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Questions to be Challenged in

GATE 2020

Instrumentation Engineering

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Corporate Office: 44-A/1, Kalu Sarai, New Delhi - 110016 | **Ph:** 011-45124612, 9958995830

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Q.24 Two 100 Ω resistors having tolerance 3% and 4% are connected in series. The effective tolerance of the series combination (in %, rounded off to one decimal place) is _____.

Ans. (3.5)

Given,

$$R_1 = 100\ \Omega \pm 3\%$$
$$R_2 = 100\ \Omega \pm 4\%$$
$$R = R_1 + R_2 = 100 + 100 = 200\ \Omega$$

Here,

$$\frac{\delta R_1}{R_1} \times 100 = 3$$

$$\delta R_1 = \frac{100 \times 3}{100} = 3\ \Omega$$

$$\frac{\delta R_2}{R_2} \times 100 = 4$$

$$\delta R_2 = \frac{100 \times 4}{100} = 4\ \Omega$$

We know,

$$\delta R = \delta R_1 + \delta R_2 = 3 + 4 = 7\ \Omega$$

∴

$$\% \in_r \text{ in } R = \frac{\delta R}{R} \times 100 = \frac{7}{200} \times 100 = 3.5\%$$

GATE Ans. Key (2.5)

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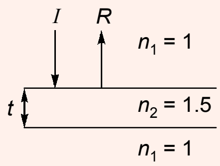
Q.46 As shown in figure, a slab of finite thickness t with refractive index n_2 = 1.5, has air (n_1 = 1) above and below it. Light of free space wavelength 600 mm is incident normally from air as shown. For a destructive interference to be observed at R, the minimum value of thickness of the slab t (in nm) is _____.



Ans. (300)

Given; Wavelength (λ) = 600 nm;

Refractive index of air (N_1) = 1

Refractive Index of slab (N_2) = 1.5

Thickness of slab = t mm

Path difference of light ray in given setup is

$$PD = (N_2 - N_1) \times t$$

for the minimum thickness to be found, central destructive fringe should be observed.

So, $$PD = (2n + 1)l/2$$

$$2 \times (N_2 - N_1) \times t = l/2 \qquad (\because n = 0)$$

$$2 \times (1.5 - 1) \times t = l/2$$

$$t = l/2$$

$$t = 600/2 = 300 \text{ nm}$$

GATE Ans. Key (200)

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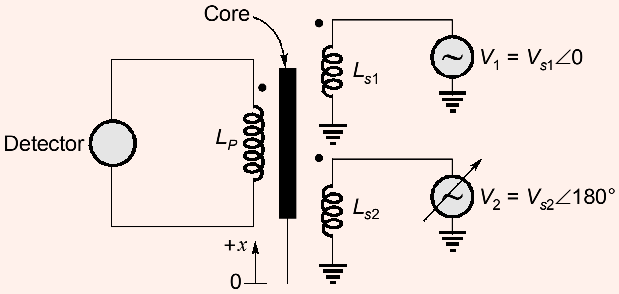
Q.50 The mutual inductances between the primary coil and the secondary coils of a linear variable differential transformer (LVDT) shown in the figure are M_1 and M_2. Assume that the self-inductances L_{S1} and L_{S2} remain constant and are independent of x. When $x = 0$, $M_1 = M_2 = M_0$. When x is in the range ± 10 mm, M_1 and M_2 change linearly with x. At x = +10 mm or –10 mm, the change in the magnitude of M_1 and M_2 is 0.25 M_0. For a particular displacement $x = D$, the voltage across the detector becomes zero when $|V_2| = 1.25\,|V_1|$. The value of D (in mm, rounded off to one decimal place) is _____.



Ans. (10)

Given that,

Self-inductances L_{s1} and L_{s2} remain constant and are independent of x.

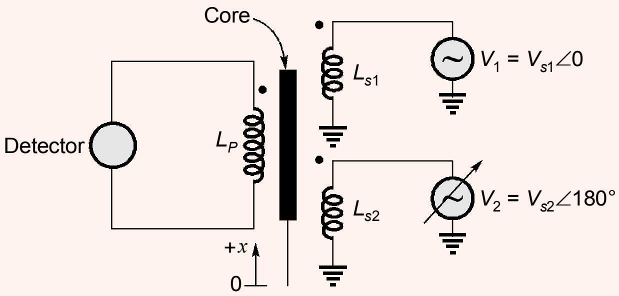
At $x = 0$, $M_1 = M_2 = M_0$

M_1 and M_2 change linearly with x. This means

$$M_1 = M_0 + k_1 x$$
$$M_2 = M_0 + k_2 x$$

at $x = +\ 10$ mm

$$M_1 = M_0 + k_1 \times 10 \times 10^{-3}$$
$$M_2 = M_0 + k_2 \times 10 \times 10^{-3}$$
$$M_1 - M_2 = (k_1 - k_2) \times 10 \times 10^{-3} = 0.25\ M_0$$
$$(k_1 - k_2) = 25\ M_0 \qquad \text{...(i)}$$



Voltage across the detector (V_D) = Volteage develpped across the primary coil (I_P)

$$V_D = V_{LP}$$

Voltage develped across the primarycoil depends on the primary current and current in the secondary coils.

So, $$V_D = V_{LP} = L_P \frac{di_p}{dt} + M_1 \frac{di_{s_1}}{dt} - M_2 \frac{di_{s_2}}{dt} \quad \text{...(ii)}$$

($\because$ i_{s1} and i_{s2} are out of phase)

Accroding to the given information detector output voltage (V_D) = 0 at $x = D$ and there can't be any primary current (i_p)

So, equation (ii) can be written as

$$M_1 \frac{di_{s_1}}{dt} - M_2 \frac{di_{s_2}}{dt} = 0 \quad \text{...(iii)}$$

From the diagram, voltages across secodnary coils can be written as

$$V_1 = L_{s_1} \frac{di_{s_1}}{dt}$$

$$V_2 = L_{s_2} \frac{di_{s_2}}{dt}$$

as L_{s_1}, L_{s_2} are not changing and initial voltages across both should be zero.

So, $$L_{s_1} = L_{s_2} = L_s$$

$$V_1 = L_s \frac{di_{s_1}}{dt} \quad \text{and} \quad V_2 = L_s \frac{di_{s_2}}{dt} \quad \text{... (iv)}$$

Consider equation (iii) xL_s

Then, $$M_1 L_s \frac{di_{s_1}}{dt} - M_2 L_s \frac{di_{s_2}}{dt} = 0$$

$$M_1 V_1 - M_2 V_2 = 0 \quad \text{...(v)}$$

at $x = D$

$$M_1 = M_0 + k_1 D$$
$$M_2 = M_0 + k_2 D$$
$$V_2 = 1.25\, V_1$$

From equation (v)

$$(M_0 + k_1 D) V_1 - (M_0 + k_2 D) \times 1.25 V_1 = 0$$
$$(k_1 - k_2) D = 0.25\, M_0$$
$$D = \frac{0.25 M_0}{k_1 - k_2} = \frac{0.25 M_0}{25 M_0} = 10 \times 10^{-3} \text{ (From eq.(i))}$$
$$D = 10 \text{ mm}$$

GATE Ans. Key (4.5)

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