Scilab Textbook Companion for Electronic and Electrical Measuring Instruments & Machines by Bakshi And Bakshi[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

Electronic Voltmeters

Scilab code Exa 1.1 calculate multiplier resistance

```
//Chapter-1,Example1_1,pg 1_17
Erms=10
Ep=sqrt(2)*Erms
Eav=0.6*Ep
E=Eav/2
Edc=0.45*Erms
Idc=1*10^-3
Rm=200
Rs=(Edc/Idc)-Rm
printf("required multiplier resistance")
printf("Rs=%.2f ohm \n",Rs )
```

Scilab code Exa 1.2 calculate multiplier resistance

```
//Chapter-1,Example1_2,pg 1_18
Eav=9
Erms=10
Rm=500
```

```
Idc=2*10^-3
Edc=0.9*Erms
Rs=(Edc/Idc)-Rm
printf("required multiplier resistance")
printf("Rs=%.2f ohm \n",Rs )
```

Scilab code Exa 1.3 calculate form factor and error

```
//Chapter-1,Example1_3,pg 1_20
Kf=1//Erms=Em for 1 time period
Kf1=1.11//Kf(sine)/Kf(square)
pere=(Kf-Kf1)/Kf*100//percentage error
printf("percentage error ")
printf("pere=%.2f ",pere)
```

Scilab code Exa 1.4 calculate percentage error

```
//Chapter-1,Example1_4,pg 1_20
A=50
T=2
function E=f(t),E=(50*t)^2,endfunction//e=At(ramp
    function)
exact=-2.5432596188;
I=intg(0,T,f)
abs(exact-I)
Erms=sqrt((1/T)*I)
function e=f1(t),e=50*t,//e=At(ramp function)
endfunction
exact=-2.5432596188;
I1=intg(0,T,f)
Eav=(1/T)*I1
Kf=Erms/Eav
kf1=0.961//Kf(sine)/Kf(sawtooth)
```

```
pere=(1-kf1)/1*100//percentage error
printf("percentage error ")
printf("pere=%.2f ",pere)
```

Scilab code Exa 1.5 calculate series resistance

```
//Chapter-1,Example1_5,pg 1_27
Idc=25*10^-3
Erms=200
Rm=100
Rf=500
Rd=2*Rf
Rm1=Rm+Rd//total meter resistance
Rs=(0.9*Erms)/Idc-Rm1
printf("total meter resistance")
printf("Rs=%.2f ohm",Rs)
```

Scilab code Exa 1.6 calculate meter current

```
//Chapter-1,Example1_6,pg 1_38
V1=2
Rm=50
Rd=15*10^3
gm=0.006
rd=100*10^3
Im=(gm*rd*Rd/(rd+Rd)*V1)/((2*(rd*Rd/(rd+Rd))+Rm))
printf("meter current")
printf("Im=%.4f A",Im)
```

Scilab code Exa 1.7 calibrate meter

```
//Chapter-1,Example1_7,pg 1_38
V1=1
Rm=50
Rd=15*10^3
gm=0.006
rd=100*10^3
Im=(gm*rd*Rd/(rd+Rd)*V1)/((2*(rd*Rd/(rd+Rd))+Rm))
printf("meter current")
printf("Im=%.4f A",Im)
```

Scilab code Exa 1.8 design FET voltmeter

```
//Chapter-1,Example1_8,pg 1_39
V1=1
Vin=30
Rin=9*10^6
R4=Rin/100//for Vin=100V
R3=(Rin-50*R4)/50//for Vin=50V
R2=(Rin-30*R3-30*R4)/30//for Vin=30V
R1=Rin-R2-R3-R4
printf("resitance values are\n")
printf("R1=%.2f ohm\n",R1)
printf("R2=%.2f ohm\n",R2)
printf("R3=%.2f ohm\n",R3)
printf("R4=%.2f ohm\n",R4)
```

Scilab code Exa 1.9 calculate series resistance

```
//Chapter-1,Example1_9,pg 1_40
rd=10*10^3
gm=0.003
rdf=rd/(1+gm*rd)//actual rd
Rs=15*10^3
```

```
V1=1//input voltage
Vo=(gm*rdf*Rs)*V1/(rdf+Rs)
Rth=(2*Rs*rdf/(Rs+rdf))
Rm=1800
Im=Vo/(Rth+Rm)
Img=0.1*10^-3//meter current given
Rf=(Vo/Img)-Rth-Rm//series resistance
printf("current Im=%.5f A\n",Im)
printf("seires resistance\n")
printf("Rf=%.2f ohm\n",Rf)
```

Scilab code Exa 1.10 find calibration resistance

```
//Chapter-1,Example1_10,pg 1_41
rd=200*10^3
gm=0.004
Rs=40*10^3
Rm=1000
V1=1
rdf=rd/(1+gm*rd)//actual rd
Rth=(2*Rs*rdf/(Rs+rdf))
Vo=(gm*rdf*Rs)*V1/(rdf+Rs)
Im=50*10^-6
Rcal=(Vo/Im)-Rth-Rm//caliberation resistance
printf("caliberation resistance\n")
printf("Rcal=%.2f ohm",Rcal)
```

Scilab code Exa 1.11 design FET voltmeter

```
//Chapter-1,Example1_11,pg 1_42
Vin=3
V1=1
Rin=1*10^6//input resistance of FET
```

```
R4=Rin/100//for Vin=100V
R3=(Rin-30*R4)/30//for Vin=30V
R2=(Rin-3*R3-3*R4)/3//for Vin=3V
R1=Rin-R2-R3-R4
printf("Resistances are\n")
printf("R1=%.2f ohm\n",R1)
printf("R2=%.2f ohm\n",R2)
printf("R3=%.2f ohm\n",R3)
printf("R4=%.2f ohm",R4)
```

Chapter 2

Digital To Analog Converters

Scilab code Exa 2.1 design 4 bit DAC

```

//Chapter-2,Example2_1,pg 2_9
Vr=10
n=4
Res=0.5//resolution
Rt=Vr/((2^n)*Res)
Rf=10*10^3
R=Rt*Rf
printf("input resistance\n")
printf("r=%.2f ohm\n",R)
printf("feedback resistance\n")
printf("Rf=%.f ohm",Rf)
```

Scilab code Exa 2.2 calculate resolution

```
//Chapter-2,Example2_2,pg 2_11
n=8
Res1=2^n
```

```
Vofs=2.55//full scale output voltage
Res2=Vofs/(Res1-1)
printf("resolution through method-1\n")
printf("Res1=%.2f \n",Res1)
printf("resolution through method-2\n")
printf("Res2=%.2f \n",Res2)
```

Scilab code Exa 2.3 calculate final output voltage

```
//Chapter-2,Example2_3,pg 2_12
n=4
Vofs=15
Res=Vofs/((2^n)-1)
D=bin2dec('0110')//decimal equivalent
Vo=Res*D
printf("output voltage\n")
printf("Vo=%.2f V",Vo)
```

Scilab code Exa 2.4 calculate full scale output

```
//Chapter-2,Example2_4,pg 2_12
Res=20*10^-3
n=8
Vofs=Res*((2^n)-1)
D=bin2dec('10000000')
Vo=Res*D
printf("output voltage\n")
printf("Vo=%.2f V\n",Vo)
printf("full scale output voltage\n")
printf("Vofs=%.2f V",Vofs)
```

Scilab code Exa 2.5 find step size and analog output

```
//Chapter-2,Example2_5,pg 2_12
n=4
Vofs=5
Res=Vofs/((2^n)-1)
D1=bin2dec('1000')
Vo1=Res*D1
D2=bin2dec('1111')
Vo2=Res*D2
printf("output voltage1\n")
printf("Vo1=%.2f V\n",Vo1)
printf("output voltage2\n")
printf("Vo2=%.2f V\n",Vo2)
```

Scilab code Exa 2.6 find output voltage

```
//Chapter-2,Example2_6,pg 2_13
n=12
Res=8*10^-3
Vofs=Res*((2^n)-1)
perR=Res/Vofs*100
Vo=Res*bin2dec('010101101101')
printf("percentage resolution\n")
printf("perR=%.2f \n",perR)
printf("output voltage\n")
printf("Vo=%.2f V",Vo)
```

Chapter 3

Analog To Digital Converters And Digital Voltmeters

Scilab code Exa 3.1 find resolution and digital output

```

//Chapter-3,Example3_1,pg 3_5
n=8
Res1=2^n
Vifs=5.1
Res2=Vifs/((2^n)-1)
Res=Res2*1000//in mv/LSB
Vi=1.28
D=Vi/Res2
str=dec2bin(64)
printf("Resolution\n")
printf("Res2=%.f mv/LSB\n",Res)
printf("digital output voltage \n")
printf("D=%.f LSBs\n",D)
```

Scilab code Exa 3.2 calculate quantisation error

```
//Chapter-3,Example3_2,pg 3_6
Vifs=4.095
n=12
Qe=Vifs/(((2^n)-1)*2)
printf("quantisation error\n")
printf("Qe=%.5f V",Qe)
```

Scilab code Exa 3.3 calculate time period

```
//Chapter-3,Example3_3,pg 3_10
V1=100*10^-3
Vr=100*10^-3
t1=83.33
t2=(V1/Vr)*t1
printf("t2=%.5f ms\n",t2)
Vi=200*10^-3//input voltage
t2=(Vi/Vr)*t1
printf("t2=%.5f ms",t2)
```

Scilab code Exa 3.4 find digital output

```
//Chapter-3,Example3_4,pg 3_10
fclk=12*10^3//clock frequency
t1=83.33*10^-3
V1=100*10^-3
Vr=100*10^-3
D=fclk*t1*(V1/Vr)
printf("digital output\n")
printf("D=%.f counts",D)
```

Scilab code Exa 3.5 find conversion time

```
//Chapter-3,Example3_5,pg 3_13
F=1*10^6
T=1/F
n=8
Tc=T*(n+1)
printf("converstion time\n")
printf("Tc=%.7f sec",Tc)
```

Scilab code Exa 3.6 find maximum input frequency

```
//Chapter-3,Example3_6,pg 3_15
Tc=9*10^-6
n=8
fmax=1/(2*%pi*Tc*(2^n))
printf("maximum input frequency\n")
printf("fmax=%.2f Hz",fmax)
```

Scilab code Exa 3.7 find resolution

```
//Chapter-3,Example3_7,pg 3_37
n=3//3 full digits
R=1/(10^n)
//for 1V range
Res1=1*R
//for 50V range
Res2=50*R
printf("least diffrence in readings for 50V range\n"
    )
printf("Res=%.2f V",Res2)
```

Scilab code Exa 3.8 find percentage error

```

//Chapter-3,Example3_8,pg 3_38
n=3
R=1/(10^n)
//for 10V range
R=R*10
err1=R//1-digit error
//reading is 5V
err=(0.5/100)*5//error due to reading
errt=err1+err//total error
printf("error when reading is 5V\n")
printf("errt=%.4f V\n",errt)
//reading is 0.1V
err=(0.5/100)*0.1//error due to reading
errt=err+err1//total error
errp=(errt/0.1)*100
printf("percent error when reading is 0.1V\n")
printf("errp=%.1f ",errp)
```

Scilab code Exa 3.9 find senstivity of meter

```
//Chapter-3,Example3_9,pg 3_38
n=4
fsmin=10*10^-3//full scale value on min. range
R=1/(10^n)
S=fsmin*R
printf("senstivity of meter\n ")
printf("s=%.7f",S)
```

Scilab code Exa 3.10 find resolution and display voltage

```
//Chapter-3,Example3_10,pg 3_39
n=4
R=1/(10^n)
//for 10V range
R=10*R
printf("12.98 would be displayed as 12.980 for 10V
    range\n")
//for 1V range
R=1*R
printf("0.6973 would be displayed as 0.6973 for 1V
    range\n")
//for 10V range
printf("0.6973 would be displayed as 0.697 for 10V
    range\n")
```

Chapter 4

Frequency Meters And Phase Meters

Scilab code Exa 4.1 plot graph between phase voltage and output

```

//Chapter-4,Example4_1,pg 4-22
E1mag=[0 3 5 7 9 12 15 18 21]
E1rms=E1mag/sqrt(2)
Erms=5//given
Einrms=(((E1rms)^2)+((Erms)^2))^(1/2)
Eab=(2*sqrt(2).*Einrms)/%pi
xlabel('E1(Volts)','fontsize',5)
ylabel('Eab(Volts)','fontsize',5)
title('Phase Meter','fontsize',5)
printf("E1 mag    E1 rms    Ein Rms    Eab output")
k=[0    0    5    4.501;
   3    2.121    5.431    4.889;
   5    3.53    6.123    5.513;
   7    4.949    7.035    6.334;
   9    6.363    8.093    7.286;
   12    8.485    9.848    8.867;
   15    10.606    11.726    10.557;
   18    12.727    13.674    12.311;
```

```
    21      14.849     15.668     14.106   ]
disp(k)
plot(E1mag,Eab)
```

Scilab code Exa 4.2 calculate output voltage

```
//Chapter-4,Example4_2,pg 4-24
E1rms=10
E2rms=15
E1m=E1rms*sqrt(2)
E2m=E2rms*sqrt(2)
//voltage across AB is proportional to E1+E2 in
    positive half cycle
Ep=(1/(2*%pi))*(2*E1m+E2m)//output in positive half
    cycle
//voltage across AB is proportional to E1-E2 in
    negative half cycle
En=(1/(2*%pi))*(2*E1m-E2m)//output in negative half
    cycle
Eab=Ep-En
printf("output voltage\n")
printf("Eab=%.2f V",Eab)
```

Chapter 6

Oscilloscopes

Scilab code Exa 6.1 calculate bandwidth of CRO

```
//Chapter-6,Example6_1,pg 6-26
Trs=17*10^-6
Trd=21*10^-6
Tro=sqrt((Trd^2)-(Trs^2))
BW=0.35/Tro
printf("bandwidth of CRO\n")
printf("BW=%.2f Hz",BW)
```

Scilab code Exa 6.2 find minimum rise time of plulse

```
//Chapter-6,Example6_2,pg 6-53
SR=200*10^6//sampling rate
trmin=1/SR
printf("minimum rise time of pulse\n")
printf("trmin=%.10f s",trmin)
```

Scilab code Exa 6.3 calculate amplitude and rms value

```
//Chapter-6,Example6_3,pg 6-63
//from plot 1 subdivision=0.2 units
pp=2+3*0.2//positive peak
np=2+3*0.2//negative peak
Nd=pp+np//no. of divisions
Vd=2*10^-3//volts per division
Vpp=Nd*Vd
Vm=Vpp/2
Vrms=Vm/sqrt(2)
printf("peak value of voltage\n")
printf("Vm=%.4f V\n",Vm)
printf("RMS value of voltage\n")
printf("Vrms=%.4f V\n",Vrms)
```

Scilab code Exa 6.4 calculate frequency and rms value

```
//Chapter-6,Example6_4,pg 6-64
Vd=2
Tb=2*10^-3//time base
Vd=2
Nd=3
Vpp=Nd*Vd
Vm=Vpp/2
Vrms=Vm/sqrt(2)
Hd=2//horizontal occupancy
T=Tb*Hd
f=1/T
printf("RMS value of voltage\n")
printf("Vrms=%.2f V\n",Vrms)
printf("frequency of voltage across resistor\n")
printf("f=%.2f Hz",f)
```

Scilab code Exa 6.5 find phase difference between two waves

```
//Chapter-6,Example6_5,pg 6-67
y1=8
y2=10
phi=asin(y1/y2)//phase difference
phi=phi*(180/%pi)
printf("phase difference\n")
printf("phi=%.2f deg",phi)
```

Scilab code Exa 6.6 find frequency at vertical plate

```
//Chapter-6,Example6_6,pg 6-69
Nv=2
Nh=5
fh=1*10^3
fv=(5/2)*fh//(fv/fh)=(Nh/Nv)=(5/2)
printf("vertical signal frequency\n")
printf("fv=%.f Hz",fv)
```

Chapter 7

Basic Measuring Instruments

Scilab code Exa 7.1 calculate deflection

```
//Chapter-7,Example7_1,pg 7-13
N=100
B=0.15
A=10*8*10^-6
I=5*10^-3
Td=N*B*A*I//deflecting torque
K=0.2*10^-6//spring const.
theta=Td/K//deflecting angle
printf("deflection theta=%.2f deg",theta)
```

Scilab code Exa 7.2 find deflection

```
//Chapter-7,Example7_2,pg 7-21
x=poly(0,"x")
L=(12+6*x-(x^2))//x is deflection in rad from zero
dl=derivat(L)
K=12
I=8
```

```
x=6/(((2*K)/(I^2))+2)//x=((I^2)dl)/(2*k)
z=x*(180/%pi)
y=horner(L,x)
printf("deflection for given current\n")
printf("x=%.2f deg\n",z)
printf("inductance for given deflection\n")
printf("L=%.2f uH",y)
```

Scilab code Exa 7.3 calculate value of shunt resistance

```
//Chapter-7,Example7_3,pg 7-23
Rm=100
Im=2*10^-3
I=150*10^-3
Rsh=(Im*Rm)/(I-Im)
printf("value of shunt resistance\n")
printf("Rsh=%.2f ohm",Rsh)
```

Scilab code Exa 7.4 calculate shunt current and meter resistance

```
//Chapter-7,Example7_4,pg 7-23
Vsh1=400*10^-3
Rsh=0.01
Ish=Vsh1/Rsh
printf("current through shunt\n")
printf("Ish=%.2f A\n",Ish)
Ish=50
Vsh=Ish*Rsh
printf("voltage through shunt\n")
printf("Ish=%.2f V\n",Vsh)
Rm=750//coil resistance
Im=Vsh1/Rm
Rm1=Vsh/Im//meter resistance
```

```
printf("meter resistance\n")
printf("Rm1=%.2f ohm\n",Rm1)
```

Scilab code Exa 7.5 design multirange dc milliammeter

```
//Chapter-7,Example7_5,pg 7-25
I1=10*10^-3
Im=2*10^-3
Rm=75
R1=(Im*Rm)/(I1-Im)
I2=50*10^-3
R2=(Im*Rm)/(I2-Im)
I3=100*10^-3
R3=(Im*Rm)/(I3-Im)
printf("designed multi-range ammeter\n")
printf("full scale deflection Im=%.5f A\n",Im)
printf("meter resistance Rm=%.2f ohm\n",Rm)
printf("R1=%.2f ohm\n",R1)
printf("R2=%.2f ohm\n",R2)
printf("R3=%.2f ohm\n",R3)
```

Scilab code Exa 7.6 design aryton shunt

```
//Chapter-7,Example7_6,pg 7-27
I1=10
Im=1*10^-3
Rm=50
//in position-1 R1 is in shunt with R2+R3+Rm
//R1=10^-4(R2+R3+50)......(1)
//in position-2 (R1+R2) is in shunt with R3+Rm
//R1+R2=2*10^-4(R3+50).....(2)
//in position-3 R1+R2+R3 is in shunt with Rm
//R1+R2+R3=0.05............(3)
```

```
//from.....(3)
//R1+R2=0.05−R3
//substituting in........(2)
R3=0.04/1.0002
//R2=0.01−R1........(4)
//substituing in (1)
R1=5.00139*10^-3/1.0001
R2=0.01-R1//from........(4)
printf("various sections of aryton shunt are\n")
printf("full scale deflection Im=%.4f A\n",Im)
printf("meter resistance Rm=%.2f ohm\n",Rm)
printf("R1=%.4f ohm\n",R1)
printf("R2=%.4f ohm\n",R2)
printf("R3=%.4f ohm\n",R3)
```

Scilab code Exa 7.7 calculate multiplier resistance

```
//Chapter−7,Example7_7,pg 7−30
Rm=500
Im=40*10^-6
V=10
Rs=(V/Im)-Rm
printf("multiplier resistance\n")
printf("Rs=%.2f ohm",Rs)
```

Scilab code Exa 7.8 calculate shunt and multiplier resistance

```
//Chapter−7,Example7_8,pg 7−30
Im=20*10^-3
Vm=200*10^-3
Rm=(Vm/Im)
I=200
Rsh=(Im*Rm)/(I-Im)
```

```
printf("required shunt resistance\n")
printf("Rsh=%.4f ohm\n",Rsh)
V=500
Rs=(V/Im)-Rm
printf("required multipler resistance\n")
printf("Rs=%.2f ohm",Rs)
```

Scilab code Exa 7.9 design D arsonoval movement voltmeter

```
//Chapter-7,Example7_9,pg 7-33
Rm=50
Im=2*10^-3
//for position V4 multipler is R4
V4=10
R4=(V4/Im)-Rm//Rs=(V/Im)-RmV3 m
//for position V3 multipler is R3+R4
V3=50
R3=(V3/Im)-Rm-R4
//for position V2 multiplier is R2+R3+R4
V2=100
R2=(V2/Im)-Rm-R3-R4
//for position V1 multiplier is R1+R2+R3+R4
V1=500
R1=(V1/Im)-Rm-R3-R4-R2
printf("series string of multipliers\n")
printf("R1=%.2f ohm\n",R1)
printf("R2=%.2f ohm\n",R2)
printf("R3=%.2f ohm\n",R3)
printf("R4=%.2f ohm\n",R4)
```

Scilab code Exa 7.10 senstivity method design

```
//Chapter-7,Example7_10,pg 7-35
```

```
Rm=50
Im=2*10^-3
V1=500
V2=100
V3=50
V4=10
S=1/Im//senstivity
R4=S*V4-Rm
R3=S*V3-(R4+Rm)
R2=S*V2-(R4+Rm+R3)
R1=S*V1-(R4+Rm+R3+R2)
printf("series string of multipliers\n")
printf("R1=%.2f ohm\n",R1)
printf("R2=%.2f ohm\n",R2)
printf("R3=%.2f ohm\n",R3)
printf("R4=%.2f ohm\n",R4)
```

Scilab code Exa 7.11 find multiplier resistance

```
//Chapter-7,Example7_11,pg 7-36
Im=50*10^-6
S=1/Im
Rm=200
V=500//V is voltage range
Rs=S*V-Rm
printf("multipler resistance\n")
printf("Rs=%.2f ohm",Rs)
```

Scilab code Exa 7.12 sensitivity of meter comparison

```

//Chapter-7,Example7_12,pg 7-36
//for meter A
```

```
Rs=25*10^3
Rm=1*10^3
V=100
S=(Rs+Rm)/V
printf("senstivity of meter A\n")
printf("S=%.2f ohm/volt\n",S)
//for meter B
Rs=150*10^3
Rm=1*10^3
V=1000
S=(Rs+Rm)/V
printf("senstivity of meter B\n")
printf("S=%.2f ohm/volt",S)
```

Scilab code Exa 7.13 accuracy of meter comparison

```
//Chapter-7,Example7_13,pg 7-37
R1=20*10^3
R2=25*10^3
V=250//voltage supply
VR2=R2*V/(R1+R2)//voltage across R2
//case-1
S=500
Vr=150//voltage range of resistor
Rv=S*Vr
Req=R2*Rv/(R2+Rv)
VReq=Req*V/(Req+R1)//voltage across Req
printf("first voltmeter reading\n")
printf("VReq=%.2f V\n",VReq)
//case-2
S=10*10^3
Rv=S*Vr
Req=R2*Rv/(R2+Rv)
VReq=Req*V/(Req+R1)
printf("second voltmeter reading\n")
```

```
printf("VReq=%.2f  V",VReq)
```

Scilab code Exa 7.14 error and accuracy measurement

```
//Chapter-7,Example7_14,pg 7-38
Rb=1*10^3
Ra=5*10^3
V=25
VRb=Rb*V/(Ra+Rb)//voltage across Rb
Vr=5
//case-1
S=1*10^3
Rv=S*Vr
Req=Rb*Rv/(Rb+Rv)
VReq=Req*V/(Req+Ra)
err=(VRb-VReq)*100/VRb
acc=100-err
printf("voltmeter reading case-1\n")
printf("VReq=%.2f  V\n",VReq)
printf("percentage error\n")
printf("err=%.2f  \n",err)
printf("percentage accuracy\n")
printf("acc=%.2f\n",acc)
//case-2
S=20*10^3
Rv=S*Vr
Req=Rb*Rv/(Rb+Rv)
VReq=Req*V/(Req+Ra)
err=(VRb-VReq)*100/VRb
acc=100-err
printf("voltmeter reading case-2\n")
printf("VReq=%.2f  V\n",VReq)
printf("percentage error\n")
printf("err=%.2f  \n",err)
printf("percentage accuracy\n")
```

```
printf("acc=%.2f\n",acc)
```

Scilab code Exa 7.15 basic PMMC measurement

```
//Chapter-7,Example7_15,pg 7-41
Rm=50
Im=20*10^-3
I=10
Rsh=(Im*Rm)/(I-Im)
printf("shunt resistance for I=10A\n")
printf("Rsh=%.2f ohm\n",Rsh)
I=20
Rsh=(Im*Rm)/(I-Im)
printf("shunt resistance for I=20A\n")
printf("Rsh=%.2f ohm\n",Rsh)
V=150
Rs=(V/Im)-Rm
printf("series resistance for V=150V\n")
printf("Rs=%.2f ohm\n",Rs)
V=300
Rs=(V/Im)-Rm
printf("series resistance for V=300V\n")
printf("Rs=%.2f ohm",Rs)
```

Scilab code Exa 7.16 find shunt current and resistance for fsd

```
//Chapter-7,Example7_16,pg 7-42
Rsh=0.02
R=1000
Vm=500*10^-3
Im=Vm/R
Ish=Vm/Rsh
printf("shunt current\n")
```

```
printf("Ish=%.2f A\n",Ish)
Ish1=10
V=Ish1*Rsh
R=V/Im
printf("resistance for Ish=10A\n")
printf("R=%.2f ohm\n",R)
Ish2=75
V=Ish2*Rsh
R=V/Im
printf("resistance for Ish=75A\n")
printf("R=%.2f ohm\n",R)
```

Scilab code Exa 7.17 determine inductance of instrument

```
//Chapter-7,Example7_17,pg 7-50
K=5.73*10^-6
I=20
theta=110*(%pi/180)//full scale deflection
dtheta=theta//change in theta
L=4*10^-6
dm=(theta*K/(I^2))*dtheta//change in inductance
Lf=L+dm
printf("final inductance\n")
printf("Lf=%.8f H",Lf)
```

Scilab code Exa 7.18 find deflecting torque

```
//Chapter-7,Example7_18,pg 7-50
x=30//deflection
dM=5*sin((x+45)*(%pi/180))*10^-3//diffrentiate M w.r.t x
I=10*10^-3
Td=(I^2)*dM//deflecting torque
```

```
printf("deflecting torque\n")
printf("Td=%.8f Nm",Td)
```

Scilab code Exa 7.19 difference between dc and ac readings of voltmeter

```
//Chapter-7,Example7_19,pg 7-51
I=100*10^-3
Td=0.8*10^-4
dtheta=90*%pi/180//in radians
theta=90//deflection
dM=Td*dtheta/(I^2)
Mo=0.5//original M
M=Mo+dM//total M
//case-1
Vdc=100
R=Vdc/I
w=2*%pi*50
Z=R+(%i*w*M)
Z=abs(Z)
Vac=R*Vdc/Z
dif=Vdc-Vac//difference between readings
//case-2
Vdc1=50
I1=Vdc1/R
theta1=theta*((I1/I)^2)//theta=kI^2
theta1=theta1*%pi/180//in radians
dM1=Td*theta1/(I^2)
M1=dM1+Mo
Z1=R+(%i*w*M1)
Z1=abs(Z1)
Vac1=R*Vdc1/Z1
dif1=Vdc1-Vac1
printf("difference in readings Vdc=100V\n")
printf("dif=%.2f V\n",dif)
printf("difference in readings Vdc=50V\n")
```

```
printf("dif1=%.2f V\n",dif1)
```

Scilab code Exa 7.20 find revolutions and percentage error

```
//Chapter-7,Example7_20,pg 7-65
I=20
V=230
Pf=0.8//power factor
t=3600
K=100
Et=V*I*Pf*t
Et=Et/(3600*10^3)//in kWh
N=360
Er=3.6//in kWh
err=(Er-Et)/Et
err=err*100
printf("percentage error\n")
printf("err=%.2f\n",err)
printf("negative sign shows that meter is slow and
   Er<Et")
```

Scilab code Exa 7.21 determine meter errror at half load

```
//Chapter-7,Example7_21,pg 7-65
K=1800
V=230
I=10
Pf=1//half load
Ihl=I/2//half load current
t=138
Et=V*Ihl*Pf*t
Et=Et/(3600*10^3)
N=80//no. of revolutions
```

```
Er=N/K//in kWh
err=(Er-Et)/Et
err=err*100
printf("percentage error\n")
printf("err=%.2f\n",err)
printf("positive sign shows that meter is fast and
   Er>Et")
```

Scilab code Exa 7.22 calculate power factor of load

```
//Chapter-7,Example7_22,pg 7-66
V=230
I=4
t=6
Pf=1
N=2208
Et=V*I*Pf*t
K=N/Et
printf("meter constant\n")
printf("K=%.2f rev/Wh\n",K)
V=230
I=5
t=4
N=1472
Et=V*I*Pf*t
Er=N/K
Pf=(Er/Et)
printf("power factor\n")
printf("Pf=%.2f lagging",Pf)
```

Scilab code Exa 7.23 find speed of disc and error of meter

```
//Chapter-7,Example7_23,pg 7-66
```

```
I=5
V=220
Pf=1
K=3275
t=1/60//in hr
E=V*I*Pf*t
E=E/10^3//in kWh
Rev=E*K//no. of revolutions
printf("speed of disc\n")
printf("s=%.2f r.p.m\n",Rev)
//at half load
I=I/2
t=59.5
Et=V*I*Pf*t
Et=Et/(3600*10^3)//in kWh
N=30
Er=N/K
err=(Er-Et)/Et
err=err*100
printf("percentage error\n")
printf("err=%.2f\n",err)
printf("Er>Et meter is fast")
```

Scilab code Exa 7.24 find error at given power factor

```
//Chapter-7,Example7_24,pg 7-67
V=240
I=10
Pf=0.8
t=1/60
K=600
E=V*I*Pf*t
E=E/10^3//in kWh
Rev=E*K//no. of revolutions
printf("speed of disc\n")
```

```
printf("s=%.2f r.p.m\n",Rev)
del=90//for correct lag adjustment
del1=86*%pi/180//given in radian
phi=0//case-1 unity power factor
err=(sin(del1-phi)-cos(phi))/cos(phi)
err=err*100
printf("percentage error in case-1\n")
printf("err=%.2f \n",err)
Pf=0.5//case-2
phi=60*%pi/180//in radians
err=(sin(del1-phi)-cos(phi))/cos(phi)
err=err*100
printf("percentage error in case-2\n")
printf("err=%.2f \n",err)
```

Scilab code Exa 7.25 limits of error of wattmeter

```
//Chapter-7,Example7_25,pg 7-67
V=240
I=5
K=1200
N=40
Er=N/K
W=V*I
t=99.8
Td=500//total divisions
div=K/Td//1 division
We=0.1*div//wattmeter error
Ce=0.05*K/100//construction wattmeter error
Te=We+Ce//total error
Wru=K+Te
Wrl=K-Te//wattmeter reading limits
He=0.05//human error
Se=0.01//stopwatch error
Tte=He+Se//total timing error
```

```
Sru=t+Tte//stopwatch reading limits
Srl=t-Tte
Eu=Wru*Sru*1/(3600*10^3)//energy obtained limits
El=Wrl*Srl*1/(3600*10^3)
errl=(Er-El)/El
errl=errl*100
erru=(Er-Eu)/Eu//error limits
erru=erru*100
printf("percentage error upperlimt\n")
printf("erru=%.3f \n",erru)
printf("percentage error lowerlimt\n")
printf("errl=%.3f \n",errl)
```

Scilab code Exa 7.26 estimate line current

```
//Chapter-7,Example7_26,pg 7-79
I1=250
I2=5
I=I1/I2
//as ammeter is in secondary I2=2.7
I1=I*2.7//line current
printf("line current\n")
printf("I1=%.2f A",I1)
```

Scilab code Exa 7.27 estimate line voltage

```
//Chapter-7,Example7_27,pg 7-82
V1=11000
V2=110
V=V1/V2
V2=87.5
V1=87.5*V//line voltage
printf("line voltage\n")
```

```
printf("V1=%.2f V",V1)
```

Scilab code Exa 7.28 find percentage ratio error

```
//Chapter-7,Example7_28,pg 7-88
Im=120
Ic=38
Kn=1000/5
//at full load
Is=5
Ns=1000
Np=5
n=Ns/Np//turns ratio
R=n+(Ic/Is)
err=(Kn-R)/R//ratio error
err=err*100
printf("percentage ratio error\n")
printf("err=%.2f ",err)
```

Scilab code Exa 7.29 calculate actual primary current and ratio error

```
//Chapter-7,Example7_29,pg 7-88
Im=90
Ic=40
delta=28*(%pi/180)//in radians
Is=5
Ns=400
Np=1
n=Ns/Np
Kn=n
R=n+((Im*sin(delta)+Ic*cos(delta))/Is)
Ip=R*Is//actual primary current
err=(Kn-R)/R
```

```
err=err*100
printf("percentage ratio error\n")
printf("err=%.2f ",err)
```

Chapter 8

Measurement Of Resistance Capacitance And Inductance

Scilab code Exa 8.1 calculate R1 and R2 of ohmmeter

```
//Chapter-8,Example8_1,pg 8_6
Rh=1000
Rm=50
V=3
Ifsd=1*10^-3
R1=Rh-(Ifsd*Rm*Rh)/V
R2=(Ifsd*Rm*Rh)/(V-Ifsd*Rh)
printf("R1=%.2f ohm\n",R1)
printf("R2=%.2f ohm\n",R2)
//due to 5% voltage drop
V=V-0.05*V
R2=(Ifsd*Rm*Rh)/(V-Ifsd*Rh)
printf("change in value R2 \n")
printf("R2=%.2f ohm",R2)
```

Scilab code Exa 8.2 find unknown resistance

```
//Chapter-8,Example8_2,pg 8_18
R1=10*10^3
R2=2*10^3
R3=5*10^3
//R4=Rx
R4=(R1*R3)/R2
printf("unknown resistance\n")
printf("R4=%.2f ohm",R4)
```

Scilab code Exa 8.3 find current through galvanometer

```
//Chapter-8,Example8_3,pg 8_18
R1=7*10^3
R2=2*10^3
R3=4*10^3
R4=20*10^3
E=8
Rg=300
Vth=(E*R4/(R3+R4))-(E*R1 /(R1+R2))//voltage divider
   rule
Req=(R1*R2/(R1+R2))+(R3*R4/(R3+R4))
Ig=Vth/(Req+Rg)
printf("current through galvanometer\n")
printf("Ig=%.7f A",Ig)
```

Scilab code Exa 8.4 find unknown resisance

```
//Chapter-8,Example8_4,pg 8_25
R3=100.03*10^-6
R2=100.24
R1=200
b=100.31
a=200
```

```
Ry=700*10^-6
Rx=R1*R3/R2
Rx=Rx+(b*Ry/(Ry+a+b))*((R1/R2)-(a/b))
printf("unknown resistance\n")
printf("Rx=%.7f ohm",Rx)
```

Scilab code Exa 8.5 find constants of unknown impedance

```
//Chapter-8,Example8_5,pg 8_35
Z2=250
Z3=200
Z1=50
Z4=Z2*Z3/Z1//magnitude condition
theta1=80
theta2=0
theta3=30
theta4=theta2+theta3-theta1//angle condition
theta4=theta4*%pi/180//in radians
Rx=Z4*cos(theta4)//real part
Ry=Z4*sin(theta4)//imag. part
Z4=Rx+%i*Ry
printf("unknown impedance\n")
disp(Z4)
```

Scilab code Exa 8.6 determine balance of bridge

```
//Chapter-8,Example8_6,pg 8_35
Z1=sqrt(((50*cos(40*%pi/180))^2)+(50*sin(40*%pi/180)
    )^2)//angle in radians
Z2=sqrt(((100*cos(-90*%pi/180))^2)+(100*sin(-90*%pi
    /180))^2)
Z3=sqrt(((15*cos(45*%pi/180))^2)+(15*sin(45*%pi/180)
    )^2)
```

```
Z4=sqrt(((30*cos(30*%pi/180))^2)+(30*sin(30*%pi/180))^2)
//mag(Z1*Z4)=mag(Z2*Z3)....magnitude condition
magl=Z1*Z4//lhs
magr=Z2*Z3//rhs
printf("magl=%.f\n",magl)
printf("magr=%.f\n",magr)
printf("lhs=rhs hence,magnitude condition is satisfied \n")
theta1=40
theta2=-90
theta3=45
theta4=30
//theta1+theta4=theta2+theta3.......angle condition
thetal=theta1+theta4//lhs
thetar=theta2+theta3//rhs
printf("thetal=%.f\n",thetal)
printf("thetar=%.f\n",thetar)
printf("angle condition is not satisfied \n")
```

Scilab code Exa 8.7 find equivalent series circuit

```
//Chapter-8,Example8_7,pg 8_37
C3=10*10^-6
R1=1.2*10^3
R2=100*10^3
R3=120*10^3
Rx=R2*R3/R1
Cx=R1*C3/R2
printf("equivalent series circuit\n")
printf("Rx=%.f ohm\n",Rx)
printf("Cx=%.9f F",Cx)
```

Scilab code Exa 8.8 find equivalent series circuit

```
//Chapter-8,Example8_8,pg 8_39
L3=8*10^-3
R1=1*10^3
R2=25*10^3
R3=50*10^3
Rx=R2*R3/R1
Lx=R2*L3/R1
printf("equivalent series circuit\n")
printf("Rx=%.f ohm\n",Rx)
printf("Lx=%.5f H",Lx)
```

Scilab code Exa 8.9 find components of branch BC

```
//Chapter-8,Example8_9,pg 8_44
//from the bridge
C1=0.5*10^-6
R1=1200
R2=700
R3=300
Rx=R2*R3/R1
Lx=R2*R3*C1
printf("components of branch RC\n")
printf("Rx=%.f ohm\n",Rx)
printf("Lx=%.5f H\n",Lx)
```

Scilab code Exa 8.10 find constants of unknown impedance

```
//Chapter-8,Example8_10,pg 8_49
//from hay's balance bridge
w=1000
R1=5.1*10^3
```

```
C1=2*10^-6
R2=7.9*10^3
R3=790
Rx=((w^2)*R1*(C1^2)*R2*R3)/(1+((w^2)*(R1^2)*(C1^2)))
Lx=R2*R3*C1/(1+((w^2)*(R1^2)*(C1^2)))
printf("unknown inductance and resistance\n")
printf("Rx=%.f ohm\n",Rx)
printf("Lx=%.5f H",Lx)
```

Scilab code Exa 8.11 calculate unknown capacitance and dissipation factor

```
//Chapter-8,Example8_11,pg 8_56
R1=1.2*10^3
R2=4.7*10^3
C1=1*10^-6
C3=1*10^-6
f=0.5*10^3
w=2*%pi*f
Rx=R2*C1/C3
Cx=R1*C3/R2
D=w*Cx*Rx
printf("unknown capacitance and resistance\n")
printf("Rx=%.f ohm\n",Rx)
printf("Cx=%.8f F\n",Cx)
printf("dissipation factor\n")
printf("D=%.3f",D)
```

Scilab code Exa 8.12 find deflection of galvanometer

```
//Chapter-8,Example8_12,pg 58
R1=200
R2=100
```

```
R3=1000
R4=2000
Rg=200
R41=2005//changed by delR
Si=12//senstivity
E=10
Vth=E*((R41/(R3+R41))-(R1/(R1+R2)))
Req=(R1*R2/(R1+R2))+(R3*R41/(R3+R41))
Ig=Vth/(Rg+Req)
theta=Si*Ig*10^6//deflection of galvanometer(mm)
printf("deflection of galvanometer\n")
printf("theta=%.4f mm",theta)
```

Scilab code Exa 8.13 find deflection of galvanometer

```
//Chapter-8,Example8_13,pg 59
R1=1000
R2=1000
R3=119
R4=121
Rg=200
S1=1
E=5
Vth=E*((R4/(R3+R4))-(R1/(R1+R2)))
Req=(R1*R2/(R1+R2))+(R3*R4/(R3+R4))
Ig=Vth/(Rg+Req)
theta=S1*Ig*10^6//deflection of galvanometer(mm)
printf("deflection of galvanometer\n")
printf("theta=%.4f mm",theta)
```

Scilab code Exa 8.14 find current through galanometer

```
//Chapter-8,Example8_14,pg 59
```

```
R=500
delR=20
E=10
Vth=E*delR/(4*R)
Req=R
Rg=125
Ig=Vth/(Req+Rg)
printf("current through galvanometer\n")
printf("Ig=%.8f A",Ig)
```

Scilab code Exa 8.15 calculate smallest change in resistance

```
//Chapter-8,Example8_15,pg 60
R=1000
E=20
Ig=1*10^-9
Req=R
//Ig=Vth/Req......Rg=0
delR=Ig*4*R^2/E
printf("change in resitance\n")
printf("delR=%.8f ohm",delR)
```

Scilab code Exa 8.16 calculate balance temperature and error

```
//Chapter-8,Example8_16,pg 61
//R4=Rv
R1=10*10^3
R2=10*10^3
R3=10*10^3
R4=R1*R3/R2
E=10
printf("bridge is balanced at 80deg. from graph when
    Rv=10k\n")
```

```
//at 60deg bridge is unbalanced
R4=9*10^3//from graph
e=E*((R4/(R3+R4))-(R1/(R1+R2)))//thevenin's voltage
printf("error voltage\n")
printf("e=%.4f V\n",e)
printf("negative sign indicates opposite polarity of
    error voltage")
```

Scilab code Exa 8.17 find value of unknown resistance

```
//Chapter-8,Example8_17,pg 8_62
R1=100
R2=10
R3=4
R4=50
E=10
Rg=20
Vth=E*((R4/(R3+R4))-(R1/(R1+R2)))
Req=(R1*R2/(R1+R2))+(R3*R4/(R3+R4))
Ig=Vth/(Rg+Req)
//for null deflection
R4=R3*R1/R2
printf("unbalanced current in galvanometer\n")
printf("Ig=%.5f A\n",Ig)
printf("resistance for null deflection\n")
printf("R4=%.f ohm",R4)
```

Scilab code Exa 8.18 find unknown resisance and unbalance in bridge

```
//Chapter-8,Example8_18,pg 8_62
R1=1000
R2=100
R3=4*10^3
```

```
R4=40*10^3
Rth=(R1*R2/(R1+R2))+(R3*R4/(R3+R4))
Si=70
theta=3*10^-6//deflection
E=10
Rg=80
delR=(theta*(Rth+Rg)*((R3+R4)^2))/(Si*E*R3)
printf("change in resistance\n")
printf("delR=%.4f ohm",delR)
```

Scilab code Exa 8.19 find series resistance

```
//Chapter-8,Example8_19,pg 8_63
P=0.4
Rarm=150//resistance in each arm
I=sqrt(P/Rarm)//P=(I^2)*R
//applying KVL to loop ABCEFA
r=1
E=25
R=(-I*Rarm-I*Rarm+E-2*I*r)/(2*I)
printf("series resistance\n")
printf("R=%.4f ohm",R)
```

Scilab code Exa 8.20 find unknown resisance Rx

```
//Chapter-8,Example8_20,pg 8_63
R1=10
R2=R1/0.5//given
Rba=1/1200//Rb/Ra
Rx=R2*Rba
printf("unknown resistance\n")
printf("Rx=%.4f ohm",Rx)
```

Scilab code Exa 8.21 find constants of arm CD

```
//Chapter-8,Example8_21,pg 8_64
w=2*%pi*1000
C1=0.2*10^-6
R2=500
R3=300
C3=0.1*10^-6
Z4=(%i*w*C1*R2)/((1/R3)+(%i*w*C3))//from basic
    balance equaton
Zx=Z4//unknown impedance
Rx=real(Zx)
Xl=imag(Zx)
Lx=Xl/w//Xl=w*Lx
printf("unknown resistance\n")
printf("Rx=%.2f ohm\n",Rx)
printf("unknown inductance\n")
printf("Lx=%.5f H",Lx)
```

Scilab code Exa 8.22 find constants of Zx

```
//Chapter-8,Example8_22,pg 8_67
Z1=300
R2=200
w=2*%pi*10^3
C2=5*10^-6
Z2=R2-%i*(1/(w*C2))
R3=500
C3=0.2*10^-6
Z3=R3-%i*(1/(w*C3))
Z4=Z2*Z3/Z1//balance equation
Zx=Z4
```

```
printf("unknown impedance\n")
disp(Zx)
```

Scilab code Exa 8.23 find unknown impedance

```
//Chapter-8,Example8_23,pg 8_67
Z1=10*10^3
Z2=50*10^3
w=2*%pi*2*10^3
C3=100*10^-6
R3=100*10^3
Z3=R3-%i*(1/(w*C3))
Z4=Z2*Z3/Z1
Zx=Z4
Rx=real(Zx)
Xc=-imag(Zx)
Cx=1/(Xc*w)
printf("unknown resistance\n")
printf("Rx=%.f ohm\n",Rx)
printf("unknown capacitance\n")
printf("Cx=%.8f F",Cx)
```

Scilab code Exa 8.24 find unknown impedance and dissipation factor

```
//Chapter-8,Example8_24,pg 8_68
R2=4.8
r2=0.4
w=2*%pi*450
C2=0.5*10^-6
Z2=R2+r2-%i*(1/(w*C2))
Z3=200
Z4=2850
//I1*Z1=I2*Z2........null deflection detector
```

```
Z1=Z2*Z3/Z4
R1=real(Z1)
Xc1=-imag(Z1)
C1=1/(w*Xc1)
D=w*R1*C1//dissipation factor
printf("arm-1 resistance\n")
printf("R1=%.4f ohm\n",R1)
printf("arm-1 capacitance\n")
printf("C1=%.6f F\n",C1)
printf("dissipation factor\n")
printf("D=%.6f \n",D)
```

Scilab code Exa 8.25 determine unknown parameters of arm AB

```
//Chapter-8,Example8_25,pg 8_70
R2=842
w=2*%pi*10^3
C2=0.135*10^-6
Z2=R2-%i*(1/(w*C2))
Z3=10
C4=10^-6
Z4=-%i*(1/(w*C4))
Z1=Z2*Z3/Z4
R1=real(Z1)
Xl1=imag(Z1)
L1=Xl1/w
printf("resistance of arm AB\n")
printf("R1=%.3f ohm\n",R1)
printf("inductance of arm AB\n")
printf("L1=%.4f H",L1)
```

Scilab code Exa 8.26 find resistance and inductance of coil

```
//Chapter-8,Example8_26,pg 8_71
//balance is obtained when
L1=47.8*10^-3
R1=1.36
//at balance 100(r1+jwL1)=100((R2+r2)+jwL2)
L2=L1
r1=32.7
r2=r1-R1
printf("inductance of branch-CD\n")
printf("L2=%.4f H\n",L2)
printf("resistance of branch-CD\n")
printf("r2=%.2f ohm",r2)
```

Scilab code Exa 8.27 find limiting values of unknown resistance

```
//Chapter-8,Example8_27,pg 8_72
R1=100
R2=100
R3=230
R4=R1*R3/R2
lerrR1=0.02/100
lerrR3=0.01/100
lerrR2=0.02/100//lerrR........limiting error in R
lerrR4=lerrR1+lerrR3+lerrR2
R4u=R4+lerrR4*R4
R4l=R4-lerrR4*R4//limiting ranges of R4
printf("limiting range of R4\n")
printf("upper limit=%.3f ohm\n",R4u)
printf("lower limit=%.3f ohm",R4l)
```

Chapter 9

DC Motors

Scilab code Exa 9.1 calculate generated emf

```
//Chapter-9,Example9_1,pg 9_14
P=4
Z=440
phi=0.07//flux(in Wb)
N=900
//for lap-wound
A=P
E=phi*P*N*Z/(60*A)
printf("e.m.f for lap wound\n")
printf("E=%.f V\n",E)
//for wave wound
A=2
E=phi*P*N*Z/(60*A)
printf("e.m.f for wave wound\n")
printf("E=%.f V\n",E)
```

Scilab code Exa 9.2 calculate speed and generated emf

```
//Chapter-9,Example9_2,pg 9_15
P=4
phi=21*10^-3//flux(in Wb)
N=1120
C=42//coils
tpC=8//turns per coil
t=C*tpC//total turns
Z=2*t
//for lap wound
A=P
E=phi*P*N*Z/(60*A)
printf("e.m.f for lap wound\n")
printf("E=%.f V\n",E)
//for wave wound
A=2
E=263.424
N=E*60*A/(phi*P*Z)
printf("speed of generator for wave wound\n")
printf("N=%.f r.p.m\n",N)
```

Scilab code Exa 9.3 calculate induced emf

```
//Chapter-9,Example9_3,pg 9_20
V=220
Ia=30
Ra=0.75
Eb=V-Ia*Ra
printf("back e.m.f of motor\n")
printf("Ebb=%.2f V",Eb)
```

Scilab code Exa 9.4 calculate back emf and speed

```
//Chapter-9,Example9_4,pg 9_21
```

```
P=4
A=P
V=230
Ra=0.6
Z=250
phi=30*10^-3//flux(in Wb)
Ia=40
Eb=V-Ia*Ra
N=Eb*60*A/(phi*P*Z)
printf("back e.m.f\n")
printf("Eb=%.f V\n",Eb)
printf("speed of motor\n")
printf("N=%.f r.p.m",N)
```

Scilab code Exa 9.5 calculate gross torque

```
//Chapter-9,Example9_5,pg 9_24
P=4
A=P
Z=480
phi=20*10^-3//flux(in Wb)
Ia=50
Ta=0.159*phi*Ia*(P*Z/A)
printf("gross torque\n")
printf("Ta=%.3f N",Ta)
```

Scilab code Exa 9.6 calculate induced emf and lost torque

```
//Chapter-9,Example9_6,pg 9_25
P=4
A=P
No=1000//speed of motor
Z=540
```

```
V=230
phi=25*10^-3//flux(In Wb)
Ra=0.8
Ebo=phi*P*No*Z/(60*A)//induced e.m.f
Iao=(V-Ebo)/Ra//armature current
SL=Ebo*Iao//stray losses
wo=2*%pi*No/60//angular velocity
Tf=Ebo*Iao/wo//loss torque
printf("induced e.m.f\n")
printf("Ebo=%.f V\n",Ebo)
printf("armature current\n")
printf("Ia=%.2f A\n",Iao)
printf("stray losses\n")
printf("Sl=%.2f W\n",SL)
printf("loss torque\n")
printf("Tf=%.3f Nm",Tf)
```

Scilab code Exa 9.7 calculate speed

```
//Chapter-9,Example9_7,pg 9_37
P=4
Z=200
V=250
A=2
phi=25*10^-3
Ia=60
Il=Ia
Ra=0.15
Rse=0.2
Eb=V-Ia*(Ra+Rse)
N=Eb*60*A/(phi*P*Z)
printf("speed of motor\n")
printf("N=%.f r.p.m",N)
```

Scilab code Exa 9.8 find armature current and back emf

```
//Chapter -9,Example9_8 , pg 9_38
V=250
Il=20
Ra=0.3
Rsh=200
Ish=V/Rsh
Ia=Il-Ish
Eb=V-Ia*Ra
printf("back e.m.f\n")
printf("Eb=%.3f V",Eb)
```

Scilab code Exa 9.9 calculate speed on full load

```
//Chapter -9,Example9_9 , pg 9_38
No=1000
V=220
Rsh=110
Ra=0.3
Ish=V/Rsh
Ilo=6
Iao=Ilo-Ish
Rao=0.3
Ebo=V-Iao*Ra
//on full load
Il=50
IaFL=Il-Ish
EbFL=V-IaFL*Ra
//N=k*Eb/phi
NFL=No*EbFL/Ebo
printf("speed at full load\n")
```

```
printf("NFL=%.3f r.p.m",NFL)
```

Scilab code Exa 9.10 calculate speed on new load

```
//Chapter-9,Example9_10,pg 9_39
N1=800
I1=20
V=250
Ia1=I1
I2=50
Ia2=I2
Ra=0.2
Ise1=I1
Ise2=I2
Rse=0.3
Eb1=V-Ia1*Ra-Ise1*Rse
Eb2=V-Ia2*Ra-Ise2*Rse
//from speed equation
N2=N1*(Eb2/Eb1)*(Ia1/Ia2)
printf("speed of motor on new load\n")
printf("N2=%.3f r.p.m",N2)
```

Scilab code Exa 9.11 find new speed and armature current

```
//Chapter-9,Example9_11,pg 9_45
V=250
Rsh=250
Ra=0.25
Rx=Rsh
Ia1=20
Ish1=V/Rsh
Ish2=V/(Rsh+Rx)
N1=1500
```

```
Eb1=V-Ia1*Ra
//phi=k*Ish
//T1=T2
Ia2=Ish1*Ia1/Ish2//new current
Eb2=V-Ia2*Ra
//from speed equation
N2=N1*(((Eb1/Eb2)*(Ish2/Ish1))^-1)//new speed
printf("new current\n")
printf("Ia2=%.f A\n",Ia2)
printf("new speed\n")
printf("N2=%.3f r.p.m",N2)
```

Scilab code Exa 9.12 find external resistance

```
//Chapter-9,Example9_12,pg 9_46
V=250
Ra=0.5
Rsh=250
Ia1=20
Ish1=V/Rsh
Eb1=V-Ia1*Ra
N1=600
N2=800
//T1=T2
//Ish1*Ia1=Ish2*Ia2
//Ish2*Ia2 = 20............(1)
//(N1/N2)=(Eb1/Eb2)*(Ish2/Ish1)...........(2)
//using (1) and (2)
//240*(Ish2^2)-187.5*Ish2+7.5=0.........(3)
b=-187.5
a=240
c=7.5
Ish2=(-b+sqrt(((b^2)-4*a*c)))/(2*a)//neglecting lower value
Rx=(V/Ish2)-Rsh
```

```
printf("resistance in shunt feild\n")
printf("Rx=%.3f ohm",Rx)
```

Scilab code Exa 9.13 calculate speed of motor

```
//Chapter-9,Example9_13,pg 9_51
V=250
Ra=0.15
Rx=0.1
Rse=0.1
N1=800
Ise1=30
Ia1=30//Ia1=Ise1
I1=Ia1
//phi=k*Ise
//T2=T1+0.5*T1(increased by 50%)..........(1)
//Ise2=Ia2*Rx/(Rx+Rse)
//putting values of Rx and Rse Ise2=0.5*Ia2 .........(2)
//putting (1) and (2) in torque equation
Ia2=sqrt(2700)
Ise2=0.5*Ia2//from (2)
Eb1=V-Ia1*Ra-Ise1*Rse
Eb2=V-Ia2*Ra-Ise2*Rse
//using speed equation
N2=N1*Eb2*Ise1/(Eb1*Ise2)
printf("speed of motor\n")
printf("N2=%.3f r.p.m",N2)
```

Scilab code Exa 9.14 find out speed of motor

```
//Chapter-9,Example9_14,pg 9_52
V=220
```

```
Ise1=15
Ia1=Ise1
Ia2=10
Ise2=Ia2
I2=Ia2
N1=900
Ra=0.5
Rse=0.5
Rx=4
Eb1=V-Ia1*Ra-Ise1*Rse
Eb2=V-Ia2*Ra-Ise2*Rse-I2*Rx
N2=N1*Eb2*Ise1/(Eb1*Ise2)
printf("speed of motor\n")
printf("N2=%.3f r.p.m",N2)
```

Scilab code Exa 9.15 find speed and torque of motor

```
//Chapter-9,Example9_15,pg 9_64
P=6
V=500
A=2//wave wound
Z=1200
phi=20*10^-3//flux
Ra=0.5
Rsh=250
Il=20
Ish=V/Rsh
Ia=Il-Ish
Eb=V-Ia*Ra
N=Eb*60*A/(phi*P*Z)
Pm=Eb*Ia//mechanical power
w=2*%pi*N/60//angular velocity
Tg=Pm/w
ML=900//mechanical losses
Pout=Pm-ML
```

```
Tsh=Pout/w//usefull torque
Pin=V*Il
n=Pout*100/Pin//efficiency at load
printf("usefull torque\n")
printf("Tsh=%.2f Nm\n",Tsh)
printf("efficiency at load\n")
printf("n=%.2f",n)
```

Scilab code Exa 9.16 find speed on full load

```
//Chapter-9,Example9_16,pg 9_65
V=120
Ra=0.2
Rsh=60
//for full load
Il1=40
N1=1800
//for shunt motor
Ish=V/Rsh
Ia1=Il1-Ish
Eb1=V-Ia1*Ra
//for half load T2=T1/2
Ia2=Ia1*0.5//T=k*Ia
Eb2=V-Ia2*Ra
N2=N1*Eb2/Eb1//from torque equation
printf("speed of motor\n")
printf("N2=%.2f r.p.m",N2)
```

Scilab code Exa 9.17 determine armature current ansd speed of machine

```
//Chapter-9,Example9_17,pg 9_66
Ra=0.08
Eb1=242
```

```
V=250
Ia=87
Vt=V//generator supply
Nm=1500
Ia1=(V-Eb1)/Ra
//at start N=0, Eb=0
Ias=V/Ra//Ia(start)
Ia2=120
Eb2=V-Ia2*Ra
Eg=Vt+Ia*Ra//generator e.m.f
Ng=Nm*Eg/Eb1//speed as generator
printf("speed as generator\n")
printf("Ng=%.2f r.p.m",Ng)
```

Scilab code Exa 9.18 determine mechanical power on full load

```
//Chapter-9,Example9_18,pg 9_67
V=250
Po=59680
Rsh=250
Ra=0.04
n=80//efficiency
N1=1200
Il=Po*100/(V*n)//Pi=V*Il
Ish=V/Rsh
Ia=Il-Ish
Eb=V-Ia*Ra
Pm=Eb*Ia//gross mechanical power
SL=Pm-Po//stray losses
printf("gross mechanical power\n")
printf("Pm=%.3f W\n",Pm)
printf("stray losses\n")
printf("SL=%.2f W\n",SL)
//on no load
//Pg=S, Ebo*Iao=SL..........(1)
```

```
//Ebo=V-Iao*Ra.............(2)
//putting (2) in (1)
//(Iao^2)-6250*Iao+278303.24=0
b=-6250
a=1
c=278303.24
Iao=(-b-sqrt((b^2)-4*a*c))/(2*a)
I=Iao-Ish//current drawn on no load
Ebo=V-Iao*Ra
No=N1*Ebo/Eb
printf("no load speed\n")
printf("No=%.3f r.p.m",No)
```

Scilab code Exa 9.19 calculate full load speed

```
//Chapter-9,Example9_19,pg 9_69
V=250
P=4
Ra=0.1
Rsh=125
Vbr=2//brush drop
//no load condition
Ilo=4
No=1200
Il1=61
Ish=V/Rsh
Iao=Ilo-Ish
Ebo=V-Iao*Ra-Vbr
//full load condition
//phi1=phio-o.o5*phio          (weakened by 5%)
//phi=phi1/phio
phi=0.95
Ia1=Il1-Ish
Eb1=V-Ia1*Ra-Vbr
N1=No*Eb1/(Ebo*phi)
```

```
printf(" full load speed\n")
printf("N1=%.3f r.p.m",N1)
```

Scilab code Exa 9.20 determine full load speed and efficiency

```
//Chapter-9,Example9_20,pg 9_70
V=250
Ra=0.15
Rsh=166.67
No=1280
Il1=67
Ish=V/Rsh
Ia1=Il1-Ish
Eb1=V-Ia1*Ra
//on no load
Ilo=6.5
Ish=1.5
Iao=Ilo-Ish
Ebo=V-Iao*Ra
N1=Eb1*No/Ebo
Sr=(No-N1)*100/No//speed regulation
SL=Ebo*Iao
Po=Eb1*Ia1-SL//full load shaft output
hp=Po/746//horse power rating
Pi=V*Il1
n=Po*100/Pi
printf(" full load speed\n")
printf("N1=%.3f r.p.m\n",N1)
printf("speed regulation\n")
printf("Sr=%.2f \n",Sr)
printf("hp rating of machine\n")
printf("hp=%.2f hp\n",hp)
printf(" full load efficiency\n")
printf("n=%.2f ",n)
```

Scilab code Exa 9.21 find speed for parallel field groups

```
//Chapter-9,Example9_21,pg 9_71
Ra=0.1
V=110
P=4
Ia1=50
I1=Ia1
Rse=0.02
N1=700
Eb1=V-Ia1*Ra-Ia1*Rse
//using torque  equation T=k*phi*Ia
Ia2=sqrt(2)*Ia1
Eb2=V-Ia2*Ra-Ia2*Rse/4//parallel speed groups
//using speed equation N=k*Eb/phi
N2=N1*Eb2*2*Ia1/(Eb1*Ia2)
printf("speed of motor\n")
printf("N2=%.3f r.p.m",N2)
```

Scilab code Exa 9.22 find new speed and armature current

```
//Chapter-9,Example9_22,pg 9_73
P=4
Ia1=50
N1=2000
V=230
//coils connected in series
//phi1=k*Ia1*(4*n)=k*200*n
//coils connected in parallel groups of series coils
//phi2=k*((Ia2*2*n/2)+(Ia2*2*n/2))=k*2*n*Ia2
//phi1/phi2=100/Ia2........(1)
//N1/N2=phi2/phi1........(2)
```

```
//T=kN^2..........(3)
Ia2=(Ia1*(100^3))^(1/4)//using (1) in (3)
N2=(((N1^3)*Ia2)/Ia1)^(1/3)
printf("new speed of motor\n")
printf("N2=%.3f r.p.m",N2)
```

Scilab code Exa 9.23 find external resistance

```
//Chapter-9,Example9_23,pg 9_76
V=200
Ia1=30
Ra=0.75
Rse=0.75
R=Ra+Rse
Eb1=V-Ia1*R
//N2=0.6*N1
N=0.6//N=N2/N1
//using T=k*Ia^2 and T=k*N^3
Ia2=sqrt(((0.6^3)*30^2))
//using speed equation N=k*Eb/Ia
Eb2=N*Eb1*Ia2/Ia1
//Eb2=V-Ia2*(R+Rx)
Rx=-(Eb2-V+Ia2*R)/Ia2
printf("extra resistance to reduce speed\n")
printf("Rx=%.3f ohm",Rx)
```

Scilab code Exa 9.24 estimate supply voltage

```
//Chapter-9,Example9_24,pg 9_77
R=1
V1=230
N1=300
Ia1=15
```

```
N2=375
//using torque equation T=k*N^2
Ia2=N2*Ia1/N1
//using speed equation N=k*Eb/Ia........(1)
Eb1=V1-Ia1*R
//case-2
//Eb2=V2-Ia2*R=V2-18.75......(2)
//putting (2) in (1)
V2=(N2*Eb1*Ia2/(N1*Ia1))+18.75
printf("new supply voltage\n")
printf("V2=%.3f V",V2)
```

Scilab code Exa 9.25 find efficiency and power input

```
//Chapter-9,Example9_25,pg 9_78
V=400
Po1=18.5*10^3
Pi1=22.5*10^3
Rsh=200
Ra=0.4
Po2=9*10^3
I1=Pi1/V
Ish=V/Rsh
Ia1=I1-Ish
Acl=(Ia1^2)*Ra//armature copper loss
Scl=(Ish^2)*Rsh//shunt feild copper loss
TL=Pi1-Po1//total losses
SFl=TL-(Acl+Scl)//stray and friction loss
//case-2
Pm=Po2+SFl//mechanical power
//Pm=Eb2*Ia2.........(1)
//Eb2=V-Ia2*Ra.......(2)
//using (1) and (2)
//0.4*(Ia2^2)-400*Ia2+11022.75=0
a=0.4
```

```
b=-400
c=11022.775
Ia2=(-b-sqrt((b^2)-4*a*c))/(2*a)//neglecting higher
    value
Pi2=Po2+(Ia2^2)*Ra+(Ish^2)*Rsh+SFl
n=Po2*100/Pi2//efficiency
printf("power input in case-2\n")
printf("Pi2=%.3f W\n",Pi2)
printf("efficiency of motor\n")
printf("n=%.2f ",n)
```

Scilab code Exa 9.26 calculate efficiency and armature current

```
//Chapter-9,Example9_26,pg 9_79
V=250
Ilo=4
Ra=1
Rsh=250
Ish=V/Rsh
Il1=20
Iao=Ilo-Ish
Ia1=Il1-Ish
Ebo=V-Iao*Ra
Po=Ebo*Iao
Eb1=V-Ia1*Ra
P1=Eb1*Ia1
Pout=P1-Po
Pi=V*Il1
n=Pout*100/Pi
//fro max. efficiency
//const. losses=variable losses
Ia=sqrt(Po+(Ish^2)*Rsh)
Ebm=V-Ia*Ra
Pm=Ebm*Ia
Pout=Pm-Po
```

```
Pi=V*(Ia+Ish)
nm=Pout*100/Pi
printf("maximum efficiency\n")
printf("nm=%.2f",nm)
```

Scilab code Exa 9.27 calculate back emf

```
//Chapter-9,Example9_27,pg 9_81
V=250
FLo=16*10^3//full scale output
n=80
I=FLo*100/n//input
Il=I/V
Il=Il
Ia=1.5*Il
//at start
Ra=V/Ia
Rac=0.18//Ra actual
Ras=Ra-Rac//Ra starter
Ia=Il//Ia drops as motor starts
Eb=V-Ia*(Ra)
printf("back e.m.f\n")
printf("Eb=%.2f V",Eb)
```

Scilab code Exa 9.28 calculate torque and efficiency

```
//Chapter-9,Example9_28,pg 9_82
Po=20*735.5//(in W)
V=230
N=1150
P=4
A=P
Z=882
```

```
Ia=73
Ish=1.6
T=60*Po/(2*%pi*N)
phi=T*A/(0.159*Ia*P*Z)//flux per pole
Il=Ia+Ish
Pin=V*Il
n=Po*100/Pin
printf("electromagnetic torque\n")
printf("T=%.3f Nm\n",T)
printf("flux per pole\n")
printf("phi=%.3f Wb\n",phi)
printf("efficiency of motor\n")
printf("n=%.3f",n)
```

Scilab code Exa 9.29 determine efficiency and speed of motor

```
//Chapter-9,Example9_29,pg 9_83
Pr=12*10^3//rated output
V=200
Rsh=80
N1=800
n=0.9//efficiency
Out=0.8*Pr//output is 80% of rated
In=Out/n//input
TL=In-Out
//for max. efficiency
Iln=70//new current
//TL=Wc+(Ia1^2)*Ra
//bur Wc=(Ia1^2)*Ra
Wc=TL/2
Il=In/V
Ish=V/Rsh
Ia1=Il-Ish
Ra=Wc/(Ia1^2)
Ia2=Iln-Ish
```

```
Wcn=Wc//const. losses remain same
TL=(Ia2^2)*Ra+Wcn
Pi=V*Iln
n=(Pi-TL)*100/Pi
Eb1=V-Ia1*Ra
Eb2=V-Ia2*Ra
N2=N1*Eb2/Eb1
printf("speed of motor\n")
printf("N2=%.3f r.p.m",N2)
```

Scilab code Exa 9.30 calculate efficiency of motor

```
//Chapter-9,Example9_30,pg 9_85
Po=8.952*10^3
V=440
Ra=1.1
Rsh=650
Rint=0.4
Rreg=50
Ml=450
Vbr=2//brush drop
Il=24
Rat=Ra+Rint//series connection
Rsht=Rsh+Rreg//series connection
Ish=V/Rsht
Ia=Il-Ish
Acl=(Ia^2)*Rat//armature copper loss
Fcl=(Ish^2)*Rsht//feild copper loss
Bdl=Vbr*Ia//brush drop loss
TL=Acl+Fcl+Bdl+Ml
n=Po*100/(Po+TL)
printf("efficiency of motor\n")
printf("n=%.2f ",n)
```

Scilab code Exa 9.31 calculate speed of motor combination

```
//Chapter-9,Example9_31,pg 9_85
//for first motor
N1=700
R=0.5//Ra+Rse
I1=70
V=500
Eb1=V-I1*R
K1=Eb1/(N1*I1)
//for second motor
N2=750
R=0.5
I2=70
V=500
Eb2=V-I2*R
K2=Eb2/(N2*I2)
//motors in series
It=70
Rt=2*R
Eb=V-It*Rt
N=Eb/(K1*It+K2*It)
printf("speed of motors\n")
printf("N=%.3f r.p.m",N)
```

Scilab code Exa 9.32 calculate efficiency and power output

```
//Chapter-9,Example9_32,pg 9_86
Po=7.46*10^3
V=250
Ilo=5
Ra=0.5
```

```
Rsh=250
Ish=V/Rsh
Iao=Ilo-Ish
Acl=(Iao^2)*Ra
Fcl=(Ish^2)*Rsh
Pi=V*Ilo
FWl=Pi-Acl-Fcl//friction and windage loss
//Pin=Eb*Ia=(V-Ia*Ra)*Ia
//0.5*(Ia^2)-250*Ia+8452=0
b=-250
a=0.5
c=8452
Ia=(-b-sqrt((b^2)-4*a*c))/(2*a)//neglecting higher
    value
TL=(Ia^2)*Ra+(Ish^2)*Rsh+FWl
n=Po*100/(Po+TL)
//for max. efficiency
Ia=sqrt((FWl+Fcl)/Ra)
Eb=V-Ia*Ra
Pm=Eb*Ia
//Po at nmax
Po=Pm-FWl
printf("maximum efficiency output\n")
printf("Po=%.3f W",Po)
```

Scilab code Exa 9.33 calculate speed on given load

```
//Chapter-9,Example9_33,pg 9_87
V=500
Ra=1.2
Rsh=500
Ish=V/Rsh
Ilo=4
Iao=Ilo-Ish
Ebo=V-Iao*Ra
```

```
Il1=26
Ish1=1
Ia1=Il1-Ish1
Eb1=V-Ia1*Ra
No=1000
N1=No*Eb1/Ebo
Rx=2.3//connected in series with armature
Eb2=V-Ia1*(Ra+Rx)
N2=N1*Eb2/Eb1
printf("speed of motor case-1\n")
printf("N2=%.3f r.p.m\n",N2)
Ish3=Ish1-0.15*Ish1//reduced by 15%
Ia3=Ish1*Ia1/(Ish3)
Eb3=V-Ia3*Ra
N3=N1*Eb3*Ish1/(Eb1*Ish3)
printf("speed of motor case-2\n")
printf("N3=%.3f r.p.m\n",N3)
```

Chapter 10

Three Phase Induction Motors

Scilab code Exa 10.1 calculate full load slip

```
//Chapter-10,Example10_1,pg10_14
P=4
f=50
N=1410
Ns=120*f/P
s=(Ns-N)/Ns
s=s*100//%s
printf("full load slip\n")
printf("s=%.f ",s)
```

Scilab code Exa 10.2 calculate full load speed

```
//Chapter-10,Example10_2,pg10_14
P=4
f=50
sfl=4/100
Ns=120*f/P
Nfl=Ns-sfl*Ns
```

```
printf("full load speed of motor\n")
printf("Nfl=%.f r.p.m",Nfl)
```

Scilab code Exa 10.3 calculate rotor frequency

```
//Chapter-10,Example10_3,pg10_16
P=4
f=50
N=1470
Ns=120*f/P
s=(Ns-N)/Ns
fr=s*f
printf("frequency of induced e.m.f\n")
printf("fr=%.f Hz",fr)
```

Scilab code Exa 10.4 find full load slip and speed

```
//Chapter-10,Example10_4,pg10_20
P=8
f=50
fr=2
s=fr/f
s=s*100
printf("full load slip\n")
printf("s=%.f \n",s)
s=s/100
Ns=120*f/P
N=Ns*(1-s)
printf("speed of motor\n")
printf("N=%.f r.p.m",N)
```

Scilab code Exa 10.5 calculate rotor frequency and induced emf

```
//Chapter-10,Example10_5,pg10_20
P=4
f=50
N=1455
E1line=415
Ns=120*f/P
s=(Ns-N)/Ns
fr=s*f
E1ph=E1line/sqrt(3)
E2ph=0.5*E1ph//K=2
E2r=s*E2ph
printf("frequency of rotor e.m.f\n")
printf("fr=%.2f Hz\n",fr)
printf("magnitude of induced e.m.f standstill\n")
printf("E2ph=%.2f V\n",E2ph)
printf("magnitude of induced e.m.f running\n")
printf("E2r=%.3f V",E2r)
```

Scilab code Exa 10.6 find rotor current and rotor power factor

```
//Chapter-10,Example10_6,pg10_21
P=4
f=50
R2=0.2
X2=1
E2line=120
E2ph=E2line/sqrt(3)
Ns=120*f/P
//at start
pf=R2/sqrt((R2^2)+(X2^2))//power factor
I2=E2ph/sqrt((R2^2)+(X2^2))
printf(" at start\n")
printf("pf=%.3f lagging\n",pf)
```

```
printf(" I2=%.2f A\n",I2)
//on full load
N=1440
s=(Ns-N)/Ns
pf=R2/sqrt((R2^2)+((s*X2)^2))
I2=E2ph*s/sqrt((R2^2)+((s*X2)^2))
printf(" on full load\n")
printf("pf=%.3f lagging\n",pf)
printf("I2=%.2f A",I2)
```

Scilab code Exa 10.7 calculate full load torque

```
//Chapter-10,Example10_7,pg10_24
P=4
f=50
R2=0.1
X2=1
N=1440
K=0.5
Ns=120*f/P
E1line=400
E1ph=E1line/sqrt(3)
E2ph=0.5*E1ph
s=(Ns-N)/Ns
ns=Ns/60//synchronous speed (r.p.s)
T=(3/(2*%pi*ns))*(s*(E2ph^2)*R2/((R2^2)+((s*X2)^2)))
printf("torque on full load\n")
printf("T=%.2f N-m",T)
```

Scilab code Exa 10.8 calculate starting torque and full load torque

```
//Chapter-10,Example10_8,pg10_27
P=4
```

```
f=50
K=1/4
R2=0.01
X2=0.1
E1line=400
E1ph=E1line/sqrt(3)
E2=E1ph/4
Ns=120*f/P
//at start
s=1
ns=Ns/60
k=3/(2*%pi*ns)
Tst=k*(E2^2)*R2/((R2^2)+(X2^2))
printf("starting torque\n")
printf("Tst=%.3f N-m\n",Tst)
//slip at max torque
sm=R2/X2
sm=sm*100
printf("slip at which max torque occurs\n")
printf("sm=%.f \n",sm)
//speed at max torque
sm=sm/100
N=Ns*(1-sm)
printf("speed at which max torque occurs\n")
printf("N=%.f r.p.m\n",N)
//max. torque
Tm=k*(E2^2)/(2*X2)
sf=0.04
Tfl=k*sf*(E2^2)*R2/((R2^2)+((sf*X2)^2))
printf("max torque\n")
printf("Tm=%.2f N-m\n",Tm)
printf("full load torque\n")
printf("Tfl=%.2f N-m",Tfl)
```

Scilab code Exa 10.9 star connected induction motor

```
//Chapter-10,Example10_9,pg10_33
P=24
f=50
R2=0.016
X2=0.265
N=247
Ns=120*f/P
sf=(Ns-N)/Ns
sm=R2/X2
Tfm=2*sm*sf/((sm^2)+(sf^2))
Tsm=2*sm/(1+(sm^2))
printf("full load torque to max torque\n")
printf("Tfm=%.4f \n",Tfm)
printf("starting torque to max torque\n")
printf("Tsm=%.4f \n",Tsm)
```

Scilab code Exa 10.10 calculate external resistance

```
//Chapter-10,Example10_10,pg10_36
R2=0.04
X2=0.2
//for Tm=Tst, sm=1
R21=X2
Rex=R2-R21
//for Tst=Tm/2........(1)
//Tst=k*(E2^2)*R21/((R21^2)+(X2^2))......(2) with added resistance
//from (1) and (2)
//(R21^2)-0.8*R21+0.04=0
a=1
b=-0.8
c=0.04
R21=(-b-sqrt((b^2)-4*a*c))/(2*a)//neglecting higher value
Rex=R21-R2
```

```
printf("external resistance\n")
printf("Rex=%.4f ohm per phase",Rex)
```

Scilab code Exa 10.11 calculate rotor copper loss

```
//Chapter-10,Example10_11,pg10_42
Tsh=190
P=8
f=50
fr=1.5
ML=700
s=fr/f
Ns=120*f/P
N=Ns*(1-s)
Po=Tsh*(2*%pi*N/60)
Pm=Po+ML
Pc=Pm*s/(1-s)
printf("rotor copper loss\n")
printf("Pc=%.3f W",Pc)
```

Scilab code Exa 10.12 calculate full load efficiency

```
//Chapter-10,Example10_12,pg10_43
P=4
f=50
Pi=50*10^3
N=1440
Sl=1000
Fl=650
Ns=120*f/P
s=(Ns-N)/Ns
P2=Pi-Sl
Pc=s*P2
```

```
Pm=P2-Pc
Po=Pm-Fl
n=Po*100/Pi
printf("full load efficiency\n")
printf("n=%.2f",n)
```

Scilab code Exa 10.13 calculate slip and rotor resistance per phase

```
//Chapter-10,Example10_13,pg10_44
P=4
f=50
Tsh=300
Tlost=50
fr=120/60//Hz
s=fr/f
s=s*100
printf("slip s=%.f \n",s)
Ns=120*f/P
s=s/100
N=Ns*(1-s)
Po=Tsh*2*%pi*N/60
Fl=Tlost*2*%pi*N/60
Pm=Po+Fl
Pc=Pm*s/(1-s)
Rcl=Pc/3//rotor copper loss per phase
P2=Pc/s
n=Pm*100/P2
I2r=60
R2=Rcl/(I2r^2)
printf("net output power\n")
printf("Po=%.3f W\n",Po)
printf("rotor copper loss per phase\n")
printf("Rcl=%.3f W\n",Rcl)
printf("rotor efficiency\n")
printf("n=%.2f \n",n)
```

```
printf("rotor resistance per phase\n")
printf("R2=%.4f ohm/ph",R2)
```

Scilab code Exa 10.14 calculate gross mechanical power and efficiency

```
//Chapter-10,Example10_14,pg10_45
Po=25*10^3
f=50
P=4
Ns=120*f/P
N=1410
s=(Ns-N)/Ns
Ml=850
Pm=Po+Ml
Pc=Pm*s/(1-s)
I2r=65
R2=Pc/(3*(I2r^2))
Sl=1.7*Pc
P2=Pc/s
Pin=P2+Sl
n=Po*100/Pin
printf("gross mechanical power\n")
printf("Pm=%.f W\n",Pm)
printf("rotor copper losses\n")
printf("Pc=%.f W\n",Pc)
printf("rotor resistance per phase\n")
printf("R2=%.3f ohm/ph\n",R2)
printf("full load efficiency\n")
printf("n=%.2f",n)
```

Scilab code Exa 10.15 calculate shaft torque and full load efficiency

```
//Chapter-10,Example10_15,pg10_47
```

```
Po=24*10^3
Il=57
Is=Il
P=8
N=720
f=50
Vl=415
pf=0.707
Ns=120*f/P
s=(Ns-N)/Ns
Ml=1000
Pm=Po+Ml
Pc=Pm*s/(1-s)
Tsh=Po*60/(2*%pi*N)
T=Pm*60/(2*%pi*N)
Rcl=1041.66//rotor copper loss
P2=Pc/s
Pi=sqrt(3)*Vl*Il*pf
Rs=0.1
Scl=3*(Is^2)*Rs//stator copper loss
Sl=Pi-P2
Sil=Sl-Scl//stator iron loss
n=Po*100/Pi
printf("shaft torque\n")
printf("Tsh=%.3f N-m\n",Tsh)
printf("gross torque \n")
printf("T=%.3f N-m\n",T)
printf("rotor copper losses\n")
printf("Pc=%.2f W\n",Pc)
printf("stator copper losses\n")
printf("Scl=%.2f W\n",Scl)
printf("stator iron losses\n")
printf("Sil=%.2f W\n",Sil)
printf("overallefficiency\n")
printf("n=%.2f",n)
```

Scilab code Exa 10.16 calculate tapping and supply start current

```
//Chapter-10,Example10_16,pg10_52
sf=0.05
//Tst=Tfl
Ifs=1/6//Isc/Ifl=6
x=sqrt((Ifs^2)/sf)//tapping on transformer
t=x*100
Ist=(x^2)*6
printf("supply current\n")
printf("Ist=%.2f times Ifl",Ist)
```

Scilab code Exa 10.17 determine ratios of torques

```
//Chapter-10,Example10_17,pg10_54
R2=0.4
X2=4
//Tm=k*(E2^2)/(2*X2)
//Tfl=Tm/2.5
//Tfl=k*(E2^2)/20
//Tst=k*(E2^2)*R2/((R2^2)+(X2^2))
//E2=E2/sqrt(3)
T=20*R2/(3*(((R2^2)+(X2^2))))
printf("ratio of starting torque to full load torque
    \n")
printf("T=%.3f ",T)
```

Scilab code Exa 10.18 calculate rotor current and external resistance

```
//Chapter-10,Example10_18,pg10_57
Vl=1000
f=50
K=3.6
R2=0.01
X2=0.2
E1line=1000
E1=E1line/sqrt(3)
E2=E1/K
//at start,s=1
I2=160.37/sqrt((R2^2)+(X2^2))
pf=R2/sqrt((R2^2)+(X2^2))
printf("rotor current at start\n")
printf("I2=%.2f A\n",I2)
printf("rotor power factor\n")
printf("pf=%.3f lagging (answer in book is wrong)\n"
    ,pf)
//at s=0.03
s=0.03
I2r=s*160.37/sqrt((R2^2)+((s*X2)^2))
printf("rotor current at slip 0.03\n")
printf("I2r=%.2f A\n",I2r)
I2=200
R21=sqrt(((E2/I2)^2)-(X2^2))
Rex=R21-R2
printf("external resistance \n")
printf("Rex=%.4f ohm/ph (answer in book is wrong)",
   Rex)
```

Scilab code Exa 10.19 calculate starting torque and speed

```
//Chapter-10,Example10_19,pg10_58
P=12
f=50
```

```
R2=0.15
X2=0.25
E2=32
Ns=120*f/P
ns=Ns/60
Tst=3*(E2^2)*R2/((2*%pi*ns)*((R2^2)+(X2^2)))
N=480
s=(Ns-N)/Ns
Tfl=3*s*(E2^2)*R2/((2*%pi*ns)*((R2^2)+((s*X2)^2)))
Tm=3*(E2^2)/(2*%pi*ns*2*X2)
sm=R2/X2
N=Ns*(1-sm)
printf("starting torque\n")
printf("Tst=%.2f Nm\n",Tst)
printf("full load torque\n")
printf("Tfl=%.3f Nm\n",Tfl)
printf("maximum torque\n")
printf("Tm=%.3f Nm\n",Tm)
printf("speed at max torque\n")
printf("N=%.f r.p.m",N)
```

Scilab code Exa 10.20 calculate efficiency on full load

```
//Chapter-10,Example10_20,pg10_59
Po=50*735.5//(in W)
s=0.04
//Rcl=X...............rotor copper loss
//Sil=1.25X...........stator iron loss
//Ml=Y, Y=(Y+1.25X)/3, Y=0.625X
//TL=Sil+Rcl+Scl+Ml, TL=3.875X.........(a)
//Pm=Po+Y, 36775+625X..........(1)
//Pc=Pm*s/(1-s).............(2)
//Pc=X, from (1) and (2)
X=(s*Po)/(1-s-s*0.625)
TL=3.875*X//from (a)
```

```
n=Po*100/(Po+TL)
printf("efficiency on full load\n")
printf("n=%.2f ",n)
```

Scilab code Exa 10.21 calculate new speed

```
//Chapter-10,Example10_21,pg10_61
P=4
f=50
R2=0.25
X2=0.55
Ns=120*f/P
N1=1440
s1=(Ns-N1)/Ns
Rex=0.2
R21=R2+Rex
//T1 at s1=T2 at s2
//0.3025*s2^2-2.8342*s2+0.2025=0, s1=0.04
a=0.3025
b=-2.8342
c=0.2025
s2=(-b-sqrt((b^2)-4*a*c))/(2*a)//neglecting higher
    value
N2=Ns*(1-s2)
printf("new speed of motor\n")
printf("N2=%.f r.p.m",N2)
```

Scilab code Exa 10.22 find rotor current and rotor emf per phase

```
//Chapter-10,Example10_22,pg10_62
E2line=50
R2=0.5
X2=3
```

```
E2=E2line/sqrt(3)
//at start
s=1
I2r=s*E2/(sqrt((R2^2)+((s*X2)^2)))
printf("rotor current atstart\n")
printf("I2r=%.3f A\n",I2r)
Rx=6
I2r=s*E2/(sqrt(((R2+Rx)^2)+((s*X2)^2)))
printf("rotor current for rheostat of 6 ohm\n")
printf("I2r=%.3f A\n",I2r)
//at full load
s=0.04
I2r=s*E2/(sqrt((R2^2)+((s*X2)^2)))
pf=R2/(sqrt((R2^2)+((s*X2)^2)))
printf("full load rotor current\n")
printf("I2r=%.3f A\n",I2r)
printf("full load power factor\n")
printf("pf=%.3f lagging\n",pf)
E2r=s*E2
printf("rotor e.m.f on full load\n")
printf("E2r=%.3f V",E2r)
```

Scilab code Exa 10.23 calculate starting torque and speed

```
//Chapter-10,Example10_23,pg10_63
P=12
f=50
R2=0.15
X2=0.25
E2=32
Ns=120*f/P
ns=Ns/60
k=3
Tst=k*(E2^2)*R2/((2*%pi*ns)*((R2^2)+(X2^2)))
N=480
```

```
s=(Ns-N)/Ns
Tfl=k*s*(E2^2)*R2/((2*%pi*ns)*((R2^2)+((s*X2)^2)))
Tm=k*(E2^2)/(2*%pi*ns*2*X2)
sm=R2/X2
N=Ns*(1-sm)
printf("starting torque\n")
printf("Tst=%.2f Nm\n",Tst)
printf("full load torque\n")
printf("Tfl=%.3f Nm\n",Tfl)
printf("maximum torque\n")
printf("Tm=%.3f Nm\n",Tm)
printf("speed at max torque\n")
printf("N=%.f r.p.m",N)
```

Scilab code Exa 10.24 calculate full load torque and external resistance

```
//Chapter-10,Example10_24,pg10_64
P=4
f=50
R2=0.4
X2=2
E2b=520//between slip rings
E2ph=E2b/sqrt(3)
Ns=120*f/P
N=1425
sf=(Ns-N)/Ns
ns=Ns/60
Tfl=3*sf*(E2ph^2)*R2/((2*%pi*ns)*((R2^2)+((sf*X2)^2)
  ))
Tst=3*(E2ph^2)*R2/((2*%pi*ns)*((R2^2)+((X2)^2)))
T=Tst/Tfl
Tm=3*(E2ph^2)/((2*%pi*ns)*((R2^2)+((X2)*2)))
T1=Tm/Tfl
//at start
sm=1
```

```
R21=X2
Rex=R21-R2
printf("full load torque\n")
printf("Tfl=%.2f Nm\n",Tfl)
printf("ratio of Tst to Tfl\n")
printf("T=%.4f \n",T)
printf("ratio of Tm to Tfl\n")
printf("T1=%.4f \n",T1)
printf("external resistance required\n")
printf("Rex=%.2f ohm/ph",Rex)
```

Scilab code Exa 10.25 calculate slip and line current

```
//Chapter-10,Example10_25,pg10_65
Po=33.73*10^3
P=4
Vl=400
f=50
Nfl=1440
pf=0.8
Ml=1.3*10^3
Ns=120*f/P
s=(Ns-Nfl)/Ns
fr=s*f
Pm=Po+Ml
Pc=Pm*s/(1-s)
Pcp=Pc/3//copper loss per phase
P2=Pc/s
Sl=1.4*10^3
Pi=P2+Sl
n=Po*100/Pi
Il=Pi/(sqrt(3)*Vl*pf)
printf("slip at full load\n")
printf("s=%.3f \n",s)
printf("rotor frequency\n")
```

```
printf("fr=%.f Hz\n",fr)
printf("rotor copper loss per phase\n")
printf("Pcp=%.2f W\n",Pcp)
printf("total copper loss\n")
printf("Pc=%.2f W\n",Pc)
printf("efficiency at full load\n")
printf("n=%.2f \n",n)
printf("line current drawn\n")
printf("Il=%.3f A\n",Il)
```

Scilab code Exa 10.26 find power factor of rotor

```
//Chapter-10,Example10_26,pg10_66
R2=0.04
X2=0.2
sfl=0.03
//at Tst, s=1
//Tfl=Tst
//(R21^2)-1.3633*R21+0.04=0
a=1
b=-1.3633
c=0.04
R21=(-b+sqrt((b^2)-4*a*c))/(2*a)
Rex=R21-R2
pf=R21/sqrt((R21^2)+(X2^2))
printf("power factor of rotor\n")
printf("pf=%.3f lagging",pf)
```

Scilab code Exa 10.27 determine full load speed and speed at max torque

```
//Chapter-10,Example10_27,pg10_67
P=4
f=50
```

```
Po=8*10^3
//Tst=1.5*Tfl and Tm=2*Tfl
//(R2^2)+((sfl*X2)^2)=1.5*sfl*((R2^2)+(X2^2))..................(1)
//(R2^2)+((sfl*X2)^2)=2*(sfl/sm)*((R2^2)+((sm*X2)^2))..........(2)
//dividing (1) and (2) by (X2^2) on both sides and R2/X2=sm
//(sm^2)+(sfl^2)=5*(1+(sm^2))*sfl.............(3)
//(sm^2)+(sfl^2)=2*(2*(sm^2))*(sfl/sm)=4*sm*sfl............(4)
//dividing (3) by (4)
//(sm^2)-2.667*sm+1=0
a=1
b=-2.667
c=1
sm=(-b-sqrt((b^2)-4*a*c))/(2*a)
Ns=120*f/P
//substituting sm in (4)
//(sfl^2)-1.8052*sfl+0.2036=0
a=1
b=-1.8052
c=0.2036
sfl=(-b-sqrt((b^2)-4*a*c))/(2*a)
N=Ns*(1-sfl)
Nm=Ns*(1-sm)
printf("full load speed\n")
printf("N=%.2f r.p.m\n",N)
printf("speed at max. torque\n")
printf("Nm=%.2f r.p.m\n",Nm)
```

Scilab code Exa 10.28 calculate starting torque

```
//Chapter-10,Example10_28,pg10_68
Po=10*735.5//(in W)
```

```
Nfl=1410
P=4
f=50
Ns=120*f/P
sfl=(Ns-Nfl)/Ns
Nm=1200
sm=(Ns-Nm)/Ns
T=2*sfl*sm/((sm^2)+(sfl^2))//Tfl/Tm
T1=(1+(sm^2))/(2*sm)//Tm/Tst
T2=T1*T//Tfl/Tst
Tfl=Po*60/(2*%pi*Nfl)
Tst=Tfl/T2
printf("starting torque\n")
printf("Tst=%.2f Nm",Tst)
```

Scilab code Exa 10.29 calculate speed torque and external resistance

```
//Chapter-10,Example10_29,pg10_70
P=4
f=50
R2=0.025
X2=0.15
sfl=0.04
Tfl=150
sm=R2/X2
Tm=Tfl*((R2^2)+((sfl*X2)^2))*sm/(sfl*((R2^2)+((sm*X2)^2)))
Ns=120*f/P
N=Ns*(1-sm)
//at start
R21=X2
Rex=R21-R2
printf("maximum torque\n")
printf("Tm=%.2f Nm\n",Tm)
printf("speed N=%.f r.p.m\n",N)
```

```
printf("external resistance\n")
printf("Rex=%.3f ohm/ph",Rex)
```

Scilab code Exa 10.30 calculate motor output and efficiency

```
//Chapter-10,Example10_30,pg10_70
Tsh=162.84
P=6
f=50
Tlost=20.36
fr=1.5
s=fr/f
Ns=120*f/P
N=Ns*(1-s)
Po=Tsh*(2*%pi*N)/60
Fl=Tlost*(2*%pi*N)/60
Pm=Po+Fl
Pc=Pm*s/(1-s)
P2=Pc/s
Sl=830
Pi=P2+Sl
n=Po*100/Pi
printf("motor output\n")
printf("Po=%.4f W\n",Po)
printf("copper loss in rotor\n")
printf("Pc=%.3f W\n",Pc)
printf("motor input\n")
printf("Pi=%.3f W\n",Pi)
printf("efficiency of motor\n")
printf("n=%.2f ",n)
```

Scilab code Exa 10.31 find ratio of torques

```
//Chapter-10,Example10_31,pg10_71
f=50
P=8
R2=0.01
X2=0.1
sfl=0.04
//for Tmax
sm=R2/X2
//for Tfl
s=sfl
T=sm*R2*((R2^2)+((sfl*X2)^2))/((sfl*R2)*((R2^2)+((sm
    *X2)^2)))//Tmax/Tfl
Ns=120*f/P
sm=0.1
N=Ns*(1-sm)
printf("ratio of max to full load torque\n")
printf("T=%.2f\n",T)
printf("speed at max torque\n")
printf("N=%.f r.p.m",N)
```