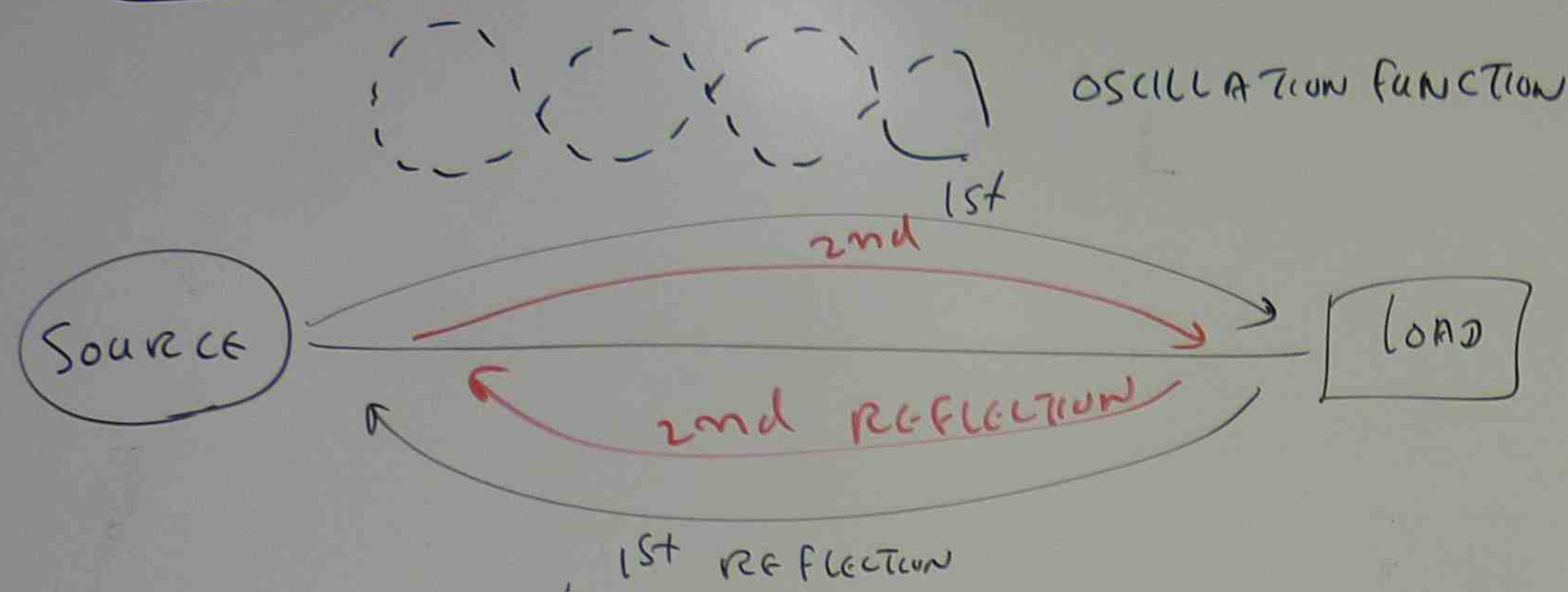
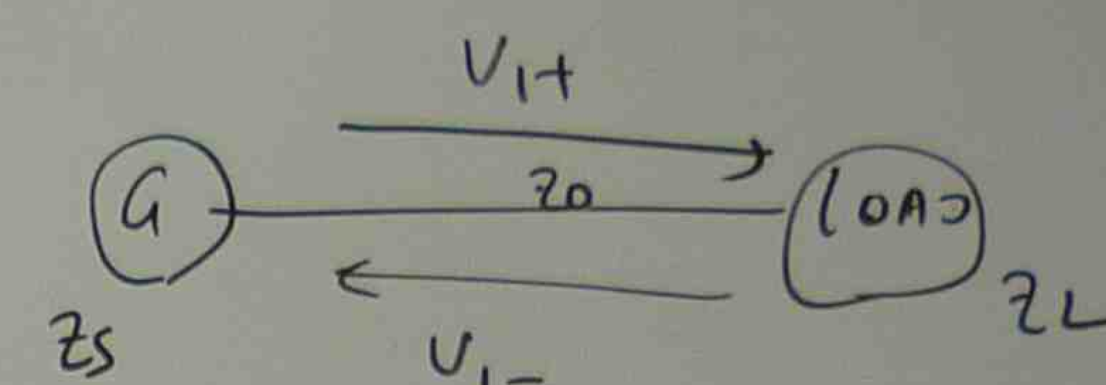
G047





Z_L = LOAD IMPEDANCE

Z_0 = LINE IMPEDANCE

Z_S = SOURCE IMPEDANCE

1st REFLECTION AT LOAD

$$V_t = V_{1+} + V_{1-}$$

$$V_{1+} = V_s \frac{Z_0}{Z_0 + Z_S}$$

$$V_{1-} = V_{1+} \times \Gamma_L \qquad \Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$$

2nd REFLECTION AT SOURCE $\Rightarrow$

$$V_t = V_{1+} + V_{1-} + V_{2+}$$

$$V_{2+} = V_{1(-)} \Gamma_S \qquad \Gamma_S = \frac{Z_S - Z_0}{Z_S + Z_0}$$

3rd REFLECTION AT LOAD $\Rightarrow$

$$V_t = V_{1+} + V_{1-} + V_{2+} + V_{2-}$$

$$V_{2-} = V_{2+} \Gamma_L \qquad \Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$$

Ex

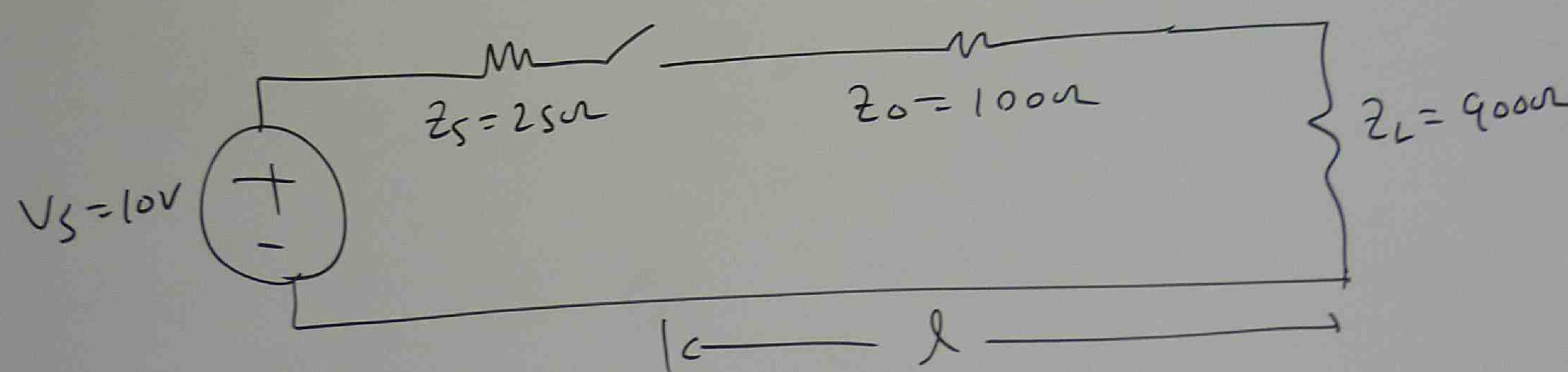
A 10V DC SOURCE WITH AN INTERNAL RESISTANCE OF 25Ω IS CONNECTED TO A TRANSMISSION LINE OF LENGTH "L" HAVING AN IMPEDANCE OF 100Ω BY SWITCH. THE TRANSMISSION LINE IS TERMINATED WITH A 900Ω RESISTOR. T = AMOUNT OF TIME REQUIRED FOR SIGNAL TO TRAVEL THE LENGTH OF THE LINE.

CALCULATE (a) THE VOLTAGE WHEN THE SWITCH IS CLOSED AT T=0

(b) FIRST REFLECTION AT LOAD

(c) SECOND REFLECTION AT SOURCE

(d) THIRD REFLECTION AT LOAD



(a) VOLTAGE AT $t=0$

$$V_{1+} = V_S \times \frac{Z_0}{Z_0 + Z_S}$$

$$= 10 \times \frac{100}{100+25} = 8V$$

(b) $V_{1(-)}$

FIRST REFLECTI[...] AT LOAD

(c) V_2

IS

AN

S

TIME

E.

$T=0$

$Z_L = 900\Omega$

$= 8V$

S

(b) $V_{1(-)} = V_{1(+)} \Gamma_L$

$= 8 \times \dfrac{Z_L - Z_0}{Z_L + Z_0}$

$= 8 \times \dfrac{900-100}{900+100}$

$= 8 \times \dfrac{800}{1000} = 6.4V$

FIRST REFLECTION AT LOAD $V_{(+)} = V_{1(+)} + V_{1(-)}$

$= 8 + 6.4$

$= 14.4V$

(c) $V_{2+} = V_{(-)} \times \Gamma_S$

$= 6.4 \times \dfrac{Z_S - Z_0}{Z_S + Z_0}$

$= 6.4 \times \dfrac{25-100}{25+100}$

$= -3.84V$

2nd REFLECTION AT SOURCE $= V_{1(+)} + V_{1(-)} + V_{2(+)}$

$= 8 + 6.4 + (-3.84)$

$= 10.56V$

(d) $V_{2(-)} = V_{2(+)} \Gamma_L$

$= (-3.84) \times \dfrac{Z_L - Z_0}{Z_L + Z_0}$

$= -3.84 \times \dfrac{900-100}{900+100}$

$= -3.072V$

3rd REFLECTION AT LOAD $= V_{1(+)} + V_{1(-)} + V_{2(+)} + V_{2(-)}$

$= 8 + 6.4 + (-3.84) + (-3.072)$

$= 7.488V$

MILL

R_1

E_1

$E_{eq} =$

$R_{eq} =$

E_{eq}

Ex

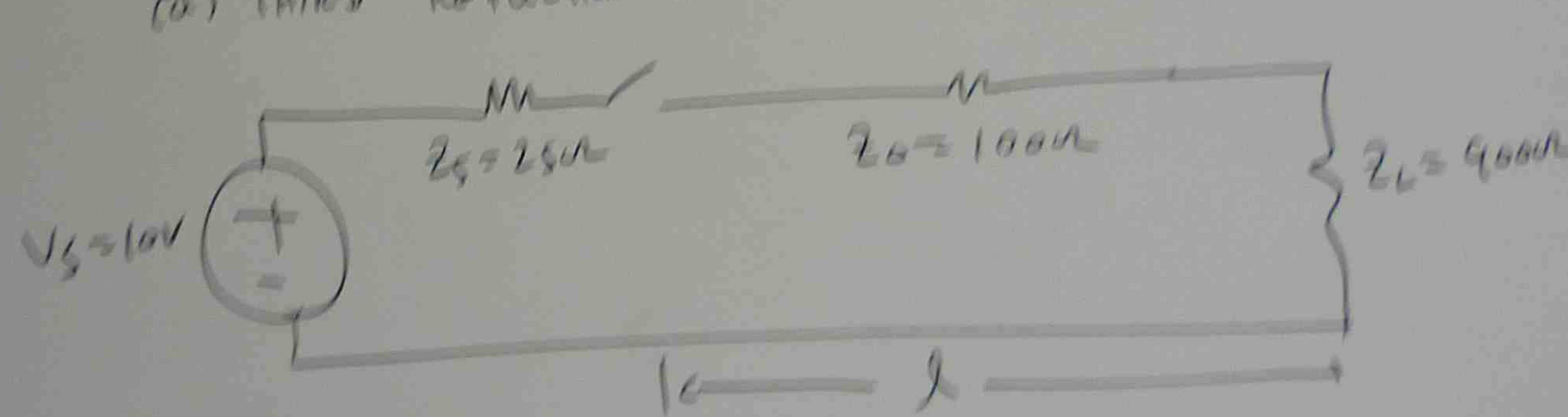
A 10V DC source with an internal resistance of 25 Ω is connected to a transmission line of length "L" having an impedance of 100 Ω by switch. The transmission line is terminated with a 400 Ω resistor. T = amount of time required for signal to travel the length of the line.

Calculate (a) the voltage when the switch is closed at T=0

(b) first reflection at load

(c) second reflection at source

(d) third reflection at load



(a) Voltage at $t=0$

$$V_{1+} = V_S \times \frac{Z_0}{Z_0 + Z_S}$$

$$= 10 \times \frac{100}{100+25} = 8V$$

(b) $V_{1(-)} = V_1$

$= 8$

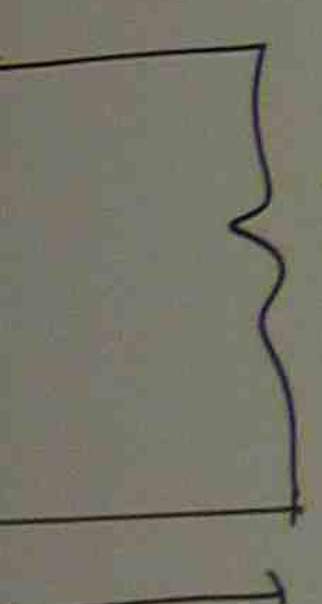
$= 8$

$= 8$

First reflection at load V_1

(c) $V_{2+} =$

S Ω IS
G AN
IS
F TIME
LINE.
AT $T=0$



$\Big\} Z_L = 900\Omega$

$\overline{\quad 25} = 8V$

(b) $V_{1(-)} = V_{1(+)} \Gamma_L$

$= 8 \times \dfrac{Z_L - Z_0}{Z_L + Z_0}$

$= 8 \times \dfrac{900-100}{900+100}$

$= 8 \times \dfrac{800}{1000} = 6.4V$

FIRST REFLECTION AT LOAD $\quad V_{(+)} = V_{1(+)} + V_{1(-)}$

$= 8 + 6.4$

$= 14.4V$

(c) $V_{2+} = V_{(-)} \times \Gamma_S$

$= 6.4 \times \dfrac{Z_S - Z_0}{Z_S + Z_0}$

$= 6.4 \times \dfrac{25-100}{25+100}$

$= -3.84V$

2^{nd} REFLECTION AT SOURCE $\quad = V_{1(+)} + V_{1(-)} + V_{2(+)}$

$= 8 + 6.4 + (-3.84)$

$= 10.56V$

(d) $V_{2(-)} = V_{2(+)} \Gamma_L$

$= (-3.84) \times \dfrac{Z_L - Z_0}{Z_L + Z_0}$

$= -3.84 \times \dfrac{900-100}{900+100}$

$= -3.072V$

3^{rd} REFLECTION AT LOAD $\quad = V_{1(+)} + V_{1(-)} + V_{2(+)} + V_{2(-)}$

$= 8 + 6.4 + (-3.84) + (-3.072)$

$= 7.488V$

AP
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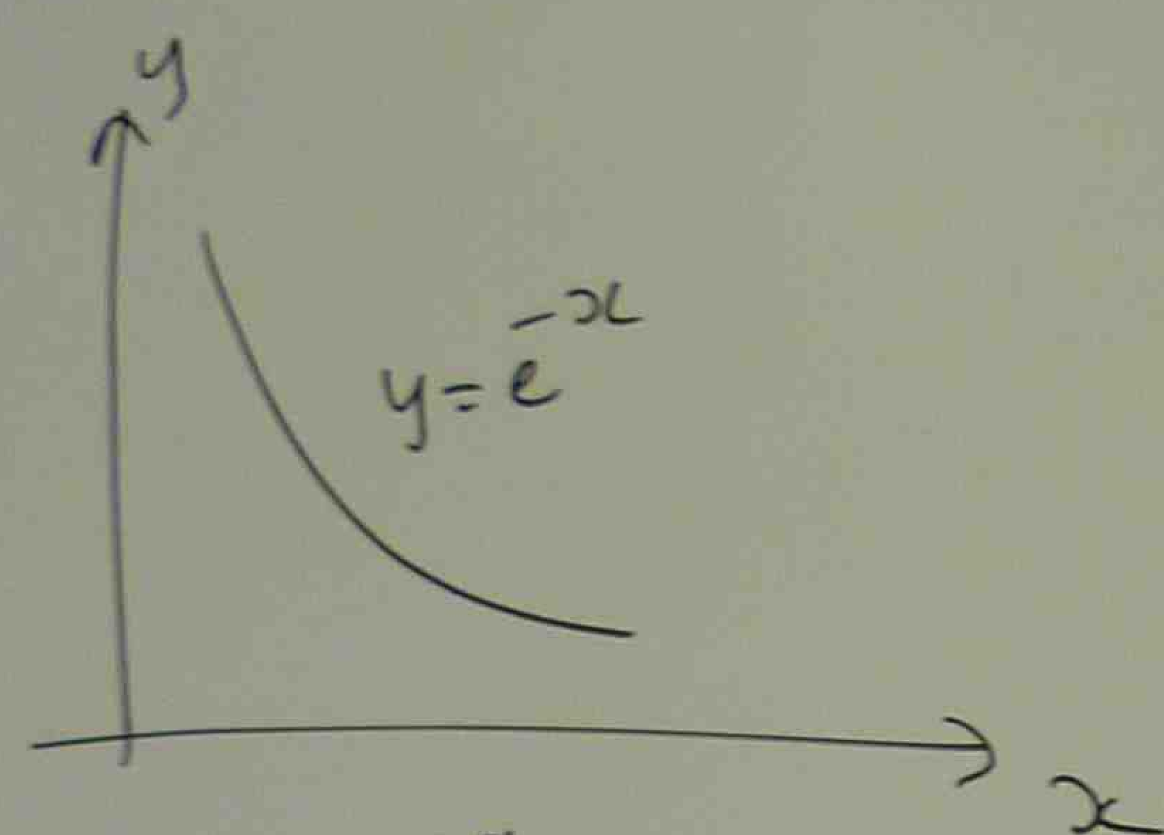
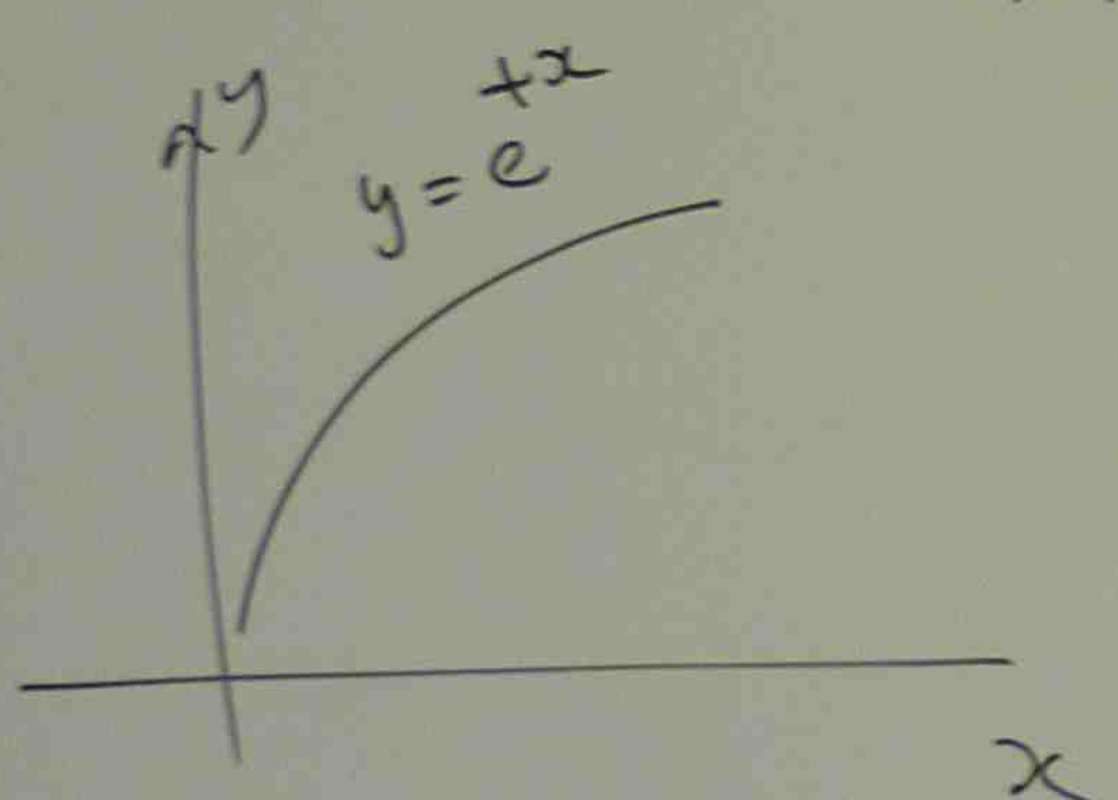
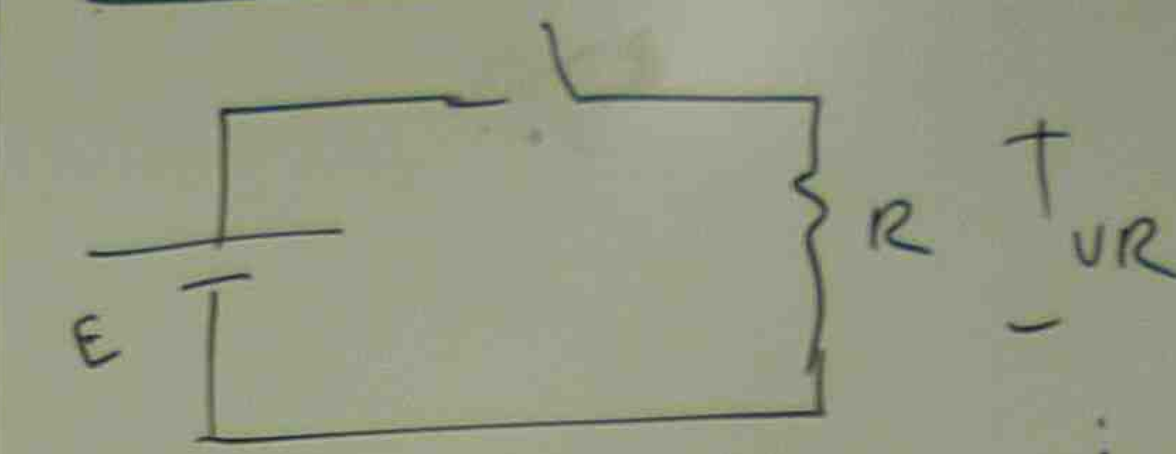
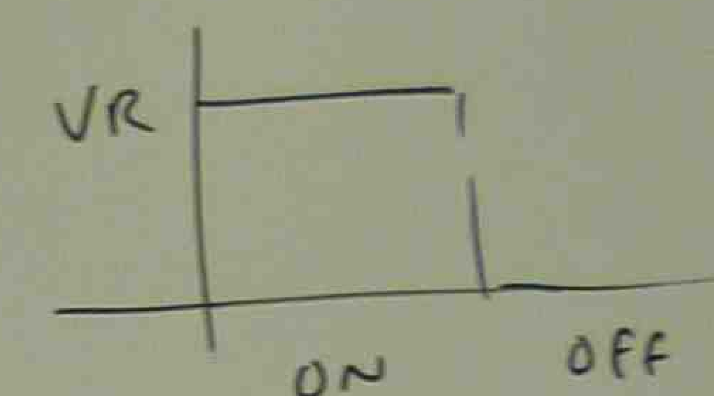
APPLICATION OF EXPONENTIAL FUNCTION IN POWER ENGINEERING CALCULATIONS

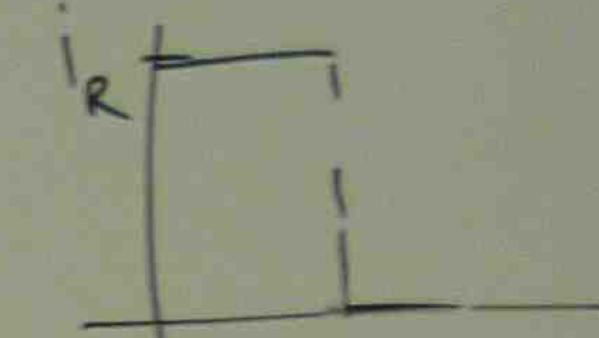


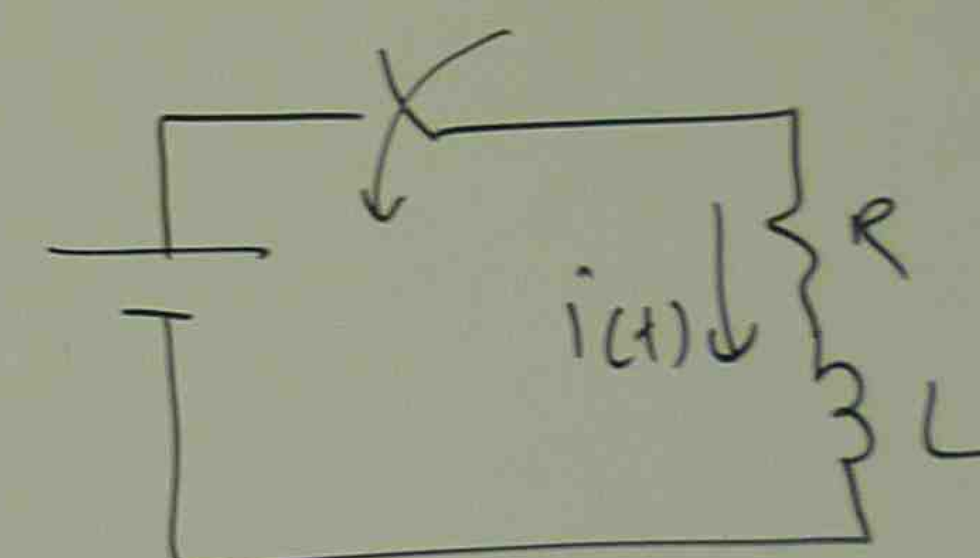


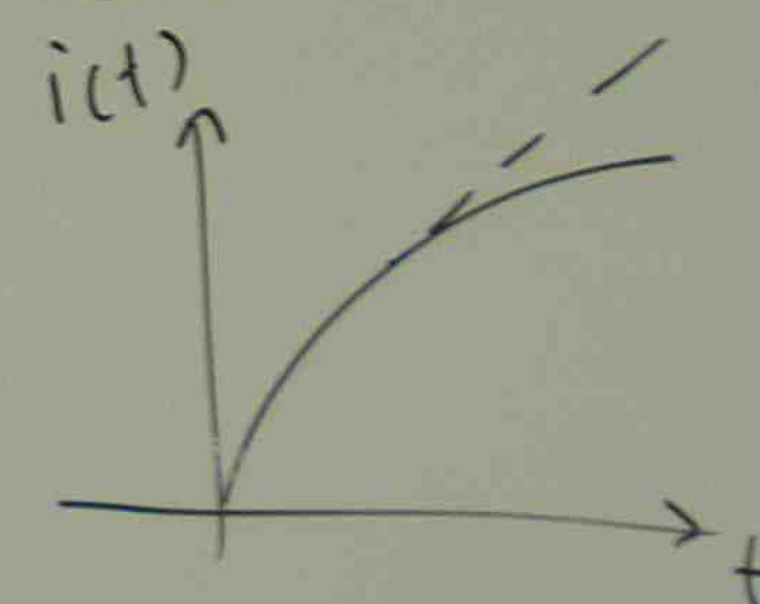
PURE RESISTANCE





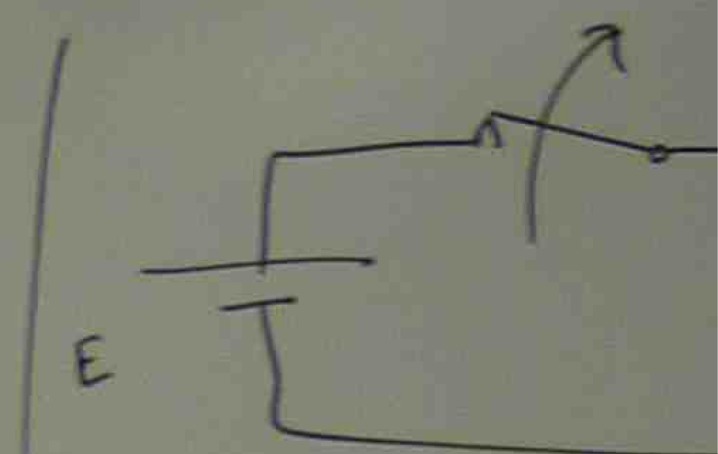


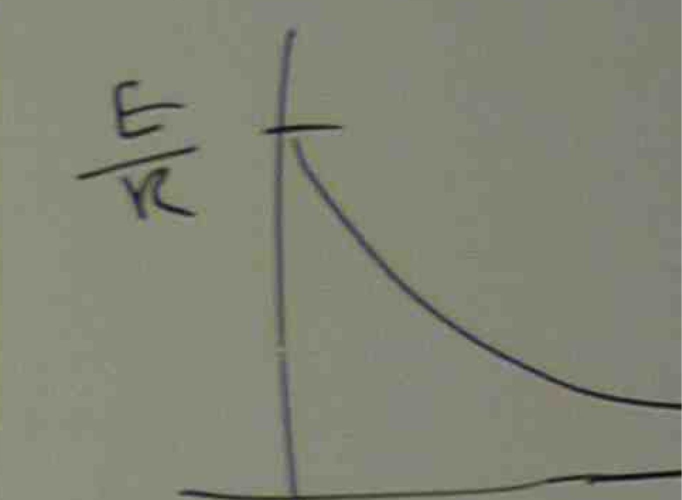




$$i(t) = \frac{V}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$$

INITIAL STATE FAULT CURRENT



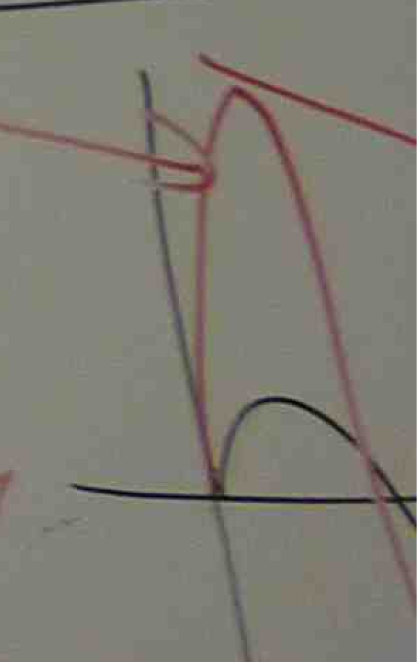


$i(t) = \frac{E}{R}$

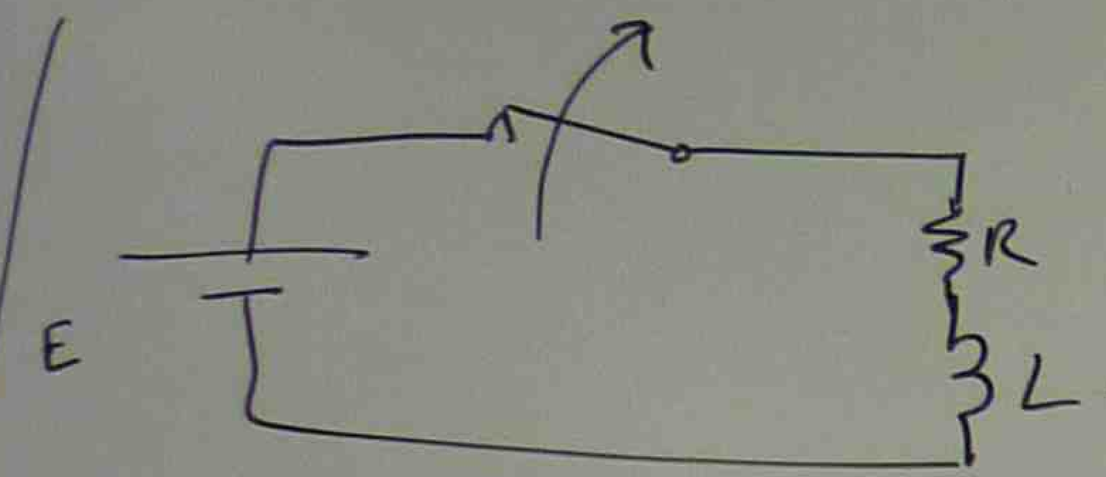
TRANSIENT

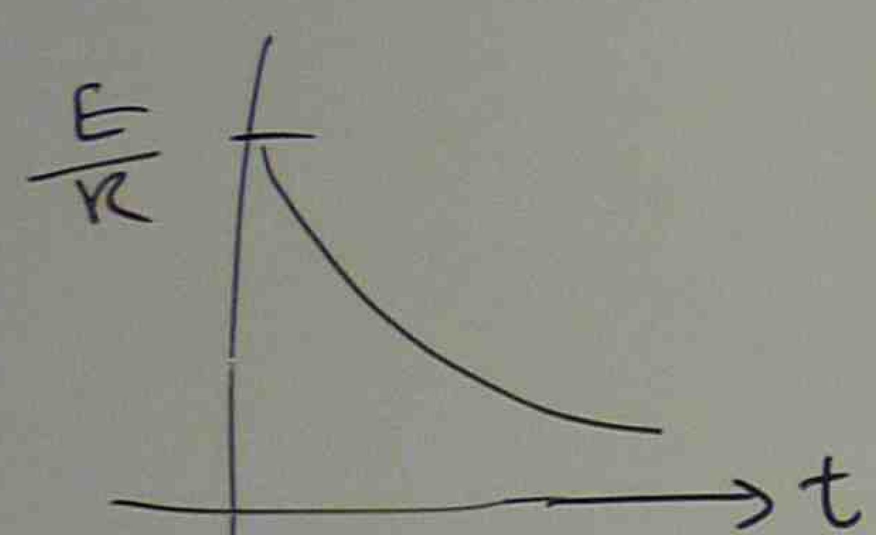
USES EXP

POWER LINE



$+(-307x)$



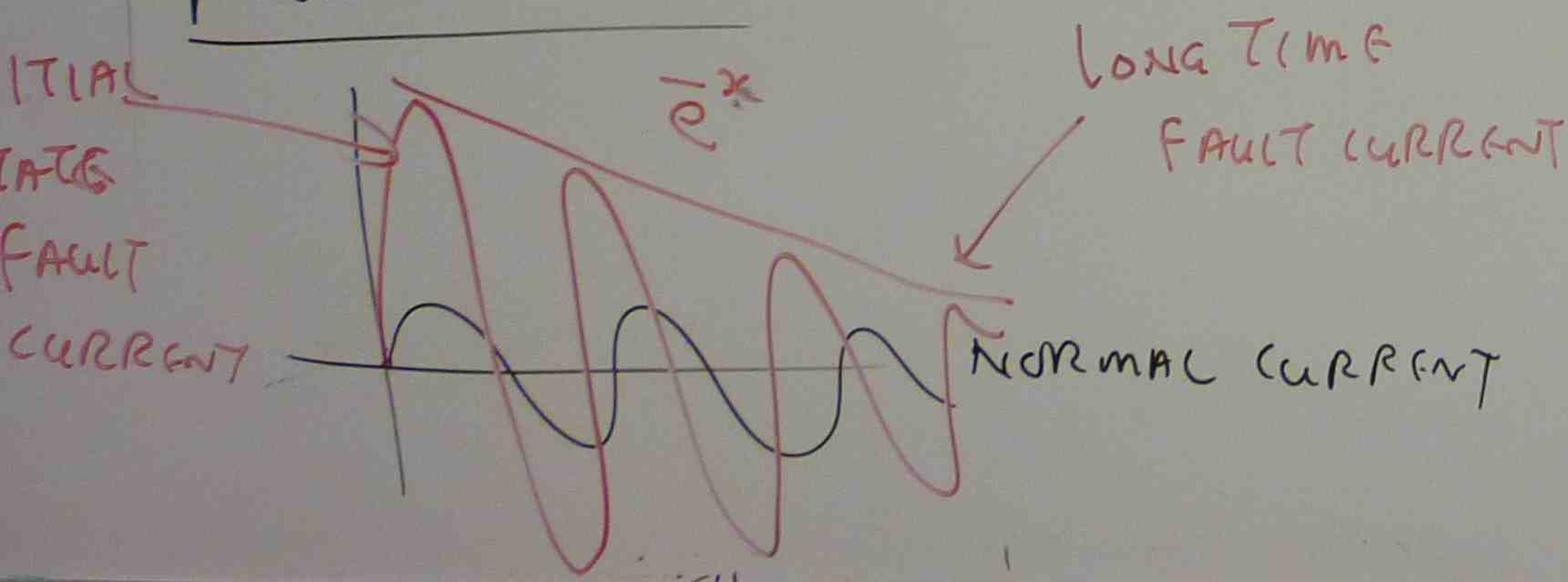


$$i(t) = \frac{E}{R}\, e^{-\frac{Rt}{L}}$$

TRANSIENT CIRCUIT CALCULATION

USES EXPONENTIAL FUNCTION

POWER LINE FAULT



Ex

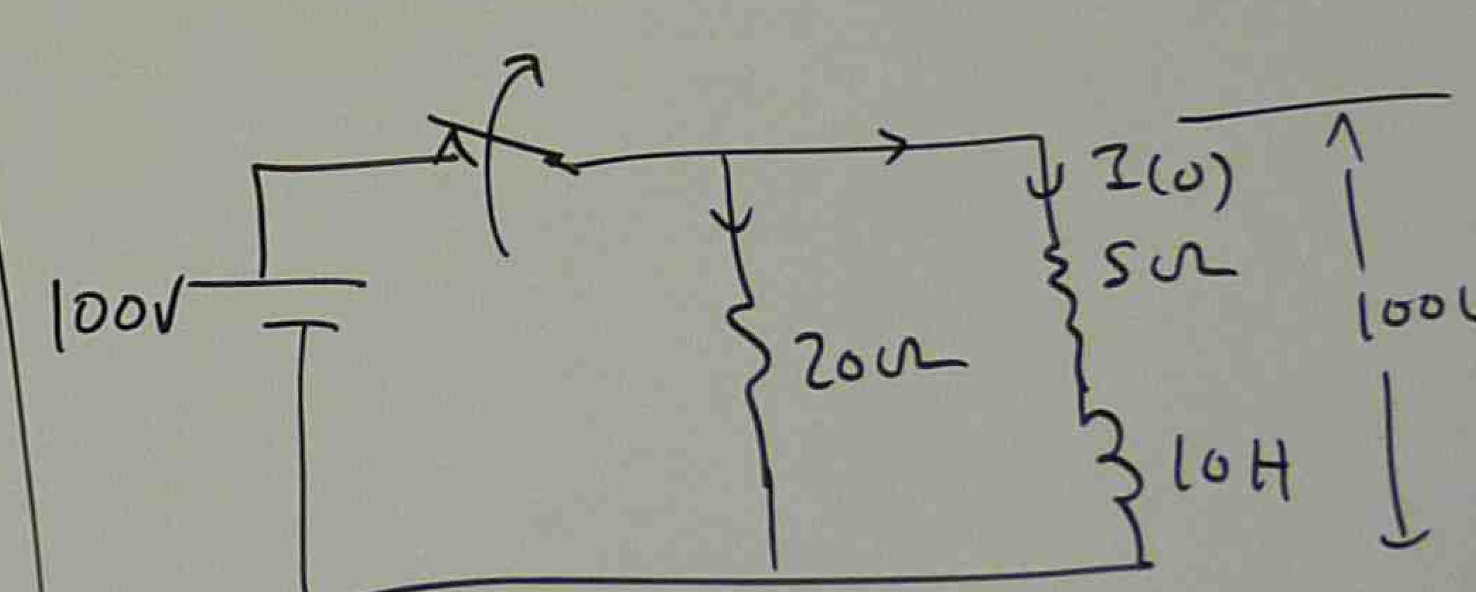
A COIL OF 10 H INDUCTANCE AND 5 OHM RESISTANCE IS CONNECTED IN PARALLEL WITH A 20 OHM RESISTOR ACROSS A 100 V DC SUPPLY WHICH IS SUDDENLY DISCONNECTED.

FIND (a) INITIAL RATE OF CHANGE OF CURRENT AFTER SWITCHING

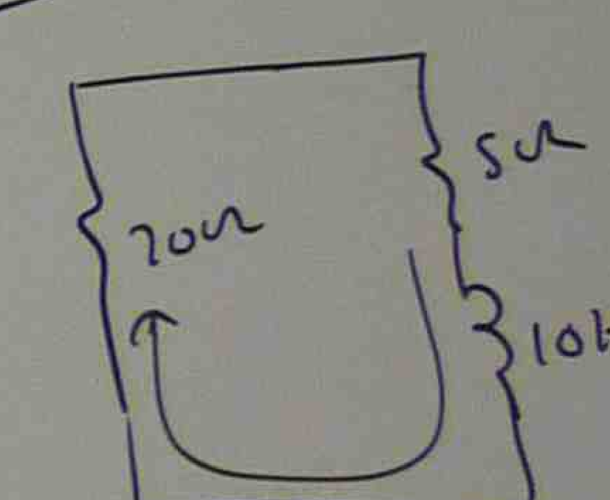
(b) THE VOLTAGE ACROSS 20 Ω RESISTOR INITIALLY AFTER 0.3 S

(c) THE VOLTAGE ACROSS THE SWITCH CONTACTS AT THE INSTANCE OF SEPARATION

(d) THE RATE AT WHICH THE COIL IS LOSING STORED ENERGY 0.3 Sec AFTER SWITCHING.



OFF THE SWITCH



$$I(0) = \frac{100}{5} = 20A$$

I(t)

R =

L =

I(t)

(a)

$\frac{dI}{dt}$

RESISTANCE IS
TOR ACROSS A
CTED.

AFTER SWITCHING

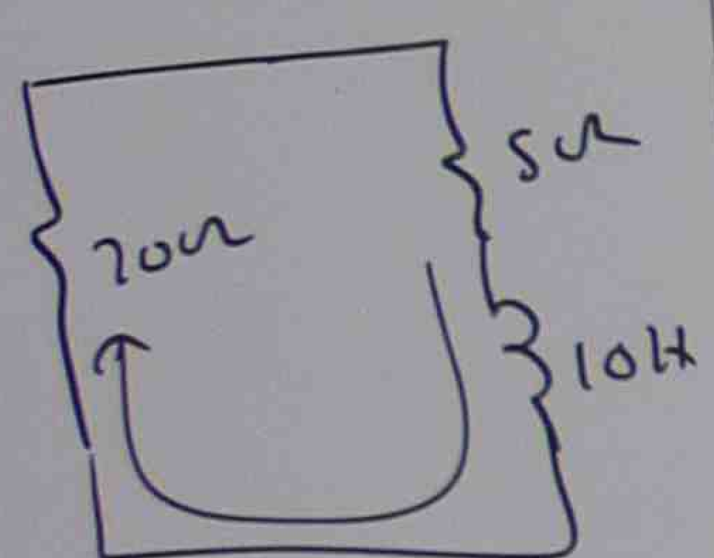
INITIALLY

CTS AT THE

OSING STORED

HING.

OFF THE SWITCH



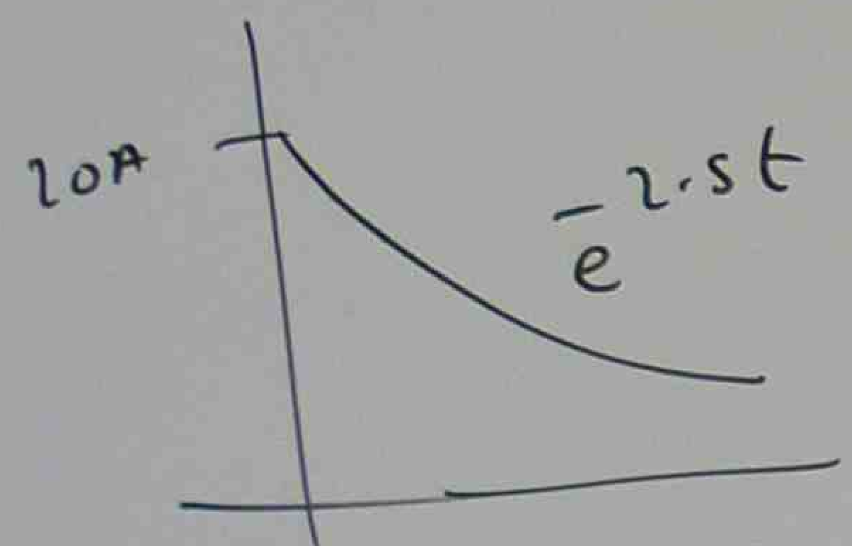
$$I(t) = I(0)\, e^{-\frac{Rt}{L}}$$

$$R = 20+5 = 25\Omega$$

$$L = 10H$$

$$I(t) = 20\, e^{-\frac{25t}{10}}$$

$$= 20\, e^{-2.5t}$$



(a)

$$\frac{dI(t)}{dt} = \frac{d}{dt}\left(20e^{-2.5t}\right)$$

$$= 20(-2.5)\, e^{-2.5t}$$

$$= -50\, e^{-2.5t}$$

(b)

$$V_{20\Omega}(t) = I(t) \times 20\Omega$$

$$= 20\, e^{-2.5t} \times 20$$

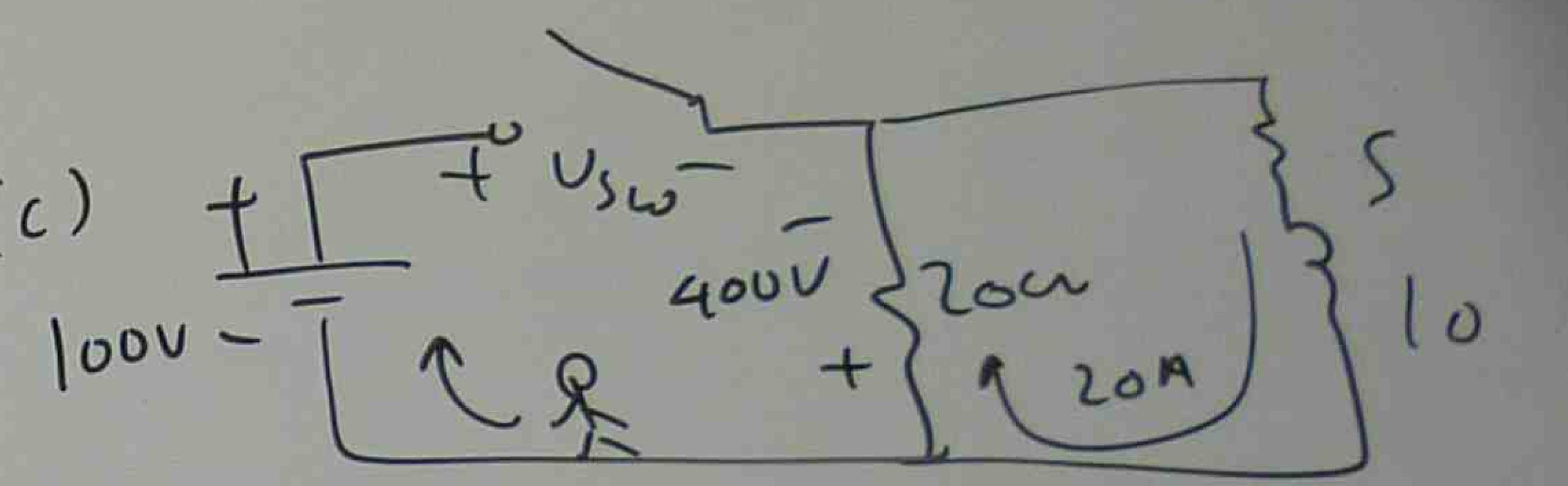
$$= 400\, e^{-2.5t}$$

$$V_{20\Omega}(0.3) = 400 \times e^{-2.5\times 0.3}$$

$$= 400 \times e^{-0.75}$$

$$= 188V$$

(c)



$$V_{20\Omega}(0) = 20\times 20 = 400V$$

$$(-100) + V_{sw} + (-400) = 0$$

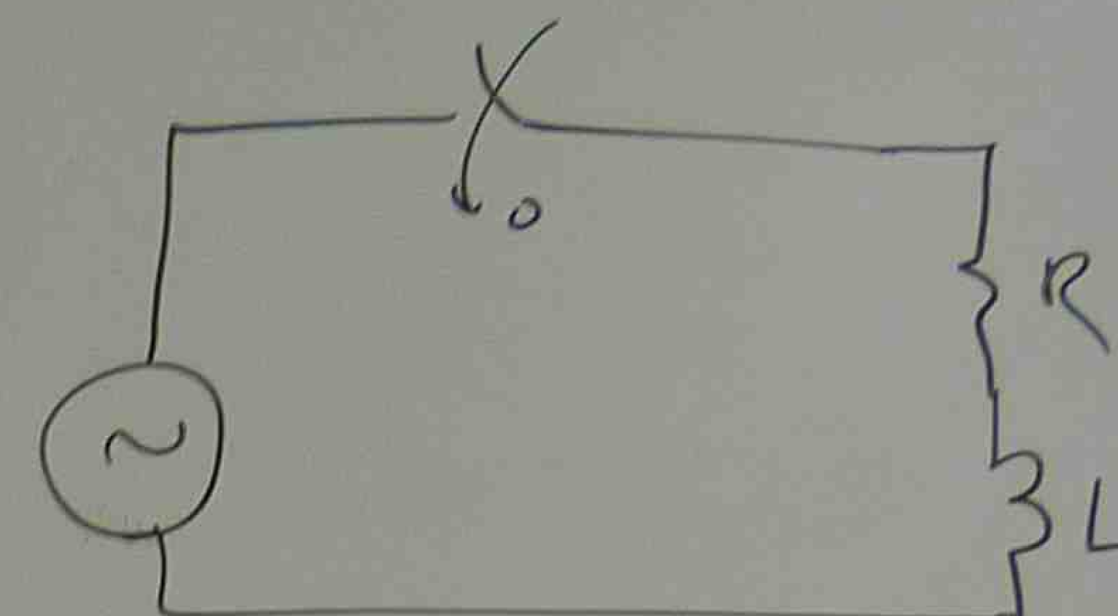
$$V_{sw} = 500\, V$$

(d)

$$\text{STORED ENERGY} = L\frac{di(t)}{dt} \times i(t)$$

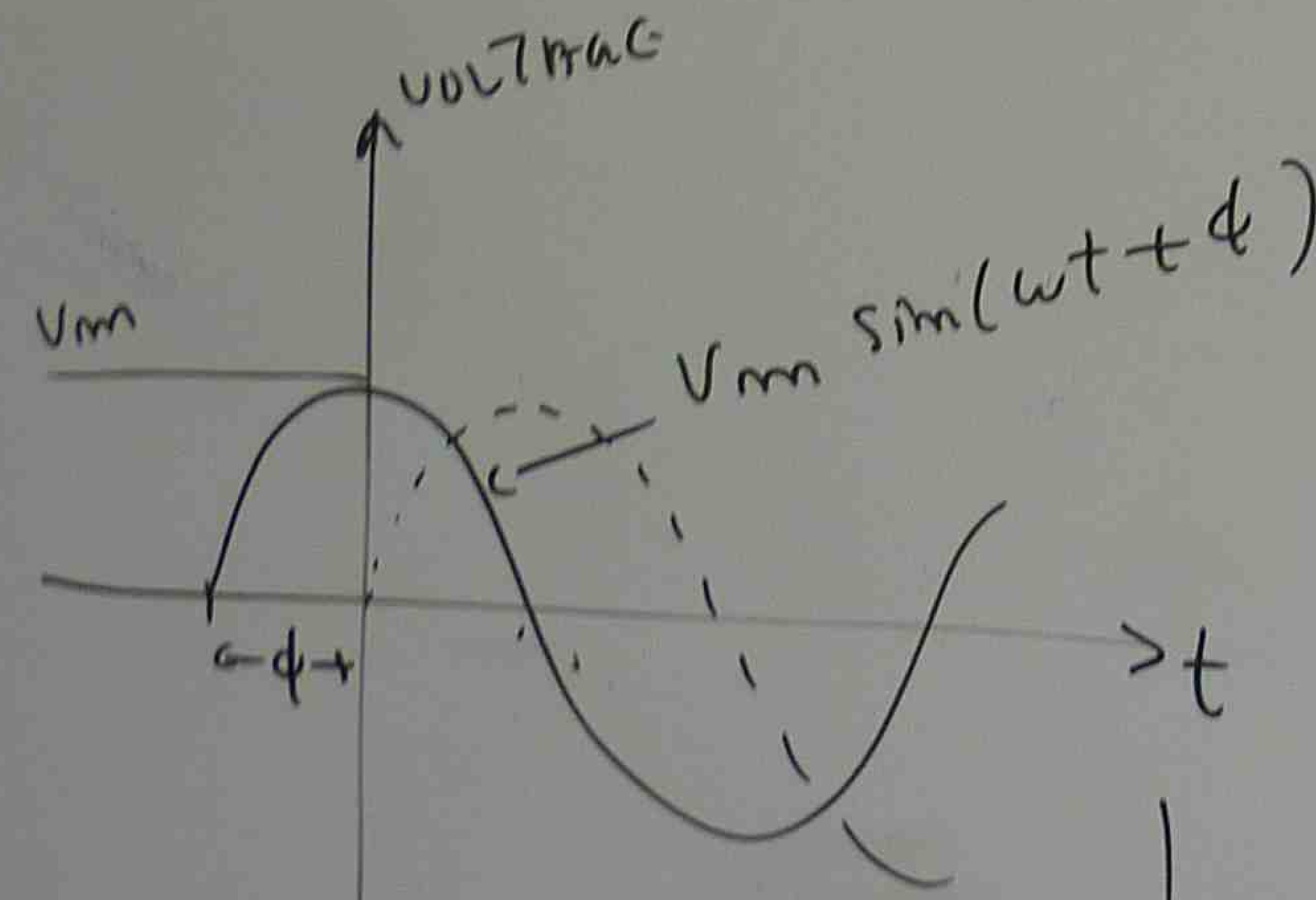
$$10 \times (-50e^{-2.5t}) \times 20e^{-2.5t} = -10000\, e^{-5t}$$

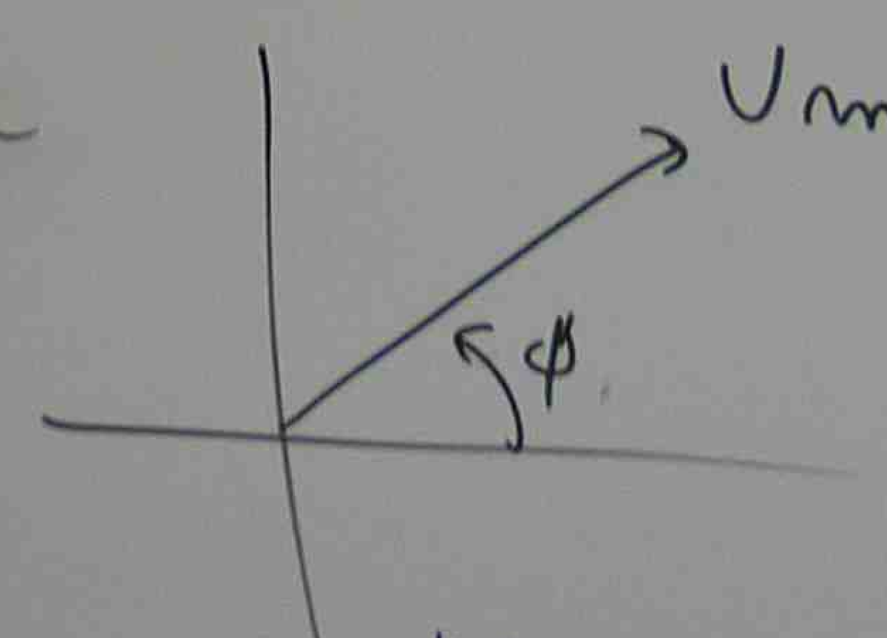
TRANSIENT / EXPONENTIAL FUNCTION IN AC CIRCUITS



$$V = V_m \sin(\omega t + \phi)$$

TIME DOMAIN REPRESENTATION

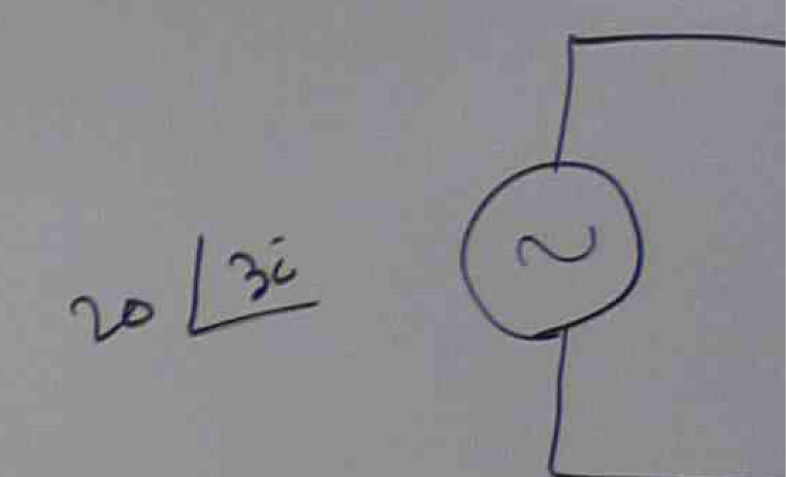




VECTOR

$$V = \frac{V_m}{\sqrt{2}} \angle \phi$$

FREQUENCY DOMAIN REPRESENTATION



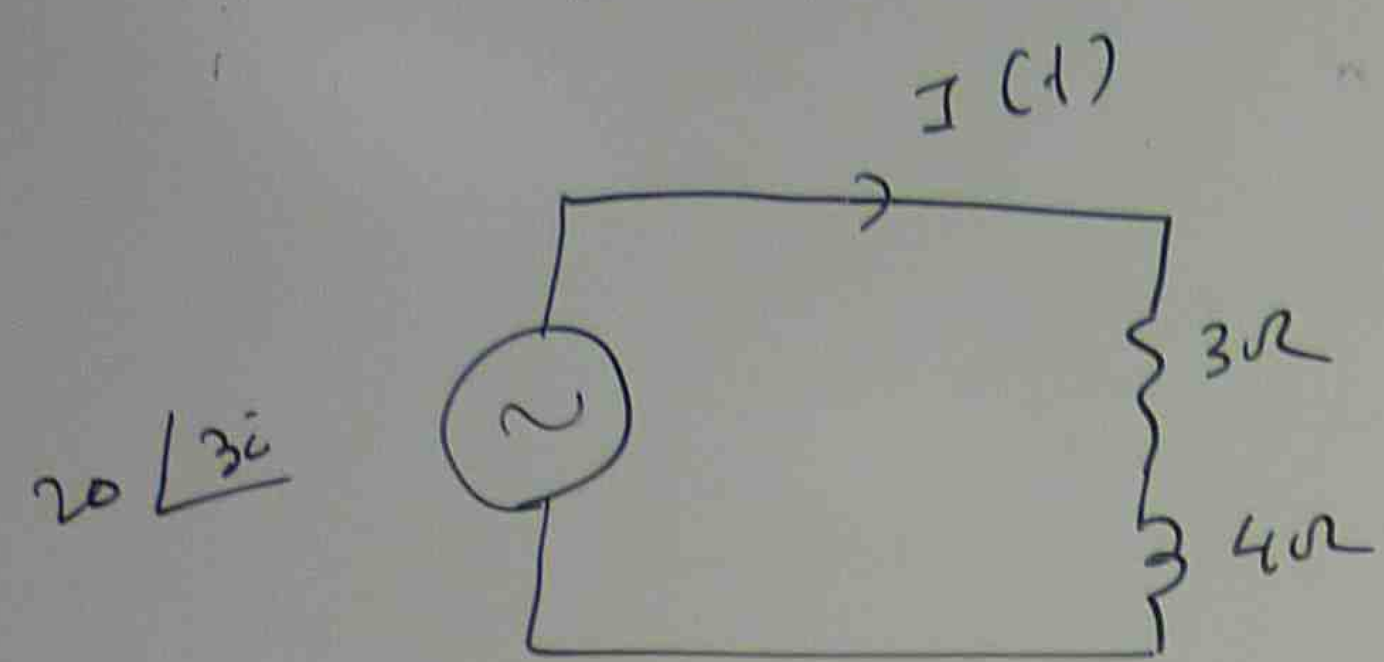
FIND THE

(a

(b

F

I



FIND THE CURRENT IN

(a) FREQUENCY DOMAIN REPRESENTATION

(b) TIME DOMAIN REPRESENTATION

FREQUENCY = 50Hz

$$I = \frac{V}{Z} = \frac{20\angle 30}{3+j4} = \frac{20\angle 30}{\sqrt{3^2+4^2}\ \angle \tan^{-1} 4/3}$$

$$= \frac{20\angle 30}{5\angle 53.2}$$

(a) FREQUENCY DOMAIN CURRENT $= 4\angle -23.2$

(b) TIME DOMAIN CURRENT

$$I(t) = I_m \sin(\omega t + \phi)$$

$$= \sqrt{2} \times 4 \sin(2\pi f t + (-23.2))$$

$$= 1.4142 \times 4 \sin(2 \times 3.1416 \times 50t - 23.2)$$

$$= 5.62 \sin(314t - 23.2)$$

(b) TIME DOMAIN CURRENT

$$I(t) = I_m \sin(\omega t + \phi)$$

$$= \sqrt{2} \times 4 \sin(2\pi f t + (-23.2))$$

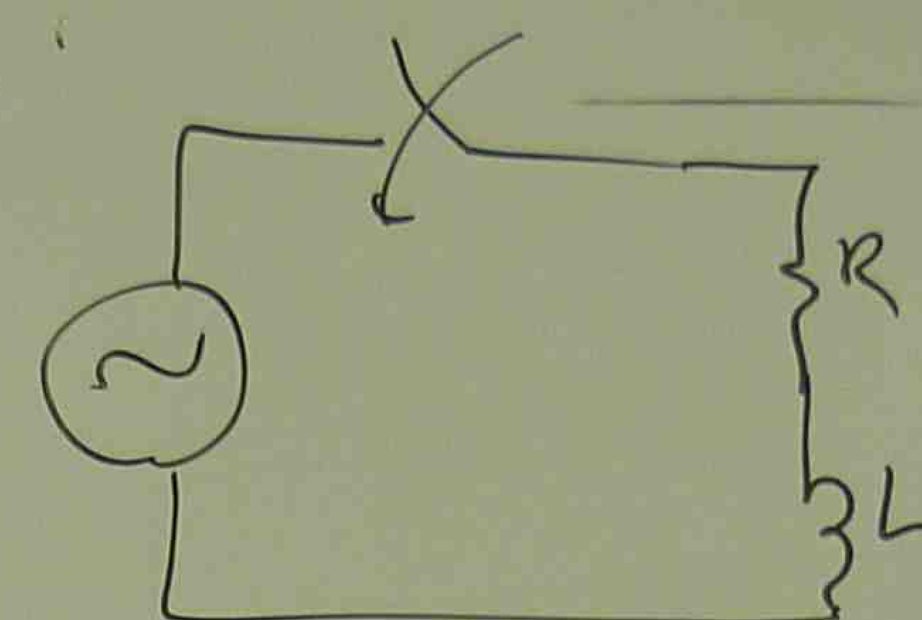
$$= 1.4142 \times 4 \sin(2 \times 3.1416 \times 50 t - 23.2)$$

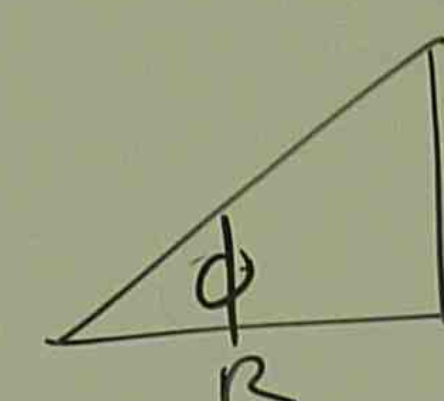
$$= 5.62 \sin(314 t - 23.2)$$

$$\frac{20\angle 30}{\sqrt{3^2+4^2}\ \angle \tan^{-1} 4/3}$$

$$\frac{20\angle 30}{5\angle 53.2}$$

$$4\angle -23.2$$



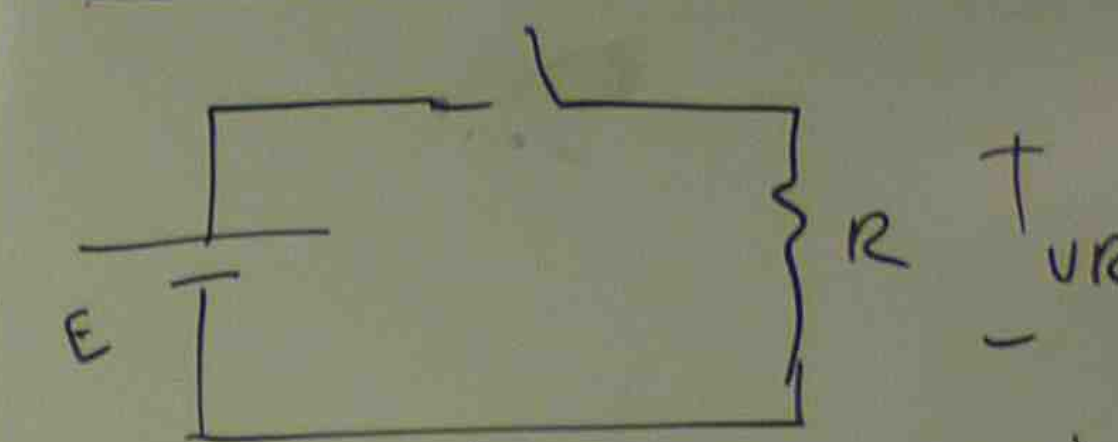


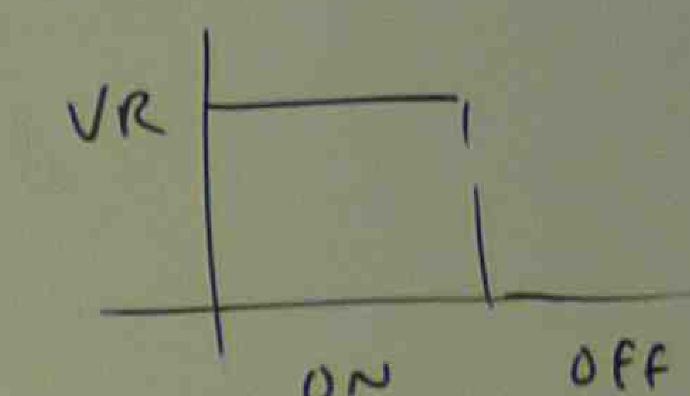
$$X_L = 2\pi f L = \omega L$$

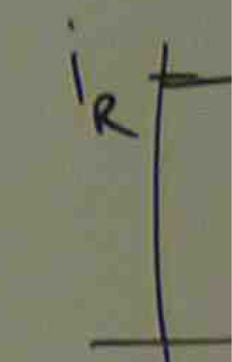
$$i(t) = \frac{V_m}{\sqrt{R^2 + \omega^2 L^2}} \left(\sin(\omega t - \phi) + \sin\phi\ e^{-\frac{Rt}{L}} \right)$$

$$\phi = \tan^{-1} \frac{\omega L}{R}$$

PURE RESISTANCE



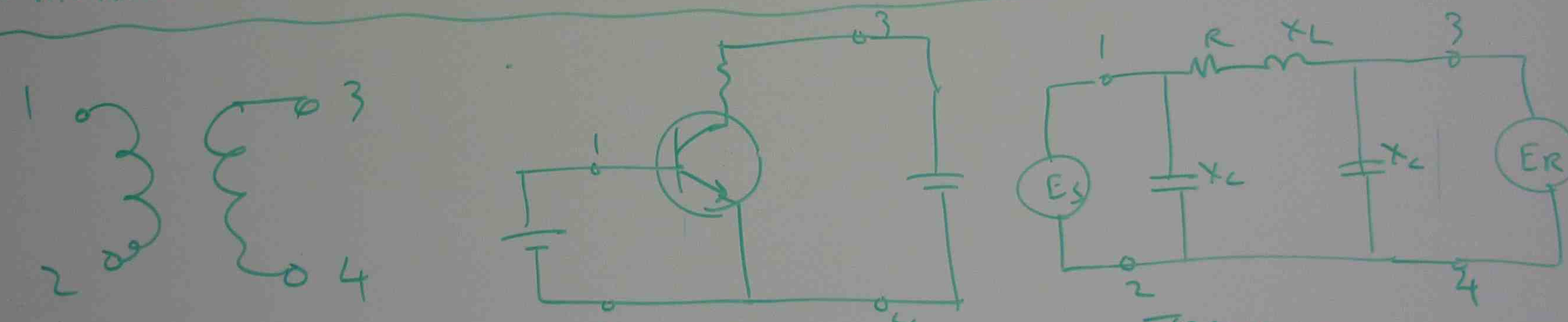




SOLVING SIMULTANEOUS EQUATIONS IN POWER ENGINEERING PROBLEMS

MATHEMATICAL MODELLING – REPRESENTING ELECTRICAL MODEL BY MATHEMATICAL EQUATIONS.

MATHEMATICAL EQUATIONS FOR FOUR TERMINAL NETWORKS

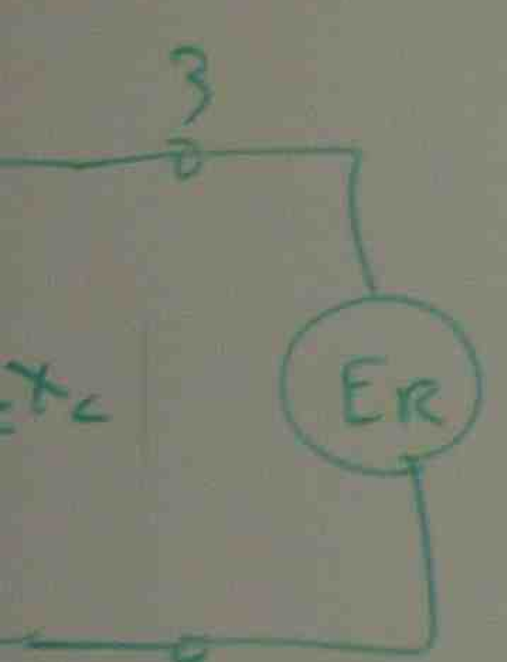


TRANSFORMER TRANSISTOR TRANSMISSION LINE

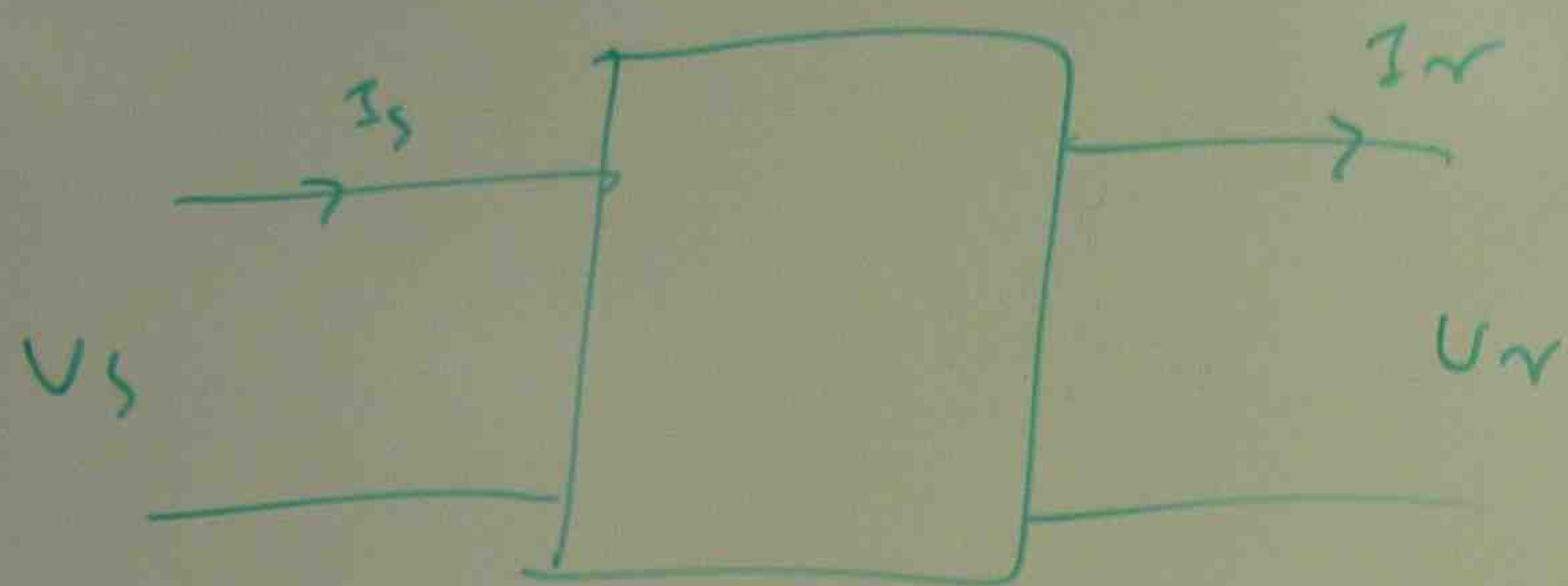
V_S

$\overline{V_S}$ =

$\overline{I_S}$

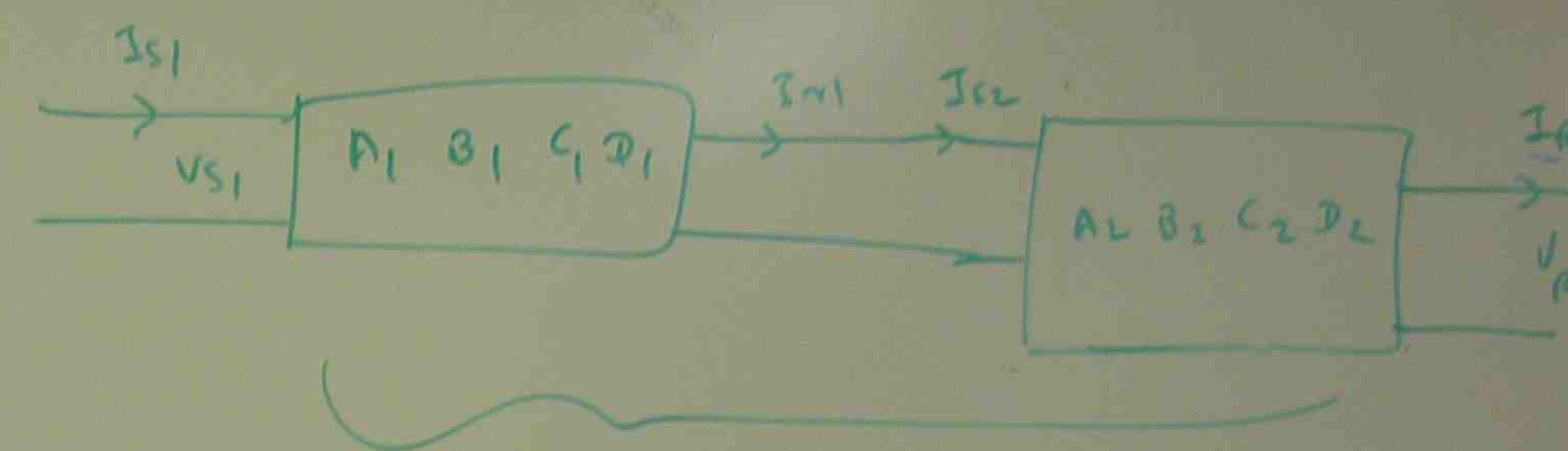


N LINE



$$\bar{V}_s = A\bar{V}_r + B\bar{I}_r$$

$$\bar{I}_s = C\bar{V}_r + D\bar{I}_r$$



$$A_{eq} = A_1A_2 + B_1C_2$$

$$B_{eq} = A_1B_2 + B_1D_2$$

$$C_{eq} = C_1A_2 + D_1C_2$$

$$D_{eq} = C_1B_2 + D_1D_2$$

$$\bar{V}_s = A_{eq}\bar{V}_r + B_{eq}\bar{I}_r$$

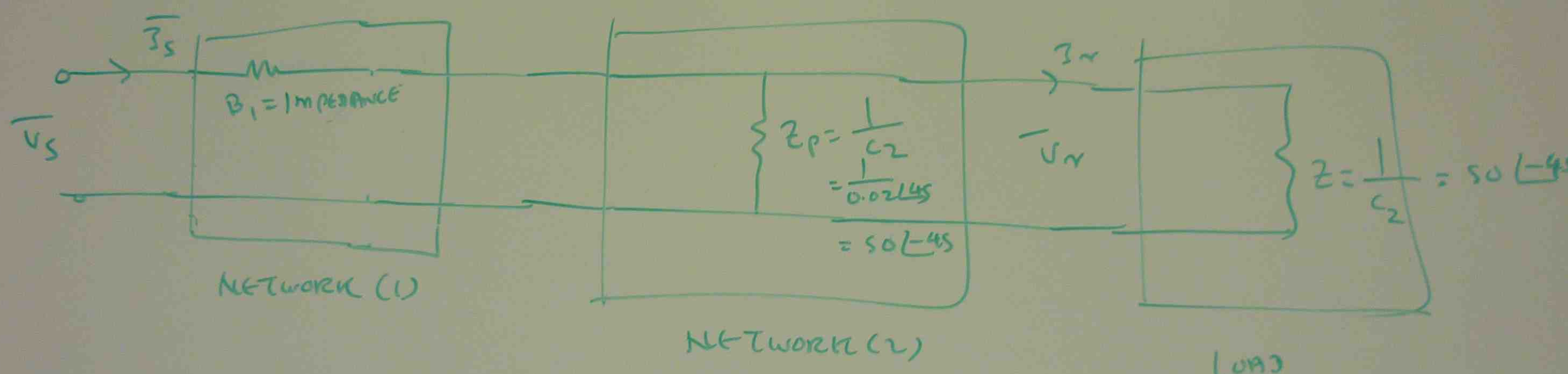
$$\bar{I}_s = C_{eq}\bar{V}_r + D_{eq}\bar{I}_r$$

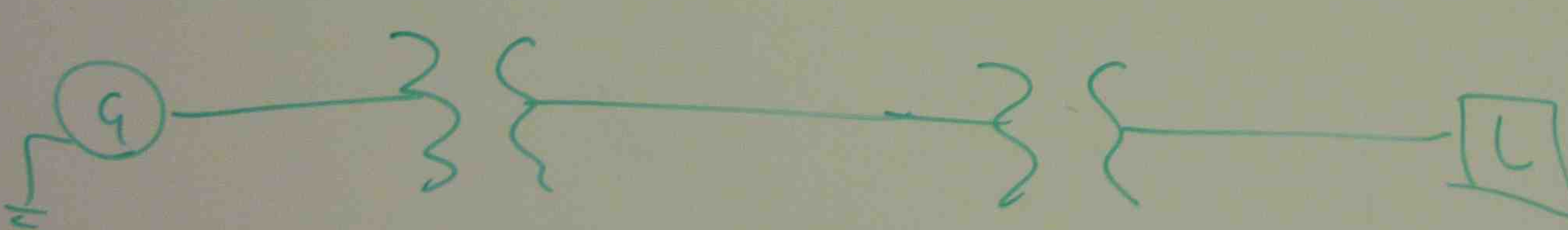
pb

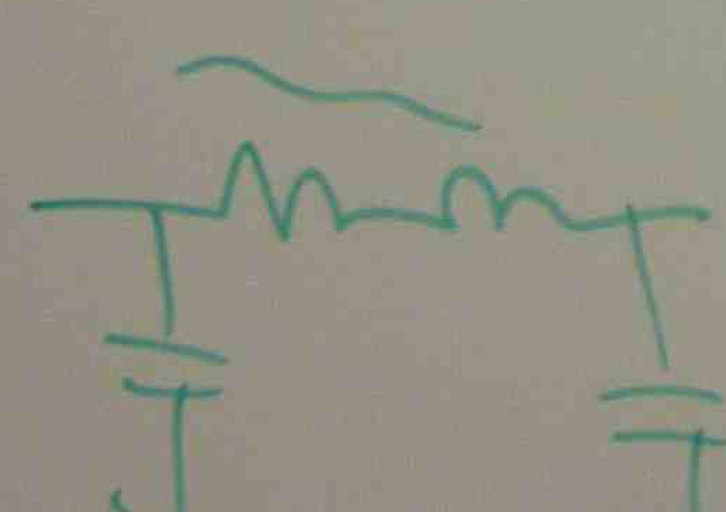
DETERMINE THE EQUIVALENT A, B, C, D CONSTANTS OF THE GIVEN NETWORK.

$A_1 = 1.0$ $\quad B_1 = 20\angle 30\ \Omega$ $\quad C_1 = 0\ \mho$ $\quad D_1 = 1.0$

$A_2 = 1.0$ $\quad B_2 = 0$ $\quad C_2 = 0.02\angle 45\ \mho$ $\quad D_2 = 1.0$







I_{R_2}

V_{R_2}

$A_{eq} =$

B_{eq}

C_{eq}

12

$$A_{eq} = A_1 A_2 + B_1 C_2 = 1.0 \times 1.0 + 20\angle 30 \times 0.02\angle 45$$
$$= 1 + 0.4\angle 75$$
$$= 1 + 0.4(\cos 75 + j\sin 75)$$
$$= 1 + 0.4(0.2588 + j0.965)$$
$$= 1 + 0.1 + j0.4965$$
$$= 1.1 + j0.4965$$
$$= \sqrt{1.1^2 + 0.4965^2}\ \angle \tan^{-1}\frac{0.4965}{1.1}$$
$$A_{eq} = 1.206\angle 24.2$$

$$B_{eq} = A_1 B_2 + B_1 D_2 = 1.0 \times 0 + 20\angle 30 \times 1.0$$
$$= 0 + 20\angle 30 = 20\angle 30$$

$$C_{eq} = C_1 A_2 + D_1 C_2 = 0 \times 1.0 + 1.0 \times 0.02\angle 45$$
$$= 0.02\angle 45$$

$$D_{eq} = C_1 B_2 + D_1 D_2$$
$$= 0 \times 0 + 1.0 \times 1.0$$
$$= 1.0$$

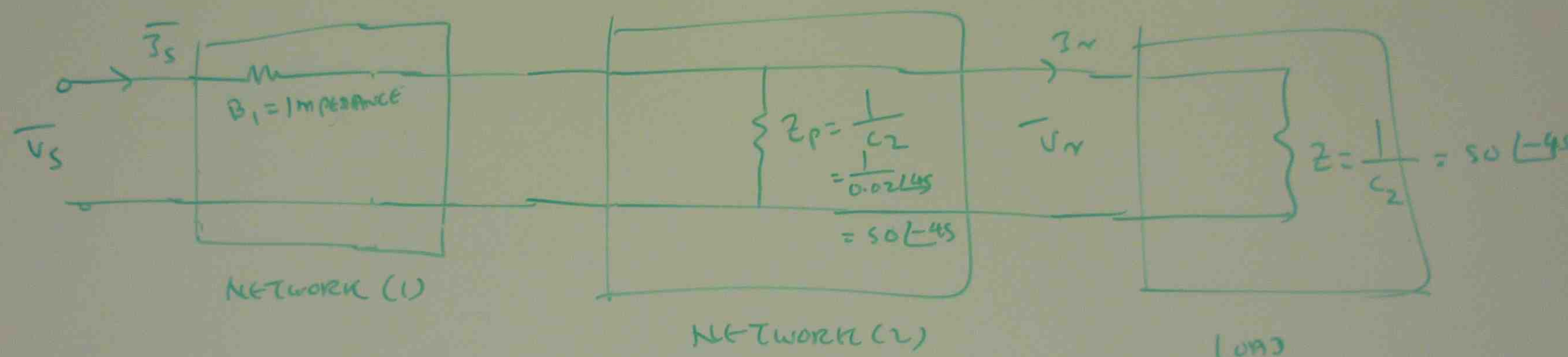
$$\bar{V}_s = A_{eq}\bar{V}_r + B_{eq}\bar{I}_r$$
$$= 1.206\angle 24.2 \cdot \bar{V}_r + 20\angle 30\ \bar{I}_r$$

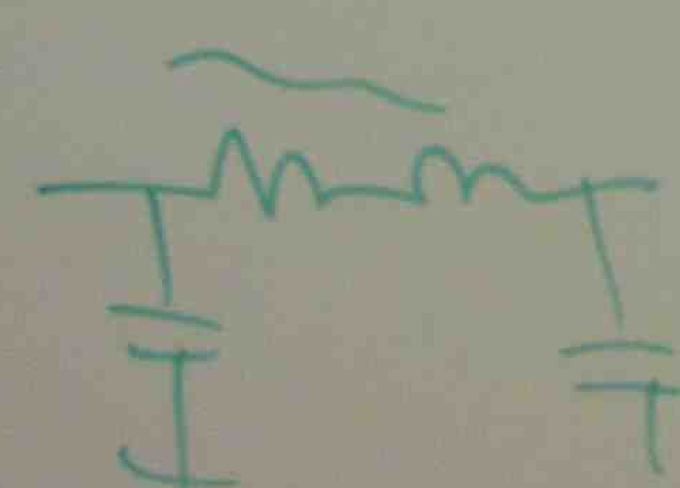
$$\bar{I}_s = C_{eq}\bar{V}_r + D_{eq}\bar{I}_r$$
$$= 0.02\angle 45\ \bar{V}_r + 1.0\ \bar{I}_r$$

pb DETERMINE THE EQUIVALENT A, B, C, D CONSTANTS of THE GIVEN NETWORK.

$A_1 = 1.0$ $\quad B_1 = 20\angle 30\ \Omega$ $\quad C_1 = 0\ \mho$ $\quad D_1 = 1.0$

$A_2 = 1.0$ $\quad B_2 = 0$ $\quad C_2 = 0.02\angle 45\ \mho$ $\quad D_2 = 1.0$





$A_{eq} =$

$B_{eq} =$

$C_{eq} =$

12

$A_{eq} = A_1A_2 + B_1C_2 = 1.0 \times 1.0 + 20\angle 30 \times 0.02\angle 45$

$= 1 + 0.4\angle 75$

$= 1 + 0.4(\cos 75 + j\sin 75)$

$= 1 + 0.4(0.2588 + j0.965)$

$= 1 + 0.1 + j0.4465$

$= 1.1 + j0.4465$

$= \sqrt{1.1^2 + 0.4465^2}\ \angle \tan^{-1}\frac{0.4465}{1.1}$

$A_{eq} = 1.206\angle 24.2$

$B_{eq} = A_1B_2 + B_1D_2 = 1.0 \times 0 + 20\angle 30 \times 1.0$

$= 0 + 20\angle 30 = 20\angle 30$

$C_{eq} = C_1A_2 + D_1C_2 = 0 \times 1.0 + 1.0 \times 0.02\angle 45$

$= 0.02\angle 45$

$D_{eq} = C_1B_2 + D_1D_2$

$= 0 \times 0 + 1.0 \times 1.0$

$= 1.0$

$\bar{V}_s = A_{eq}\bar{V}_r + B_{eq}\bar{I}_r$

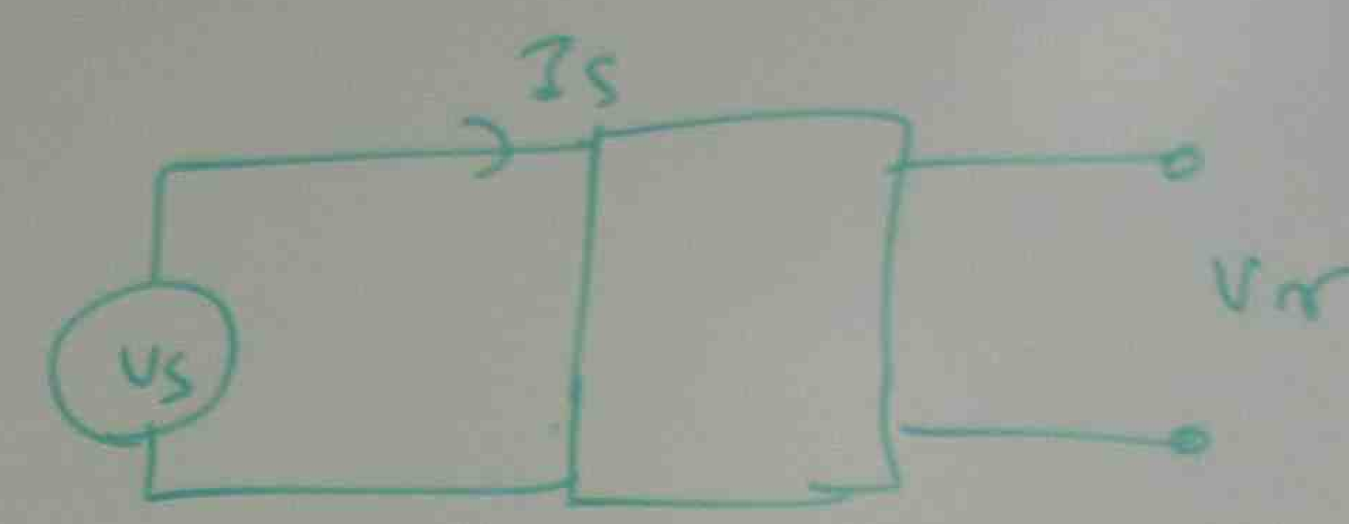
$= 1.206\angle 24.2\ \bar{V}_r + 20\angle 30\ \bar{I}_r$

$\bar{I}_s = C_{eq}\bar{V}_r + D_{eq}\bar{I}_r$

$= 0.02\angle 45\ \bar{V}_r + 1.0\ \bar{I}_r$

$\angle 45$

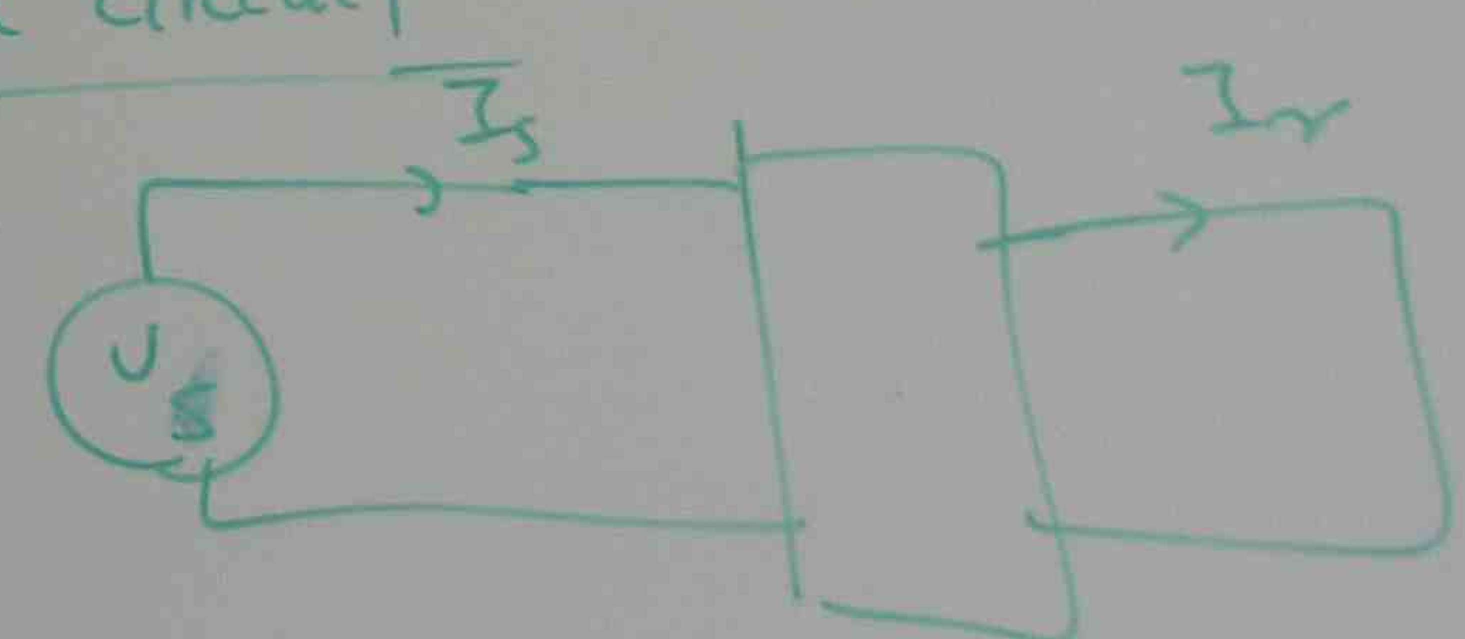
OPEN CIRCUIT



$$A_{eq} = \frac{V_s}{V_r}$$

$$C_{eq} = \frac{I_s}{V_s}$$

SHORT CIRCUIT



$$B_{eq} = \frac{V_s}{I_r} \qquad D_{eq} = \frac{I_s}{I_r}$$

pb

DETERMINE …

THE FOLLOWING …

RECEIVER OPEN…

$\overline{V_s} = 100$ …

$\overline{V_r} = 707$ …

$\overline{I_s} = 1.4$ …

$\overline{I_r} = 0$

OPEN

A = …

C …

pb

DETERMINE THE A, B, C, D CONSTANTS OF THE NETWORK IN WHICH THE FOLLOWING TEST RESULTS HAVE BEEN OBSERVED.

RECEIVER OPEN CIRCUIT

$\bar{V}_s = 100 \angle 0° \, V$

$\bar{V}_r = 70.7 \angle -45° \, V$

$\bar{I}_s = 1.41 \angle -45° \, A$

$\bar{I}_r = 0$

RECEIVER SHORT CIRCUIT

$\bar{V}_r = 0$

$\bar{V}_s = 100 \angle 0° \, V$

$\bar{I}_s = 2.0 \angle -90 \, A$

$\bar{I}_r = 2.0 \angle -90 \, A$

OPEN

$A = \frac{V_s}{V_r} = \frac{100 \angle 0}{70.7 \angle -45} = 1.41 \angle 45$

$C = \frac{I_s}{V_s} = \frac{1.41 \angle -45}{100 \angle 0} = 0.0141 \angle -45$

SHORT

$B = \frac{V_s}{I_r}$

$= \frac{100 \angle 0}{2.0 \angle 90}$

$= 50 \angle 90$

$D = \frac{I_s}{I_r} = \frac{2 \angle -90}{2 \angle -90}$

$= 1$

C, D CONSTANTS OF THE NETWORK IN WHICH

S HAVE BEEN OBSERVED.

RECEIVER SHORT CIRCUIT

$\bar{V}_r = 0$

$\bar{V}_s = 100\angle 0^\circ \text{ V}$

$\bar{I}_s = 2.0\angle -90 \text{ A}$

$\bar{I}_r = 2.0\angle -90 \text{ A}$

$$\frac{\ldots 0\angle 0}{\ldots 7\angle -45} = 1.41\angle 45$$

$$\frac{1.41\angle -45}{\ldots 00\angle 0} = 0.0141\angle -45$$

SHORT

$$B = \frac{V_s}{I_r} = \frac{100\angle 0}{2.0\angle 90} = 50\angle 90$$

$$D = \frac{I_s}{I_r} = \frac{2\angle -90}{2\angle -90} = 1$$

$$\bar{V}_s = A\bar{V}_r + B\bar{I}_r$$

$$\bar{V}_s = 1.41\angle 45\, V_r + 50\angle 90\, I_r$$

$$\bar{I}_s = C\bar{V}_r + D\bar{I}_r$$

$$\bar{I}_s = 0.0141\angle -45\, \bar{V}_r + 1\, \bar{I}_r$$

ph DETER…

THE GE…

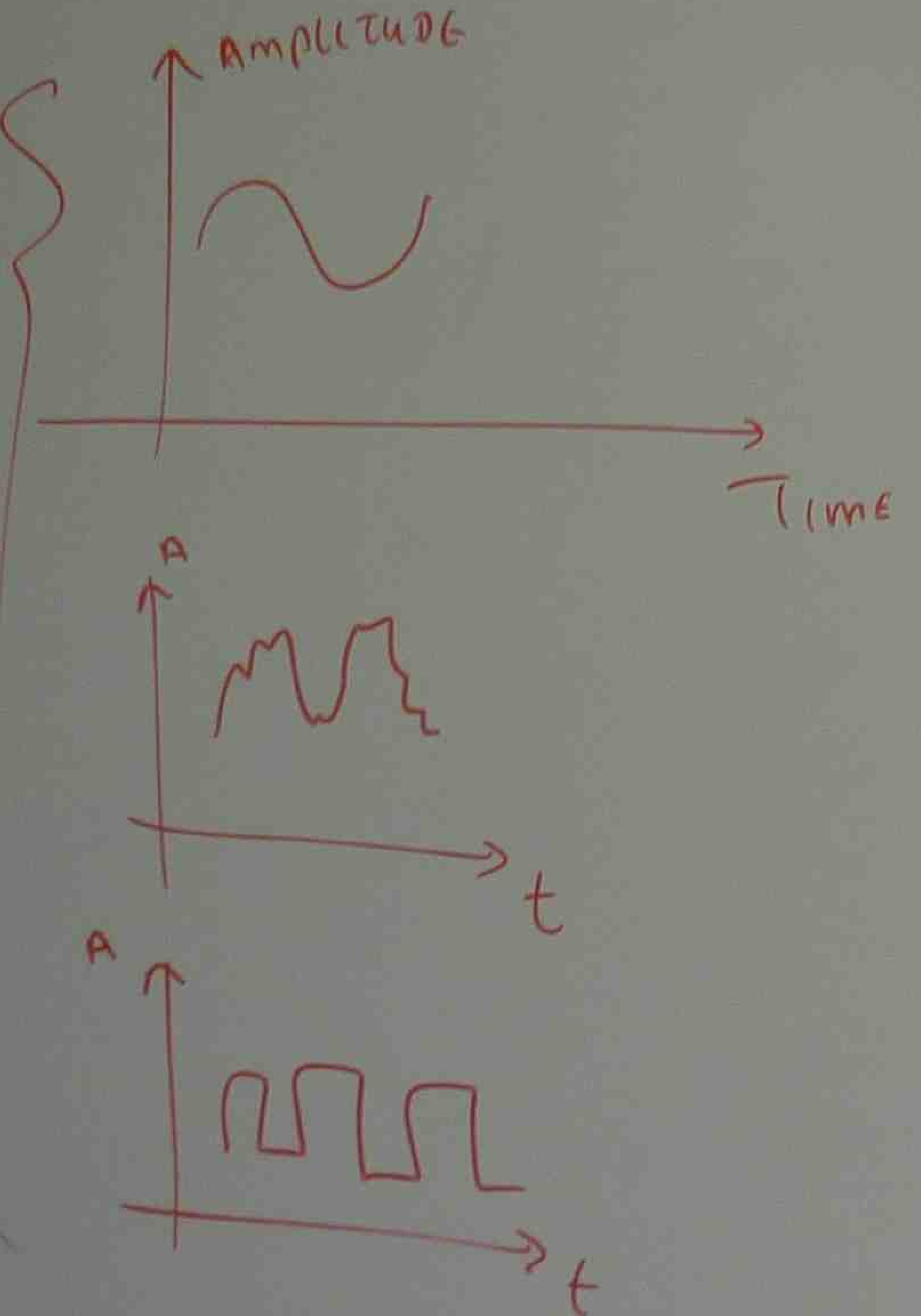
$A_1 =$

$A_2 =$

$\bar{V}_s$

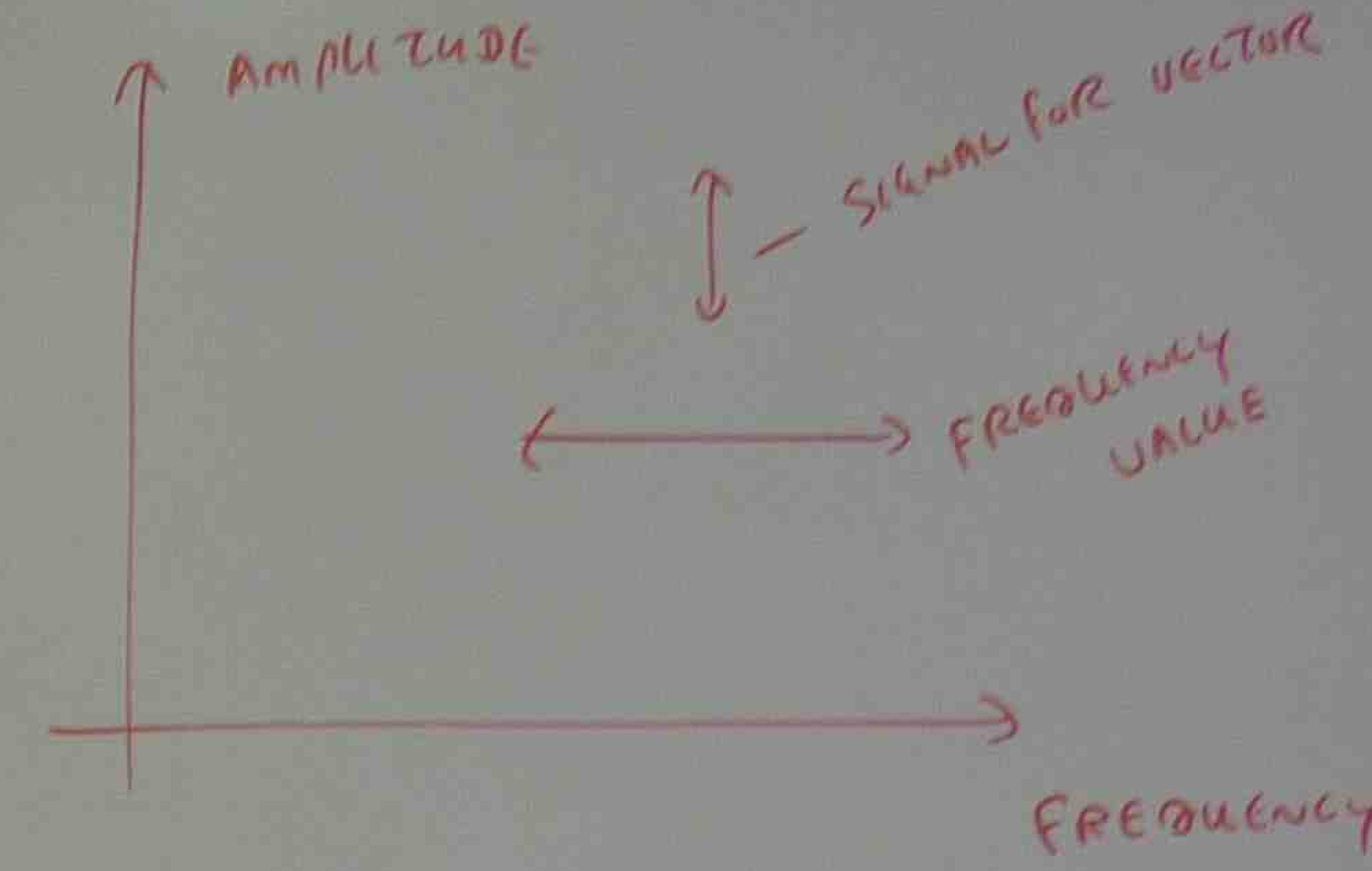
APPLICATION OF PERIODIC WAVE FUNCTION IN POWER ENGINEERING

TIME DOMAIN EXPRESSION



$f(t) = A \sin \omega t \pm \phi$ ← TRANSIENT CALCULATIONS

FREQUENCY DOMAIN EXPRESSION



$f(z) = A \angle \pm \phi$

↑

STEADY STATE CALCULATION.

Har

multi

Fund

Secon

Thir

...NAL FOR VECTOR

FREQUENCY VALUE

→ FREQUENCY

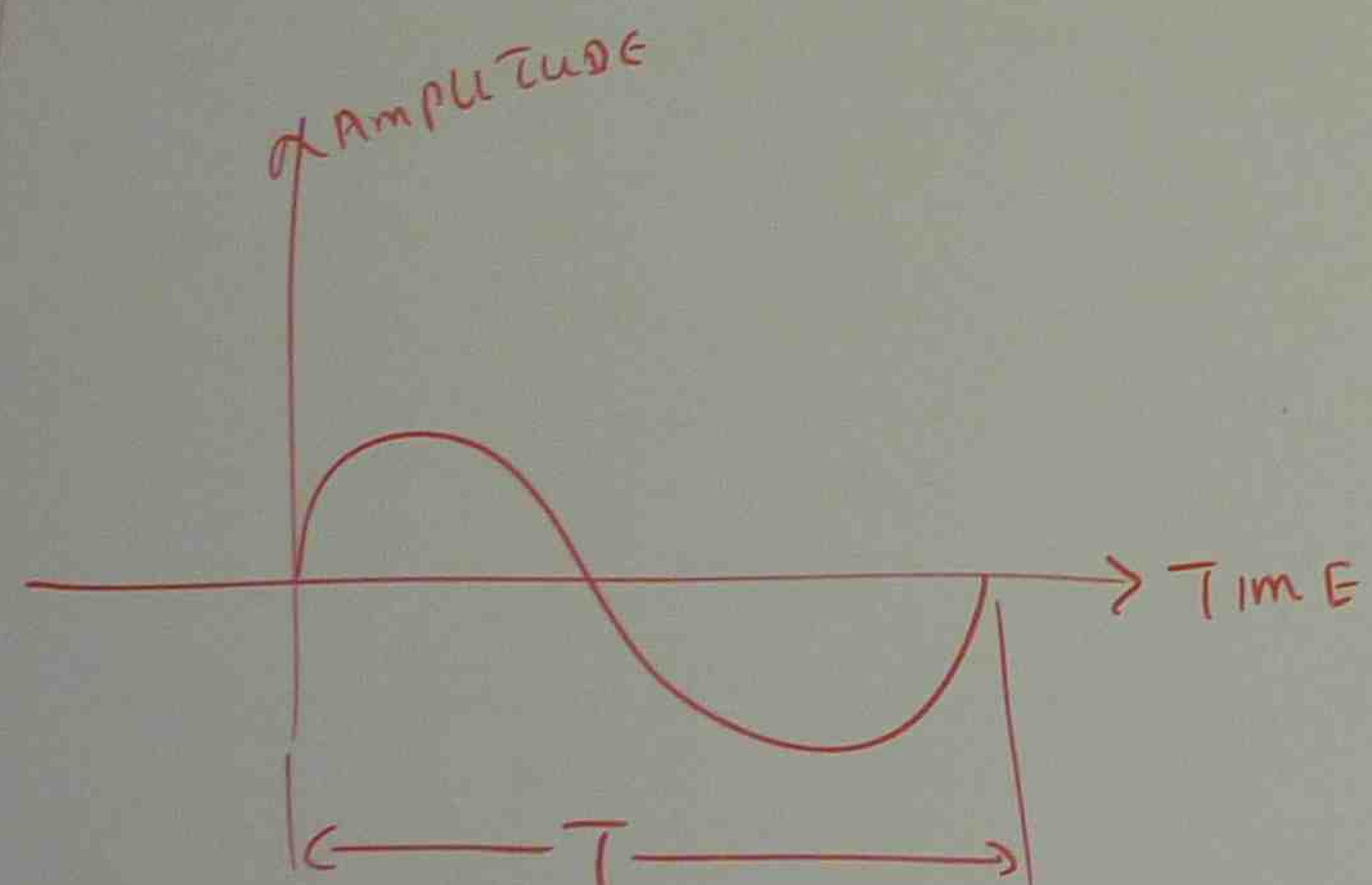
HARMONICS

MULTIPLE FACTOR OF FUNDAMENTAL FREQUENCY

FUNDAMENTAL $f_0 = 50\text{HZ}$

SECOND HARMONIC $f_2 = 2 \times 50\text{HZ} = 100\text{HZ}$

THIRD HARMONIC $f_3 = 3 \times 50\text{HZ} = 150\text{HZ}$



$$f = \frac{1}{T}$$

f = FREQUENCY

T = PERIOD

pb/ A WAVE FORM HAS A PERIOD $T = 40\text{ms}$. CALCULATE THE FREQUENCY OF THE FUNDAMENTAL, THE SECOND AND THIRD HARMONICS.

FUNDAMENTAL FREQUENCY $f = \frac{1}{T} = \frac{1}{40\text{ms}} = \frac{1}{40 \times 10^{-3}}$

$= \frac{10^3}{40} = 25\text{ HZ}$

SECOND HARMONICS $= 2f = 2 \times 25\text{HZ} = 50\text{HZ}$

THIRD HARMONICS $= 3f = 3 \times 25\text{HZ} = 75\text{HZ}$

FOURTH HARMONICS $= 4f = 4 \times 25\text{HZ} = 100\text{HZ}$

AL FREQUENCY

Hz = 100 HZ

z = 150 HZ

IME

ENCY

D

pb

A WAVE FORM HAS A PERIOD $T = 40ms$. CALCULATE THE FREQUENCY OF THE FUNDAMENTAL, THE SECOND AND THIRD HARMONICS.

FUNDAMENTAL FREQUENCY $f = \frac{1}{T} = \frac{1}{40ms} = \frac{1}{40\times10^{-3}}$

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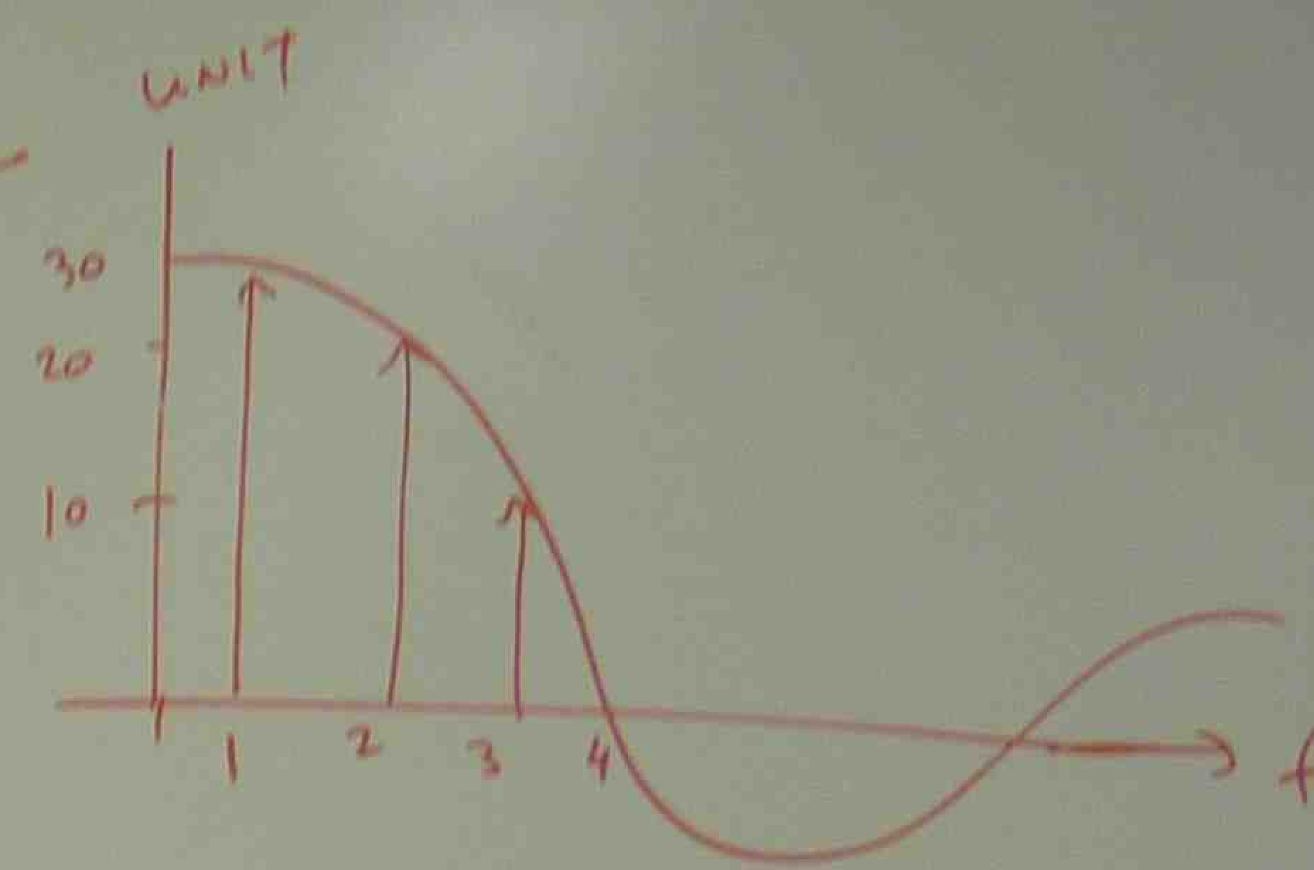
FOURTH HARMONICS $= 4f = 4\times25HZ = 100\ HZ$

pb



FIND 1^{st}, 2^{nd}, 3^{rd} AND 4^{th} HARMONICS AMPLITUDES OF GIVEN WAVE FORM.

1^{st} = FUNDAMENTAL = 30 UNIT

2^{nd} = HARMONICS = 20 UNIT

3^{rd} = HARMONICS = 10 UNIT

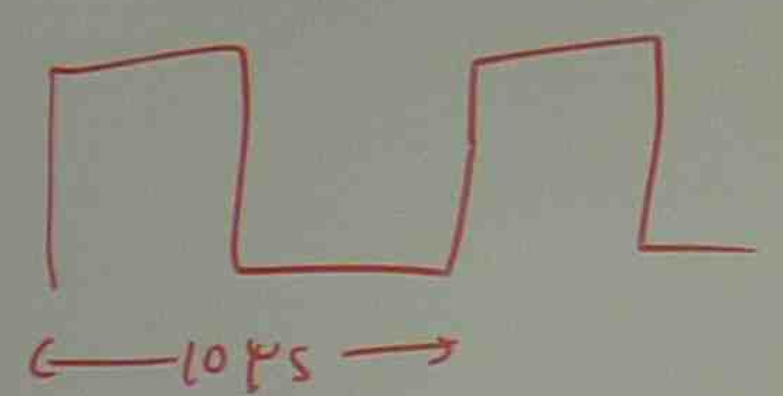
pb (a)

$f = \frac{1}{T}$

CALCULATE THE FREQUENCIES

p7

(a)



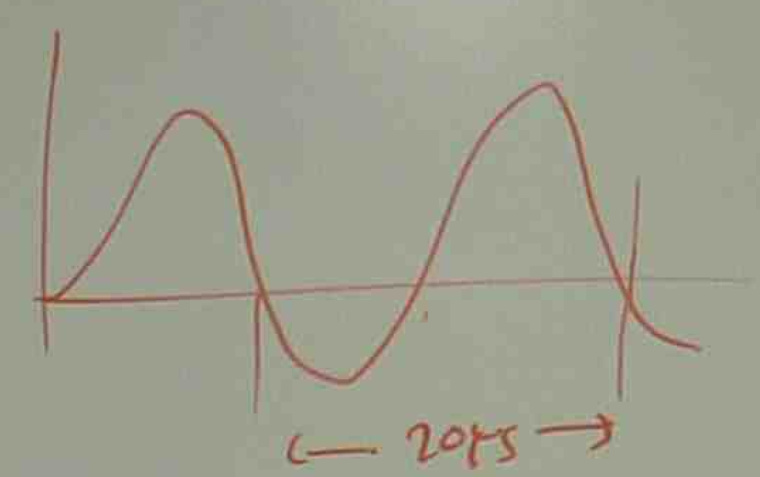
$$f = \frac{1}{T} = \frac{1}{10 \times 10^{-6}}$$

$$= \frac{10^6}{10}$$

$$= 10^5 \text{ Hz}$$

$$= 100 \text{ kHz}$$

(b)



$$f = \frac{1}{T}$$

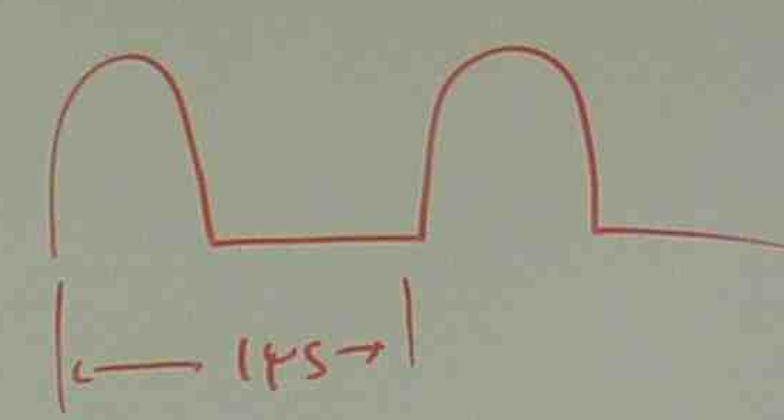
$$= \frac{1}{20 \times 10^{-6}}$$

$$= \frac{10^6}{20}$$

$$= \frac{1000 \times 10^3}{20}$$

$$= 50 \text{ kHz}$$

(c)



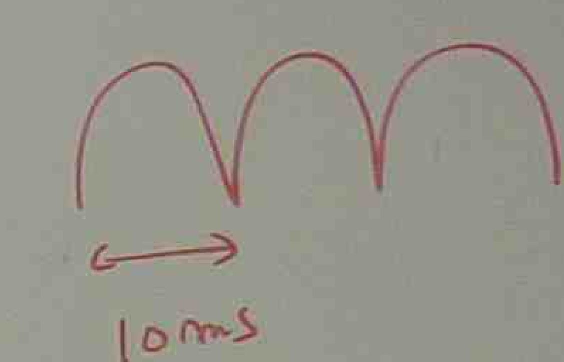
$$f = \frac{1}{T}$$

$$= \frac{1}{1 \times 10^{-6}}$$

$$= 10^6 \text{ Hz}$$

$$= 1 \text{ MHz}$$

(d)



$$f = \frac{1}{T}$$

$$= \frac{1}{10 \times 10^{-3}}$$

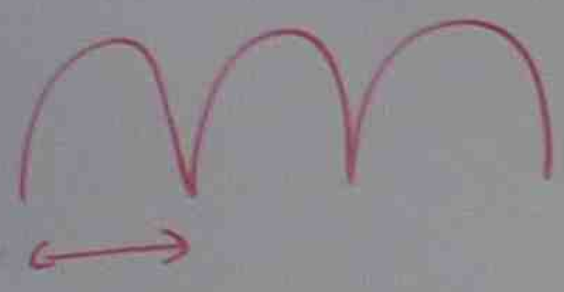
$$= \frac{10^3}{10}$$

$$= 100 \text{ Hz}$$

$\to f$

...monics

(a)



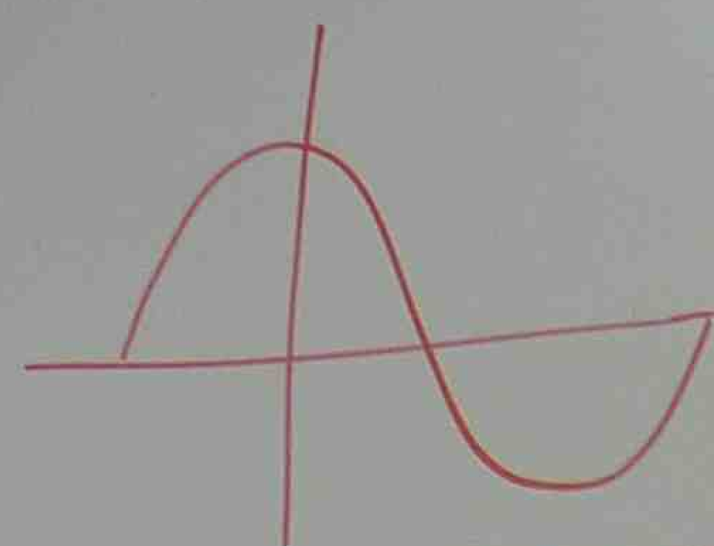
$$f = \frac{1}{T}$$

$$= \frac{1}{10 \times 10^{-3}}$$

$$= \frac{10^3}{10}$$

$$= 100\ \text{Hz}$$

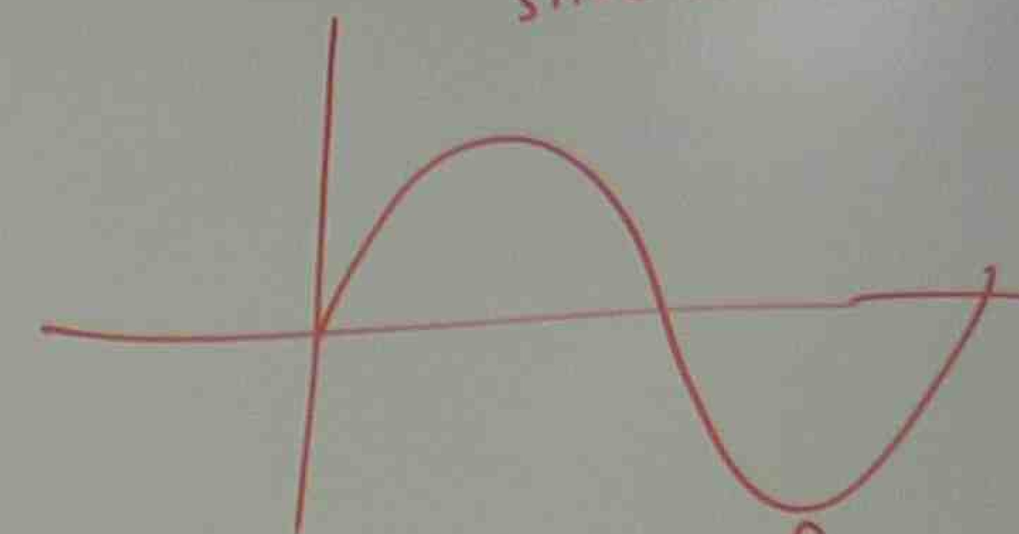
MATHEMATICAL EXPRESSION OF HARMONICS WAVE FORMS



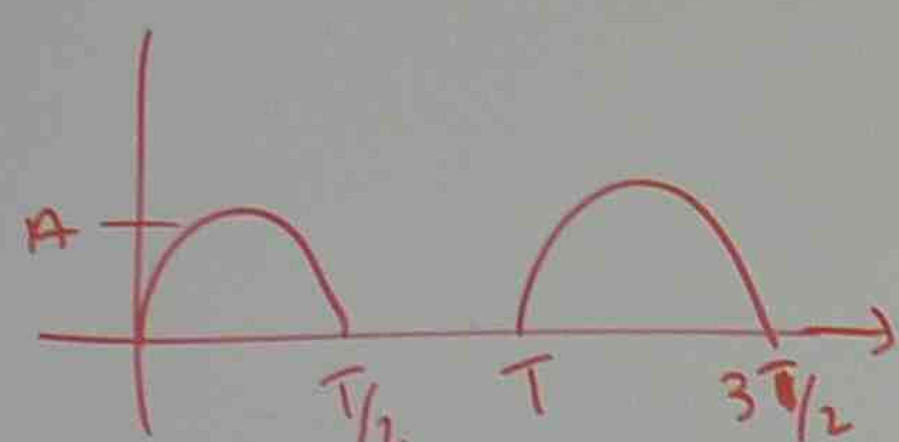
$v(t) = A \cos 2\pi f t$

COSINE WAVE

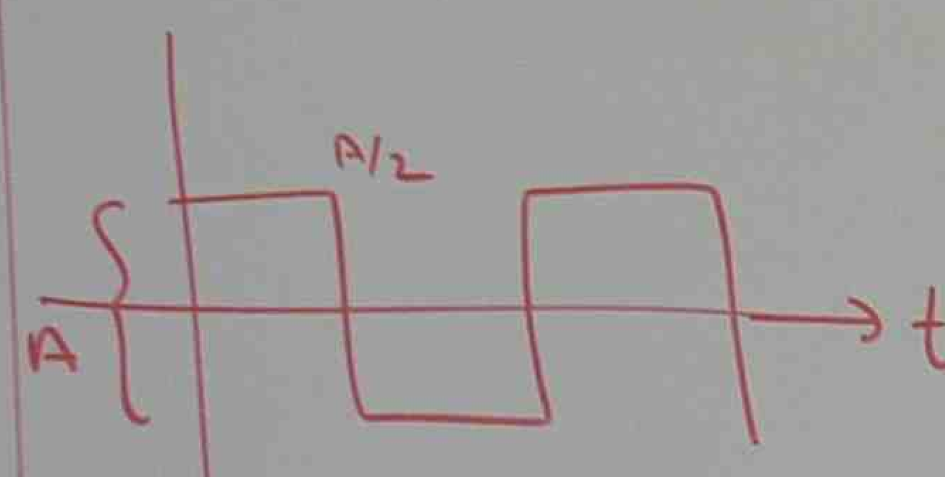
SINE WAVE



$v(t) = A \sin 2\pi f t$



$$v(t) = \frac{A}{2} + \frac{A}{2} \sin 2\pi f_0 t + \sum_{n=2}^{\infty} \frac{A\left[1 + (-1)^n\right]}{\pi(1-n^2)} \cos 2\pi (n f_0) t$$



$$v(t) = \sum_{n=0}^{\infty} \frac{2A}{n\pi} \sin 2\pi n f_0 t$$

ncy

$2\pi(nf_0)t$

$\left(\frac{2A}{n\pi}\right)\sin 2\pi(nf_0)t$

pb

A WAVE FORM HAS A PERIOD $T = 40ms$. CALCULATE THE FREQUENCY OF THE FUNDAMENTAL, THE SECOND AND THIRD HARMONICS.

FUNDAMENTAL FREQUENCY $f = \frac{1}{T} = \frac{1}{40ms} = \frac{1}{40\times10^{-3}}$

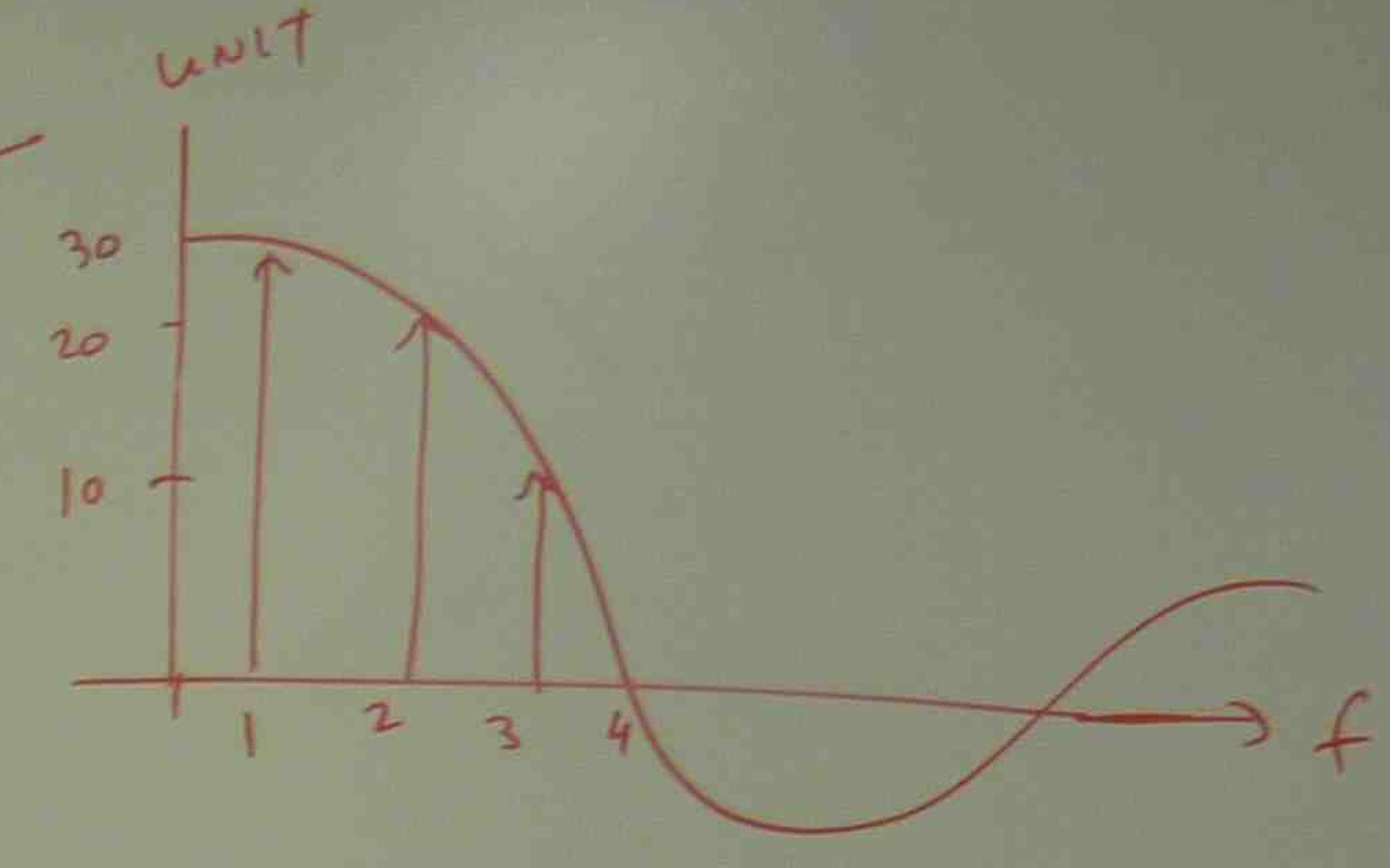
$= \frac{10^3}{40} = 25\ HZ$

SECOND HARMONICS $= 2f = 2\times25HZ = 50HZ$

THIRD HARMONICS $= 3f = 3\times25HZ = 75\ HZ$

FOURTH HARMONICS $= 4f = 4\times25HZ = 100HZ$

pb



FIND 1^{st}, 2^{nd}, 3^{rd} AND 4^{th} HARMONICS AMPLITUDES OF GIVEN WAVE FORM.

1^{st} = FUNDAMENTAL = 30 UNIT.

2^{nd} = HARMONICS = 20UNIT

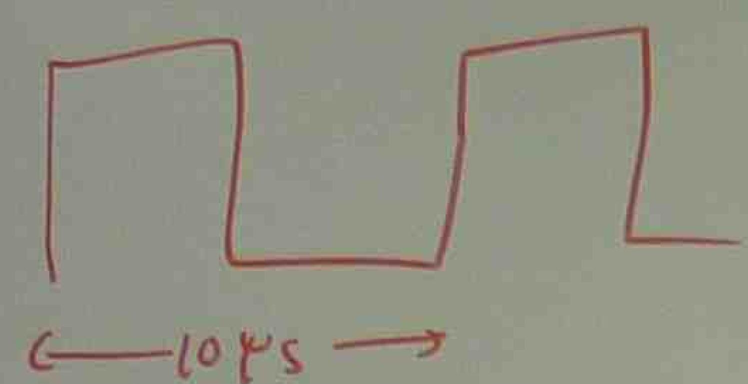
3^{rd} = HARMONICS = 10UNIT

pb

f-

CALCULATE THE FREQUENCIES

pn (a)



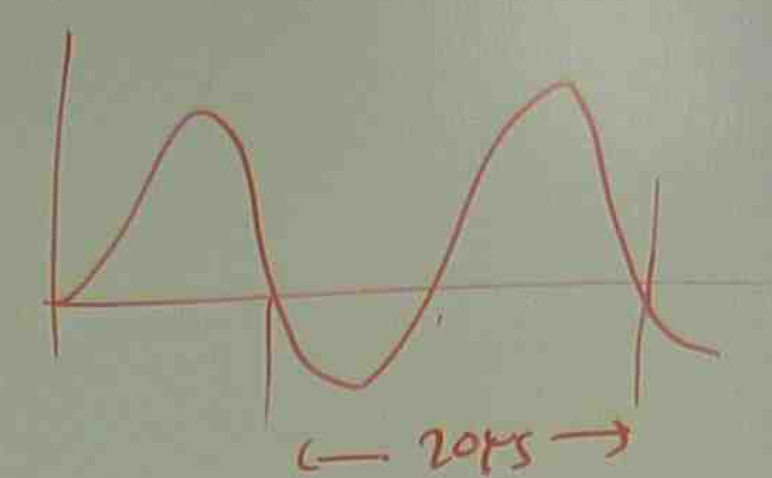
$$f = \frac{1}{T} = \frac{1}{10 \times 10^{-6}}$$

$$= \frac{10^6}{10}$$

$$= 10^5 \text{ Hz}$$

$$= 100 \text{ kHz}$$

(b)



$$f = \frac{1}{T}$$

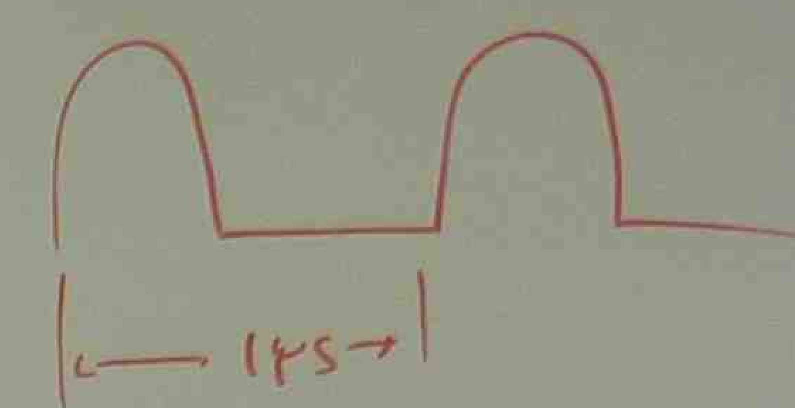
$$= \frac{1}{20 \times 10^{-6}}$$

$$= \frac{10^6}{20}$$

$$= \frac{1000 \times 10^3}{20}$$

$$= 50 \text{ kHz}$$

(c)



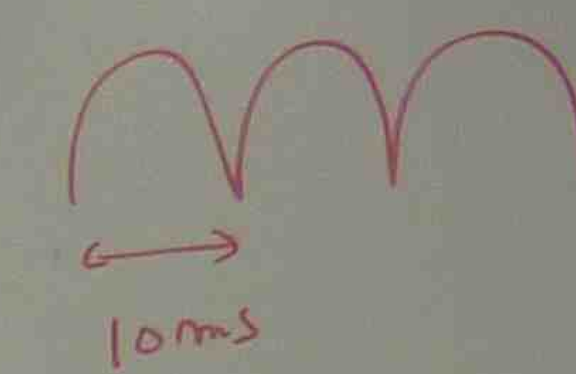
$$f = \frac{1}{T}$$

$$= \frac{1}{1 \times 10^{-6}}$$

$$= 10^6 \text{ Hz}$$

$$= 1 \text{ MHz}$$

(d)



$$f = \frac{1}{T}$$

$$= \frac{1}{10 \times 10^{-3}}$$

$$= \frac{10^3}{10}$$

$$= 100 \text{ Hz}$$

4th HARMONICS

WAVE FORM.

UNIT.

UNIT

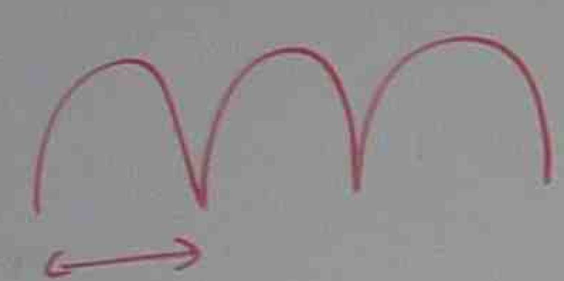
UNIT

MATH

A

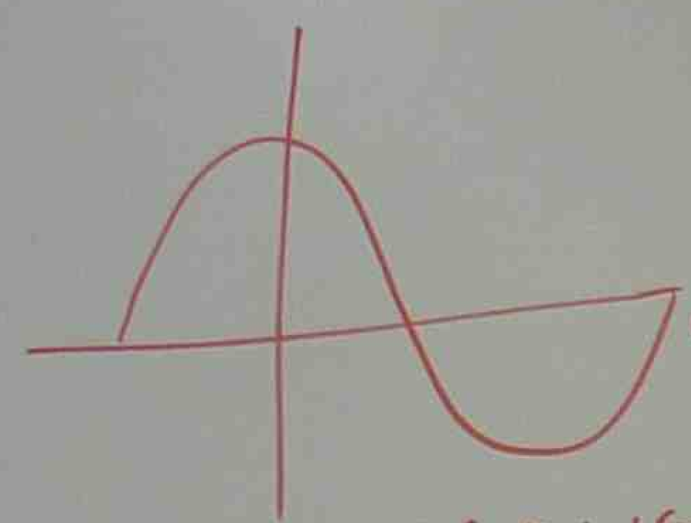
A

(a)



$$f = \frac{1}{T}$$
$$= \frac{1}{10 \times 10^{-3}}$$
$$= \frac{10^3}{10}$$
$$= 100 \text{ Hz}$$

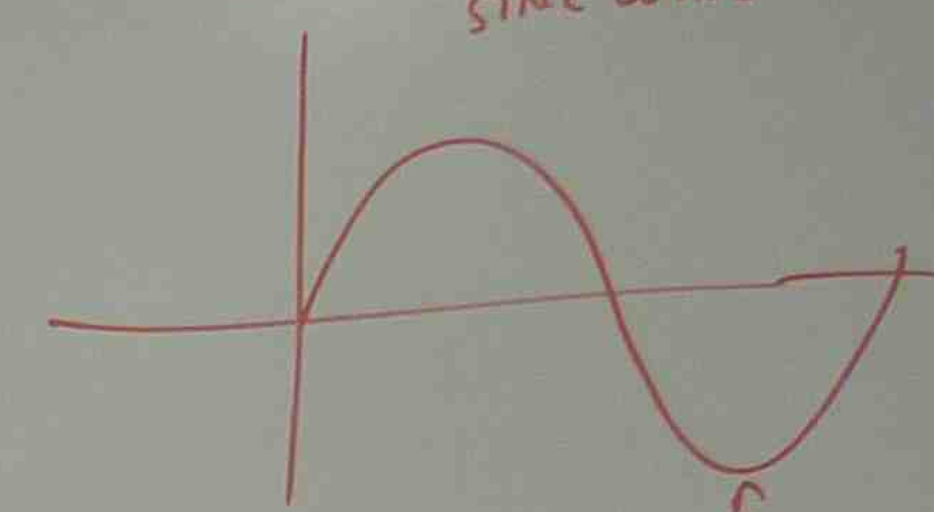
MATHEMATICAL EXPRESSION OF HARMONICS WAVE FORMS



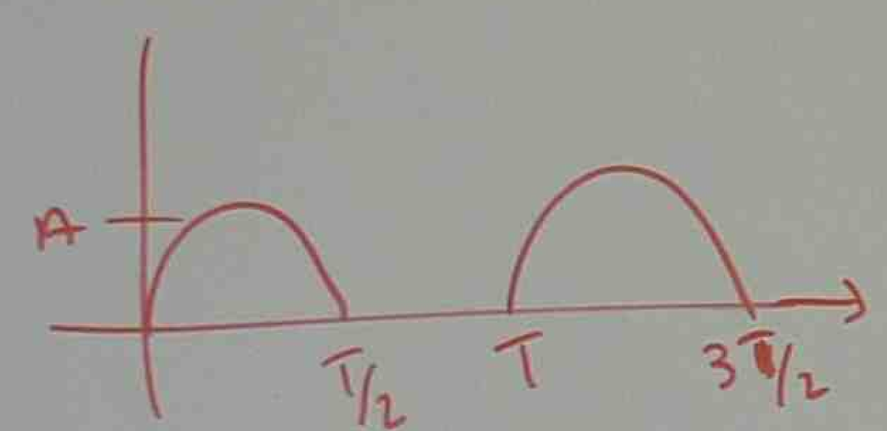
$v(t) = A \cos 2\pi f t$

COSINE WAVE

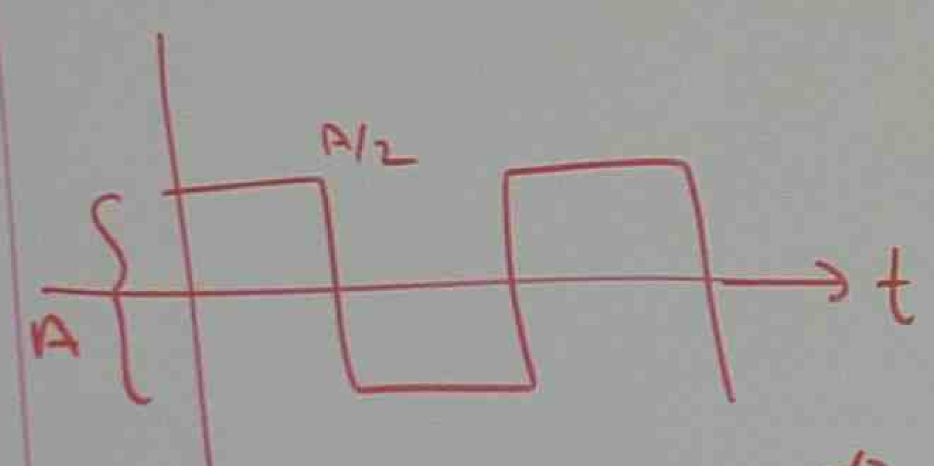
SINE WAVE



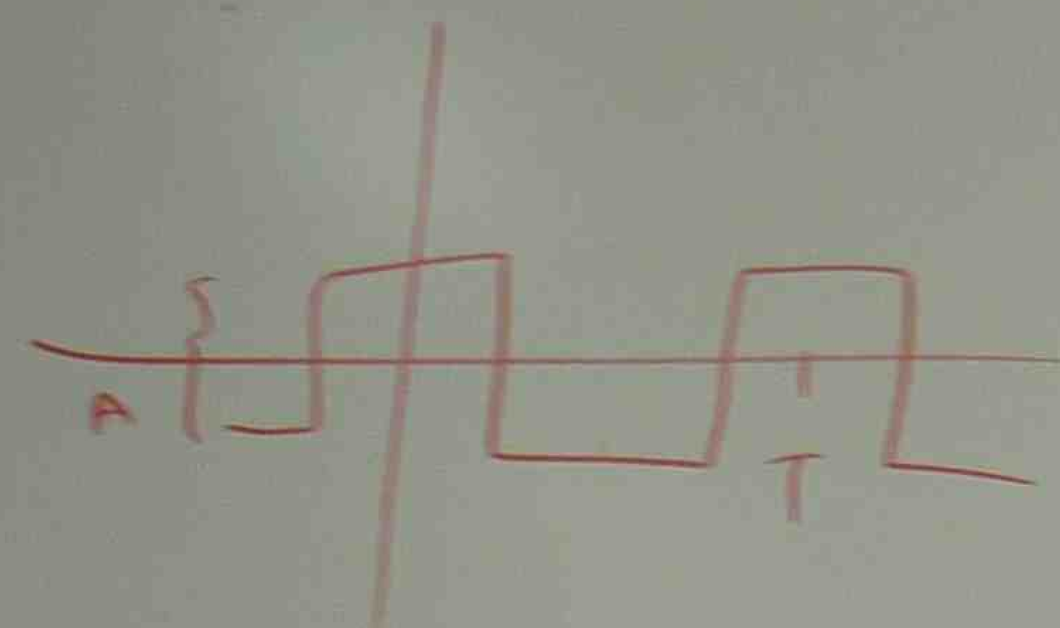
$v(t) = A \sin 2\pi f t$



$$v(t) = \frac{A}{\pi} + \frac{A}{2} \sin 2\pi f_0 t + \sum_{n=2}^{\infty} \frac{A\left[1 + (-1)^n\right]}{\pi (1 - n^2)} \cos 2\pi (n f_0) t$$



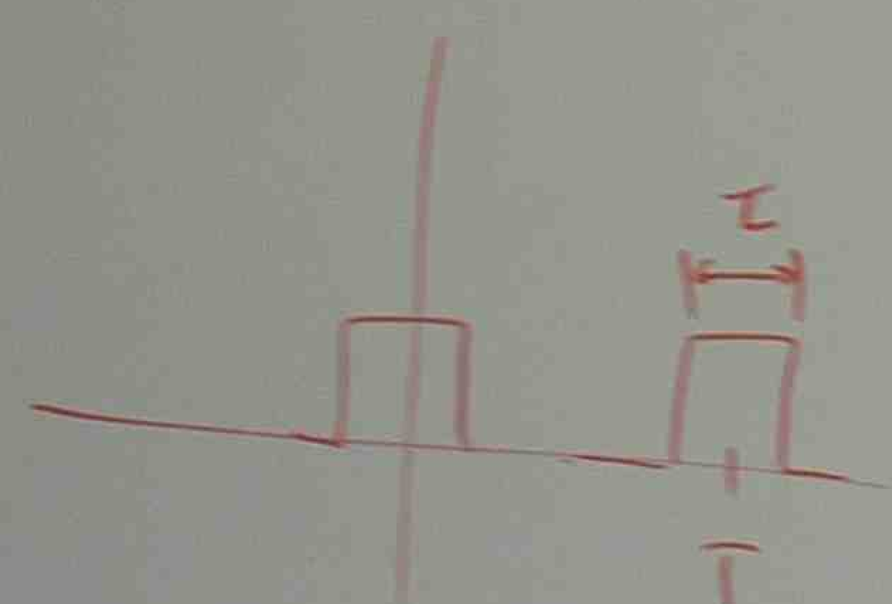
$$v(t) = \sum_{n=0}^{\infty} \frac{2A}{n\pi} \sin 2\pi n f_0 t$$



$$V(t) = \sum_{n=odd}^{\infty} \left(A \frac{\sin n\frac{\pi}{2}}{n\frac{\pi}{2}} \right) \cos 2\pi (n f_0) t$$

ODD = 1, 3, 5, 7

EVEN = 2, 4, 6, 8



$$V(t) = \frac{A\tau}{T} + \sum_{n=3}^{\infty} \left(2A\frac{\tau}{T} \right) \left(\frac{\sin n\pi \tau/T}{2\pi \tau/T} \right) \cos 2\pi (n f_0) t$$

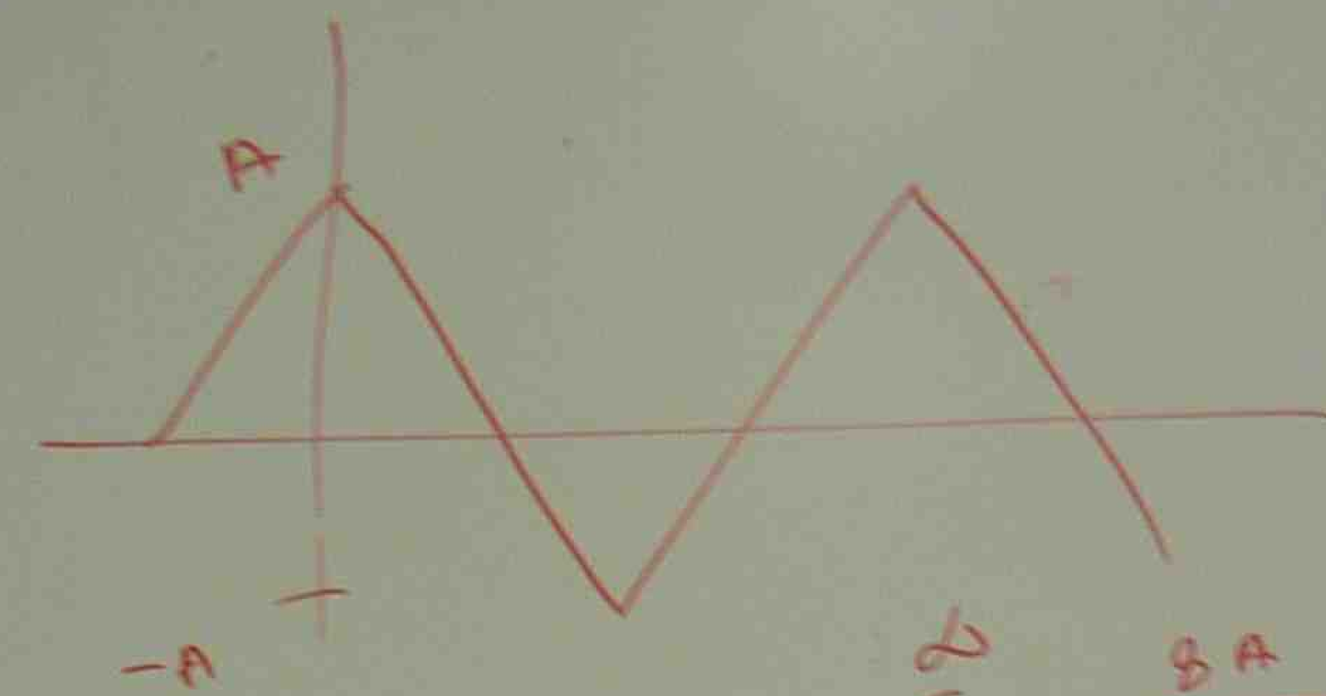
$n f_0)t$

ODD = 1, 3, 5, 7

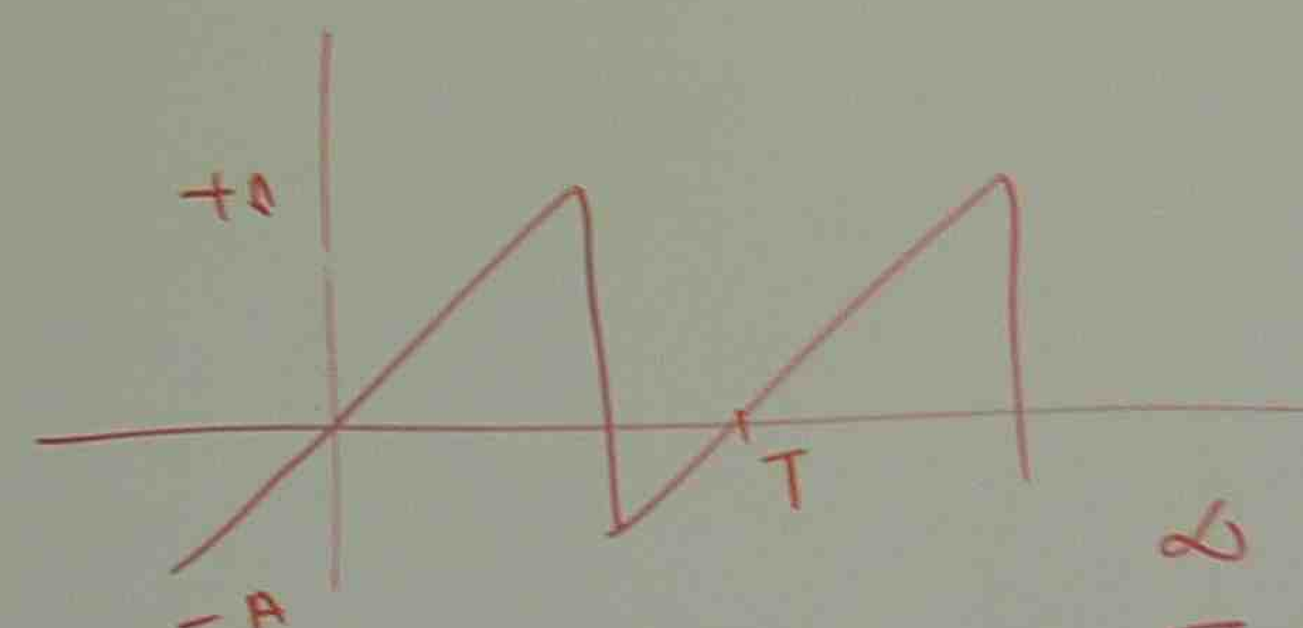
EVEN = 2, 4, 6, 8

$=]\left(\frac{\sin n\pi \tau/T}{2\pi \tau/T}\right) \cos 2\pi (n f_0)t$

ncy



$$V(t) = \sum_{n=odd}^{\infty} \frac{8A}{(n\pi)^2} \cos 2\pi (n f_0)t$$



$$V(t) = \sum_{n=1}^{\infty} (-1)^{n+1} \left(\frac{2A}{n\pi}\right) \sin 2\pi (n f_0)t$$

pb

A WAVE FO

THE FREQUENC

THIRD HARMO

FUNDAMENTAL FR

SECOND HARMON

THIRD HARMONI

FOURTH HARMO

REVIEW QUESTIONS FOR POWER ENGINEERING MATHS (TEST)

(1) 3 TOWNS (A, B, C) ARE LOCATED AS FOLLOWS.

DETERMINE THE MOST SUITABLE PLACE TO LOCATE THE ELECTRICAL POWER STATION TO SUPPLY THOSE TOWNS

A → 100 MW (3, 5) km, B → 300 MW (7, 10) km

C → 400 MW (4, 17) km

(2) A TRANSMISSION LINE HAS 200m SPAN BETWEEN SUPPORTS. THE CONDUCTOR WEIGHT IS 10 N/m AND TENSION IN CONDUCTOR IS 11.5 kN. CALCULATE SAG.

(3) 3 PHASE 66 kV TRANSMISSION LINE IS DELIVERING 2 MW LOAD AT 0.95 PF LAGGING. LINE CONDUCTORS HAVE 12 Sq mm. THE DISTANCE BETWEEN THEM ARE 1.5m, 2m AND 3m.

NG MATHS (TEST)

ATED AS FOLLOWS.

PLACE TO LOCATE

TO SUPPLY THOSE

300 MW (7, 10) KM

200m SPAN BETWEEN

WEIGHT IS 10 N/m AND

IS 11.5 kN. CALCULATE SAG.

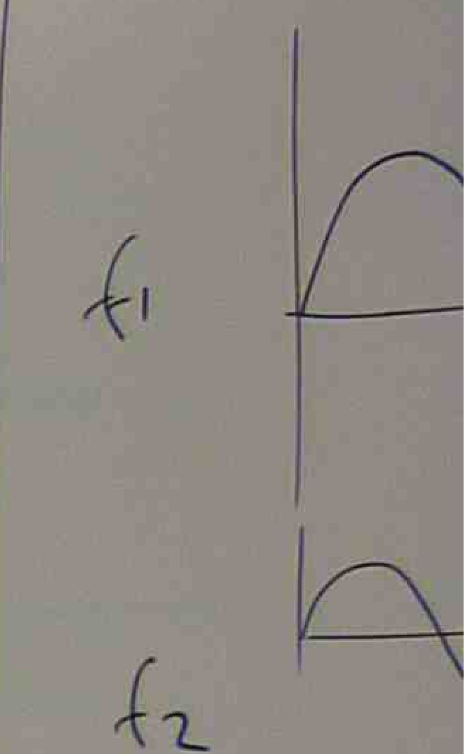
MISSION LINE IS DELIVERING

OF LAGGING. LINE CONDUCTORS

DISTANCE BETWEEN THEM ARE

THE LINE IS 300 km, LONG. LINE RESISTANCE IS 0.06 Ω/km. CALCULATE TOTAL LINE INDUCTIVE REACTANCE AND CAPACTIVE REACTANCE AT LINE FREQUENCY 50HZ.

(4) A SINGLE CORE CONCENTRIC CABLE IS TO BE MANUFACTURED FOR 200KV, 60HZ LINE. THE PAPER USED HAS MAXIMUM PERMISSIBLE SAFE STRESS 10^7 V/m (rms) AND DIELECTRIC CONSTANT 4.5. CALCULATE THE DIMENSION FOR THE MOST ECONOMICAL CABLE AND CHARGING CURRENT PER KM.



$f(t) =$

P

NG. LINE RESISTANCE

LATE TOTAL LINE

ACTIVE REACTANCE

RIC CABLE IS

R 200KV, 60HZ

S MAXIMUM

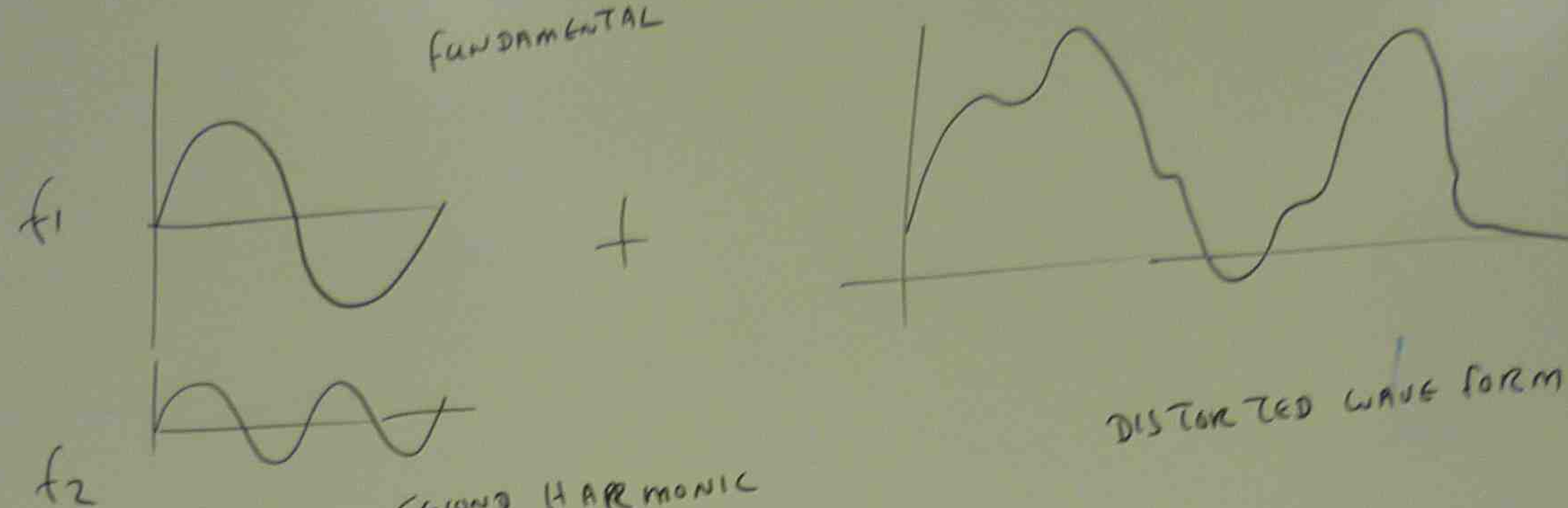
S 10^7 V/m (rms)

4.5.

FOR THE MOST

CHARGING CURRENT

HARMONICS



$$f(t) = A_1 \sin \omega t + A_2 \sin(2\omega t \pm \phi_1) + A_3 \sin(3\omega t \pm \phi_2) + \cdots$$

P_t = TOTAL POWER = $P_{1m} + P_{3m} + P_{5m} + \cdots$

$$V = \sqrt{\frac{V_{1m}^2 + V_{3m}^2 + V_{5m}^2}{2}}$$

$$I_m = \sqrt{\frac{I_{1m}^2 + I_{3m}^2 + I_{5m}^2}{2}}$$

pb A VOLTAG

e = 30

VOLT IS

IS GIVEN

i = 0.5 S

Amp.

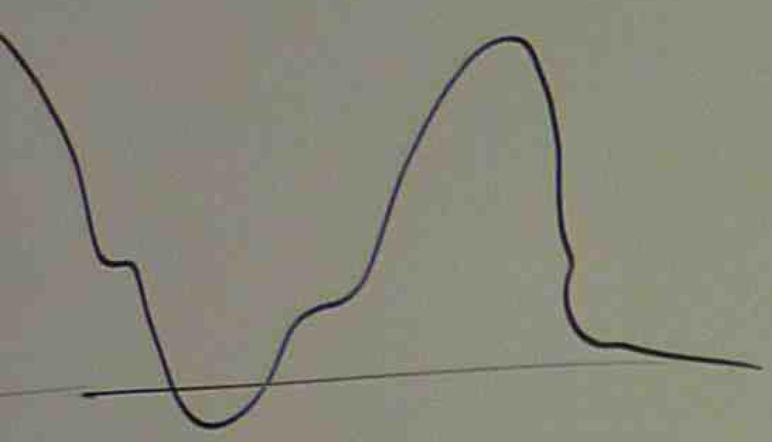
FIND TOT

$P_m =$

$P_{1m} =$

$P_{3m} =$

$P_{5m} =$



DISTORTED WAVE FORM

$\phi_1) + A_3 \sin(3\omega t \pm \phi_2) + - - -$

$+ P_{5m} + - -$

pb A VOLTAGE IS GIVEN BY

$e = 30 \sin \omega t + 20 \sin(3\omega t + 30^\circ) + 10 \sin(5\omega t - 90)$

VOLT IS APPLIED TO A CIRCUIT AND THE RESULTING CURRENT IS GIVEN BY

$i = 0.5 \sin(\omega t - 17) + 0.1 \sin(3\omega t - 15) + 0.09 \sin(5\omega t - 150)$

Amp.

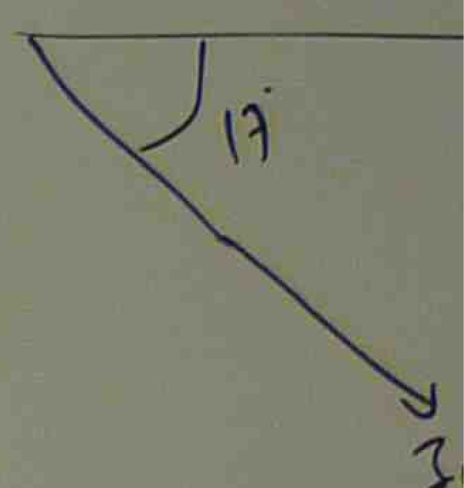
FIND TOTAL POWER APPLIED AND OVER ALL POWER FACTOR

$$P_m = \frac{V_m I_m}{2} \cos\theta_{I_m}^{V_m}$$

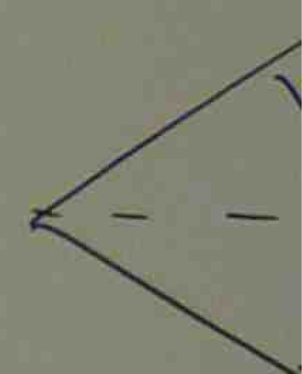
$$P_{1m} = \frac{V_{1m} I_{1m}}{2} \cos\theta_{I_{1m}}^{V_{1m}}$$

$$P_{3m} = \frac{V_{3m} I_{3m}}{2} \cos\theta_{I_{3m}}^{V_{3m}}$$

$$P_{5m} = \frac{V_{5m} I_{5m}}{2} \cos\theta_{I_{5m}}^{V_{5m}}$$



$P_{1m} = \frac{30 \times 0.5}{2}$



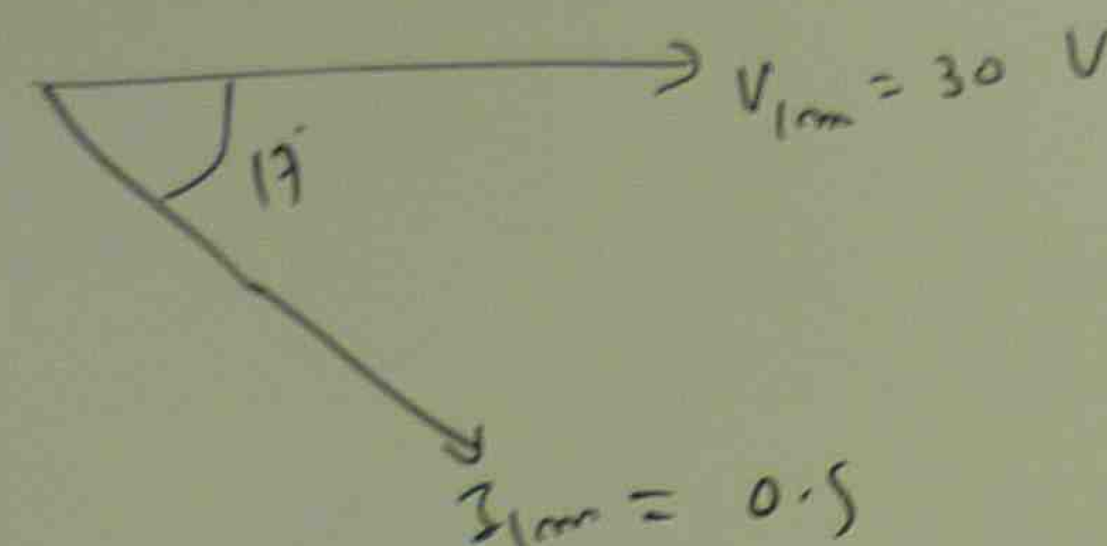
$P_{3m} = \frac{20 \times 0.1}{2}$

$(5\omega t - 90)$

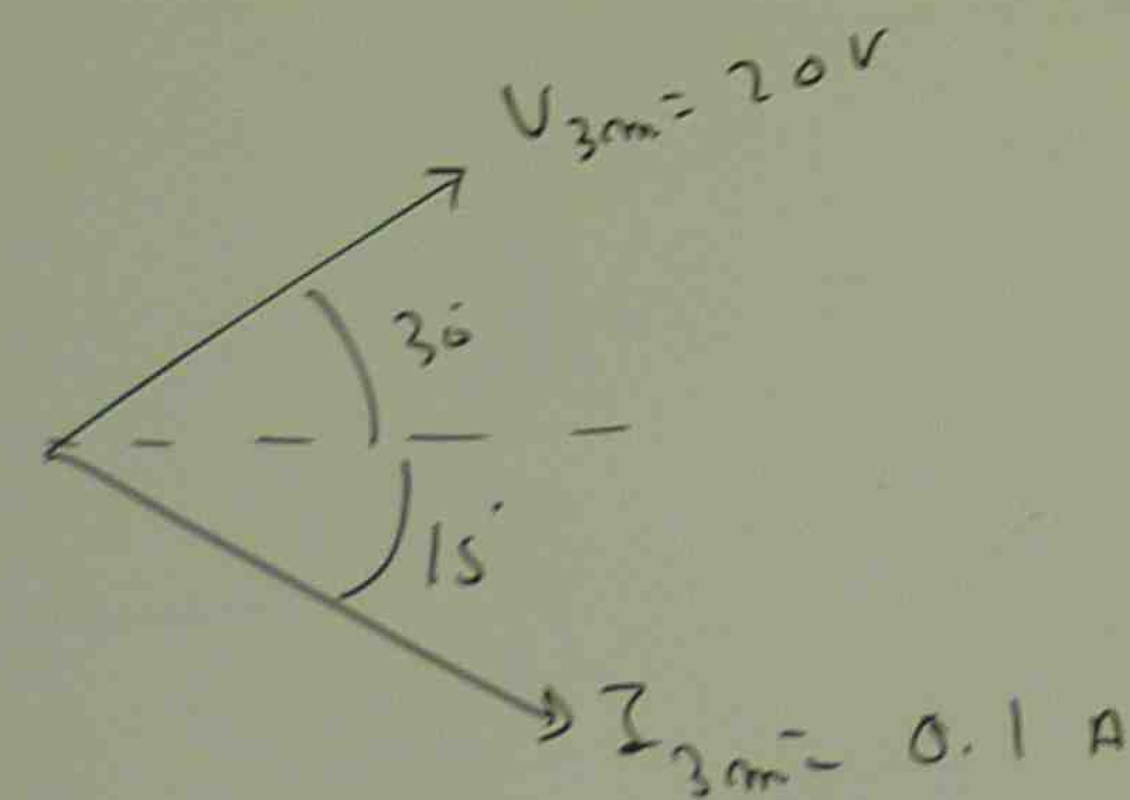
TING CURRENT

.09 $\sin(5\omega t - 150)$

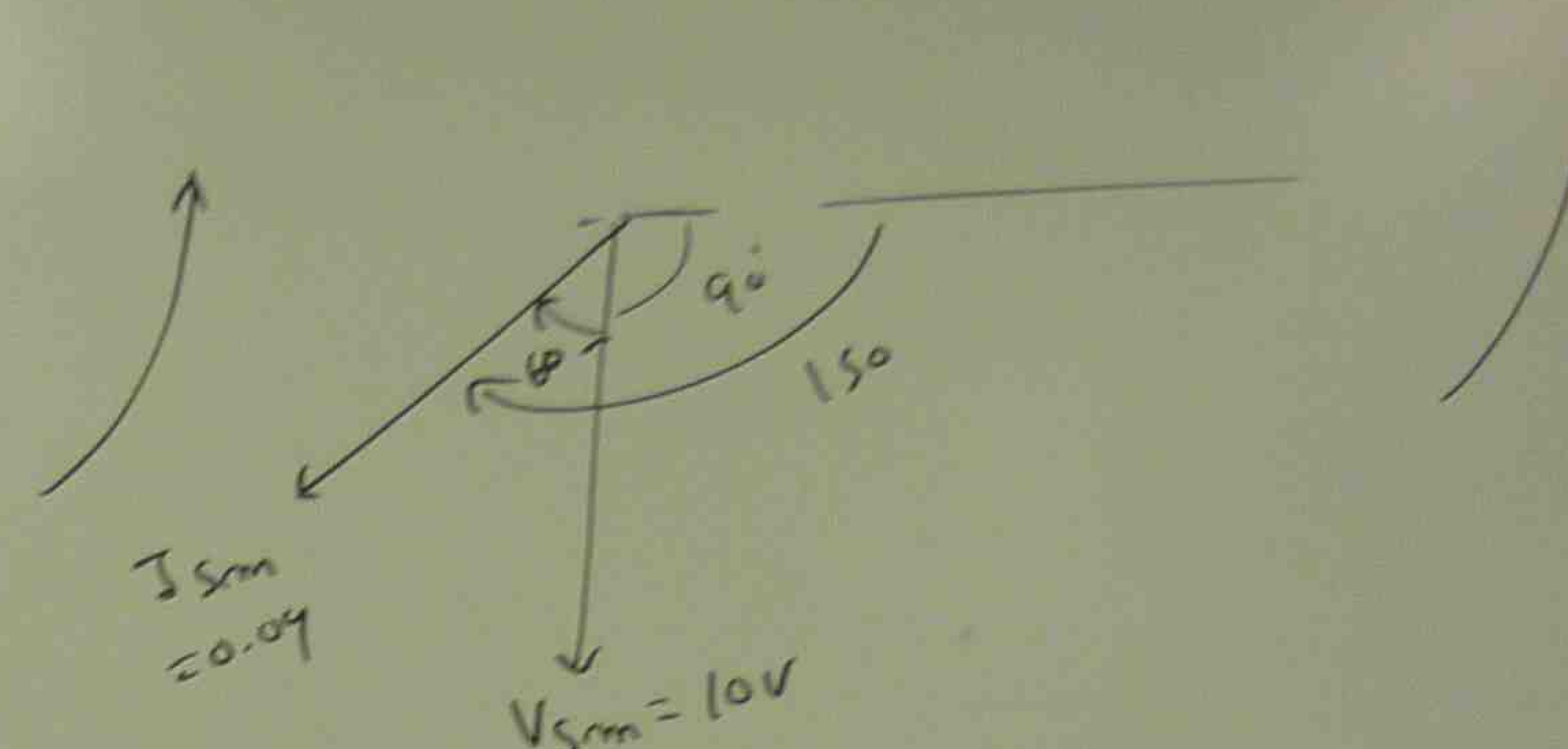
LL POWER FACTOR



$$P_{1m} = \frac{30 \times 0.5}{2} \cos 17 = 7.1\text{W}$$



$$P_{3m} = \frac{20 \times 0.1}{2} \cos 45 = 0.7\text{W}$$



$$P_{5m} = \frac{10 \times 0.09}{2} \cos 60$$

$$= 0.23 \text{ W}$$

$$P_T = P_{1m} + P_{3m} + P_{5m}$$

$$= 7.1 + 0.7 + 0.23$$

$$= 8.03 \text{ W}$$

$V_{rrms} = \sqrt{\;}$

$I_{rrms} = \sqrt{\;}$

To

PF =

$\cos 60$

$+ P_{5m}$

$7 + 0.23$

W

$$V_{rms} = \sqrt{\frac{V_{1m}^2 + V_{3m}^2 + V_{5m}^2}{2}} = \sqrt{\frac{30^2 + 20^2 + 10^2}{2}} = 18.7V$$

$$I_{rms} = \sqrt{\frac{I_{1m}^2 + I_{3m}^2 + I_{5m}^2}{2}} = \sqrt{\frac{0.5^2 + 0.1^2 + 0.04^2}{2}} = 1.5 \text{ Amp.}$$

$$\text{TOTAL } V.A = V_{rms} \; I_{rms}$$

$$= 18.7 \times 1.5 = 28.06 \text{ V.A}$$

$$PF = \frac{P_T}{\text{TOTAL } V.A} = \frac{8.03}{28.06} = 0.281$$