ESE (Mains) 2019
Electronic Measurement & Instrumentation

Important Questions with Solutions

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1. The unknown inductance is given by the expression

$$L_x = \frac{Cp\left[r\left(Q+S\right)+Q.S\right]}{S}$$

When C = 1 μF ± 1.0% P = 1,000 Ω ± 0.4%; Q = 2,000 Ω ± 1.0%; Q = 2,000 Ω ± 1.0%; r = 200 Ω ± 0.5% and S = 2000 Ω ± 0.5%

Determine the magnitude of unknown inductance in Henry and limiting error in percentage

Solution:

Unknown inductance:

$$L_x = \frac{Cp}{S}\left[r\left(Q+S\right)+QS\right]$$

$$= \frac{1\times10^{-6}\times1,000}{2,000}\times$$

$$\left[200\left(2,000+2,000\right)+2,000\times2,000\right]$$

$= 0.5 \times 10^{-6} \times [0.8 \times 10^6 + 4 \times 10^6]$

= 2.4 Henry

Let u = Q + S = 2,000 + 2,000 = 4,000Ω

Percentage error is u

$$= \left[\frac{Q}{u}\cdot\frac{\delta Q}{Q}+\frac{S}{u}+\frac{\delta S}{S}\right]$$

$$= \pm\left[\frac{2,000}{4,000}\times1.0+\frac{2,000}{4,000}\times0.5\right]$$

$$= \pm0.75\%$$

Let v = r (Q + S) ru = 200 × (2,000 + 2,000) = $0.8 \times 10^6 = 4.8 \times 10^6$

Percentage error in u

$$= \frac{\delta r}{r}+\frac{\delta u}{u} = \pm0.5\pm0.5 = \pm1.25\%$$

Let x = QS = 2,000 × 2,000 = 4×10^6

Percentage error in X

$$= \frac{\delta Q}{Q}+\frac{\delta S}{S} = \pm1.0\pm0.5 = \pm1.5\%$$

Let y = r (Q + S) + QS = V + X = $0.8 \times 10^6 + 4 \times 10^6 = 4.8 \times 10^6$

Percentage error in y

$$= \left[\frac{u}{y}\cdot\frac{\delta v}{v}+\frac{x}{y}\cdot\frac{\delta x}{x}\right]$$

$$= \pm\left[\frac{0.8\times10^6}{4.8\times10^6}\times1.25+\frac{4\times10^6}{4.8\times10^6}\times1.5\right]$$

$$= \pm1.458\%$$

Percentage of error in inductance

$$L_x = \frac{\delta C}{C}+\frac{\delta P}{P}+\frac{\delta S}{S}+\frac{\delta y}{y}$$

$$= \pm1.0\pm0.4\pm0.5\pm1.458 = \pm3.358\%$$

2. A PMMC ammeter having a resistance of 10 ohms gives full scale deflection when a current of 5 mA is passed through it. Explain how this instrument can be used for the measurement of:

(i) current upto 1A

(ii) voltage upto 5V

Solution:

Resistance of the milli-ammeter, R_m = 10Ω

Full scale deflection current, I_m = 5mA = 0.005A

(i) To measure current upto 1 A:

Resistance of the shunt, R_{sh}:

Since voltage drop across the milliammeter and the shunt are equal

$I_mR_m = I_{sh}R_{sh} = (I - I_m) R_{sh}$

$$\therefore R_{sh} = \frac{I_m R_m}{\left(I - I_m\right)} = \frac{0.005\times10}{\left(1-0.005\right)} = 0.05025\Omega$$

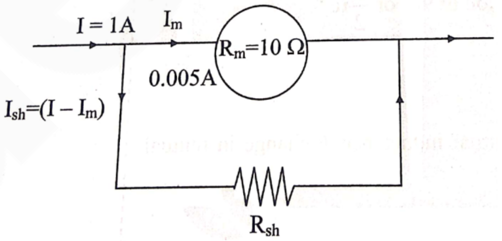


Fig 1

(ii) To measure voltage upto 5V:

The value of external series resistance, R: Refer to Fig.2

Now, voltage across supply loads

= voltage drop across the milliammeter

+ Voltage drop across external series resistance R_s

$V = I_mR_m + I_mR_s$

$5 = 0.005 \times 10 + 0.05 R_s$

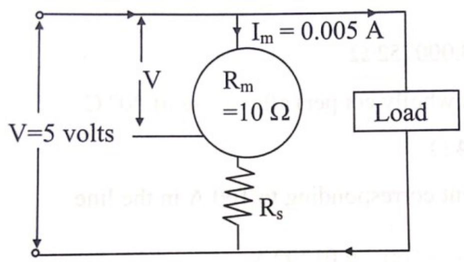
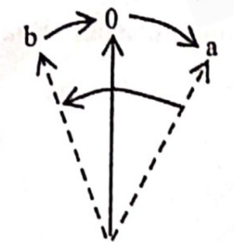


Fig . 2

$$R_s = \frac{5-0.005\times10}{0.005} = 990\Omega$$

3. Explain deflecting system, controlling system and damping system along with the torque related to them with reference to an electrical indicating instrument.
Solution:
1. Deflecting system:
The deflecting or operating torque is required for moving the pointer from its zero position. The system producing the deflecting torque is called "Deflecting system or Moving System." The deflecting torque can be produced by utilizing any of effects mentioned earlier. Thus the deflecting system of an instrument converts the electric current of potential into a mechanical force called deflecting torque. The deflecting system thus acts as the prime mover responsible for deflecting of the pointer.
2. Controlling system:
Controlling torque is required in an indicating instrument in order that the current produces deflection of the pointer proportional to its magnitude. This system producing a controlling torque is called a "Controlling System."
3. Damping torque:
When a deflecting torque is applied to the moving system, it deflects and it should come to rest at a position where the deflecting torque is balanced by the controlling torque. Consider figure shown below suppose O is the equilibrium or final steady position. Because of inertia the moving system moves to position 'a'. Now for any position 'a' beyond the equilibrium position the controlling torque is more than the deflecting torque and hence the moving swings back. Due to inertia it cannot settle at 'O' but swings to a position say 'b' behind the equilibrium position. At 'b' the deflecting torque is more than the controlling torque and hence the moving system again swings ahead.

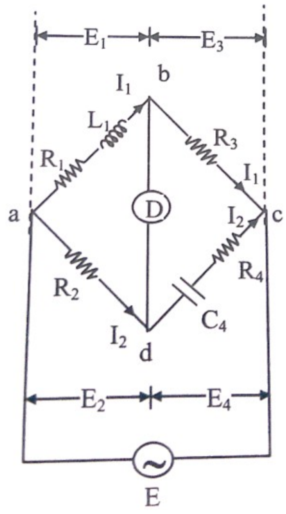


The pointer thus oscillates about its final steady (equilibrium) position with decreasing amplitude till its kinetic energy (on account of inertia) is dissipated in friction and therefore, it will settle down at its final steady position. If extra torques are not provided will "damp" these oscillations, the moving system will take a considerable time to settle to the final position and hence time consumed in taking readings will be very large. Therefore, damping torques are necessary so that the moving system comes to its equilibrium position rapidly and smoothly without any oscillations.

4. What are the advantage and disadvantages of Ultrasonic flow meter.
Solution:
Advantages:
- Expression shows that output is independent of C, therefore the effects of pressure and temperature are avoided.
- Also the output is linearly proportional to the velocity of fluid flow.
- The measurement is insensitive to viscosity, pressure and temperature variations.
- The other advantages are no obstruction to flow, bidirectional measuring capabilities, good accuracy, fast response, wide frequency range and its versatility in that it can be employed for any pipe size.

Disadvantages:
- However the complexity and relatively high cost limit its use for individual applications.

5. Describe Hay's bridge. Derive expressions for the unknown parameters in it. Draw the phasor diagram for current and voltages.
Solution:
Hay's bridge is a modification of Maxwell's bridge, using Maxwell's bridge, we can measure inductance of a coil having low quality factor ($Q < 1$) where as in Hay's bridge we can measure inductance of coil having high quality factor ($Q > 10$).



Let L_1→ Unknown inductance having a Resistance R_1.
R_2, R_3, R_4, → known non-inductance resistances
C_4→ Standard capacitor.

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

$$R_1 R_4 + \frac{L_1}{C_4} + j\omega L_1 R_4 - \frac{jR_1}{\omega C_4} = R_2 R_3$$

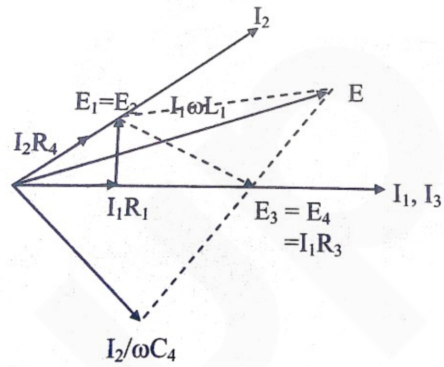
Separating the imaginary and real terms we obtain,

$$R_1 R_4 + \frac{L_1}{C_4} = R_2 R_3 \text{ and } L_1 = \frac{R_1}{\omega^2 R_4 C_4}$$

Solving the above two equations

$$L_1 = \frac{R_2 R_3 C_4}{1 + \omega^2 C_4^2 R_4^2} \quad ....(1)$$

$$R_1 = \frac{\omega^2 R_2 R_3 R_4 C_4^2}{1 + \omega^2 C_4^2 R_4^2} \quad ....(2)$$



Phasor diagram

The Q– factor of the coil

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

$$L_1 = \frac{R_2 R_3 C_4}{1 + \left(\frac{1}{Q}\right)^2} \cong R_2 R_3 C_4 \text{ for Q > 10}$$