Solutions for Examples/Problems

M.S. Naidu/V.Kamaraju

Solutions for Examples/Problems given in Book H.V. Engg.

CHAPTER 2

Q 2.15 Breakdown Voltage as given by Pacheu's Law is

$$V = \frac{Bpd}{\ln\left\{\dfrac{Apd}{\ln\left(1+\dfrac{1}{\gamma}\right)}\right\}}$$

$$A = 15/\text{cm}$$
$$\text{B} = 360/\text{cm}$$
$$p = 760 \text{ torr}$$
$$d = 1 \text{ cm}$$

$V = 31{,}500$ Volts $\quad \therefore \quad pd = 760 - \text{torr cm}$

substituting the values in the formula given $31{,}500 = \dfrac{360 \times 760}{\ln\left(\dfrac{15 \times 760}{\ln(1+1/\gamma)}\right)}$

$$\ln\left\{\frac{11400}{\ln(1+1/\gamma)}\right\} = \frac{360 \times 760}{31{,}500} = \frac{304}{35} = 8.6857$$

$$\frac{11400}{\ln(1+1/\gamma)} = 5917.765966$$

$$\ln(1 + 1/\gamma) = 1.926402646$$

$$1 + 1/\gamma = 6.86470$$

$$\therefore \quad \frac{1}{\gamma} = 5.86470$$

$$\gamma = 0.17050$$

Q 2.16 For Breakdown Condition

$$\gamma e^{\alpha d} = 1.0 \qquad \alpha = 7.5/\text{cm}$$

$$d = 6 \text{ mm} = 0.6 \text{ cm}$$

$$\alpha d = 4.5$$

$$\gamma = 1/e^{\alpha d} = e^{-\alpha d} = e^{-4.5} = 0.0111$$

Q 2.18 $\alpha = APe^{-BP/E} = AP^{-BPd/V}$ given $A = 15$/cm; $B = 360$, $E/P = 150$ V/cm – tor assuming the pressure to be 1 torr.

$$\alpha = 15e^{-360/150} = 15e^{-2.4} = 1.360/\text{cm}$$

with $\gamma = 10^{-4}$, $pd_{\min} = \dfrac{e}{A}\ln\left(1+\dfrac{1}{\gamma}\right)$

$$V_{b\,\min} = \frac{eB}{A}\ln\left(1+\frac{1}{\gamma}\right) = e\,pd_{\min}$$

$$pd_{\min} = \frac{2.718}{15}\ln\left(1+\frac{1}{10^{-4}}\right) \approx 1.669 \text{ torr} - \text{cm}$$

$$V_{b\,\min} = 601 \text{ V}$$

Q 2.19 $V = 24.22\left[\dfrac{293\text{ pd}}{760\text{ T}}\right] + 6.08\left[\dfrac{293\text{ pd}}{760\text{ T}}\right]^{1/2}$

$d = 1$ cm, $p = 70$ torr, $T = 273 + 35 = 308$°K

$$\therefore \quad V = 24.22\left[\frac{293\times 70\times 1}{760\times 308}\right] + 6.08\left[\frac{293\times 70\times 1}{760\times 308}\right]^{1/2}$$

$$= 2.122 + 1.499 = 3.921 \text{ kV}$$

or 3921 Volts.

Q 2.20 $E_b = 30md\left[1+\dfrac{0.301}{\sqrt{dr}}\right]$

$$r = 0.5 \text{ cm}, \qquad m = 1$$

$$d = \frac{0.392b}{273+T}, \qquad P = 760 \text{ torr}, T = 35°\text{C}.$$

$$d = \frac{0.392\times 750}{273+35} = 0.9545$$

$$E_b = 30 \times 1.0 \times 0.9545\left[1+\frac{0.301}{\sqrt{0.9545\times 0.5}}\right] = 33.06 \text{ kV}$$

CHAPTER 3

3.10 The Power law to be fitted is $V_b = V_o d^n$

$\therefore$ $\ln V_b = \ln V_o + n \ln d$

For oil A					
	gap d (mm)	3	6	9	10
	V_b(kV)	86	148	169	219
	$\ln d$	1.098	1.792	2.197	2.302
	$\ln V$	4.454	4.997	5.131	5.389

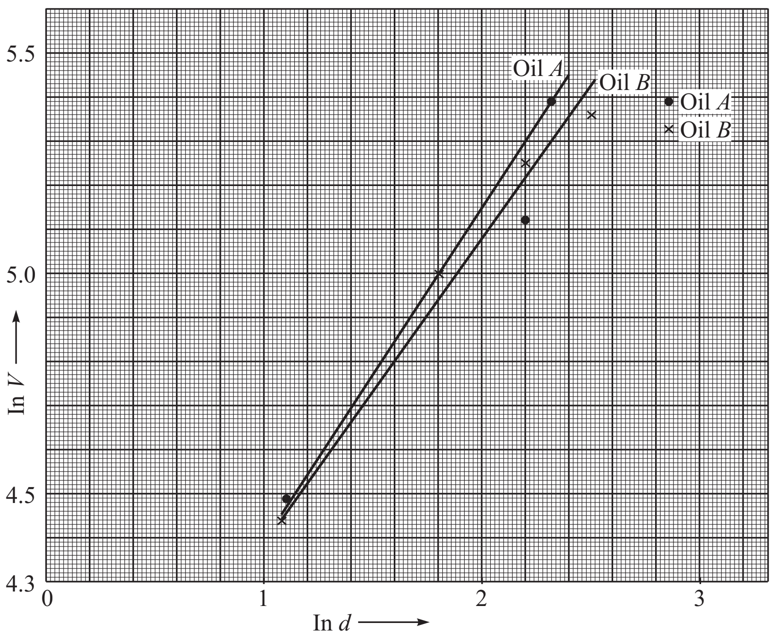
The graph is shown in the figure. From the figure, the slope 0.84 = n and V_o = 32.6.

Power law is $V_b = 32.6\, d^{0.84}$, Breakdown strength = 210 kV/cm (1 cm or 10 mm gap)

For oil B					
	gap d(mm)	3	6	9	12
	V_b(kV)	84	143	192	214
	$\ln d$	1.098	1.792	2.197	2.485
	$\ln V$	4.431	4.962	5.257	5.366

The graph is shown in the figure. From it the slope is 0.82 = n and V_o = 31.4.

Power law is $V_b = 31.4 d^{0.82}$ Breakdown strength = 204 kV/cm



Chapter 6

6.21 Generator capacitance $(C_1) \dfrac{0.12\ \mu F}{12} = 0.01\ \mu F$

$$\text{Load capacitor } C_2 = 1000 \text{ pf} = 1 \text{ nF}$$
$$= 0.001\ \mu F$$
$$R_1 = 1.2 \text{ k}\Omega,\ R_2 = 4 \text{ k}\Omega$$

$$\text{Time to front} = 3 \times \frac{C_1 C_2}{C_1 + C_2} \cdot R_1$$

$$= \frac{3 \times 0.01 \times 0.001 \times 1.25 \times 10^3}{0.01 + 0.001} = 3.14\ \mu \text{ sec}$$

$$\text{Wave fail} = 0.7(C_1 + C_2)(R_1 + R_2)$$
$$= 0.7 \times (0.01 + 0.001)(1.25 + 4) \times 1$$
$$= 40.4\ \mu \text{ sec}$$

Changing voltage $12 \times 200 = 2400$

$$\text{efficiency} = \frac{1}{R_1 C_2 (\alpha - \beta)},\ \alpha \approx \frac{1}{R_1 C_2},\ \beta = \frac{1}{R_2 C_1}$$

substituting the values of R_1, R_2, C_1 and C_2 efficiency is 0.6895
Hence output peak voltage is $0.6895 \times 2400 = 1655$ kV

6.22 Discharge energy $= (n)\left(\frac{1}{2} CV^2\right)$

$$= 8 \times \frac{1}{2} \times 1.2 \times 10^{-6} \times (167 \times 10^3)$$
$$= 133 \text{ kJ}$$

$$C_1 = \frac{1.2}{8} = 0.15\ \mu F,\ C_2 = 15{,}000 \text{ pf} = 0.015\ \mu$$

$$t_1 = 0.3(R_1)\left(\frac{C_1 C_2}{C_1 + C_2}\right) = 1\ \mu \text{ sec}$$

substituting for C_1 and C_2, $R_1 = 24.4\ \Omega$

$$t_2 = 0.7(R_1 + R_2)(C_1 + C_2) = 50$$
$$R_1 + R_2 = 434\ \Omega$$
$$R_2 = 434 - 24.4$$
$$= 409.6\ \Omega$$

6.23 With short circuit test leakage reactance X_L is obtained.

$$X_L = \frac{0.1 \times 350}{10} = 3.5 \text{ k ohms}$$

6.24 I = full load current is $\dfrac{3500\text{ kVA}}{350\text{ kV}} = 10\text{ A}$

2% Voltage rise is $350 \times 0.02 = 7\text{ kV}$

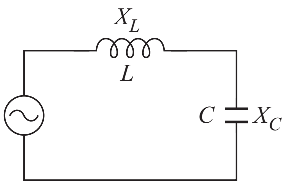
$$\therefore \quad \text{Current} = \frac{7\text{ kV}}{3.5\text{ k}\Omega} = 2\text{ A}$$

$$\therefore \quad X_C = \frac{1.02 \times 350}{2\text{ A}} = 178.5\text{ k}\Omega$$

$$\therefore \quad C = \frac{1}{\omega X_C} = \frac{1}{100\pi \times 178.5 \times 10^3}$$

(f = 50 Hz, $\therefore\ \omega = 100\pi$)

$$C = 0.0178 \times 10^{-6}\text{ F} = 17.8\text{ nF}$$



X_L: Tr leakage reactance, L: inductance
C: Self Capacitance, X_C reactance

6.25 10 stages

$\therefore$ Capacitors $n = 20$, $I = 10$ ma, $C = 0.01\ \mu$F

$$\text{peak ripple } \delta V = \frac{n(n+1)}{2} \cdot \frac{I}{fc} = \frac{20 \times 21}{2} \times \frac{10}{400 \times 0.01}\text{ kV}$$
$$= 52.5\text{ kV}$$

$$\text{Avg ripple: } \frac{52.5}{2} = 26.25\text{ kV}$$

$$\%\text{ ripple } \frac{52.5}{100\sqrt{2} \times 10} \times 100 = 3.71\%$$

Voltage drop (stages = 10), $n = 10$

$$\Delta V = \frac{I}{fc}\left\{2/3n^3 + \frac{n^2}{2} - n/6\right\}$$

$$= \frac{1}{4}[2/3 \times 10^3 + 10^2/2 - 10/6)\text{ kV} = 715$$

% regulation is $715/(100\sqrt{2} \times 10) = 50.5\%$

6.26 Ripple $\delta V = \dfrac{I}{fc}(1 + 2) = \dfrac{3I}{fc}$

$I = 4$ ma, $f = 50$ Hz and $C = 0.01$ μF

$$\therefore \qquad \delta V = \frac{4 \times 3}{50 \times 0.01} = 24 \text{ kV}$$

$$\text{Avg ripple} = 12 \text{ kV}$$

$\therefore$ Output voltage $200 - 12 = 188$ kV

6.27 $L_1 = 0.093$ H, $L_2 = 0.011$ H, $M = 0.026$ H
$C_1 = 1.5$ μF, $C_2 = 18$ nF

$$\omega_1 = \frac{1}{\sqrt{L_1 C_1}} = \frac{1}{\sqrt{0.093 \times 1.5 \times 10^{-6}}} = 2.677 \times 10^3 \text{ r/sec}$$

$$\omega_2 = \frac{1}{\sqrt{L_2 C_2}} = \frac{1}{\sqrt{0.011 \times 18 \times 10^{-9}}} = 7.10 \times 10^4 \text{ r/sec}$$

$$K = \frac{M}{\sqrt{L_1 L_2}} = \frac{0.026}{\sqrt{0.093 \times 0.011}} = 0.873$$

$$\therefore \qquad \sigma = \sqrt{1 - 0.813^2} = 0.58226$$

$$\sigma^2 = 0.339031$$

$$\gamma_1^2 = \frac{\omega_1^2 + \omega_2^2}{2} + \sqrt{\frac{\omega_1^2 + \omega_2^2}{2} - \sigma^2 \omega_1^2 \omega_2^2}$$

and $$\gamma_2^2 = \frac{\omega_1^2 + \omega_2^2}{2} - \sqrt{\frac{\omega_1^2 + \omega_2^2}{2} - \sigma^2 \omega_1^2 \omega_2^2}$$

substituting ω_1 and ω_2 and simplifying

$$\gamma_1 = 1.606 \times 10^3; \quad \gamma_2 = 71.13 \times 10^3$$

$$V_2(\text{peak}) = \frac{VM}{\sigma L_1 L_2 C_2} \cdot \frac{1}{\gamma_2^2 - \gamma_1^2}$$

substituting and simplifying

$$V_2 = 9.22 \text{ kV}$$

and output is $9.22(\cos \gamma_1 t - \cos \gamma_2 t)$ kV

6.28 Energy $W = \frac{1}{2} CV^2 = 60$ kw sec, $C = 53$ μF.

$R = 0.0156\ \Omega$ and $L = 1.47$ μH

$$\therefore \qquad V = \sqrt{\frac{2W}{C}} = \sqrt{\frac{2 \times 60 \times 10^3}{53 \times 10^{-6}}} = 47.5 \text{ kV}$$

$$\alpha = \frac{R}{2L} = \frac{0.0156}{2 \times 1.47 \times 10^{-6}} = 5.306 \times 10^3$$

$$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}} = \sqrt{\frac{1}{53 \times 1.47 \times 10^{-6} \times 10^{-6}} - (5.306 \times 10^3)^2}$$

$$= 113.2 \times 10^3$$

$$= \frac{V}{\omega L} = \frac{47.5 \times 10^3}{113.2 \times 10^3 \times 1.47 \times 10^{-6}}$$

$$= 286 \times 10^3$$

$$= 286 \text{ kV}$$

$$\therefore \quad I(t) = 286 e^{-\alpha t} \sin \omega t$$

$$\text{time to front} = \frac{1}{\omega} \tan^{-1} \frac{\omega}{\alpha} = 13.46 \ \mu \text{ sec}$$

$$\text{time to tail} = \frac{\pi}{\omega} = 27.75 \ \mu \text{ sec}$$

$$I_{peak} = (286 e^{-\alpha \times 13.46 \times 10^{-6}}) = 266 \text{ kA}$$

6.29 Voltage rating of testing transformer 2.2 (system voltage) = 2.2 × 230 ≈ 500 kV.

$$\text{Current} = \omega CV = 100\pi \times 2000 \times 10^{-12} \times 500 \times \pi$$

$$= 100\pi \times 10^{-3} \text{ A.}$$

$$\therefore \quad \text{kVA rating} = 500 \times 100\pi \times 10^{-3}$$

$$= 50\pi \approx 150 \text{ kVA}$$

CHAPTER 7

7.17 $I_{rms} = \dfrac{VC_m}{\sqrt{2}} \cdot \omega, \quad V = 250$ kV

$$\omega = \frac{1500 \times 2\pi}{60} = 50\pi$$

$$I_{rms} = 20 \ \mu\text{A}$$

$$\therefore \quad C_m = \frac{\sqrt{2}\, I_{rms}}{V \cdot \omega} = \frac{\sqrt{2} \times 20 \times 10^{-6}}{250 \times 10^3 \times 50\pi}$$

$$= 0.5093 \text{ pf}$$

7.18 F = Force in gms wt is $\dfrac{d^2}{2825}\left(\dfrac{V}{s}\right)^2 \quad V = 50$ kV

$d = 15$ cm

$s = 1.5$ cm

$$\therefore \quad F = \frac{15^2}{2852} \times \frac{50 \times 50}{1.5 \times 1.5} \approx 88.57 \text{ gms}$$

7.19 For compensated divider $R_1C_1 = R_2C_2$

$R_1 = 25 \times 10^3\ \Omega \quad R_2 = 75\ \Omega$

$C_1 = 400$ pf

$$\therefore \quad C_2 = \frac{R_1 C_1}{R_2} = \frac{25 \times 10^3 \times 400 \times 10^{-12}}{75}$$

$$= 133.3 \times 10^{-9} \text{ F} = 133.3 \text{ nF.}$$

7.21 $R_1C_1 = R_2C_2$ and $Z_0 = R_3 + \dfrac{R_1R_2}{R_1 + R_2}$

Here $\quad R_1 = 100\ \Omega, \quad C_1 = 400$ pf

$R_2 = 0.175\ \Omega$

$$\therefore \quad C_2 = \frac{R_1 C_1}{R_2} = \frac{100 \times 400 \times 10^{-12}}{0.175}$$

$$C_2 = 0.2285\ \mu\text{F}$$

$$Z_0 = 75 = R_3 + \frac{100 \times 0.175}{100 + 0.175} = R_3 + 0.1747$$

$\therefore \quad R_3 \approx Z_0 = 75$

R_4 is taken equal to Z_0 or $R_3 = 75\ \Omega$

and $\quad R_4C_4 \approx R_2C_2 = R_1C_1$

$$\text{Hence} \quad C_4 = \frac{R_1 C_1}{R_4} = \frac{100 \times 400 \times 10^{-12}}{75} = 533.3 \text{ pf}$$

$$\text{effective ratio} = 1 + \frac{C_2}{C_1} = 1 + \frac{0.2285 \times 10^{-6}}{400 \times 10^{-12}}$$

$$= 572.25$$

7.23 $R = 1$ mΩ, Rise time $T = 0.237 \dfrac{\mu d^2}{\rho} = 10$ n sec

$\rho = 50 \times 10^{-6}\ \Omega$ cm $l = 10$ cm (assumed)

$= 50 \times 10^{-8}\ \Omega$m

$$10 \times 10^{-9} = \frac{0.237 \times 4\pi \times 10^{-7} \times d^2}{5 \times 10^{-8}}$$

$$\therefore \quad d^2 = \frac{10 \times 10^{-9} \times 5 \times 10^{-8}}{0.237 \times 4\pi \times 10^{-7}} \text{ m}$$

$$= 0.01679 \times 10^{-6} \text{ m}$$

$\therefore \qquad d = 0.1296 \times 10^{-3}$ m ≈ 0.13 mm

$$R = 1\ \text{m}\Omega = \frac{\rho l}{a} = \frac{\rho l}{(2\pi r) \times d}$$

$$\therefore \qquad r = \frac{\rho l}{(R)\ 2\pi d} = \frac{50 \times 10^{-8} \times 10 \times 10^{-2}}{10^{-3} \times 2\pi \times 0.13 \times 10^{-3}}$$

$$\approx 2.55 \times 10^{-2}\ \text{m}$$

or 2.55 cm

[**Note:** if l assumed as 15 cm then r, radius of tube will be 4 cm]

7.24 $V_m = \dfrac{M}{CR} I(\text{t})$

$$\frac{dI}{dt} = 10^4 \text{A}/\mu\ \text{sec} = 10^{10} \text{A/sec}$$

$$\therefore \qquad \frac{M}{CR} = \frac{V_m}{I(t)} = \frac{10}{10^4} = 10^{-3}$$

with sinusoidal variation of current $\dfrac{10^4}{10^{10}} = 10^6$

$$= \frac{1}{4} \text{ of a cycle}$$

$$\therefore \qquad f = 10^6/4 \text{ Hz}$$

$$\omega = 2\pi f = \frac{\pi}{2} \times 10^6\ r/\text{sec}$$

Taking $\dfrac{1}{CR} \approx \dfrac{\omega}{20\pi} = 10^5/4$

or $\qquad CR = 4 \times 10^{-5}$

Taking $M = 10^{-3} CR$

$= 4 \times 10^{-3} \times 10^{-5}$

$= 4 \times 10^{-8}$ or 0.04 μH

Taking $R \approx 10$ kΩ

$$C = \frac{CR}{R} = \frac{4 \times 10^{-5}}{10 \times 10^3} = 4 \times 10^{-9} = 4 \text{ nF.}$$

7.26 $l = 10$ cm radius $= 2.5$ cm thickness $d = 0.2$ mm $\rho = 50 \times 10^{-6}\ \Omega$ cm
$= 50 \times 10^{-8}\ \Omega - \text{m}$

$$\text{Resistance } R = \frac{\rho l}{a} = \frac{\rho l}{(2\pi r) d} = \frac{50 \times 10^{-8} \times 10 \times 10^{-2}}{2\pi \times 2.5 \times 10^{-2} \times 0.2 \times 10^{-2}}$$

$$= 0.159 \times 10^{-2}\ \Omega$$

$$\approx 1.6\ \text{m}\Omega$$

$$\text{Band width } B = \frac{1.46R}{L_0} = \frac{1.46\rho}{\mu_0 d^2}$$

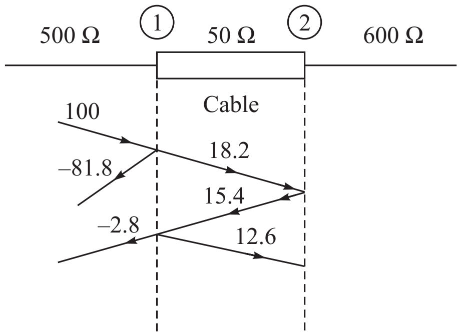
$$= \frac{1.46 \times 50 \times 10^{-8}}{4\pi \times 10^{-7} \times 0.2 \times 10^{-3} \times 0.2 \times 10^{-3}} \approx 14.5 \text{ mHz}$$

$$L_0 = \frac{1.46R}{B} = \frac{1.46 \times 1.6 \times 10^{-3}}{14.5 \times 10^{6}} \approx 0.16 \text{ µH.}$$

$$\text{Voltage drop} = I_R = 1.6 \times 10^{-3} \times 10 \times 10^{3} = 16 \text{ V}$$

CHAPTER 8

8.16 At 500 Ω and cable junction reflection Coe $\cdot \dfrac{Z_2 - Z_1}{Z_2 + Z_1} = \dfrac{50 - 500}{50 + 500} - \dfrac{9}{11}$.



Transmission Coe $\cdot \dfrac{2Z_2}{Z_1 + Z_2} = \dfrac{2}{11}$

junction voltage after 1st reflection $\dfrac{2}{11} \times 100 = 18.2$ kV

reflection coefficient at 50 Ω and 600 Ω junction $\dfrac{600 - 50}{600 + 50} = \dfrac{11}{13}$.

Reflected voltage from 2nd junction $= \dfrac{11}{13} \times 18.2 = 15.4$ kV.

∴ Transmitted voltage into the cable at 1st junction

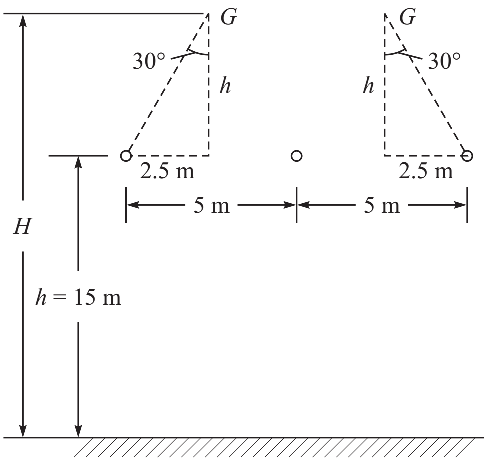
$$= 15.4 \times \frac{9}{11} = 12.6 \text{ kV}$$

Reflected voltage into the line $15.4 \times \frac{2}{11} = 2.7$ kV.

$\therefore$ Junction voltage after 2nd reflection

$$18.2 + 12.6 - 2.7 \approx 27.9 \text{ kV}.$$

8.18 Taking 30° cone angle for the ground wires above the conductors for protection $\tan 30° = \frac{1}{\sqrt{3}} = \frac{2.5}{h}$

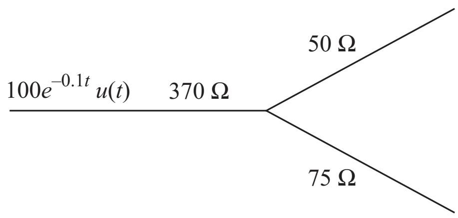


$\therefore$ $$h = 2.5\sqrt{3} = 4.33 \text{ m}$$

Height of ground wire above ground = 15 + 4.33 = 19.33 m

[**Note:** Two ground wires are needed to protects all the phase wires. Otherwise, the Height of the ground wire will very very large.]

8.19



effective impedance of two cables is $\frac{50 \times 75}{50 + 75} = 30\ \Omega$

$\therefore$ reflection Coe. to the 370 Ω line is

$$\frac{30 - 370}{30 + 370} = -\frac{340}{400}$$

$\therefore$ reflected voltage is $-\dfrac{340}{400} \times 100e^{-0.1t}\,u(t)$

$= -85e^{-0.1t}\,u(t)$

$\therefore$ junction voltage is $(100 + 85)e^{-0.1t}\,u(t)$

$= 185e^{-0.1t}\,u(t)$

Transmitted voltage $= 100 - 85 = 15e^{-0.1t}u(t)$

This voltage is shared in the inverse ratio of the impedances of the cables.

$\therefore$ Voltage length 50 Ω cable is $\dfrac{75}{125} \times 15e^{-0.1t}u(t) = 9e^{-0.1t}\,u(t)$

Voltage length 75 Ω cable is $\dfrac{50}{125} \times 15e^{-0.1t}u(t) = 6e^{-0.1t}\,u(t)$

Chapter 9

9.20 For a Schering Bridge

$$C_X = \frac{R_3}{R_4}C_S \quad \text{and} \quad \tan\delta_x \text{ loss factor} = \omega C_3 R_3$$

Here $C_S = 500$ pf and 100 pf

$R_4 = 1$ ohm to 1 k ohms

$C_3 = 1$ nF to 2 μF, $R_3 = 100$ to 1000 Ω

(a) $$\max C_X = \frac{R_3(\text{max}) \cdot C_S(\text{higher value})}{R_4(\text{min})}$$

$$= \frac{1000 \times 500 \times 10^{-12}}{1} = 5 \times 10^{-7}\text{ F} = 0.5\ \mu\text{F}$$

$$\min C_X = \frac{R_3(\text{min}) \times C_S(\text{lower value})}{R_4 \text{ max}}$$

$$= \frac{100 \times 100 \times 10^{-12}}{1000} = 10 \times 10^{-12}\text{ F} = 10\text{ pf}$$

(b) $\tan\delta_x = \omega C_3 R_3$

$= \omega C_X R_X$

$C_X = 200$ pf, $C_3 = 10$ nF and $R_4 = 1$ kΩ

$$R_3 = \frac{C_X R_4}{C_S} = \frac{200 \times 10^{-12}}{500 \times 10^{-12}} \times 1000 = 400\ \Omega$$

$\tan\delta_X = 100\pi \times 10 \times 10^{-9} \times 400 = 4\pi \times 10^{-4} = 1.25 \times 10^{-3}$

(c) with $C_X = 10$ μF

$$R_4 = \frac{R_3 C_S}{C_X} = \frac{500 \times 1000 \times 10^{-12}}{10 \times 10^{-6}} = 5 \times 10^{-2}\ \Omega$$

min R_4 available is 1 Ω

Hence shunt S needed is $\dfrac{S \times R_4}{S + R_4} = 5 \times 10^{-2}$

$$\frac{S \times 1}{S + 1} = 5 \times 10^{-2}$$

$$\therefore \qquad S = \frac{1}{19}\ \Omega$$

CHAPTER 11

11.4 Clearances allowed 200 kV/m AC (rms)
275 kV/m DC
≈ 400 kV/m Impulse

AC Transformer : 250 kV, min clearance $\dfrac{250}{200} = 1.25$ m

Impulse generator : 800 kV " $\dfrac{800}{400} = 2.00$ m

Voltage Divider : 900 kV " $\dfrac{900\text{ kV}}{400} = 2.25$ m

gas filled capacitor : 200 kV " $\dfrac{200}{200} = 1$ m

Hence size of the room: Height: max size + max clearance
= 3 m + 2.25 m = 5.25 m
Allow 1.5 m for sphere gap
= 6.75 m

width: Assuming the testing Transformer and Impulse generator one placed in a row. Wall clearance + equipment width + wall clearance
= 1.5 m + 1.5 m + 1.5 m = 4.5 m
Allowing 1 m space for doors etc., gross widh = 5.5 m

length: wall clearance + AC unit width + cleance + I.G. size + clearance
= 1.5 + 1.2 + 2.0 + 1.5 + 2 = 10.2 m
allow about 1.8 at doors
gross length = 10.2 + 1.8 = 12 m

Check for sphere gap: Sphere gap size
ht of top sphere bottom (A) + sphere size + clearance for 900 kV
$= 5D + D + 2.25$ m
$= 6 \times 0.75 + 2.25$ m $= 6.75$ m

Hence the over all dimensions of room may be

$$12 \text{ m} \times 5.5 \text{ m} \times 6.75 \text{ m} \quad (40' \times 18' \times 22')$$