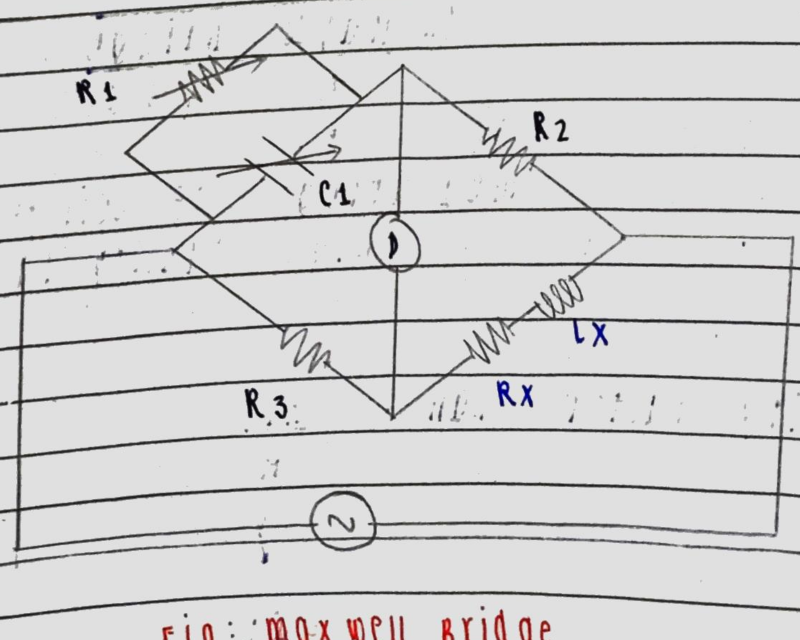

Fig: Maxwell Bridge

Here,

$$Y_1 = \frac{1}{Z_1}$$

$$= \frac{1}{R_1} + j\omega C_1$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_4 = R_x + j\omega L_x$$

At balanced condn

$$Z_1 Z_4 = Z_2 Z_3$$

$$\text{or, } Z_4 = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 Y_1$$

$$\text{or, } R_x + j\omega L_x = R_2 R_3 \left\{ \frac{1}{R_1} + j\omega C_1 \right\}$$

$$\text{or, } R_x + j\omega L_x = \frac{R_2 R_3}{R_1} + j\omega R_2 R_3 C_1$$

Equating real & imag parts,

$$R_x = \frac{R_2 R_3}{R_1} \quad \text{(i)}$$

$L_x = R_3 R_2 C_1$ — (ii)

Now,
quality factor 'Q' of coil will be:

$$Q = \frac{\omega L_x}{R_x}$$

$$= \frac{\omega \cancel{R_3} \cancel{R_2} C_1}{\frac{\cancel{R_3} \cancel{R_2}}{R_1}}$$

$$\therefore Q = \omega R_1 C_1$$ — (iii)

The sum of ∠ of arm 2 & arm 3 → = 0

so,
acc. to 2nd balance condn
• sum of ∠ of arm x & arm 1 must be 0

4 If ↑ Q factor coil is taken then

∠ of arm x $\xrightarrow[\text{equal to}]{\text{nearly}}$ +90°

So, $\angle$ of arm 1 must be $\xrightarrow[\text{equal to}]{\text{nearly}}$ -90°

for this resistance value of R_1 must be really ↑

The cost of decade resistance box (Rheostat) ↑ w.
↑ in resistance.

So, this bridge becomes uneconomical for coil having ↑ Q factor.

b) Hay's Bridge

(Q > 10)

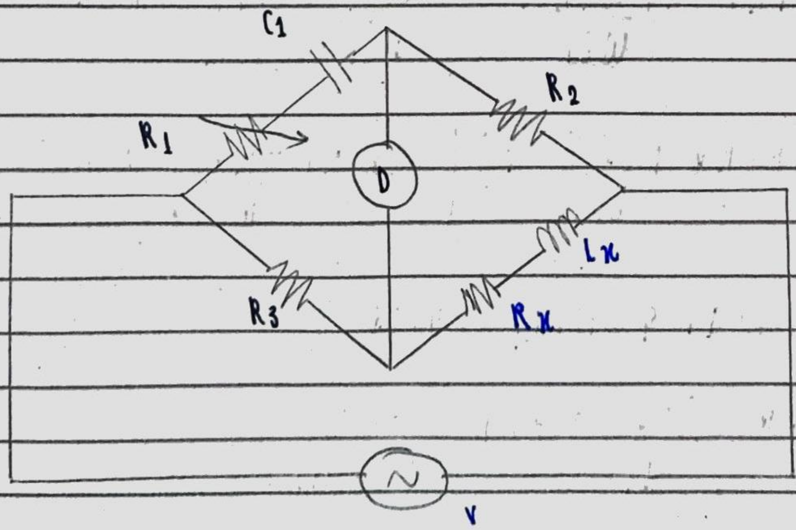

Fig: Hay's Bridge

Here,

$$Z_1 = R_1 - \frac{j}{\omega C_1}$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$$Z_4 = R_x + j\omega L_x$$

At balanced cond^n

$$Z_1 Z_4 = Z_2 Z_3$$

or, $\left(R_1 - \frac{j}{\omega C_1}\right)(R_x + j\omega L_x) = R_2 R_3$

or, $R_1 R_x + j\omega L_x R_1 - \frac{R_x j}{\omega C_1} + \frac{\cancel{\omega} L_x}{\cancel{\omega} C_1} = R_2 R_3$

or, $\left(R_1 R_x + \frac{L_x}{C_1}\right) + j\left(\omega L_x R_1 - \frac{R_x}{\omega C_1}\right) = R_2 R_3$

Equating real & imag parts

- $R_1 R_x + \frac{L_x}{C_1} = R_2 R_3$ — (i)

- $\omega L_x R_1 - \frac{R_x}{\omega C_1} = 0 \Rightarrow \frac{R_x}{\omega C_1} - \omega L_x R_1 = 0$ — (ii)

From eqⁿ (ii)

$$R_x = \omega^2 L_x R_1 C_1 \quad \text{(iii)}$$

Substituting value of R_x in eqⁿ (i)

or, $R_1 (\omega^2 L_x R_1 C_1) + \frac{L_x}{C_1} = R_2 R_3$

or, $L_x \left(\frac{R_1^2 \omega^2 C_1^2 + 1}{C_1} \right) = R_2 R_3$

$$\therefore L_x = \frac{R_2 R_3 C_1}{(\omega^2 R_1^2 C_1^2 + 1)} \quad \text{(iv)}$$

Substituting value of L_x in eqⁿ (iv)

$$R_x = \frac{\omega^2 R_1 R_2 R_3 C_1^2}{(\omega^2 R_1^2 C_1^2 + 1)} \quad \text{(v)}$$

Now,

Quality Factor (Q)

$$Q = \frac{\omega L_x}{R_x}$$

$$= \frac{\dfrac{\cancel{\omega} \cancel{R_2} \cancel{R_3} \cancel{C_1}}{(\omega^2 R_1^2 \cancel{C_1^2} + 1)}}{\dfrac{\omega^{\cancel{2}} R_1 \cancel{R_2} \cancel{R_3} C_1^{\cancel{2}}}{(\omega^2 R_1^2 \cancel{C_1^2} + 1)}}$$

Measurement of Capacitance

a) Schering Bridge

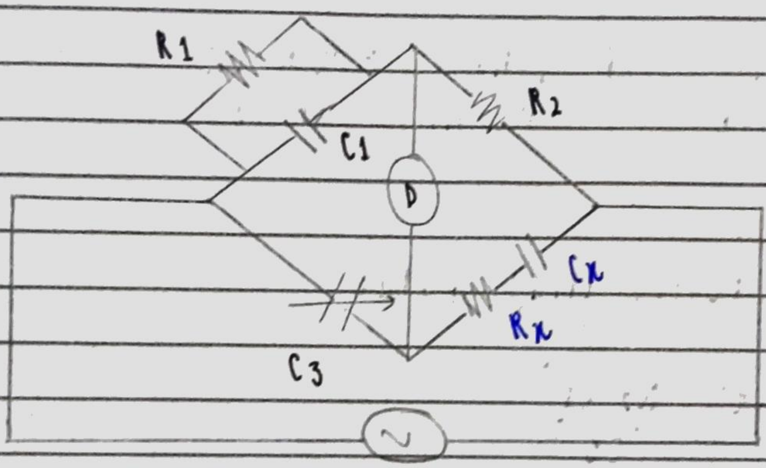

Fig: Schering Bridge

Here,

$$Y_1 = \frac{1}{Z_1}$$

$$= \frac{1}{R_1} + j\omega C_1$$

$$Z_2 = R_2$$

$$Z_3 = \frac{-j}{\omega C_3}$$

$$Z_4 = R_x - \frac{j}{\omega C_x}$$

For balanced condn

$Z_1 Z_4 = Z_2 Z_3$

or, $Z_4 = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 Y_1$

or, $R_x - \frac{j}{\omega C_x} = \frac{-jR_2}{\omega C_3} \left(\frac{1}{R_1} + j\omega C_1 \right)$

or, $R_x - \frac{j}{\omega C_x} = \frac{-jR_2}{\omega C_3 R_1} + \frac{\cancel{\omega} R_2 C_1}{\cancel{\omega} C_3}$

Equating real & imag parts

- $R_x = \frac{R_2 C_1}{C_3}$ — (i)

- $\frac{\cancel{-}1}{\cancel{\omega} C_x} = \frac{\cancel{-}R_2}{\cancel{\omega} R_1 C_3}$

$\therefore C_x = \frac{R_1 C_3}{R_2}$ — (ii)

13th Dec

Numericals

1. A voltmeter having accuracy 1% & full scale range 100 V is used to measure
   a) 80 V
   b) 12 V

   How accurately will the reading be? Comment on your ans.

2072 magh. A voltmeter whose accuracy is 2% of full scale reading is used on its 0-50 V scale.

   It is used to measure a voltage of 15 V & 42 volt. Calculate the possible error of both reading. Comment on your ans.

① Soln

ⓐ True value = 80V

measured value = 80 ± 1% of 100
= 80 ± 1
= 79 or 81

Then,

$$\% \text{ Error} = \frac{T.V. - M.V.}{T.V.} \times 100\%$$

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$= \frac{80-79}{80} \times 100\%$

$= \pm 1.25\%$

(b) 12 V

T.V. = 12 V

m.V. = 12 ± 1% of 100
= 12 ± 1
= 11 or 13

Thus,

$\%\ Error = \frac{T.V. - m.V.}{T.V.} \times 100\% \Rightarrow \frac{12-11}{12} \times 100\%$

$= \pm 8.33\%$

(c) So,
to ↓ the error in measurement system,
the range of meter should be close to T.V. of quantity of measurement.

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(2) Soln

(a) T.V. = 15V

m.v. = 15 ± 2% of 50
= 15 ± 1
= 14 or 16

Then,

$$\% \text{ Error} = \frac{\text{T.V.} - \text{m.v.}}{\text{T.V.}} \times 100\%$$

$$= \frac{15-14}{15} \times 100\%$$

$$= 6.67\%$$

(b) T.V. = 42 V

m.v. = 41 or 43

Then,

$$\% \text{ Error} = \frac{42-41}{42} \times 100\%$$

$$= 2.38\%$$

Note: Accuracy always in full scale reading

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3) 3 resistors have following rating

$R_1 = 37 \pm 5\%$

$R_2 = 75\Omega \pm 5\%$

$R_3 = 50\Omega \pm 5\%$

Determine the mag. & limiting error in Ω & in % of resistance connected in series.

soln

$R_1 = 37 \pm 5\%$

→ 5% of 37

$= 37 \pm \frac{5}{100} \times 37$

$= 37\Omega \pm 1.85\Omega$

$R_2 = 75 \pm 5\%$

→ 5% of 75

$= 75 \pm \frac{5}{100} \times 75$

$= 75\Omega \pm 3.75\Omega$

$R_3 = 50\Omega \pm 5\%$

→ 5% of 50

$= 50\Omega \pm \frac{5}{100} \times 50$

$= 50\Omega \pm 2.5\Omega$

Thus,

error in add hunxa

$$R_1 + R_2 + R_3 = (37 + 75 + 50) \pm (1.85 + 3.75 + 2.5)$$

$$= 162\,\Omega \pm 8.1\,\Omega$$

nominal value (actual T.V.)

max. error

limiting error

$\therefore$ limiting error $= \pm 8.1\,\Omega$

% limiting error $= \pm \dfrac{8.1}{162} \times 100\%$

$= \pm 5\%$

1. wattmeter is used to measure power in the ckt w. the help of $P = \dfrac{E^2}{R}$, where limiting value of voltage & resistor are $E = 200\,V \pm 1\%$ & $R = 1000\,\Omega \pm 5\%$.

calculate:

a) nominal power consumed

b) limiting error of power in watt & %.

• voltmeter & ammeter no limiting error nikalne.

$\% \ L.E. \Rightarrow \frac{70-71.5}{70} * 100\%$

$E = 200 \pm 1\%$ → 90

$\Rightarrow 2.142\%$.

2. A voltmeter reading of 70V on its 100V range & an ammeter reading of 80mA on its 150mA range are used to determine the power dissipation in a resistor.

T.V.

• Ammeter → 2.8125%.

accuracy dekho not limiting error

Both of these instruments are guaranteed to be accurate within ±1.5% of full scale deflection.

Determine power & limiting error of power.

→ $P = VI$

$= 70 * 80 = 5.6$

3. The impedance of RL ckt operating on AC is given by $Z = \sqrt{R^2 + \omega^2 L^2}$

The resistance R is known to be 100Ω with an uncertainity of 5%, L is known to be 2H w. an uncertainity of 10%. & ω is known exactly,

$2\pi * 50$.

Determine the uncertainity in the measurement of Z.

① soln

$$P = \frac{E^2}{R}$$

$E = 200V \pm 1\%$.
$R = 1000\Omega \pm 5\%$.

ⓐ Nominal power
↳ no error only T.V.

$$P = \frac{E^2}{R}$$
$$= \frac{(200)^2}{1000}$$

$= 40W$ is the nominal value.

ⓑ limiting error
↓
$$\frac{dP}{P} * 100\%.$$

i) Taking ln on both sides
$$P = \frac{E^2}{R}$$

or, $\ln P = \ln E^2 - \ln R$

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or, $\ln P = 2\ln E - \ln R$

(ii) Diff. w.r.t. P on B.S.

Thus,

diff. w.r.t. P on B.S.

or, $\frac{1}{P} = 2\frac{1}{E} \cdot \frac{dE}{dP} - \frac{1}{R} \cdot \frac{dR}{dP}$

or, $\frac{dP}{P} = \frac{2 \cdot dE}{E} - \frac{dR}{R}$ → 5%

1%

or, $\frac{dP}{P} = 2\frac{dE}{E} + \frac{dR}{R}$

maximum value

limiting error (a)

$= 2 * 1 + 5$

$\therefore \frac{dP}{P} = \pm 7\%$

Then,

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For power in watt

$\Rightarrow$ 7% of Nominal value
= 7% of 40W

$= \frac{7}{100} \times 40 = 2.8\,W$

- Alternative method.

(*) V & R ko limiting error nikalne

↳ • limiting error in voltage = 1% of 200

= 2V

• Limiting error in resistance

= 5% of 1000 Ω.

= 50 Ω

(**) max Error nikalne

$P = \frac{E^2 \uparrow}{R \downarrow}$

max power reading dinxa

*** $\uparrow E$ & $\downarrow R$ holera P nikalne

$E = 200 + 2$

$= 202\,V$

$R = 1000 - 50 = 950\,V$

Then,

measured value of power

$$\Rightarrow \frac{(202)^2}{950}$$

$= 42.95\,W$

$\therefore$ limiting error

$\Rightarrow 42.95 - 40$

$\Rightarrow 2.95\,W$

Thus,

$$\%\ L.E. = \frac{T.V. - m.V.}{T.V.} * 100\,\%$$

$$= \frac{2.95}{40} * 100\,\%$$

$= \pm 7.37\,\%$

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Page

1 A wheatstone bridge req. a change of 7 Ω in the unknown arm of the bridge to produce a change in deflection of 3 mm in a Galvanometer. → o/p

i/p

Determine sensitivity & deflection factor.

$$\frac{\Delta o/p}{\Delta i/p} \rightarrow \frac{3\times10^{-3}}{7}$$

$$\frac{1}{\text{sensitivity}} \quad 0.43 \text{ mm}/\Omega$$

Soln

we know,

change in i/p (Δ i/p) = 7 Ω

change in o/p (Δ o/p) = 3 mm

$= 3\times10^{-3}$ m

• sensitivity

$$\Rightarrow \frac{\Delta o/p}{\Delta i/p}$$

$$= \frac{3\times10^{-3}}{7} \; (m/\Omega)$$

• Deflection factor

$$\Rightarrow \frac{1}{\text{sensitivity}}$$

$$\Rightarrow \frac{7}{3\times10^{-3}} \; (\Omega/m)$$