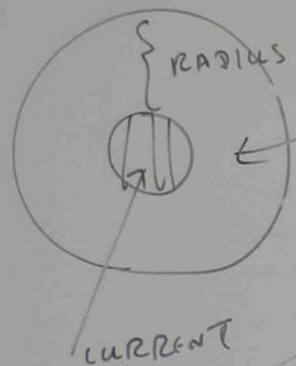
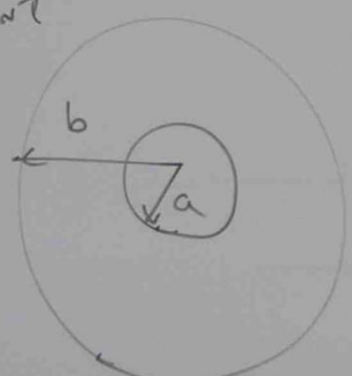
(iii) APPLICATION OF GRADIENT IN POWER ENGINEERING CALCULATIONS

LOAD / UNIT ARE = STRESS



INSULATION IS SUBJECT TO LINE VOLTAGE

$$\text{VOLTAGE STRESS} = \frac{\text{SYSTEM VOLTAGE}}{\text{THICKNESS OF CONDUCTOR}}$$



a = CONDUCTOR RADIUS

b = OVER ALL. RADIUS

FOR CABLE DESIGN

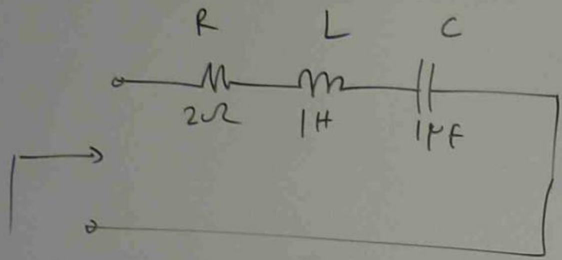
$b = e \times a$

$e = 2.718$

$$\text{CAPACITANCE OF UNDERGROUND CABLE} = \frac{2\pi\varepsilon}{\ln\frac{b}{a}} \ F/km$$

ε = DIELECTRIC CONSTANT

APPLICATION OF COMPLEX NUMBERS



TOTAL IMPEDANCE

$f = 50Hz$

R = RESISTANCE = 1Ω

L = INDUCTANCE = $1\ H$

X_L = INDUCTIVE REACTANCE $= 2\pi f L$

$$= 2 \times 3.1416 \times 50 \times 1$$

$$= 314.16\Omega$$

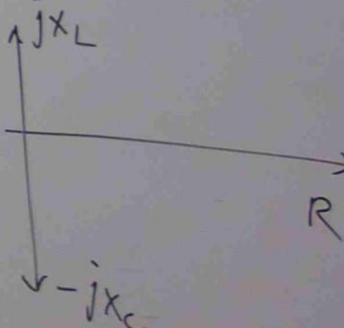
$1\mu F = 10^{-6} F$

X_C = CAPACITIVE REACTANCE (Ω) $= \dfrac{1}{2\pi f C}$

$$= \frac{1}{2 \times 3.1416 \times 50 \times 1 \times 10^{-6}}$$

$$= \frac{10^6}{314.16}$$

$$= 3183\Omega$$



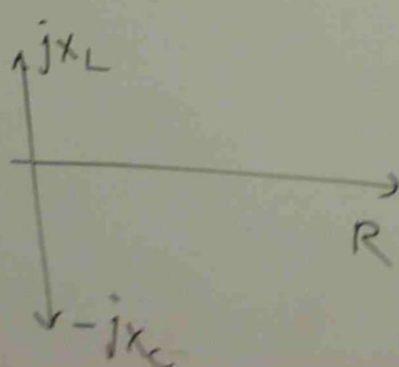
$1\mu F = 10^{-6} F$

X_C = CAPACITIVE REACTANCE (Ω) $= \dfrac{1}{2\pi f C}$

$= \dfrac{1}{2 \times 3.1416 \times 50 \times 1 \times 10^{-6}}$

$= \dfrac{10^6}{314.16}$

$\doteq 3183\,\Omega$



$Z = R + jX_L + (-jX_C)$

$= 1 + j314.16 - j31830$

$= 1 - j31515$

$Z = \sqrt{1^2 + 31515^2} \angle -\tan^{-1} \dfrac{31515}{1}$

$\doteq 31515.2 \angle -89^\circ\ \Omega$

0x 1

ADDITION, SUBSTRACTION, MULTIPLICATION AND DIVISION OF COMPLEX NUMBERS

Ex CALCULATE

(a) $(3+j4)+(4-j7)$

(b) $(3+j7)-(3-j11)$

(c) $(3+j4)(1+j2)$

(d) $(3+j4)(1-j2)$

(e) $\dfrac{3+j4}{4+j3}$

(f) $\dfrac{4+j3}{4-j3}$

(a) $(3+j4)+(4-j7)$

$= 3+4 + j4-j7$

$= 7 - j3$

$= \sqrt{7^2+3^2} \angle -\tan^{-1}\frac{3}{7}$

$= 7.615 \angle -\tan^{-1} 0.428$

$= 7.615 \angle -23.17$

(b) $(3+j7)-(3-j11)$

$3+j7-3+j11$

$0+j18$

$18 \angle 90^\circ$

(c) $(3+j4)(1+j2)$

METHOD (1)

$$\boxed{\begin{aligned} Z_1\angle\theta_1 \times Z_2\angle\theta_2 &= Z_1 Z_2 \angle\theta_1+\theta_2 \\ \frac{Z_1\angle\theta_1}{Z_2\angle\theta_2} &= \frac{Z_1}{Z_2}\angle\theta_1-\theta_2 \end{aligned}}$$

$$\left(\sqrt{3^2+4^2}\angle\tan^{-1}\frac{4}{3}\right) \times \left(\sqrt{1^2+2^2}\angle\tan^{-1}\frac{2}{1}\right)$$

$$5\angle\tan^{-1}1.333 \times 2.236\angle 63.4$$

$$5\angle 53.1 \times 2.236\angle 63.4$$

$$11.18\angle 53.1+63.4$$

$$11.18\angle 116.5$$

$$\boxed{\begin{aligned} a+jb &= \sqrt{a^2+b^2}\angle\tan^{-1} b/a \\ a-jb &= \sqrt{a^2+b^2}\angle-\tan^{-1} b/a \end{aligned}}$$

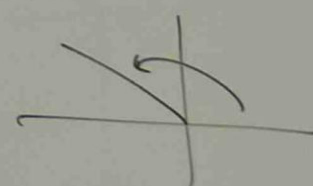
METHOD (2)

$$\boxed{j \times j = -1}$$

$$(3+j4)\times(1+j2)$$

$$\begin{array}{r} 3+j4 \\ 1+j2 \\ \hline 3+j4 \\ j6-8 \\ \hline 3+j10-8 \end{array}$$

$$= -5+j10$$



$$= \sqrt{5^2+10^2}\angle 180-\tan^{-1}\frac{10}{5}$$

$$= 11.18\angle 180-\tan^{-1}2$$

$$= 11.18\angle 180-63.43 = 11.18\angle 116.5$$

(d) $(3+j4)(1-j2)$

$\left(\sqrt{3^2+4^2}\ \angle \tan^{-1} 4/3\right) \times \left(\sqrt{1^2+2^2}\ \angle -\tan^{-1} 2/1\right)$

$5 \angle 53.1 \times 2.236 \angle -63.4$

$11.18 \angle -10.3$

(e) $\dfrac{3+j4}{4+j3}$

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

$$\frac{\sqrt{25}\ \angle \tan^{-1} 1.333}{\sqrt{25}\ \angle \tan^{-1} 0.75}$$

$$\frac{5 \angle 53.1}{5 \angle 36.8} = 1 \angle 53.1-36.8$$

$1 \angle 16.3$

(f) $\dfrac{4+j3}{4-j3}$

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

$$\frac{\sqrt{25}\ \angle \tan^{-1} 0.75}{\sqrt{25}\ \angle -\tan^{-1} 0.75}$$

$$\frac{5 \angle 36.8}{5 \angle -36.8}$$

$1 \angle 36.8-(-36.8)$

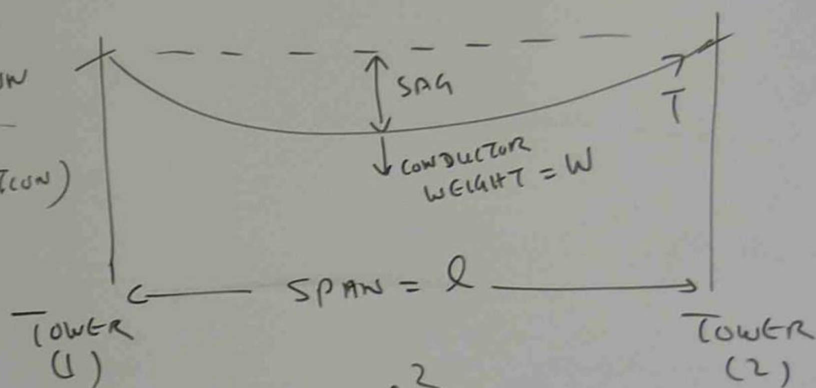
$1 \angle 73.6$

APPLICATION OF EQUATIONS AND FORMULA IN POWER ENGINEERING CALCULATIONS

SAG OF TRANSMISSION LINE

(1) SQUARE FUNCTION

(PARABOLIC FUNCTION)



$$SAG = \frac{W l^2}{8T}$$

W = WEIGHT OF CONDUCTORS (N/m)

l = LINE SPAN (DISTANCE BETWEEN ADJACENT TOWERS) (m)

T = TENSION IN CONDUCTOR (N)

Ex

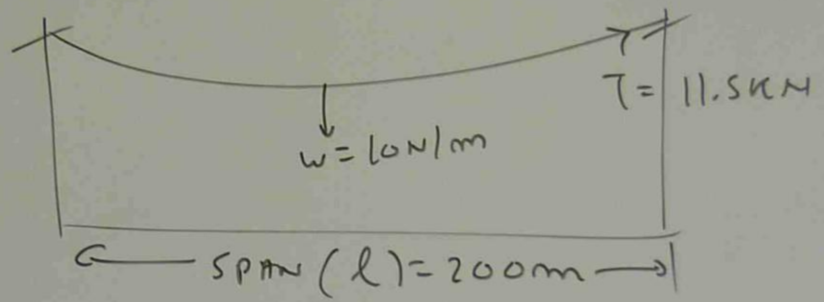
A

Su

Ten

Sa

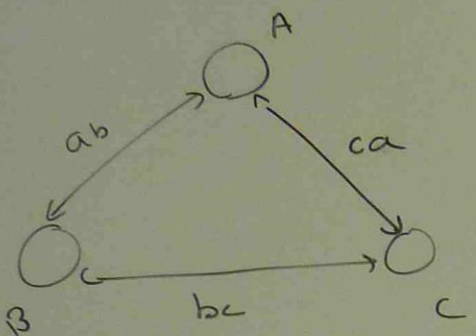
EX A TRANSMISSION LINE HAS 200 m SPAN BETWEEN SUPPORTS. THE CONDUCTOR WEIGHT IS 10N/m AND TENSION IN CONDUCTOR IS 11.5 KN. CALCULATE SAG.



$$SAG = \frac{W l^2}{8T} = \frac{10 \times (200)^2}{8 \times 11.5 \times 10^3}$$

$$= 4.35 \text{ m}$$

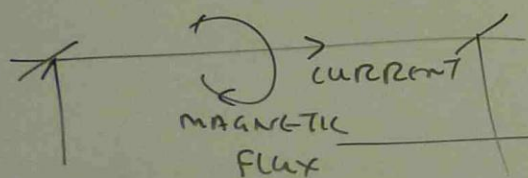
(ii) APPLICATION OF GEOMETRIC MEAN AND LOGARITHM IN POWER ENGINEERING CALCULATIONS



ab, bc, ca = DISTANCE BETWEEN CONDUCTORS.

GMD = GEOMETRIC MEAN DISTANCE

$$GMD = \sqrt[3]{ab \times bc \times ca}$$



→ LINE INDUCTANCE

POWER LINE

$$L = 0.05 + 0.46 \log \frac{\text{GMD OF CONDUCTORS (GMD)}}{\text{RADIUS OF CONDUCTORS } (r)}$$

L: LINE INDUCTANCE (mH/km)

EX

3φ 66KV TRANSMISSION LINE IS DELIVERING 2MW LOAD AT PF 0.95 PF LAGGING. LINE CONDUCTORS HAVE 12 Sq.mm. THE DISTANCE BETWEEN THEM ARE 1.5m, 2m, 3m. THE LINE IS 300km LONG. LINE RESISTANCE IS 0.06 Ω/km. CALCULATE TOTAL LINE INDUCTIVE REACTANCE AND CAPACITIVE REACTANCE AT 50HZ.

$$\boxed{C = \frac{0.241}{\log \frac{GMD}{r}} \quad \mu F/km}$$

C.SA = 12 Sq mm

$$\boxed{\pi r^2 = C.SA}$$

r = RADIUS $\quad \pi = 3.1416$

$3.1416 \times r^2 = 12$

$$r = \sqrt{\frac{12}{3.1416}} = 1.954\ mm$$

$$GMD = \sqrt[3]{1.5 \times 2 \times 3} = 2.08\ m$$

$$L = 0.05 + 0.46 \log \frac{GMD}{r} \quad (mH/km)$$

$$= 0.05 + 0.46 \log \frac{2.08}{1.954 \times 10^{-3}}$$

$$= 0.05 + 0.46 \log \frac{2.08 \times 10^{3}}{1.954} = 1.44\ mH/km$$

L

TOTA

$$L_{TOTAL} = 1.44\times10^{-3}\ mH/km \times 300\ km = 0.432\ H$$

$$X_L = 2\pi fL = 2\times3.1416\times50\times0.432 = 135.7\Omega$$

$$C = \frac{0.241}{\log\frac{GMD}{r}}\ \mu F/km$$

$$= \frac{0.241}{\log\frac{2.08\times10^3}{1.934}} = 0.00798\ \mu F/km$$

$$C_{total} = 0.00798\times300 = 2.39\ \mu f$$

$$X_c = \frac{1}{2\pi fC} = \frac{1}{2\times3.1416\times50\times2.39\times10^{-6}}$$

$$= \frac{10^6}{2\times3.1416\times50\times2.39} = 1333\Omega$$

km