Scilab Textbook Companion for High Voltage Engineering by C. L. Wadhwa[1]

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Book Description

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

Chapter 1

Breakdown Mechanism of Gases Liquid and Solid Materials

Scilab code Exa 1.1 Example 1

```
//Chapter 1,Example 1.1 Page 51
clc
clear
I = 600 // micor amps
x = 0.5 // distance in cm
V = 10 // kV
I2 = 60 // micro amps
x2 = 0.1 // distance in cm
//Calculation 600 = I0*exp(0.5*alpha) and 60 = I0*exp(0.1*alpha)
alpha = log(600/60)/(0.5-0.1)
printf("Townsends first ionising coefficient = %f ionizing collisions/cm", alpha)

//Answers may vary due to round of error
```

Scilab code Exa 1.2 Example 2

```
//Chapter 1,Example 1.2 Page 52
clc
clear
// Refering the table in example 1.2
// slope between any two points (log(I/I0)/x)
// taking the gap between 2 and 2.5 mm
I1= 1.5*10^-12
I2= 5.6*10^-12
I0 = 6*10^-14
gi1 = log(I1/I0) // gradual increase when gap is 2
gi2 = log(I2/I0) // gradual increase when gap is 2.5 //claculation in text is wrong
slope = (gi1-gi2)/0.05
printf(" Slope = %f \n", -slope)
//evaluvating ghama
e1 = exp(-slope*0.5)
e2 = exp(-slope*0.5) // -1 is ignored due to the large magnitude
ghama = (7*10^7-6*e1)/(e2*7*10^7)
printf(" Ghama for set 1= %e /cm \n ", ghama)
//Gap between the slope for set 2
alpha = log(12/8)/0.05
printf(" Alpha = %e collosions/cm \n", alpha)
e1 = exp(alpha*0.5)
e2 = exp(alpha*0.5) // -1 is ignored due to the large magnitude
ghama = (2*10^5-e1)/(e2*2*10^5)
printf(" Ghama for set 2= %e colissions/cm \n", ghama)

//Answers may vary due to round of error
```

Scilab code Exa 1.3 Example 3

```
//Chapter 1,Example 1.3 Page 53
clc
clear
//employing equation Vb = K*d^n
//88 = K*4^n --- eq(1)  165 = K*8^n ---eq(2)
//dividing eq(2)/q(1)
Vb1 = 88
Vb2 = 165
n1 = 0.6286/0.693
K1 = Vb1/4^n1
//135 = K*6^n --- eq(1)  212 = K*10^n ---eq(2)
//dividing eq(2)/q(1)
Vb1 = 135
Vb2 = 212
n2 = 0.4513/0.5128
K2 = Vb1/6^n2
n = (n1+n2)/2
K = (K1+K2)/2
printf (" n = %f (approx.) K = %f (approx.)",n,K)

//Answer may vary due to round of error
```

Scilab code Exa 1.4 Example 4

```
//Chapter 1,Example 1.4 Page 53
// Determine (pd)min Vbmin
clc
clear
A = 12
B = 365
```

```
e = 2.718
ghama = 0.02
K = 51
pd = (e/A)*log(1+(1/ghama))
Vbmin = (B/A)*e*log(K)
printf (" (pd)min = %f Vbmin = %f Volts",pd,Vbmin)

//Answers may vary due to round of error
```

Chapter 2

Generation of High DC and AC Voltages

Scilab code Exa 2.1 Example 1

```
//Chapter 2,Example 2.1 Page 78
clc
clear
//(i) Determine volatge regulation
C = 0.06 // micro farad
I = 1 //mA
f = 150 //Hz
n = 10
V = (1/(f*C))*((2*n^3/3)+(n^2/2))
perc = (V*100)/(2*10*100)
printf (" (ia) Volatge regulation = %f kV \n ",V)
printf (" (ib) percentage volatge regulation = %f \n
    ",perc)
//(ii) Ripple volatge
delV = (1/(f*C))*(n*(n+1)/2)
perc = (delV*100)/(2*10*100)
printf (" (iia) The ripple votage = %f kV \n ",delV)
printf (" (iib) percentage ripple votage = %f \n ",
   perc)
```

```
//(iii) Optimum no. of stages
Vmax = 100
I = 10^-3
OnS = sqrt(Vmax*f*C*10^-6*10^3/I)
//(iv) Maximum output volatge
Vout = OnS*(4/3)*Vmax
printf (" (iii) Optimum no. of stages = %d  \n ",OnS
   )
printf (" (iv) Maximum output volatge = %d KV\n ",
   Vout)

// Answers may vary due to round off error
```

Scilab code Exa 2.2 Example 2

```
//Chapter 2,Example 2.2 Page 79
clc
clear
// based on the circuit Fig.Ex.2.2
V = 100 // kVA
R = (1/100)*(200^2/0.1) // Resistance of transformer
r = (5/100)*(200^2/0.1) // reactance of transformer
printf (" Resistance of transformer = %d ohm \n ",R)
printf (" Reactance of transformer = %d ohm \n ",r)
rC = 400/0.5 // Reactance of capacitor
rI = 20 // Inductive reactance
ArI = rC-rI // Additional inductive reactance
Ic = ArI*1000/314 // inductance required
TrC = 8 // total reactance in cercuit in Kohm
I = 0.5
Vsec = I*TrC // Secondary voltage
Vp = 4*(250/200) // primary voltage
printf (" Reactance of capacitor = %d K ohm \n ",rC)
printf (" Inductive reactance = %d ohm \n ",rI)
printf (" Additional inductive reactance k Ohm= %d
```

```
    \n ",ArI)
printf (" Inductive required = %d H \n ",Ic)
printf (" Total reactance in cercuit = %d Kohm \n ",
    TrC)
printf (" Secondary voltage = %d kV \n ",Vsec)
printf (" Secondary voltage = %d volts \n ",Vp)

// Answers may vary due to round off error
```

Scilab code Exa 2.3 Example 3

```
//Chapter 2,Example 2.3 Page 68
// based on equation 2.18
clc
clear
E = 30*10^3 // V/cm
E0 = 8.854*10^-12 // Epselon
b = 1
v = 10
sigma = E0*E
printf (" sigma = %e C/m^2 \n ",sigma)
I = sigma*b*v
printf (" I = %e Amp",I)
//Answers may vary due to round of error
```

Chapter 3

Generation of Impulse Voltages and Currents

Scilab code Exa 3.1 Example 1

```
//Chapter 3,Example 3.1 Page 104
clc
clear
R1 = 75 //ohms
R2 = 2600 //ohms
C1 = 25 // nF
C2 = 2.5 //nF
alpha = (10^9/2)*(1/(R2*C1)+1/(R1*C1)+1/(R1*C2))
beeta = (1/2)*sqrt(4*alpha^2-4*10^18/(R1*R2*C1*C2))
t1 = (1/(2*beeta))*log((alpha+beeta)/(alpha-beeta))
K = 0.7/(t1*(alpha-beeta))+1
t2 = K*t1
printf (" alpha = %e  \n ",alpha)
printf (" beta = %e \n ",beeta)
printf (" K = %f \n ",K)
printf (" t1 = %e micro sec \n ",t1*10^6)
printf (" t2 = %f micro sec \n ",t2*10^6)

//Aproximating the circuit and neglecting R2
```

```
t1 = 3*((C1*C2*10^-18)/(C1+C2*10^-9))*R1
// C1 and C2 are in  parallel and R1 and R2 in
   series
t2 = 0.7*(R1+R2)*(C1+C2)*10^-9
printf (" t1 = %f micro sec \n ",t1*10^9*10^6)
printf (" t2 = %f micro sec \n ",t2*10^6)
printf ("On comparison with the values obtained
   through exact formulate it is found that whereas
   wave tail time is more or less same, \n the wave
   front time as calculated through approximate
   formula is quite erroneous.")

// Answers may vary due to round off error
```

Scilab code Exa 3.2 Example 2

```
//Chapter 3,Example 3.2 Page 106
clc
clear
t1 = 1.2*10^-6
C1 = (0.3/12)*10^3
C2 = 0.4
R1 = (C1+C2)*t1/(3*(C1*C2*10^-9))
t2 = 50*10^-6
R1R2 = t2/(0.7*(C1+C2)*10^-9)// (R1+R2)
R2 = R1R2-R1
printf (" R1 = %f ohm \n ",R1)
printf (" R2 = %f ohm \n ",R2)
// Alternative method
ab = 0.7*10^-6/(t2-t1) // alpha-beta
ghama = C1/C2 // large value therefore
R2 = 10^3/(C1*ab) // mentioned wrong in the text
// alpha = beta and based on the eq: t1 = (2/(2*
   alpha))log((2*alpha)/(alpha-beta))
alpha = 2.43
```

```
beeta = 2.415656
R1 = (10^3/C1)*((1/(alpha+beeta))+(62.5/(alpha+beeta
    )))
V0 = 125*12
Vmax = V0/(2*R1*C2*10^-3*beeta)
printf (" ghama = %f (large value)\n ",ghama)
printf (" R2 = %f ohm \n Since alpha aprox. equla to
     beta ",R2)
printf (" \n R1 = %f ohm \n ",R1)
printf (" Vmax = %f kV \n ",Vmax)

//Answers vary due to round of error
```

Scilab code Exa 3.3 Example 3

```
//Chapter 3,Example 3.3 Page 107
clc
clear
R = 1
C = 15*10^-6
L = 2*10^-3
V = 125 // kV
v = R/2*sqrt(C/L)
pow = -v*asin(sqrt(1-v^2))/sqrt(1-v^2)
e = exp(pow)
Imax = 2*V*v*e
t1 = sqrt(L*C)*asin(sqrt(1-v^2))/sqrt(1-v^2)
// based on trila and error t2=1275 micro sec
t2 = 1275 // micro sec
RHS = 0.5286*sin(t2/173.2)
printf (" Imax = %f KA \n ",Imax)
printf (" t1 = %f micro sec \n ",t1*10^6)
printf (" t2 = %f micro sec \n ",t2)
printf (" RHS = %f \n ",RHS)
printf ("Therefore, time to 50 percent value is 1275
```

```
sec")
```

Chapter 4

Measurement of High Voltages and Currents

Scilab code Exa 4.1 Example 1

```
//Chapter 4,Example 4.1 Page 144
clc
clear
//Determine the voltge when S=2 cm
S = 0.2 // cm
Vb = 24.22*S+6.08*sqrt(S)
printf (" Vb when S = 2 cm is %f kV \n ",Vb)
//Determine the voltge when S=1.5 cm
S = 1.5 // cm
Vb = 24.22*S+6.08*sqrt(S)
printf (" Vb when S = 1.5 is %f kV \n ",Vb)
b = 75
t = 35
D = (3.92*b)/(273+t)
printf (" Air density correction factor= %f \n ",D)

//Answer may vary due to round off error
```

Scilab code Exa 4.2 Example 2

```
//Chapter 4,Example 4.2 Page 145
clc
clear
// Determine the potential difference
AP = 8^2/4 // Area of plate
d = 4 // mm
FA = 0.2*9.8*10^-3 // Force of attraction
V = sqrt(FA*2*36*16*10^-6/(10^-9*16*10^-4))
printf (" Area of plate =  %f    sq.cm \n ",AP)
printf (" V = %f V \n ",V)

//Answers may vary due to round off error
```

Scilab code Exa 4.3 Example 3

```
//Chapter 4,Example 4.3 Page 145
clc
clear
d = 1 //mm
V = 10^3 // V
F = 5*10^-3 // pull between the plates in N
E = 1/(36) // epselon
A = 10^2/4 // Area of the plate
d1 = sqrt((1/(2*F))*E*10^-9*V^2*A*10^-4) //
    calculation done in the text is wrong
d21 = 1/(d1*10^4)
d22 = 1/(d1*10^4+d)
C = (V*E*10^-9*A*10^-4)*(d21-d22)
printf (" d = %f mm \n ",d1*10^4)
```

```
printf (" charge in capacitance = %f pF \n ",C
   *10^12)

//Answers may vary due to round off error
```

Scilab code Exa 4.4 Example 4

```
//Chapter 4,Example 4.4 Page 145
clc
clear
Imin = 2*10^-6 // A
Imax = 35*10^-6 // A
V = 15*10^4 // V
w = 2*%pi*1500/60
Cm = sqrt(2)*Imin/(V*w)
Ipeak = 2*250/15
printf (" Cm = %f pF \n ",Cm*10^13)
printf (" At 250 kV, the current indicated will be =
    %f  A \n ",Ipeak)

//Answers vary due to round off error
```

Scilab code Exa 4.5 Example 5

```
//Chapter 4,Example 4.5 Page 146
clc
clear
V1 = 150*10^3 // V
PD = 1200 // potential divider ratio
I = 10^-6 // A
t = 8 // sec
V = V1/PD
R = V/I
```

```
C = t*10^6/R
printf (" V = %f V \n ",V)
printf (" R = %f M    \n ",R*10^-6)
printf (" C = %f   F  \n ",C)

// Answers provided in the textbook are wrong
```

Scilab code Exa 4.6 `Example 6`

```
//Chapter 4,Example 4.6 Page 146
clc
clear
i = 8*10^3 // i(t)
V0 = 8 // V0(t)
I = 8*10^3 // A
rcI = 10^10 // rate of change of current in A/sec
R = 8*10^3 // ohm
RCbyM = i/V0 // R*C/M
t = I/rcI // 1/4 of cycle
T = t*4
f = 1/T
CR = 5/f
M = CR/RCbyM
C = CR/R
printf (" Time for 1/4 cycle = %e sec \n ",t)
printf (" Full time = %e sec \n ",T)
printf (" f = %e Hz \n ",f)
printf (" M = %e H \n ",M)
printf (" C = %e F \n ",C)
printf (" R = %e     \n ",R)

// Answers may vary due to round off error
```

Chapter 6

Nondestructive Insulation Test Techniques

Scilab code Exa 6.1 Example 1

```
//Chapter 6,Example 6.1 Page 198
clc
clear
Cs = 106 // micro F
C2 = 0.35 // micro F
R2 = 318 // ohms
R1 = 130 // ohms
w = 314
Rs = R1*(C2/Cs)
Cs1 = Cs*(R2/R1)
tang = w*Cs1*10^-6*Rs
cosp = tang
printf (" Rs = %f ohm \n ",Rs)
printf (" Cs = %f   F  \n ",Cs1)
printf (" tan     s = %f \n ",tang)
printf (" cos      = %f \n ",cosp)

//Answers may vary due to round off error
```

Scilab code Exa 6.2 Example 2

```
//Chapter 6,Example 6.2 Page 199
clc
clear
Cs = 106 // micro F
C2 = 0.35 // micro F
R2 = 318 // ohms
R1 = 130 // ohms
w = 314
Cp = Cs*(R2/R1)
Rp = R1/(w^2*C2*Cs*10^-12*R2^2)
tang = 1/(w*Rp*Cp*10^-6)
printf (" Rp = %f ohm \n ",Rp)
printf (" Cp = %f   F  \n ",Cp)
printf (" tan     = %f \n ",tang)

//Answers may vary due to round off error
```

Scilab code Exa 6.3 Example 3

```
//Chapter 6,Example 6.3 Page 199
clc
clear
Cs = 500*10^-12 // F
R1 = 800 // ohm
R2 = 180 // ohm
C2 = 0.15 // micro F
w = 314
V = 33*10^3
Cp = Cs*(R2/R1)
Rp = R1/(w^2*C2*Cs*10^-6*R2^2)
```

```
tang = 1/(w*Rp*Cp)
pl = V^2/Rp
printf (" Rp = %e ohm \n ",Rp)
printf (" Cp = %e F \n ",Cp)
printf (" tan    = %f \n ",tang)
printf (" Power loss = %f watts \n ",pl)

//Answer may vary due to round off error
```

Scilab code Exa 6.4 Example 4

```
//Chapter 6,Example 6.4 Page 200
clc
clear
t = 60
C = 600*10^-12
V = 250
v = 92
R = t/(C*log(V/v))
printf (" R = %e ohm \n ",R)
```

Scilab code Exa 6.5 Example 5

```
//Chapter 6,Example 6.5 Page 200
clc
clear
Ca = 50 // pF
C = 190 // pF
loss = 0.0085 // loss angle of electrodes
Er = C/Ca
tang = 0.0085
Er1 = Er*tang
E0 = 8.854*10^-1
```

```
E1 = E0*Er
jE1 = E0*Er1
printf (" The dielectric constant = %f \n ",Er)
printf (" tan     = %f \n ",tang)
printf (" E = (%f - j %f ) * 10^-11 F/m \n ",E1,jE1)

//Answer may vary due to round off
```

Scilab code Exa 6.6 Example 6

```
//Chapter 6,Example 6.6 Page 201
clc
clear
w = 314
E0 = 8.854*10^-12
Er = 3.8
tang = 0.0085
E = 40*10^5
sigE = w*E0*Er*tang*E^2
printf ("   E ^2 = %f Watts/m^3\n ",sigE)

//Answers may vary due to round off
```

Scilab code Exa 6.7 Example 7

```
//Chapter 6,Example 6.7 Page 201
clc
clear
//Refer Fig Ex. 6.7
Er = 3.8
v = 21 // KV/cm
ind = v/Er // internal discharge in kV/cm
V = (ind*0.9)+(v*0.1)
```

```
printf (" Internal discharge = %f kV/cm\n ",ind)
printf (" V = %f kV rms\n ",V)

//Answer may vary due to round off error
```

Chapter 7

Transients in Power Systems and Insulation Coordination

Scilab code Exa 7.1 Example 1

```
//Chapter 7,Example 7.1 Page 221
clc
clear
//(i)The natural impedence of the line
d = 100
r = 0.75
E0 = 10^-9/36 //Epselon
L = 2*10^-7*log(d/r) // inductance per unit length
C = 2*E0/log(d/r) // capacitance per phase per unit
    length
NI = sqrt(L/C) // nautral impedence
printf ("(i) The natural impedence of the line \n")
printf (" The natural impedance = %f ohms \n\n",NI)
//(ii) the line current
V = 11000 // V
R = 1000
Z2= 1000
Z1 = 294
I = V/(sqrt(3)*NI) // the line current
```

```
printf ("(ii) The line current \n")
printf (" The line current = %f amps \n\n",I)
//(iii) the rate of power consumption
E1 = 2*V*R/(sqrt(3)*(Z1+Z2))
P = 3*E1^2*1000/R
printf ("(iii) The rate of power consumption \n")
printf (" The rate of power consumption = %f kW \n",P*10^-6)
E2 = ((Z2-Z1)/(Z2+Z1))*(11/sqrt(3))
Er = 3*(E2^2)*1000/Z1
printf (" The rate of reflected energy = %f kW \n\n",Er)
//(iv) the rate of reflected energy
printf ("(iv) The rate of reflected energy \n")
printf (" In order that the incident wave when reaches the terminating resistance, \n does not suffer reflection, the terminating resistance should be equal to \n the surge impedance of the line, i.e.%f ohms \n\n",NI)
//(v) The amount of reflected and transmitted power
printf ("(v) The amount of reflected and transmitted power \n")
L = 0.5*10^-8
C = 10^-12
SI = sqrt(L/C) // surge impedence of the cable
printf (" Surge impedence of the cable = %f ohm \n",SI)
ReffV = (2*SI/(Z1+SI))*(11/sqrt(3)) // refracted voltage
Rif = ((SI-Z1)/(Z1+SI))*(11/sqrt(3)) // reflected voltage
refP = 3*ReffV^2*1000/SI
rifp = 3*Rif^2*1000/Z1
printf (" Refracted powers = %f kW \n",refP) // refracted powers
printf (" Reflected powers = %f kW \n",rifp) // reflected powers
```

```
// Answers may vary due to round off error
```

Scilab code Exa 7.2 Example 2

```
//Chapter 7,Example 7.2 Page 222
clc
clear
Lc = 0.3*10^-3 // H
Cc= 0.4*10^-6 // F
Ll = 1.5*10^-3 // H
Cl = 0.012*10^-6 //F
V = 15 // kV
Ic = sqrt(Lc/Cc) // The natural impedence of the
    cable
Il = sqrt(Ll/Cl) // The natural impedence of the
    line
E = 2*Il*V/(Ic+Il)
printf ("The natural impedence of the cable = %f
    ohms \n",Ic) // unit failed to be mentioned
printf (" The natural impedence of the line = %f
    ohms \n",Il)
printf ("  E       = %f kV \n",E)

// Answers may vary due to round of error
```

Scilab code Exa 7.3 Example 3

```
//Chapter 7,Example 7.3 Page 223
clc
clear
E = 100
Z1 = 1/600 // 1/Z1
Z2 = 1/800 // 1/Z2
```

```
Z3 = 1/200 // 1/Z3
E11 = (2*E*Z1)/((Z1+Z2+Z3)*10^-3)
Iz2 = E11*1000*Z2
Iz3 = E11*1000*Z3
printf (" E'' = %f kV \n",E11*10^-3)
printf (" Iz2 = %f amps \n",Iz2*10^-3)
printf (" Iz3 = %f amps \n",Iz3*10^-3)

//Answers may vary due to round off error
```

Scilab code Exa 7.4 Example 4

```
//Chapter 7,Example 7.4 Page 226
clc
clear
E = 500
t = 2*10^-6
Z = 350
C = 3000
E1 = 2*E*(1-exp((-t*10^12)/(Z*C)))
printf (" E'' = %f kV \n",E1)

//Answers may vary due to round off error
```

Scilab code Exa 7.5 Example 5

```
//Chapter 7,Example 7.5 Page 226
clc
clear
E = 500
Z = 350
L = 800
E1 = E*(1-exp(-(2*Z/L)*2))
```

```
printf (" E'' = %f kV \n",E1)

//Answers may vary due to round off error
```

Scilab code Exa 7.6 Example 6

```
//Chapter 7,Example 7.6 Page 228
clc
clear
e0 = 50
x = 50
R = 6
Z = 400
v = 3*10^5
//(i)Value of the voltage wave when it has travelled
    through a distance of 50 km
pow = (-1/2)*(6/400)*50
e = e0*exp(pow)
//(ii)The power loss and the heat loss
PL = e^2*1000/Z // power loss
t = x/v
i0 = e0*1000/Z
HL = -x*i0*Z*(exp(-0.75)-1)/(R*v) // Heat loss
printf (" e = %f kV \n",e)
printf (" Power loss = %f kW \n",PL)
printf (" Heat loss = %f kJ \n",HL)

// Answers may vary due to round off error
```

Scilab code Exa 7.7 Example 7

```
//Chapter 7,Example 7.7 Page 213
clc
```

```
clear
//Based on equation 7.3, 7.5 and 7.7
v = 1/sqrt((4/36)*10^-9*10^-7)
printf (" v = %e meters/sec ",v)
```