Electrical Measurements & Measuring Instruments

Assignment No 1

What are the various effects that produce damping in a D'Arsonval Galvanometer? Derive relation for resistance required for critical damping.

Electrical Measurement & Measuring Instruments

Tutorial Sheet 1

Q1. A current galvanometer has the following parameters: $B = 10X10^{-3}wb/m^2$, $N = 200$, $l=16$ mm $d = 16$ mm, $K = 12X10^{-9}$ NM/rad, $J = 50X10^{-9}$ Kg-m^2, $D = 5X10^{-9}$ NM/rad s^{-1}. The resistance of the coil is 120 Ωs. Calculate (a) the deflection of galvanometer in radians and in mm when a current of 1μA flows through it. the scale being 1m away. (b) the current sensitivity (c) the voltage sensitivity (d) the meghom sensitivity (e) the frequency of damped oscillations (f) the period of free oscillations (g) relative damping (h) the first max deflection (i) the logarithmic decrement.

Q2. The following data refers to a moving coil galvanometer whose resistance is 460 Ωs and a resistance of 1970 Ωs is connected in series with it. Number of turns = 250, flux density = 0.1 wb/m^2, control constant = $0.15X10^{-6}$ NM/rad, dimensions of coil = 30X30 mm, MOI of coil = $0.2X10^{-6}$ Kg-m^2. Calculate (a) the resistance to be connected to generator for critical damping. (b) relative damping (c) logarithmic decrement (d) frequency of damped oscillations (e) period of undamped and damped oscillations (f) first maximum deflection.

Q3. A ballistic galvanometer has a resistance of 150 Ωs. and an undamped period of 7.5 s. A steady emf of 3.5 mVproduces a deflection of 210 mm. Determine the quantity of electricity discharged from a capacitor if the deflection produced is 750 mm. The relative damping is 0.8.

Q4. In an undamped galvanometer with a periodic time of 10 s, a current of 0.1 mA produces a steady deflection of 150 divisions. Find the instantaneous quantity of electricity to produce first swing of 100 divisions. (a) when the instrument is undamped (b) when the instrument is damped so that its logarithmic decrement is 1.1.

Q5. The constants of a galvanometer are , $K= 0.23X10^{-6}$ NM/rad. $J = 0.18X10^{-6}$ Kg-m^2. It is proposed to increase the periodic time to 15 secby attaching small weights on the light arms fixed to the coil spindle. Determine by how much these weights must increae the MOI of the coil.

Q6. The coil of a moving coil galvanometer has 330 turns and is in a uniform field of 0.1 Wb/m^2 The control constant is $0.2X10^{-6}$ NM/rad. The coil is 20 mm wide and 25 mm high , with a MOI of $0.15X10^{-6}$ Kg-m^2. If the galvanometer resistance is 200 Ωs, calculate the resistance which when connected in the gal circuit will give critical damping. Assume the damping to be entirely electromagnetic.

Analog Ammeters and Voltmeters

Ammeters and voltmeters are grouped togethers as the deflecting torque is produced in both types by a current element.

In an ammeter, this torque is produced by current to be measured.

In a voltmeter, this torque is produced by a current which is proportional to the voltage to be measured.

Essential Requirements of measuring instrument

(i) Its introduction into circuit, where measurement are to be made doesnt alter the circuit conditions.

(ii) Power consumed by them for their operation is small.

Connections to be made:

	Ammeter	Voltmeter
1.	Connected in series in the circuit whose current is to be measured.	Connected in // in ciruit whose voltage is to be measured.
2.	They should have low resistance. This is necessary as they cause small voltage drop & absorb small power.	They should have high resistance. This is necessary as the current drawn by them is small & thus power absorbed is small.

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Ammeter	Voltmeter
Power loss, $P = I^2 R_a$	Voltmeter power loss $P = \frac{V^2}{R_V}$
R_a: ammeter resistance	R_V: voltmeter resistance.

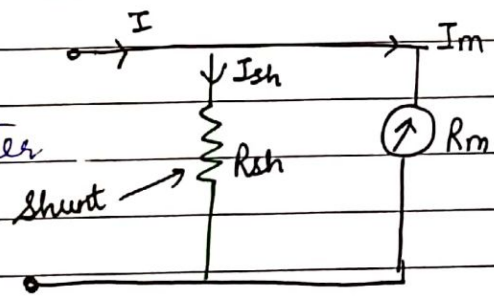
TYPES OF INSTRUMENTS used as Ammeter & Voltmeter

(i) PMMC — direct current (dc) only.
(ii) Induction — alternating " (ac) only.
(iii) Moving Iron
(iv) Hot wire
(V) Thermo couple
(vi) Electrostatic
Vii Rectifier
Viii, Electro-dynamometer

(iii)–(viii): ac and dc both.

(i) PMMC DC AMMETER

The basic movement of a dc ammeter is a PMMC d'Arsonval galvanometer



The coil winding of a basic movement is small and light and can carry very small currents.

When currents greater than 100 mA are to be

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measured, the major part of the current is bypassed through a low resistance called shunt.

Rshunt, Rsh can be calculated as follows

Rm = internal resistance of coil
I = current to be measured.
Rsh = Resistance of shunt.
Im = f.s.d current of coil
Ish = shunt current.

$$V_{shunt} = V_{meter}$$

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

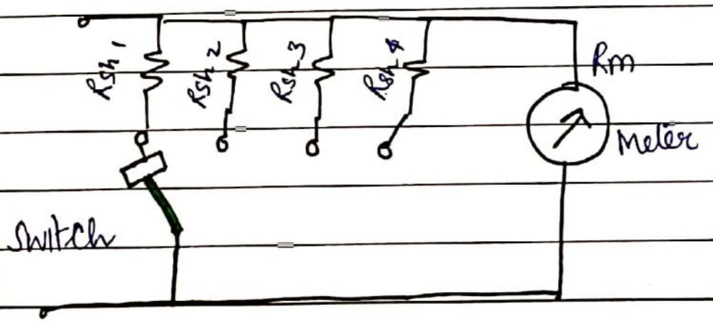
$$R_{sh} = \frac{I_m R_m}{I_{sh}}$$

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

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

Shunt resistance used with a basic movement may consist of a length of constant temp resistance wire within the case of instrument or it may be external shunt having a very low resistance.

MULTI RANGE AMMETER



current range of a dc ammeter may be further extended by a number of shunt selected by a range switch.

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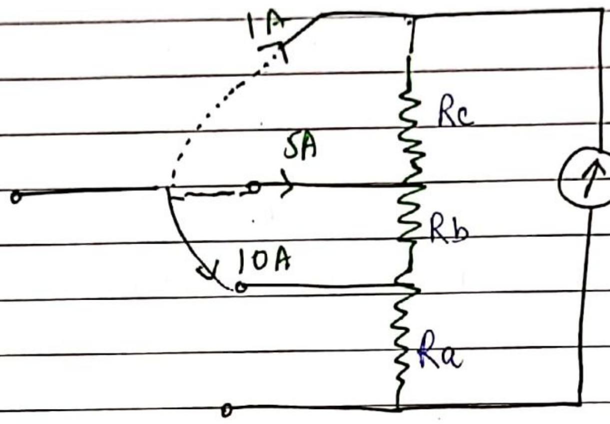
Switch 'S' is a multiplication position switch, make-before-break type switch so that the movement will not be damaged, unprotected in the circuit without a shunt as the range is changed.

UNIVERSAL OR AYRTON SHUNT

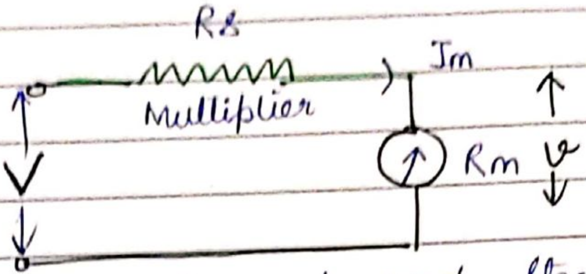


Universal shunt eleminates the possibility of having meter in the circuit without a shunt. ~~matter~~
This advantage is gained at the price of a slightly higher overall meter resistance.

Universal shunt provides an excellent opportunity to apply basic n/w theory to a practical circuit

DC VOLTMETER

The series resistance is known as multiplier.



The combination of the meter movement and the multiplier is put across the circuit whose voltage is to be measured.

The multiplier limits current through meter so that it doesn't exceed the value for full scale deflection & thus prevents the movement from being damaged.

$I_m = I_{fs}$ = f.s.d current of meter

R_m = internal resistance of meter movement.

R_s = multiplier resistance

v = Voltage across meter for I_m.

V = full range voltage of instrument.

$$V = I_m(R_s + R_m)$$

$$R_s = \frac{V - I_m R_m}{I_m}$$

$$R_s = \frac{V}{I_m} - R_m$$

Multiplying factor, $m = \frac{V}{v} = \frac{I_m(R_s + R_m)}{I_m R_m}$

$$m = 1 + R_s/R_m$$

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

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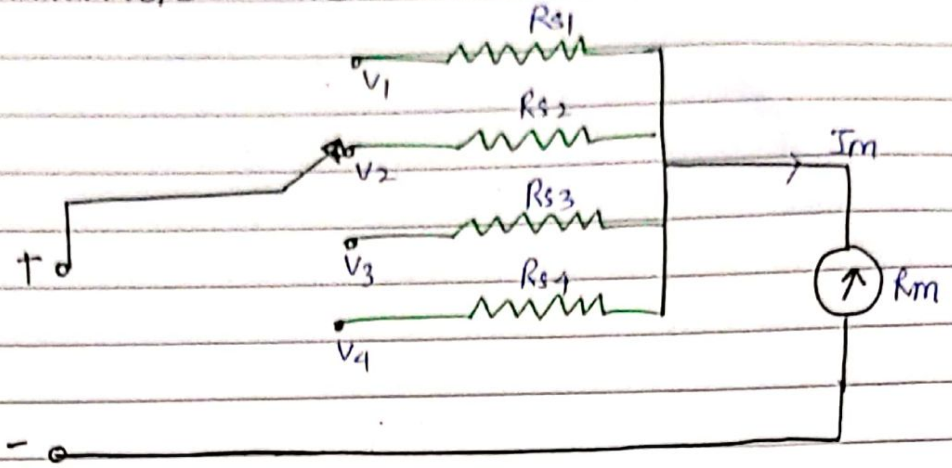
MULTIRANGE VOLTMETER



The addition of a no' of multiplier together with a range or switch provides the instrument with a workable no' of voltage range.

SENSITIVITY OF VOLTMETER

Current sensitivity is defined as deflection per unit current.

A less sensitive instrument is wound with few turns of thick wire.

More sensitive instrument will have large resistance becoz it is wound with many turns of fine wire.

∴ Resistance of meter is an indication of sensitivity. ∴ Voltage sensitivity is defined as Ω/V.

$$S_V = \frac{1}{I_{fsd}} = \frac{1}{I_m} \ \Omega/V$$

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S_V can also be used to be calculate multiplier in a dc voltmeter.

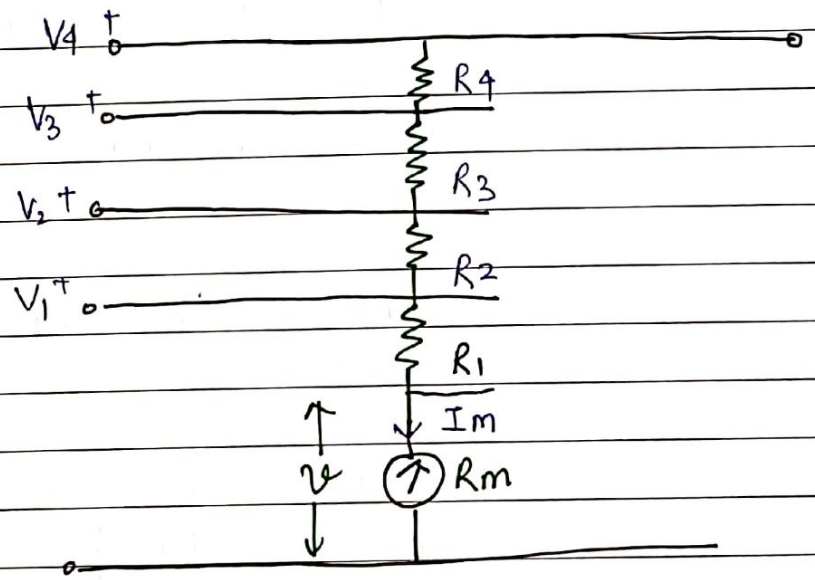
Q. A basic meter movement with an internal resistance $R_m = 100\Omega$ and f.s.d current of $I_m = 1\,mA$ is to be converted into a multi range ammeter with ranges (0 – 10 V), (0 – 50 V), (0 – 250 V), (0 – 500V).

Find values of various resistances using pot divider method & sensitivity method.

(i) Potential divider method.

Voltage across meter movement $v = I_m R_m$

$v = 1 \times 100 = 100\,mV = 100 \times 10^{-3}\,V$.



Voltage multiplying factors are :-

(0 – 10 V) : $m_1 = \frac{10}{100 \times 10^{-3}} = 100 \quad \left(\frac{V}{v}\right)$

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(0 – 50 V)

$$m_2 = \frac{50}{100 \times 10^{-3}} = 500$$

(0 – 250 V)

$$m_3 = \frac{250}{100 \times 10^{-3}} = 2500$$

(0 – 500 V)

$$m_4 = \frac{500}{100 \times 10^{-3}} = 5000$$

$$R_1 = \left(\frac{V_1}{I_m}\right) - R_m \Rightarrow \frac{V_1}{(v/R_m)} - R_m \Rightarrow m_1 R_m - R_m$$

$$\boxed{R_1 = (m_1 - 1) R_m}$$

$$\therefore R_1 = (100 - 1) 100 = 9900\,\Omega$$

$$R_2 = \left(\frac{V_2}{I_m}\right) - R_m - R_1$$

$$= \frac{V_2}{(v/R_m)} - R_m - (m_1 - 1) R_m$$

$$= m_2 R_m - R_m - (m_1 - 1) R_m$$

$$\boxed{R_2 = (m_2 - m_1) R_m}$$

$$R_2 = (500 - 100) 100 = 40 \times 10^3 = 40\,k\Omega$$

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$R_3 = \frac{V_3}{I_m} - R_m - R_1 - R_2$

$R_3 = (m_3 - m_2) R_m$

$= (2500 - 500) 100 = 200 k\Omega$

$R_4 = \frac{V_4}{I_m} - R_m - R_1 - R_2 - R_3$

$R_4 = (m_4 - m_3) R_m$

$= (5000 - 2500) \times 100 \, \Omega = 250 k\Omega$

Voltage sensitivity method

$S_V = \frac{1}{I_m} = \frac{1}{1 \times 10^{-3} A} = 1000 \, \Omega/V$

(0-10 V) $R_1 = S_V . V_1 - R_m$

$= 1000 \times 10 - 100$

$= 9900 \, \Omega$

(0-50 V) $R_2 = S_V . V_2 - (R_m + R_1)$

$= 1000 \times 50 - (100 + 9900) = 40 k\Omega$

(0-250 V) $R_3 = S_V . V_3 - (R_m + R_1 + R_2)$

$= 1000 \times 250 - (100 + 9900 + 40,000)$

$= 200 k\Omega$

(0-500 V) $R_4 = S_V . V_4 - (R_m + R_1 + R_2 + R_3)$

$= 1000 \times 500 - (100 + 9900 + 40,000 + 200,00$

$= 250 k\Omega$

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LOADING EFFECT The sensitivity of a dc voltmeter is an important factor when selecting a meter for a certain voltage measurement.

A low sensitivity meter may give correct readings when measuring voltage in low resistance circuits, but it is certain to produce very unreliable readings in high resistance circuits.

A voltmeter when connected across two points in a highly resistive circuit acts as a shunt for that portion of the circuit

The meter will then give a lower indication of the voltage drop than actually existed before the meter was connected.

This effect is called the 'loading effect of an instrument, caused principally by low sensitivity instruments.