th January. Measuring Instruments

RANKA DATE / / PAGE

Specification of Instrument

1) Accuracy

It is a measure of closeness to the true value of quantity.

Eg → 5A { 4.9A ← better accuracy
4.7A
4.6A

II) Precission

It is the reproducability of measure

Ex → 4.91, 4.92, 4.91, 4.91, 4.91 high prec
4.92, 4.93, 4.94, 4.91, 4.96 low "

III) Sensitivity

It is a ratio of magnitude of outp signal to that of i/p signal.

$$\frac{\text{Mag. of o/p signal}}{\text{" " i/p "}}$$

When there is small change in i occur there is a lot of changes in then that instrument is called highly sensitive instrument.

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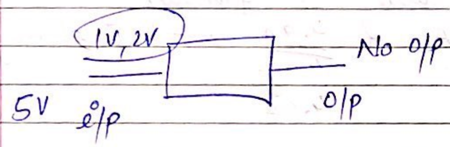
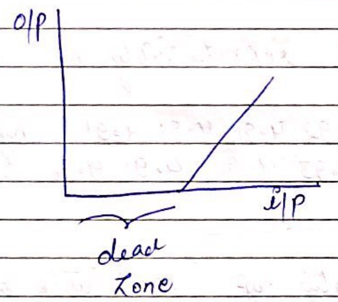
iv) Dead Zone

It is a largest ~~FAA~~ changes of i/p quantity for which there is no ~~change~~ o/p of the instrument.





v) Dead time

It is the time req. by the an instrum-ent to response the changes in the i/p.

vi) Resolution

It is the smallest observable changes in the input that an ins. can response.

Error

Diff. of true value & measured value.

1) Static Error

Measured value - True value

Error Correction

if M.V = 4.5
T.V = 5

EC = -0.5

ii) Relative static Error

$$\frac{\text{Measured value} - \text{True value}}{\text{True Value}}$$

Types of Error

1) Gross Error → Error due to Reading, Recording & calculation

ii) Systematic Error

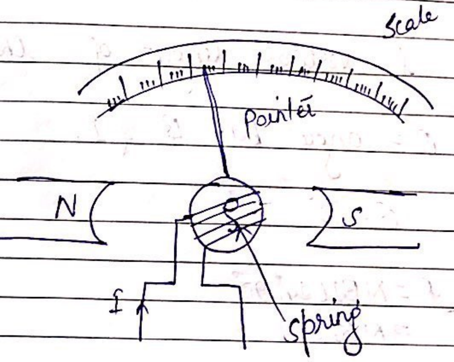
a) Instrumental Error (Instrument)
b) Envrionmental Error (temp, atm pres, wind)
c) Observational Error (human Eye)
d) Random Error (unknown)

PMMC - Permanent Magnet Moving coil
MI - Moving Iron

V/I	DC Bridge (Resistance)	AC Bridge (Capacitance, Inductance)
1. PMMC (DC)	Low resistance (Below 1 ohm): Ammeter / Voltmeter, Potentiometer, Kelvin Bridge	Inductance: Maxwell Inductance Bridge
2. MI (AC/DC)	Medium Resistance (1-100 kohm): Substitution, Wheat stone Bridge, Cary-Foster Slide-wire Bridge	Inductance: Maxwell Inductance Capacitance Bridge
3. Dynamo Meter (AC/DC)	High Resistance (Above 100kOhm): Direct Deflection, Loss of Charge, Megaohms, Megger	Inductance: Hay's Bridge
4. Electrostatic (AC/DC)		Inductance: Anderson Bridge
5. Thermal Instr./ Hot Wire (AC/DC)		Inductance: Owen Bridge
6. Rectifier (AC/DC)		Capacitance: De-Sauty Bridge
7. Induction type (AC)		Capacitance: Schering Bridge

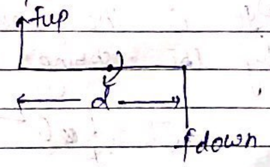
17th January

1. PMMC (Permanent Magnet Moving coil)



When a current carrying coil is placed in a magnetic field it experience a force due to this the force on the meter ~~due~~ deflect. The deflection of the pointer is directly proportional to the amount of current passing through the coil. (Faraday's law).

Expression of torque in PMMC:



force on the coil = $NBIL \sin\theta$.

N = no. of turn of the coil
B = Magnetic flux density (Wb/m^2)

I = amount of current passing through the coil (A)

l = vertical length of the coil (m)

θ = angle bet. B & I.

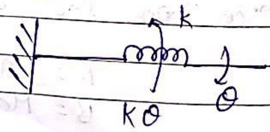
$\theta = 90^\circ$

$F = NBIl \sin 90^\circ$
$= NBIl.$

deflecting Torque due to both side of the coil
= force × ⊥ distance
$= NBIl \times d$
$= NBIld$
$= NBIA.$
↑ Area

Controlling torque (torque because of the spring)
It is the restraining torque provided by the spring control.

$T_c = k\theta$ ← deflecting angle
↓ spring constant



At balance point or null deflection (steady state)

$T_d = T_c$

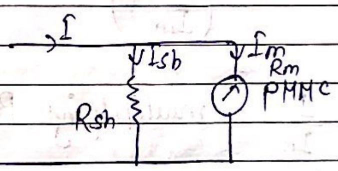
$NBIA = k\theta$

$\theta = \frac{NBIA}{k}$

$= \left(\frac{NAB}{k}\right) I$

$\boxed{\theta \propto I}$ — scale is linear

Ammeter Shunt in PMMC.
Connecting resistance in parallel with PMMC.



R_{sh} = Shunt Resistance
R_m = Meter Resistance
I = current to ~~the~~ be measured
I_m = full scale deflection current
I_{sh} = Shunt current.

$V_{sh} = V_m$.

$I_{sh} R_{sh} = I_m R_m$.

$$R_{sh} = \frac{I_m R_m}{I_{sh}}$$

$I = I_{sh} + I_m$.

$$\boxed{I_{sh} = I - I_m}$$

$$R_{sh} = \frac{I_m R_m}{I - I_m}$$

divide num. & den. by I_m

$$R_{sh} = \frac{R_m}{\left(\frac{I}{I_m} - 1\right)}$$

$\frac{I}{I_m}$ = (multiplying Power) m.

$$R_{sh} = \frac{R_m}{m-1}$$

Property of ammeter shunt

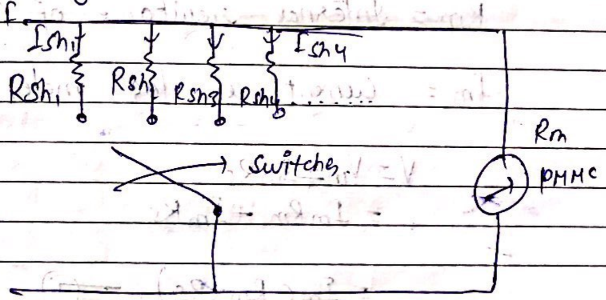
1) The resistance of the shunt should not vary with time.

ii) It should have a low temp. coeff. and size should be small.

iii) It ~~is~~ is usually made up of Manganin.

Multirange Ammeter

The current range of a dc-meter may be further extended by a no. of shunt resistance which are usually selected by a range switch which is called as Multirange Ammeter.

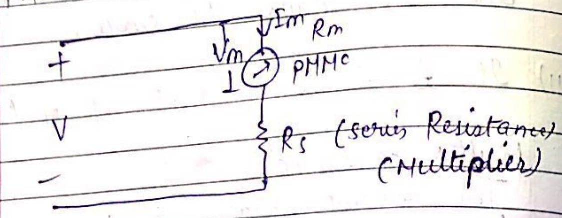


$$R_{sh_1} = \frac{R_m}{(m_1 - 1)}$$

$$R_{sh_2} = \frac{R_m}{(m_2 - 1)}$$

⋮

PMMC as Voltmeter



V = full range Voltage of the instrument.

R_m = Internal resistance of the meter

I_m = current in the meter

$$V = V_m + I_m R_s$$
$$= I_m R_m + I_m R_s$$
$$= I_m (R_m + R_s) \quad \text{— (I)}$$
$$V_m = I_m R_m \quad \text{— (II)}$$

(I) ÷ (II)

$$\frac{V}{V_m} = \frac{R_m + R_s}{R_m}$$

Multiplying factor (m_v)

$$m_v = 1 + \frac{R_s}{R_m}$$

$$(m_v - 1) = \frac{R_s}{R_m}$$

$$\boxed{R_s = R_m (m_v - 1)}$$

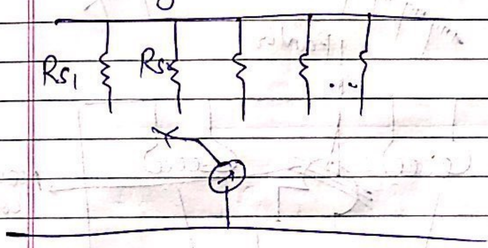
Properties of Multiplier

1) It is not changing with time.

II) It is non-inductive.

III) Variation of resis. with temp. should be small

Multirange Voltmeter



$$R_{s_1} = (m_{v_1} - 1) R_m$$

$$R_{s_2} = (m_{v_2} - 1) R_m$$

why it is non ...

Some advantage of PMMC

1) scale is linear.

11) Highly sensitive.

111) High accuracy.

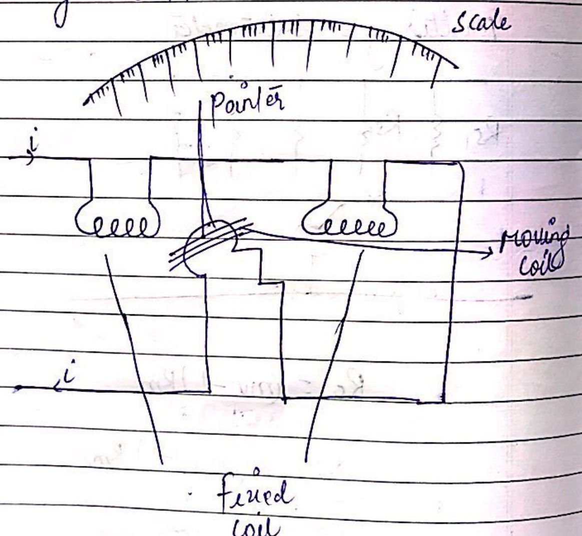
1V) Low power consumption.

disadvantage

1) Meant for only dc purposes.

11) It is costly.

20th Jan Electrodynamometer



It consists of two ~~pat~~ coil : fixed coil (FC) and moving coil (MC).
fixed coil is splitted into two part in order to have an uniform distribution of magnetic flux around the moving coil.
fixed coil is used to provide the operating magnetic field and moving coil is like current carrying coil ~~on~~ on which the deflection torque is produced.

Expression of Torque
Deflecting Torque in dynamometer is given by

$$T_d = i_1 i_2 \cdot \frac{dM}{d\theta}$$

i_1 = current in the fixed coil
i_2 = " " " moving "
M = Mutual inductance effect bet^n FC & MC.

Controlling Torque

$$T_c = K\theta \leftarrow \text{deflecting angle}$$

Spring cons.

Steady state / Null deflection

$$T_c = T_d$$

$$i_1 \cdot i_2 \frac{dM}{d\theta} = K\theta$$

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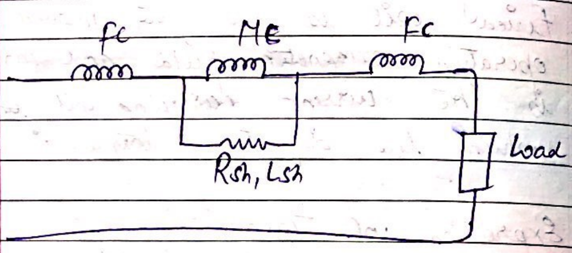
$$\theta = \frac{i_1 i_2}{K}\frac{dM}{d\theta}$$

meter

a) Electrodynamometer type Ammeter



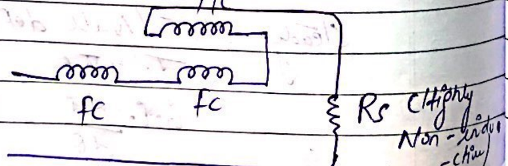
$i_1 = i_2 = i$ {at balance condⁿ}

i_1 — current in FC; i_2 — current in MC

$$\theta = \frac{i^2}{K}\frac{dM}{d\theta}$$

$\boxed{\theta \propto i^2}$ Not-linear, Non-uniform

II) Electrodynamometer type Voltmeter



$i_1 = i_2 = i$ (Null deflection/Balance condⁿ)

$$T_d = \frac{i^2}{\cancel{K}}\frac{dM}{d\theta} \qquad \left(i = \frac{V}{Z}\right)$$

$$T_d = \left(\frac{V}{Z}\right)^2 \frac{dM}{d\theta}$$

$$T_c = K\theta$$

Steady State

$$T_d = T_c$$

$$\left(\frac{V}{Z}\right)^2 \frac{dM}{d\theta} = K\theta$$

$$\theta = \frac{1}{K}\left(\frac{V}{Z}\right)^2 \frac{dM}{d\theta}$$

$\boxed{\theta \propto V^2}$ Non-linear, Non-uniform

Advantage

I) High accuracy

II) Free from hysteresis and eddy current losses.

Disadvantage

I) Scale is non-uniform.

II) It is expensive.

III) Friction loss are very high.

IV) High power consumption

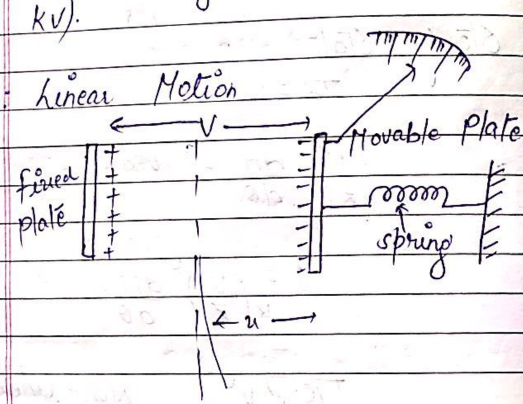
Electrostatic type Instrument

It is because of the static electric field.

In this type of instrument the deflecting torque ~~of~~ is produced by the action of electric field on the charge conductor.

The applied voltage is very high (around kV).

Case I: Linear Motion



because the moving spring meter deflects.

deflecting force

$$f_d = \frac{V^2}{2}\left(\frac{dc}{dx}\right)$$

V → Voltage C → Capacitance

x → Movable distance.

Spring control force

$f_c = Kx$ K → spring constant

Null deflection

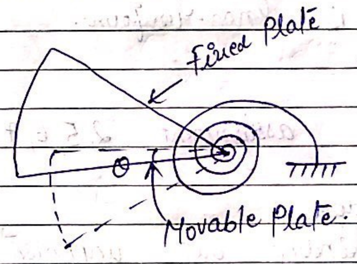
$$f_d = f_c$$

$$Kx = \frac{V^2}{2}\left(\frac{dc}{dx}\right)$$

$$x = \frac{V^2}{2K}\left(\frac{dc}{dx}\right)$$

$\boxed{x \propto V^2}$ Non-uniform.

Case II Angular Motion



Deflecting Torque

$$T_d = \frac{1}{2} V^2 \frac{dc}{d\theta}$$

Spring control

$$T_c = K\theta$$

Balance cond^n.

$$\theta = \frac{V^2}{2k}\frac{dc}{d\theta}$$

$$\boxed{\theta \propto V^2}$$

Advantage
1. We can measure high voltage using this instrument.
2. It is not affected by stray magnetic field.

Disadvantage
1. Size is very large.
2. Scale is non-uniform.
3. Costly.

Q. Write assignment 2, 5, 6, 7 (from U/R).

21st January

AC Bridge
for finding out unknown inductance, capacitance, frequency

Types of Sources:
Low frequency :- Power line supply.

High frequency :- Oscillator

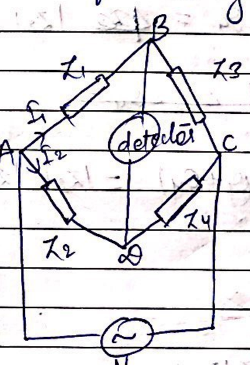
Types of detector
1) Headphone : 250Hz to 4kHz (Most sensitive)

11) Vibration Galvanometer : 5Hz to 1kHz. (Audible range).

111) Tunable Amplifier detector : 10Hz to 100KHz.

1V) CRO (Cathode Ray Oscilloscope) : Above 5KHz

Condition for bridge balancing



$V_1 = V_2$.
$I_1 Z_1 = I_2 Z_2$.

At balance condition

$$I_1 = \frac{V}{Z_1 + Z_3}.$$

$$I_2 = \frac{V}{Z_2 + Z_4}.$$

$$\frac{V Z_1}{Z_1 + Z_3} = \frac{V Z_2}{Z_2 + Z_4}$$

$$\frac{1}{1 + \left(\frac{Z_3}{Z_1}\right)} = \frac{1}{1 + \left(\frac{Z_4}{Z_2}\right)}$$

$$\cancel{1} + \frac{Z_4}{Z_2} = \cancel{1} + \frac{Z_3}{Z_1} \Rightarrow \frac{Z_4}{Z_2} = \frac{Z_3}{Z_1}.$$

$$\boxed{Z_1 \cdot Z_4 = Z_2 \cdot Z_3}$$

condn for bridge balance.

$Z_1 = |Z_1| \angle \theta_1$

$Z_2 = |Z_2| \angle \theta_2$.

$Z_3 = |Z_3| \angle \theta_3$

$Z_4 = |Z_4| \angle \theta_4$

$|Z_1| \angle \theta_1 \; |Z_4| \angle \theta_4 = |Z_2| \angle \theta_2 \; |Z_3| \angle \theta_3$

$\cancel{|Z_1||Z_4| \angle \theta_1 \angle \theta_4 =}$

$|Z_1| \; |Z_4| \quad \angle(\theta_1 + \theta_4) = |Z_2| \; |Z_3| \; \angle(\theta_2 + \theta_3)$

Condition 1:

1. $|Z_1||Z_4| = |Z_2||Z_3|$

Product of magnitude of opp. arm must be equal

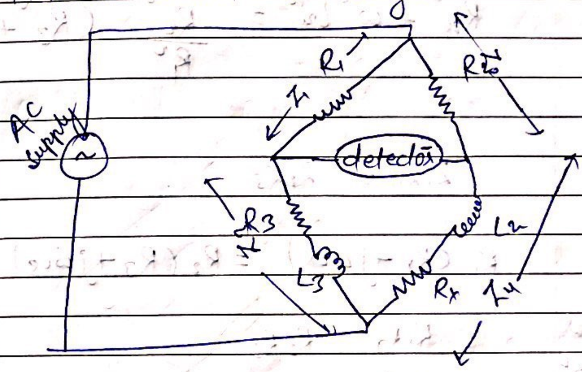
2. $\angle\theta_1 + \angle\theta_4 = \angle\theta_2 + \angle\theta_3$.

Sum of the ~~for~~ phase angle of the opp. arm must be equal

Measurement of inductance

1. Maxwell Inductance Bridge
2. " " capacitance Bridge
3. Hay's Bridge
4. Anderson's Bridge
5. Owen Bridge.

1. Maxwell Inductance Bridge



This bridge is for finding unknown medium inductance.

$Z_1 = R_1$

$Z_4 = R_x + j\omega L_x$

$Z_2 = R_2$

$Z_3 = R_3 + j\omega L_3$

$|Z_1| \, |Z_4| = |Z_2| \, |Z_3|$

$|R_1| \sqrt{R_x^2 + \omega^2 L_x^2} = |R_2| \sqrt{R_3^2 + \omega^2 L_3^2}$

Scanned with CamScanner

$$\sqrt{\frac{R_x^2+\omega^2L_x^2}{R_3^2+\omega^2L_3^2}} = \left|\frac{R_2}{R_1}\right|$$

$$\frac{R_x^2+\omega^2L_x^2}{R_3^2+\omega^2L_3^2} = \frac{R_2^2}{R_1^2}$$

$$R_x^2+\omega^2L_x^2 = \frac{R_2^2}{R_1^2}(R_3^2+\omega^2L_3^2)$$

$$Z_1Z_4 = Z_2Z_3$$

$$R_1(R_x+j\omega L_x) = R_2(R_3+j\omega L_3)$$

Real Part

$$R_1R_x = R_2R_3$$

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

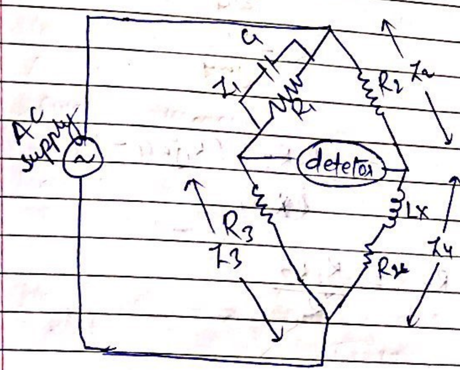
Imag. Part

$$R_1L_x\omega = R_2\omega L_3$$

$$L_x = \frac{R_2L_3}{R_1}$$

Quality factor → $Q = \frac{\omega L_x}{R_x} = \frac{\omega L_3}{R_3}$

11) Maxwell Inductance Capacitance Bridge



$$\cancel{Z_1 = R_1 + j\omega R_1}$$

$$Z_1 = R_1 \parallel \frac{1}{j\omega C_1}$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

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

$$\cancel{|Z_1| \, |Z_4|}$$

Bridge Balancing

$$Z_1Z_4 = Z_2Z_3.$$

$$\left(R_1 \parallel \frac{1}{j\omega C_1}\right)(R_x+j\omega L_x) = R_2R_3.$$

$$R_x + j\omega L_x = \frac{R_2 R_3}{\dfrac{\frac{R_1}{j\omega C_1}}{R_1 + \frac{1}{j\omega C_1}}}$$

$$= \frac{R_2 R_3}{R_1} (R_1 j\omega C_1 + 1)$$

Real Part

$$R_x = \frac{R_2 R_3}{R_1}$$

Img. Part

$$L_x = R_2 R_3 C_1$$

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

$$\boxed{Q = \omega C_1 R_1}$$

Quality factor of the unknown arm

Medium $(Q = 1 \text{ to } 100)$

must be in this range

Medium Q of

Advantage.

1) It is independent of frequency of excitation.

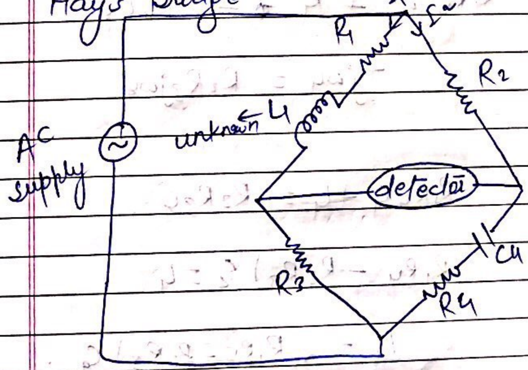
11) It can be measured at audio & power freq. range.

Disadvantage

1) Quality factor of low and high value is not suitable

11) The capacitor used is very costly.

Hay's Bridge



$$Z_1 Z_4 = Z_2 Z_3.$$

$$(R_1 + j\omega L_1)\left(R_4 + \frac{1}{j\omega C_4}\right) = R_2 R_3.$$

$$\cancel{R_1 R_4 + \frac{R_1}{j\omega C_4} + R_4 j\omega L_1 + \frac{L_1}{C_1}} = R_2 R_3$$

R_1

$$\left(R_1 + j\omega L_1\right)\left(R_4 + \frac{1}{j\omega C_4}\right) = R_2R_3$$

$$R_1 + j\omega L_1 = \frac{R_2R_3}{R_4 + \frac{1}{j\omega C_4}}$$

$$= \frac{R_2R_3 j\omega C_4}{R_4 j\omega C_4 + 1}$$

$$R_1R_4 j\omega C_4 + R_1 - \omega^2 R_4 L_1 C_4 + j\omega L_1 = R_2R_3 j\omega C_4$$

R.P

$$R_1R_4C_4 + L_1 = R_2R_3C_4$$

$$(R_1R_4 - R_2R_3)C_4 = L_1$$

$$L_1 = (R_1R_4 - R_2R_3)C_4 \quad \text{— (I)}$$

I.P

$$\omega^2 R_4 L_1 C_4 = \cancel{j\omega}\cdot R_1$$

$$L_1 = \frac{R_1}{R_4C_4\omega^2} \quad \text{— (II)}$$

$$Q_1 = \frac{\omega L_1}{R_1}$$

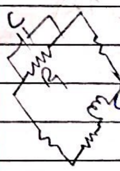
$$= \frac{\omega}{R_4C_4\omega^2}$$

$$= \frac{1}{\omega R_4 C_4}$$

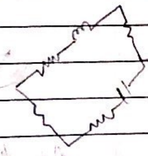
from (I) & (II)

$$\frac{R_1}{R_4C_4\omega^2} = (R_1R_4 - R_2R_3)C_4$$

$$R_1 = R_4C_4^2\omega^2(R_1R_4 - R_2R_3)$$



$$L_1 = \frac{R_4C_4^2\omega^2(R_1R_4 - R_2R_3)}{R_4C_4\omega^2}$$



from (I) & (II)

$$L_1 = \frac{R_2R_3C_4}{1+\omega^2R_4^2C_4^2}$$

$$Q = \frac{\omega L_1}{R_1} = \frac{\omega R_2R_3C_4}{R_1 + \omega^2 R_1 R_4^2 C_4^2}$$

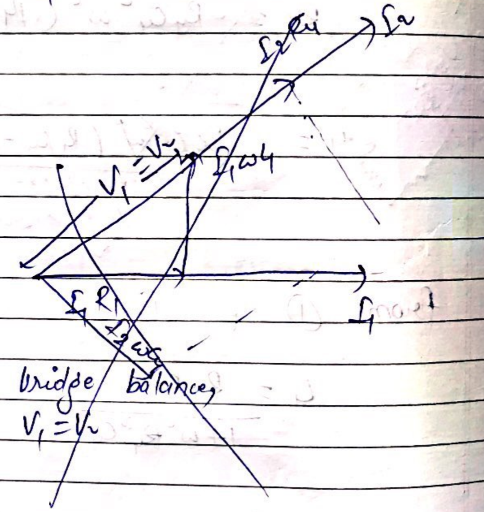
$$Q = \frac{\omega L_1}{R_1} = \frac{\omega}{R_4C_4\omega^2} = \frac{1}{\omega R_4 C_4}$$

$$\boxed{Q = \frac{1}{\omega R_4 C_4}}$$

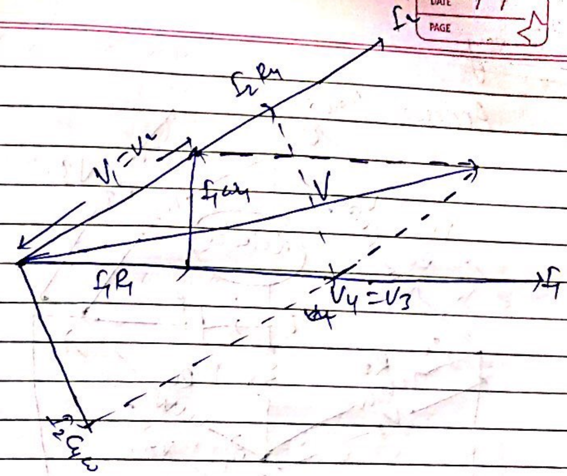
Quality factor depends upon opp. arm. ~~of the parameter~~

Phasor diagram

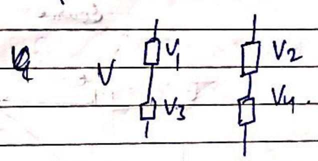
Let V_1 = voltage in arm 1
V_2 = " " " 2
V_3 = " " " 3
V_4 = " " " 4.



At bridge balance,
$V_1 = V_2$



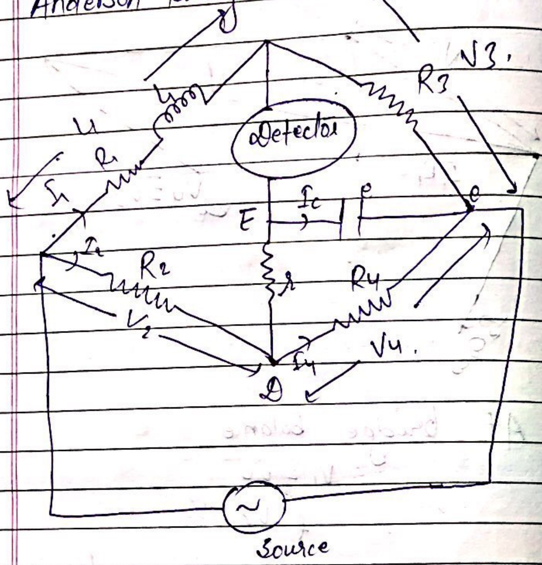
At bridge balance
$V_1 = V_2$
& $V_3 = V_4$.

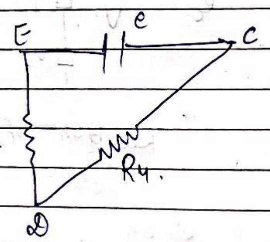


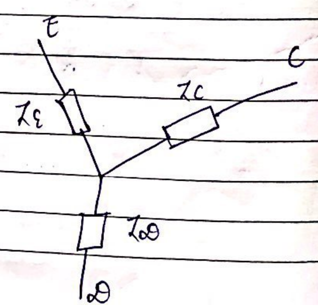
Resultant of V_1 & V_3 or V_2 & V_4 is V.

24th January

Anderson Bridge







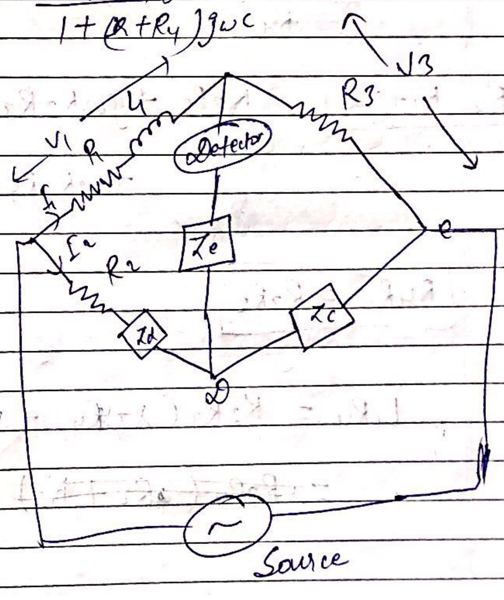
$$Z_E = \frac{r \times \frac{1}{j\omega C}}{r + \frac{1}{j\omega C} + R_4} \qquad Z_C = \frac{R_4 \times \frac{1}{j\omega C}}{\frac{1}{j\omega C} + R_4 + r}$$

~~Z_D~~

$$Z_E = \frac{r}{j\omega C r + 1 + R_4 j\omega C} \qquad Z_C = \frac{R_4}{1 + (r + R_4) j\omega C}$$

$$Z_D = \frac{r \times R_4}{r + R_4 + \frac{1}{j\omega C}}$$

$$= \frac{r \times R_4 j\omega C}{1 + (r + R_4) j\omega C}$$



$$\frac{R_1 + j\omega L_1}{R_2 + \frac{r R_4 j\omega C}{1 + j\omega C(r+R_4)}} = \frac{R_3}{\frac{R_4 \times \frac{1}{j\omega C}}{r + \frac{1}{j\omega C} + R_4}}$$

$$\frac{(R_1 + j\omega L_1)(1 + j\omega C(r+R_4))}{R_2 + j\omega R_2 C(r+R_4) + r R_4 j\omega C}$$

$$= \frac{R_3 j\omega C}{R_4}(1 + j\omega C(r+R_4))$$

$$R_4(R_1 + j\omega L_1) = R_3R_2 + j\omega R_2R_3C(r+R_4) + rR_3R_4 j\omega C$$

$$\boxed{R_4R_1 = R_3R_2}$$

$$L_1R_4 = R_2R_3(r+R_4) + rR_3R_4C$$

$$\cancel{= rR_3R_4(rR_2 + R_2)}$$

$$L_1 = R_2R_3\left(\frac{r}{R_4} + 1\right) + rR_3C$$

$$= R_3C\left[\frac{rR_2}{R_4} + 1 + r\right]$$

$$= \frac{R_3R_2Cr}{R_4} + R_3C + R_3Cr$$

$$= \frac{\cancel{R_4}R_1Cr}{\cancel{R_4}} + R_3C + R_3Cr$$

$$= C(R_1r + R_3 + R_3r)$$

$$\cancel{= CR_3[r+1] + CR_1}$$

$$Q = \frac{\omega L_1}{R_1}$$

$$= \frac{\omega C(R_1r + R_3(1+r))}{R_1}$$

$$= \omega Cr + \frac{\omega CR_3(r+1)}{R_1}$$

Advantage

~~1. low Q coil < 1~~

1. low Quality coil
$Q < 1$

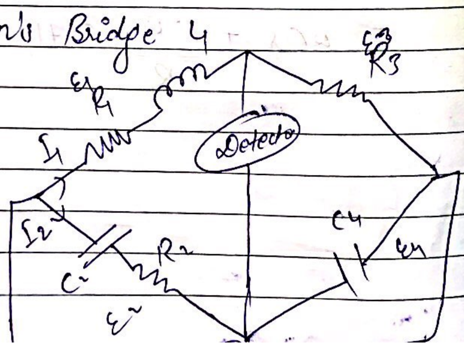
2. Cheaper

3. Accurate estimation of capacitance in terms of inductance is possible.

Disadvantage
1. Complex Circuit
2. Balancing the eqn is difficult.

Phasor Diagram.

Owen's Bridge



$$\frac{R_1 + j\omega L_1}{R_2 + \frac{1}{j\omega C_2}} = \frac{R_3}{\frac{1}{j\omega C_4}}$$

$$L_1 = R_2 R_3 C_4$$

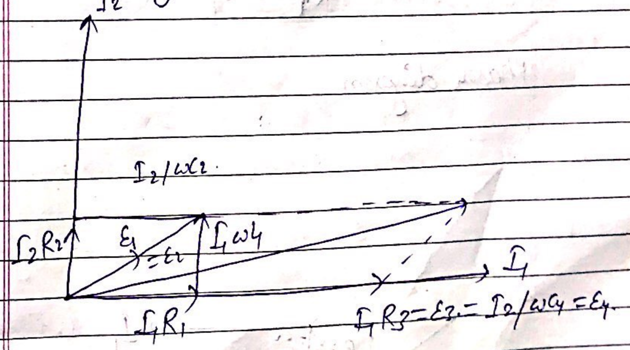
$$R_1 = R_3 \frac{C_4}{C_2}$$

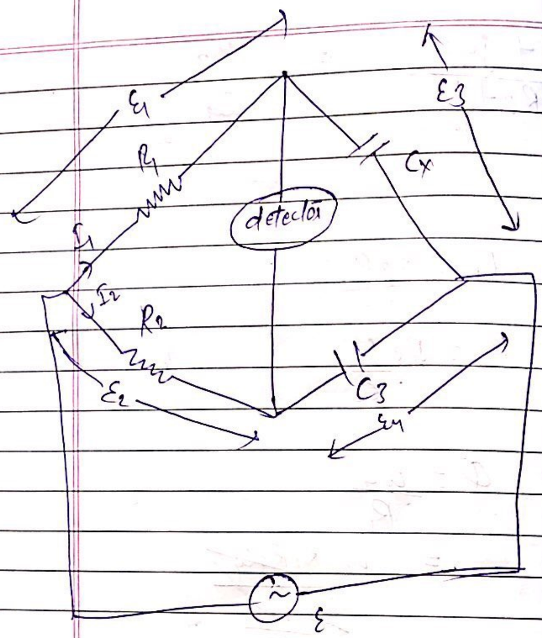
$$Q = \frac{\omega L_1}{R_1}$$

$$= \frac{\omega R_2 \cancel{R_3 C_4}}{\frac{\cancel{R_3 C_4}}{C_2}}$$

$$= \omega R_2 C_2$$

Phasor Diagram

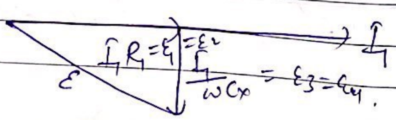




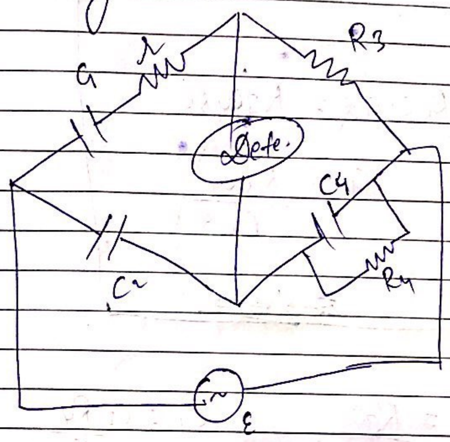
C_x = Unknown capacitance

$$C_x = \frac{R_2}{R_1} C_3$$

Phasor diagram



De-Sauty



Balance cond^n

$$\left(r + \frac{1}{j\omega C_1}\right) \times \left(R_4 \,\|\, \frac{1}{j\omega C_4}\right) = R_3 \times \frac{1}{j\omega C_3}$$

$$(j\omega C_1 r + 1)\left(\frac{R_4 \times \frac{1}{j\omega C_4}}{R_4 + \frac{1}{j\omega C_4}}\right) = \frac{R_3}{C_3}.$$

$$(1 + C_1 r j\omega)\left(\frac{R_4}{1 + j\omega R_4 C_4}\right) = \frac{R_3}{C_3}.$$

$$R_4 C_3 (1 + C_1 r j\omega) = R_3(1 + j\omega R_4 C_4).$$

$$\cancel{R_3 R_4 C_4} = \cancel{R_4 C_3 C_1 r}.$$

$R_4 C_3 = R_3$.

$\cancel{R_4} C_3 C_1 r = R_3 C_4 \cancel{R_4}$.

$C_1 = \dfrac{R_3 C_4}{C_3 r}$

$= \cancel{R_3 C_4}$

$r = \dfrac{R_3 C_4}{C_2}$ $\qquad C_1 = \dfrac{C_2 R_4}{R_3}$.

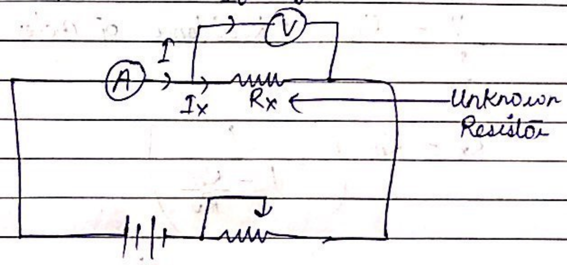
$D = \dfrac{V_C}{V_R} = \dfrac{1}{\omega RC}$.

4th Feb. DC Bridge (Resistance).

Low Resistance (<1)	Medium (1 to 100 Ω)	High
1. Ammeter / Voltmeter	1. Ammeter / Voltmeter	1. Direct deflection
2. Potentiometer	2. Substitution	2. Loss of charge
3. Kelvin Bridge	3. Wheatstone	3. Megaohm
	4. Carey-Foster Slide wire Bridge	4. Megger.

Ammeter / Voltmeter Method

Case I Voltmeter is directly connected across resistor.



Current through the ammeter = current through the unknown resistor (R_x) and current through the voltmeter.

$I = I_V + I_x$. $\qquad R_x = \dfrac{V}{I_x}$.

$I_x = I - I_V$. $\qquad \boxed{R_x = \dfrac{V}{I - I_V}}$

R_V → Internal resistance of the voltmeter.

$I_V = \dfrac{V}{R_V}$

$R_x = \dfrac{V}{I - \frac{V}{R_V}} = \cancel{\dfrac{V R_V}{I R_V - V}}$

$$= \frac{V}{I}\left(\frac{1}{1-\frac{V}{IR_v}}\right)$$

$\frac{V}{I} = R_m$ = Resistance of meter

$$R_x = R_m\left(\frac{1}{1-\frac{R_m}{R_v}}\right)$$

$$= R_m\left(1-\frac{R_m}{R_v}\right)^{-1}$$

Binomial Expansion

$$\boxed{R_x = R_m\left(1+\frac{R_m}{R_v}\right)}$$

[As $R_v >> R_m$]

Relative Error

$$= \frac{R_m - R_x}{R_x}$$

$$= \frac{\cancel{R_m} - \cancel{R_m} - \frac{R_m}{R_v}}{\cancel{R_m}\left(1+\frac{R_m}{R_v}\right)}$$

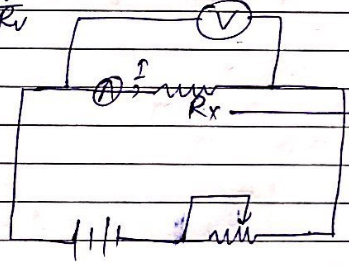
$$= \frac{\cancel{R_m}\,\frac{-1}{R_v}}{1+\frac{R_m}{R_v}}$$

$$= \frac{-1}{R_v + R_m}$$

Case II Voltmeter is directly connected across Resistor & Ammeter.

$$I_v = \frac{V}{R_v}$$

$R_A \rightarrow$ Internal resistance of Ammeter



~~$I_x = I + I_v$~~.

~~As $I_v = \frac{V}{R_v}$~~.

$$V = IR_A + IR_x.$$

$$R_A + R_x = \frac{V}{I} = R_m$$

$$\boxed{R_x = R_m - R_A}$$

Relative error

$$\frac{R_m - R_x}{R_x}$$

$$= \frac{\cancel{R_m} - \cancel{R_m} + R_A}{R_m - R_A}$$

$$= \left(\frac{1}{\frac{R_m}{R_A} - 1}\right)$$