

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

Student Name:

Question	1	2	3	4	5	6	7	8
Answer	c ✓	a ✓	b ✓	c ✓	d ✓	b ✗	b ✗	d ✓
Question	9	10	11	12	13	14	15	
Answer	b ✓	d ✓	c ✓	a ✓	b ✓	d ✓	d ✗	

SHOW YOUR CALCULATIONS

Question # 1 (15 points)

Select the correct answer for each of the following statements and fill it in the table.

1.1 A transformer transforms:

- a. the frequency.
- b. the power at constant frequency.
- c. the voltage at constant power.
- d. both the power and the voltage.

1.2 When conducting the no-load and short circuit tests for single-phase transformers, it is not recommended to:

- a. Apply the rated voltage during SC test.
- b. Apply the rated voltage during OC test.
- c. Apply the rated current during SC test.
- d. None of the above.

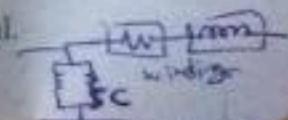
1.3 In single phase transformers, what type of losses always exist regardless of the load:

- a. Copper losses.
- b. Core losses.
- c. (a) and (b)
- d. None of the above.

1.4 Eddy current losses can be reduced by

- a. using high quality magnetic material.
- b. using light weigh magnetic material.
- c. using thin magnetic material.
- d. using heavy weigh magnetic material.

$$R = \frac{\rho L}{A}$$



1.5 Short circuit test is conducted in transformers to find:

- a. winding resistance
- b. winding leakage reactance
- c. core resistance
- d. none of the above

1.6 The rated primary and secondary currents of a 20 kVA, 1200/120 V single-phase transformer this transformer delivers a load of 12 kW at PF = 0.8 lagging are A and A.

- a. $I_{1(\text{rated})} = 10$, $I_{2(\text{rated})} = 100$
- b. $I_{1(\text{rated})} = 12.5$, $I_{2(\text{rated})} = 125$
- c. $I_{1(\text{rated})} = 16.7$, $I_{2(\text{rated})} = 167$
- d. $I_{1(\text{rated})} = 13.4$, $I_{2(\text{rated})} = 134$

1.7 A magnetic circuit has eddy-current loss $P_e = 1000$ W and hysteresis loss $P_h = 800$ W at rated voltage and rated frequency. If the frequency is reduced by 20% while the flux density remains constant, the eddy-current loss P_e and hysteresis loss P_h become W and W.

$$P_e = \nu_c f^2 \sigma_m^2$$

$$P_h = \nu_h f G_m^2$$

$$a. P_e = 640, P_h = 640$$

$$b. P_e = 200, P_h = 160$$

$$c. P_e = 400, P_h = 160$$

$$d. P_e = 800, P_h = 640$$

$$\frac{f_2}{f_1} = 0.2 f_1$$

$$\frac{P_{e2}}{P_{e1}} = \frac{f_2}{f_1} \times \left(\frac{\sigma_m 2}{\sigma_m 1} \right)^2$$

$$P_{e2} = 0.2 \times 1000$$

$$\frac{P_{h2}}{P_{h1}} = \frac{f_2}{f_1}$$

$$P_{h2} = 0.2 \times 800$$

- 1.11 A single-phase transformer has 400 primary turns and 200 secondary turns. The net iron cross-sectional area of the core is 40 cm^2 . If the primary winding is connected to a 60 Hz supply at 600 V. The maximum value of the core flux density, B_m is ... T.

a. $B_m = 2.8$

b. $B_m = 0.7$

c. $B_m = 1.4$

d. $B_m = 5.6$

$$\Phi = V_p = N_p \frac{d\Phi}{dt}$$

$$\Phi = \frac{1}{N} \int V_i H dt$$

$$V = \frac{1}{T_0} \times \int_{0}^{T_0} \Phi d\theta$$

$$\Phi = \frac{1}{400 \times 60} \sin(60t)$$

$$\Phi = \frac{600}{400 \times 60 \pi}$$

$$\Rightarrow \frac{3.935 \times 10^{-3}}{\pi} \text{ T}$$

$$\frac{B}{P} = 8.4$$

Ans

- 1.12 How many turns must the primary and the secondary windings of a 220/110-V, 50-Hz ideal transformer have if the core flux is not allowed to exceed 5 mWb?

a. $N_p = 198$,
 $N_s = 99$

b. $N_p = 220$,
 $N_s = 110$

c. $N_p = 40$,
 $N_s = 20$

d. $N_p = 2$,
 $N_s = 1$

$$V_p = N_p \frac{d\Phi}{dt}$$

$$\Phi = \frac{1}{NP} \int V_p dt \cos(\omega t) dt$$

$$5 \times 10^{-3} = \frac{120}{2 \times 50 \times NP}$$

$$\Phi_{max} = \frac{1}{NP} \int_{0}^{T_0} V_p dt \cos(\omega t) dt$$

$$5 \times 10^{-3} = \frac{1}{NP} \times \frac{120 \times \pi}{2 \times 50}$$

$$5 \times 10^{-3} = \frac{120}{NP \times 2 \times 50}$$

- 1.13 A 1.2-kVA, 240/120-V, 400 Hz transformer is desired to be used at a frequency of 50 Hz. The kVA rating of the transformer under reduced frequency would be:

a. 9.6 kVA

b. 0.15 kVA

c. 76.8 kVA

d. 1.92 kVA

$$\frac{S_2}{S_1} = \frac{f_2}{f_1}$$

$$N_p = 130 \quad N_s = 45 \quad \frac{120}{95}$$

- 1.14 A single-phase transformer has 180 and 45 turns, respectively, on its primary and secondary windings. The corresponding resistances are $R_p = 0.242\Omega$ and $R_s = 0.076\Omega$, respectively. The equivalent resistance R_{eq} referred to the primary is Ω .

a. $R_{eq} = 0.55$

b. $R_{eq} = 0.32$

c. $R_{eq} = 0.14$

d. $R_{eq} = 1.46$

$$a = \frac{180}{45} = 4$$

$$\frac{3.832}{1.914}$$

- 1.15 A 500-kVA, 2300/230-V transformer has a series impedance referred to the secondary $Z'' = 0.002 + j0.006\Omega$. The percentage voltage regulation when the transformer is delivering its rated load lagging is:

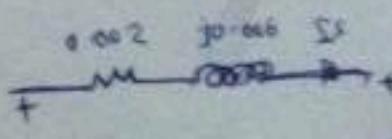
$a = 10$

a. $\%VR = 2.05\%$

b. $\%VR = 4.97\%$

c. $\%VR = -3.26\%$

d. None of these



$$\frac{V_p}{V_s} = (0.002 + j0.006) \times (770.1) \quad \text{Ans}$$

$S = VI$

$P = VI \cos \phi$

$$\Sigma S = \frac{500 \times 10^3 \times 0.5}{230}$$

$$1.239.1 \angle -36.57^\circ$$

$$2391.2$$

$$234.1$$

$$\%VR = \frac{234.1 - 230}{230} \times 100$$

NP = 400

A = 40 cm²

N_P = 800

V_P = 600

f₁ = 60

- 1.11 A single-phase transformer has 400 primary turns and 800 secondary turns. The net iron cross sectional area of the core is 40 cm². If the primary winding is connected to a 60 Hz supply at 600 V. The maximum value of the core flux density, B_m is ... T.

a. $B_m = 2.8$

b. $B_m = 0.7$

c. $B_m = 1.4$

d. $B_m = 5.6$

$$\frac{d\phi}{dt} = \frac{V_p}{N_p} = \frac{d\phi}{dt}$$

$$\phi = \frac{1}{400 \times \omega} \int_0^t 600 \sin(\omega t) dt$$

$$\phi = \frac{1}{2} \int_0^t 600 \sin(2\pi 60t) dt$$

$$\phi = \frac{600}{400 \times 2\pi \times 60}$$

$$\phi = \frac{3.9788 \times 10^{-3}}{A}$$

$$\frac{\phi}{P} = \frac{B \cdot A}{P} = B$$

- 1.12 How many turns must the primary and the secondary windings of a 220/110-V, 50-Hz ideal transformer have if the core flux is not allowed to exceed 5 mWb?

a. $N_p = 198$, $N_s = 99$

b. $N_p = 220$, $N_s = 110$

c. $N_p = 40$, $N_s = 20$

d. $N_p = 2$, $N_s = 1$

$$V_p = N_p \frac{d\phi}{dt}$$

$$\phi_{max} = \frac{1}{NP} \int_0^T V_p \cos(\omega t) dt$$

$$\phi = \frac{1}{NP} \int_0^T V_p \cos(\omega t) dt$$

$$5 \times 10^{-3} = \frac{120}{2\pi \times 50 \times NP}$$

$$5 \times 10^{-3} = \frac{1}{NP} * \frac{120 \sin(\omega t)}{\omega}$$

$$5 \times 10^{-3} = \frac{120}{NP \times 2\pi \times 50}$$

- 1.13 A 1.2-kVA, 240/120-V, 400 Hz transformer is desired to be used at a frequency of 50 Hz. The kVA rating of the transformer under reduced frequency would be:

a. 9.6 kVA

b. 0.15 kVA

c. 76.8 kVA

d. 1.92 kVA

$$\frac{S_2}{S_1} = \frac{f_2}{f_1}$$

$$\omega \propto f$$

$$N_P = 180 \quad N_S = 45$$

$$\frac{180}{45}$$

- 1.14 A single-phase transformer has 180 and 45 turns, respectively, on its primary and secondary windings. The corresponding resistances are $R_1 = 0.242\Omega$ and $R_2 = 0.076\Omega$, respectively. The equivalent resistance R'_{eq} referred to the primary is Ω .

a. $R'_{eq} = 0.55$

b. $R'_{eq} = 0.32$

c. $R'_{eq} = 0.14$

d. $R'_{eq} = 1.46$

$$a = \frac{180}{45} = 4$$

$$\begin{matrix} 3.872 \\ 1.714 \end{matrix}$$

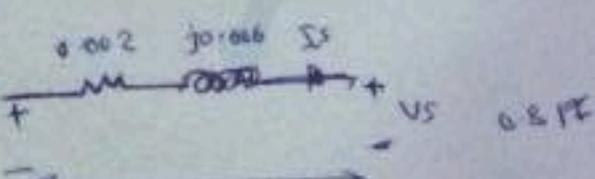
- 1.15 A 500-kVA, 2300/230-V transformer has a series impedance referred to the secondary $Z''_s = 0.002 + j0.006\Omega$. The percentage voltage regulation when the transformer is delivering its rated load at 0.8 PF lagging is:

a. %VR = 2.05%

b. %VR = 4.97%

c. %VR = -3.26%

d. Non of these



$$\frac{V_p}{I_p} = (0.002 + j0.006) \times 2300$$

$$S = VI$$

$$P = VI \cos \phi$$

$$\Sigma S = \frac{500 \times 10^3 \times 0.8}{230}$$

$$1739.1 \angle -36.87^\circ$$

$$2391.2$$

$$234.1$$

$$\%VR = \frac{2391.2 - 234.1}{2300}$$

$$L = 36 \times 10^{-2}$$

$$A = 3 \times 10^{-4}$$

$$N = 400$$

$$NI = \Phi \cdot R$$

$$\frac{400 \times 1.4}{1.4 \times 10^{-2}} = 1.4 \times 10^3 \times R$$

$$R = 400 \times 10^3$$

$$R \approx \frac{L}{MA}$$

- 1.8 A ferromagnetic ring with a mean circumference $L_m = 36$ cm and a cross-sectional area $A_s = 3$ cm² is wound with 400 turns of wire as shown in Fig. 1. When the excitation current is 1.4 A, the flux is found to be $\phi = 1.4$ mWb. The relative permeability of the iron μ_r is

a. $\mu_r = 238732$

b. $\mu_r = 238.7$

c. $\mu_r = 0.2387$

d. $\mu_r = 2387$

$$M_F = \frac{L}{RA} = \frac{36 \times 10^{-2}}{400 \times 10^3 \times 3 \times 10^{-4}} = 3 \times 10^{-3}$$

$$\mu = M_F M_0$$

$$\mu_r = \frac{3 \times 10^{-3}}{M_0} = 2387.$$

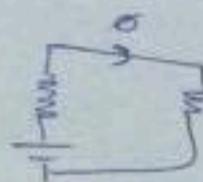
- 1.9 The solenoid shown in the Fig. 2 consists of a 500 turn coil on a uniformly sized core. The core has a cross-sectional area $A_c = 4$ cm². The length of the air gap is $l_g = 5$ mm long. If the reluctance of the core is negligible and the coil exciting current $I = 10$ A, the total magnetic flux ϕ that circulates in the core is mWb.

a. $\phi = 1.25$

b. $\phi = 0.50$

c. $\phi = 5$

d. $\phi = 12.5$



$$Nl = \frac{\mu_0}{B} \cdot L_g$$

$$\mu_0 = \frac{500 \times 10^3}{5 \times 10^{-3}} = 1 \times 10^6$$

$$H_g \propto H_0 = B$$

$$B = 1.256$$

- 1.10 A cast steel ring, as shown in Fig. 3 with B-H data as shown in Table 1, has a mean length of $L_m = 30$ cm and an air gap of $l_g = 2$ mm length. The number of ampere-turns (NI) required to produce a flux density $B = 0.6$ T in the air gap is ... At.

a. $NI = 1084$

b. $NI = 955$

c. $NI = 129$

d. $NI = 0.86$

Table 1: B-H data for Cast Steel

B (T)	0.4	0.6	0.8
H (At/m)	130	430	720

$$L = 30 \times 10^{-2}$$

$$L_g = 2 \times 10^{-2}$$

$$B_g = 0.6 \text{ T}$$

$$H_{g0} = 430$$

$$L_g = 2 \times 10^{-3}$$

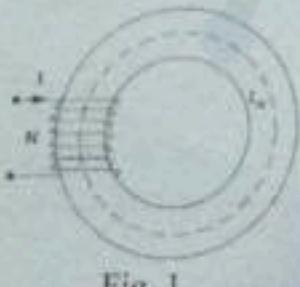


Fig. 1

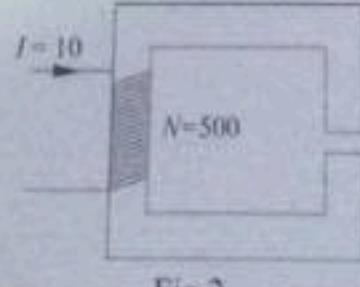


Fig. 2

$$B = \frac{H}{\mu_0} = \frac{430}{4 \pi \times 10^{-7}} = 1.36 \times 10^6 \text{ At/m}$$

$$B = 0.6 \text{ T}$$

$$H_g = \frac{0.6}{0.4} \times 10^6 = 1.5 \times 10^6 \text{ At/m}$$

$$H_g = \frac{1.5 \times 10^6}{430} = 3.48 \text{ At/m}$$

$$H_g = \frac{3.48}{130} = 2.68 \text{ At/m}$$

$$H_g = \frac{2.68}{130} = 0.02 \text{ At/m}$$

$$H_g = \frac{0.02}{130} = 0.000154 \text{ At/m}$$

$$H_g = \frac{0.000154}{130} = 0.00000118 \text{ At/m}$$

$$H_g = \frac{0.00000118}{130} = 8.38 \times 10^{-9} \text{ At/m}$$

$$H_g = \frac{8.38 \times 10^{-9}}{130} = 6.38 \times 10^{-10} \text{ At/m}$$

$$H_g = \frac{6.38 \times 10^{-10}}{130} = 4.88 \times 10^{-11} \text{ At/m}$$

$$H_g = \frac{4.88 \times 10^{-11}}{130} = 3.78 \times 10^{-12} \text{ At/m}$$

$$H_g = \frac{3.78 \times 10^{-12}}{130} = 2.88 \times 10^{-13} \text{ At/m}$$

$$H_g = \frac{2.88 \times 10^{-13}}{130} = 2.18 \times 10^{-14} \text{ At/m}$$

$$H_g = \frac{2.18 \times 10^{-14}}{130} = 1.68 \times 10^{-15} \text{ At/m}$$

$$H_g = \frac{1.68 \times 10^{-15}}{130} = 1.28 \times 10^{-16} \text{ At/m}$$

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$$H_g = \frac{9.68 \times 10^{-17}}{130} = 7.38 \times 10^{-18} \text{ At/m}$$

$$H_g = \frac{7.38 \times 10^{-18}}{130} = 5.68 \times 10^{-19} \text{ At/m}$$

$$H_g = \frac{5.68 \times 10^{-19}}{130} = 4.38 \times 10^{-20} \text{ At/m}$$

$$H_g = \frac{4.38 \times 10^{-20}}{130} = 3.38 \times 10^{-21} \text{ At/m}$$

$$H_g = \frac{3.38 \times 10^{-21}}{130} = 2.68 \times 10^{-22} \text{ At/m}$$

$$H_g = \frac{2.68 \times 10^{-22}}{130} = 2.08 \times 10^{-23} \text{ At/m}$$

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$$H_g = \frac{3.38 \times 10^{-97}}{130} = 2.68 \times 10^{-98} \text{ At/m}$$

$$H_g = \frac{2.68 \times 10^{-98}}{130} = 2.08 \times 10^{-99} \text{ At/m}$$

$$H_g = \frac{2.08 \times 10^{-99}}{130} = 1.68 \times 10^{-100} \text{ At/m}$$

$$H_g = \frac{1.68 \times 10^{-100}}{130} = 1.38 \times 10^{-101} \text{ At/m}$$

$$H_g = \frac{1.38 \times 10^{-101}}{130} = 1.08 \times 10^{-102} \text{ At/m}$$

$$H_g = \frac{1.08 \times 10^{-102}}{130} = 8.68 \times 10^{-103} \text{ At/m}$$

$$H_g = \frac{8.68 \times 10^{-103}}{130} = 6.88 \times 10^{-104} \text{ At/m}$$

$$H_g = \frac{6.88 \times 10^{-104}}{130} = 5.28 \times 10^{-105} \text{ At/m}$$

$$H_g = \frac{5.28 \times 10^{-105}}{130} = 4.08 \times 10^{-106} \text{ At/m}$$

$$H_g = \frac{4.08 \times 10^{-106}}{130} = 3.08 \times 10^{-107} \text{ At/m}$$

$$H_g = \frac{3.08 \times 10^{-107}}{130} = 2.38 \times 10^{-108} \text{ At/m}$$

$$H_g = \frac{2.38 \times 10^{-108}}{130} = 1.88 \times 10^{-109} \text{ At/m}$$

$$H_g = \frac{1.88 \times 10^{-109}}{130} = 1.48 \times 10^{-110} \text{ At/m}$$

$$H_g = \frac{1.48 \times 10^{-110}}{130} = 1.18 \times 10^{-111} \text{ At/m}$$

$$H_g = \frac{1.18 \times 10^{-111}}{130} = 9.68 \times 10^{-112} \text{ At/m}$$

$$H_g = \frac{9.68 \times 10^{-112}}{130} = 7.38 \times 10^{-113} \text{ At/m}$$

$$H_g = \frac{7.38 \times 10^{-113}}{130} = 5.68 \times 10^{-114} \text{ At/m}$$

$$H_g = \frac{5.68 \times 10^{-114}}{130} = 4.38 \times 10^{-115} \text{ At/m}$$

$$H_g = \frac{4.38 \times 10^{-115}}{130} = 3.38 \times 10^{-116} \text{ At/m}$$

$$H_g = \frac{3.38 \times 10^{-116}}{130} = 2.68 \times 10^{-117} \text{ At/m}$$

$$H_g = \frac{2.68 \times 10^{-117}}{130} = 2.08 \times 10^{-118} \text{ At/m}$$

$$H_g = \frac{2.08 \times 10^{-118}}{130} = 1.68 \times 10^{-119} \text{ At/m}$$

$$H_g = \frac{1.68 \times 10^{-119}}{130} = 1.38 \times 10^{-120} \text{ At/m}$$

$$H_g = \frac{1.38 \times 10^{-120}}{130} = 1.08 \times 10^{-121} \text{ At/m}$$

$$H_g = \frac{1.08 \times 10^{-121}}{130} = 8.68 \times 10^{-122} \text{ At/m}$$

$$H_g = \frac{8.68 \times 10^{-122}}{130} = 6.88 \times 10^{-123} \text{ At/m}$$

$$H_g = \frac{6.88 \times 10^{-123}}{130} = 5.28 \times 10^{-124} \text{ At/m}$$

$$H_g = \frac{5.28 \times 10^{-124}}{130} = 4.08 \times 10^{-125} \text{ At/m}$$

$$H_g = \frac{4.08 \times 10^{-125}}{130} = 3.08 \times 10^{-126} \text{ At/m}$$

$$H_g = \frac{3.08 \times 10^{-126}}{130} = 2.38 \times 10^{-127} \text{ At/m}$$

$$H_g = \frac{2.38 \times 10^{-127}}{130} = 1.88 \times 10^{-128} \text{ At/m}$$

$$H_g = \frac{1.88 \times 10^{-128}}{130} = 1.48 \times 10^{-129} \text{ At/m}$$

$$H_g = \frac{1.48 \times 10^{-129}}{130} = 1.18 \times 10^{-130} \text{ At/m}$$

$$H_g = \frac{1.18 \times 10^{-1$$