G001

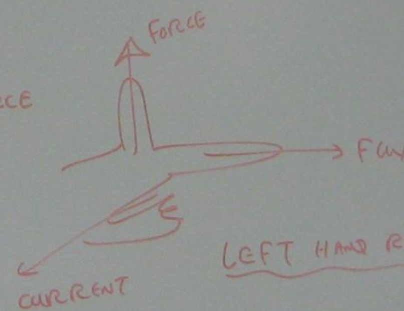
APPLICATION OF MAGNETISM

POWER TRANSFORMER PRINCIPLE

ELECTRICAL MACHINE — CHANGE VOLTAGE/CURRENT LEVEL — MAGNETIC FLUX PASSES THROUGH COIL → INDUCED VOLTAGE

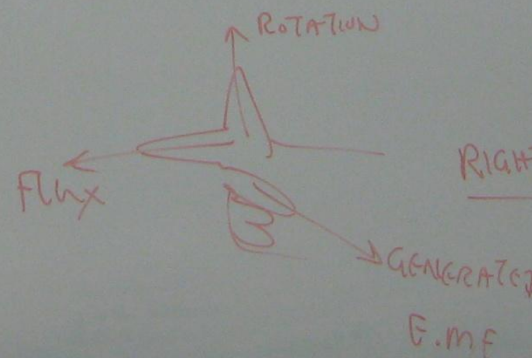
ELECTRICAL MACHINE — ROTATIONAL FORCE

- STATIC
- DYNAMIC



LEFT HAND RULE

AC / DC MOTORS



RIGHT HAND RULE

AC/DC GENERATOR

AC SOUR

...GH COIL → INDUCED VOLTAGE

$$V = L\frac{di}{dt} = N\frac{d\phi}{dt}$$

NO. OF TURNS

RATE OF CHANGE OF MAGNETIC FLUX

NO. OF TURNS DETERMINE THE VOLTAGE

TRANSFORMER

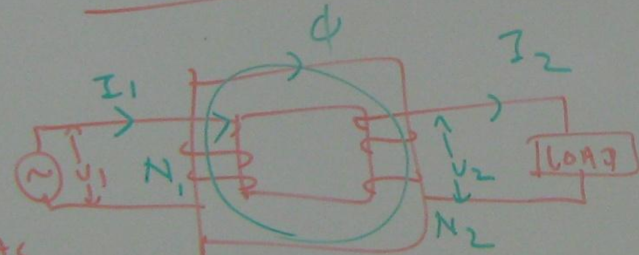
MOTORS

AC | DC

GENERATOR

...RULE

CONSTRUCTION OF TRANSFORMER



AC SOURCE

$$\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1} = a$$

TURN RATIO

WHEN PRIMARY WINDING OF TRANSFORMER IS CONNECTED TO AC SUPPLY, THE FLOW OF CURRENT PRODUCES THE MAGNETIC FLUX.

THE FLUX IS LINKED TO SECONDARY WINDING AND VOLTAGE IS INDUCED.

THE INDUCED VOLTAGE DEPENDS ON NUMBER OF

TURN...

$E_1 =$

E_2

Ph(

C

TURNS AND RATE OF CHANGE OF FLUX

$E_1 = 4.44\ f\ N_1\ \phi_{max}$ VOLT

E_1 = PRIMARY VOLTAGE / ph

N_1 = PRIMARY NO. OF TURNS

f = FREQUENCY

ϕ_{MAX} = FLUX (wb)

$E_2 = 4.44\ f\ N_2\ \phi_{MAX}$

Pb ① $N_p = 350$ TURNS , $E_p = 2200\,V_{rms}$

$f = 50\,HZ$, $C.S.A = 250\,cm^2$

CALCULATE MAXIMUM FLUX DENSITY OF CORE.

$E_p = 4.44\ f\ N_p\ \phi_{MAX}$

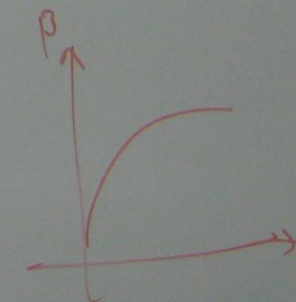
$2200 = 4.44 \times 50 \times 350 \times \phi_{MAX}$

$\phi_{MAX} = \dfrac{2200}{4.44 \times 50 \times 350} = 0.0276\ wb$

$B_{MAX} = \dfrac{\phi_{MAX}}{A} = \dfrac{0.0276}{250 \times (10^{-2})^2} = \dfrac{0.0276}{250 \times 10^{-4}}$

$= \dfrac{0.0276 \times 10^4}{250}$

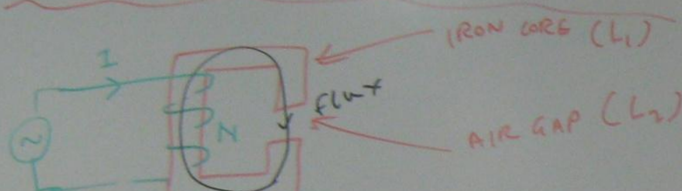
$= 1.1$ TESLA



FLUX DENSITY

$\frac{\ldots 0276}{\ldots 0\times 10^{-4}}$

CALCULATION OF MAGNETIZING FORCE IN MAGNETIC CORE



MAGNETO FORCE = CURRENT × NO. OF TURNS

$= I \times N$

$= NI$

$NI = H \times l$

H: MAGNETIZING FORCE AMP-TURNS/m

l: LENGTH OF MAGNETIC PATH (m)

$B = \mu H$

B: FLUX DENSITY

μ: PERMEABILITY

H: MAGNETIZING FORCE

$H = \frac{B}{\mu}$, $\mu = \mu_0 \times \mu_r$

$\mu_0 = 4\pi \times 10^{-7}$ (PERMEABILITY OF AIR)

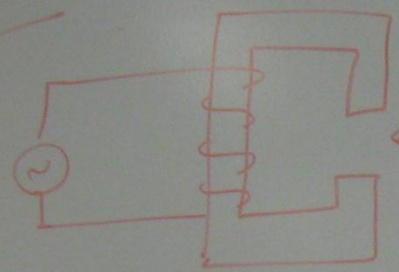
μ_r = RELATIVE PERMEABILITY

$H = \frac{B}{\mu_0 \mu_r}$

$NI = H_{IRON} \times L_{IRON} + H_{AIRGAP} \; L_{AIRGAP}$

$NI = \frac{B}{\mu_0 \mu_r} \times L_1 + \frac{B}{\mu_0} \; L_2$

Pb 2



CORE LENGTH $L_1 = 1250$ mm

AIR GAP LENGTH $L_2 = 0.15$ mm

MAGNETIC FLUX DENSITY = 1.105 T

$\mu_0 = 4\pi \times 10^{-7}$

μ_r FOR STEEL = 1800

CALCULATE TOTAL MAGNETIZING FORCE.

IF NO. OF TURNS ON CORE IS 350 TURNS, CALCULATE I_{MAX} AND I_{RMS} FOR THE COIL.

TOTAL MAGNETIZING FORCE = IRON CORE + AIR GAP

$= H_I \times L_I + H_A L_A$

$=$

$= \frac{B}{\mu_0 \mu_r}$

$= \frac{1.105}{4\pi \times 10^{-7} \times 180\ldots}$

$\rightarrow$ 625…

$=$ 75…

$N I =$

$350 \times I_{MAX} =$

$I_{MAX} =$

$=$

$I_{RMS} =$

-CORE LENGTH $L_1 = 1250\,mm$

AIR GAP LENGTH $L_2 = 0.15\,mm$

MAGNETIC FLUX DENSITY = 1.105 T

$= 4\pi \times 10^{-7}$

-FOR STEEL = 1800

ING FORCE.

E IS 350 TURNS, CALCULATE

FOR THE COIL.

ORE + AIR GAP

$L_I + H_A \; L_A$

$$= \frac{B}{\mu_0 \mu_r} \times L_1 + \frac{B}{\mu_0} L_2$$

$$= \frac{1.105}{4\pi \times 10^{-7} \times 1800} \times \frac{1250}{1000} + \frac{1.105}{4\pi \times 10^{-7}} \times \frac{0.15}{1000}$$

$$\Rightarrow 625 + 131.9$$

$$= 756.9 \text{ Amp Turn}$$

$$N I = 756.9$$

$$350 \times I_{MAX} = 756.9$$

$$I_{MAX} = \frac{756.9}{350}$$

$$= 2.16 \text{ Amp}$$

$$I_{Rms} = \frac{I_{MAX}}{\sqrt{2}} = \frac{2.16}{1.4142} = 1.53 \text{ Amp}$$

VOLTAGE RA

Rms VALUE OF

CONTINUOUS THAT

APPLIED TO WIN

$E = 4.44 f N$

F

f = FRE

N = NO

E = VOL

$- \times \frac{0.15}{1000}$

RATING OF TRANSFORMER

VOLTAGE RATING

RMS VALUE OF HIGHEST CONTINUOUS THAT CAN BE APPLIED TO WINDING

$E = 4.44 f N \phi$

ϕ = FLUX (Wb)

f = FREQUENCY (Hz)

N = NO. OF TURNS.

E = VOLTAGE

CURRENT RATING

RMS VALUE OF HIGHEST CONTINUOUS CURRENT THAT CAN BE APPLIED WITHOUT CAUSING EXCESSIVE TEMPERATURE RISE

$I^2 R$ = COPPER LOSS

R = WINDING RESISTANCE

V.A RATING (POWER RATING)

NOMINAL VOLTAGE $\times$ NOMINAL CURRENT

$$\text{LOAD RATIO} = \frac{\text{V.A AT ANY LOAD}}{\text{RATED V.A}}$$

$$\text{V.A AT ANY LOAD} = \text{LOAD RATIO } (L) \times \text{RATED V.A}$$

$$\text{WATT AT ANY LOAD} = L \times \text{RATED V.A} \times \text{POWER FACTOR}$$

np

G OF TRANSFORMER

CURRENT RATING

RMS VALUE OF HIGHEST CONTINUOUS CURRENT THAT CAN BE APPLIED WITHOUT CAUSING EXCESSIVE TEMPERATURE RISE

$$I^2 R = \text{COPPER LOSS}$$

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V.A RATING (POWER RATING)

NOMINAL VOLTAGE × NOMINAL CURRENT

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$$\text{WATT AT ANY LOAD} = L \times \text{RATED V.A} \times \text{POWER FACTOR}$$

pb3 FIND PRIMARY AND SECONDARY CURRENT OF 4 KVA 400/200 V 1φ TRANSFORMER

$$V_p I_p = V_s I_s = \text{RATED VA}$$

$$V_p I_p = \text{RATED V.A}$$

$$400 I_p = 4000$$

$$I_p = \frac{4000}{400} = 10 \text{ Amp}$$

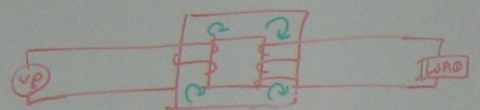
$$V_s I_s = 4000$$

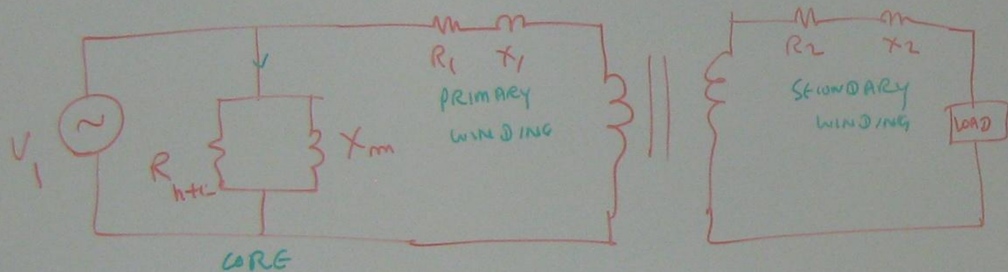
$$200 I_s = 4000$$

$$I_s = \frac{4000}{200}$$

$$= 20 \text{ Amp}$$

LOSSES IN TRANSFORMER & EQUIVALENT CIRCUIT





R_{h+e} = HYSTERESIS AND EDDY CURRENT RESISTANCE OF TRANSFORMER CORE

X_m = MAGNETIZING INDUCTIVE REACTANCE OF TRANSFORMER CORE

$R_2' = a^2 R_2$

R_2': SECONDARY WINDING RESISTANCE REFERRED TO PRIMARY

a: TURN RATIO

$a = \frac{V_1}{V_2} = \frac{N_1}{N_2}$

$X_2' = a^2 X_2$

X_2': SECONDARY WINDING REACTANCE REFERRED TO PRIMARY

R_e' = TOTAL EQUIVALENT RESISTANCE REFERRE…

X_e' = TOTAL EQUIVALENT REACTANCE REFERRE…

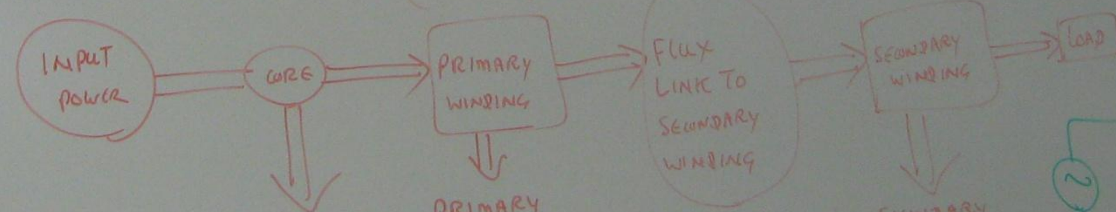
Z_e' = TOTAL EQUIVALENT IMPEDANCE REFER…

$R_e' = R_1 + a^2 R_2$

$X_e' = X_1 + a^2 X_2$

$Z_e' = \sqrt{(R_e')^2 + (X…}$

(POWER FLOW DIAGRAM OF TRANSFORMER)



CORE LOSS

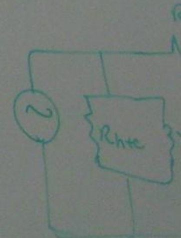
$\frac{V_1^2}{R_{h+e}}$

PRIMARY WINDING POWER LOSS

$I_1^2 R_1$

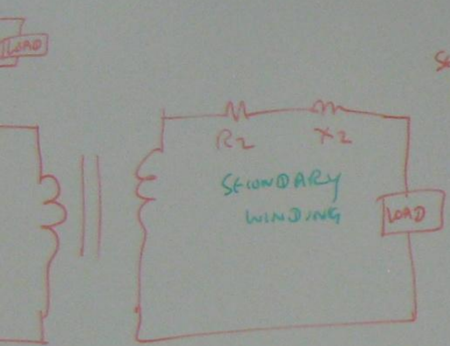
SECONDARY WINDING POWER LOSS

$I_2^2 R_2$



EQUIVA…

...ALENT CIRCUIT



$R_2' = a^2 R_2$

SECONDARY WINDING RESISTANCE REFERRED TO PRIMARY

TURN RATIO

$a = \frac{V_1}{V_2} = \frac{N_1}{N_2}$

$X_2' = a^2 X_2$

SECONDARY WINDING REACTANCE REFERRED TO PRIMARY

R_e' = TOTAL EQUIVALENT RESISTANCE REFERRED TO PRIMARY

X_e' = TOTAL EQUIVALENT REACTANCE REFERRED TO PRIMARY

Z_e' = TOTAL EQUIVALENT IMPEDANCE REFERRED TO PRIMARY

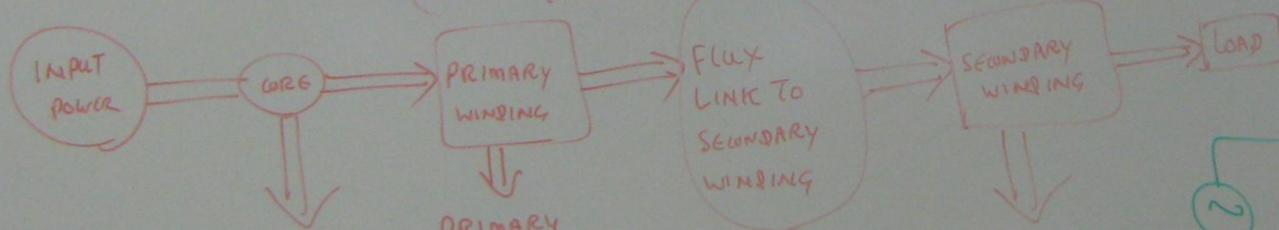
$R_e' = R_1 + a^2 R_2$

$X_e' = X_1 + a^2 X_2$

$Z_e' = \sqrt{(R_e')^2 + (X_e')^2}$

(POWER FLOW DIAGRAM OF TRANSFORMER)

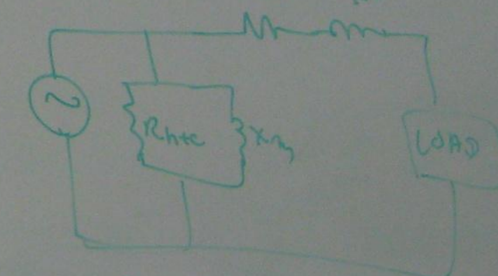
...ENT
...CORE
...ANCE



$\frac{V_1^2}{R_{hte}}$

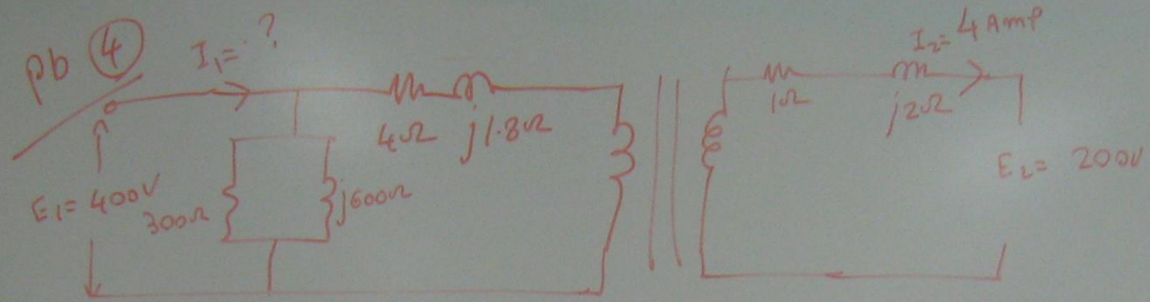
$I_1^2 R_1$

$I_2^2 R_2$



EQUIVALENT CIRCUIT

pb 4



IN ABOVE CIRCUIT, CALCULATE

(i) SECONDARY RESISTANCE REFERRED TO PRIMARY

(ii) SECONDARY INDUCTIVE REACTANCE REFERRED TO PRIMARY

(iii) TOTAL EQUIVALENT RESISTANCE REFERRED TO PRIMARY

(iv) TOTAL EQUIVALENT INDUCTIVE REACTANCE REFERRED TO PRIMARY

(v) PRIMARY CURRENT

(vi) DRAW A SIMPLIFIED EQUIVALENT CIRCUIT DIAGRAM.

(i) $R_2 = 1\Omega$

$R_2' = ?$

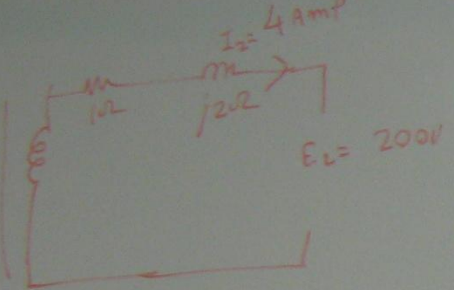
$R_2' = a^2 R_2 =$

(ii) $X_2' =$

(iii) $R_e' =$

(iv) $X_e' = X$

(v) $\frac{V_1}{V_2}$



...ATE

...EFERRED TO PRIMARY

...TANCE REFERRED TO PRIMARY

...ANCE REFERRED TO PRIMARY

...IVE REACTANCE REFERRED TO

...ED EQUIVALENT CIRCUIT

(i) $R_2 = 1\Omega$

$R_2' = ?$ $\qquad a = \frac{E_1}{E_2} = \frac{400}{200} = 2$

$R_2' = a^2 R_2 = 2^2 \times 1 = 4\Omega$

(ii) $X_2' = a^2 X_2 = 2^2 \times 2 = 8\Omega$

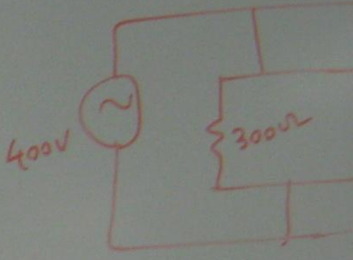
(iii) $R_e' = R_1 + a^2 R_2 = 4 + 4 = 8\Omega$

(iv) $X_e' = X_1 + a^2 X_2 = 1.8 + 2^2 \times 2 =$

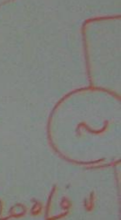
$= 1.8 + 8 = 9.8\Omega$

(v) $\frac{V_1}{V_2} = a = \frac{I_2}{I_1}$

$2 = \frac{4}{I_1} \Rightarrow I_1 = \frac{4}{2} = 2$ Amp



Pb 5



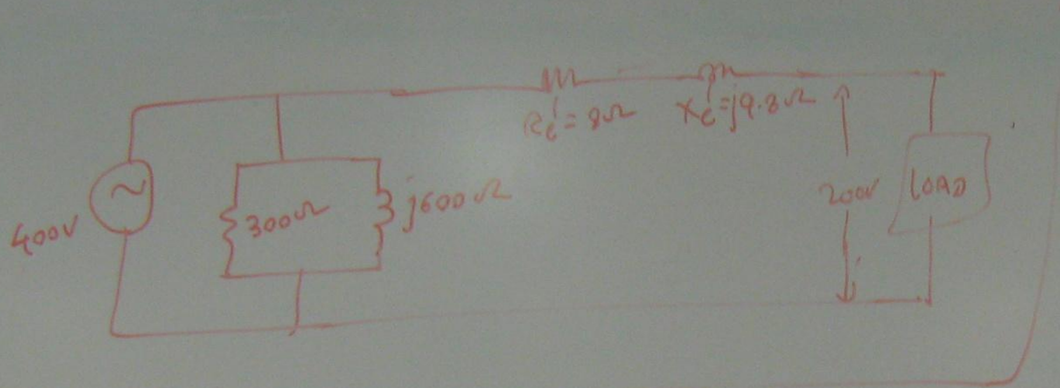
CALC...

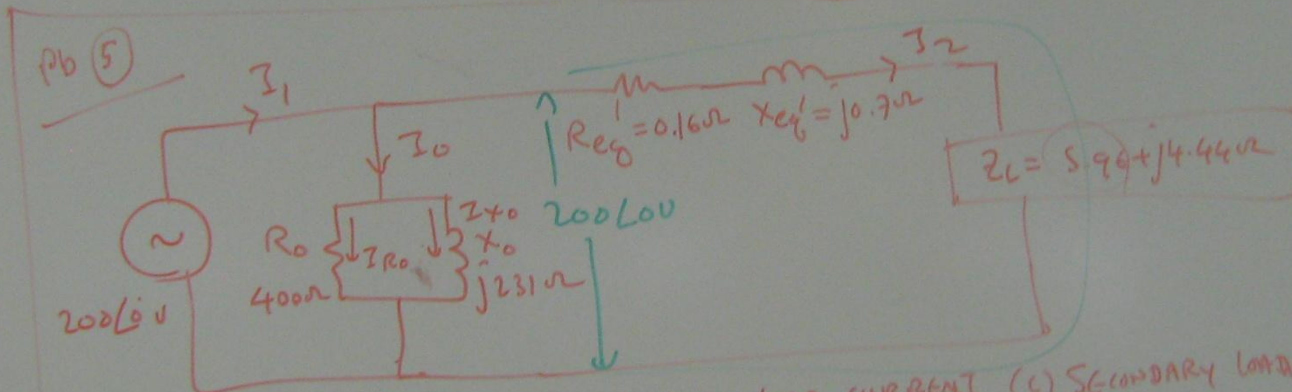
8Ω

=

7.8Ω

$\frac{4}{2} = 2$ Amp





CALCULATE (a) IRON LOSS (b) NO LOAD CURRENT (c) SECONDARY LOAD CURRENT
(d) TOTAL PRIMARY CURRENT (e) COPPER LOSS (f) POWER CONSUMED BY LOAD
(g) EFFICIENCY OF GIVEN CIRCUIT.

(a) IRON LOSS $= \dfrac{V_1^2}{R_0} = \dfrac{200^2}{400} = \dfrac{200 \times 200}{400} = 100W$

(b) $I_0 = I_{R0} + I_{X0}$

$= \dfrac{200}{400} + \dfrac{200}{j231}$

$= 0.5 + \dfrac{0.86}{j}$

$j = \sqrt{-1}$

$= 0.5 + \dfrac{0.86}{j} \times \dfrac{j}{j}$

sumes by $j^2 = -1$

$= 0.5 + \dfrac{j0.86}{(j)^2}$

$= 0.5 + \dfrac{j0.86}{-1}$

$I_0 = 0.5 - j0.86$

$I_0 = \sqrt{0.5^2 + 0.86^2} \angle -\tan^{-1}\dfrac{0.86}{0.5}$

$= 1 \angle -59.8°$ Amp.

(c) $I_2 = \dfrac{200\angle 0}{0.16 + j0.7 + 5.96 + j4.44}$

$= \dfrac{200\angle 0}{6.12 + j5.14}$

$= \dfrac{200\angle 0}{\sqrt{6.12^2 + 5.14^2} \angle \tan^{-1}\dfrac{5.14}{6.12}}$

$= \dfrac{200\angle 0}{7.9 \angle 39.2} = 25.3 \angle -39.2$ A

(d) $I_1 = I$

(e)

(d) $I_1 = I_0 + I_2$

$= 0.5 - j0.86 + 25.3 \angle -39.2$

$= 0.5 - j0.86 + 25.3(\cos 39.2 - j \sin 39.2)$

$= 0.5 - j0.86 + 19.6 - j16$

$= 20.1 - j16.86$

$= \sqrt{20.1^2 + 16.86^2} \angle -\tan^{-1}\frac{16.86}{20.1}$

$= 26.2 \angle -40^\circ$ Amp

(e) COPPER LOSS $= I_2'^2 R_{eq} =$

$= (25.3)^2 \times 0.16$

$= 102.4$ WATT

(f) POWER CONSUMED BY LOAD $= I_2^2 R_L$

$= 25.3^2 \times 5.96$

$= 3815$ WATT

(g) INPUT POWER = LOAD POWER + IRON LOSS + COPPER LOSS

$= 3815 + 100 + 102.4$

$= 4017.4$ W

EFFICIENCY $= \frac{\text{OUTPUT}}{\text{INPUT}} \times 100 = \frac{3815}{4017.4} \times 100$

$= 95\%$

A