Scilab Textbook Companion for Basic Electrical Engineering by A. Mittle and V. N. Mittle[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

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Chapter 1

DC Circuits

Scilab code Exa 1.1 Example on Ohms Law

```

//By KCL, I1 + I2=2.25
I1=10/(2+8)
I2=2.25-I1
r=(10-5*I2)/I2
mprintf("r=%d ohm, current in branch ABC=%d A and
    current in branch ADC=%f A", r, I1, I2)
```

Scilab code Exa 1.2 Example on Ohms Law

```

//i1, i2, i3 be the currents in the branches CD, EF
    and GH respectively
//i1+i2+i3=1.5
i2=(20-1.5*10)/15
i3=(20-1.5*10)/15
i1=1.5-i2-i3
r=(20-1.5*10)/i1
mprintf("r=%f ohm", r)
```

Scilab code Exa 1.3 Example on Ohms Law

```
//points A,E,F,G are at the same potential
Rab=20
Reb=50
R1=Rab*Reb/(Rab+Reb)  //equivalent resistance of Rab
    and Reb
Rbc=25
R2=R1+Rbc  //equivalent resistance of R1 and Rbc
Rfc=50
R3=Rfc*R2/(Rfc+R2)  //equivalent resistance of R2
   and Rfc
Rcd=30
R4=R3+Rcd  //equivalent resistance of R3 and Rcd
R=R4*50/(50+R4)  //equivalent resistance between A
   and D
i=200/R  //Ohm's Law
mprintf("Current drawn by circuit=%f A", i)
```

Scilab code Exa 1.4 Example on Kirchhoffs Law

```
//refer Fig. 1.10 in the textbook
//applying KCL, I1+I2=20; -I2+I3=30
//applying KVL
//for mesh ABGHA, -0.1*I2+20*R1=108
//for mesh BCFGB, 0.3*I2+20*R1-30*R2=0
//for mesh CDEFC, 0.2*I2+30*R2=114
a=[-0.1 20 0;0.3 20 -30;0.2 0 30]
b=[108;0;114]
```

```
x=inv(a)*b
I2=x(1,1)
R1=x(2,1)
R2=x(3,1)
I1=20-I2
I3=30+I2
mprintf("R1=%f ohm, R2=%f ohm, I1=%f A, I2=%f A, I3=
    %f A", R1, R2, I1, I2, I3)
```

Scilab code Exa 1.5 Example on Kirchhoffs Law

```

//refer Fig.1.11 in the textbook
//applying KVL over loops ABEFA and BCDEB, I2=3.5*
    I1; -2*I1+7*I2=10
a=[3.5 -1;-2 7]
b=[0;10]
i=inv(a)*b
I1=i(1,1)
I2=i(2,1)
I=I2-I1
mprintf("Current through 8 ohm resistance=%f A from
    E to B", I)
```

Scilab code Exa 1.6 Example on Kirchhoffs Law

```

//refer Fig.1.12 in the textbook
//Applying KVL
//for mesh AHGBA, -23*i1+20*i2+3*i4=0
//for mesh GFCBG, 20*i1-43*i2+20*i3+3*i4=0
//for mesh FEDCF, 20*i2-43*i3+3*i4=0
//for mesh ABCDJIA, 3*i1+3*i2+3*i3-9*i4+50=0
```

```
a=[-23 20 0 3;20 -43 20 3;0 20 -43 3;3 3 3 -9]
b=[0;0;0;-50]
i=inv(a)*b
i1=i(1,1)
i2=i(2,1)
i3=i(3,1)
i4=i(4,1)
V1=3*(i4-i1)
V2=3*(i4-i2)
V3=3*(i4-i3)
mprintf("Voltage across branch AB=%f V, Voltage
   across branch BC=%f V, Voltage across branch CD=
   %f V", V1, V2, V3)
```

Scilab code Exa 1.7 Example on Kirchhoffs Law

```

//refer Fig.1.13 in the textbook
//by applying KVL
//for mesh ABCDA, 7.45*i1 -3.25*i2=10
//for mesh EFBAE, 8.55*i2 -5.3*i3 -3.25*i1=10
//for mesh HGBFEAH, 11.3*i3 -5.3*i2=80
a=[7.45 -3.25 0;-3.25 8.55 -5.3;0 -5.3 11.3]
b=[10;10;80]
i=inv(a)*b
i1=i(1,1)
i2=i(2,1)
i3=i(3,1)
mprintf("Current in 6 ohm resistor=%f A, current in
   3 ohm resistor=%f A", i3, i2-i1)
```

Scilab code Exa 1.8 Example on Superposition Theorem

```

//using Superposition Theorem
//consider E1 alone
E1=1.5
R1=(1+1)*2/(1+1+2)+2  //total resistance
I1=E1/R1  //current supplied
i1=I1/2  //current in branch AB from B to A
//consider E2 alone
E2=1.1
R2=(1+1)*2/(1+1+2)+1+1  //total resistance
I2=E2/R2  //current supplied
i2=I2/2  //current in branch AB from B to A
mprintf("Current through 2 ohm resistor=%f A", i1+i2)
```

Scilab code Exa 1.9 Example on Superposition Theorem

```

//refer Fig.1.20 in the textbook
//applying KVL
//for mesh  BAEFB, 4*I1+2*I2=1.5
//for mesh  BACDB, 2*I1+4*I2=1.1
a=[4 2;2 4]
b=[1.5;1.1]
i=inv(a)*b
I1=i(1,1)
I2=i(2,1)
mprintf("Current through 2 ohm resistor=%f A from B to A", I1+I2)
```

Scilab code Exa 1.10 Example on Thevenin Theorem

```

```

```
//refer Fig.1.22(a) in the textbook
//resistance between A and B is removed
//I1 be current in branch CD
//applying KCL
//100-I1 is the current in branch AF
//I1-50 is the current in branch DE
//70-I1 is the current in branch FE
//applying KVL for mesh CDEFC, we get,
I1=56
V=.1*I1+.15*(I1-50)  //thevenin's voltage
r=(.1+.15)*(.1+.15)/(.25+.25)  //thevenin's
    equivalent resistance
I=V/(r+.05)
mprintf("Current flowing in the branch AB of 0.05
    ohm resistance is %f A", I)
```

Scilab code Exa 1.11 Example on Norton Theorem

```

//by Norton's Theorem
I=2*10//total current produced by current source
r=2*2/(2+2)//resultant resistance of current source
In=20*r/(r+1)//norton current
Rn=1+r//norton resistance
I=In*Rn/(Rn+8)
mprintf("Current through the load resistance of 8
    ohm=%f A from A to B", I)
```

Scilab code Exa 1.12 Example on Nodal Analysis

```

//circuit has 4 nodes, viz, A, B, C and D
//node D is taken as reference node
```

```
//voltages at A, B and C be Va, Vb and Vc respectively
//applying KCL
//at node A, 7*Va-Vb-Vc=25
//at node B, -4*Va+19*Vb-10*Vc=0
//at node C, -4*Va-10*Vb+19*Vc=-40
a=[7 -1 -1;-4 19 -10;-4 -10 19]
b=[25;0;-40]
v=inv(a)*b
Va=v(1,1)
Vb=v(2,1)
Vc=v(3,1)
I=(Va-Vc)/5
mprintf("Current in 5 ohm AC branch=%f A from A to C", I)
//error in textbook answer
```

Scilab code Exa 1.13 Example on Maximum Power Transfer Theorem

```

V=3*20/(2+3)//thevenin's voltage
r=1+2*3/(2+3)//thevenin's equivalent resistance
R=r
Pmax=V^2/(4*r)
mprintf("Max power transferred to the load is %f W when load resistance is %f ohm", Pmax, R)
```

Scilab code Exa 1.14 Example on Delta to Star and Star to Delta Transformation

```

//inner delta DEF is transformed to equivalent star connection having resistances Ra, Rb, Rc
```

```
Ra=1.5*2.5/(1.5+2.5+1)
Rb=1.5*1/(1.5+2.5+1)
Rc=1*2.5/(1.5+2.5+1)
//inner portion of obtained star network ABC is converted into equivalent delta with resistances R1, R2, R3
R1=4+5.05+4*5.05/5
R2=4+5+4*5/5.05
R3=5+5.05+5*5.05/4
//now the network reduces to the form in which the resistances across a branch are in parallel
//let equivalent resistances be Rac, Rbc and Rab
Rac=5*R1/(5+R1)
Rbc=5*R2/(5+R2)
Rab=5*R3/(5+R3)
R=(Rac+Rbc)*Rab/(Rac+Rbc+Rab)
mprintf("Equivalent resistance between A and B=%f ohm",R)
```

Scilab code Exa 1.16 Example on Delta to Star and Star to Delta Transformation

```

//by Superposition Theorem
//consider 2 V battery alone
R1 =(3+1)*2/(3+1+2)  //equivalent resistance of Raf, Rfg, Rab
R2 =(1+R1)*12/(1+R1+12)  //equivalent resistance of Rad, R1, Rde
R=1+2+R2  //total resistance of the circuit
I1=2/R
I2=I1*12/(1+R1+12)
I3=I2*4/(2+4)  //current through 2 ohm
//consider 4 V battery alone
I4=34/71  //current through 2 ohm
```

```
I=I3+I4
mprintf("By Superposition Theorem, current through the 2 ohm resistance is %f A from A to B\n", I)
//by Thevenin's Theorem
//applying KCL
//for mesh CDHIC, 15*i1+12*i2=2
//for mesh DEGHD, 12*i1+17*i2=4
a=[15 12;12 17]
b=[2;4]
i=inv(a)*b
i1=i(1,1)
i2=i(2,1)
Vab=4-3*i2-i2
R1=(1+2)*12/(1+2+12)  //R1 is equivalent resistance of Rcd, Rci, Rdh
R=(1+R1)*(3+1)/(1+R1+3+1)  //thevenin's equivalent resistance
I=Vab/(R+2)
mprintf("By Thevenin Theorem, current through 2 ohm resistance is %f A from A to B\n", I)
//by Maxwell Mesh Analysis
//applying KVL
//for mesh CDEHC, 15*I1-12*I2=2
//for mesh DABED, -12*I1+15*I2+2*I3=0
//for mesh AFGBA, 2*I2+6*I3=4
a=[15 -12 0;-12 15 2;0 2 6]
b=[2;0;4]
i=inv(a)*b
I1=i(1,1)
I2=i(2,1)
I3=i(3,1)
mprintf("By Maxwell Mesh Analysis, current through 2 ohm resistance is %f A from A to B ", I2+I3)
```

Chapter 2

Electrostatics

Scilab code Exa 2.1 Example on Coulombs Law

```
epsilon=8.854D-12
r=sqrt(.1^2+.1^2)//distance b/w A and C
Fca=(2D-6)*(4D-6)/(4*%pi*epsilon*r^2)//from A to C
Fcb=(4D-6)*(2D-6)/(4*%pi*epsilon*.1^2)//from C to B
Fcd=(4D-6)*(4D-6)/(4*%pi*epsilon*.1^2)//from C to D
//Fr has horizontal and vertical components as Frx and Fry respectively
Frx=Fcd-Fca*cos(45*%pi/180)
Fry=Fcb-Fca*sin(45*%pi/180)
Fr=sqrt(Frx^2+Fry^2)
mprintf("Resultant force acting on charge at C=%f N", Fr)
//error in textbook answer
```

Scilab code Exa 2.2 Example on Electric Intensity

```

```

```
epsilon=8.854D-12
E1=(4D-8)/(4*%pi*epsilon*.05^2)//field intensity due to charge at A, direction is from D to A
r=sqrt(2*.05^2)//distance b/w B and D
E2=(4D-8)/(4*%pi*epsilon*r^2)//field intensity due to charge at B, direction is from B to D along diagonal BD
E3=(8D-8)/(4*%pi*epsilon*.05^2)//field intensity due to charge at C, direction is from D to C
//Er has horizontal and vertical components as Erx and Ery respectively
Erx=E3-E2*cos(45*%pi/180)
Ery=-E1+E2*sin(45*%pi/180)
Er=sqrt(Erx^2+Ery^2)
theta=atand(Ery/Erx)
mprintf("Resultant intensity on charge at C=%f*10^4 N/C at angle %f degrees", Er/10^4,-theta)
```

Scilab code Exa 2.3 Example on Electric Potential

```

epsilon=8.854D-12
AB=.05
BC=.07
AC=sqrt(.05^2+.07^2)
V1=2D-10/(4*%pi*epsilon*.05)//potential at A due to charge at B
V2=-8D-10/(4*%pi*epsilon*AC)//potential at A due to charge at C
V3=4D-10/(4*%pi*epsilon*.07)//potential at A due to charge at D
V=V1+V2+V3
mprintf("Potential at A due to charges at B, C and D =%f V", V)
```

Scilab code Exa 2.4 Example on charging and discharging of capacitor

```
C=30D-6
R=500
T=C*R
mprintf("Time constant T=%f sec\n", T)
//at t=0sec, voltage across capacitor is zero
V=100//aplied voltage
I=V/R//Ohm's Law
mprintf("Initial current=%f A\n", I)
t=.05
Q=C*V
q=Q*(1-exp(-t/T))
mprintf("Charge on the capacitor after 0.05 sec is
    %f C\n", q)
i1=I*exp(-t/T)
mprintf("Charging current after 0.05 sec is %f A\n",
    i1)
t=.015
i2=I*exp(-t/T)
mprintf("Charging current after 0.015 sec is %f A\n"
    ,i2)
V=i1*R
mprintf("Voltage across 500 ohm resistor after 0.05
    sec is %f V", V)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 2.5 Example on charging and discharging of capacitor

```
C=100D-6
V=200
Q=C*V
Ct=100D-6+50D-6//total capacitance
Vt=Q/Ct
mprintf("P.D. across the combination =%f V\n", Vt)
EE1=100D-6*V^2/2
mprintf("Electrostatic energy before capacitors are connected in parallel=%f J\n", EE1)
EE2=Ct*Vt^2/2
mprintf("Electrostatic energy after capacitors are connected in parallel=%f J", EE2)
```

Scilab code Exa 2.6 Example on charging and discharging of capacitor

```

C1=100D-6  //capacitance of first capacitor which is to be charged
V=200  //voltage across C1
Q=C1*V
//Let Q1, Q2, Q3, Q4 be the charges on respective capacitors after connection
Q2=4000D-6
Q3=5000D-6
Q4=6000D-6
Q1=Q-(Q2+Q3+Q4)
C2=C1*(Q2/Q1)
C3=C1*(Q3/Q1)
C4=C1*(Q4/Q1)
mprintf("Three capacitors have capacitances %d microF, %d microF and %d microF\n", C2*10^6,C3*10^6,C4*10^6)
Vt=Q1/C1
mprintf("Voltage across the combination =%f V", Vt)
```

Chapter 3

Electromagnetism

Scilab code Exa 3.2 Example on Field Strength and Flux Density

```

mu_not=4D-7*%pi
N=150  //no. of turns of coil
I=4  //current carried by coil
l=.3  //length of solenoid in mtrs
Bc=mu_not*N*I/l
mprintf("Flux density at centre =%f*10^-3 Wb/m^2",
   Bc*10^3)
```

Scilab code Exa 3.3 Example on Field Strength and Flux Density

```

mu_not=4D-7*%pi
//calculating flux density at centre of coil B=
   mu_not*I/(2*R)
I=50
R=4D-2
B=mu_not*I/(2*R)
```

```
mprintf("Flux density at centre of coil=%f*10^-6 Wb/m^2(Tesla)\n", B*10^6)
//calculating flux density perpendicular to plane of coil at a distance of 10 cm from it
z=10D-2
B=mu_not*I*R^2/(2*(R^2+z^2)^1.5)
mprintf("Flux density perpendicular to plane of coil at a distance of 10 cm from it=%f*10^-6 Wb/m^2(Tesla)", B*10^6)
```

Scilab code Exa 3.4 Example of Force on on Current Carrying Conductor

```


mu_not=4D-7*%pi
I1=30//current in wire A
I2=30//current in wire B
R=10D-2//distance b/w 2 wires
F=mu_not*I1*I2/(2*%pi*R)
mprintf("Force per metre length is %d*10^-4 N/m in both cases (i)and (ii). However in case(i), it is attractive and in case(ii), it is repulsive", F*10^4)
```

Scilab code Exa 3.5 Example of Force on on Current Carrying Conductor

```

B=.06//flux density
I=40D-3//current in coil
l=4D-2//length of coil side
F=B*I*l
N=50//no. of turns
```

```
mprintf("Force acting on each coil side=%f*10^-3 N",
   F*N*10^3)
```

Chapter 4

Magnetic Circuit

Scilab code Exa 4.1 Example on Series Magnetic Circuit

```


mu_not=4D-7*%pi
a=(3D-2)^2//cross-sectional area
La=(20-1.5-1.5)*1D-2//length of flux path in part A
mu_r=1000//relative permeability for part A
Sa=La/(mu_not*mu_r*a)
mprintf("Reluctance of part A=%f*10^4AT/Wb\n",Sa
    /10^4)
Lb=(17+8.5+8.5)*1D-2//length of flux path in part B
mu_r=1200//relative permeability for part B
Sb=Lb/(mu_not*mu_r*a)
mprintf("Reluctance of part B=%f*10^4AT/Wb\n",Sb
    /10^4)
Lg=(2+2)*1D-3//length of flux path in air gap
Sg=Lg/(mu_not*a)
mprintf("Reluctance of 2 air gaps=%f*10^4 AT/Wb\n",
    Sg/10^4)
S=Sa+Sb+Sg
mprintf("Total reluctance of magnetic circuit=%f
    *10^4 AT/Wb\n", S/10^4)
```

```
N=1000//no. of turns on each coil
I=1//current in coil
mmf=2*N*I
mprintf("mmf=%d AT\n", mmf)
flux=mmf/S
mprintf("Flux in magnetic circuit=%f*10^-4 Wb\n", flux*10^4)
flux_density=flux/a
mprintf("Flux density=%f Tesla", flux_density)
```

Scilab code Exa 4.2 Example on Series Magnetic Circuit

```
Bg=.7//flux density in air gap
Lg=3D-3//length of air gap
ATg=.796*Bg*Lg*1D+6
Bs=Bg//flux density in iron path
H=660//ampere turns corresponding to Bs from B-H curve(Fig.4.2) of textbook
Li=40D-2//length of flux path in iron portion
ATs=H*Li
AT=round(ATg)+round(ATs)
mprintf("Total ampere turns to be provided on the electromagnet=%d AT", AT)
//answer vary from the textbook due to round off error
```

Scilab code Exa 4.3 Example on Series Magnetic Circuit

```
mu_not=4D-7*%pi
N=700  //no. of turns on steel ring
```

```
I=2 //current carried by the winding on the ring
AT=N*I
mprintf("mmf produced=%d AT\n",AT)
ATi=.35*AT //iron portion takes 35% of total mmf
ATg=AT-ATi
l=1.5D-3 //length of flux path in air gap
B=mu_not*ATg/l
mprintf("Flux density=%f Wb/m^2\n", B)
d=3D-2 //diameter of circular section of ring
A=%pi*d^2/4 //cross-sectional area of ring
flux=B*A
mprintf("Magnetic flux=%f milliWb\n", flux*10^3)
S=AT/flux //Ohm's law for magnetic circuits
mprintf("Reluctance=%f*10^6 AT/Wb\n", S/10^6)
l=%pi*25D-2 //length of mean flux path in steel ring
H=ATi/l
mu_r=B/(H*mu_not)
mprintf("Rel. permeability of steel ring=%d", round(mu_r))
```

Scilab code Exa 4.4 Example on Series Magnetic Circuit

```

phi=.26D-3//flux
d=2D-2//diameter of circular cross-section of ring
A=%pi*d^2/4
B=phi/A
H=740//ampere turns per length of flux path corresponding to B as obtained from B-H curve of cast steel
L=90D-2//length of mean flux path in the cast steel ring
AT=H*L
N=800//no. of turns of the coil wound on the ring
```

```
I=AT/N
mprintf("Current in the coil=%f A\n",I)
Lg=2D-3//length of air gap
Li=L-Lg//length of mean flux path in ring
mu=B/H
Bg=AT/(Li/mu+.796*Lg*1D+6)
flux=Bg*A
mprintf("Magnetic flux produced=%f*10^-4 Wb\n",flux
    *1D+4)
//calculating value of current which will produce
    the same flux as in (i)
ATi=H*Li
ATg=.796*B*Lg*1D+6
AT=ATi+ATg
I=AT/N
mprintf("Current in the coil which will give the
    same flux as in (i)=%f A",I)
```

Scilab code Exa 4.5 Example on Series Magnetic Circuit

```

mu_not=4D-7*%pi
N=400   //number of turns on the coil wound on iron
    ring
I=1.2  //current through the coil
AT=N*I
l=1  //mean flux path in ring in mtrs
H=AT/l
B=1.15  //flux Density
mu_r=B/(H*mu_not)
mprintf("Rel permeability of iron ring mu_r=%d",
    round(mu_r))
//error in textbook answer
```

Scilab code Exa 4.6 Example on Series Magnetic Circuit

```
mu_not=4D-7*%pi
Li=50d-2//length of flux path in iron
mu_r=1300//relative permeability
a=12D-4//cross sectional area
Si=Li/(mu_not*mu_r*a)
mprintf("Reluctance of iron part of magnetic circuit
    =%f*10^3 AT/Wb\n",Si/10^3)
Lg=.4D-2//length of flux path in air gap
Sg=Lg/(mu_not*a)
mprintf("Reluctance of air gap of magnetic circuit=
    %f*10^3 AT/Wb\n",Sg/10^3)
S=Si+Sg
mprintf("Total reluctance of magnetic circuit=%f
    *10^3 AT/Wb\n",S/10^3)
N=400+400  //total no. of turns
I=1  //current through each coil
mmf=N*I
flux=mmf/S
mprintf("Total flux=%f milliWb\n", flux*10^3)
B=flux/a
mprintf("Flux density in air gap=%f Wb/m^2", B)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 4.7 Example on Series Magnetic Circuit

```
mu_not=4D-7*%pi
N=300//no. of turns in coil
```

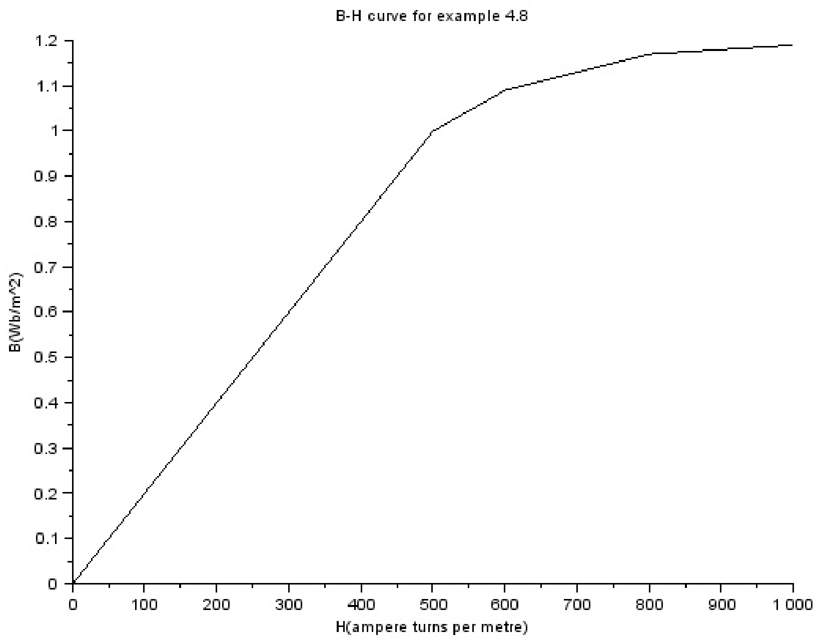

Figure 4.1: Example on Series Magnetic Circuit

```
I=.7//current through coil
AT=N*I
L=60D-2//length of ring
Lg=2D-3//length of air gap
Li=L-Lg//length of flux path in ring
mu_r=300//rel permeability of iron
B=AT/(Li/(mu_not*mu_r)+.796*Lg*1D+6)
mprintf("Flux density=%f Wb/m^2", B)
```

Scilab code Exa 4.8 Example on Series Magnetic Circuit

```
mu_not=4D-7*%pi
phi=.0006//flux
A=5.5D-4//cross-sectional area of ring
B=phi/A
h=[0 200 400 500 600 800 1000]
b=[0 .4 .8 1 1.09 1.17 1.19]
plot2d(h,b)
xtitle("B-H curve for example 4.8", "H(ampere turns
    per metre)", "B(Wb/m^2)")
H=600//corresponding to B from B-H curve
L=270D-2//length of ring
Lg=4.5D-3//length of air gap
Li=L-Lg//length of flux path in iron portion of ring
ATi=H*Li
ATg=.796*B*Lg*1D+6
AT=round(ATi)+round(ATg)
mprintf("Total ampere turns=%d", AT)
//error in textbook answer
```

Scilab code Exa 4.9 Example on Series Magnetic Circuit

```
mu_not=4D-7*%pi
flux=1.1D-3
A=4*4*1D-4//cross-sectional area
B=flux/A
mu_r=2000//rel permeability
H=B/(mu_not*mu_r)
//calculating ampere turns required for potion C
l=.25//length of mean flux path
ATc=H*l
//calculating ampere turns required for potion D
l=.3//length of mean flux path
ATd=H*l
```

```
//calculating ampere turns required for air gap
ATg=.796*B*.002*10^6
AT=round(ATc)+round(ATd)+round(2*ATg)
mprintf("Total ampere turns required=%d", AT)
//answer vary from the textbook due to round off
   error
```

Scilab code Exa 4.10 Example on Series Magnetic Circuit

```

mu_not=4D-7*%pi
flux=.018
//consider part A
a=205D-4  //cross sectional area
Ba=flux/a
H=760  //corresponding to Ba as obtained from Fig.
   4.2 in the textbook
l=(38-.25)*1D-2  //length of mean flux path in iron
   portion of part A
ATi=H*l
ATg=.796*Ba*2.5D-3*10^6
ATa=ATi+ATg
//consider part B
a=255D-4
Bb=flux/a
H=670  //corresponding to Bb as obtained from Fig.
   4.2 in the textbook
l=.25  //length of mean flux path in iron portion of
    part B
ATb=H*l
AT=round(ATa)+round(ATb)
mprintf("Total ampere turns required for complete
   magnetic circuit=%d", AT)
```

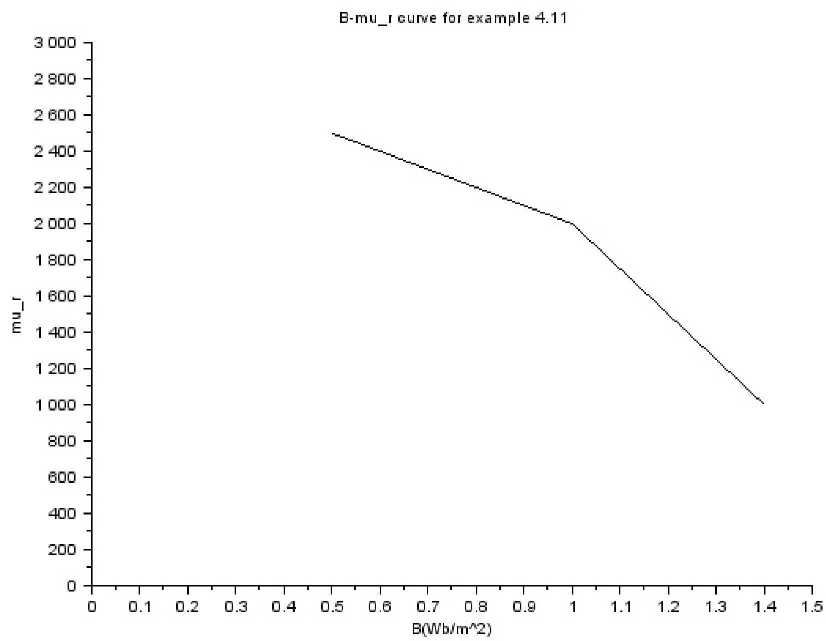

Figure 4.2: Example on Series Magnetic Circuit

Scilab code Exa 4.11 Example on Series Magnetic Circuit

```

mu_not=4D-7*%pi
b=[.5 1 1.2 1.4]
mu_r=[2500 2000 1500 1000]
plot2d(b,mu_r,rect=[0,0,1.5,3000])
xtitle("B-mu_r curve for example 4.11", "B(Wb/m^2)",
    "mu_r")

```

```
phi=.38D-3  //flux in ring
A=3D-4  //cross-sectional area
B=phi/A
mu_r=1300  //correspondng to B from B-mu_r curve
    plotted
H=B/(mu_not*mu_r)  //ampere turns per metre of flux
    path length
l=%pi*58D-2  //length of mean flux path
AT_iron=H*l
mprintf("Total ampere turns required by iron ring=%d
    \n", round(AT_iron))
//after saw cut of 1 mm width has been made
l=l-.1D-2  //length of mean flux path in iron
    portion of ring
ATi=H*l
ATg=.796*B*1D-3*1D+6
AT=round(ATi)+round(ATg)
mprintf("Extra ampere turns required =%d", round(AT)
    -round(AT_iron))
```

Scilab code Exa 4.12 Example on Series Parallel Magnetic Circuit

```

//two parallel magnetic circuits have equal
    reluctances
phi_cc=1.2D-3  //flux in central core
phi_ol=phi_cc/2  //flux in each outer limb
//calculating AT for central core
a=9D-4  //cross-sectional area
B_cc=phi_cc/a
H=1600 //corresponding to B_cc from Fig 4.2 in the
    textbook
l=.15  //length of mean flux path
AT_cc=H*l
//calculating AT for outer limbs
```

```
a=5D-4   //cross-sectional area
B_ol=phi_ol/a
H=1200   //corresponding to B_ol from Fig 4.2 in the
    textbook
l=.35   //length of mean flux path
AT_ol=H*l
AT=AT_cc+AT_ol
N=400
mprintf("Current required in the coil=%f A", AT/N)
```

Scilab code Exa 4.13 Example on Series Parallel Magnetic Circuit

```

mu_not=4D-7*%pi
phi_cc=1.2D-3   //flux in central core
phi_ol=phi_cc/2   //flux in each outer limb
//consider central core
a=9D-4   //cross-sectional area
B_cc=phi_cc/a   //flux density
H=1600   //corresponding to B_cc from Fig 4.2 in the
    textbook
l=(15-.2)*1D-2   //length of mean flux path of cast
    steel
AT_cc=H*l
ATg=.796*B_cc*2D-3*10^6
//consider outer limb
a=5D-2//cross-sectional area
B_ol=phi_ol/a
H=1200   //corresponding to B_ol from Fig 4.2 in the
    textbook
l=.35   //length of mean flux path
AT_ol=H*l
AT=AT_cc+ATg+AT_ol
N=400
mprintf("Exciting current in the coil=%f A",AT/N)
```

Chapter 5

Electromagnetic Induction

Scilab code Exa 5.1 Example on Induced EMF

```

N=1000//no. of turns in the coil
dphi=-2*900D-6//change in flux in Wb
dt=.2//time in sec in which change takes place
emf=-N*dphi/dt
mprintf("Average emf induced in the coil=%d V",round
   (emf))
```

Scilab code Exa 5.2 Example on Induced EMF

```

l=80D-2//length of conductor
B=1.2//flux density of uniform magnetic field
v=30//velocity of conductor in m/s
//when the direction of motion is perpendicular to
   field
e=B*l*v
mprintf("emf induced in the conductor when the
```

```
direction of motion is perpendicular to field=%f V\n",e)
//when the direction of motion is inclined 45 degrees to field
e=B*l*v*sin(%pi/4)
mprintf("emf induced in the coil when the direction of motion is inclined 45 degrees to field=%f V",e)
```

Scilab code Exa 5.3 Example on Induced EMF

```

N=120//no. of turns in coil
dphi=(.3-.8)*1D-3//change in flux due to motion of conductor
dt=.08//time taken for change in flux
e=-N*dphi/dt
mprintf("Induced emf in the coil=%f V\n",e)
R=200//resistance offered by the coil
I=e/R
mprintf("Induced current=%f mA",I*1000)
```

Scilab code Exa 5.4 Example on Induced EMF

```

mu_not=4D-7*%pi
N=3500//no. of turns on iron rod
I=.6//current through coil
AT=N*I
B=.45//flux density in Wb/m^2
l=25D-2//length of mean magnetic flux path
H=AT/l
mu_r=B/(H*mu_not)
```

```
mprintf("Relative permeability of metal=%f\n",mu_r)
A=%pi*2.5D-2^2/4//cross sectional area of ring
phi=B*A
L=N*phi/I
mprintf("Self inductance of coil=%f H\n",L)
//solving part(iii)
dphi=.08*phi-phi//change in flux
dt=.0015//time taken for change
e=-N*dphi/dt
mprintf("emf induced in the coil when value of flux
    falls to 8 percent its valiue in 0.0015 sec=%f V"
    ,e)
```

Scilab code Exa 5.5 Example on Induced EMF

```

mu_not=4D-7*%pi
H=3500//ampere turns per metre of flux path length
l=%pi*40D-2//length of mean flux path in ring
AT=H*l
N=440//no. of turns on coil
I=AT/N//exciting current
mprintf("Exciting current=%d A\n",round(I))
B=.9//flux density
A=15D-4//cross-sectional area of ring
phi=B*A
L=N*phi/I
mprintf("Self-inductance of coil=%f H\n",L)
//solving part(iii)
l=(l-1/10^2)//length of mean flux path in steel ring
ATi=H*l//ampere turns required for iron portion
ATg=.796*B*1D-2*1D+6//ampere turns for air gap
AT=ATi+ATg
I=AT/N
mprintf("When an air gap 1 cm long is cut in the
```

```
    ring, exciting current I=%f A and self inductance
     of coil=%f H\n",I,N*phi/I)
```

Scilab code Exa 5.6 Example on Induced EMF

```

N=800//no. of turns
dI=10-5//change in current
dB=1.2-.8//corresponding change in flux density
A=15D-4//cross sectional area
L=A*N*dB/dI
mprintf("Self inductance of coil,L=%f H\n",L)
di=5-10//change in current
dt=.04//time taken for change
e=-L*di/dt
mprintf("Induced emf when the current falls
    uniformly from 10 A to 5 A in 0.04 sec=%d V",
    round(e))
```

Scilab code Exa 5.7 Example on Induced EMF

```

mu_not=4D-7*%pi
N=1200//no. of turns in the coil on solenoid
l=80D-2//length of solenoid
A=%pi/4*(5D-2)^2//cross-sectional area
L=N*(mu_not*N*A/l)
mprintf("Self inductance=%f mH\n",L*1000)
//calculating induced emf
di=-5-5
dt=.03
e=-L*di/dt
mprintf("Induced emf=%f V",e)
```

Scilab code Exa 5.8 Example on Induced EMF

```
N=1500//no. of turns in coil A
phi=.04D-3//flux linking coil A in Wb
I=4//current in coil
La=N*phi/I
mprintf("Self inductance of coil A=%f mH. As the
   coils are identical, coil B will also have the
   same self-inductance. Hence, self-inductance of
   coil B=%f mH\n",La*1000,La*1000)
k=.7
M=N*k*phi/I
mprintf("Mutual inductance of arrangement=%f mH\n",M
   *1000)
di=-8
dt=.02
e=-M*di/dt
mprintf("Emf induced in the coil B due to a change
   of current in coil A=%f V\n",e)
```

Scilab code Exa 5.9 Example on Induced EMF

```
mu_not=4D-7*%pi
Ns=400//no. of turns on search coil
N=1000//no. of turns of wire on solenoid
M=mu_not*Ns*N*25D-4/80D-2
mprintf("Mutual inductance of arrangement=%f mH\n",M
   *1000)
//di/dt=200
```

```
e=-M*200
mprintf("emf induced in search coil=%f V",e)
```

Scilab code Exa 5.10 Example on Induced EMF

```

mu_not=4D-7*%pi
N=800//no. of turns for each solenoid
l=90D-2//length of each solenoid
Ax=%pi*(3D-2)^2/4//cross-sectional area of solenoid X
Ay=%pi*(6D-2)^2/4//cross-sectional area of solenoid Y
M=N*N*mu_not*Ax/l
mprintf("Mutual inductance of arrangement=%f mH\n",1000*M)
//calculating coupling co-efficient
Lx=N*mu_not*N*Ax/l
Ly=N*mu_not*N*Ay/l
k=M/sqrt(Lx*Ly)
mprintf("Coupling co-efficient=%f",k)
```

Scilab code Exa 5.11 Example on Induced EMF

```

mu_not=4D-7*%pi
Nb=500//no. of turns in coil B
l=120D-2//mean length of flux path in iron circuit
Na=50//no. of turns in coil A
mu_r=2000//relative permeability of iron
A=80*10^-4//cross-sectional area
M=Nb*mu_not*mu_r*Na*A/(l)
mprintf("Mutual inductance M=%f H\n",M)
```

```
di=12
dt=.015
e=-M*di/dt
mprintf("Emf induced in coil B=%f V",e)
```

Scilab code Exa 5.12 Example on Growth and Decay of Current in Inductive Circuits

```

V=110//applied voltage
L=.5//inductance of coil
r=V/L
mprintf("Rate of change of current=%d A/s\n",r)
R=8//resistance of coil
I=V/R
mprintf("Final steady current=%f A\n",I)
T=L/R
mprintf("Time constant=%f sec\n",T)
//solving part(iv)
t=-log(.5)*T
mprintf("Time taken for the current to rise to half
   its final value=%f sec",t)
```

Scilab code Exa 5.13 Example on Growth and Decay of Current in Inductive Circuits

```

//calculating time it will take current to reach .8
   of its final steady value
L=5//inductance of winding
R=50//resistance of winding
T=L/R
V=110//applied voltage
```

```
I=V/R//final steady current
i=.8*I
t=-T*log(1-i/I)
mprintf("Current grows to .8 times its final steady value, %f sec after the switch is closed\n",t)
//calculating time it will take for the current to reach .9 of its final steady value
i=.9*I
t=-T*log(1-i/I)
mprintf("Time taken for the current to grow to .9 time its final steady value is %f sec\n",t)
//calculating average emf induced
e=-L*(-2.2/.05)
mprintf("emf induced=%d V\n",round(e))
```

Scilab code Exa 5.14 Example on Growth and Decay of Current in Inductive Circuits

```

//calculating inductance and resistance of the relay
T=.004//time constant which is time taken for the current to rise to .632 of its final steady value
I=.35/.632//final steady value
V=200//applied voltage
R=V/I
L=T*R
mprintf("Resistance of relay circuit=%f ohm\nInductance of relay circuit=%f H\n",R,L)
//calculating initial rate of rise of current
r=V/L
mprintf("Initial rate of rise of current=%f A/s",r)
```

Scilab code Exa 5.15 Example on Growth and Decay of Current in Inductive Circuits

```

R=.5+40+15//total resistance
L=1//total inductance
T=L/R
V=12//emf of battery
I=V/R//final steady current in the circuit
i=.04//current at time t after closing the circuit
t=-T*log(1-i/I)
mprintf("The relay will begin to operate %f sec
   after the relay circuit is closed\n",t)
```

Scilab code Exa 5.16 Example on Energy Stored in Magnetic Field

```

mu_not=4*%pi*1D-7
//calculating inductance
N=4000//number of turns
I=2//current flowing in the solenoid
d=8D-2//diameter of solenoid
As=%pi/4*d^2
l=80D-2//length of solenoid in mtrs
phi=mu_not*N*I*As/l
L=N*phi/I
mprintf("Inductance=%f H\n",L)
//calculating energy stored in the magnetic field
E=L*I^2/2
mprintf("Energy stored in the magnetic field=%f J",E
   )
```

Scilab code Exa 5.17 Example on Energy Stored in Magnetic Field

```
mu_not=4D-7*%pi
//calculating exciting current
B=1.2//flux density
mu_r=500//rel permeability for iron
H=B/(mu_not*mu_r)
D=10D-2//mean diameter
l=%pi*D//length of flux path in the ring
AT=H*l
N=300//number of turns on the ring
I=AT/N
mprintf("Exciting current=%d A\n",round(I))
//calculating inductance
As=8D-4//cross-sectional area
phi=B*As
L=N*phi/I
mprintf("Inductance=%f H\n",L)
//calculating energy stored
E=L*I^2/2
mprintf("Energy stored=%f J\n",E)
//consider the case in which an air gap of 2 mm in the ring is made
li=l-2D-3//length of flux path in iron portion
lg=2D-3//length of air gap
ATi=H*li//ampere turns for iron portion
ATg=.796*B*lg*10^6//ampere turns for air gap
AT=ATi+ATg
I=AT/N
mprintf("When there is an air gap of 2mm in the ring\nExciting current=%f A\n",I)
L=N*phi/I
mprintf("Inductance=%f mH\n",L*1000)
E=L*I^2/2
mprintf("Energy stored=%f J\n",E)
```

Scilab code Exa 5.18 Example on Energy Stored in Magnetic Field

```

mu_not=4D-7*%pi
//calculating pull on the armature
mu_r=300//rel permeability of iron
AT=2000//total ampere turns
li=50D-2//length of iron path
lg=1.5D-3//length of air gap
B=AT/(li/(mu_not*mu_r)+.796*lg*10^6)
A=3D-4//area of each pole shoe
x=B^2*A/(2*mu_not)//pull on the armature at each
    pole
p=2*x
mprintf("Total pull due to both the poles=%f N\n",p)
//considering the gap closes to .2 mm
lg=.2*1D-3
B=AT/(li/(mu_not*mu_r)+.796*lg*10^6)
x=B^2*A/(2*mu_not)
p=2*x
mprintf("When the gap closes to .2 mm, total force
    needed due to both the poles, to pull the
    armature away=%f N",p)
//answer vary from the textbook due to round off
    error
```

Chapter 6

Fundamentals of Alternating Current

Scilab code Exa 6.1 Example on AC Wave Shapes

```

//plotting graph for i1
theta=linspace(0,2*%pi,100)
i1=50*sin(theta)+50*sin(theta-%pi/4)
plot(theta,i1)
//plotting graph for i2
theta=linspace(0,2*%pi,100)
i2=50*cos(theta)+50*cos(theta+%pi/4)
plot(theta,i2,"o")
//plotting graph for i3
i3=50*cos(theta)-20*sin(theta)
plot(theta,i3,"-*")
xtitle("Graphs of i1(-),i2(oo) and i3(-*)","theta","
    current")
//round off error while plotting graphs
```

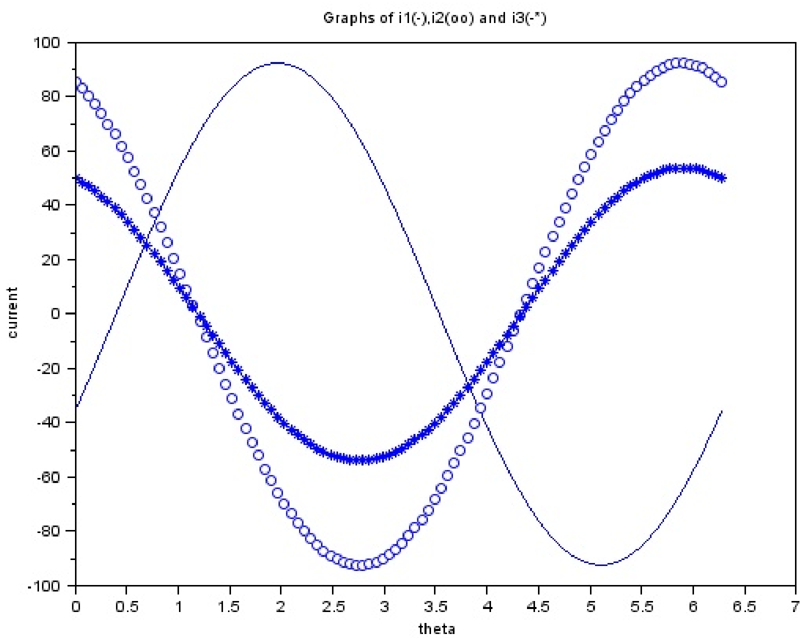

Figure 6.1: Example on AC Wave Shapes

Scilab code Exa 6.2 Example on AC Wave Shapes

```


//i=Imax*sin(2*%pi*f*t)
Imax=100//max value of current
f=25//frequency in Hz
//calculating time after which current becomes 20 A
i=20
t=asin(i/Imax)/(2*%pi*f)
mprintf("Time after which current becomes 20 A=%f
    sec\n",t)
//calculating time after which current becomes 50 A
i=50
t=asin(i/Imax)/(2*%pi*f)
mprintf("Time after which current becomes 50 A=%f
    sec\n",t)
//calculating time after which current becomes 100 A
i=100
t=asin(i/Imax)/(2*%pi*f)
mprintf("Time after which current becomes 100 A=%f
    sec\n",t)
```

Scilab code Exa 6.3 Example on AC Wave Shapes

```

//calculating instantaneous voltage at .005 sec
    after the wave passes through zero in positive
    direction
f=50//frequency
Emax=350//max value of voltage
t=.005
```

```
e1=Emax*sin(2*%pi*f*t)
mprintf("Voltage at .005 sec after the wave passes
   through zero in positive direction=%d V\n",e1)
//calculating instantaneous voltage at .008 sec
   after the wave passes through zero in negative
   direction
t=.008
e2=-Emax*sin(2*%pi*f*t)
mprintf("Voltage at .008 sec after the wave passes
   through zero in negative direction=%f V",e2)
```

Scilab code Exa 6.4 Example on AC Wave Shapes

```

//e=100*sin(100*%pi*t)
//calculating rate of change of voltage at t=.0025
   sec
t=.0025
r1=10000*%pi*cos(100*%pi*t)
mprintf("Rate of change of voltage at .0025 sec=%f V
   /sec\n",r1)
//calculating rate of change of voltage at t=.005
   sec
t=.005
r2=10000*%pi*cos(100*%pi*t)
mprintf("Rate of change of voltage at .005 sec=%d V/
   sec\n",r2)
//calculating rate of change of voltage at t=.01 sec
t=.01
r3=10000*%pi*cos(100*%pi*t)
mprintf("Rate of change of voltage at .01 sec=%f V/
   sec\n",r3)
//error in textbook answer in first and last case
```

Scilab code Exa 6.5 Example on AC Wave Shapes

```


//calculating greatest rate of change of current
//i=50*sin(100*%pi*t)
mprintf("Greatest rate of change of current=%f A/sec
    \n",50*100*%pi)
//calculating average value of current
f=50//frequency of the wave
T=1/f
Imean=1/.01*integrate("50*sin(100*%pi*t)","t",0,T/2)
mprintf("Average value of the given current=%f A\n",
    Imean)
Irms=sqrt(integrate("(50*sin(theta))^2","theta",0,2*
    %pi)/(2*%pi))
mprintf("RMS value of current=%f A\n",Irms)
//calculating time interval between a maximum value
    and next zero value
t=(%pi/2)/(100*%pi)
mprintf("Time interval between a maximum value and
    the next zero value is %f sec to %f sec",t,2*t)
//value of greatest rate of change of current is
    given wrong in the textbook due to approximation
```

Scilab code Exa 6.6 Example on AC Wave Shapes

```

i=linspace(0,0,2)
t=linspace(0,1,2)
```

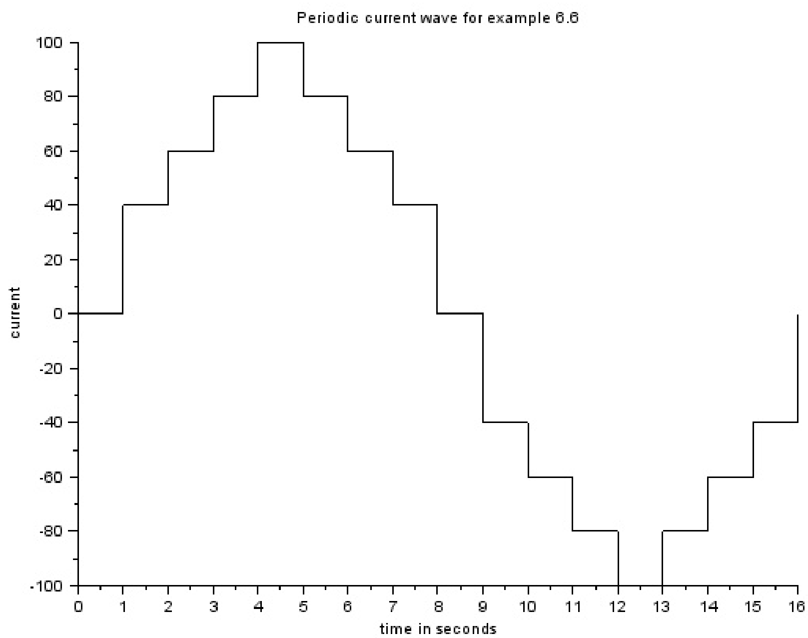

Figure 6.2: Example on AC Wave Shapes

```
plot2d(t,i)
for j=0:3
    i=linspace(40+20*j,40+20*j,2)
    t=linspace(j+1,j+2,2)
    plot2d(t,i)
    if j==0 then
        t=linspace(j+1,j+1,2)
        i=linspace(0,40,2)
        plot2d(t,i)
    else
        t=linspace(j+1,j+1,2)
        i=linspace(40+20*(j-1),40+20*j,2)
        plot2d(t,i)
    end
end
for j=1:3
    i=linspace(100-20*j,100-20*j,2)
    t=linspace(j+4,j+5,2)
    plot2d(t,i)
    i=linspace(100-20*(j-1),100-20*j,2)
    t=linspace(j+4,j+4,2)
    plot2d(t,i)
end
i=linspace(40,0,2)
t=linspace(8,8,2)
plot2d(t,i)
i=linspace(0,0,2)
t=linspace(8,9,2)
plot2d(t,i)
for j=0:3
    i=linspace(-(40+20*j),-(40+20*j),2)
    t=linspace(j+9,j+10,2)
    plot2d(t,i)
    if j==0 then
        t=linspace(j+9,j+9,2)
        i=linspace(0,-40,2)
        plot2d(t,i)
    else
```

```
        t=linspace(j+9,j+9,2)
        i=linspace(-40-20*(j-1),-40-20*j,2)
        plot2d(t,i)
end
end
for j=1:3
    i=linspace(-(100-20*j),-(100-20*j),2)
    t=linspace(j+12,j+13,2)
    plot2d(t,i)
    i=linspace(-100+20*(j-1),-100+20*j,2)
    t=linspace(j+12,j+12,2)
    plot2d(t,i)
end
i=linspace(0,-40,2)
t=linspace(16,16,2)
plot2d(t,i)
xtitle("Periodic current wave for example 6.6","time in seconds","current")

//calculating average value for this wave shape
Iavg=(0+40+60+80+100+80+60+40)/8
mprintf("Average value of current of given wave shape=%f A\n",Iavg)
//calculating RMS value for the given wave shape
Irms=sqrt((0^2+40^2+60^2+80^2+100^2+80^2+60^2+40^2)/8)
mprintf("RMS value of current of given wave shape=%f A\n",Irms)
//calculating form factor
x=Irms/Iavg
mprintf("Form factor of given wave form=%f\n",x)
//calculating peak factor
Imax=100//maximum value of current wave
y=Imax/Irms
mprintf("Peak factor of given wave=%f\n",y)
//calculating average and RMS value of current considering the wave to be sinusoidal having peak value of 100 A
```

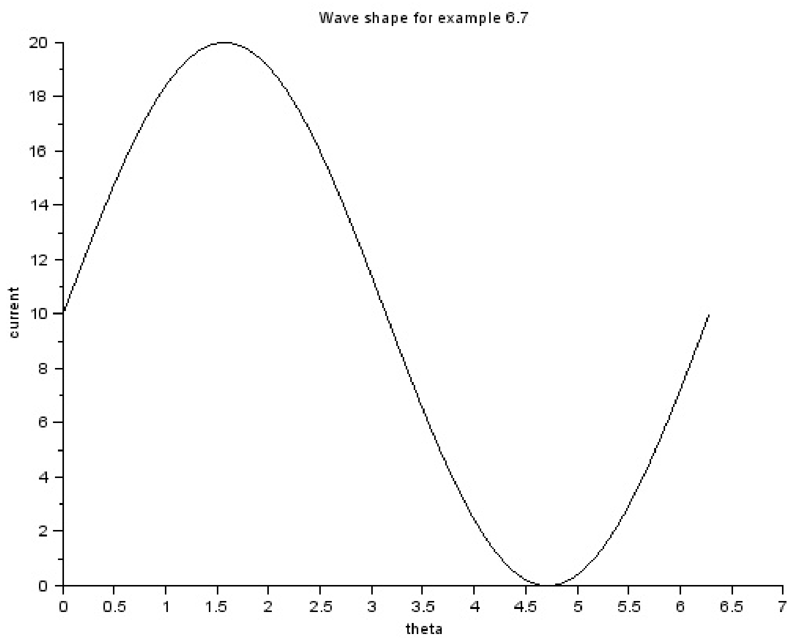

Figure 6.3: Example on AC Wave Shapes

```
Iavg=integrate('100/%pi*sin(theta)','theta',0,%pi)
mprintf("Average value of sine wave=%f A\n",Iavg)
Irms=sqrt(integrate('(100*sin(theta))^2/%pi','theta'
    ,0,%pi))
mprintf("RMS value of sine wave=%f A",Irms)
```

Scilab code Exa 6.7 Example on AC Wave Shapes

```

theta=linspace(0,2*%pi,100)
i=10+10*sin(theta)//expression for the resultant
```

```
wave
plot2d(theta,i)
xtitle("Wave shape for example 6.7","theta","current")

//calculating average value of the resultant wave
Iavg=integrate('10+10*sin(theta)','theta',0,2*%pi)/(2*%pi)
mprintf("Average value of the resultant current wave=%d A\n",Iavg)
//calculating RMS value of current of the resultant wave
Irms=sqrt(integrate('(10+10*sin(theta))^2','theta',0,2*%pi)/(2*%pi))
mprintf("RMS value of the resultant current wave=%f A",Irms)
```

Scilab code Exa 6.8 Example on AC Wave Shapes

```

theta=linspace(0,2*%pi,100)
i=50*sin(theta)
xset('window',0)
plot2d(theta,i)
xtitle("Current wave shape for example 6.8-->(a)","theta","current")

xset('window',1)
theta=linspace(0,%pi,100)
i=50*sin(theta)
plot2d(theta,i)
theta=linspace(%pi,2*%pi,100)
i=-50*sin(theta)
plot2d(theta,i)
xtitle("Current wave shape for example 6.8-->(b)","
```

```
    theta","current")

xset('window',2)
theta=linspace(0,0,2)
i=linspace(0,50,2)
plot2d(theta,i)
theta=linspace(0,%pi,2)
i=linspace(50,50,2)
plot2d(theta,i)
theta=linspace(%pi,%pi,2)
i=linspace(50,-50,2)
plot2d(theta,i)
theta=linspace(%pi,2*%pi,2)
i=linspace(-50,-50,2)
plot2d(theta,i)
i=linspace(-50,0,2)
theta=linspace(2*%pi,2*%pi,2)
plot2d(theta,i)
xtitle("Current wave shape for example 6.8-->(c)","
    theta","current")

xset('window',3)
theta=linspace(0,%pi/2,2)
i=linspace(0,50,2)
plot2d(theta,i)
theta=linspace(%pi/2,%pi,2)
i=linspace(50,0,2)
plot2d(theta,i)
theta=linspace(%pi,3*%pi/2,2)
i=linspace(0,-50,2)
plot2d(theta,i)
theta=linspace(3*%pi/2,2*%pi,2)
i=linspace(-50,0,2)
plot2d(theta,i)
xtitle("Current wave shape for example 6.8-->(d)","
    theta","current")

//consider wave shape (a)
```

```
mprintf("For wave shape (a)\nAs the negative and positive parts of the wave are equal, reading of moving coil ammeter is zero\n")
Irms=sqrt(integrate('(50*sin(theta))^2','theta',0,2*%pi)/(2*%pi))
mprintf("Reading of moving iron ammeter=%f A\n",Irms)

//consider wave shape (b)
Iavg=integrate('50*sin(theta)','theta',0,%pi)/%pi
mprintf("For wave shape (b)\nReading on the moving coil ammeter=%f A\n",Iavg)
Irms=sqrt(integrate('(50*sin(theta))^2','theta',0,2*%pi)/(2*%pi))
mprintf("Reading on moving iron ammeter=%f A\n",Irms)

//consider case (c)
mprintf("For wave shape (c)\nAverage value over one complete period is clearly zero. Thus reading on moving coil ammeter is zero. As the value of current remains constant at 50 A during various intervals, RMS value will be 50 A only. Hence, reading on moving iron ammeter=50 A\n")

//consider case(d)
Iavg=(0+10+20+30+40+50++40+30+20+10+0+(-10)+(-20)+(-30)+(-40)+(-50)+(-40)+(-30)+(-20)+(-10)+0)/20
mprintf("For wave shape (d)\nReading on moving coil ammeter=%d\n",Iavg)
Irms=sqrt((0^2+10^2+20^2+30^2+40^2+50^2+40^2+30^2+20^2+10^2+0^2+(-10)^2+(-20)^2+(-30)^2+(-40)^2+(-50)^2+(-40)^2+(-30)^2+(-20)^2+(-10)^2+0^2)/20)
mprintf("Reading on moving iron ammeter=%f A\n",Irms)
```

Scilab code Exa 6.9 Example on AC Wave Shapes

```
//let us assume V=1 V, T=1 sec
//e=V*t/T
V=1
T=1
Erms=sqrt(integrate("(V*t/T)^2","t",0, T)/T)
mprintf("RMS value of voltage is %f times maximum voltage\n",Erms/V)
Emean=integrate("V*t/T","t",0,T)/T
k=Erms/Emean
mprintf("Form factor of this wave=%f",k)
```

Scilab code Exa 6.10 Example on AC Wave Shapes

```
//the graph is drawn considering R=%pi
R=%pi
theta=linspace(-%pi,%pi,100)
V=sqrt(R^2-theta^2)
plot2d(theta,V)
xtitle("Wave shape for example 6.10","theta","Voltage")
theta=linspace(%pi,3*%pi,100)
V=-sqrt(R^2-(theta-2*%pi)^2)
plot2d(theta,V)

Vrms=sqrt(integrate('(R^2-x^2)/(2*R)','x',-R,R))
```

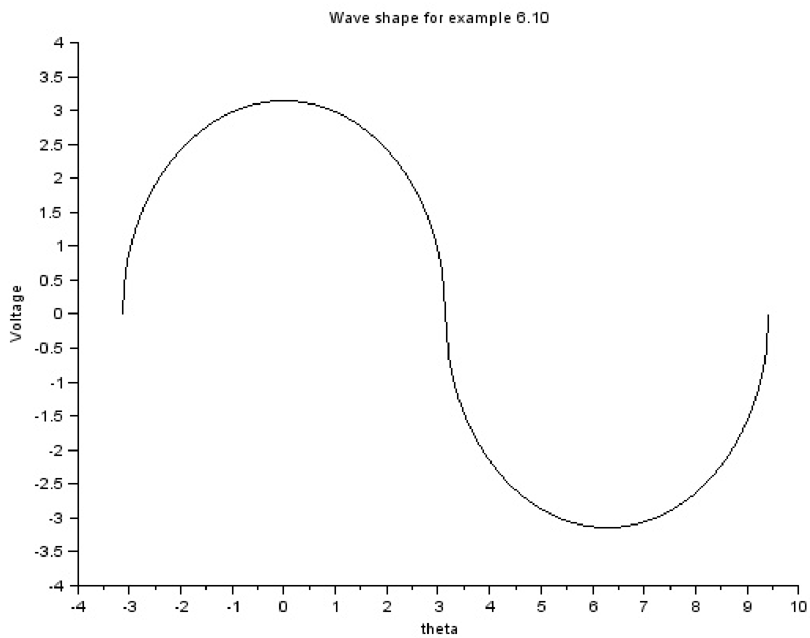

Figure 6.4: Example on AC Wave Shapes

```
mprintf("RMS value of such a wave shape will be %f of its maximum voltage",Vrms/R)
```

Scilab code Exa 6.11 Example on Phase Difference

```

//consider part (i)
phi=%pi/12
mprintf("For part (i)\nVoltage leads the current wave by %d degrees\n",round(phi*180/%pi))
f=377.16/(2*%pi)
mprintf("Frequency of the wave shape=%d Hz\n",f)
//consider part (ii)
phi=%pi/3
mprintf("For part (ii)\nVoltage leads the current by %d degrees\n",round(phi*180/%pi))
mprintf("Frequency of the wave shape=omega/(2*pi)\n")
//consider part (iii)
phi=0-(-%pi/2)
mprintf("For part (iii)\nVoltage leads the current wave by %d degrees\n",round(phi*180/%pi))
mprintf("Frequency of the wave shape=omega/pi\n")
//consider part (iv)
mprintf("For part (iv)\nCurrent wave lags the voltage by an angle=alpha+atan(x/R) and the frequency of this wave shape is omega/(2*pi)")
```

Scilab code Exa 6.13 Example on Simple AC Circuits

```

V=230//applied voltage
L=60D-3//inductance of coil
```

```
f=50 //frequency of supply
Xl=2*%pi*f*L
I=230/Xl
//if frequency is reduced to 20 Hz
Xl=2*%pi*20*L
I1=V/Xl
mprintf("Current through the coil if frequency is
    reduced to 20 Hz=%f A\n",I1)
//if frequency is increased to 60 Hz
Xl=2*%pi*60*L
I2=V/Xl
mprintf("Current through the coil if frequency is
    increased to 60 Hz=%f A\n",I2)
//if frequency is increased to 100 Hz
Xl=2*%pi*100*L
I3=V/Xl
mprintf("Current through the coil if frequency is
    increased to 100 Hz=%f A\n",I3)
```

Scilab code Exa 6.14 Example on Simple AC Circuits

```

//calculating reactance of capacitor
C=100D-6
Xc=1/(2*%pi*50*C)
mprintf("Capacitive reactance,Xc=%f ohm\n",Xc)
//calculating RMS value of current
V=200
Irms=V/Xc
mprintf("RMS value of current=%f A\n",Irms)
//calculating max current
Imax=Irms*sqrt(2)
mprintf("Maximum current=%f A",Imax)
```

Chapter 7

AC Series Circuit

Scilab code Exa 7.1 Example on AC Series Circuit

```
//calculating current flowing in the circuit
L=0.1//inductance
f=50//frequency
Xl=2*%pi*f*L
R=15//total resistance in the circuit
Z=sqrt(R^2+Xl^2)
V=230//voltage applied to series circuit
I=V/Z
mprintf("Current flowing in the circuit=%f A\n",I)
//calculating power factor
pf=R/Z
mprintf("Power factor of the circuit is %f(lagging)\nVoltage across reactor=%f V\nVoltage across resistor=%f V",pf,I*Xl,I*R)
```

Scilab code Exa 7.2 Example on AC Series Circuit

```
V1=200//voltage applied to non-inductive load
I1=20//current flowing through the load
R=V1/I1
V=230//applied voltage to series connection of R and L
I=I1
Z=V/I
Xl=sqrt(Z^2-R^2)
L=Xl/(2*%pi*50)
phi=atand(Xl/R)
mprintf("Inductance of the reactor=%f H, phase angle between applied voltage and the current is %f degrees",L,phi)
```

Scilab code Exa 7.3 Example on AC Series Circuit

```
//calculating resistance, reactance and impedance of choke coil
I=7.5//current flowing through the circuit
V1=110//voltage across non-inductive resistor
R=V1/I
V2=180//voltage across choke coil
Z=V2/I
Zt=230/I//impedance of whole circuit
r=(Zt^2-R^2-Z^2)/(2*R)
Xl=sqrt(Z^2-r^2)
mprintf("Reactance of coil=%f ohm\nResistance of coil=%f ohm\nImpedance of coil=%f ohm\n",Xl,r,Z)
//calculating total resistance and impedance of the circuit
Rt=r+R
Zt=sqrt(Rt^2+Xl^2)
mprintf("Total resistance of circuit=%f ohm\nTotal
```

```
   impedance of circuit=%f ohm\n",Rt,Zt)
//calculating power absorbed by the coil
P1=I^2*r
mprintf("Power absorbed by the coil=%f W\n",P1)
//calculating power drawn by circuit
P2=I^2*(r+R)
mprintf("Power drawn by the circuit=%f W\n",P2)
//calculating power factor of whole circuit
pf=Rt/Zt
mprintf("Power factor of the whole circuit=%f
   lagging",pf)
//answers vary from the textbook due to round off
   error
```

Scilab code Exa 7.4 Example on AC Series Circuit

```

//calculating current drawn at 50 Hz
V=220//voltage applied to choke coil
f=50//frequency of supply
I1=12//current taken by choke coil
R1=0//resistance of coil is negligible
Xl=V/I1
I2=16.5//current taken by the resistor
R=V/I2
Z=sqrt(R^2+Xl^2)
I=V/Z
mprintf("Current taken by the circuit at 50 Hz=%f A\
   n",I)
//calculating current drawn at 30 Hz
Xl_dash=30/50*Xl
Z_dash=sqrt(Xl_dash^2+R^2)
I=V/Z_dash
mprintf("Current drawn by the circuit at 30 Hz=%f A\
   n",I)
```

Scilab code Exa 7.5 Example on AC Series Circuit

```

//let resistance and inductance of the coil be R and
    L respectively
V=220//voltage applied to coil
f=50//frequency of supply
I=60//current indicated by ammeter
Z1=V/I
//when the frequency is increased to 100 Hz
I=40//current indicated by ammeter
Z2=V/I
//on solving for L
L=sqrt((Z2^2-Z1^2)/3)/(100*%pi)
R=sqrt(Z1^2-(100*%pi*L)^2)
mprintf("Resistance of coil=%f ohm\nInductance of
   coil=%f H",R,L)
```

Scilab code Exa 7.6 Example on AC Series Circuit

```

//calculating parameters of each coil
I=3//current through the circuit
//for coil A
Ra=12/3//resistance
Va=15//voltage drop
Za=Va/I
Xa=sqrt(Za^2-Ra^2)
//for coil B
Rb=6/3//resistance
Vb=9//voltage drop
```

```
Zb=Vb/I
Xb=sqrt(Zb^2-Rb^2)
//for coil C
Rc=9/3//resistance
Vc=12//voltage drop
Zc=Vc/I
Xc=sqrt(Zc^2-Rc^2)
mprintf("Parameters of\nCoilA: Ra=%f ohm, Xa=%f ohm\
    nCoil B: Rb=%f ohm, Xb=%f ohm\nCoil C: Rc=%f ohm,
     Xc=%f ohm\n",Ra,Xa,Rb,Xb,Rc,Xc)
//calculating power factor of each coil
pf_a=Ra/Za
pf_b=Rb/Zb
pf_c=Rc/Zc
mprintf("power factor of the coils are\npf_a=%f(
    lagging)\npf_b=%f(lagging)\npf_c=%f(lagging)\n",
    pf_a,pf_b,pf_c)
//calculating power dissipated for each coil
Pa=I^2*Ra
Pb=I^2*Rb
Pc=I^2*Rc
mprintf("Power dissipated in these coils:\nPa=%f W\
    nPb=%f W\nPc=%f W\n",Pa,Pb,Pc)
//calculating power factor of whole circuit
Rt=Ra+Rb+Rc
Xt=Xa+Xb+Xc
Zt=sqrt(Rt^2+Xt^2)
pf=Rt/Zt
mprintf("Power factor of the whole circuit=%f
    lagging\n",pf)
//calculating voltage applied across the whole
    circuit
V=I*Zt
mprintf("Voltage applied across the whole circuit=%f
     V",V)
```

Scilab code Exa 7.7 Example on AC Series Circuit

```

//r1 be the variable resistance
X=10//total inductive reactance of circuit
V=200//rms value of applied voltage
//RMS value of current I=200/sqrt((2+r1)^2+10^2)
//power consumed is P=I^2*r1
//For max power, dP/dr=0
//on solving
r1=sqrt(104)
mprintf("Value of variable resistor at the instant
    of max power consumed in it is %f ohm\n",r1)
//solving part(ii), let r2 be the variable
    resistance-I=200/sqrt((200+r2)^2+10^2),P=I^2*(2+
    r2)
//for max power, dP/dr=0
//on solving
r2=10-2
mprintf("Value of variable resistor=%d ohm for the
    condition of max power consumed by the circuit\n"
    ,round(r2))
I1=200/sqrt((2+r1)^2+10^2)
I2=200/sqrt((2+r2)^2+10^2)
pf1=(2+r1)/sqrt((2+r1)^2+10^2)
pf2=(2+r2)/sqrt((2+r2)^2+10^2)
mprintf("Current in case(i)=%f A at %f pf lagging\
    nCurrent in case(ii)=%f A at %f pf lagging\n",I1,
    pf1,I2,pf2)
```

Scilab code Exa 7.8 Example on AC Series Circuit

```

//both the coils draw lagging currents , hence both
    are inductive
//for coil A
Va=10//voltage applied
Ia=2//current drawn
Za=Va/Ia
pf=.8//power factor
Ra=pf*Za
Xa=sqrt(Za^2-Ra^2)
//for coil B
Vb=5//voltage applied
Ib=2//current drawn
Zb=Vb/Ib
pf=.7//power factor
Rb=pf*Zb
Xb=sqrt(Zb^2-Rb^2)

Rt=Ra+Rb//total resistance of circuit
Xt=Xa+Xb//total reactance of circuit
Z=sqrt(Rt^2+Xt^2)
V=Ia*Z
pf=Rt/Z
mprintf("Voltage to be applied to the circuit of
    coils A and B in series=%f V and pf=%f lagging",V
    ,pf)
```

Scilab code Exa 7.9 Example on AC Series Circuit

```

//calculating capacitance
Xc=4//capacitive reactance
f=50
omega=2*%pi*f
C=1/(omega*Xc)
```

```
mprintf("Capacitance C=%f microF\n",C*1D+6)
//calculating impedance
R=5//resistance of circuit
Z=sqrt(R^2+Xc^2)
mprintf("Impedance of circuit=%f ohm\n",Z)
//calculating current taken by circuit
V=200
I=V/Z
mprintf("Current drawn by circuit=%f A\n",I)
//calculating voltage drop across the resistance
Vr=I*R
mprintf("Voltage drop across the resistance=%f V\n",
   Vr)
//calculating voltage drop across the reactance
Vc=I*Xc
mprintf("Voltage drop across the reactance=%f V\n",
   Vc)
//calculating power factor
pf=R/Z
mprintf("Power factor of the circuit=%f leading",pf)
```

Scilab code Exa 7.10 Example on AC Series Circuit

```

//rating of bulb is 100 W,110 V
P=100
V=110
I=P/V//normal current of bulb
//voltage across bulb should be 110 V
Vc=sqrt(230^2-V^2)//voltage across the capacitance
Xc=Vc/I
C=1/(100*%pi*Xc)
mprintf("Capacitance of %f microF must be connected
   in series with the bulb",C*1D+6)
```

Scilab code Exa 7.11 Example on AC Series Circuit

```

C=35D-6//capacitance
f=50//frequency
Xc=1/(2*%pi*f*C)
Z=2*Xc//voltage applied across the capacitance is
    equal to half of total voltage applied
R=sqrt(Z^2-Xc^2)
mprintf("Resistance of variable resistor, R=%f ohm",
    R)
```

Scilab code Exa 7.12 Example on AC Series Circuit

```

//calculating current drawn
V=230//voltage applied
R=15+10//total resistance of the circuit
L=.04+.1//total inductance
Xl=2*%pi*50*L
C=100D-6//capacitance
Xc=1/(2*%pi*50*C)
X=Xl-Xc
Z=sqrt(R^2+X^2)
I=V/Z
mprintf("Current drawn=%f A\n",I)
//calculating voltages V1 and V2
Z1=sqrt(15^2+(2*%pi*50*.04)^2)
V1=I*Z1
phi1=atand(2*%pi*50*.04/15)
mprintf("V1=%f V and leads the current by %f degrees
    \n",V1,round(phi1))
```

```
Z2=sqrt(10^2+(2*%pi*50*.1-1/(2*%pi*50*100D-6))^2)
V2=I*Z2
phi2=acosd(10/Z2)
mprintf("V2=%f V and lags the current by %f degrees\n",V2,phi2)
//calculating power factor of overall circuit
pf=R/Z
mprintf("Power factor of overall circuit=%f lagging",pf)
//The answers vary from the textbook due to round off error
```

Scilab code Exa 7.13 Example on AC Series Circuit

```

//solving part(i)
Rb=5//resistance of coil B
Xb=2*%pi*50*.02//inductive reactance of coil B
Zb=sqrt(Rb^2+Xb^2)
phi_b=atand(Xb/Rb)//phase difference of Vb with current as reference phasor
phi_a=90*%pi/180-phi_b*%pi/180//Va and Vb are in quadrature
//Xc/R=tan(phi_a)
//Vb=2*Va-->R^2+Xc^2=Zb^2/4
//on solving for R and Xc
R=sqrt((Zb^2/4)/(1+tan(phi_a)^2))
Xc=tan(phi_a)*R
C=1/(2*%pi*50*Xc)
mprintf("R=%f ohm\nC=%f microF\n",R,C*1D+6)
//solving part(ii)
Rt=5+R//total resistance of circuit
Xt=Xb-Xc//resultant reactance of circuit
Zt=sqrt(Rt^2+Xt^2)
V=220//applied voltage
```

```
I=V/Zt
mprintf("Current drawn by the circuit=%f A\n",I)
//solving part(iii)
//as the reactance is positive, circuit is inductive
pf=Rt/Zt//lagging
mprintf("Power factor of the circuit=%f(lagging)\n",
    pf)
//the answers vary from the textbook due to round
    off error
```

Scilab code Exa 7.14 Example on AC Series Circuit

```

//calculating frequency of applied voltage
C=25.5D-6//capacitance
I=.4//current through circuit
V=50//voltage across capacitor
Xc=V/I
f=1/(2*%pi*C*Xc)
mprintf("Frequency=%d Hz\n",round(f))
//calculating parameters of choke coil
V=35//voltage across choke coil
Z=V/I//impedance of choke coil
//r^2+(100*%pi*L)^2=Z^2
R=20/.4
Vac=45//voltage across ac portion of circuit
Zac=Vac/I//impedance of ac portion
//(R+r)^2+(100*%pi*L)^2=Zac^2
//solving for r and L
r=(Zac^2-Z^2-R^2)/(2*R)
L=sqrt(Z^2-r^2)/(100*%pi)
Xl=2*%pi*50*L
mprintf("Parameters of choke coil:\nResistance=%f
    ohm\nInductance=%f H\nInductive reactance=%f ohm\
    n",r,L,Xl)
```

```
//calculating applied voltage
Z=sqrt((R+r)^2+(Xl-Xc)^2)
V=I*Z
mprintf("Voltage applied to the circuit=%f V\n",V)
//calculating losses in choke coil
W=I^2*r
mprintf("Losses in choke coil=%d W\n",round(W))
```

Scilab code Exa 7.15 Example on AC Series Circuit

```

//calculating capacitance to give resonance
Xl=2*%pi*50*.4
Xc=Xl
C=1/(2*%pi*50*Xc)
mprintf("Capacitance=%f microF\n",C*1D+6)
//calculating current
R=5
Z=R
V=110
I=V/Z
mprintf("current drawn=%f A\n",I)
//calculating voltage across inductance
Xl=2*%pi*50*.4
Vl=I*Xl
mprintf("Voltage across inductance=%f V\n",Vl)
//calculating voltage across capacitance
Xc=Xl
Vc=I*Xc
mprintf("Voltage across capacitance=%f V\n",Vc)
//calculating Q-factor
Q_factor=Vl/V
mprintf("Q-factor of the circuit=%f",Q_factor)
```

Chapter 8

AC Parallel Circuit

Scilab code Exa 8.1 Example on Phasor Method

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
//calculating current in each branch and its angle
    of lag or lead
V=230
f=50
```

```
//for branch A
Ra=10//resistance
L=.04//inductance
Xl=2*%pi*f*L//inductive reactance
Za=sqrt(Ra^2+Xl^2)//impedance
Ia=V/Za
phi_a=atand(Xl/Ra)
//for branch B
R=25//resistance
Zb=R//impedance
Ib=V/Zb
phi_b=0
mprintf("Current in branch A, Ia=%f A lagging the applied voltage by %f degrees\nCurrent in branch B, Ib=%f A in phase with applied voltage\n",Ia,phi_a,Ib)
//calculating current drawn by the circuit
Ia=pol2rect(Ia,phi_a)
Ib=pol2rect(Ib,0)
I=Ia+Ib
mprintf("Total current drawn by the circuit=%f A\n",mag(I))
phi=atand(imag(I)/real(I))
mprintf("Phase angle of combination=%f degrees and power factor =%f lagging",phi,cos(phi*%pi/180))
```

Scilab code Exa 8.2 Example on Phasor Method

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
```

```
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
//solving part (i)
Xa=2*%pi*50*.1//inductive reactance of branch A
Za=sqrt(50^2+Xa^2)
Ia=230/Za
phi_a=atand(Xa/50)//angle of lag of Ia w.r.t. applied voltage
Ia=pol2rect(Ia,-phi_a)
Xb=1/(2*%pi*50*100D-6)//capacitive reactance of branch B
Zb=sqrt(45^2+Xb^2)
Ib=230/Zb
phi_b=atand(Xb/45)//angle of lead of Ib w.r.t. applied voltage
Ib=pol2rect(Ib,phi_b)
I=Ia+Ib
mprintf("Current drawn by the circuit=%f A\n", mag(I))
//calculating power factor
phi=atan(imag(I)/real(I))//phase angle of the circuit
pf=cos(phi)
mprintf("Power factor of the circuit=%f(leading)\n",pf)
//calculating power taken by the parallel circuit
P=230*mag(I)*pf
mprintf("Power taken by the parallel circuit=%d W",round(P))
//The answers vary from the textbook due to round
```

```
off error
```

Scilab code Exa 8.3 Example on Phasor Method

```


function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
//calculating current in coil A
Xa=2*%pi*50*.02//inductive reactance of coil A
Za=sqrt(12^2+Xa^2)
Ia=200/Za
phi_a=atand(Xa/12)//angle of lag of Ia w.r.t.
   applied voltage
mprintf("Ia=%f A, lagging the applied voltage by %f
   degrees\n", Ia, phi_a)
//calculating current in coil B
Xb=2*%pi*50*.03//inductive reactance of coil B
Zb=sqrt(6^2+Xb^2)
Ib=200/Zb
phi_b=atand(Xb/6)//angle of lag of Ib w.r.t. applied
```

```
voltage
mprintf("Ib=%f A, lagging the applied voltage by %f degrees\n", Ib, phi_b)
//calculating total current in the circuit
Ia=pol2rect(Ia,-phi_a)
Ib=pol2rect(Ib,-phi_b)
I=Ia+Ib
mprintf("Total current drawn by circuit=%f A lagging the applied voltage by %f degrees\n", mag(I),-atand(imag(I)/real(I)))
//calculating total current when additional circuit is added
Xc=1/(2*%pi*50*120D-6)//capacitive reactance
Zc=sqrt(15^2+Xc^2)
Ic=200/Zc
phi_c=atand(Xc/15)//angle of lag of Ic w.r.t. applied voltage
Ic=pol2rect(Ic,phi_c)
I=Ia+Ib+Ic
phi=atand(imag(I)/real(I))
mprintf("For the new circuit , total current drawn=%f A lagging the applied voltage by %f degrees , i.e . pf=%f(lagging)", mag(I),-phi,cos(phi*%pi/180))
```

Scilab code Exa 8.4 Example on Phasor Method

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
```

```
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
//for coil A
Ia=5//current taken
Va=110//voltage applied
Pa=300//power dissipated
Ra=Pa/Ia^2
Za=Va/Ia
Xa=sqrt(Za^2-Ra^2)
//for coil B
Ib=5//current taken
Vb=110//voltage applied
Pb=400//power dissipated
Rb=Pb/Ib^2
Zb=Vb/Ib
Xb=sqrt(Zb^2-Rb^2)
//calculating current drawn and power factor when
   coils conected in series
R=Ra+Rb
Xl=Xa+Xb
Z=sqrt(R^2+Xl^2)//impedance of series circuit
I=Va/Z
pf=R/Z
mprintf("Current in the series circuit=%f A at pf=%f
    lagging\n", I,pf)
//calculating current drawn and power factor when
   coils conected in parallel
Ia=pol2rect(Ia,-acosd(Ra/Za))
Ib=pol2rect(Ib,-acosd(Rb/Zb))
I=Ia+Ib
phi=atan(imag(I)/real(I))
mprintf("Total current drawn by the parallel circuit
```

```
=%f A at pf=%f(lagging)", mag(I),cos(phi))
```

Scilab code Exa 8.5 Example on Admittance Method

```

function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//solving part (i)
//for coil 1
Z1=5+2*%pi*50*.03*j//impedance
Y1=1/Z1
G1=real(Y1)
B1=imag(Y1)
mprintf("For coil 1,\nConductance=%f mho\
   nSuspectance=%f mho\nAdmittance=%f mho\n", G1,-B1
   ,mag(Y1))
//for coil 2
Z2=3+2*%pi*50*.04*j//impedance
Y2=1/Z2
G2=real(Y2)
B2=imag(Y2)
mprintf("For coil 2,\nConductance=%f mho\
   nSuspectance=%f mho\nAdmittance=%f mho\n", G2,-B2
   ,mag(Y2))
//solving part(ii)
Y=Y1+Y2//total admittance
I=200*Y
phi=atan(imag(I)/real(I))
pf=cos(phi)
mprintf("Total current drawn by the circuit=%f A at
   pf of %f(lagging)\n",mag(I),pf)
```

```
//calculating power
P=200*mag(I)*pf
mprintf("Power absorbed by the circuit=%f W\n",P)
//solving part(iv)
Z=1/Y
R=real(Z)
Xl=imag(Z)
L=Xl/(2*%pi*50)
mprintf("R=%f ohm, L=%f H of single coil which will
    take the same current and power as taken by the
    original circuit",R,L)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 8.6 Example on Symbolic Method

```

function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//voltage V is taken as reference phasor
Z1=5+10*j//impedance of inductive branch
Z2=10-15*j//impedance of capacitive branch
I=20//total current
V=I/mag(1/Z1+1/Z2)
mprintf("Applied voltage=%f V\n",V)
//calculating power factor of total current
I1=V/Z1
I2=V/Z2
I=I1+I2
phi=atan(imag(I)/real(I))//angle of lag
pf=cos(phi)
```

```
mprintf("Power factor of the total circuit=%f(lagging)\n",pf)
//calculating power taken by each branch
R1=5//resistance of branch 1
P1=mag(I1)^2*R1
R2=10//resistance of branch 2
P2=mag(I2)^2*R2
mprintf("Power taken by inductive branch=%f W\nPower taken by capacitive branch=%f W", P1,P2)
//answers vary from the textbook due to round off error
```

Scilab code Exa 8.7 Example on Symbolic Method

```

function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
//for coil A
Va=10//voltage applied
Ia=2//current taken
pf=.8//lagging power factor
Ia=pol2rect(Ia,-acosd(pf))
Za=Va/Ia//impedance
//for coil B
Vb=5//voltage applied
Ib=2//current taken
pf=.7//lagging power factor
```

```
Ib=pol2rect(2,-acosd(pf))
Zb=Vb/Ib//impedance
//calculating voltage required to produce a current of 2 A with A and B in series
I=2
Z=Za+Zb//impedance of series circuit
V=I*mag(Z)
mprintf("Voltage required to produce a current of 2 A with A and B in series=%f V\n", V)
//calculating voltage required to produce a current of 2 A with A and B in parallel
Z=Za*Zb/(Za+Zb)//impedance of parallel circuit
V=I*mag(Z)
mprintf("Voltage required to produce a current of 2 A with A and B in parallel=%f V\n", V)
//The answers vary from the textbook due to round off error
```

Scilab code Exa 8.8 Example on Symbolic Method

```

//calculating value of unknown capacitance
V=110//applied voltage
R=30//resistance of resistive circuit
Ir=V/R//Ohm's Law
I=5//total current drawn
Xc=V/sqrt(I^2-Ir^2)
f=50//frequency of supply
C=1/(2*%pi*f*Xc)
mprintf("Capacitance=%f microF\n",C*10^6)
//calculating unknown frequency
I=4//total current drawn
f=sqrt(I^2-Ir^2)/(V*2*%pi*C)
mprintf("To decrease the total current to 4 A, the frequency of the supply should be adjusted to %f
```

```
    Hz",f)
//The answers vary from the textbook due to round
    off error
```

Scilab code Exa 8.9 Example on Symbolic Method

```

function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction

j=%i
R1=12//resistance of series circuit
X1=2*%pi*50*.025//inductive reactance of the series
    circuit
Z1=R1+X1*j
pf1=R1/mag(Z1)//power factor of the series circuit(
    lagging)
//the impedances and power factor of the parallel
    circuit are to be same as that of series circuit
//on solving, we get, R*Xl/sqrt(R^2+Xl^2)=mag(Z1);
    Xl/(sqrt(R^2+Xl^2))=pf1
R=mag(Z1)/pf1
//solving for Xl
Xl=pf1*R/sqrt(1-pf1^2)
L=Xl/(2*%pi*50)
mprintf("Resistance=%f ohm; Inductance=%f H\n",R,L)
//calculating current in each case
V=230//applied voltage
I1=V/mag(Z1)
mprintf("Current in series circuit=%f A\n",I1)
I2=V/mag(Z1)
mprintf("Current drawn by parallel circuit=%f A",I2)
```

```
//The answers vary from the textbook due to round
   off error
```

Scilab code Exa 8.10 Example on Series Parallel Circuit

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//calculating impedance of overall circuit
Za=2+0*j//impedance of branch A
Zb=3+4*j//impedance of branch B
Zab=Za*Zb/(Za+Zb)//equivalent impedances of branches
    A and B
Zc=2-2*j
Z1=Zab*Zc/(Zab+Zc)//equivalent impedance of parallel
    circuit
Zd=1+1*j//impedance of branch D
Z=Z1+Zd
[Z theta]=rect2pol(Z)
mprintf("Total impedance of overall circuit=%f ohm
```

```
at angle %f degrees\n", Z,theta)
//calculating current taken by overall circuit
V=110//voltage applied to the overall circuit
I=V/Z
mprintf("Current taken by the overall circuit=%f A\n", I)
//Calculating power consumed in each branch and total power consumed
Id=I//current in the series branch
Rd=1//resistance of branch D
Pd=I^2*Rd//power consumed by branch D
Ia=I*mag(Z1)/mag(Za)//current in branch A
Ib=I*mag(Z1)/mag(Zb)//current in branch B
Ic=I*mag(Z1)/mag(Zc)//current in branch C
Ra=2
Pa=Ia^2*Ra
Rb=3
Pb=Ib^2*Rb
Rc=2
Pc=Ic^2*Rc
P=Pa+Pb+Pc+Pd
mprintf("Power consumed by branch A=%f W,\nPower consumed by branch B=%f W,\nPower consumed by branch C=%f W,\nPower consumed by branch D=%f W,\nTotal power consumed=%f W",Pa,Pb,Pc,Pd,P)
//The answers vary from the textbook due to round off error
```

Scilab code Exa 8.11 Example on AC Network Theorems

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
```

```
    theta=atand(y/x)
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//using Maxwell's mesh analysis
//refer Fig.8.14 in the textbook
//considering mesh FDCEF, (18+8*j)*I1-(10+8*j)*I2=24
//considering mesh ABCDA, (10+8*j)*I1-(14+10*j)*I2=0
a=[18+8*j -(10+8*j);10+8*j -(14+10*j)]
b=[24;0]
x=inv(a)*b
I1=x(1,1)
I2=x(2,1)
[I2 theta]=rect2pol(I2)
mprintf("By Maxwell Mesh Analysis, current in branch AB of the circuit shown is %f A, lagging the applied voltage by %f degrees\n",I2, -theta)
//using thevenin's theorem
//refer Fig.8.14(a),(b) and (c)
Zth=8*(10+8*j)/(8+10+8*j)+(-4*j)//thevenin's impedance
//for calculating the equivalent Thevenin's voltage Vth, I1 be the current flowing in the branch CD
I1=24/(8+10+8*j)
Vth=I1*(10+8*j)//equivalent thevenin's voltage
I=Vth/((4+6*j+Zth))
[I theta]=rect2pol(I)
mprintf("By Thevenin Theorem, current in the branch AB is %f A lagging the voltage by %f degrees\n",I,-theta)
```

Scilab code Exa 8.12 Example on Resonance in Parallel Circuits

```

function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
V=200
//calculating supply frequency
L=.1//inductance of branch A
//Xa=2*%pi*f*.1
Ra=10//resistance of branch A
C=150D-6//capacitance of branch B
//Xb=1/(2*%pi*f*150D-6)
Rb=0//resistance of branch B
//Zb=-Xb*j
//total current I=Ia+Ib, total current is in phase
   with voltage-->j component of I=0
//on solving for f,
f=sqrt((V*2*%pi*L)*(1/(2*%pi*C))/V-Ra^2)/(2*%pi*L)
mprintf("Frequency of the supply which is also the
   resonant frequency, f=%f Hz\n", f)
Xa=2*%pi*f*.1
Za=Ra+Xa*j
Ia=V/Za
Xb=1/(2*%pi*f*150D-6)
Zb=-Xb*j
Ib=V/Zb
I=Ia+Ib
mprintf("Total current drawn by the circuit=%f A",
   mag(I))
//The answers vary from the textbook due to round
   off error
```

Scilab code Exa 8.13 Example on Resonance in Parallel Circuits

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//calculating branch currents
Z1=15+12*j//impedance of branch 1
I1=200/Z1
phi1=atand(12/15)
Z2=25-17*j//impedance of branch 2
I2=200/Z2
phi2=atand(17/25)
mprintf("I1=%f A at angle of %f degrees\nI2=%f A at
   angle of %f degrees\n",mag(I1),phi1,mag(I2),phi2)
//calculating total current
I=I1+I2
[I phi]=rect2pol(I)
mprintf("Total current drawn by the circuit I=%f A,
   angle of lag=%f degrees and power factor=%f
   lagging\n",I,-phi,cos(phi*%pi/180))
//power factor is to be raised to unity-a capacitor
   has to be connected in parallel
//at unity power factor, imaginary part of I must be
    zero
```

```
Xc=-200/imag(I1+I2)
f=40
C=1/(2*%pi*f*Xc)
mprintf("If power factor is to be raised to unity-a
   capacitor of %f microF has to be connected in
   parallel to given circuit", C*1D+6)
```

Chapter 9

Three Phase Systems

Scilab code Exa 9.1 Example on Three Phase Circuits

```

function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction

j=%i
//considering coils to be star connected
Vl=400//line voltage
Vph=Vl/sqrt(3)
Rph=15//resistance of load
Xl=2*%pi*50*.03//inductive reactance of each coil
Zph=Rph+Xl*j
Iph=Vph/mag(Zph)
Il=Iph
pf=Rph/mag(Zph)//power factor
P=sqrt(3)*Vl*Il*pf
mprintf("In star connected circuit,\nPhase current=
    %f A,\nLine current=%f A,\nPower absorbed=%f kW\n
    ", Iph, Il,P/10^3)
```

```
//considering coils to be delta connected
Vph=Vl
Iph=Vph/mag(Zph)
Il=sqrt(3)*Iph
P=sqrt(3)*Vl*Il*pf
mprintf("In delta connected circuit,\nPhase current=
    %f A,\nLine current=%f A,\nPower absorbed=%f kW\n
    ", Iph, Il,P/10^3)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 9.2 Example on Three Phase Circuits

```

//calculating phase current
Vl=440//line voltage
Vph=Vl
Pout=200D+3//output
e=.91//efficiency
Pin=Pout/e//input
pf=.86//power factor
Iph=Pin/(3*Vph*pf)
mprintf("Current drawn by each motor phase=%f A\n",
    Iph)
//calculating line current
Il=sqrt(3)*Iph
mprintf("Line current=%f A\n", Il)
//calculating active and reactive components of
    phase current
phi=acos(pf)
Iact=Iph*pf
Ireact=Iph*sin(phi)
mprintf("Active component of phase current=%f A\
    nReactive component of phase current=%f A",Iact,
    Ireact)
```

Scilab code Exa 9.3 Example on Three Phase Circuits

```
Vl=400//line voltage across alternator and motor
Vph=Vl//as the motor is delta connected
Pout=112D+3//output of motor
e=.88//efficiency of motor
Pin=Pout/e//input to motor
pf=.86
phi=acos(pf)
Il=Pin/(sqrt(3)*Vl*pf)
Iph=Il/sqrt(3)
mprintf("Current in each motor phase, Iph=%f A\n",Iph)
//alternator is star connected
mprintf("Current in each alternator phase=%f A\n",Il)
//calculating active and reactive components of current in each phase of motor
Iact=Iph*pf
Ireact=Iph*sin(phi)
mprintf("Active component of current in each phase of motor=%f A\nReactive component of current in each phase of motor=%f A\n", Iact,Ireact)
//phase angle between the phase voltage and phase current will be the same for both motor and alternator if we neglect line impedance
Iph=Il
Iact=Iph*pf
Ireact=Iph*sin(phi)
mprintf("Active component of current in each phase of alternator=%f A\nReactive component of current in each phase of alternator=%f A\n", Iact,Ireact)
```

```
//The answers vary from the textbook due to round
   off error
```

Scilab code Exa 9.4 Example on Three Phase Circuits

```

function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction

//calculating current in each line
Vl=400//line voltage
Vph=Vl/sqrt(3)//phase voltage
Ir=8D+3/Vph
Iy=6D+3/Vph
Ib=4D+3/Vph
mprintf("Current in R-phase,Ir=%f A\nCurrent in Y-
   phase,Iy=%f A\nCurrent in B-phase,Ib=%f A\n",Ir,
   Iy,Ib)
//Loads on three phases are resistive
Ir=pol2rect(Ir,0)
Iy=pol2rect(Iy,-120)
Ib=pol2rect(Ib,-240)
In=Ir+Iy+Ib
mprintf("Current in the neutral=%f A", mag(In))
```

Scilab code Exa 9.5 Example on Three Phase Circuits

```
Pout=30D+3//output
e=.86//efficiency
Pin=Pout/e//input
Vl=440//line voltage
pf=.83//power factor
Il=Pin/(sqrt(3)*Vl*pf)
mprintf("Line current=%f A\n", Il)
Iph=Il/sqrt(3)//motor is delta connected
mprintf("Phase current=%f A", Iph)
```

Scilab code Exa 9.6 Example on Three Phase Circuits

```
function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//calculating phase currents-let the sequence be RYB
Vl=440//line voltage
```

```
Vph=Vl//delta connected load
Zph1=150//impedance of the phase between A and B(resistive)
I1=Vph/Zph1
mprintf("I1=%f A at 0 degrees w.r.t. Vry\n", I1)
Zph2=30+50*j//impedance of the phase between B and C
I2=Vph/mag(Zph2)
//as the load is inductive, current will lag the voltage Vyb by phi2
phi2=atand(50/30)
mprintf("I2=%f A at -%f degrees w.r.t. Vyb\n", I2, phi2)
C=20D-6
f=50
Xc=-(1/(2*%pi*f*C))*j
I3=Vph/mag(Xc)
//as the load is capacitive, current will lead the voltage Vbr by 90 degrees
mprintf("I3=%f A at 90 degrees w.r.t. Vbr\n", I3)

//calculating line currents-
Vry=pol2rect(440,0)
Vyb=pol2rect(440,-120)
Vbr=pol2rect(440,-240)
I1=Vry/Zph1
I2=Vyb/Zph2
I3=Vbr/Xc
//using KCL
Ir=I1-I3
Iy=I2-I1
Ib=I3-I2
mprintf("Current in line R, Ir=%f A,\nCurrent in line Y, Iy=%f A,\nCurrent in line B, Ib=%f A,\n", mag(Ir),mag(Iy),mag(Ib))
```

Scilab code Exa 9.7 Example on Three Phase Circuits

```
Vl=1100//line voltage
Vph=Vl/sqrt(3)//star connected load
Il=80//current through load
Iph=Il
Zph=Vph/Iph
P=100D+3//power drawn by load
pf=P/(sqrt(3)*Vl*Il)//power factor
Rph=Zph*pf
Xc=sqrt(Zph^2-Rph^2)
f=50
C=1/(2*%pi*f*Xc)
mprintf("Capacitance per phase=%f microF", C*10^6)
//Answer vary from the textbook due to round off
   error
```

Scilab code Exa 9.8 Example on Power Measurement

```
W1=15D+3//reading of first wattmeter
W2=-1.5D+3//reading of second wattmeter
W=W1+W2//total power fed to the load
mprintf("Total power fed to the load=%f kW\n",W
   /10^3)
phi=atand(sqrt(3)*(W1-W2)/W)
mprintf("Power factor angle, phi=%f degrees\nPower
   factor of load=%f", phi, cos(phi*%pi/180))
```

Scilab code Exa 9.9 Example on Power Measurement

```
W1=115D+3
W2=50D+3
//calculating input to motor
W=W1+W2
mprintf("Power input to the motor=%f kW\n", W/1000)
//calculating power factor
phi=atand(sqrt(3)*(W1-W2)/(W1+W2))
mprintf("Power factor angle, phi=%f degrees\nPower
    factor of load=%f A\n", phi, cos(phi*%pi/180))
//calculating line current
Il=W/(sqrt(3)*440*cos(phi*%pi/180))
mprintf("Line current drawn by the motor=%f A\n",Il)
//calculating efficiency
Pout=150D+3//output of motor
e=Pout/W*100
mprintf("Efficiency of the induction motor=%f
    percent",e )
```

Scilab code Exa 9.10 Example on Power Measurement

```

//calculating phase voltage
Vl=440//line voltage
Vph=Vl/sqrt(3)//star connected circuit
mprintf("Phase voltage=%f V\n", Vph)
Iph=20//phase current
Zph=Vph/Iph//impedance of load per phase
//calculating load parameters-current in each phase
    lags behind its voltage by 40 degrees
//on solving for R
R=Zph/sqrt(1+(tan(40*%pi/180))^2)
X=R*tan(40*%pi/180)
mprintf("Load parameters are\nR=%f ohm\nX=%f ohm\n",
    R,X)
//calculating total power
```

```
P=3*Vph*Iph*cos(40*%pi/180)
mprintf("Total power consumed=%f kW\n",P*10^-3)
//calculating W1 and W2-->W1+W2=P, W1-W2=P*tan(phi)/sqrt(3)
a=[1 1;1 -1]
b=[P;P*tan(40*%pi/180)/sqrt(3)]
w=inv(a)*b
mprintf("W1=%f kW,\nW2=%f kW", w(1,1)/1000, w(2,1)/1000)
```

Scilab code Exa 9.11 Example on Power Measurement

```

Pout=37.3D+3//power output
e=.88//efficiency
Pin=Pout/e//input power
pf=.82//power factor
phi=acosd(pf)
//calculating W1 and W2-->W1+W2=Pin, W1-W2=Pin*tan(phi)/sqrt(3)
a=[1 1;1 -1]
b=[Pin;Pin*tan(phi*%pi/180)/sqrt(3)]
w=inv(a)*b
mprintf("Readings of two wattmeters are:\nW1=%f kW,\nW2=%f kW\n", w(1,1)/1000, w(2,1)/1000)
Vl=440//line voltage
Il=Pin/(sqrt(3)*Vl*pf)
mprintf("Full load line current=%f A", Il)
```

Scilab code Exa 9.12 Example on Power Measurement

```

//considering star connected circuit
```

```
Rph=20//resistance of coil
Xph=15//reactance of coil
Vl=400//line voltage
Vph=Vl/sqrt(3)//phase voltage
Zph=sqrt(Rph^2+Xph^2)//impedance per phase
Iph=Vph/Zph//phase current
Il=Iph//line current
pf=Rph/Zph//power factor
phi=acosd(pf)
Pin=sqrt(3)*Vl*Il*pf//input power
//calculating W1 and W2-->W1+W2=Pin, W1-W2=Pin*tan(
    phi)/sqrt(3)
a=[1 1;1 -1]
b=[Pin;Pin*tan(phi*%pi/180)/sqrt(3)]
w=inv(a)*b
mprintf("Readings of two wattmeters in case of star
    connection are\nW1=%f W,\nW2=%f W\n", w(1,1), w
    (2,1))
//considering delta connected circuit
Iph=Vl/Zph//phase current
Il=sqrt(3)*Iph//line current
Pin=sqrt(3)*Vl*Il*pf//input power
//calculating W1 and W2-->W1+W2=Pin, W1-W2=Pin*tan(
    phi)/sqrt(3)
a=[1 1;1 -1]
b=[Pin;Pin*tan(phi*%pi/180)/sqrt(3)]
w=inv(a)*b
mprintf("Readings of two wattmeters in case of delta
     connection are\nW1=%f W,\nW2=%f W", w(1,1), w
    (2,1))
//The answers vary from the textbook due to round
    off error
```

Chapter 10

Measuring Instruments

Scilab code Exa 10.1 Example on Moving Coil Instruments

```

//calculating resistance of the shunt
i=20D-3  //current throught the coil
r=4  //resistance of coil
V=i*r
I=2  //total current to be measured
Is=I-i  //current through shunt
R=V/Is  //Ohm's law
mprintf("Resistance of the shunt=%f ohm\n", R)
//solving part (ii)
V=30  //voltage to be measured
R=V/i-r
mprintf("Resistance to be connected in series with
   moving coil=%d ohm", R)
```

Scilab code Exa 10.2 Example on Moving Coil Instruments

```

```

```
i=20D-3  //current throught the coil
r=4  //resistance of coil
V=30  //voltage to be measured
R=(V-r*i)/i  //resistance in series to read upto 30
   V
//to read upto 60 V
V=60
R1=V/i-r
mprintf("Additional resistance needed to read upto
   60 V=%d ohm\n", R1-R)
//to read upto 90 V
V=90
R2=V/i-r
mprintf("Additional resistance needed to read upto
   90V=%d ohm",R2-R1)
```

Scilab code Exa 10.3 Example on Moving Coil Instruments

```

i=20D-3  //current throught the coil
r=4  //resistance of coil
V=i*r
//when total current to be measured=2 A
Is=2-i  //shunt current
R1=V/Is
mprintf("Resistance of shunt for 2A range=%f ohm\n",
   R1)
//when total current to be measured=4 A
Is=4-i  //shunt current
R2=V/Is
mprintf("Resistance of shunt for 4A range=%f ohm\n",
    R2)
//when total current to be measured=6 A
Is=6-i  //shunt current
R3=V/Is
```

```
mprintf("Resistance of shunt for 6A range=%f ohm",R3
    )
```

Scilab code Exa 10.4 Example on Moving Coil Instruments

```

//calculating deflecting torque
N=50 //no. of turns in coil
B=.12 //flux density in Wb/m^2
A=5D-4 //area of coil in m^2
I=15D-3 //current through coil
Td=N*B*A*I
mprintf("Deflecting torque=%fD-6 N-m\n",Td*10^6)
//calculating deflection of pointer
C=18D-7 //constant for spring in N-m per degree
Tc=Td //controlling torque
theta=Tc/C
mprintf("Deflection=%d degrees", theta)
```

Scilab code Exa 10.5 Example on Moving Coil Instruments

```

N=80 //no. of turns in coil
B=.5 //flux density
A=15D-4 //area of coil
Tc=2D-4 //controlling torque at full scale
    deflection
Td=Tc //under final steady condition
I=Td/(N*B*A)
n=100 //no. of divisions
v=2 //voltage measured per division
V=n*v //at full scale deflection
R=V/I
```

```
mprintf("Series resistance=%f ohm",R)
```

Scilab code Exa 10.6 Example on Moving Coil Instruments

```

//calculating resistance of manganin shunt to extend
    range to 1 A
R=10  //resistance of instrument coil
I=10D-3  //current through coil
V=I*R
Is=1-I  //shunt current
r=V/Is
mprintf("Resistance of manganin shunt to extend
   range to 1 A=%f ohm\n", r)
//calculating value of series resistance to extend
   the range to 15 V
v=15-V  //voltage across series resistance
Rs=v/I
mprintf("Series resistance to be connected to extend
    range to 15 V=%d ohm", Rs)
```

Chapter 13

Temperature Rise and Ventilation in Electrical Machines

Scilab code Exa 13.1 Example on Heating and Cooling of Electrical Machines

```

//temp. rise at any time t is theta=theta_f-(theta_f
    -theta_1)*exp(-t/T)
theta_1=0//initial temperature
//theta =25 degree C when t=1 hr; theta =37.5 degree
     C when t=2 hr
//on solving for T
T=1/log(2)
mprintf("Heating time constant=%f hr\n", T)
//on solving for theta_f
theta_f=25/(1-exp(-1/T))
mprintf("Final steady full load temperature rise
    theta_f=%f degree C\n", theta_f)
//Temp. fall at any time t is theta'=theta_f'+(
    theta_2-theta_f')*exp(-t/T')
//As the transformer is disconnected now, theta_f'=0
```

```
theta_2=theta_f
theta_dash=40-30
t=1.5
T=t/log(theta_2/theta_dash)
mprintf("Cooling time constant =%f hr", T)
//The answers vary from the textbook due to round
    off error
```

Scilab code Exa 13.2 Example on Heating and Cooling of Electrical Machines

```

//temp. rise of the motor at any time t is theta=
    theta_f-(theta_f-theta_1)*exp(-t/T)
theta_f=50//final steady temp rise
T=100//heating time constant in min
t=20//full load working period in min
//during cooling process, temp. decreases to theta_1
    =theta*exp(-t/T')
t=40//stationary period in min
T=140//cooling time constant in min
//solving simultaneous equations
a=[1 -exp(-20/100);-exp(-40/140) 1]
b=[50-50*exp(-20/100);0]
c=inv(a)*b
theta=c(1,1)
mprintf("Maximum temp attained=%f degree C", theta)
```

Chapter 14

Single Phase Transformers

Scilab code Exa 14.1 Example on EMF Equation

```

//calculating Bm
Ep=400//induced emf in primary winding
Np=350//no. of turns in primary
Ai=55D-4//cross-sectional area
f=50//frequency in Hz
Bm=Ep/(4.44*f*Ai*Np)
mprintf("Maximum value of flux density in the core=
   %f Tesla(Wb/m^2)\n",Bm)
//calculating voltage induced in secondary winding
Ns=1050
Es=Ep*Ns/Np
mprintf("Voltage induced in the secondary winding=%d
    V",round(Es))
```

Scilab code Exa 14.2 Example on EMF Equation

```

```

```
//calculating no. of turns in secondary winding
Es=500//no load voltage of low voltage winding
phi=.06//flux
f=50//frequency in Hz
Ns=round(Es/(4.44*f*phi))
mprintf("No. of turns in low voltage winding=%f\n",
    Ns)
//calculating no. of turns in primary winding
Np=Ns*6600/500
mprintf("Np=%f(not possible)\n",Np)
//Here, the no. of turns finally taken is 500 and
    not 502
mprintf("No. of turns finally taken is 500 ,because
    the high voltage winding will be split up into a
    no. of coils")
```

Scilab code Exa 14.3 Example on Equivalent Circuit

```

Rp=.8
Xp=3.2
Rs=.009
Xs=.03
Rs_dash=(2200/220)^2*Rs
mprintf("Equivalent resistance referred to primary=
    %f ohm\n",Rp+Rs_dash)
Xs_dash=(2200/220)^2*Xs
mprintf("Equivalent reactance referred to primary=%f
     ohm\n",Xp+Xs_dash)
Rp_dash=(220/2200)^2*Rp
mprintf("Equivalent resistance referred to secondary
    =%f ohm\n",Rp_dash+Rs)
Xp_dash=(220/2200)^2*Xp
mprintf("Equivalent reactance referred to secondary=
    %f ohm",Xp_dash+Xs)
```

Scilab code Exa 14.4 Example on Equivalent Circuit

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//calculating current in primary
Is=10//at 0.8 pf lagging
Ip_dash=Is*400/200//at 0.8 pf lagging
Ip_dash=pol2rect(Ip_dash,-acosd(.8))
Im=200/300//magnetizing current
Iw=200/600//active component of no load current
I0=Iw-Im*j//no load current
Ip=Ip_dash+I0
[Ip theta]=rect2pol(Ip)
mprintf("Current in primary is %f A, lagging at an
    angle of %f degrees\n",Ip,-theta)
//calculating terminal voltage
Ip=pol2rect(Ip,-theta)
Ep=Ip_dash*(.15+.37*j)
```

```
Es_dash=200-Ep
[Es_dash theta]=rect2pol(Es_dash)
Es=Es_dash*400/200
mprintf("Secondary terminal voltage=%f V, lagging at
    an angle of %f degrees",Es,-theta)
```

Scilab code Exa 14.5 Example on Regulation and Efficiency

```

//calculating voltage regulation at full load with
    0.8 pf lagging
Ip=2000/400//primary current at full load
Rp=3
Xp=4
phi=acos(.8)
Vp=400
VR=Ip*(Rp*cos(phi)+Xp*sin(phi))/Vp*100
mprintf("Voltage regulation at full load with 0.8 pf
    lagging=%f percent\n",VR)
//calculating voltage regulation at full load with
    0.8 pf leading
VR=Ip*(Rp*cos(phi)-Xp*sin(phi))/Vp*100
mprintf("Voltage regulation at full load with 0.8 pf
    leading=%f percent\n",VR)
//calculating regulation at half load with 0.8 pf
    lagging
Ip=Ip/2//half load primary current
VR=Ip*(Rp*cos(phi)+Xp*sin(phi))/Vp*100
mprintf("Voltage regulation at half load with 0.8 pf
    lagging=%f percent",VR)
```

Scilab code Exa 14.6 Example on Regulation and Efficiency

```
//Is*Rs=.02*Vs,Is*Xs=.05*Vs
//calculating regulation at .8 pf lagging
VR=(.02*.8+.05*.6)*100
mprintf("Voltage regulation at .8 pf lagging=%f
    percent\n",VR)
//calculating regulation at .8 pf leading
VR=(.02*.8-.05*.6)*100
mprintf("Voltage regulation at 0.8 pf leading=%f
    percent",VR)
```

Scilab code Exa 14.7 Example on Regulation and Efiiciency

```
Wcu_fl=425//copper losses at full load
//calculating efficiency at full load, unity pf
Pout=50*1000*1//output
e=Pout/(Pout+350+425)*100
mprintf("Efficiency at full load, unity pf=%f
    percent\n",e)
//calculating efficiency at half load, unity pf
Pout=Pout/2//output
Wi=350//iron losses
Wcu=Wcu_fl/2^2//copper losses
e=Pout/(Pout+Wi+Wcu)*100
mprintf("Efficiency at half load, unity pf=%f
    percent\n",e)
//calculating efficiency at full load, 0.8 pf
    lagging
Pout=(50D+3)*.8//output
e=Pout/(Pout+Wi+Wcu_fl)*100
mprintf("Efficiency at full load, .8 pf lagging=%f
    percent\n",e)
//calculating maximum efficiency
Wcu=Wi//copper losses
```

```
x=sqrt(Wcu/Wcu_fl)//load at which maximum efficiency
    occurs
mprintf("At %f percent of the full load, maximum
   efficiency will occur\n",x*100)
Pout=(x*50D+3*1)
e_max=Pout/(Pout+2*Wi)*100
mprintf("Maximum efficiency=%f percent\nLoad at
   maximum efficiency=%f kVA",e_max,Pout/1000)
```

Scilab code Exa 14.8 Example on Regulation and Efficiency

```

Wi=1100//iron losses
Wcu=400//copper losses at 50% load
Is=100*1000/10000//secondary full load current
//calculating efficiency at 25% load, unity pf
Is1=Is/4//secondary current
Wcu1=(25/50)^2*400//copper losses
Pout=.25*100*1000//output
e=Pout/(Pout+Wcu1+Wi)*100
mprintf("Efficiency at 25 percent load, unity pf=%f
   percent\n",e)
//calculating efficiency at 25% load, 0.8 pf
e=(Pout*.8)/(Pout*.8+Wcu1+Wi)*100
mprintf("Efficiency at 25 percent load, .8 pf=%f
   percent\n",e)
//calculating efficiency at 50% load,unity pf
Pout=.5*100*1000//output
e=Pout/(Pout+Wi+Wcu)*100
mprintf("Efficiency at 50 percent load, unity pf=%f
   percent\n",e)
//calculating efficiency at 50% load, 0.8 pf
e=Pout*.8/(Pout*.8+Wi+Wcu)*100
mprintf("Efficiency at 50 percent load, 0.8 pf=%f
   percent\n",e)
```

```
//calculating efficiency at full load, unity pf
Pout=100*1000//output
Wcu3=(10/5)^2*400//copper losses
e=Pout/(Pout+Wcu3+Wi)*100
mprintf("Efficiency at full load, unity pf=%f
   percent\n",e)
//calculating efficiency at full load, .8 pf
e=(Pout*.8)/(Pout*.8+Wcu3+Wi)*100
mprintf("Efficiency at full load, 0.8 pf=%f percent\
   n",e)
//calculating load for max efficiency at unity pf
x=sqrt(Wi/Wcu3)
mprintf("Load for max efficiency=%f kVA\nLoad for
   max efficiency will remain the same irrespective
   of power factor",x*Pout/1000)
//error in the textbook answer for efficiency at 50
   % load at unity pf as well as at .8 pf
```

Scilab code Exa 14.9 Example on Regulation and Efficiency

```

e=.9//efficiency at full load
Pout=500//output at full load
//we get, .9=500/(500+Wi+Wcu)
//efficiency at half load is also the same
   -->.9=(500/2)/(500/2+Wi+Wcu/4)
//solving for Wi and Wcu at full load
a=[.9 .9;.9 .225]
b=[50;25]
z=inv(a)*b
Wi=z(1,1)
Wcu=z(2,1)
//calculating efficiency at 75% load
Pout=.75*500//output
Wcu1=.75^2*Wcu//copper losses
```

```
e=Pout/(Pout+Wi+Wcu1)*100
mprintf("Efficiency at 75 percent full load=%f
    percent",e)
```

Scilab code Exa 14.10 Example on Regulation and Efficiency

```

e_max=.98//max efficiency
Pout=.75*500*1000//output of transformer at max
    efficiency
Wi=Pout*(1-e_max)/(2*e_max)
Wcu1=Wi//copper losses at 3/4 full load
Wcu=Wcu1/(.75)^2//copper losses at full load
Is=500*1000/500//secondary current
Vs=500//secondary voltage
VR=(Wcu/(Vs*Is)*.8+sqrt(.1^2-(Wcu/(Vs*Is))^2)*.6)
    *100
mprintf("Regulation at full load, 0.8 pf lagging=%f
    percent",VR)
```

Scilab code Exa 14.11 Example on Regulation and Efficiency

```

e1=.985//efficiency at full load, .8 pf lagging
//.985=100D+3*.8/(100D+3*.8+Wi+Wcu)-->.985*Wi+.985*
    Wcu=1200
e2=.99//efficiency at half load, unity pf
//.99=((100D+3)/2)/((100D+3)/2+Wi+Wcu/4)-->.99*Wi
    +.2475*Wcu=500
//solving for Wi and Wcu
a=[.985 .985;.99 .2475]
b=[1200;500]
w=inv(a)*b
```

```
Wi=w(1,1)
Wcu=w(2,1)
mprintf("Iron losses=%f W\nFull load copper losses=
   %f W",Wi,Wcu)
```

Scilab code Exa 14.12 Example on Regulation and Efficiency

```

//calculating regulation at full load, 0.8 pf
   lagging
Pout1=.75*500D+3//output at max efficiency
Wi=375D+3*(1-.97)/(2*.97)
Wcu1=Wi//copper losses at 3/4th full load
Wcu=(4/3)^2*Wcu1//copper losses at full load
Is=500D+3/220
Rs=Wcu/Is^2
Vs=220//secondary voltage
Zs=220*.1/Is
Xs=sqrt(Zs^2-Rs^2)
VR=(Is*Rs*.8+Is*Xs*.6)/Vs*100
mprintf("Regulation at .8 pf lagging=%f percent\n",
   VR)
//calculating regulation at full load, 0.8 pf
   leading
VR=(Is*Rs*.8-Is*Xs*.6)/Vs*100
mprintf("Regulation at .8 pf leading=%f percent\n",
   VR)
```

Scilab code Exa 14.13 Example on Regulation and Efficiency

```

e_max=.98//max efficiency of transformer
```

```
P=15D+3//load at which max efficiency occurs at
    unity pf
Wi=P*(1-e_max)/(2*e_max)
Wcu=Wi
//in the first interval
P1=3D+3/0.6//load on the transformer
Wcu1=Wcu*(P1/P)^2
//in the second interval
P2=10D+3/0.8//load on the transformer
Wcu2=Wcu*(P2/P)^2
//in the third interval
P3=18D+3/0.9//load on the transformer
Wcu3=Wcu*(P3/P)^2
//load on the transformer during last interval=0-->
    copper losses=0, iron losses=0
Wi=Wi*24//total iron losses
Wcu=10*Wcu1+5*Wcu2+5*Wcu3//total copper losses
Pout=(3*10+10*5+18*5)*10^3//total output
e=Pout/(Pout+Wi+Wcu)*100
mprintf("All day efficiency=%f percent",e)
```

Scilab code Exa 14.14 Example on Testing of Transformer

```

//for no load test
V0=400//applied voltage
I0=1//current
W0=60//power consumed
Iw=W0/V0
R0=V0/Iw
Im=sqrt(I0^2-Iw^2)
Xm=V0/Im
mprintf("No load parameters:\nR0=%f ohm,\nXm=%f ohm\
    n",R0,Xm)
//for short circuit test
```

```
Vsc=15//applied voltage
Isc=12.5//current
Wsc=50//power consumed
Zp=Vsc/Isc
Rp=Wsc/Isc^2
Xp=sqrt(Zp^2-Rp^2)
mprintf("Equivalent resistance and reactance
   referred to primary is %f ohm and %f ohm\n",Rp,Xp
   )
//calculating regulation at full load, 0.8 pf
   lagging
Vp=400
Ip=5D+3/400
VR=Ip*(Rp*.8+Xp*.6)/Vp*100
mprintf("Voltage regulation=%f percent\n",VR)
//calculating iron and copper losses
Wi=W0
Wcu=Wsc
mprintf("Iron losses=%f W\nCopper losses at full
   load=%f W\n",Wi,Wcu)
//calculating efficiency at full load and 0.8 pf
   lagging
e=5D+3*.8/(5D+3*.8+Wi+Wcu)*100
mprintf("Efficiency at full load and .8 pf lagging=
   %f percent",e)
```

Scilab code Exa 14.15 Example on Testing of Transformer

```

W0=1300//power consumed in no load test
Wsc=2400//power consumed in short circuit test
   performed at full load current
Wi=W0
Wcu=Wsc
Pout=(8*200*.8+10*.5*200*1)*10^3//total output
```

```
Wit=1300*24//total iron losses
Wcut=2400*8+2400/4*10//total copper losses
e=Pout/(Pout+Wit+Wcut)*100
mprintf("All day efficiency=%f percent",e)
```

Scilab code Exa 14.16 Example on Testing of Transformer

```

Woc=60//power consumed in OC test at 220 V
//iron losses in transformer are proportional to square of applied voltage
Wi=60*(200/220)^2//iron losses at normal voltage of 200 V
Is=5D+3/400//full load current on HV side
//for SC test
Isc=10//current
Wsc=120//power consumed
Wcu=(Is/Isc)^2*Wsc//full load copper losses
e=(5D+3*.8)/(5D+3*.8+Wi+Wcu)*100
mprintf("Efficiency at full load=%f percent",e)
```

Scilab code Exa 14.17 Example on Parallel Operation

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
```

```
    z=x+y*%i
endfunction

j=%i
I=pol2rect(300,-acosd(.8))//total load to be shared
   by transformers A and B at .8 pf lagging
Za=.011+.042*j//impedance of transformer A
Zb=.044+.072*j//impedance of transformer B

//calculating load shared by transformer A
Ia=Zb*I/(Za+Zb)
[Ia theta]=rect2pol(Ia)
mprintf("Load shared by transformer A=%f A, lagging
   by an angle of %f degrees\n",Ia,-theta)

//calculating load shared by transformer B
Ib=Za*I/(Za+Zb)
[Ib theta]=rect2pol(Ib)
mprintf("Load shared by transformer B=%f A, lagging
   by an angle of %f degrees",Ib,-theta)
//answers vary from the textbook due to round off
   error
```

Scilab code Exa 14.18 Example on Parallel Operation

```

function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction

j=%i
Zl=8+6.2*j//load impedance
//for transformer A
```

```
Ea=6600//secondary induced emf
Za=.3+3.2*j//equivalent impedance referred to
    secondary
//for transformer B
Eb=6400//secondary induced emf
Zb=.2+1.2*j//equivalent impedance referred to
    secondary
Ia=(Ea*Zb+(Ea-Eb)*Zl)/(Za*Zb+(Za+Zb)*Zl)
Ib=(Eb*Za-(Ea-Eb)*Zl)/(Za*Zb+(Za+Zb)*Zl)
mprintf("Current delivered by transformer A is %f A\
    nCurrent delivered by transformer B is %f A",mag(
    Ia),mag(Ib))
```

Chapter 15

Three Phase Transformers

Scilab code Exa 15.1 Example on three phase transformer

```


P=50D+3  //power per phase
Power_rating=3*P
Vpp=2300  //primary phase voltage
Vsp=230  //secondary phase voltage
Vpl=sqrt(3)*Vpp  //primary normal line voltage
Vsl=Vsp  //secondary normal line voltage
mprintf("Rating of 3-phase transformer will be-\n3-
    phase, %d kVA, %d/%d V, star/delta connection\n",
    Power_rating/1D+3,round(Vpl),round(Vsl))
Ipp=P/Vpp
Ipl=Ipp
Isp=P/Vsp
Isl=sqrt(3)*Isp
mprintf("Primary phase current=%f A\nPrimary line
    current=%f A\nSecondary phase current=%f A\
    nSecondary line current=%f A\n",Ipp,Ipl,Isp,Isl)
//calculating voltage regulation
Rp_dash=1.2  //equivalent resistance referred to
    primary
```

```
Xp_dash=1.6  //equivalent reactance referred to
    primary
VR=Ipp*(Rp_dash*.8+Xp_dash*.6)*100/Vpp
mprintf("Voltage Regulation=%f percent", VR)
```

Scilab code Exa 15.2 Example on three phase transformer

```

//calculating no. of turns per phase
Vsp=440/sqrt(3)  //secondary phase voltage
Et=8  //emf per turn in volt
Ts=round(Vsp/Et)
Vpp=1100  //primary phase voltage
Tp=Ts*Vpp/Vsp
mprintf("No. of turns per phase on primary winding=
    %d\nNo. of turns per phase on secondary winding=
    %d\n", Tp, Ts)
//calculating net cross-sectional area of core
f=50  //frequency
Bm=1.3  //flux density
Ai=Et/(4.44*f*Bm)
mprintf("Net cross-sectional area of core, Ai=%d cm
    ^2", round(Ai*1D+4))
```

Scilab code Exa 15.3 Example on three phase transformer

```

//calculating currents in the main and teaser
    transformer
P2=600D+3//output
V2=110//applied voltage
pf=.707//lagging power factor
I2=P2/(pf*V2)
```

```
I1t=1.15*I2*110/6600
I1m=I2*110/6600
mprintf("Currents in primary winding of main and
   teaser transformer is %f A and %f A respectively\
   n", I1m,I1t)
//calculating line currents
Ic=I1t
Ib=sqrt(I1m^2+(I1t/2)^2)
Ia=Ib
mprintf("Line currents are %f A, %f A and %f A", Ia,
   Ib,Ic)
```

Scilab code Exa 15.4 Example on three phase transformer

```

function[r, theta]=rect2pol(x,y)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
Q=750//total load to be shared
pf=.8//lagging power factor
theta=-acosd(.8)
Q=rect2pol(Q*cos(theta),Q*sin(theta))
Zb=rect2pol(.35,3.3)//per phase impedance of
   transformer B
Za=rect2pol(.2,1.8)//per phase impedance of
   transformer A
Qa=Zb*Q/(Za+Zb)
Qb=Za*Q/(Za+Zb)
mprintf("Transformer A of 500 kVA rating shares a
   load of %f kVA whereas transformer B of 250 kVA
   rating shares a load of %f kVA", Qa,Qb)
```

Chapter 16

Electromechanical Energy Conversion

Scilab code Exa 16.2 Example on Electromechanical Energy Conversion Devices

```

i=3//current in coil
x=5D-2//length of air gap
lambda=sqrt(i/(121*x^2))
//calculating field energy W_f
W_f=integrate("121*lambda^2*.05^2","lambda", 0,
    lambda)
mprintf("Field energy stored=%f watt-sec\n", W_f)
//calculating coenergy
W_f_dash=integrate("i^.5/(11*.05)","i",0, i)
mprintf("Co-energy=%f watt-sec\n", W_f_dash)
//calculating mechanical force on moving part-
    keeping lambda constant
function y=f(x)
    y=121*x^2*lambda^3/3
endfunction
F_f=-1*derivative(f,x)
mprintf("Mechanical force developed F_f=%d N-m",
```

```
round(F_f))
```

Scilab code Exa 16.3 Example on Electromechanical Energy Conversion Devices

```

mu_not=4D-7*%pi
i=120/6  //current flowing in coil
N=300  //no. of turns
x=.005  //length of air gap
Ag=36D-4  //cross-sectional area at gap
//calculating stored field energy
W_f=mu_not*N^2*Ag*i^2/(4*x)
mprintf("Stored field energy=%f watt-sec\n", W_f)
//calculating mechanical force developed
F_f=mu_not*N^2*i^2*Ag/(4*x^2)
mprintf("Mechanical force developed=%f N-m", F_f)
```

Chapter 17

Fundamentals of DC Machines

Scilab code Exa 17.1 Example on DC Winding

```
P=6//no. of poles
a=P//no. of parallel circuits
n=150//no. of slots
c=8//no. of conductors per slot
Z=n*c//total no. of conductors
T=Z/2//no. of turns
Lmt=250D-2//mean length of one turn
S=10*2.5*1D-6//cross sectional area
rho=2.1D-8//resistivity at 80 degree C
R=(rho*Lmt*T)/(a^2*S)
mprintf("Resistance=%f ohm\n",R)
```

Scilab code Exa 17.2 Example on DC Winding

```
P=4//no. of poles
n=24//no. of slots
```

```
c=2//conductors per slot
Z=n*c//total no. of conductors
p=Z/4//pole pitch
Ybp=p+1//back pitch
Yfp=p-1//front pitch
Y=Ybp-Yfp
mprintf("Resultant pitch=%f",Y)
```

Scilab code Exa 17.3 Example on EMF Equation

```

P=6//no. of poles
A=P//no. of parallel paths
phi=.018//flux per pole
N=600//speed of rotation in rpm
Z=840//total no. of conductors
Eg=P*phi*N*Z/(60*A)
mprintf("Emf generated=%f V\n",Eg)
```

Scilab code Exa 17.4 Example on EMF Equation

```

P=6//no. of poles
A=2//no. of parallel paths
Z=300//no. of conductors on armature
N=1000//speed of rotation in rpm
Eg=400//emf generated on open circuit
phi=60*Eg*A/(P*N*Z)
mprintf("Flux per pole=%f Wb\n", phi)
```

Scilab code Exa 17.5 Example on EMF Equation

```
Eg=400//emf generated
n=80//no. of slots on armature
c=10//conductors per slot
Z=n*c//total no. of conductors on armature
N=1000//speed in rpm
phi=60*Eg/(N*Z)
Eg=220//desired value of generated voltage
N=60*Eg/(phi*Z)
mprintf("Speed of rotation to generate 220 V=%f rpm\n", round(N))
```

Scilab code Exa 17.6 Example on EMF Equation

```
n=60//no. of slots on armature
c=6//conductors per slot
Z=n*c//total no. of conductors
A=2//no. of parallel paths in armature winding
N=750//speed of rotation
P=4//no. of poles
Eg=230//emf generated on open circuit
phi=60*Eg*A/(P*N*Z)
mprintf("Useful fux per pole=%f Wb\n",phi)
Eg=115//emf to be generated at no load
A=P*N*Z*phi/(60*Eg)//required no. of parallel paths in armature winding
mprintf("As the machine has equal number of poles and parallel paths in armature winding, the armature will be lap connected to generate 115 V at the same speed")
```

Scilab code Exa 17.7 Example on Types of DC Machines

```

//calculating terminal voltage
P=10D+3//load supplied
Vl=220//voltage at load terminals
Il=P/Vl
R=.1//resistance of feeders
Vd=Il*R//voltage drop on feeders
V=Vd+Vl
mprintf("Terminal voltage across the armature
    terminals=%f V\n",V)
//Calculating shunt field current
Rsh=100//shunt resistance
Ish=V/Rsh
mprintf("Shunt field current=%f A\n",Ish)
//Calculating generated emf
Ra=.05//resistance of armature
Eg=V+Il*Ra
mprintf("Generated emf Eg=%f V",Eg)
```

Scilab code Exa 17.8 Example on Types of DC Machines

```

//calculating total armature current
V=200//terminal voltage across armature
Rsh=80//shunt field resistance
Ish=V/Rsh//shunt field current
Il=100//load current
Ia=Il+Ish
mprintf("Armature current=%f A\n",Ia)
//calculating current per armature path
```

```
A=4//no. of parallel paths
mprintf("Current per armature path=%f A\n",Ia/A)
//calculating emf generated
Ra=.1//armature resistance
e=2//brush contact drop
Eg=V+Ia*Ra+e
mprintf("Emf generated=%f V\n",Eg)
```

Scilab code Exa 17.9 Example on Types of DC Machines

```

V=100//terminal voltage
Il=200//load current
Rse=.03//resistance of series field winding
Ra=.04//resistance of armature winding
Rsh=60//resistance of shunt
Vd=Il*Rse//voltage drop in series field winding
V_dash=V+Il*Rse//terminal voltage across armature
Ish=V_dash/Rsh
Ia=Il+Ish
Eg=V+Il*Rse+Ia*Ra
mprintf("Generated emf=%f V",Eg)
```

Scilab code Exa 17.10 Example on Types of DC Machines

```

V=250//terminal voltage
Il=450//load current
Rsh=50//shunt field resistance
Ish=V/Rsh
Ia=Ish+Il
Ra=.05//armature resistance
Eg=V+Ia*Ra
```

```
P=4//no. of poles
phi=.05//flux per pole in Wb
n=120//no. of slots on armature
c=4//conductors per slot
Z=n*c//total no. of conductors
A=P//no. of parallel paths
N=60*Eg*A/(P*phi*Z)
mprintf("Speed of rotation=%f rpm", round(N))
```

Scilab code Exa 17.11 Example on Types of DC Machines

```

//when the dc shunt machine works as a generator
V=250//terminal voltage
Il=80//load current
Rsh=100//field resistance
Ra=.12//armature resistance
Ish=V/Rsh
Ia=Il+Ish
Eg=V+Ia*Ra

//when the dc shunt machine works as a motor
V=250//applied voltage to motor
Il=80//line current drawn by the motor
Ia=Il-Ish
Eb=V-Ia*Ra
//for a machine, P*phi*Z/(60*A) is a constant
x=Eg/Eb
mprintf("speed as generator/speed as motor=%f",x)
```

Scilab code Exa 17.12 Example on Types of DC Machines

```
//calculating back emf
V=120//applied voltage
Il=200//line current
Rsh=30//shunt field resistance
Ra=.02//armature winding resistance
Ish=V/Rsh
Ia=Il-Ish
Eb=V-Ia*Ra
mprintf("Back emf=%f V\n",Eb)
n=90//no. of slots on armature
c=4//conductors per slot
Z=n*c//total no. of conductors on armature
phi=.04
N=60*Eb/(phi*Z)
mprintf("Speed at which motor will run when flux per
    pole is .04 Wb=%d rpm",round(N))
```

Scilab code Exa 17.13 Example on Types of DC Machines

```

//calculating load current
i=30//current drawn by each motor
I=5*i//current drawn by 5 motors
P=150*60//total lighting load
V=110//applied voltage
I1=P/V//current taken by lighting load
I=I1+I
mprintf("Total load current=%d A\n",round(I))
//calculating terminal voltage
V_dash=110//voltage at terminals of load
R=.04//resistance of feeders
Vd=I*R//voltage drop in feeders
V=V_dash+Vd
mprintf("Terminal voltage across the generator
   terminals=%f V\n",V)
```

```
//calculating emf generated
Rsh=55//resistance of shunt field
Ish=V/Rsh
Ia=I+Ish
Ise=Ia
Rse=.04//series field resistance
Ra=.03//armature resistance
Eg=V+Ia*(Ra+Rse)
mprintf("Generated emf, Eg=%f V",Eg)
```

Scilab code Exa 17.14 Example on Types of DC Machines

```

//when the machine is working as generator
V=240//terminal voltage across the load
P=40D+3//load on generator
Il=P/V//load current
Rsh=60//resistance of shunt field
Ish=V/Rsh
Ia=Il+Ish
Ra=.03//armature resistance
e=2*1//voltage drop at brushes
Eg=V+Ia*Ra+e
N=450//speed as a generator at this load
//let k=P*phi*Z/(60*A)
k=Eg/N
//when the machine is working as motor
Ia=Il-Ish
Eb=V-Ia*Ra-e
N=Eb/k
mprintf("Speed as a motor=%d rpm", round(N))
```

Chapter 18

DC Generators

Scilab code Exa 18.1 Example on Magnetization Characteristics

```

i=linspace(0,1.6,9)
V=[0 40 66 86 101 112 121 128 133]
plot(i,V,rect=[0 0 1.6 133])
xtitle("Magnetization curve for example 18.1","Field
    Current","Generated emf")

//refer Fig. 18.4 in the textbook
Rsh=94//resistance of shunt field winding
//OA is the field resistance line for this
   resistance
Voc=126//voltage corresponding to point A
mprintf("Open circuit voltage when the field circuit
    resistance is 94 ohm=%d V\n",Voc)
//D is point on OCC corresponding to 110 V. OD
   represents the field resistance line to generate
   this voltage
R=70/.6//total resistance of shunt field circuit
mprintf("Additional resistance in the shunt field
```

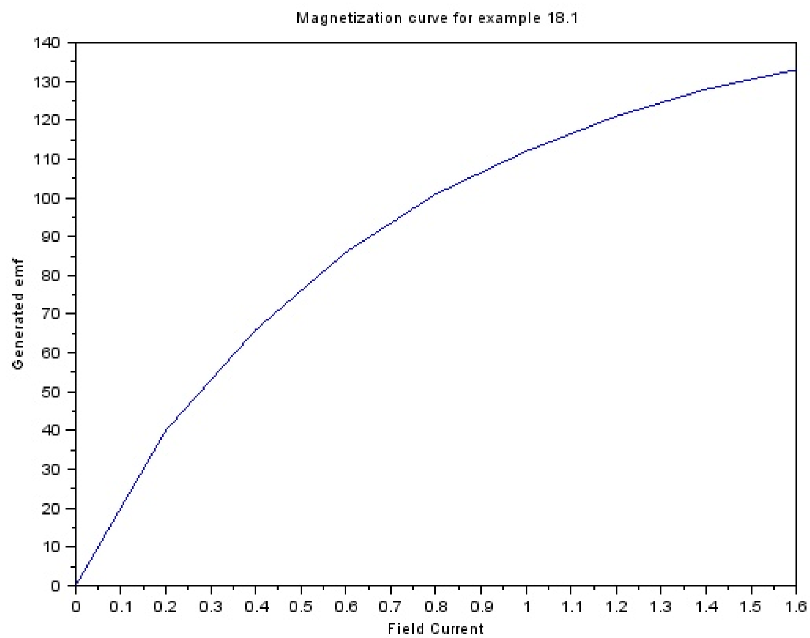

Figure 18.1: Example on Magnetization Characteristics

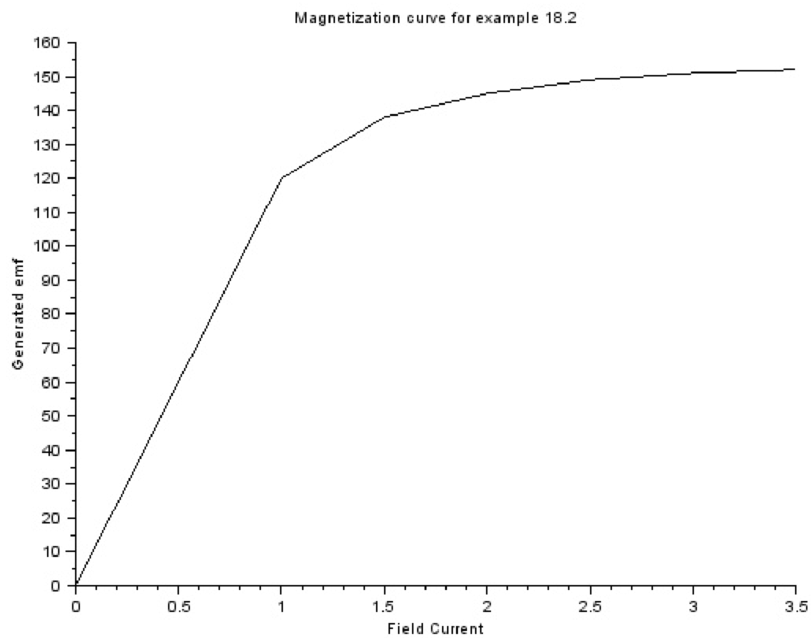

Figure 18.2: Example on Magnetization Characteristics

```
    circuit is %f ohm\n", R-Rsh)
//line OE represents the critical resistance of
    shunt field
Rc=40/.2
mprintf("Critical resistance=%d ohm",Rc)
```

Scilab code Exa 18.2 Example on Magnetization Characteristics

```

i=linspace(0,3.5,8)
V=[0 60 120 138 145 149 151 152]
```

```
plot2d(i,V)
xtitle("Magnetization curve for example 18.2","Field
    Current","Generated emf")

//refer Fig. 18.5 in the textbook
Rsh=60//shunt field resistance
//line OA is field resistance line
Voc=149//voltage corresponding to point A
mprintf("Open circuit voltage=%d V\n",Voc)
//resistance represented by OE is critical
    resistance
Rc=120
mprintf("Critical resistance of shunt field=%d ohm\n
    ",Rc)
//when the load has a resistance of 4 ohm
R=4
//load current I=V/4
//Ish=V/60
//Ia=I+Ish
Eg=Voc
Ra=.1//armature resistance
//V=Eg-Ia*Ra
V=Eg/(1+(1/R+1/Rsh)*Ra)
mprintf("Terminal voltage, V=%f V\n",V)
//when the terminal voltage is 100 V
V=100//terminal voltage
Ia=(Eg-V)/Ra
Ish=V/Rsh
I=Ia-Ish
mprintf("Load current=%f A",I)
```

Scilab code Exa 18.3 Example on Magnetization Characteristics

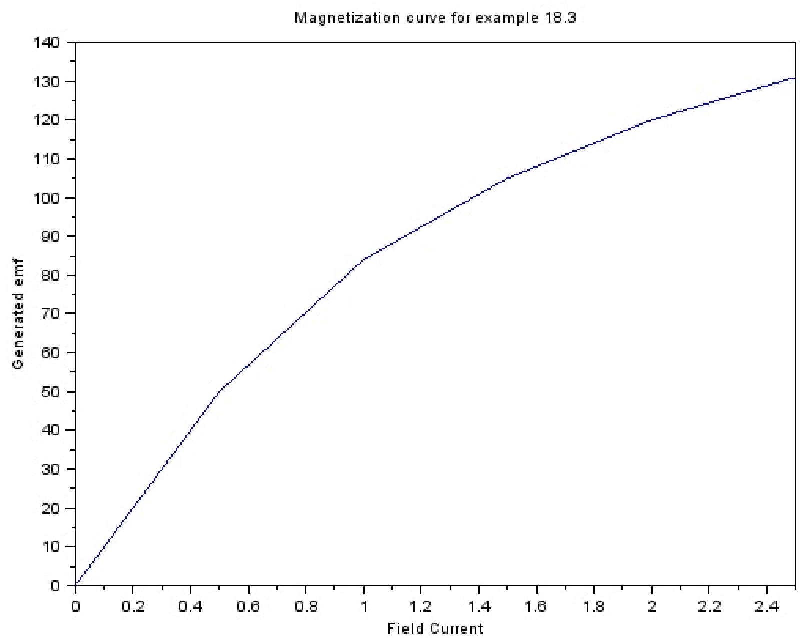

Figure 18.3: Example on Magnetization Characteristics

```
i=linspace(0,2.5,6)
V=[0 50 84 105 120 131]
plot(i,V)
xtitle("Magnetization curve for example 18.3","Field
    Current","Generated emf")

//refer Fig.18.6 in the textbook
//OE is the field resistance line of critical
   resistance
Rc=100
//solving (iii)
Rsh=70//field resistance
N=750//speed in rpm
Nc=Rsh/Rc*N
mprintf("When the field resistance is 70 ohm,
   critical speed=%d rpm\n",round(Nc))
//solving (iv)
Eg=100//open-circuit voltage
Rsh=55//shunt field resistance
//now, the operating point is M instead of A
//LM/LN=N1/N
//from the graph, LM/LN=100/115
N1=100/115*N//desired speed
mprintf("With shunt field resistance of 55 ohm,
   reduction in speed to make the open circuit
   voltage equal to 100 V=%d rpm",round(N-N1))
```

Scilab code Exa 18.4 Example on Magnetization Characteristics

```

//generated emf is directly proportional to speed
//readings for OCC at 1000 rpm are
```

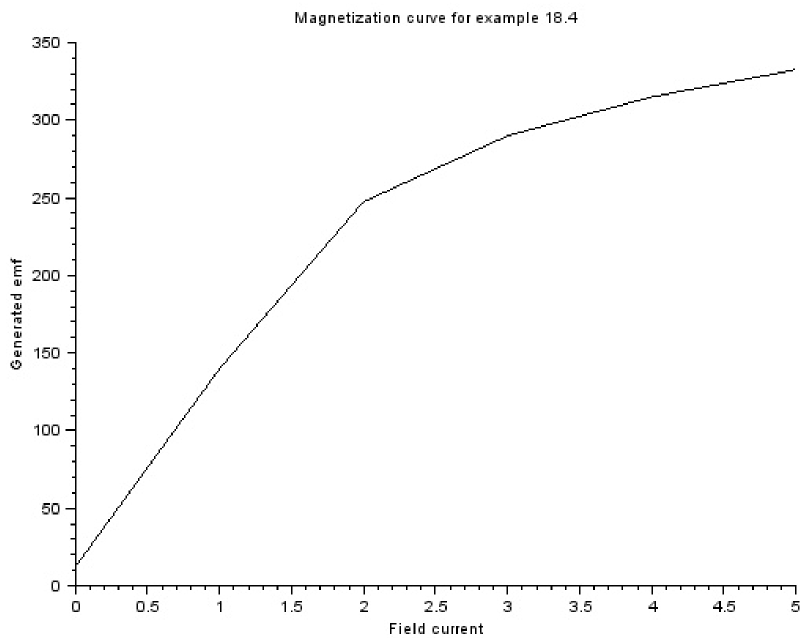

Figure 18.4: Example on Magnetization Characteristics

```
Eg2=[10*(1000/800) 112*(1000/800) 198*(1000/800)
    232*(1000/800) 252*(1000/800) 266*(1000/800)]
i=linspace(0,5,6)
plot2d(i,Eg2)
xtitle("Magnetization curve for example 18.4","Field
    current","Generated emf")

//refer Fig.18.7 in the textbook
Rsh=70//resistance of field circuit
//line OA is field resistance line
V=330//voltage corresponding to point A
mprintf("No load terminal voltage is %d V\n",V)
//now, no load terminal voltage is 270 V
V=270
//the operating point is D
//line OD is corresponding field resistance line
R=V/2.4//resistance represented by line OD
mprintf("Additional resistance required in the field
    circuit to reduce the voltage to 270 V=%f ohm\n"
    ,R-Rsh)
```

Scilab code Exa 18.5 Example on Parallel Operation

```

//for generator A
V1=240//initial terminal voltage
V2=225//final terminal voltage
Ia=120//armature current
Ra=(V1-V2)/Ia//armature resistance
//for generator B
V1=230//initial terminal voltage
V2=215//final terminal voltage
Ib=100//armature current
Rb=(V1-V2)/Ib//armature resistance
I=200//total load current
```

```
//I1+I2=I, V=240-I1*Ra, V=230-I2*Rb
//solving for V, I1 and I2
a=[1 1 0;Ra 0 1;0 Rb 1]
b=[200;240;230]
x=inv(a)*b
I1=x(1,1)
I2=x(2,1)
V=x(3,1)
mprintf("Bus-bar voltage=%f V,\nGenerator A supplies
    %f A,\nGenerator B supplies %f A", V,I1,I2)
```

Scilab code Exa 18.6 Example on Parallel Operation

```

Ra=.03//armature resistance of each generator
Rsh=60//field resistance of each generator
I=4500//total load current
//I1+I2=4500, Ish=V/60
//Ia1=I1+V/60
//Ia2=I2+V/60
Ea1=500//induced emf in generator 1
//500=V+Ia1*.03
Ea2=510//induced emf in generator 2
//510=V+Ia2*.03
//solving for V,I1 and I2
a=[1 1 0;.03 0 1+.03/60;0 .03 1+.03/60]
b=[4500;500;510]
x=inv(a)*b
I1=x(1,1)
I2=x(2,1)
V=x(3,1)
mprintf("Bus-bar voltage=%f V,\nLoad shared by
   generator 1=%f A,\nLoad shared by generator 2=%f
   A", V,I1,I2)
```

Scilab code Exa 18.7 Example on Parallel Operation

```

//Let V be bus-bar voltage and I1, I2 be the
   currents supplied by generators 1 and 2
   respectively
Il=3000//total load current
//I1+I2=Il
//for generator 1
Rsh1=30//field resistance
Ra1=.05//armature resistance
Eg1=400//induced emf
//for generator 2
Rsh2=25//field resistance
Ra2=.03//armature resistance
Eg2=380//induced emf
//Ish1=V/Rsh1
//Ish2=V/Rsh2
//Ia1=I1+Ish1
//Ia2=I2+Ish2
//Eg1=V+Ia1*Ra1;Eg2=V+Ia2*Ra2
//solving for I1,I2 and V
a=[1 1 0;Ra1 0 1+Ra1/Rsh1;0 Ra2 1+Ra2/Rsh2]
b=[Il;Eg1;Eg2]
x=inv(a)*b
I1=x(1,1)
I2=x(2,1)
V=x(3,1)
P1=V*I1
P2=V*I2
mprintf("Output of generator 1=%f kW\nOutput of
   generator 2=%f kW", P1/1000,P2/1000)
//answers vary from the textbook due to round off
   error
```

Chapter 19

DC Motors

Scilab code Exa 19.1 Example on Torque and Speed

```

//calculating torque deveoped
P=6//no. of poles
A=6//no. of parallel circuits
Ia=300//armature current
n=500//no. of armature turns
Z=2*500//total no. of conductors
phi=75D-3//flux per pole
Ta=.159*P*phi*Ia*Z/A
mprintf("Torque developed=%f N-m\n",Ta)
//calculating shaft torque
T=2.5*Ta/100//torque lost in windage, friction and iron losses
Tsh=Ta-T
mprintf("Shaft torque=%f N-m\n",Tsh)
//calculating shaft power
N=400//speed in rpm
Psh=2*%pi*N*Tsh/60
mprintf("Shaft power=%f kW",Psh/1000)
//answer vary from the textbook due to round off error
```

Scilab code Exa 19.2 Example on Torque and Speed

```

//calculating torque developed by armature
V=200//voltage applied across the motor
Rsh=40//resistance of shunt field winding
Ish=V/Rsh
I=100//total current drawn by motor
Ia=I-Ish
Ra=.1//armature resistance
Eb=V-Ia*Ra
P=Eb*Ia//mechanical power developed
N=750//speed in rpm
Ta=60*P/(2*%pi*N)
mprintf("Torque developed by armature=%f N-m\n",Ta)
//calculating copper losses
Wcu1=V*Ia-Eb*Ia//armature copper losses
Wcu2=Ish^2*Rsh//field copper losses
mprintf("Total copper losses=%f W\n",Wcu1+Wcu2)
//calculating shaft power
Wc=1500//friction and iron losses
Pi=200*100//input to motor
Psh=Pi-(Wc+Wcu1+Wcu2)
mprintf("Shaft power=%f kW\n",Psh/1000)
//calculating shaft torque
Tsh=60*Psh/(2*%pi*N)
mprintf("Shaft torque=%f N-m\n",Tsh)
//calculating efficiency
e=Psh/Pi*100
mprintf("Efficiency=%f percent",e)
```

Scilab code Exa 19.3 Example on Torque and Speed

```
Po=60D+3//full load output of the motor
e=0.905//efficiency of the motor
Pin=Po/e
V=400//applied voltage
I=Pin/V//line current drawn by the motor
Rsh=200//resistance of the shunt field winding
Ish=V/Rsh
Ia=I-Ish
Ra=0.1//armature resistance
Eb=V-Ia*Ra
A=2//no. of parallel paths in armature winding
P=4//no. of poles
phi=45D-3//flux per pole
Z=450//total number of conductors
N=round(60*Eb*A/(P*phi*Z))
mprintf("Full load speed=%d rpm\n",N)
//calculating armature torque
Ta=0.159*P*phi*Ia*Z/A
mprintf("Torque developed by the armature of the DC
    motor=%f N-m\n",Ta)
//calculating useful torque
Psh=60D+3//shaft power
Tsh=60*Psh/(2*%pi*N)
mprintf("Useful torque=%f N-m",Tsh)
//error in the textbook answer for useful torque
```

Scilab code Exa 19.4 Example on Torque and Speed

```
V=220//voltage applied to motor
Rsh=157//shunt field resistance
Ra=0.3//armature resistance
Ish=V/Rsh
I0=4.5//current drawn by the motor at no load
```

```
Ia0=I0-Ish
Eb0=V-Ia0*Ra
//under loaded conditions,
I=30//current drawn by motor
Ia=I-Ish
Eb=V-Ia*Ra
//phi=.97*phi0
//back emf is directly proportional to flux and
   speed
N0=1000//speed at no load
N=Eb*N0/(Eb0*.97)
mprintf("Speed under loaded condition=%d rpm", round
   (N))
```

Scilab code Exa 19.5 Example on Torque and Speed

```

//calculating shaft power
V=100//voltage applied to series motor
Ra=.22//armature resistance
Rse=.13//series field resistance
Rm=Ra+Rse//total resistance
Ia=45//current in armature circuit
Eb=V-Ia*Rm
Pm=Eb*Ia//mechanical power developed
Wc=750//iron and friction losses
Psh=Pm-Wc
mprintf("Shaft power=%f kW\n",Psh/1000)
//calculating torque developed
N=750//speed in rpm
Ta=60*Pm/(2*%pi*N)
mprintf("Total torque=%f N-m\n",Ta)
//calculating shaft torque
Tsh=60*Psh/(2*%pi*N)
mprintf("Shaft torque=%f N-m",Tsh)
```

Scilab code Exa 19.6 Example on Torque and Speed

```

//calculating speed
P=4//no. of poles
V=220//applied voltage
Ia=46//current in armature circuit
Ra=.25//field resistance
Rse=.15//series field resistance
Rm=Ra+Rse
Eb=V-Ia*Rm
A=2//no. of parallel circuits
phi=20D-3//flux per pole
Z=1200//total conductors on armature
N=round(60*Eb*A/(P*phi*Z))
mprintf("Speed, N=%d rpm\n", N)
//calculating total torque
Ta=.159*P*phi*Ia*Z/A
mprintf("Total torque=%f N-m\n",Ta)
//calculating shaft power
Pm=Eb*Ia//mechanical power developed
Wc=900//iron and friction losses
Po=Pm-Wc
mprintf("Shaft power=%f kW\n",Po/1000)
//calculating shaft torque
Tsh=60*Po/(2*%pi*N)
mprintf("Shaft torque Tsh=%f N-m\n", Tsh)
//calculating efficiency
Pin=V*Ia//input to motor
e=Po/Pin*100
mprintf("Efficiency=%f percent",e)
```

Scilab code Exa 19.7 Example on Torque and Speed

```

//working as motor
V1=110//applied voltage to motor
Rsh=45//shunt field resistance
Ish1=V1/Rsh//shunt field current
Il=230
Ia1=Il-Ish1
Ra=.03//armature resistance
Eb1=V1-Ia1*Ra
N1=450//speed in rpm
V2=210//changed value of applied voltage
Ish2=V2/Rsh
Il=85//current drawn by the motor from the main
Ia2=Il-Ish2
Eb2=V2-Ia2*Ra
//back emf is directly proportional to shunt field
    current and speed
N2=(Eb2/Eb1)*(Ish1/Ish2)*N1
mprintf("Speed of the motor=%d rpm\n",N2)
//working as generator
V=200//terminal voltage across the load
Ish3=V/Rsh
Il=140//load current on the generator
Ia3=Il+Ish3
Eg=V+Ia3*Ra
N3=(Eg/Eb1)*(Ish1/Ish3)*N1
mprintf("Speed at which generator would have to run=
    %d rpm",N3)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 19.8 Example on Speed Control of DC Motors

```
V=230//voltage applied to motor
N1=1000//initial speed
Ia=35//armature current
Ra=.3//resistance of armature circuit
Eb1=V-Ia*Ra
N1=1000//speed in rpm
Ia=25//armature current in new situation
N2=750//changed speed in rpm
//back emf is directly proportional to speed
R=((V-Ia*Ra)*N1-N2*Eb1)/(Ia*N1)
mprintf("Additional resistance in armature circuit=
   %f ohm",R)
```

Scilab code Exa 19.9 Example on Speed Control of DC Motors

```
N1=600//initial speed of the motor in rpm
Ia1=20//armature current
V=200//applied voltage
Ra=.4//armature resistance
Eb1=V-Ia1*Ra
Rf1=200//field resistance
If1=200/200//field current
N2=900//increased speed in rpm
//If2=200/Rf
//phi1/phi2=If1/If2=Rf/200
//Ia2=Ia1*phi1/phi2=.1*Rf
//Eb2=200-.04*Rf
//back emf is directly proportional to flux and
   speed
//we get a quadratic equation in Rf as .04*Rf^2-200*
   Rf+57600=0
//solving for Rf
Rf2=(200-sqrt(200^2-4*.04*57600))/(2*.04)
```

```
mprintf("Additional resistance in the shunt field
    circuit=%f ohm",Rf2-Rf1)
```

Scilab code Exa 19.10 Example on Speed Control of DC Motors

```

V=500//applied voltage
N1=700//initial speed of motor
Ia1=50//armature current
Ra=.4//effective armature resistance
Eb1=V-Ia1*Ra
N2=600//reduced speeed of motor
Ia2=Ia1//as torque and flux remains same
//back emf is directly proportional to speed
R=((V-Ia2*Ra)*N1-Eb1*N2)/(Ia2*N1)
mprintf("Additional resistance in the armature
    circuit is %f ohm",R)
```

Scilab code Exa 19.11 Example on Speed Control of DC Motors

```

R=.25+.05//total resistance of the armature circuit
N1=500//normal speed
V=250//applied voltage
Ia1=100//armature current at normal speed
Eb1=V-Ia1*R
//solving part (i)
R1=R+1//total resisitance in the armature circuit
Ia2=50//armature current
Eb2=V-Ia2*R1
//back emf is directly proportional to speed
N2=Eb2/Eb1*N1
mprintf("For(i)\nSpeed=%d rpm\n",round(N2))
```

```
//solving part (ii)
Ia3=50//armature current
Eb3=V-Ia3*R
//Ish3=.6*Ish1-->phi3/phi1=.6
//back emf is directly proportional to flux and
   speed
N3=(Eb3/Eb1)*N1/.6
mprintf("For(ii)\nSpeed=%d rpm", N3)
```

Scilab code Exa 19.12 Example on Speed Control of DC Motors

```

//solving (i)
Il=70//current drawn by the motor
V=200//applied voltage
Rsh=100//shunt field resistance
Ish=V/Rsh//shunt field current
Ia1=Il-Ish
N1=500//initial speed
Ra1=.2//armature resistance
Eb1=200-Ia1*Ra1
N2=350//reduced speed of motor
Ia2=Ia1//armature current remains same
//Eb2=200-68*(R+.2)
//back emf is proportional to speed
R=((V-Ia2*Ra1)*N1-Eb1*N2)/(Ia2*N1)
mprintf("Additional resistance in the armature
   circuit=%f ohm\n",R)
//solving (ii)
Ra2=R+Ra1//armature resistance
Ia3=35//armature current
Eb3=V-Ia3*Ra2
N3=N1*Eb3/Eb1
mprintf("Speed=%d rpm",N3)
//answer vary from the textbook due to round off
```

```
error
```

Scilab code Exa 19.13 Example on Speed Control of DC Motors

```

V=250//voltage applied to the motor
Eb1=V//Ra is negligible
N1=500//speed in rpm
Ia1=40//armature current
R=25//additional resistance
//as flux remains same, back emf is directly
    proportional to speed; and torque is directly
    proportional to armature current
//Eb2=250-Ia2*25, N2=500-50*Ia2
//also, torque varies as cube of speed
//from these conditions, we get, Ia2^3-30*Ia2^2+325*
    Ia2-1000=0
//solving this equation, we get
Ia2=5
N2=(Ia2/Ia1)^(1/3)*N1
mprintf("Speed of the motor with 25 ohm resistor in
    the armature circuit=%d rpm",N2)
```

Chapter 20

Testing of DC Machine

Scilab code Exa 20.1 Example on losses in DC Machine

```

E1=400//eddy current losses
//for a machine, eddy current losses is directly
   proportional to Bmax^2 and f^2
//Bmax is proportional to flux
//f is proportional to speed
//when speed and flux increased by 10%
E2=1.1^2*1.1^2*E1 //Eddy current losses under
   changed condition
mprintf("Increase in eddy current losses=%f W", E2-
   E1)
```

Scilab code Exa 20.2 Example on losses in DC Machine

```

N=1500//speed in rpm
E1=300//hysteresis losses
//E1=k1*N
```

```
k1=E1/N
E2=150//eddy current losses
//E2=k2*N^2
k2=E2/N^2
E=E1+E2//total iron losses
//when iron losses are reduced to half
//k1*N1+k2*N1^2=.5*E
//solving for N1
N1=(-k1+sqrt(k1^2-4*k2*(-.5*E)))/(2*k2)
mprintf("Total iron losses will be halved if speed
    is reduced to %d rpm", round(N1))
```

Scilab code Exa 20.3 Example on losses in DC Machine

```

//calculating efficiency at full load
Il=200  //current supplied
Rsh=100  //shunt field resistance
V=500  //terminal voltage
Ish=V/Rsh
Ia=Il+Ish
Wcu=Ia^2*.1  //armature copper losses
Wc=4000 //constant losses including field copper
    losses
Wt=Wcu+Wc  //total losses
Po=V*Il  //output power
e=Po*100/(Po+Wt)
mprintf("Efficiency at full load=%f percent\n", e)
//Calculating efficiency at half load
Il=200/2
Ia=Il+Ish
Wcu=Ia^2*.1
Wt=Wc+Wcu
Po=V*Il
e=Po*100/(Po+Wt)
```

```
mprintf("Efficiency at half load=%f percent\n", e)
//Calculating efficiency at 1.5 times the full load
Il=1.5*200
Ia=Il+Ish
Wcu=Ia^2*.1
Wt=Wc+Wcu
Po=V*Il
e=Po*100/(Po+Wt)
mprintf("Efficiency at 1.5 times the full load=%f
    percent", e)
```

Scilab code Exa 20.4 Example on losses in DC Machine

```

Po=10D+3  //output power of each motor at full load
e=.85  //efficiency at full load
Pi=Po/e
W=Pi-Po  //total losses at full load for each motor
//calculating half load efficiency for motor A
Wc=500  //constant losses
Wcu1=(W-Wc)/2^2  //copper losses
W1=Wc+Wcu1  //total losses
P1=Po/2  //output
e1=P1/(P1+W1)*100
mprintf("Efficiency at half load for motor A=%f
    percent\n", e1)
//calculating half load efficiency for motor B
Wc=600  //constant losses
Wcu2=(W-Wc)/2^2  //copper losses
W2=Wc+Wcu2  //total losses
P2=Po/2  //output
e2=P2/(P2+W2)*100
mprintf("Efficiency at half load for motor B=%f
    percent", e2)
```

Scilab code Exa 20.5 Example on losses in DC Machine

```

//calculating power required at the driving shaft at
    full load
Po=30D+3  //output power of dc shunt generator
Wi=1300  //mechanical and iron losses
Rsh=125  //shunt field resistance
V=250  //terminal voltage
Ra=.13  //armature resistance
Ish=V/Rsh
Wcu=V*Ish  //shunt field copper losses
Wc=Wi+Wcu  //constant losses of generator
Il=Po/V
Ia=Il+Ish
Wcu=Ia^2*Ra  //armature copper loss
Wt=Wc+Wcu  //total losses
Pi=Po+Wt
mprintf("Power required at the driving shaft at full
    load=%f kW\n", Pi/10^3)
//calculating efficiency at full load
e=Po/Pi*100
mprintf("Efficiency at full load=%f percent\n", e)
//calculating efficiency at half load
Il=(Po/2)/V
Ia=Il+Ish
Wcu=Ia^2*Ra  //copper losses
Wt=Wc+Wcu  //total losses
e=(Po/2)/(Po/2+Wt)*100
mprintf("Efficiency at half load=%f percent\n", e)
//at maximum efficiency
Wcu=Wc  //copper losses
Ia=sqrt(Wcu/Ra)
Il=Ia-Ish
```

```
mprintf("Power output at max efficiency=%f kW\n",Il*
   V/10^3)
//calculating max efficiency
e_max=Il*V/(Il*V+2*Wc)*100
mprintf("Max efficiency=%f percent", e_max)
//answer vary from the textbook due to round off
   error
```

Scilab code Exa 20.6 Example on losses in DC Machine

```

V=500  //voltage applied to motor
Ra=.2  //armature resistance
Il0=4  //no load current taken by motor
Ish=1  //shunt current
Pi=V*Il0  //power input at no load
Ia0=Il0-Ish
Wcu=Ia0^2*Ra  //armature copper losses at no load
Wc=Pi-Wcu  //constant losses
//when input current=20 A
Il=20
Ia=Il-Ish
Wcu=Ia^2*Ra  //armature copper losses
Wt=Wc+Wcu  //total losses
Pi=V*Il  //power input to motor
Po=Pi-Wt
e=Po/Pi*100
mprintf("When input current=20 A, output is %f W and
    efficiency of motor is %f percent\n",Po, e)
//when input current =100 A
Il=100
Ia=Il-Ish
Wcu=Ia^2*Ra  //armature copper losses
Wt=Wc+Wcu  //total losses
Pi=V*Il  //power input to motor
```

```
Po=Pi-Wt
e=Po/Pi*100
mprintf("When input current=100 A, output is %f W and efficiency of motor is %f percent\n", Po,e)
```

Scilab code Exa 20.7 Example on losses in DC Machine

```

//shunt generator was run as a shunt motor at no load
I0=5  //current drawn
Ish=1.5  //shunt field current
Ia0=I0-Ish
Ra=.15  //armature circuit resistance
V=440  //terminal voltage
Wcu=Ia0^2*Ra  //armature copper loss
Pi=V*I0  //power input
Wc=Pi-Wcu  //constant losses
//calculating efficiency of shunt generator at full load
Po=50D+3  //output of generator
Il=Po/V  //load current
Ia=Il+Ish
Wcu=Ia^2*Ra //copper losses
Wt=Wc+Wcu  //total losses
e=Po/(Po+Wt)*100
mprintf("Efficiency of shunt generator at full load=%f percent\n", e)
//calculating efficiency at 3/4th load
I1=3/4*Il  //load current
Ia=I1+Ish
Wcu=Ia^2*Ra  //copper losses
Wt=Wc+Wcu  //total losses
e=(3/4*Po)/(3/4*Po+Wt)*100
mprintf("Efficiency at 3/4th load=%f percent\n", e)
```

```
//calculating efficiency at half load
I2=.5*I1  //load current
Ia=I2+Ish
Wcu=Ia^2*.15  //copper losses
Wt=Wc+Wcu  //total losses
e=(.5*Po)/(.5*Po+Wt)*100
mprintf("Efficiency at half load=%f percent", e)
```

Scilab code Exa 20.8 Example on losses in DC Machine

```

I1=50  //input current from mains
Po=100D+3  //output of generator on full load in W
V=500  //terminal voltage
I2=Po/V  //load current of generator
Rg=.1  //armature resistance of generator
Rm=.1  //armature resistance of motor
Pi=25D+3  //input power from mains
Pr=(Pi-I2^2*Rg-(I1+I2)^2*Rm)/2  //iron and
    mechanical losses in each machine
I3=4  //shunt field current of generator
I4=3  //shunt field current of motor
//calculating efficiency of generator
Wt=Pr+V*I3+I2^2*Rg  //total losses
e=Po/(Po+Wt)*100
mprintf("Efficiency of generator=%f percent\n", e)
//calculating efficiency of motor
Pi=V*(I1+I2+I4)  //power input
Wt=Pr+V*I4+(I1+I2)^2*Rm  //total losses
e=(Pi-Wt)/Pi*100
mprintf("Efficiency of motor=%f percent", e)
```

Chapter 21

Three Phase Alternators

Scilab code Exa 21.1 Example on emf Equation

```

//calculating speed
f=50//frequency
P=20//no. of poles
N=120*f/P
mprintf("Speed at which alternator must be run=%d
  rpm\n", N)
//calculating the generated emf per phase
x=180//total no. of slots
y=x/P//slots per pole
m=y/3//slots per pole per phase
alpha=180/9//phase displacement between adjacent
  slots
Kd=sin((m*alpha/2)*%pi/180)/(m*sin((alpha/2)*%pi
  /180))//distribution factor
Kc=1//coil span factor
Kw=Kd*Kc//winding factor
Z=180*8//total no. of conductors
a=Z/3//conductors per phase
T=a/2//turns per phase
phi=25D-3//flux per pole
```

```
Eph=round(4.44*Kw*f*phi*T)
mprintf("Generated emf per phase=%d V\n", Eph)
//calculating line emf
El=sqrt(3)*round(Eph)
mprintf("Line emf=%d V", round(El))
//answer vary from the textbook due to round off
   error
```

Scilab code Exa 21.2 Example on emf Equation

```

funcprot(0)
m=2//no. of slots per pole per phase
x=m*3//no. of slots per pole
alpha=180/x//phase displacement between adjacent
   slots in degrees
Kd=sin((m*alpha/2)*%pi/180)/(m*sin((alpha/2)*%pi
   /180))//distribution factor
beta=180-150//in degrees
Kc=cos((beta/2)*%pi/180)//coil span factor
Kw=Kd*Kc//winding factor
P=10//no. of poles
n=m*P//no. of slots per phase
Zph=n*10//no. of conductors per phase
Tph=100//no. of turns per phase
N=600//speed of the alternator in rpm
f=P*N/120//frequency
phi=.05//useful flux per pole in Wb
Eph=4.44*Kw*f*phi*Tph
mprintf("Stator emf per phase at no load=%d V",
   round(Eph))
```

Scilab code Exa 21.3 Example on emf Equation

```
funcprot(0)
//calculating pitch factor
beta=0//full pitch coil
Kc=cos((beta/2)*%pi/180)
mprintf("Pitch factor, Kc=%d\n", Kc)
//calculating distribution factor
m=4//no. of slots per pole per phase
x=m*3//no. of slots per pole
alpha=180/x//phase displacement between adjacent
    slots in degrees
Kd=sin((m*alpha/2)*%pi/180)/(m*sin((alpha/2)*%pi
    /180))
mprintf("Distribution factor of stator winding=%f\n"
    , Kd)
//calculating emf generated per phase
Kw=Kd*Kc
y=m*8//no. of slots per phase
n=y*10//no. of conductors per phase
Tph=160//no. of turns per phase
f=50//frequency
phi=.04//flux per pole
Eph=round(4.44*f*Kw*Tph*phi)
mprintf("Emf per phase at no load=%d V\n", Eph)
//calculating line emf
El=sqrt(3)*Eph
mprintf("Line emf=%d V", round(El))
//answer vary from the textbook due to round off
    error
```

Scilab code Exa 21.4 Example on emf Equation

```
funcprot(0)
//calculating distribution factor of stator winding
```

```
m=9//no. of slots per pole per phase
x=m*3//no. of slots per pole
alpha=180/x
Kd=sin((m*alpha/2)*%pi/180)/(m*sin((alpha/2)*%pi
    /180))
mprintf("Distribution factor of stator winding, Kd=
    %f\n",Kd)
//calculating pitch factor of stator winding
beta=2*20/3
Kc=cos((beta/2)*%pi/180)
mprintf("Pitch factor=%f\n", Kc)
//calculating useful flux per pole
Zph=9*2*4//no. of conductors per phase
Tph=36//turns per phase of stator winding
P=2//no. of poles
N=3000//speed in rpm
f=P*N/120
V=3.3D+3//line voltage
Eph=V/sqrt(3)
phi=Eph/(4.44*f*Kd*Kc*Tph)
mprintf("Useful flux per pole=%f Wb", phi)
```

Scilab code Exa 21.5 Example on emf Equation

```

funcprot(0)
m=5//no. of slots per pole per phase
x=m*3//no. of slots per pole
alpha=180/x//in degrees
Kd=sin((m*alpha/2)*%pi/180)/(m*sin((alpha/2)*%pi
    /180))//distribution factor
beta=3*12//in degrees
Kc=cos((beta/2)*%pi/180)//pitch factor of stator
    winding
Tph=5*2*4/2//no. of turns per phase
```

```
V=6D+3//line voltage
Eph=V/sqrt(3)
phi=.857//flux in Wb
f=round(Eph/(4.44*Kd*Kc*Tph*phi))
P=4//no. of poles
N=120*f/P
mprintf("Speed of rotation of alternator , N=%d rpm",
    round(N))
//answer vary from the textbook due to round off
    error
```

Scilab code Exa 21.6 Example on Regulation

```

//calculating regulation at full load at unity pf
V=3300//line voltage
Vph=V/sqrt(3)
P=500D+3//output
Ia=P/(sqrt(3)*V)
Ra=.4//resistance per phase
Xs=3.8//reactance per phase
pf=1//power factor
Ef=[(Vph*1+Ia*Ra)^2+(Vph*0+Ia*Xs)^2]^.5//open
    circuit voltage per phase
VR=(Ef-Vph)/Vph*100
mprintf("Regulation at full load at unity pf=%f
    percent\n", VR)
//calculating regulation at full load at .8 pf
    lagging
Ef=[(Vph*.8+Ia*Ra)^2+(Vph*0.6+Ia*Xs)^2]^.5
VR=(Ef-Vph)/Vph*100
mprintf("Regulation full load at .8 pf lagging=%f
    percent\n", VR)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 21.7 Example on emf Equation

```

//calculating synchronous impedance
Voc=90//open circuit voltage per phase
Isc=15//short circuit current
Zs=Voc/Isc
mprintf("Synchronous impedance=%d ohm\n", Zs)
//calculating synchronous reactance
Ra=1//armature resistance per phase
Xs=sqrt(Zs^2-Ra^2)
mprintf("Synchronous reactance=%f ohm\n", Xs)
//Solving part (iii)
V=400//line voltage
Vt=round(V/sqrt(3))//phase voltage at the terminals
    of load
Ia=15//load current
Ef=round([(Vt*.8+Ia*Ra)^2+(Vt*.6+Ia*Xs)^2]^.5)
mprintf("Voltage rises from %d V to %d V, when the
    load is thrown off\n", Vt,Ef)
//solving part (iv)
//at 0.8 pf lagging
VR=(Ef-Vt)/Vt*100
mprintf("Regulation at .8 pf lagging=%f percent\n",
    VR)
//at unity pf
Ef=[(Vt*1+Ia*Ra)^2+(Vt*0+Ia*Xs)^2]^.5
VR=(Ef-Vt)/Vt*100
mprintf("Regulation at unity pf=%f percent", VR)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 21.8 Example on Regulation

```

//refer Fig. 21.19 in the textbook
AT=15D+3//PE represents the armature reaction ampere
    turns
mprintf("Armature reaction ampere turns=%d\n", AT)
Pout=15D+6//output of the alternator
Vl=10.2D+3//line voltage
Il=Pout/(sqrt(3)*Vl)
Iph=Il
Ia=Il
//line DE represents the leakage reactance drop in
    terms of line values
Es=1.3D+3
Eph=Es/sqrt(3)
Xl=Eph/Ia
mprintf("Leakage reactance per phase, Xl=%f ohm\n",
    Xl)
//calculating regulation for full load at .8 pf
    lagging
Rt=.53//resistance of the stator winding between
    terminals
Ra=Rt/2//resistance per phase
Rd1=Ia*Ra//resistance drop in terms of phase value
Rd2=sqrt(3)*Rd1//resistance drop in terms of line
    value
//refer Fig.21.20(a) in the textbook
Ifg=21.67D+3
Ifs=1.67D+3
Ifsc=18D+3
//refer Fig.21.20(b) in the textbook
Ifl=40.67D+3//total field ampere turns
Ef=12.85D+3//no load voltage
Vt=10.2D+3//full load rated voltage
VR=(Ef-Vt)/Vt*100
mprintf("Regulation at full load, 0.8 pf lagging=%d
    percent", round(VR))
```

Scilab code Exa 21.9 Example on Regulation

```

function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
Vt=1100/sqrt(3)//terminal voltage,taken as reference
    phasor
Vt=pol2rect(Vt,0)
Ia=1200*1000/(3*Vt)//armature current
pf=.8//lagging power factor
phi=acosd(pf)
Ia=pol2rect(Ia,-phi)
Xq=1.2*j
Xd=1.8*j
//refer Fig.21.24 in the textbook, phasor OB in the
   direction of Ef is given as
OB=Vt+Ia*Xq
delta=29//power angle
Id=Ia*sin((delta+phi)*%pi/180)
Ef=mag(OB)+mag(Id)*mag(Xd-Xq)
mprintf("Excitation voltage Ef=%d V", round(Ef))
```

Scilab code Exa 21.10 Example on Regulation

```
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//terminal voltage is taken as reference phasor and
   the rated quantities are taken as 1 p.u.
Vt=pol2rect(1,0)//terminal voltage
pf=.8//lagging power factor
phi=acosd(pf)
Ia=pol2rect(1,-phi)//armature current
Xd=.8*j
Xq=.4*j
//refer to Fig.21.24 in the textbook
OB=Vt+Ia*Xq
delta=14.47//power angle
Id=Ia*sin((delta+phi)*%pi/180)
Ef=mag(OB)+mag(Id)*mag(Xd-Xq)
mprintf("Excitation voltage per phase is %f p.u.",
   Ef)
```

Chapter 22

Synchronous Motors

Scilab code Exa 22.1 Example on Phasor Diagram and Power angle Characteristics

```
function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
Va=400/sqrt(3)//per phase applied voltage
Ef=Va//per phase excitation voltage
delta=4*2//equivalent electrical degrees by which
   the rotor is retarted
Xs=2//per phase synchronous reactance
Vt=pol2rect(Va,0)
Ef=pol2rect(Ef,-8)
Xs=pol2rect(2,90)
```

```
Ia=(Vt-Ef)/Xs
[Ia theta]=rect2pol(Ia)
mprintf("Armature current drawn by the motor is %f A
   , lagging the applied voltage by %f degrees", Ia,
    -theta)
```

Scilab code Exa 22.2 Example on Phasor Diagram and Power angle Characteristics

```

//calculating armature current
Pout=7.46D+3//output power
Wc=500//iron amd mechanical losses
P=Pout+Wc//total mechanical power developed
Pm=P/3
Va=440/sqrt(3)//applied voltage per phase
pf=.75//lagging power factor
Ra=.5//effective resistance per phase
//Pm=Va*Ia*pf-Ia^2*Ra
//solving this quadratic equation
Ia=(Va*pf-sqrt((Va*pf)^2-4*Ra*Pm))/(2*Ra)
mprintf("Armature current=%f A\n", Ia)
//calculating total power supplied
Pin=Va*Ia*pf
Pi=3*Pin//total input to stator
Pe=650//excitation loss
Pt=Pi+Pe
mprintf("Total power supplied=%f W\n", Pt)
//calculating efficiency
e=Pout/Pt*100
mprintf("Efficiency=%f percent", e)
//answers vary from the textbook due to round off
   error
```

Scilab code Exa 22.3 Example on Phasor Diagram and Power angle Characteristics

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
f=50
P=4
Ns=120*f/P
//calculating excitation voltage and power angle
Va=400/sqrt(3)
Va=pol2rect(Va,0)
pf=1//power factor
Pin=3000//input to motor
Ia=Pin/(3*mag(Va))
Xs=8
Ef=mag(Va)-%i*Ia*Xs
[Ef theta]=rect2pol(Ef)
mprintf("Excitation voltage Ef=%f V, power angle=%f
   degrees\n", Ef,-theta)
```

```
//calculating torque developed
omega_s=2*%pi*Ns/60
T=3*mag(Va)*Ef/(Xs*omega_s)*sin(-theta*%pi/180)
mprintf("Mechanical torque developed T=%f N-m\n",T)
//calculating max torque developed
Tmax=3*mag(Va)*Ef/(Xs*omega_s)
mprintf("Max torque developed or pull out torque=%f N-m",Tmax)
```

Scilab code Exa 22.4 Example on Phasor Diagram and Power angle Characteristics

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
//calculating per phase current drawn from the supply
Pout=100*746//output power
Va=500/sqrt(3)//per phase applied voltage
Zs=.06+j*.6//synchronous impedance per phase
```

```
e=.89//efficiency of motor at full load
Pin=Pout/e//input to the motor
pf=.8//leading power factor
Ia=Pin/(3*Va*pf)
theta=acosd(.8)
mprintf("Current drawn from the supply is %f A leading the applied voltage by %f degrees\n", Ia, theta)
//calculating excitation voltage per phase
Va=pol2rect(Va,0)
Ia=pol2rect(Ia,theta)
Ef=Va-Ia*Zs
[Ef delta]=rect2pol(Ef)
mprintf("Excitation voltage per phase is %f V\nPower angle=%f degrees\n", mag(Ef),-delta)
//calculating mechanical power developed Pm
Ra=.06//stator winding resistance per phase
Pm=Pin-3*mag(Ia)^2*Ra
mprintf("Mechanical power developed=%f W\n", Pm)
```

Scilab code Exa 22.5 Example on Phasor Diagram and Power angle Characteristics

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
```

```
j=%i
Pout=10D+3//output of the motor at full load
e=.85//efficiency at full load
Pin=Pout/e//input at full load
Zs=.4+j*3//synchronous impedance per phase
Va=400/sqrt(3)//per phase applied voltage
pf=.8//leading power factor
Ia=Pin/(3*Va*pf)
Ia=pol2rect(Ia,acosd(pf))
Ef=Va-Ia*Zs
[Ef delta]=rect2pol(Ef)
mprintf("Motor must be excited to a voltage of %f V
    per phase and the angle of retard is %f degrees\n
    ", Ef,-delta)
```

Scilab code Exa 22.6 Example on Phasor Diagram and Power angle Characteristics

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction


j=%i
Va=400/sqrt(3)//applied voltage per phase
Zs=.5+j*4//synchronous impedance per phase
pf=1//power factor
Ia=15
Ef=Va-Ia*Zs
[Ef delta]=rect2pol(Ef)
```

```
mprintf("Excitation voltage is %f V and power angle
   is equal to %d degrees", Ef,-delta)
```

Scilab code Exa 22.7 Example on Phasor Diagram and Power angle Characteristics

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction

j=%i
//applied voltage per phase is taken as the
   reference phasor
Va=1//applied voltage per phase in p.u.
pf=.8//lagging power factor
theta=acosd(pf)
Ia=pol2rect(1,-theta)//armature current per phase
Xq=.4*j
Xd=.8*j
OC=Va-Ia*Xq
[OC alpha]=rect2pol(OC)
```

```
delta=-alpha//power angle
Id=Ia*sin((theta-delta)*%pi/180)
Ef=OC-mag(Id)*mag(Xd-Xq)//armature resistance is
    neglected
mprintf("Excitation voltage per phase is %f p.u.
    lagging the applied voltage by %f degrees\n",Ef,
    delta)
//calculating power due to excitation
Pf=Va*Ef*sin(delta*%pi/180)/mag(Xd)
mprintf("Per phase power developed due to field
    excitation is %f p.u.\n",Pf)
//calculating power due to saliency
Pr=Va^2*mag((Xd-Xq)/(2*Xd*Xq))*sin(2*delta*%pi/180)
mprintf("Per phase power developed due to saliency
    of the motor is %f p.u.\n",Pr)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 22.8 Example on Variation of Excitation

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
j=%i
//calculating new power angle
Va=400/sqrt(3)//applied voltage per phase
```

```
Pin=8.5D+3/3//power input per phase
pf=.8//lagging power factor
Ia=Pin/(Va*pf)//armature current per phase
theta=acosd(pf)
Ia=pol2rect(Ia,-theta)
Zs=4*j
Ef=Va-Ia*Zs
[Ef theta]=rect2pol(Ef)
delta=-theta
//the excitation voltage is increased by 50%
Ef_dash=1.5*Ef
//as the power developed remains same
delta_dash=asind(Ef*sin(delta*%pi/180)/Ef_dash)
mprintf("The new power angle is %f degrees\n",
    delta_dash)
//calculating new armature current and power factor
Ef_dash=pol2rect(Ef_dash,-delta_dash)
Ia_dash=(Va-Ef_dash)/Zs
[Ia_dash theta]=rect2pol(Ia_dash)
mprintf("The armature current drawn from the supply
    is %f A and is now leading the applied voltage by
     %f degrees with power factor=%f(leading)\n",
    Ia_dash,theta,cos(theta*%pi/180))
//answers vary from the textbook due to round off
    error
```

Chapter 23

Three Phase Induction Motor

Scilab code Exa 23.1 Example on Slip and Rotor Frequency

```
//calculating full load speed of induction motor
P1=8//no. of poles of alternator
N=750//speed at which alternator runs
f=P1*N/120//frequency of alternator
P2=6//no. of poles of induction motor
Ns=120*f/P2//synchronous speed
s=.03//full load slip
Nr=Ns*(1-s)
mprintf("Full load speed of induction motor=%d rpm\n
   ", round(Nr))
//calculating frequency of rotor emf
fr=s*f
mprintf("Frequency of rotor emf=%f Hz", fr)
```

Scilab code Exa 23.2 Example on Slip and Rotor Frequency

```
//calculating no. of poles
Ns=1200//synchronous speed of rotating magnetic
   field
f=60//frequency of the supply to the stator
P=120*f/Ns
mprintf("No. of poles=%d\n", P)
//calculating slip at full load
Nr=1140//full load speed
s=(Ns-Nr)/Ns
mprintf("Percentage slip at full load=%f percent\n",
   s*100)
//calculating frequency of rotor voltage
fr=s*f
mprintf("Frequency of rotor voltage=%d Hz\n",fr)
//calculating speed of rotor field w.r.t. rotor
N1=120*fr/P//speed
mprintf("Speed of rotor field w.r.t. rotor=%d rpm\n"
   ,N1)
//calculating speed of rotor field w.r.t. stator
N2=1140//speed of the rotor w.r.t. stator
mprintf("Speed of the rotor field w.r.t. stator=%d
   rpm\nSpeed of the rotor field w.r.t. stator field
   =%d rpm\n", N2+N1,N1+N2-Ns)
s=.1
N1=(1-s)*Ns
mprintf("Speed of the rotor at 10 percent slip=%d
   rpm\nRotor frequency at 10 percent slip=%d Hz\n",
   N1,s*f)
Eph=230//applied voltage per phase
E1ph=Eph//induced emf per phase in the stator
   winding
E2ph=E1ph*.5//rotor induced emf at standstill
E2ph_dash=s*E2ph
mprintf("Rotor induced emf at standstill=%f V\nRotor
    induced emf at 10 percent slip=%f V",E2ph,
   E2ph_dash)
```

Scilab code Exa 23.3 Example on Slip and Rotor Frequency

```

//calculating synchronous speed
f=50//frequency
P=4//no. of poles
Ns=120*f/P
mprintf("Synchronous speed=%f rpm\n",Ns)
//calculating speed of rotating air gap field
mprintf("Rotating field in air gap rotates at synchronous speed,hence its speed=%f rpm\n",Ns)
//calculating speed of induction motor
s=.04//slip
Nr=(1-s)*Ns
mprintf("Speed of induction motor=%f rpm\n",Nr)
//calculating slip in rpm
mprintf("Slip of the motor in rpm=%f rpm\n",s*Ns)
mprintf("The rotor field rotates at synchronous speed w.r.t. stator, hence relative speed=%f rpm\n",Ns)
mprintf("Both rotor and stator field rotate at synchronous speed,relative to the stator, hence, speed of rotor field w.r.t. stator field=0 rpm\n")
mprintf("Speed of the rotor field w.r.t. rotor=%f rpm\n",s*Ns)
//calculating frequency of rotor induced emf
fr=s*f
mprintf("Frequency of rotor induced emf=%f Hz\n",fr)
//calculating rotor induced emf per phase
k=.6//turns ratio
E1ph=400/sqrt(3)//induced emf in stator winding
E2ph=E1ph*k//rotor induced emf per phase at the instant of starting
```

```
E2ph_dash=s*E2ph
mprintf("Rotor induced emf per phase under loaded condition=%f V",E2ph_dash)
```

Scilab code Exa 23.4 Example on Equivalent Circuit

```

R2=.5//rotor resistance per phase
//at standstill
E=40//induced emf
E2=E/sqrt(3)//induced emf per phase
X2=3//rotor reactance per phase
R=4//additional resistance per phase in the rotor circuit
Rt=R2+R//total resistance per phase in the rotor circuit
Z2=sqrt(Rt^2+X2^2)//rotor impedance per phase
I2=E2/Z2
mprintf("Rotor current per phase at standstill=%f A\n", I2)
//calculating rotor current per phase at 5% slip
s=.05//slip
X2=s*X2
Z2=sqrt(R2^2+X2^2)
E2=s*E2//induced emf per phase
I2=E2/Z2
mprintf("Rotor current per phase at 5 percent slip=%f A",I2)
```

Scilab code Exa 23.5 Example on Equivalent Circuit

```

```

```
//calculating rotor starting current per phase on normal voltage with slip ring short-circuited
V=400//voltage applied to the stator winding
V1=V/sqrt(3)//phase voltage
k=2.5//transformation ratio
R2=.02//rotor resistance per phase
//at standstill
s=1//slip
E2=V1/k//induced phase voltage in the rotor winding
X2=2*%pi*50*.6D-3//rotor reactance per phase
Z2=sqrt(R2^2+X2^2)
I2=E2/Z2
mprintf("Rotor starting current per phase on normal voltage with slip ring short-circuited=%f A\n",I2)
//calculating rotor power factor at starting
pf=R2/Z2
mprintf("Rotor power factor at starting=%f\n",pf)
//calculating rotor current per phase at 3 % slip
s=.03//slip
E2=s*E2
X2=s*X2
Z2=sqrt(R2^2+X2^2)
I2=E2/Z2
mprintf("Rotor current per phase at 3 percent slip=%f A\n",I2)
//calculating rotor power factor at 3% slip
pf=R2/Z2
mprintf("Rotor power factor at 3 percent slip=%f",pf)
//answers vary from the textbook due to round off error
```

Scilab code Exa 23.6 Example on Equivalent Circuit

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
R2_dash=.16
s=.03
X2=.4
Z2_dash=R2_dash/s+X2*j//effective rotor impedance referred to stator
R0=200
Xm=20*j
Z=1/(1/R0+1/Xm+1/Z2_dash)//equivalent impedance
Z1=.15+.4*j//stator impedance
Zin=Z1+Z//total input impedance
V=400//applied voltage
//calculating stator current
V1=V/sqrt(3)//per phase stator voltage
I1=V1/Zin
[I1 theta1]=rect2pol(I1)
mprintf("Stator current=%f A at %f power factor lagging\n",I1,cos(theta1*%pi/180))
//calculating rotor current
I1=V1/Zin
E1=V1-I1*Z1
Iw=E1/R0//per phase core loss component of no load current
Im=E1/Xm//per phase magnetising current
I0=Iw+Im//no load current
I2_dash=I1-I0
```

```
[I2_dash theta2]=rect2pol(I2_dash)
mprintf("Per phase rotor current=%f A lagging by %f
    degrees\n",I2_dash,-theta2)
//calculating mechanical output power
P=I2_dash^2*R2_dash*(1-s)/s//mechanical power output
     per phase
Pout=3*P
mprintf("Total mechanical power output=%f kW\n",Pout
    /1000)
//calculating input power drawn by the motor
Pin=3*V1*mag(I1)*cos(theta1*%pi/180)
mprintf("Total input power drawn by the motor=%f kW\
    n",Pin/1000)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 23.7 Example on Equivalent Circuit

```


function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
R2_dash=.16
s=3/100//slip
Rl=R2_dash*(1-s)/s//load resistance
```

```
Z1=.15+.4*j//stator impedance
Z2_dash=.16+.4*j//equivalent rotor impedance
Z=Rl+Z1+Z2_dash//total impedance per phase
Vph=400/sqrt(3)//applied voltage per phase
I2_dash=Vph/Z
R0=200
Xm=20
Iw=Vph/R0
Im=Vph/Xm
I0=Iw-Im*j
I1=I0+I2_dash
[I1 theta]=rect2pol(I1)
pf=cos(theta*%pi/180)
p=mag(I2_dash)^2*Rl//output power per phase
Pout=3*p
Pin=3*Vph*I1*pf
mprintf("By using approximate equivalent circuit, the values of different parameters are as under\nPer phase stator current=%f A\nPer phase rotor current=%f A\nOperating power factor=%f\nInput power=%f kW\nMechanical output power=%f kW\n",I1,I2_dash,pf,Pin/10^3,Pout/10^3)
//refer Fig. 23.16 in the textbook
Z2_dash=5.3+j*0.4
Z=(j*Xm)*Z2_dash/(j*Xm+Z2_dash)//equivalent impedance
Zin=Z1+Z//total input impedance
I1=Vph/Zin
I2_dash=I1*j*Xm/(j*Xm+Z2_dash)
[I1 theta]=rect2pol(I1)
pf=cos(theta*%pi/180)
Pout=3*(mag(I2_dash))^2*R2_dash*(1-s)/s
Pin=3*Vph*I1*pf
mprintf("By solving the problem using the circuit in Fig. 23.16 in the book, the values of different parameters are as under\nPer phase stator current=%f A\nPer phase rotor current=%f A\nOperating power factor=%f\nInput power=%f kW\nMechanical
```

```
output power=%f kW\n",mag(I1),I2_dash,pf,Pin
/10^3,Pout/10^3)
```

Scilab code Exa 23.8 Example on Losses in Induction Motor

```

Pin=60D+3//power input
p=1D+3//stator losses
Pg=Pin-p//air gap power
s=3/100//slip
Pm=Pg*(1-s)
Prcu=s*Pg
mprintf("Mechanical power developed by the motor=%f
  kW with rotor copper losses of %f kW",Pm/1000,
  Prcu/1000)
```

Scilab code Exa 23.9 Example on Losses in Induction Motor

```

Po=50D+3//power output
e=90/100//efficiency
Pin=Po/e//power input
P=Pin-Po//total losses
//P=Pscu+Psi+Prcu+Pfw
//Pscu=Prcu=Psi, Pfw=Psi/3
Psi=P/(1+1+1+1/3)
Pscu=Psi//stator copper loss
Prcu=Psi
mprintf("Rotor copper loss=%d W\n",round(Prcu))
Pg=Pin-2*Pscu
mprintf("Air gap power=%d W\n",round(Pg))
s=Prcu/Pg
mprintf("Slip=%f p.u.", s)
```

```
//answers vary from the textbook due to round off
   error
```

Scilab code Exa 23.10 Example on Losses in Induction Motor

```

f=50//frequency
P=6//no. of poles
Ns=120*f/P//synchronous speed in rpm
Nr=950//speed at which the motor is running in rpm
s=(Ns-Nr)/Ns//slip
Pm=3.73D+3//mechanical power developed by the motor
//iron losses in the rotor are neglected
Prcu=s*Pm/(1-s)//rotor copper loss
P1=Pm+Prcu//rotor input
P=.25D+3//stator losses
P2=P1+P
mprintf("Stator input to the 3-phase induction motor
   =%f kW\n",P2/1000)
```

Scilab code Exa 23.11 Example on Losses in Induction Motor

```

//calculating rotor copper losses
s=.04//slip of the motor
Pout=14.92D+3//output of the motor
Pfw=200//friction and windage losses
Prcu=s*(Pout+Pfw)/(1-s)
mprintf("Rotor copper losses=%d W\n",round(Prcu))
//calculating efficiency at full load
P=Pout+Pfw+Prcu+1620//stator input
e=Pout/P*100
mprintf("Efficiency at full load=%f percent\n",e)
```

```
//calculating line current
pf=.86//power factor of load
Vl=500//line voltage
Il=P/(sqrt(3)*Vl*pf)
mprintf("Line current=%f A\n",Il)
//calculating no of complete cycles of the rotor electromotive force per minute
f=50//supply frequency
f_r=s*f//frequency of rotor emf
n=f_r*60
mprintf("No of complete cycles of the rotor electromotive force per minute=%d\n",n)
//answer vary from the textbook due to round off error, also there is an error in value of stator input given in textbook
```

Scilab code Exa 23.12 Example on Losses in Induction Motor

```

//calculating slip
n=100//no. of complete alternations per minute of rotor emf
f_r=n/60//rotor frequency in Hz
f=50//supply frequency in Hz
s=f_r/f
mprintf("Slip of the motor=%f percent\n",s*100)
//calculating rotor speed
P=6//no. of poles
Ns=120*f/P//synchronous speed
Nr=(1-s)*Ns
mprintf("Rotor speed=%d rpm\n",round(Nr))
//calculating rotor copper losses per phase
P1=75D+3//rotor input
Prcu=P1*s
mprintf("Rotor copper losses per phase=%f W\n",Prcu
```

```
/3)
//calculating mechanical power developed
Pm=P1-Prcu
mprintf("Mechanical power developed=%f kW\n",Pm/1000)
//calculating rotor resistance per phase
Ir=60//rotor current
Rr=Prcu/(3*Ir^2)
mprintf("Rotor resistance per phase=%f ohm",Rr)
//answers vary from the textbook due to round off error
```

Scilab code Exa 23.13 Example on Torque

```


//calculating ratio of maximum to full load torque
Nr=970//speed at full load torque in rpm
Ns=50*120/6//synchronous speed in rpm
s=(Ns-Nr)/Ns//slip at full load
R2=.02//rotor resistance per phase
X2=.3//rotor reactance per phase at standstill
alpha=R2/X2
//Full load torque Tf=k1*Kt
k1=s*alpha/(s^2+alpha^2)
//maximum torque Tmax=Kt/2
x=1/(2*k1)
mprintf("Ratio of maximum to full load torque=%f\n",x)
//calculating speed at maximum torque
s_m=R2/X2//slip at maximum torque
Nm=(1-s_m)*Ns
mprintf("Speed at maximum torque=%d rpm\n",round(Nm))
//calculating ratio of starting torque to full load
```

```
torque
s=1//slip at starting
//starting torque Tst=k2*Kt
k2=s*alpha/(s^2+alpha^2)
y=k2/k1
mprintf("Ratio of starting torque to full load torque=%f\n",y)
```

Scilab code Exa 23.14 Example on Torque

```

function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
j=%i
Vl=220//line voltage
Vph=Vl/sqrt(3)//stator phase voltage
n=.65//ratio of no. of rotor winding turns to no. of stator winding turns
E2=n*Vph//phase voltage induced in the rotor winding at standstill
R2=.1//rotor resistance per phase
X2=.8//standstill reactance per phase
//at 5 % slip
s=5/100
X=s*X2//reactance per phase
Z2=R2+X*j//rotor impedance
e2=s*E2//rotor phase voltage
I2=e2/mag(Z2)
mprintf("Rotor current at 5 percent slip=%f A\n",I2)
//calculating rotor input
Prcu=3*I2^2*R2//total rotor copper losses
Pg=Prcu/s
```

```
mprintf("Rotor input=%f W\n",Pg)
//calculating total torque at 5% slip
Pm=Pg-3*I2^2*R2//mechanical power developed by the
    rotor
Ns=120*50/4//synchronous speed
Nr=Ns*(1-s)//speed of the rotor
T=60*Pm/(2*%pi*round(Nr))
mprintf("Total torque developed by the rotor at 5
    percent slip=%f N-m\nTotal mechanical power at 5
    percent slip=%f kW\n",T,Pm/1000)
//calculating rotor current at maximum torque
s_m=R2/X2//slip for maximum torque
I2m=s_m*E2/sqrt(R2^2+(s_m*X2)^2)
mprintf("Rotor current at maximum torque=%d A\n",
    round(I2m))
//calculating rotor input corresponding to maximum
    torque
Sm=3*round(I2m)^2*R2//total rotor copper losses
Pg=Sm/s_m
mprintf("Rotor input corresponding to maximum torque
    =%f W\n",Pg)
//calculating maximum torque
Pm=Pg-Sm
Nm=Ns*(1-s_m)
T=60*Pm/(2*%pi*round(Nm))
mprintf("Maximum torque=%f N-m\nSpeed at maximum
    torque=%d rpm\nMaximum mechanical power=%f kW",T,
    Nm,Pm/1000)
//answers vary from the textbook due to round off
    error
```

Scilab code Exa 23.15 Example on Torque

```

Ns=120*50/4//synchronous speed
```

```
R2=.03//rotor resistance
X2=.15//rotor reactance
alpha=R2/X2
s_m=alpha//slip at maximum torque
Nr=(1-s_m)*Ns//speed at maximum torque
//alpha=(.03+r)/.15
//Tst=Kt*alpha/(1+alpha^2)
//Tmax=Kt/2
//Tst/Tmax=3/4-->3*alpha^2-8*alpha+3=0
//solving for alpha
alpha=(8-sqrt(8^2-4*3*3))/(2*3)
r=.15*alpha-.03
mprintf("If a resistance of %f ohm is added in the
    circuit , the required starting torque will be
    achieved",r)
```

Scilab code Exa 23.16 Example on Torque

```

R2=1.1//rotor resistance per phase
//at 60 Hz supply
f=60//frequency of supply
P=6//no. of poles
Ns1=120*f/P//synchronous speed
Nr=1000//speed of rotor
s_m1=(Ns1-Nr)/Ns1//slip at maximum torque
X2=R2/s_m1
L2=X2/(2*%pi*60)
//at 50 Hz supply
X2=2*%pi*50*L2
s_m2=R2/X2//slip at maximum torque
Ns2=120*50/6//synchronous speed
Nr2=(1-s_m2)*Ns2
mprintf("Rotor speed at maximum torque=%d rpm",round
    (Nr2))
```

Scilab code Exa 23.17 No load and Block Rotor Test

```

function[z]=pol2rect(r,theta)
    x=r*cos(theta)
    y=r*sin(theta)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction

j=%i
R1=.15//per phase stator winding resistance
//block rotor test
Vb=133/sqrt(3)//per phase voltage
Ib=100//per phase current
Wb=8085/3//per phase power
Zb=Vb/Ib//per phase impedance
Rb=Wb/Ib^2//per phase resistance
Xb=sqrt(Zb^2-Rb^2)//per phase reactance
R2_dash=Rb-R1//per phase rotor resistance referred
   to stator
X2_dash=Xb/2//per phase rotor reactance referred to
   stator
X1=X2_dash//per phase stator leakage reactance
//no load test
Vo=400/sqrt(3)//per phase voltage
Io=20//per phase current
Wo=2080/3//per phase power
pf=Wo/(Vo*Io)//power factor
phi0=acos(pf)
```

```
Iw=Io*cos(phi0)
Im=-Io*sin(phi0)*j
Io=pol2rect(Io,-phi0)
Z1=R1+X1*j
Ro=(Vo-Io*Z1)/Iw
Xm=(Vo-Io*Z1)/Im
mprintf("Equivalent circuit parameters are\nR1=%f
   ohm;\nX1=%f ohm;\nR2_dash=%f ohm;\nX2_dash=%f ohm
   ;\nRo=%f ohm;\nXm=%f ohm",R1,X1,R2_dash,X2_dash,
   mag(Ro),mag(Xm))
```

Scilab code Exa 23.18 Example on Circle Diagram

```

//refer Fig. 23.25 in the textbook
k1=40//current scale
Vph=400/sqrt(3)//voltage per phase
P=k1*Vph//power per phase
k2=3*P//power scale
//calculating full load stator current
P=33.6D+3//output of motor
P1=P/k2//ouput of motor to scale
//P is the corresponding operating point
OP=1.55
I1=OP*k1
phi1=28.5
mprintf("Full load stator current=%f A with %f power
    factor lagging\n",I1,cos(phi1*%pi/180))
//calculating efficiency at full load
PL=2.35
PX=2.75
e=PL/PX*100
mprintf("Efficiency at full load=%f percent\n",e)
//calculating max power output
NPm=2.6
```

```
mprintf("Maximum output power=%f kW\n",NPm*k2*10^-3)
//calculting max torque developed
MTm=3.12
mprintf("Maximum torque developed by the motor=%f kW
   ",MTm*k2*10^-3)
//answers vary from the textbook due to round off
   error
```

Scilab code Exa 23.19 Example on starting

```

//at short circuit
Vsc=100//applied voltage
Isc=15//line value of current
Iph=Isc/sqrt(3)//phase value of current
//calculating starting current drawn by the motor
V=400//line voltage
Vph=V/sqrt(3)//phase voltage
I=Iph*Vph/Vsc//phase value of starting current
Il=I
mprintf("Starting current drawn by the motor=%d A\n"
   ,Il)
//calculating ratio of starting to full load current
Pout=5D+3//output
e=.84//full load efficiency
pf=.82//power factor
I=Pout/(sqrt(3)*V*pf*e)//full load current
r=Il/I
mprintf("Ratio of starting to full load current=%f",
   r)
```

Scilab code Exa 23.20 Example on starting

```
V=400//phase voltage applied to motor
//when started directly on line
Iph=25//phase current
Il=sqrt(3)*Iph
mprintf("Line current drawn by the motor when
    started directly on line=%f A\n",Il)
//when started with auto-transformer starter with a
    tapping percent of 60 percent
Vl=.6*V//line voltage
Vph=Vl//phase voltage
Iph=25//phase current
Ist=Iph*Vph/V
Il=sqrt(3)*Ist
mprintf("When started with auto-transformer starter
    with a tapping of 60 percent\nPhase starting
    current =%f A\nLine starting current=%f A\n",Ist,
    Il)
//when started with star-delta starter
Vph=V/sqrt(3)//phase voltage
I=Iph*Vph/V
Il=I
mprintf("When started with star-delta starter\nPhase
     starting current =%f A\nLine starting current=%f
     A",I,Il)
```

Chapter 24

Single Phase Induction Motor

Scilab code Exa 24.1 Example on Equivalent Circuit

```

f=50//frequency in Hz
P=4//no. of poles
Ns=120*f/P//synchronous speed
Nr=1420
//calculating forward slip
s=(Ns-Nr)/Ns
mprintf("Forward slip=%f p.u.\n",s)
//calculating backward slip
s1=2-s
mprintf("Backward slip s_b=%f p.u.\n",s1)
//calculating effective rotor resistance in forward
    branch
R2_dash=4.5
Rf=R2_dash/(2*s)
mprintf("Effective rotor resistance in forward
    branch=%f ohm\n", Rf)
//calculating effective rotor resistance in backward
     branch
Rb=R2_dash/(2*(2-s))
mprintf("Effective rotor resistance in backward
```

```
   branch=%f ohm", Rb)
//answers vary from the textbook due to round off
   error
```

Scilab code Exa 24.2 Example on Equivalent Circuit

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
f=50//frequency
P=4//no. of poles
Ns=120*f/P//synchronous speed
Nr=1420
s=(Ns-Nr)/Ns
Xm=70
R2_dash=3.75
X2_dash=1.75
Zf=(Xm*%i/2)*(R2_dash/(2*s)+%i*X2_dash/2)/(R2_dash
   /(2*s)+%i*(Xm+X2_dash)/2)//forward impedance
Zb=(%i*Xm/2)*(R2_dash/(2*(2-s))+%i*X2_dash/2)/(
   R2_dash/(2*(2-s))+%i*(Xm+X2_dash)/2)//backward
```

```
impedance
Z1=2.5+%i*1.5
Zin=Z1+Zf+Zb//input impedance
//calculating input current
V1=pol2rect(230,0)
I1=V1/Zin
[I1 theta]=rect2pol(I1)
mprintf("Input current drawn by the motor is %f A, lagging the applied voltage by %f degrees\n", I1,-theta)
//calculating input power
Pin=mag(V1)*I1*cos(theta*%pi/180)
mprintf("Power input=%f W\n", Pin)
//calculating mechanical power developed
Pgf=I1^2*real(Zf)
Pgb=I1^2*real(Zb)
Pm=(Pgf-Pgb)*(1-s)
mprintf("Mechanical power developed=%f W\n", Pm)
//calculating resultant torque developed
omega_s=2*%pi*Ns/60
T=(Pgf-Pgb)/omega_s
mprintf("Resultant torque developed=%f N-m\n",T)
//calculating efficiency
Prot=35+60
Pout=Pm-Prot
e=Pout/Pin*100
mprintf("Efficiency=%f percent", e)
//answers vary from the textbook due to round off error
```

Scilab code Exa 24.3 Example on Equivalent Circuit

```

function[r,theta]=rect2pol(A)
    x=real(A)
```

```
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atan(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta)
    y=r*sin(theta)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
f=50//frequency
P=4//no. of poles
Ns=120*f/P//synchronous speed
Nr=1425
s=(Ns-Nr)/Ns//slip
R2_dash=7.5
X2_dash=4.5
Xm=150
Zf=(Xm*%i/2)*(R2_dash/(2*s)+%i*X2_dash/2)/(R2_dash/(2*s)+%i*(Xm+X2_dash)/2)//forward impedance
Zb=(%i*Xm/2)*(R2_dash/(2*(2-s))+%i*X2_dash/2)/(R2_dash/(2*(2-s))+%i*(Xm+X2_dash)/2)//backward impedance
Z1=2.5+4.5*%i
Zin=Z1+Zf+Zb//input impedance
//calculating input current
V1=pol2rect(230,0)
I1=V1/Zin
[I1 theta]=rect2pol(I1)
mprintf("Input current drawn by the motor is %f A at %f pf lagging\n", I1,cos(theta))
//calculating air gap power
Pgf=I1^2*real(Zf)//air gap power due to forward field
```

```
Pgb=I1^2*real(Zb)//air gap power due to backward field
Pg=Pgf+Pgb
mprintf("Air gap power=%f W\n",Pg)
//calculating rotor copper losses
Prc=s*Pgf+(2-s)*Pgb
mprintf("Rotor copper losses=%f W",Prc)
//answers vary from the textbook due to round off error
```

Scilab code Exa 24.4 Example on No Load and Block Rotor Test

```

//under block rotor condition
Vb=82.5
Ib=9.3
Zb=Vb/Ib
P=500//power consumed
Rb=P/Ib^2
Xb=sqrt(Zb^2-Rb^2)
R1=2.5//main resistance winding
R2_dash=Rb-R1//rotor resistance referred to stator
X1=Xb/2
X2_dash=X1//rotor reactance referred to stator
//under no load
I0=6.4
V0=230
Z0=V0/I0
P0=220//power consumed
R0=P0/I0^2
X0=sqrt(Z0^2-R0^2)
Xm=2*X0-3/2*Xb
mprintf("Equivalent circuit parameters of the motor are:\nR1=%f ohm,\nX1=%f ohm,\nXm=%f ohm,\nR2_dash=%f ohm,\nX2_dash=%f ohm\n", R1,X1,Xm,R2_dash,
```

```
X2_dash)
```

Scilab code Exa 24.5 Example on No Load and Block Rotor Test

```

function[r,theta]=rect2pol(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
    theta=atand(y/x)
endfunction
function[z]=pol2rect(r,theta)
    x=r*cos(theta*%pi/180)
    y=r*sin(theta*%pi/180)
    z=x+y*%i
endfunction
function[r]=mag(A)
    x=real(A)
    y=imag(A)
    r=sqrt(x^2+y^2)
endfunction
f=50//frequency
P=4//no. of poles
Ns=120*f/P//synchronous speed
Nr=1420//motor speed
s=(Ns-Nr)/Ns
R1=2.5
X1=3.365
Xm=60.945
R2_dash=3.28
X2_dash=3.365
Zf=(Xm*%i/2)*(R2_dash/(2*s)+%i*X2_dash/2)/(R2_dash/(2*s)+%i*(Xm+X2_dash)/2)//forward impedance
Zb=(%i*Xm/2)*(R2_dash/(2*(2-s))+%i*X2_dash/2)/(R2_dash/(2*(2-s))+%i*(Xm+X2_dash)/2)//backward
```

```
impedance
Z1=R1+%i*X1
Zin=Z1+Zf+Zb//input impedance
//calculating input current and power factor
V1=pol2rect(230,0)
I1=V1/Zin
[I1 theta]=rect2pol(I1)
mprintf("Input current drawn by the motor is %f A lagging the applied voltage by an angle of %f degrees, that is at %f pf lagging\n", I1,-theta,cos(theta*%pi/180))
//calculating input power
Pin=mag(V1)*I1*cos(theta*%pi/180)
mprintf("Power input=%f W\n", Pin)
//calculating torque developed
Pgf=I1^2*real(Zf)
Pgb=I1^2*real(Zb)
omega_s=2*%pi*Ns/60
T=(Pgf-Pgb)/omega_s
mprintf("Resultant torque developed=%f N-m\n",T)
//calculating output power
Pm=(Pgf-Pgb)*(1-s)//mechanical power developed
W0=220//power consumed under no load
I0=6.4//no load current
Prot=W0-I0^2*(R1+R2_dash/4)//rotational losses
Pout=Pm-Prot
mprintf("Output power developed=%f W\n", Pout)
//calculating efficiency
e=Pout/Pin*100
mprintf("Efficiency=%f percent\n", e)
//calculating air gap power
Pg=Pgf+Pgb
mprintf("Air gap power=%f W\n",Pg)
//calculating rotor copper losses
Prc=s*Pgf+(2-s)*Pgb
mprintf("Rotor copper losses=%f W",Prc)
//answers vary from the textbook due to round off error
```