

Scilab Textbook Companion for
Basic Electrical Engineering
by A. Mittle and V. N. Mittle¹

Created by
Idris Manaqibwala
Electrical Technology
Civil Engineering
VNIT Nagpur
College Teacher
Prof. V. B. Borghate
Cross-Checked by
Bhavani Jalkrish

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

Scilab numbering policy used in this document and the relation to the above book. Example (Solved example) Example (Solved example) Equation (Particular equation of the above book) Equation (Particular equation of the above book) Appendix to Example (Scilab Code that is an Appendix 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.

~~###~~ 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.

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Chapter 1

DC Circuits

Scilab code Exa 1.1 Example on Ohms Law

```
1
2 //By KCL, I1 + I2=2.25
3 I1=10/(2+8)
4 I2=2.25-I1
5 r=(10-5*I2)/I2
6 mprintf("r=%d ohm, current in branch ABC=%d A and
   current in branch ADC=%f A", r, I1, I2)
```

Chapter 2

DC Circuits

Scilab code Exa 1.1 Example on Ohms Law

```
1
2 //By KCL, I1 + I2=2.25
3 I1=10/(2+8)
4 I2=2.25-I1
5 r=(10-5*I2)/I2
6 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

```
1
2 //i1, i2, i3 be the currents in the branches CD, EF
   and GH respectively
3 //i1+i2+i3=1.5
4 i2=(20-1.5*10)/15
5 i3=(20-1.5*10)/15
6 i1=1.5-i2-i3
7 r=(20-1.5*10)/i1
8 mprintf("r=%f ohm", r)
```

Scilab code Exa 1.3 Example on Ohms Law

```
1
2 //points A,E,F,G are at the same potential
3 Rab=20
4 Reb=50
5 R1=Rab*Reb/(Rab+Reb) //equivalent resistance of Rab
   and Reb
6 Rbc=25
7 R2=R1+Rbc //equivalent resistance of R1 and Rbc
8 Rfc=50
9 R3=Rfc*R2/(Rfc+R2) //equivalent resistance of R2
   and Rfc
10 Rcd=30
11 R4=R3+Rcd //equivalent resistance of R3 and Rcd
12 R=R4*50/(50+R4) //equivalent resistance between A
   and D
13 i=200/R //Ohm's Law
14 mprintf("Current drawn by circuit=%f A", i)
```

Scilab code Exa 1.4 Example on Kirchhoffs Law

```
1
2 //refer Fig. 1.10 in the textbook
3 //applying KCL, I1+I2=20; -I2+I3=30
4 //applying KVL
5 //for mesh ABGHA, -0.1*I2+20*R1=108
6 //for mesh BCFGB, 0.3*I2+20*R1-30*R2=0
7 //for mesh CDEFC, 0.2*I2+30*R2=114
8 a=[-0.1 20 0;0.3 20 -30;0.2 0 30]
9 b=[108;0;114]
```

```

10 x=inv(a)*b
11 I2=x(1,1)
12 R1=x(2,1)
13 R2=x(3,1)
14 I1=20-I2
15 I3=30+I2
16 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

```

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

```

Scilab code Exa 1.6 Example on Kirchhoffs Law

```

1
2 //refer Fig.1.12 in the textbook
3 //Applying KVL
4 //for mesh AHGBA, -23*i1+20*i2+3*i4=0
5 //for mesh GFCBG, 20*i1-43*i2+20*i3+3*i4=0
6 //for mesh FEDCF, 20*i2-43*i3+3*i4=0
7 //for mesh ABCDJIA, 3*i1+3*i2+3*i3-9*i4+50=0

```

```

8 a=[-23 20 0 3;20 -43 20 3;0 20 -43 3;3 3 3 -9]
9 b=[0;0;0;-50]
10 i=inv(a)*b
11 i1=i(1,1)
12 i2=i(2,1)
13 i3=i(3,1)
14 i4=i(4,1)
15 V1=3*(i4-i1)
16 V2=3*(i4-i2)
17 V3=3*(i4-i3)
18 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

```

1
2 //refer Fig.1.13 in the textbook
3 //by applying KVL
4 //for mesh ABCDA, 7.45*i1 -3.25*i2=10
5 //for mesh EFBAE, 8.55*i2 -5.3*i3 -3.25*i1=10
6 //for mesh HGBFEAH, 11.3*i3 -5.3*i2=80
7 a=[7.45 -3.25 0;-3.25 8.55 -5.3;0 -5.3 11.3]
8 b=[10;10;80]
9 i=inv(a)*b
10 i1=i(1,1)
11 i2=i(2,1)
12 i3=i(3,1)
13 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


```

1
2 //using Superposition Theorem
3 //consider E1 alone
4 E1=1.5
5 R1=(1+1)*2/(1+1+2)+2 //total resistance
6 I1=E1/R1 //current supplied
7 i1=I1/2 //current in branch AB from B to A
8 //consider E2 alone
9 E2=1.1
10 R2=(1+1)*2/(1+1+2)+1+1 //total resistance
11 I2=E2/R2 //current supplied
12 i2=I2/2 //current in branch AB from B to A
13 mprintf("Current through 2 ohm resistor=%f A", i1+i2
)

```

Scilab code Exa 1.9 Example on Superposition Theorem

```

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

```

Scilab code Exa 1.10 Example on Thevenin Theorem

```

1

```

```

2 //refer Fig.1.22(a) in the textbook
3 //resistance between A and B is removed
4 //I1 be current in branch CD
5 //applying KCL
6 //100-I1 is the current in branch AF
7 //I1-50 is the current in branch DE
8 //70-I1 is the current in branch FE
9 //applying KVL for mesh CDEFC, we get ,
10 I1=56
11 V=.1*I1+.15*(I1-50) //thevenin's voltage
12 r=(.1+.15)*(.1+.15)/(.25+.25) //thevenin's
    equivalent resistance
13 I=V/(r+.05)
14 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

```

1
2 //by Norton's Theorem
3 I=2*10//total current produced by current source
4 r=2*2/(2+2)//resultant resistance of current source
5 In=20*r/(r+1)//norton current
6 Rn=1+r//norton resistance
7 I=In*Rn/(Rn+8)
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

```

1
2 //circuit has 4 nodes, viz, A, B, C and D
3 //node D is taken as reference node

```

```

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

```

Scilab code Exa 1.13 Example on Maximum Power Transfer Theorem

```

1
2 V=3*20/(2+3)//thevenin's voltage
3 r=1+2*3/(2+3)//thevenin's equivalent resistance
4 R=r
5 Pmax=V^2/(4*r)
6 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

```

1
2 //inner delta DEF is transformed to equivalent star
   connection having resistances Ra, Rb, Rc
3 Ra=1.5*2.5/(1.5+2.5+1)

```

```

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

```

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

```

1
2 //by Superposition Theorem
3 //consider 2 V battery alone
4 R1 =(3+1)*2/(3+1+2) //equivalent resistance of Raf,
   Rfg, Rab
5 R2 =(1+R1)*12/(1+R1+12) //equivalent resistance of
   Rad, Rl, Rde
6 R=1+2+R2 //total resistance of the circuit
7 I1=2/R
8 I2=I1*12/(1+R1+12)
9 I3=I2*4/(2+4) //current through 2 ohm
10 //consider 4 V battery alone
11 I4=34/71 //current through 2 ohm
12 I=I3+I4
13 printf("By Superposition Theorem, current through

```

```

    the 2 ohm resistance is %f A from A to B\n", I)
14 //by Thevenin's Theorem
15 //applying KCL
16 //for mesh CDHIC, 15*i1+12*i2=2
17 //for mesh DEGH, 12*i1+17*i2=4
18 a=[15 12;12 17]
19 b=[2;4]
20 i=inv(a)*b
21 i1=i(1,1)
22 i2=i(2,1)
23 Vab=4-3*i2-i2
24 R1=(1+2)*12/(1+2+12) //R1 is equivalent resistance
    of Rcd, Rci, Rdh
25 R=(1+R1)*(3+1)/(1+R1+3+1) //thevenin's equivalent
    resistance
26 I=Vab/(R+2)
27 mprintf("By Thevenin Theorem, current through 2 ohm
    resistance is %f A from A to B\n", I)
28 //by Maxwell Mesh Analysis
29 //applying KVL
30 //for mesh CDEHC, 15*I1-12*I2=2
31 //for mesh DABED, -12*I1+15*I2+2*I3=0
32 //for mesh AFGBA, 2*I2+6*I3=4
33 a=[15 -12 0;-12 15 2;0 2 6]
34 b=[2;0;4]
35 i=inv(a)*b
36 I1=i(1,1)
37 I2=i(2,1)
38 I3=i(3,1)
39 mprintf("By Maxwell Mesh Analysis, current through 2
    ohm resistance is %f A from A to B ", I2+I3)

```

Chapter 3

Electrostatics

Scilab code Exa 2.1 Example on Coulombs Law

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

Scilab code Exa 2.2 Example on Electric Intensity

```
1
```

```

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

```

1
2  epsilon=8.854D-12
3  AB=.05
4  BC=.07
5  AC=sqrt(.05^2+.07^2)
6  V1=2D-10/(4*%pi*epsilon*.05)//potential at A due to
   charge at B
7  V2=-8D-10/(4*%pi*epsilon*AC)//potential at A due to
   charge at C
8  V3=4D-10/(4*%pi*epsilon*.07)//potential at A due to
   charge at D
9  V=V1+V2+V3
10 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

```
1
2 C=30D-6
3 R=500
4 T=C*R
5 mprintf("Time constant T=%f sec\n", T)
6 //at t=0sec, voltage across capacitor is zero
7 V=100//aplied voltage
8 I=V/R//Ohm's Law
9 mprintf("Initial current=%f A\n", I)
10 t=.05
11 Q=C*V
12 q=Q*(1-exp(-t/T))
13 mprintf("Charge on the capacitor after 0.05 sec is
        %f C\n", q)
14 i1=I*exp(-t/T)
15 mprintf("Charging current after 0.05 sec is %f A\n",
        i1)
16 t=.015
17 i2=I*exp(-t/T)
18 mprintf("Charging current after 0.015 sec is %f A\n"
        ,i2)
19 V=i1*R
20 mprintf("Voltage across 500 ohm resistor after 0.05
        sec is %f V", V)
21 //answers vary from the textbook due to round off
        error
```

Scilab code Exa 2.5 Example on charging and discharging of capacitor

1


```

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

```

Scilab code Exa 2.6 Example on charging and discharging of capacitor

```

1
2 C1=100D-6 //capacitance of first capacitor which is
    to be charged
3 V=200 //voltage across C1
4 Q=C1*V
5 //Let Q1, Q2, Q3, Q4 be the charges on respective
    capacitors after connection
6 Q2=4000D-6
7 Q3=5000D-6
8 Q4=6000D-6
9 Q1=Q-(Q2+Q3+Q4)
10 C2=C1*(Q2/Q1)
11 C3=C1*(Q3/Q1)
12 C4=C1*(Q4/Q1)
13 mprintf("Three capacitors have capacitances %d
    microF, %d microF and %d microF\n", C2*10^6,C3
    *10^6,C4*10^6)
14 Vt=Q1/C1
15 mprintf("Voltage across the combination =%f V", Vt)

```

Chapter 4

Electromagnetism

Scilab code Exa 3.2 Example on Field Strength and Flux Density

```
1
2 mu_not=4D-7*%pi
3 N=150 //no. of turns of coil
4 I=4 //current carried by coil
5 l=.3 //length of solenoid in mtrs
6 Bc=mu_not*N*I/l
7 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

```
1
2 mu_not=4D-7*%pi
3 //calculating flux density at centre of coil B=
    mu_not*I/(2*R)
4 I=50
5 R=4D-2
6 B=mu_not*I/(2*R)
```

```

7 mprintf("Flux density at centre of coil=%f*10-6 Wb/
   m2(Tesla)\n", B*106)
8 //calculating flux density perpendicular to plane of
   coil at a distance of 10 cm from it
9 z=10D-2
10 B=mu_not*I*R2/(2*(R2+z2)1.5)
11 mprintf("Flux density perpendicular to plane of coil
   at a distance of 10 cm from it=%f*10-6 Wb/m2(
   Tesla)", B*106)

```

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

```

1
2
3 mu_not=4D-7*%pi
4 I1=30//current in wire A
5 I2=30//current in wire B
6 R=10D-2//distance b/w 2 wires
7 F=mu_not*I1*I2/(2*%pi*R)
8 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
   *104)

```

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

```

1
2 B=.06//flux density
3 I=40D-3//current in coil
4 l=4D-2//length of coil side
5 F=B*I*l
6 N=50//no. of turns

```

```
7 mprintf("Force acting on each coil side=%f*10-3 N",  
  F*N*103)
```

Chapter 5

Magnetic Circuit

Scilab code Exa 4.1 Example on Series Magnetic Circuit

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

```

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

```

Scilab code Exa 4.2 Example on Series Magnetic Circuit

```

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

```

Scilab code Exa 4.3 Example on Series Magnetic Circuit

```

1
2 mu_not=4D-7*%pi
3 N=700 //no. of turns on steel ring

```

```

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

```

Scilab code Exa 4.4 Example on Series Magnetic Circuit

```

1
2 phi=.26D-3//flux
3 d=2D-2//diameter of circular cross-section of ring
4 A=%pi*d^2/4
5 B=phi/A
6 H=740//ampere turns per length of flux path
    corresponding to B as obtained from B-H curve of
    cast steel
7 L=90D-2//length of mean flux path in the cast steel
    ring
8 AT=H*L
9 N=800//no. of turns of the coil wound on the ring

```

```

10 I=AT/N
11 mprintf("Current in the coil=%f A\n",I)
12 Lg=2D-3//length of air gap
13 Li=L-Lg//length of mean flux path in ring
14 mu=B/H
15 Bg=AT/(Li/mu+.796*Lg*1D+6)
16 flux=Bg*A
17 mprintf("Magnetic flux produced=%f*10^-4 Wb\n",flux
    *1D+4)
18 //calculating value of current which will produce
    the same flux as in (i)
19 ATi=H*Li
20 ATg=.796*B*Lg*1D+6
21 AT=ATi+ATg
22 I=AT/N
23 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

```

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

```

Scilab code Exa 4.6 Example on Series Magnetic Circuit

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

Scilab code Exa 4.7 Example on Series Magnetic Circuit

```
1
2 mu_not=4D-7*%pi
3 N=300//no. of turns in coil
```

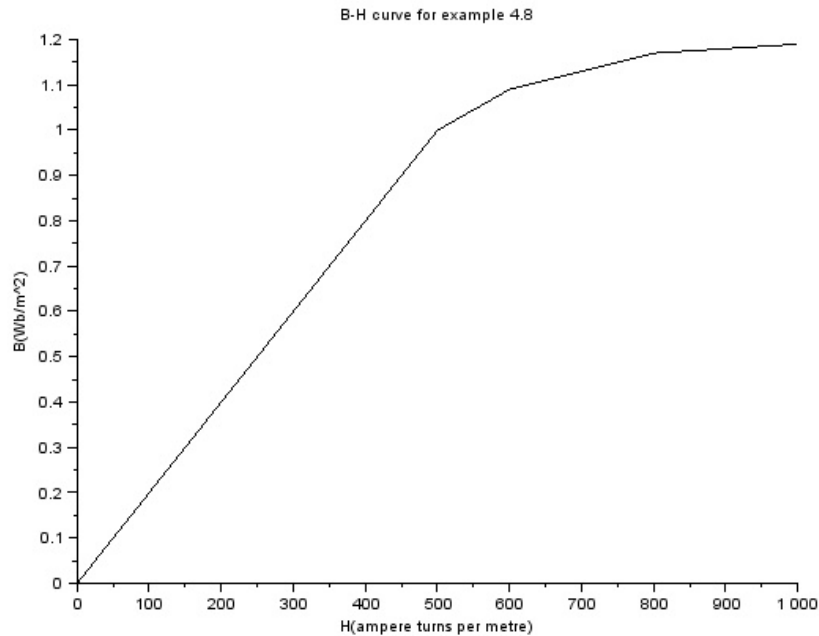


Figure 5.1: Example on Series Magnetic Circuit

```

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

```

Scilab code Exa 4.8 Example on Series Magnetic Circuit

```

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

```

Scilab code Exa 4.9 Example on Series Magnetic Circuit

```

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

```

```

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

```

Scilab code Exa 4.10 Example on Series Magnetic Circuit

```

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

```

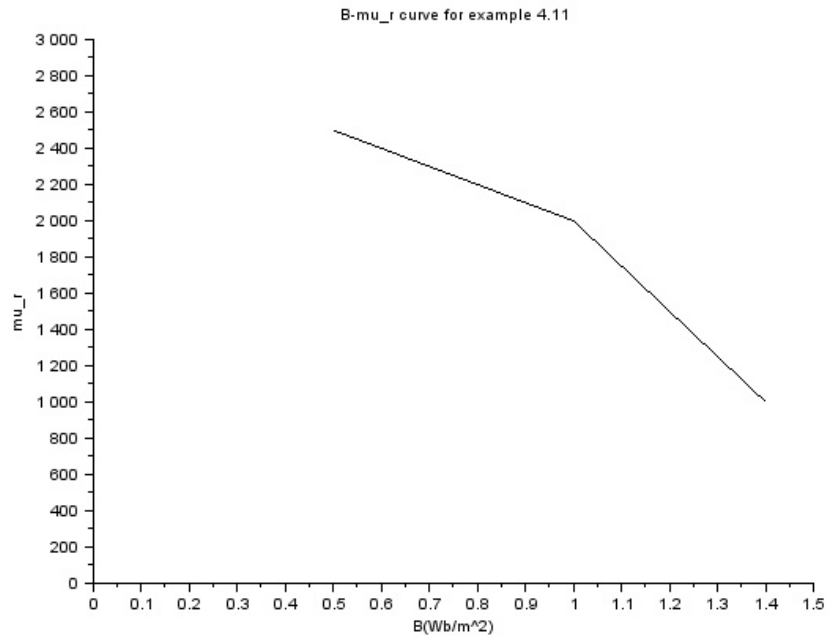


Figure 5.2: Example on Series Magnetic Circuit

Scilab code Exa 4.11 Example on Series Magnetic Circuit

```

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

```

```

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

```

Scilab code Exa 4.12 Example on Series Parallel Magnetic Circuit

```

1
2 //two parallel magnetic circuits have equal
    reluctances
3 phi_cc=1.2D-3 //flux in central core
4 phi_ol=phi_cc/2 //flux in each outer limb
5 //calculating AT for central core
6 a=9D-4 //cross-sectional area
7 B_cc=phi_cc/a
8 H=1600 //corresponding to B_cc from Fig 4.2 in the
    textbook
9 l=.15 //length of mean flux path
10 AT_cc=H*l
11 //calculating AT for outer limbs

```

```

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

```

Scilab code Exa 4.13 Example on Series Parallel Magnetic Circuit

```

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

```


Chapter 6

Electromagnetic Induction

Scilab code Exa 5.1 Example on Induced EMF

```
1
2 N=1000//no. of turns in the coil
3 dphi=-2*900D-6//change in flux in Wb
4 dt=.2//time in sec in which change takes place
5 emf=-N*dphi/dt
6 mprintf("Average emf induced in the coil=%d V",round
   (emf))
```

Scilab code Exa 5.2 Example on Induced EMF

```
1
2 l=80D-2//length of conductor
3 B=1.2//flux density of uniform magnetic field
4 v=30//velocity of conductor in m/s
5 //when the direction of motion is perpendicular to
   field
6 e=B*l*v
7 mprintf("emf induced in the conductor when the
```

```

        direction of motion is perpendicular to field=%f
        V\n",e)
8 //when the direction of motion is inclined 45
    degrees to field
9 e=B*l*v*sin(%pi/4)
10 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

```

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

```

Scilab code Exa 5.4 Example on Induced EMF

```

1
2 mu_not=4D-7*%pi
3 N=3500//no. of turns on iron rod
4 I=.6//current through coil
5 AT=N*I
6 B=.45//flux density in Wb/m^2
7 l=25D-2//length of mean magnetic flux path
8 H=AT/l
9 mu_r=B/(H*mu_not)

```

```

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

```

Scilab code Exa 5.5 Example on Induced EMF

```

1
2 mu_not=4D-7*%pi
3 H=3500//ampere turns per metre of flux path length
4 l=%pi*40D-2//length of mean flux path in ring
5 AT=H*l
6 N=440//no. of turns on coil
7 I=AT/N//exciting current
8 mprintf(" Exciting current=%d A\n",round(I))
9 B=.9//flux density
10 A=15D-4//cross-sectional area of ring
11 phi=B*A
12 L=N*phi/I
13 mprintf(" Self-inductance of coil=%f H\n",L)
14 //solving part(iii)
15 l=(l-1/10^2)//length of mean flux path in steel ring
16 ATi=H*l//ampere turns required for iron portion
17 ATg=.796*B*1D-2*1D+6//ampere turns for air gap
18 AT=ATi+ATg
19 I=AT/N
20 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

```
1  
2 N=800//no. of turns  
3 dI=10-5//change in current  
4 dB=1.2-.8//corresponding change in flux density  
5 A=15D-4//cross sectional area  
6 L=A*N*dB/dI  
7 mprintf(" Self inductance of coil ,L=%f H\n", L)  
8 di=5-10//change in current  
9 dt=.04//time taken for change  
10 e=-L*di/dt  
11 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

```
1  
2 mu_not=4D-7*%pi  
3 N=1200//no. of turns in the coil on solenoid  
4 l=80D-2//length of solenoid  
5 A=%pi/4*(5D-2)^2//cross-sectional area  
6 L=N*(mu_not*N*A/l)  
7 mprintf(" Self inductance=%f mH\n", L*1000)  
8 //calculating induced emf  
9 di=-5-5  
10 dt=.03  
11 e=-L*di/dt  
12 mprintf(" Induced emf=%f V", e)
```

Scilab code Exa 5.8 Example on Induced EMF

```
1
2 N=1500//no. of turns in coil A
3 phi=.04D-3//flux linking coil A in Wb
4 I=4//current in coil
5 La=N*phi/I
6 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)
7 k=.7
8 M=N*k*phi/I
9 mprintf("Mutual inductance of arrangement=%f mH\n",M
   *1000)
10 di=-8
11 dt=.02
12 e=-M*di/dt
13 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

```
1
2 mu_not=4D-7*%pi
3 Ns=400//no. of turns on search coil
4 N=1000//no. of turns of wire on solenoid
5 M=mu_not*Ns*N*25D-4/80D-2
6 mprintf("Mutual inductance of arrangement=%f mH\n",M
   *1000)
7 //di/dt=200
```

```

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

```

Scilab code Exa 5.10 Example on Induced EMF

```

1
2 mu_not=4D-7*%pi
3 N=800//no. of turns for each solenoid
4 l=90D-2//length of each solenoid
5 Ax=%pi*(3D-2)^2/4//cross-sectional area of solenoid
   X
6 Ay=%pi*(6D-2)^2/4//cross-sectional area of solenoid
   Y
7 M=N*N*mu_not*Ax/l
8 mprintf("Mutual inductance of arrangement=%f mH\n"
   ,1000*M)
9 //calculating coupling co-efficient
10 Lx=N*mu_not*N*Ax/l
11 Ly=N*mu_not*N*Ay/l
12 k=M/sqrt(Lx*Ly)
13 mprintf("Coupling co-efficient=%f",k)

```

Scilab code Exa 5.11 Example on Induced EMF

```

1
2 mu_not=4D-7*%pi
3 Nb=500//no. of turns in coil B
4 l=120D-2//mean length of flux path in iron circuit
5 Na=50//no. of turns in coil A
6 mu_r=2000//relative permeability of iron
7 A=80*10^-4//cross-sectional area
8 M=Nb*mu_not*mu_r*Na*A/(l)
9 mprintf("Mutual inductance M=%f H\n",M)

```

```

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

```

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

```

1
2 V=110//applied voltage
3 L=.5//inductance of coil
4 r=V/L
5 mprintf("Rate of change of current=%d A/s\n",r)
6 R=8//resistance of coil
7 I=V/R
8 mprintf("Final steady current=%f A\n",I)
9 T=L/R
10 mprintf("Time constant=%f sec\n",T)
11 //solving part(iv)
12 t=-log(.5)*T
13 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

```

1
2 //calculating time it will take current to reach .8
    of its final steady value
3 L=5//inductance of winding
4 R=50//resistance of winding
5 T=L/R
6 V=110//applied voltage
7 I=V/R//final steady current
8 i=.8*I

```

```

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

```

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

```

1
2 //calculating inductance and resistance of the relay
3 T=.004//time constant which is time taken for the
    current to rise to .632 of its final steady value
4 I=.35/.632//final steady value
5 V=200//applied voltage
6 R=V/I
7 L=T*R
8 mprintf("Resistance of relay circuit=%f ohm\
    nInductance of relay circuit=%f H\n",R,L)
9 //calculating initial rate of rise of current
10 r=V/L
11 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

```

1
2 R=.5+40+15//total resistance

```



```

3 L=1//total inductance
4 T=L/R
5 V=12//emf of battery
6 I=V/R//final steady current in the circuit
7 i=.04//current at time t after closing the circuit
8 t=-T*log(1-i/I)
9 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

```

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

```

Scilab code Exa 5.17 Example on Energy Stored in Magnetic Field

```

1
2 mu_not=4D-7*%pi
3 //calculating exciting current
4 B=1.2//flux density

```

```

5 mu_r=500//rel permeability for iron
6 H=B/(mu_not*mu_r)
7 D=10D-2//mean diameter
8 l=%pi*D//length of flux path in the ring
9 AT=H*l
10 N=300//number of turns on the ring
11 I=AT/N
12 mprintf("Exciting current=%d A\n",round(I))
13 //calculating inductance
14 As=8D-4//cross-sectional area
15 phi=B*As
16 L=N*phi/I
17 mprintf("Inductance=%f H\n",L)
18 //calculating energy stored
19 E=L*I^2/2
20 mprintf("Energy stored=%f J\n",E)
21 //consider the case in which an air gap of 2 mm in
    the ring is made
22 li=1-2D-3//length of flux path in iron portion
23 lg=2D-3//length of air gap
24 ATi=H*li//ampere turns for iron portion
25 ATg=.796*B*lg*10^6//ampere turns for air gap
26 AT=ATi+ATg
27 I=AT/N
28 mprintf("When there is an air gap of 2mm in the ring
    \nExciting current=%f A\n",I)
29 L=N*phi/I
30 mprintf("Inductance=%f mH\n",L*1000)
31 E=L*I^2/2
32 mprintf("Energy stored=%f J\n",E)

```

Scilab code Exa 5.18 Example on Energy Stored in Magnetic Field

```

1
2 mu_not=4D-7*%pi

```

```

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

```

Chapter 7

Fundamentals of Alternating Current

Scilab code Exa 6.1 Example on AC Wave Shapes

```
1
2 //plotting graph for i1
3 theta=linspace(0,2*pi,100)
4 i1=50*sin(theta)+50*sin(theta-%pi/4)
5 plot(theta,i1)
6 //plotting graph for i2
7 theta=linspace(0,2*pi,100)
8 i2=50*cos(theta)+50*cos(theta+%pi/4)
9 plot(theta,i2,"o")
10 //plotting graph for i3
11 i3=50*cos(theta)-20*sin(theta)
12 plot(theta,i3,"-*")
13 xtitle("Graphs of i1(-),i2(o) and i3(-*)" ,"theta",
        "current")
14 //round off error while plotting graphs
```

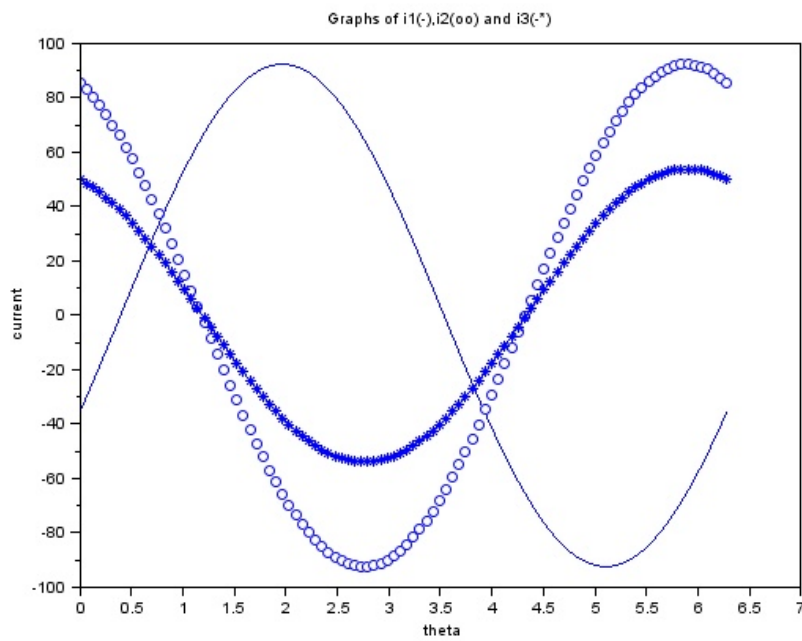


Figure 7.1: Example on AC Wave Shapes

Scilab code Exa 6.2 Example on AC Wave Shapes

```
1
2
3 //i=Imax*sin(2*%pi*f*t)
4 Imax=100//max value of current
5 f=25//frequency in Hz
6 //calculating time after which current becomes 20 A
7 i=20
8 t=asin(i/Imax)/(2*%pi*f)
9 mprintf("Time after which current becomes 20 A=%f
    sec\n",t)
10 //calculating time after which current becomes 50 A
11 i=50
12 t=asin(i/Imax)/(2*%pi*f)
13 mprintf("Time after which current becomes 50 A=%f
    sec\n",t)
14 //calculating time after which current becomes 100 A
15 i=100
16 t=asin(i/Imax)/(2*%pi*f)
17 mprintf("Time after which current becomes 100 A=%f
    sec\n",t)
```

Scilab code Exa 6.3 Example on AC Wave Shapes

```
1
2 //calculating instantaneous voltage at .005 sec
    after the wave passes through zero in positive
    direction
3 f=50//frequency
4 Emax=350//max value of voltage
5 t=.005
```

```

6 e1=Emax*sin(2*pi*f*t)
7 mprintf(" Voltage at .005 sec after the wave passes
  through zero in positive direction=%d V\n",e1)
8 //calculating instantaneous voltage at .008 sec
  after the wave passes through zero in negative
  direction
9 t=.008
10 e2=-Emax*sin(2*pi*f*t)
11 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

```

1
2 //e=100*sin(100*pi*t)
3 //calculating rate of change of voltage at t=.0025
  sec
4 t=.0025
5 r1=10000*pi*cos(100*pi*t)
6 mprintf(" Rate of change of voltage at .0025 sec=%f V
  /sec\n",r1)
7 //calculating rate of change of voltage at t=.005
  sec
8 t=.005
9 r2=10000*pi*cos(100*pi*t)
10 mprintf(" Rate of change of voltage at .005 sec=%d V/
  sec\n",r2)
11 //calculating rate of change of voltage at t=.01 sec
12 t=.01
13 r3=10000*pi*cos(100*pi*t)
14 mprintf(" Rate of change of voltage at .01 sec=%f V/
  sec\n",r3)
15 //error in textbook answer in first and last case

```

Scilab code Exa 6.5 Example on AC Wave Shapes

```
1
2
3 //calculating greatest rate of change of current
4 //i=50*sin(100*%pi*t)
5 mprintf("Greatest rate of change of current=%f A/sec
   \n",50*100*%pi)
6 //calculating average value of current
7 f=50//frequency of the wave
8 T=1/f
9 Imean=1/.01*integrate("50*sin(100*%pi*t)","t",0,T/2)
10 mprintf("Average value of the given current=%f A\n",
   Imean)
11 Irms=sqrt(integrate("(50*sin(theta))^2","theta",0,2*
   %pi)/(2*%pi))
12 mprintf("RMS value of current=%f A\n",Irms)
13 //calculating time interval between a maximum value
   and next zero value
14 t=(%pi/2)/(100*%pi)
15 mprintf("Time interval between a maximum value and
   the next zero value is %f sec to %f sec",t,2*t)
16 //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

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

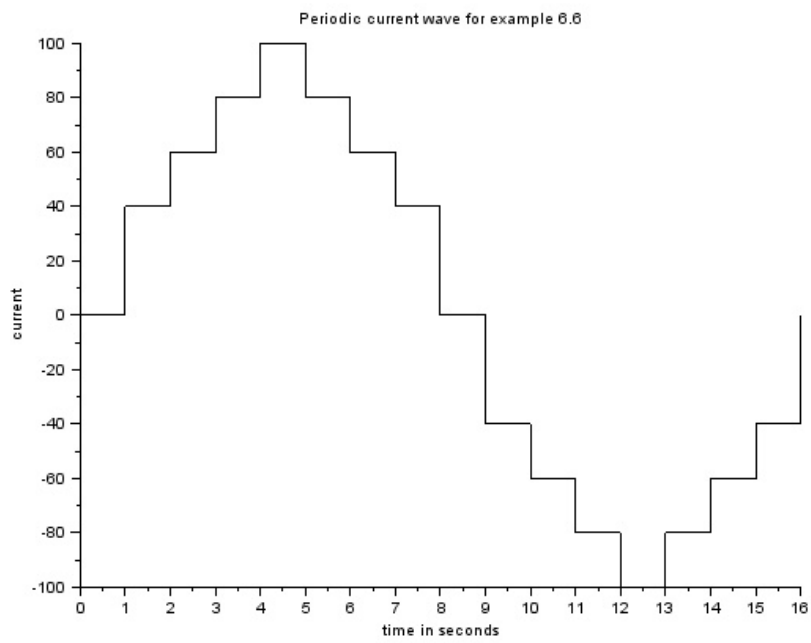



Figure 7.2: Example on AC Wave Shapes

```

4 plot2d(t,i)
5 for j=0:3
6     i=linspace(40+20*j,40+20*j,2)
7     t=linspace(j+1,j+2,2)
8     plot2d(t,i)
9     if j==0 then
10        t=linspace(j+1,j+1,2)
11        i=linspace(0,40,2)
12        plot2d(t,i)
13    else
14        t=linspace(j+1,j+1,2)
15        i=linspace(40+20*(j-1),40+20*j,2)
16        plot2d(t,i)
17    end
18 end
19 for j=1:3
20     i=linspace(100-20*j,100-20*j,2)
21     t=linspace(j+4,j+5,2)
22     plot2d(t,i)
23     i=linspace(100-20*(j-1),100-20*j,2)
24     t=linspace(j+4,j+4,2)
25     plot2d(t,i)
26 end
27 i=linspace(40,0,2)
28 t=linspace(8,8,2)
29 plot2d(t,i)
30 i=linspace(0,0,2)
31 t=linspace(8,9,2)
32 plot2d(t,i)
33 for j=0:3
34     i=linspace(-(40+20*j),-(40+20*j),2)
35     t=linspace(j+9,j+10,2)
36     plot2d(t,i)
37     if j==0 then
38        t=linspace(j+9,j+9,2)
39        i=linspace(0,-40,2)
40        plot2d(t,i)
41    else

```

```

42         t=linspace(j+9,j+9,2)
43         i=linspace(-40-20*(j-1),-40-20*j,2)
44         plot2d(t,i)
45     end
46 end
47 for j=1:3
48     i=linspace(-(100-20*j),-(100-20*j),2)
49     t=linspace(j+12,j+13,2)
50     plot2d(t,i)
51     i=linspace(-100+20*(j-1),-100+20*j,2)
52     t=linspace(j+12,j+12,2)
53     plot2d(t,i)
54 end
55 i=linspace(0,-40,2)
56 t=linspace(16,16,2)
57 plot2d(t,i)
58 xtitle("Periodic current wave for example 6.6","time
        in seconds","current")
59
60 //calculating average value for this wave shape
61 Iavg=(0+40+60+80+100+80+60+40)/8
62 fprintf("Average value of current of given wave
        shape=%f A\n",Iavg)
63 //calculating RMS value for the given wave shape
64 Irms=sqrt((0^2+40^2+60^2+80^2+100^2+80^2+60^2+40^2)
        /8)
65 fprintf("RMS value of current of given wave shape=%f
        A\n",Irms)
66 //calculating form factor
67 x=Irms/Iavg
68 fprintf("Form factor of given wave form=%f\n",x)
69 //calculating peak factor
70 Imax=100//maximum value of current wave
71 y=Imax/Irms
72 fprintf("Peak factor of given wave=%f\n",y)
73 //calculating average and RMS value of current
        considering the wave to be sinusoidal having peak
        value of 100 A

```

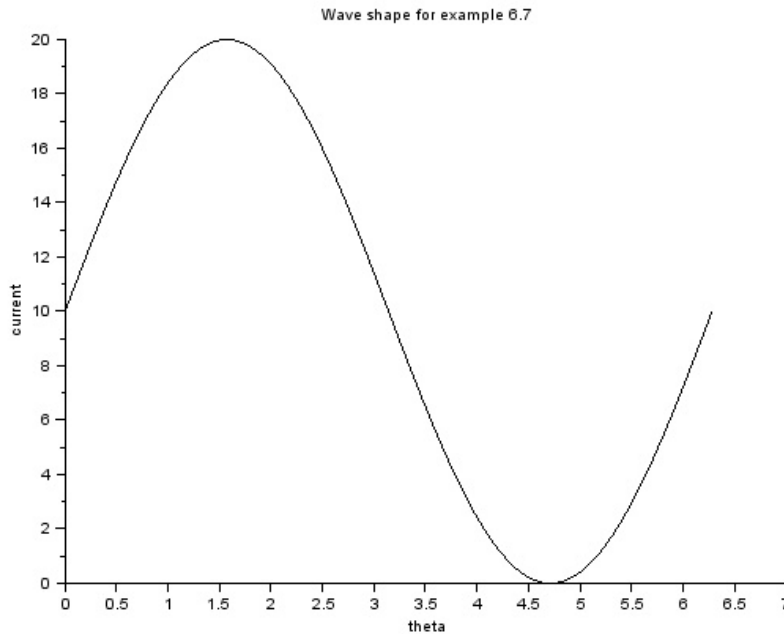


Figure 7.3: Example on AC Wave Shapes

```

74 Iavg=integrate('100/%pi*sin(theta)', 'theta', 0, %pi)
75 mprintf("Average value of sine wave=%f A\n", Iavg)
76 Irms=sqrt(integrate('(100*sin(theta))^2/%pi', 'theta',
77                    , 0, %pi))
77 mprintf("RMS value of sine wave=%f A", Irms)

```

Scilab code Exa 6.7 Example on AC Wave Shapes

```

1
2 theta=linspace(0, 2*%pi, 100)
3 i=10+10*sin(theta) //expression for the resultant

```

```

    wave
4  plot2d(theta,i)
5  xtitle("Wave shape for example 6.7","theta","current
    ")
6
7  //calculating average value of the resultant wave
8  Iavg=integrate('10+10*sin(theta)','theta',0,2*pi)
    /(2*pi)
9  mprintf("Average value of the resultant current wave
    =%d A\n",Iavg)
10 //calculating RMS value of current of the resultant
    wave
11 Irms=sqrt(integrate('(10+10*sin(theta))^2','theta'
    ,0,2*pi)/(2*pi))
12 mprintf("RMS value of the resultant current wave=%f
    A",Irms)

```

Scilab code Exa 6.8 Example on AC Wave Shapes

```

1
2  theta=linspace(0,2*pi,100)
3  i=50*sin(theta)
4  xset('window',0)
5  plot2d(theta,i)
6  xtitle("Current wave shape for example 6.8-->(a)","
    theta","current")
7
8  xset('window',1)
9  theta=linspace(0,%pi,100)
10 i=50*sin(theta)
11 plot2d(theta,i)
12 theta=linspace(%pi,2*pi,100)
13 i=-50*sin(theta)
14 plot2d(theta,i)
15 xtitle("Current wave shape for example 6.8-->(b)","

```

```

        theta", "current")
16
17 xset('window', 2)
18 theta=linspace(0,0,2)
19 i=linspace(0,50,2)
20 plot2d(theta,i)
21 theta=linspace(0,%pi,2)
22 i=linspace(50,50,2)
23 plot2d(theta,i)
24 theta=linspace(%pi,%pi,2)
25 i=linspace(50,-50,2)
26 plot2d(theta,i)
27 theta=linspace(%pi,2*%pi,2)
28 i=linspace(-50,-50,2)
29 plot2d(theta,i)
30 i=linspace(-50,0,2)
31 theta=linspace(2*%pi,2*%pi,2)
32 plot2d(theta,i)
33 xtitle("Current wave shape for example 6.8-->(c)",
        theta", "current")
34
35 xset('window', 3)
36 theta=linspace(0,%pi/2,2)
37 i=linspace(0,50,2)
38 plot2d(theta,i)
39 theta=linspace(%pi/2,%pi,2)
40 i=linspace(50,0,2)
41 plot2d(theta,i)
42 theta=linspace(%pi,3*%pi/2,2)
43 i=linspace(0,-50,2)
44 plot2d(theta,i)
45 theta=linspace(3*%pi/2,2*%pi,2)
46 i=linspace(-50,0,2)
47 plot2d(theta,i)
48 xtitle("Current wave shape for example 6.8-->(d)",
        theta", "current")
49
50 //consider wave shape (a)

```

```

51 mprintf("For wave shape (a)\nAs the negative and
    positive parts of the wave are equal, reading of
    moving coil ammeter is zero\n")
52 Irms=sqrt(integrate('(50*sin(theta))^2', 'theta', 0, 2*
    %pi)/(2*%pi))
53 mprintf("Reading of moving iron ammeter=%f A\n", Irms
    )
54
55 //consider wave shape (b)
56 Iavg=integrate('50*sin(theta)', 'theta', 0, %pi)/%pi
57 mprintf("For wave shape (b)\nReading on the moving
    coil ammeter=%f A\n", Iavg)
58 Irms=sqrt(integrate('(50*sin(theta))^2', 'theta', 0, 2*
    %pi)/(2*%pi))
59 mprintf("Reading on moving iron ammeter=%f A\n", Irms
    )
60
61 //consider case (c)
62 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")
63
64 //consider case(d)
65 Iavg=(0+10+20+30+40+50++40+30+20+10+0+(-10)+(-20)
    +(-30)+(-40)+(-50)+(-40)+(-30)+(-20)+(-10)+0)/20
66 mprintf("For wave shape (d)\nReading on moving coil
    ammeter=%d\n", Iavg)
67 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)
68 mprintf("Reading on moving iron ammeter=%f A\n", Irms
    )

```

Scilab code Exa 6.9 Example on AC Wave Shapes

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

Scilab code Exa 6.10 Example on AC Wave Shapes

```
1
2 //the graph is drawn considering R=%pi
3 R=%pi
4 theta=linspace(-%pi,%pi,100)
5 V=sqrt(R^2-theta^2)
6 plot2d(theta,V)
7 xtitle("Wave shape for example 6.10","theta","
   Voltage")
8 theta=linspace(%pi,3*%pi,100)
9 V=-sqrt(R^2-(theta-2*%pi)^2)
10 plot2d(theta,V)
11
12 Vrms=sqrt(integrate('(R^2-x^2)/(2*R)', 'x', -R, R))
```

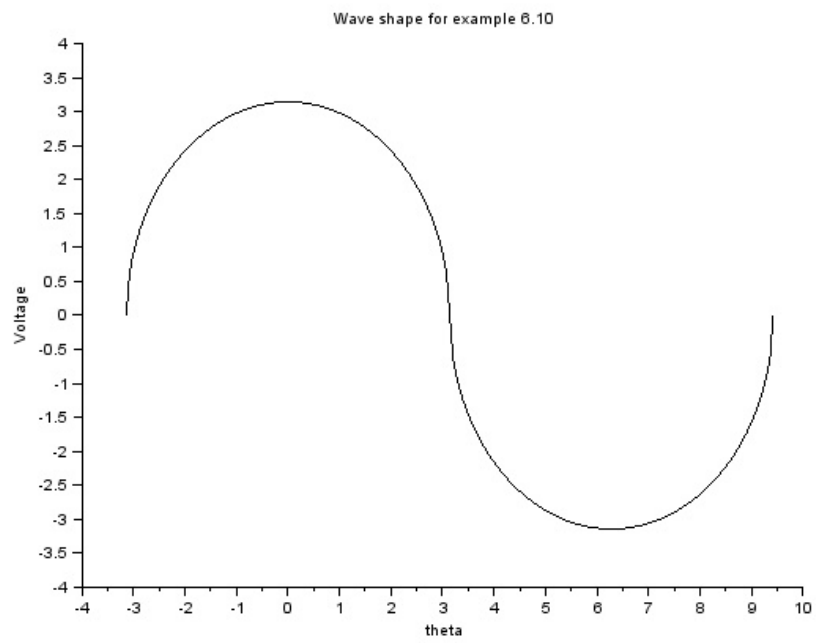



Figure 7.4: Example on AC Wave Shapes

```
13 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

```
1
2 //consider part (i)
3 phi=%pi/12
4 mprintf("For part (i)\nVoltage leads the current
    wave by %d degrees\n",round(phi*180/%pi))
5 f=377.16/(2*%pi)
6 mprintf("Frequency of the wave shape=%d Hz\n",f)
7 //consider part (ii)
8 phi=%pi/3
9 mprintf("For part (ii)\nVoltage leads the current by
    %d degrees\n",round(phi*180/%pi))
10 mprintf("Frequency of the wave shape=omega/(2*pi)\n"
    )
11 //consider part (iii)
12 phi=0-(-%pi/2)
13 mprintf("For part (iii)\nVoltage leads the current
    wave by %d degrees\n",round(phi*180/%pi))
14 mprintf("Frequency of the wave shape=omega/pi\n")
15 //consider part (iv)
16 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

```
1
2 V=230//applied voltage
3 L=60D-3//inductance of coil
```

```

4 f=50 //frequency of supply
5 Xl=2*%pi*f*L
6 I=230/Xl
7 //if frequency is reduced to 20 Hz
8 Xl=2*%pi*20*L
9 I1=V/Xl
10 mprintf("Current through the coil if frequency is
    reduced to 20 Hz=%f A\n",I1)
11 //if frequency is increased to 60 Hz
12 Xl=2*%pi*60*L
13 I2=V/Xl
14 mprintf("Current through the coil if frequency is
    increased to 60 Hz=%f A\n",I2)
15 //if frequency is increased to 100 Hz
16 Xl=2*%pi*100*L
17 I3=V/Xl
18 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

```

1
2 //calculating reactance of capacitor
3 C=100D-6
4 Xc=1/(2*%pi*50*C)
5 mprintf("Capacitive reactance ,Xc=%f ohm\n",Xc)
6 //calculating RMS value of current
7 V=200
8 Irms=V/Xc
9 mprintf("RMS value of current=%f A\n",Irms)
10 //calculating max current
11 Imax=Irms*sqrt(2)
12 mprintf("Maximum current=%f A",Imax)

```

Chapter 8

AC Series Circuit

Scilab code Exa 7.1 Example on AC Series Circuit

```
1
2 //calculating current flowing in the circuit
3 L=0.1//inductance
4 f=50//frequency
5 Xl=2*%pi*f*L
6 R=15//total resistance in the circuit
7 Z=sqrt(R^2+Xl^2)
8 V=230//voltage applied to series circuit
9 I=V/Z
10 mprintf("Current flowing in the circuit=%f A\n",I)
11 //calculating power factor
12 pf=R/Z
13 mprintf("Power factor of the circuit is %f(lagging)\n
    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

```

1
2 V1=200//voltage applied to non-inductive load
3 I1=20//current flowing through the load
4 R=V1/I1
5 V=230//applied voltage to series connection of R and
  L
6 I=I1
7 Z=V/I
8 Xl=sqrt(Z^2-R^2)
9 L=Xl/(2*%pi*50)
10 phi=atand(Xl/R)
11 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

```

1
2 //calculating resistance , reactance and impedance of
  choke coil
3 I=7.5//current flowing through the circuit
4 V1=110//voltage across non-inductive resistor
5 R=V1/I
6 V2=180//voltage across choke coil
7 Z=V2/I
8 Zt=230/I//impedance of whole circuit
9 r=(Zt^2-R^2-Z^2)/(2*R)
10 Xl=sqrt(Z^2-r^2)
11 mprintf("Reactance of coil=%f ohm\nResistance of
  coil=%f ohm\nImpedance of coil=%f ohm\n",Xl,r,Z)
12 //calculating total resistance and impedance of the
  circuit
13 Rt=r+R
14 Zt=sqrt(Rt^2+Xl^2)
15 mprintf("Total resistance of circuit=%f ohm\nTotal

```

```

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

```

Scilab code Exa 7.4 Example on AC Series Circuit

```

1
2 //calculating current drawn at 50 Hz
3 V=220//voltage applied to choke coil
4 f=50//frequency of supply
5 I1=12//current taken by choke coil
6 R1=0//resistance of coil is negligible
7 X1=V/I1
8 I2=16.5//current taken by the resistor
9 R=V/I2
10 Z=sqrt(R^2+X1^2)
11 I=V/Z
12 mprintf("Current taken by the circuit at 50 Hz=%f A\
    n",I)
13 //calculating current drawn at 30 Hz
14 X1_dash=30/50*X1
15 Z_dash=sqrt(X1_dash^2+R^2)
16 I=V/Z_dash
17 mprintf("Current drawn by the circuit at 30 Hz=%f A\
    n",I)

```

Scilab code Exa 7.5 Example on AC Series Circuit

```
1
2 //let resistance and inductance of the coil be R and
   L respectively
3 V=220//voltage applied to coil
4 f=50//frequency of supply
5 I=60//current indicated by ammeter
6 Z1=V/I
7 //when the frequency is increased to 100 Hz
8 I=40//current indicated by ammeter
9 Z2=V/I
10 //on solving for L
11 L=sqrt((Z2^2-Z1^2)/3)/(100*pi)
12 R=sqrt(Z1^2-(100*pi*L)^2)
13 mprintf(" Resistance of coil=%f ohm\nInductance of
   coil=%f H",R,L)
```

Scilab code Exa 7.6 Example on AC Series Circuit

```
1
2 //calculating parameters of each coil
3 I=3//current through the circuit
4 //for coil A
5 Ra=12/3//resistance
6 Va=15//voltage drop
7 Za=Va/I
8 Xa=sqrt(Za^2-Ra^2)
9 //for coil B
10 Rb=6/3//resistance
11 Vb=9//voltage drop
```

```

12 Zb=Vb/I
13 Xb=sqrt(Zb^2-Rb^2)
14 //for coil C
15 Rc=9/3//resistance
16 Vc=12//voltage drop
17 Zc=Vc/I
18 Xc=sqrt(Zc^2-Rc^2)
19 mprintf("Parameters of\nCoilA: Ra=%f ohm, Xa=%f ohm\n
          nCoil B: Rb=%f ohm, Xb=%f ohm\nCoil C: Rc=%f ohm,
          Xc=%f ohm\n",Ra ,Xa ,Rb ,Xb ,Rc ,Xc)
20 //calculating power factor of each coil
21 pf_a=Ra/Za
22 pf_b=Rb/Zb
23 pf_c=Rc/Zc
24 mprintf("power factor of the coils are\npf_a=%f(
          lagging)\n pf_b=%f(lagging)\n pf_c=%f(lagging)\n",
          pf_a ,pf_b ,pf_c)
25 //calculating power dissipated for each coil
26 Pa=I^2*Ra
27 Pb=I^2*Rb
28 Pc=I^2*Rc
29 mprintf("Power dissipated in these coils:\nPa=%f W\
          nPb=%f W\nPc=%f W\n",Pa ,Pb ,Pc)
30 //calculating power factor of whole circuit
31 Rt=Ra+Rb+Rc
32 Xt=Xa+Xb+Xc
33 Zt=sqrt(Rt^2+Xt^2)
34 pf=Rt/Zt
35 mprintf("Power factor of the whole circuit=%f
          lagging\n",pf)
36 //calculating voltage applied across the whole
          circuit
37 V=I*Zt
38 mprintf("Voltage applied across the whole circuit=%f
          V",V)

```

Scilab code Exa 7.7 Example on AC Series Circuit

```
1
2 //r1 be the variable resistance
3 X=10//total inductive reactance of circuit
4 V=200//rms value of applied voltage
5 //RMS value of current  $I=200/\sqrt{(2+r1)^2+10^2}$ 
6 //power consumed is  $P=I^2*r1$ 
7 //For max power,  $dP/dr=0$ 
8 //on solving
9 r1=sqrt(104)
10 mprintf("Value of variable resistor at the instant
    of max power consumed in it is %f ohm\n",r1)
11 //solving part(ii), let r2 be the variable
    resistance  $-I=200/\sqrt{(200+r2)^2+10^2}$ ,  $P=I^2*(2+r2)$ 
12 //for max power,  $dP/dr=0$ 
13 //on solving
14 r2=10-2
15 mprintf("Value of variable resistor=%d ohm for the
    condition of max power consumed by the circuit\n"
    ,round(r2))
16 I1=200/sqrt((2+r1)^2+10^2)
17 I2=200/sqrt((2+r2)^2+10^2)
18 pf1=(2+r1)/sqrt((2+r1)^2+10^2)
19 pf2=(2+r2)/sqrt((2+r2)^2+10^2)
20 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

```

1
2 //both the coils draw lagging currents , hence both
   are inductive
3 //for coil A
4 Va=10//voltage applied
5 Ia=2//current drawn
6 Za=Va/Ia
7 pf=.8//power factor
8 Ra=pf*Za
9 Xa=sqrt(Za^2-Ra^2)
10 //for coil B
11 Vb=5//voltage applied
12 Ib=2//current drawn
13 Zb=Vb/Ib
14 pf=.7//power factor
15 Rb=pf*Zb
16 Xb=sqrt(Zb^2-Rb^2)
17
18 Rt=Ra+Rb//total resistance of circuit
19 Xt=Xa+Xb//total reactance of circuit
20 Z=sqrt(Rt^2+Xt^2)
21 V=Ia*Z
22 pf=Rt/Z
23 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

```

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

```

```

7 mprintf(" Capacitance C=%f microF\n",C*1D+6)
8 //calculating impedance
9 R=5//resistance of circuit
10 Z=sqrt(R^2+Xc^2)
11 mprintf(" Impedance of circuit=%f ohm\n",Z)
12 //calculating current taken by circuit
13 V=200
14 I=V/Z
15 mprintf(" Current drawn by circuit=%f A\n",I)
16 //calculating voltage drop across the resistance
17 Vr=I*R
18 mprintf(" Voltage drop across the resistance=%f V\n",
    Vr)
19 //calculating voltage drop across the reactance
20 Vc=I*Xc
21 mprintf(" Voltage drop across the reactance=%f V\n",
    Vc)
22 //calculating power factor
23 pf=R/Z
24 mprintf(" Power factor of the circuit=%f leading",pf)

```

Scilab code Exa 7.10 Example on AC Series Circuit

```

1
2 //rating of bulb is 100 W,110 V
3 P=100
4 V=110
5 I=P/V//normal current of bulb
6 //voltage across bulb should be 110 V
7 Vc=sqrt(230^2-V^2)//voltage across the capacitance
8 Xc=Vc/I
9 C=1/(100*%pi*Xc)
10 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

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

Scilab code Exa 7.12 Example on AC Series Circuit

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

```

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

```

Scilab code Exa 7.13 Example on AC Series Circuit

```

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

```

```

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

```

Scilab code Exa 7.14 Example on AC Series Circuit

```

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

```

```

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

```

Scilab code Exa 7.15 Example on AC Series Circuit

```

1
2 //calculating capacitance to give resonance
3 Xl=2*pi*50*.4
4 Xc=Xl
5 C=1/(2*pi*50*Xc)
6 mprintf("Capacitance=%f microF\n",C*1D+6)
7 //calculating current
8 R=5
9 Z=R
10 V=110
11 I=V/Z
12 mprintf("current drawn=%f A\n",I)
13 //calculating voltage across inductance
14 Xl=2*pi*50*.4
15 Vl=I*Xl
16 mprintf("Voltage across inductance=%f V\n",Vl)
17 //calculating voltage across capacitance
18 Xc=Xl
19 Vc=I*Xc
20 mprintf("Voltage across capacitance=%f V\n",Vc)
21 //calculating Q-factor
22 Q_factor=Vl/V
23 mprintf("Q-factor of the circuit=%f",Q_factor)

```

Chapter 9

AC Parallel Circuit

Scilab code Exa 8.1 Example on Phasor Method

```
1
2 function [r, theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r, theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)
11    z=x+y*%i
12 endfunction
13 function [r]=mag(A)
14    x=real(A)
15    y=imag(A)
16    r=sqrt(x^2+y^2)
17 endfunction
18 //calculating current in each branch and its angle
    of lag or lead
19 V=230
20 f=50
```



```

21 //for branch A
22 Ra=10//resistance
23 L=.04//inductance
24 Xl=2*%pi*f*L//inductive reactance
25 Za=sqrt(Ra^2+Xl^2)//impedance
26 Ia=V/Za
27 phi_a=atand(Xl/Ra)
28 //for branch B
29 R=25//resistance
30 Zb=R//impedance
31 Ib=V/Zb
32 phi_b=0
33 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)
34 //calculating current drawn by the circuit
35 Ia=pol2rect(Ia,phi_a)
36 Ib=pol2rect(Ib,0)
37 I=Ia+Ib
38 mprintf("Total current drawn by the circuit=%f A\n",
        mag(I))
39 phi=atand(imag(I)/real(I))
40 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

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction

```

```

8 function [z]=pol2rect(r,theta)
9     x=r*cos(theta*pi/180)
10    y=r*sin(theta*pi/180)
11    z=x+y*i
12 endfunction
13 function [r]=mag(A)
14     x=real(A)
15     y=imag(A)
16     r=sqrt(x^2+y^2)
17 endfunction
18 //solving part (i)
19 Xa=2*pi*50*.1//inductive reactance of branch A
20 Za=sqrt(50^2+Xa^2)
21 Ia=230/Za
22 phi_a=atan(Xa/50)//angle of lag of Ia w.r.t.
    applied voltage
23 Ia=pol2rect(Ia,-phi_a)
24 Xb=1/(2*pi*50*100D-6)//capacitive reactance of
    branch B
25 Zb=sqrt(45^2+Xb^2)
26 Ib=230/Zb
27 phi_b=atan(Xb/45)//angle of lead of Ib w.r.t.
    applied voltage
28 Ib=pol2rect(Ib,phi_b)
29 I=Ia+Ib
30 mprintf("Current drawn by the circuit=%f A\n", mag(I
    ))
31 //calculating power factor
32 phi=atan(imag(I)/real(I))//phase angle of the
    circuit
33 pf=cos(phi)
34 mprintf("Power factor of the circuit=%f(leading)\n",
    pf)
35 //calculating power taken by the parallel circuit
36 P=230*mag(I)*pf
37 mprintf("Power taken by the parallel circuit=%d W",
    round(P))
38 //The answers vary from the textbook due to round

```

Scilab code Exa 8.3 Example on Phasor Method

```
1
2
3 function [r,theta]=rect2pol(A)
4     x=real(A)
5     y=imag(A)
6     r=sqrt(x^2+y^2)
7     theta=atand(y/x)
8 endfunction
9 function [z]=pol2rect(r,theta)
10    x=r*cos(theta*%pi/180)
11    y=r*sin(theta*%pi/180)
12    z=x+y*%i
13 endfunction
14 function [r]=mag(A)
15    x=real(A)
16    y=imag(A)
17    r=sqrt(x^2+y^2)
18 endfunction
19 //calculating current in coil A
20 Xa=2*%pi*50*.02//inductive reactance of coil A
21 Za=sqrt(12^2+Xa^2)
22 Ia=200/Za
23 phi_a=atand(Xa/12)//angle of lag of Ia w.r.t.
    applied voltage
24 mprintf("Ia=%f A, lagging the applied voltage by %f
    degrees\n", Ia, phi_a)
25 //calculating current in coil B
26 Xb=2*%pi*50*.03//inductive reactance of coil B
27 Zb=sqrt(6^2+Xb^2)
28 Ib=200/Zb
29 phi_b=atand(Xb/6)//angle of lag of Ib w.r.t. applied
```

```

    voltage
30 mprintf("Ib=%f A, lagging the applied voltage by %f
    degrees\n", Ib, phi_b)
31 //calculating total current in the circuit
32 Ia=pol2rect(Ia,-phi_a)
33 Ib=pol2rect(Ib,-phi_b)
34 I=Ia+Ib
35 mprintf("Total current drawn by circuit=%f A lagging
    the applied voltage by %f degrees\n", mag(I),-
    atand(imag(I)/real(I)))
36 //calculating total current when additional circuit
    is added
37 Xc=1/(2*%pi*50*120D-6)//capacitive reactance
38 Zc=sqrt(15^2+Xc^2)
39 Ic=200/Zc
40 phi_c=atand(Xc/15)//angle of lag of Ic w.r.t.
    applied voltage
41 Ic=pol2rect(Ic,phi_c)
42 I=Ia+Ib+Ic
43 phi=atand(imag(I)/real(I))
44 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

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r,theta)
9     x=r*cos(theta*%pi/180)

```

```

10     y=r*sin(theta*pi/180)
11     z=x+y*i
12 endfunction
13 function [r]=mag(A)
14     x=real(A)
15     y=imag(A)
16     r=sqrt(x^2+y^2)
17 endfunction
18 //for coil A
19 Ia=5//current taken
20 Va=110//voltage applied
21 Pa=300//power dissipated
22 Ra=Pa/Ia^2
23 Za=Va/Ia
24 Xa=sqrt(Za^2-Ra^2)
25 //for coil B
26 Ib=5//current taken
27 Vb=110//voltage applied
28 Pb=400//power dissipated
29 Rb=Pb/Ib^2
30 Zb=Vb/Ib
31 Xb=sqrt(Zb^2-Rb^2)
32 //calculating current drawn and power factor when
    coils conected in series
33 R=Ra+Rb
34 Xl=Xa+Xb
35 Z=sqrt(R^2+Xl^2)//impedance of series circuit
36 I=Va/Z
37 pf=R/Z
38 mprintf("Current in the series circuit=%f A at pf=%f
    lagging\n", I,pf)
39 //calculating current drawn and power factor when
    coils conected in parallel
40 Ia=pol2rect(Ia,-acosd(Ra/Za))
41 Ib=pol2rect(Ib,-acosd(Rb/Zb))
42 I=Ia+Ib
43 phi=atan(imag(I)/real(I))
44 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

```
1
2 function [r]=mag(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6 endfunction
7 j=%i
8 //solving part (i)
9 //for coil 1
10 Z1=5+2*%pi*50*.03*j//impedance
11 Y1=1/Z1
12 G1=real(Y1)
13 B1=imag(Y1)
14 mprintf("For coil 1,\nConductance=%f mho\
        nSuspectance=%f mho\nAdmittance=%f mho\n", G1,-B1
        ,mag(Y1))
15 //for coil 2
16 Z2=3+2*%pi*50*.04*j//impedance
17 Y2=1/Z2
18 G2=real(Y2)
19 B2=imag(Y2)
20 mprintf("For coil 2,\nConductance=%f mho\
        nSuspectance=%f mho\nAdmittance=%f mho\n", G2,-B2
        ,mag(Y2))
21 //solving part(ii)
22 Y=Y1+Y2//total admittance
23 I=200*Y
24 phi=atan(imag(I)/real(I))
25 pf=cos(phi)
26 mprintf("Total current drawn by the circuit=%f A at
        pf of %f(lagging)\n",mag(I),pf)
```

```

27 //calculating power
28 P=200*mag(I)*pf
29 mprintf("Power absorbed by the circuit=%f W\n",P)
30 //solving part(iv)
31 Z=1/Y
32 R=real(Z)
33 Xl=imag(Z)
34 L=Xl/(2*%pi*50)
35 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)
36 //answers vary from the textbook due to round off
        error

```

Scilab code Exa 8.6 Example on Symbolic Method

```

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

```

```

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

```

Scilab code Exa 8.7 Example on Symbolic Method

```

1
2 function [z]=pol2rect(r,theta)
3     x=r*cos(theta*%pi/180)
4     y=r*sin(theta*%pi/180)
5     z=x+y*%i
6 endfunction
7 function [r]=mag(A)
8     x=real(A)
9     y=imag(A)
10    r=sqrt(x^2+y^2)
11 endfunction
12 //for coil A
13 Va=10//voltage applied
14 Ia=2//current taken
15 pf=.8//lagging power factor
16 Ia=pol2rect(Ia,-acosd(pf))
17 Za=Va/Ia//impedance
18 //for coil B
19 Vb=5//voltage applied
20 Ib=2//current taken
21 pf=.7//lagging power factor

```



```

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

```

Scilab code Exa 8.8 Example on Symbolic Method

```

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

```

```

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

```

Scilab code Exa 8.9 Example on Symbolic Method

```

1
2 function [r]=mag(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6 endfunction
7
8 j=%i
9 R1=12//resistance of series circuit
10 X1=2*%pi*50*.025//inductive reactance of the series
    circuit
11 Z1=R1+X1*j
12 pf1=R1/mag(Z1)//power factor of the series circuit(
    lagging)
13 //the impedances and power factor of the parallel
    circuit are to be same as that of series circuit
14 //on solving , we get , R*X1/sqrt(R^2+X1^2)=mag(Z1);
    X1/(sqrt(R^2+X1^2))=pf1
15 R=mag(Z1)/pf1
16 //solving for Xl
17 Xl=pf1*R/sqrt(1-pf1^2)
18 L=Xl/(2*%pi*50)
19 mprintf(" Resistance=%f ohm; Inductance=%f H\n",R,L)
20 //calculating current in each case
21 V=230//applied voltage
22 I1=V/mag(Z1)
23 mprintf(" Current in series circuit=%f A\n",I1)
24 I2=V/mag(Z1)
25 mprintf(" Current drawn by parallel circuit=%f A",I2)

```

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

Scilab code Exa 8.10 Example on Series Parallel Circuit

```
1  
2 function [r,theta]=rect2pol(A)  
3     x=real(A)  
4     y=imag(A)  
5     r=sqrt(x^2+y^2)  
6     theta=atand(y/x)  
7 endfunction  
8 function [z]=pol2rect(r,theta)  
9     x=r*cos(theta*pi/180)  
10    y=r*sin(theta*pi/180)  
11    z=x+y*i  
12 endfunction  
13 function [r]=mag(A)  
14    x=real(A)  
15    y=imag(A)  
16    r=sqrt(x^2+y^2)  
17 endfunction  
18 j=%i  
19 //calculating impedance of overall circuit  
20 Za=2+0*j//impedance of branch A  
21 Zb=3+4*j//impedance of branch B  
22 Zab=Za*Zb/(Za+Zb)//equivalent impedances of branches  
    A and B  
23 Zc=2-2*j  
24 Z1=Zab*Zc/(Zab+Zc)//equivalent impedance of parallel  
    circuit  
25 Zd=1+1*j//impedance of branch D  
26 Z=Z1+Zd  
27 [Z theta]=rect2pol(Z)  
28 mprintf("Total impedance of overall circuit=%f ohm
```

```

        at angle %f degrees\n", Z,theta)
29 //calculating current taken by overall circuit
30 V=110//voltage applied to the overall circuit
31 I=V/Z
32 mprintf("Current taken by the overall circuit=%f A\n
        ", I)
33 //Calculating power consumed in each branch and
        total power consumed
34 Id=I//current in the series branch
35 Rd=1//resistance of branch D
36 Pd=I^2*Rd//power consumed by branch D
37 Ia=I*mag(Z1)/mag(Za)//current in branch A
38 Ib=I*mag(Z1)/mag(Zb)//current in branch B
39 Ic=I*mag(Z1)/mag(Zc)//current in branch C
40 Ra=2
41 Pa=Ia^2*Ra
42 Rb=3
43 Pb=Ib^2*Rb
44 Rc=2
45 Pc=Ic^2*Rc
46 P=Pa+Pb+Pc+Pd
47 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,\n
        Total power consumed=%f W",Pa,Pb,Pc,Pd,P)
48 //The answers vary from the textbook due to round
        off error

```

Scilab code Exa 8.11 Example on AC Network Theorems

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)

```

```

6     theta=atand(y/x)
7     endfunction
8     function [r]=mag(A)
9         x=real(A)
10        y=imag(A)
11        r=sqrt(x^2+y^2)
12    endfunction
13    j=%i
14    //using Maxwell's mesh analysis
15    //refer Fig.8.14 in the textbook
16    //considering mesh FDCEF, (18+8*j)*I1-(10+8*j)*I2=24
17    //considering mesh ABCDA, (10+8*j)*I1-(14+10*j)*I2=0
18    a=[18+8*j -(10+8*j);10+8*j -(14+10*j)]
19    b=[24;0]
20    x=inv(a)*b
21    I1=x(1,1)
22    I2=x(2,1)
23    [I2 theta]=rect2pol(I2)
24    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)
25    //using thevenin's theorem
26    //refer Fig.8.14(a),(b) and (c)
27    Zth=8*(10+8*j)/(8+10+8*j)+(-4*j)//thevenin's
           impedance
28    //for calculating the equivalent Thevenin's voltage
           Vth, I1 be the current flowing in the branch CD
29    I1=24/(8+10+8*j)
30    Vth=I1*(10+8*j)//equivalent thevenin's voltage
31    I=Vth/((4+6*j+Zth))
32    [I theta]=rect2pol(I)
33    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

```
1
2 function [r]=mag(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6 endfunction
7 j=%i
8 V=200
9 //calculating supply frequency
10 L=.1//inductance of branch A
11 //Xa=2*%pi*f*.1
12 Ra=10//resistance of branch A
13 C=150D-6//capacitance of branch B
14 //Xb=1/(2*%pi*f*150D-6)
15 Rb=0//resistance of branch B
16 //Zb=-Xb*j
17 //total current I=Ia+Ib, total current is in phase
    with voltage-->j component of I=0
18 //on solving for f,
19 f=sqrt((V*2*%pi*L)*(1/(2*%pi*C))/V-Ra^2)/(2*%pi*L)
20 mprintf("Frequency of the supply which is also the
    resonant frequency, f=%f Hz\n", f)
21 Xa=2*%pi*f*.1
22 Za=Ra+Xa*j
23 Ia=V/Za
24 Xb=1/(2*%pi*f*150D-6)
25 Zb=-Xb*j
26 Ib=V/Zb
27 I=Ia+Ib
28 mprintf("Total current drawn by the circuit=%f A",
    mag(I))
29 //The answers vary from the textbook due to round
    off error
```

Scilab code Exa 8.13 Example on Resonance in Parallel Circuits

```
1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [r]=mag(A)
9     x=real(A)
10    y=imag(A)
11    r=sqrt(x^2+y^2)
12 endfunction
13 j=%i
14 //calculating branch currents
15 Z1=15+12*j//impedance of branch 1
16 I1=200/Z1
17 phi1=atand(12/15)
18 Z2=25-17*j//impedance of branch 2
19 I2=200/Z2
20 phi2=atand(17/25)
21 mprintf("I1=%f A at angle of %f degrees\nI2=%f A at
22     angle of %f degrees\n",mag(I1),phi1,mag(I2),phi2)
23 //calculating total current
24 I=I1+I2
25 [I phi]=rect2pol(I)
26 mprintf("Total current drawn by the circuit I=%f A,
27     angle of lag=%f degrees and power factor=%f
28     lagging\n",I,-phi,cos(phi*pi/180))
29 //power factor is to be raised to unity—a capacitor
30     has to be connected in parallel
31 //at unity power factor, imaginary part of I must be
32     zero
```

```
28 Xc=-200/imag(I1+I2)
29 f=40
30 C=1/(2*pi*f*Xc)
31 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 10

Three Phase Systems

Scilab code Exa 9.1 Example on Three Phase Circuits

```
1
2 function [r]=mag(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6 endfunction
7
8 j=%i
9 //considering coils to be star connected
10 V1=400//line voltage
11 Vph=V1/sqrt(3)
12 Rph=15//resistance of load
13 Xl=2*pi*50*.03//inductive reactance of each coil
14 Zph=Rph+Xl*j
15 Iph=Vph/mag(Zph)
16 Il=Iph
17 pf=Rph/mag(Zph)//power factor
18 P=sqrt(3)*V1*Il*pf
19 mprintf("In star connected circuit,\nPhase current=
    %f A,\nLine current=%f A,\nPower absorbed=%f kW\n
    ", Iph, Il,P/10^3)
```

```

20 //considering coils to be delta connected
21 Vph=Vl
22 Iph=Vph/mag(Zph)
23 Il=sqrt(3)*Iph
24 P=sqrt(3)*Vl*I1*pf
25 mprintf("In delta connected circuit,\nPhase current=
    %f A,\nLine current=%f A,\nPower absorbed=%f kW\n
    ", Iph, Il,P/10^3)
26 //answers vary from the textbook due to round off
    error

```

Scilab code Exa 9.2 Example on Three Phase Circuits

```

1
2 //calculating phase current
3 Vl=440//line voltage
4 Vph=Vl
5 Pout=200D+3//output
6 e=.91//efficiency
7 Pin=Pout/e//input
8 pf=.86//power factor
9 Iph=Pin/(3*Vph*pf)
10 mprintf("Current drawn by each motor phase=%f A\n",
    Iph)
11 //calculating line current
12 Il=sqrt(3)*Iph
13 mprintf("Line current=%f A\n", Il)
14 //calculating active and reactive components of
    phase current
15 phi=acos(pf)
16 Iact=Iph*pf
17 Ireact=Iph*sin(phi)
18 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

```
1
2 V1=400//line voltage across alternator and motor
3 Vph=V1//as the motor is delta connected
4 Pout=112D+3//output of motor
5 e=.88//efficiency of motor
6 Pin=Pout/e//input to motor
7 pf=.86
8 phi=acos(pf)
9 I1=Pin/(sqrt(3)*V1*pf)
10 Iph=I1/sqrt(3)
11 mprintf("Current in each motor phase , Iph=%f A\n",
    Iph)
12 //alternator is star connected
13 mprintf("Current in each alternator phase=%f A\n",I1
    )
14 //calculating active and reactive components of
    current in each phase of motor
15 Iact=Iph*pf
16 Ireact=Iph*sin(phi)
17 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)
18 //phase angle between the phase voltage and phase
    current will be the same for both motor and
    alternator if we neglect line impedance
19 Iph=I1
20 Iact=Iph*pf
21 Ireact=Iph*sin(phi)
22 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
    )
```

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

Scilab code Exa 9.4 Example on Three Phase Circuits

```
1
2 function [z]=pol2rect(r,theta)
3     x=r*cos(theta*pi/180)
4     y=r*sin(theta*pi/180)
5     z=x+y*i
6 endfunction
7 function [r]=mag(A)
8     x=real(A)
9     y=imag(A)
10    r=sqrt(x^2+y^2)
11 endfunction
12
13 //calculating current in each line
14 V1=400//line voltage
15 Vph=V1/sqrt(3)//phase voltage
16 Ir=8D+3/Vph
17 Iy=6D+3/Vph
18 Ib=4D+3/Vph
19 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)
20 //Loads on three phases are resistive
21 Ir=pol2rect(Ir,0)
22 Iy=pol2rect(Iy,-120)
23 Ib=pol2rect(Ib,-240)
24 In=Ir+Iy+Ib
25 mprintf("Current in the neutral=%f A" , mag(In))
```

Scilab code Exa 9.5 Example on Three Phase Circuits

```
1
2 Pout=30D+3//output
3 e=.86//efficiency
4 Pin=Pout/e//input
5 V1=440//line voltage
6 pf=.83//power factor
7 I1=Pin/(sqrt(3)*V1*pf)
8 mprintf("Line current=%f A\n", I1)
9 Iph=I1/sqrt(3)//motor is delta connected
10 mprintf("Phase current=%f A", Iph)
```

Scilab code Exa 9.6 Example on Three Phase Circuits

```
1
2 function [r, theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r, theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)
11    z=x+y*%i
12 endfunction
13 function [r]=mag(A)
14    x=real(A)
15    y=imag(A)
16    r=sqrt(x^2+y^2)
17 endfunction
18 j=%i
19 //calculating phase currents—let the sequence be RYB
20 V1=440//line voltage
```

```

21 Vph=Vl//delta connected load
22 Zph1=150//impedance of the phase between A and B(
    resistive)
23 I1=Vph/Zph1
24 mprintf(" I1=%f A at 0 degrees w.r.t. Vry\n", I1)
25 Zph2=30+50*j//impedance of the phase between B and C
26 I2=Vph/mag(Zph2)
27 //as the load is inductive, current will lag the
    voltage Vyb by phi2
28 phi2=atand(50/30)
29 mprintf(" I2=%f A at -%f degrees w.r.t. Vyb\n", I2,
    phi2)
30 C=20D-6
31 f=50
32 Xc=-(1/(2*pi*f*C))*j
33 I3=Vph/mag(Xc)
34 //as the load is capacitive, current will lead the
    voltage Vbr by 90 degrees
35 mprintf(" I3=%f A at 90 degrees w.r.t. Vbr\n", I3)
36
37 //calculating line currents-
38 Vry=pol2rect(440,0)
39 Vyb=pol2rect(440,-120)
40 Vbr=pol2rect(440,-240)
41 I1=Vry/Zph1
42 I2=Vyb/Zph2
43 I3=Vbr/Xc
44 //using KCL
45 Ir=I1-I3
46 Iy=I2-I1
47 Ib=I3-I2
48 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

```
1
2 V1=1100//line voltage
3 Vph=V1/sqrt(3)//star connected load
4 I1=80//current through load
5 Iph=I1
6 Zph=Vph/Iph
7 P=100D+3//power drawn by load
8 pf=P/(sqrt(3)*V1*I1)//power factor
9 Rph=Zph*pf
10 Xc=sqrt(Zph^2-Rph^2)
11 f=50
12 C=1/(2*pi*f*Xc)
13 mprintf("Capacitance per phase=%f microF", C*10^6)
14 //Answer vary from the textbook due to round off
    error
```

Scilab code Exa 9.8 Example on Power Measurement

```
1
2 W1=15D+3//reading of first wattmeter
3 W2=-1.5D+3//reading of second wattmeter
4 W=W1+W2//total power fed to the load
5 mprintf("Total power fed to the load=%f kW\n", W
    /10^3)
6 phi=atand(sqrt(3)*(W1-W2)/W)
7 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

```
1
```

```

2 W1=115D+3
3 W2=50D+3
4 //calculating input to motor
5 W=W1+W2
6 mprintf("Power input to the motor=%f kW\n", W/1000)
7 //calculating power factor
8 phi=atand(sqrt(3)*(W1-W2)/(W1+W2))
9 mprintf("Power factor angle , phi=%f degrees\nPower
    factor of load=%f A\n", phi, cos(phi*pi/180))
10 //calculating line current
11 I1=W/(sqrt(3)*440*cos(phi*pi/180))
12 mprintf("Line current drawn by the motor=%f A\n", I1)
13 //calculating efficiency
14 Pout=150D+3//output of motor
15 e=Pout/W*100
16 mprintf("Efficiency of the induction motor=%f
    percent", e )

```

Scilab code Exa 9.10 Example on Power Measurement

```

1
2 //calculating phase voltage
3 V1=440//line voltage
4 Vph=V1/sqrt(3)//star connected circuit
5 mprintf("Phase voltage=%f V\n", Vph)
6 Iph=20//phase current
7 Zph=Vph/Iph//impedance of load per phase
8 //calculating load parameters—current in each phase
    lags behind its voltage by 40 degrees
9 //on solving for R
10 R=Zph/sqrt(1+(tan(40*pi/180))^2)
11 X=R*tan(40*pi/180)
12 mprintf("Load parameters are\nR=%f ohm\nX=%f ohm\n",
    R, X)
13 //calculating total power

```



```

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

```

Scilab code Exa 9.11 Example on Power Measurement

```

1
2 Pout=37.3D+3//power output
3 e=.88//efficiency
4 Pin=Pout/e//input power
5 pf=.82//power factor
6 phi=acosd(pf)
7 //calculating W1 and W2-->W1+W2=Pin, W1-W2=Pin*tan(
    phi)/sqrt(3)
8 a=[1 1;1 -1]
9 b=[Pin;Pin*tan(phi*%pi/180)/sqrt(3)]
10 w=inv(a)*b
11 mprintf("Readings of two wattmeters are:\nW1=%f kW,\n
    nW2=%f kW\n", w(1,1)/1000, w(2,1)/1000)
12 V1=440//line voltage
13 I1=Pin/(sqrt(3)*V1*pf)
14 mprintf("Full load line current=%f A", I1)

```

Scilab code Exa 9.12 Example on Power Measurement

```

1
2 //considering star connected circuit

```

```

3 Rph=20//resistance of coil
4 Xph=15//reactance of coil
5 Vl=400//line voltage
6 Vph=Vl/sqrt(3)//phase voltage
7 Zph=sqrt(Rph^2+Xph^2)//impedance per phase
8 Iph=Vph/Zph//phase current
9 Il=Iph//line current
10 pf=Rph/Zph//power factor
11 phi=acosd(pf)
12 Pin=sqrt(3)*Vl*Il*pf//input power
13 //calculating W1 and W2-->W1+W2=Pin, W1-W2=Pin*tan(
    phi)/sqrt(3)
14 a=[1 1;1 -1]
15 b=[Pin;Pin*tan(phi*%pi/180)/sqrt(3)]
16 w=inv(a)*b
17 mprintf("Readings of two wattmeters in case of star
    connection are\nW1=%f W,\nW2=%f W\n", w(1,1), w
    (2,1))
18 //considering delta connected circuit
19 Iph=Vl/Zph//phase current
20 Il=sqrt(3)*Iph//line current
21 Pin=sqrt(3)*Vl*Il*pf//input power
22 //calculating W1 and W2-->W1+W2=Pin, W1-W2=Pin*tan(
    phi)/sqrt(3)
23 a=[1 1;1 -1]
24 b=[Pin;Pin*tan(phi*%pi/180)/sqrt(3)]
25 w=inv(a)*b
26 mprintf("Readings of two wattmeters in case of delta
    connection are\nW1=%f W,\nW2=%f W", w(1,1), w
    (2,1))
27 //The answers vary from the textbook due to round
    off error

```

Chapter 11

Measuring Instruments

Scilab code Exa 10.1 Example on Moving Coil Instruments

```
1
2 //calculating resistance of the shunt
3 i=20D-3 //current through the coil
4 r=4 //resistance of coil
5 V=i*r
6 I=2 //total current to be measured
7 Is=I-i //current through shunt
8 R=V/Is //Ohm's law
9 mprintf("Resistance of the shunt=%f ohm\n", R)
10 //solving part (ii)
11 V=30 //voltage to be measured
12 R=V/i-r
13 mprintf("Resistance to be connected in series with
    moving coil=%d ohm", R)
```

Scilab code Exa 10.2 Example on Moving Coil Instruments

```
1
```

```

2 i=20D-3 //current throught the coil
3 r=4 //resistance of coil
4 V=30 //voltage to be measured
5 R=(V-r*i)/i //resistance in series to read upto 30
   V
6 //to read upto 60 V
7 V=60
8 R1=V/i-r
9 mprintf(" Additional resistance needed to read upto
   60 V=%d ohm\n", R1-R)
10 //to read upto 90 V
11 V=90
12 R2=V/i-r
13 mprintf(" Additional resistance needed to read upto
   90V=%d ohm", R2-R1)

```

Scilab code Exa 10.3 Example on Moving Coil Instruments

```

1
2 i=20D-3 //current throught the coil
3 r=4 //resistance of coil
4 V=i*r
5 //when total current to be measured=2 A
6 Is=2-i //shunt current
7 R1=V/Is
8 mprintf(" Resistance of shunt for 2A range=%f ohm\n",
   R1)
9 //when total current to be measured=4 A
10 Is=4-i //shunt current
11 R2=V/Is
12 mprintf(" Resistance of shunt for 4A range=%f ohm\n",
   R2)
13 //when total current to be measured=6 A
14 Is=6-i //shunt current
15 R3=V/Is

```

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

Scilab code Exa 10.4 Example on Moving Coil Instruments

```
1
2 //calculating deflecting torque
3 N=50 //no. of turns in coil
4 B=.12 //flux density in Wb/m^2
5 A=5D-4 //area of coil in m^2
6 I=15D-3 //current through coil
7 Td=N*B*A*I
8 mprintf(" Deflecting torque=%fD-6 N-m\n",Td*10^6)
9 //calculating deflection of pointer
10 C=18D-7 //constant for spring in N-m per degree
11 Tc=Td //controlling torque
12 theta=Tc/C
13 mprintf(" Deflection=%d degrees", theta)
```

Scilab code Exa 10.5 Example on Moving Coil Instruments

```
1
2 N=80 //no. of turns in coil
3 B=.5 //flux density
4 A=15D-4 //area of coil
5 Tc=2D-4 //controlling torque at full scale
    deflection
6 Td=Tc //under final steady condition
7 I=Td/(N*B*A)
8 n=100 //no. of divisions
9 v=2 //voltage measured per division
10 V=n*v //at full scale deflection
11 R=V/I
```

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

Scilab code Exa 10.6 Example on Moving Coil Instruments

```
1
2 //calculating resistance of manganin shunt to extend
   range to 1 A
3 R=10 //resistance of instrument coil
4 I=10D-3 //current through coil
5 V=I*R
6 Is=1-I //shunt current
7 r=V/Is
8 mprintf(" Resistance of manganin shunt to extend
   range to 1 A=%f ohm\n" , r)
9 //calculating value of series resistance to extend
   the range to 15 V
10 v=15-V //voltage across series resistance
11 Rs=v/I
12 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

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

```

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

```

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

```

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

```

Chapter 14

Single Phase Transformers

Scilab code Exa 14.1 Example on EMF Equation

```
1
2 //calculating Bm
3 Ep=400//induced emf in primary winding
4 Np=350//no. of turns in primary
5 Ai=55D-4//cross-sectional area
6 f=50//frequency in Hz
7 Bm=Ep/(4.44*f*Ai*Np)
8 mprintf("Maximum value of flux density in the core=
    %f Tesla (Wb/m^2)\n",Bm)
9 //calculating voltage induced in secondary winding
10 Ns=1050
11 Es=Ep*Ns/Np
12 mprintf("Voltage induced in the secondary winding=%d
    V",round(Es))
```

Scilab code Exa 14.2 Example on EMF Equation

```
1
```

```

2 //calculating no. of turns in secondary winding
3 Es=500//no load voltage of low voltage winding
4 phi=.06//flux
5 f=50//frequency in Hz
6 Ns=round(Es/(4.44*f*phi))
7 mprintf("No. of turns in low voltage winding=%f\n",
        Ns)
8 //calculating no. of turns in primary winding
9 Np=Ns*6600/500
10 mprintf("Np=%f(not possible)\n",Np)
11 //Here, the no. of turns finally taken is 500 and
        not 502
12 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

```

1
2 Rp=.8
3 Xp=3.2
4 Rs=.009
5 Xs=.03
6 Rs_dash=(2200/220)^2*Rs
7 mprintf("Equivalent resistance referred to primary=
        %f ohm\n",Rp+Rs_dash)
8 Xs_dash=(2200/220)^2*Xs
9 mprintf("Equivalent reactance referred to primary=%f
        ohm\n",Xp+Xs_dash)
10 Rp_dash=(220/2200)^2*Rp
11 mprintf("Equivalent resistance referred to secondary
        =%f ohm\n",Rp_dash+Rs)
12 Xp_dash=(220/2200)^2*Xp
13 mprintf("Equivalent reactance referred to secondary=
        %f ohm",Xp_dash+Xs)

```

Scilab code Exa 14.4 Example on Equivalent Circuit

```
1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r,theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)
11    z=x+y*%i
12 endfunction
13 function [r]=mag(A)
14    x=real(A)
15    y=imag(A)
16    r=sqrt(x^2+y^2)
17 endfunction
18 j=%i
19 //calculating current in primary
20 Is=10//at 0.8 pf lagging
21 Ip_dash=Is*400/200//at 0.8 pf lagging
22 Ip_dash=pol2rect(Ip_dash,-acosd(.8))
23 Im=200/300//magnetizing current
24 Iw=200/600//active component of no load current
25 I0=Iw-Im*j//no load current
26 Ip=Ip_dash+I0
27 [Ip theta]=rect2pol(Ip)
28 mprintf("Current in primary is %f A, lagging at an
        angle of %f degrees\n",Ip,-theta)
29 //calculating terminal voltage
30 Ip=pol2rect(Ip,-theta)
31 Ep=Ip_dash*(.15+.37*j)
```

```

32 Es_dash=200-Ep
33 [Es_dash theta]=rect2pol(Es_dash)
34 Es=Es_dash*400/200
35 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

```

1
2 //calculating voltage regulation at full load with
    0.8 pf lagging
3 Ip=2000/400//primary current at full load
4 Rp=3
5 Xp=4
6 phi=acos(.8)
7 Vp=400
8 VR=Ip*(Rp*cos(phi)+Xp*sin(phi))/Vp*100
9 mprintf("Voltage regulation at full load with 0.8 pf
    lagging=%f percent\n",VR)
10 //calculating voltage regulation at full load with
    0.8 pf leading
11 VR=Ip*(Rp*cos(phi)-Xp*sin(phi))/Vp*100
12 mprintf("Voltage regulation at full load with 0.8 pf
    leading=%f percent\n",VR)
13 //calculating regulation at half load with 0.8 pf
    lagging
14 Ip=Ip/2//half load primary current
15 VR=Ip*(Rp*cos(phi)+Xp*sin(phi))/Vp*100
16 mprintf("Voltage regulation at half load with 0.8 pf
    lagging=%f percent",VR)

```

Scilab code Exa 14.6 Example on Regulation and Efficiency

```

1
2 //Is*Rs=.02*Vs, Is*Xs=.05*Vs
3 //calculating regulation at .8 pf lagging
4 VR=(.02*.8+.05*.6)*100
5 mprintf(" Voltage regulation at .8 pf lagging=%f
   percent\n",VR)
6 //calculating regulation at .8 pf leading
7 VR=(.02*.8-.05*.6)*100
8 mprintf(" Voltage regulation at 0.8 pf leading=%f
   percent",VR)

```

Scilab code Exa 14.7 Example on Regulation and Efficiency

```

1
2 Wcu_fl=425//copper losses at full load
3 //calculating efficiency at full load, unity pf
4 Pout=50*1000*1//output
5 e=Pout/(Pout+350+425)*100
6 mprintf(" Efficiency at full load, unity pf=%f
   percent\n",e)
7 //calculating efficiency at half load, unity pf
8 Pout=Pout/2//output
9 Wi=350//iron losses
10 Wcu=Wcu_fl/2^2//copper losses
11 e=Pout/(Pout+Wi+Wcu)*100
12 mprintf(" Efficiency at half load, unity pf=%f
   percent\n",e)
13 //calculating efficiency at full load, 0.8 pf
   lagging
14 Pout=(50D+3)*.8//output
15 e=Pout/(Pout+Wi+Wcu_fl)*100
16 mprintf(" Efficiency at full load, .8 pf lagging=%f
   percent\n",e)
17 //calculating maximum efficiency
18 Wcu=Wi//copper losses

```

```

19 x=sqrt(Wcu/Wcu_fl)//load at which maximum efficiency
    occurs
20 mprintf("At %f percent of the full load, maximum
    efficiency will occur\n",x*100)
21 Pout=(x*50D+3*1)
22 e_max=Pout/(Pout+2*Wi)*100
23 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

```

1
2 Wi=1100//iron losses
3 Wcu=400//copper losses at 50% load
4 Is=100*1000/10000//secondary full load current
5 //calculating efficiency at 25% load, unity pf
6 Is1=Is/4//secondary current
7 Wcu1=(25/50)^2*400//copper losses
8 Pout=.25*100*1000//output
9 e=Pout/(Pout+Wcu1+Wi)*100
10 mprintf("Efficiency at 25 percent load, unity pf=%f
    percent\n",e)
11 //calculating efficiency at 25% load, 0.8 pf
12 e=(Pout*.8)/(Pout*.8+Wcu1+Wi)*100
13 mprintf("Efficiency at 25 percent load, .8 pf=%f
    percent\n",e)
14 //calculating efficiency at 50% load, unity pf
15 Pout=.5*100*1000//output
16 e=Pout/(Pout+Wi+Wcu)*100
17 mprintf("Efficiency at 50 percent load, unity pf=%f
    percent\n",e)
18 //calculating efficiency at 50% load, 0.8 pf
19 e=Pout*.8/(Pout*.8+Wi+Wcu)*100
20 mprintf("Efficiency at 50 percent load, 0.8 pf=%f
    percent\n",e)

```

```

21 //calculating efficiency at full load, unity pf
22 Pout=100*1000//output
23 Wcu3=(10/5)^2*400//copper losses
24 e=Pout/(Pout+Wcu3+Wi)*100
25 mprintf("Efficiency at full load, unity pf=%f
    percent\n",e)
26 //calculating efficiency at full load, .8 pf
27 e=(Pout*.8)/(Pout*.8+Wcu3+Wi)*100
28 mprintf("Efficiency at full load, 0.8 pf=%f percent\
    n",e)
29 //calculating load for max efficiency at unity pf
30 x=sqrt(Wi/Wcu3)
31 mprintf("Load for max efficiency=%f kVA\nLoad for
    max efficiency will remain the same irrespective
    of power factor",x*Pout/1000)
32 //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

```

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

```

```

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

```

Scilab code Exa 14.10 Example on Regulation and Efficiency

```

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

```

Scilab code Exa 14.11 Example on Regulation and Efficiency

```

1
2 e1=.985//efficiency at full load, .8 pf lagging
3 //.985=100D+3*.8/(100D+3*.8+Wi+Wcu)-->.985*Wi+.985*
    Wcu=1200
4 e2=.99//efficiency at half load, unity pf
5 //.99=((100D+3)/2)/((100D+3)/2+Wi+Wcu/4)-->.99*Wi
    +.2475*Wcu=500
6 //solving for Wi and Wcu
7 a=[.985 .985;.99 .2475]
8 b=[1200;500]
9 w=inv(a)*b

```



```

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

```

Scilab code Exa 14.12 Example on Regulation and Efficiency

```

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

```

Scilab code Exa 14.13 Example on Regulation and Efficiency

```

1
2 e_max=.98//max efficiency of transformer

```

```

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

```

Scilab code Exa 14.14 Example on Testing of Transformer

```

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

```

```

12 Vsc=15//applied voltage
13 Isc=12.5//current
14 Wsc=50//power consumed
15 Zp=Vsc/Isc
16 Rp=Wsc/Isc^2
17 Xp=sqrt(Zp^2-Rp^2)
18 mprintf("Equivalent resistance and reactance
    referred to primary is %f ohm and %f ohm\n",Rp,Xp
    )
19 //calculating regulation at full load, 0.8 pf
    lagging
20 Vp=400
21 Ip=5D+3/400
22 VR=Ip*(Rp*.8+Xp*.6)/Vp*100
23 mprintf("Voltage regulation=%f percent\n",VR)
24 //calculating iron and copper losses
25 Wi=W0
26 Wcu=Wsc
27 mprintf("Iron losses=%f W\nCopper losses at full
    load=%f W\n",Wi,Wcu)
28 //calculating efficiency at full load and 0.8 pf
    lagging
29 e=5D+3*.8/(5D+3*.8+Wi+Wcu)*100
30 mprintf("Efficiency at full load and .8 pf lagging=
    %f percent",e)

```

Scilab code Exa 14.15 Example on Testing of Transformer

```

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

```

```

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

```

Scilab code Exa 14.16 Example on Testing of Transformer

```

1
2 Woc=60//power consumed in OC test at 220 V
3 //iron losses in transformer are proportional to
  square of applied voltage
4 Wi=60*(200/220)^2//iron losses at normal voltage of
  200 V
5 Is=5D+3/400//full load current on HV side
6 //for SC test
7 Isc=10//current
8 Wsc=120//power consumed
9 Wcu=(Is/Isc)^2*Wsc//full load copper losses
10 e=(5D+3*.8)/(5D+3*.8+Wi+Wcu)*100
11 mprintf(" Efficiency at full load=%f percent",e)

```

Scilab code Exa 14.17 Example on Parallel Operation

```

1
2 function [r, theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r, theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)

```

```

11     z=x+y*i
12 endfunction
13
14 j=%i
15 I=pol2rect(300,-acosd(.8))//total load to be shared
    by transformers A and B at .8 pf lagging
16 Za=.011+.042*j//impedance of transformer A
17 Zb=.044+.072*j//impedance of transformer B
18
19 //calculating load shared by transformer A
20 Ia=Zb*I/(Za+Zb)
21 [Ia theta]=rect2pol(Ia)
22 mprintf("Load shared by transformer A=%f A, lagging
    by an angle of %f degrees\n",Ia,-theta)
23
24 //calculating load shared by transformer B
25 Ib=Za*I/(Za+Zb)
26 [Ib theta]=rect2pol(Ib)
27 mprintf("Load shared by transformer B=%f A, lagging
    by an angle of %f degrees",Ib,-theta)
28 //answers vary from the textbook due to round off
    error

```

Scilab code Exa 14.18 Example on Parallel Operation

```

1
2 function [r]=mag(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6 endfunction
7
8 j=%i
9 Zl=8+6.2*j//load impedance
10 //for transformer A

```

```
11 Ea=6600//secondary induced emf
12 Za=.3+3.2*j//equivalent impedance referred to
    secondary
13 //for transformer B
14 Eb=6400//secondary induced emf
15 Zb=.2+1.2*j//equivalent impedance referred to
    secondary
16 Ia=(Ea*Zb+(Ea-Eb)*Z1)/(Za*Zb+(Za+Zb)*Z1)
17 Ib=(Eb*Za-(Ea-Eb)*Z1)/(Za*Zb+(Za+Zb)*Z1)
18 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

```
1
2
3 P=50D+3 //power per phase
4 Power_rating=3*P
5 Vpp=2300 //primary phase voltage
6 Vsp=230 //secondary phase voltage
7 Vpl=sqrt(3)*Vpp //primary normal line voltage
8 Vsl=Vsp //secondary normal line voltage
9 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))
10 Ipp=P/Vpp
11 Ipl=Ipp
12 Isp=P/Vsp
13 Isl=sqrt(3)*Isp
14 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,Is1)
15 //calculating voltage regulation
16 Rp_dash=1.2 //equivalent resistance referred to
    primary
```

```

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

```

Scilab code Exa 15.2 Example on three phase transformer

```

1
2 //calculating no. of turns per phase
3 Vsp=440/sqrt(3) //secondary phase voltage
4 Et=8 //emf per turn in volt
5 Ts=round(Vsp/Et)
6 Vpp=1100 //primary phase voltage
7 Tp=Ts*Vpp/Vsp
8 mprintf("No. of turns per phase on primary winding=
    %d\nNo. of turns per phase on secondary winding=
    %d\n", Tp, Ts)
9 //calculating net cross-sectional area of core
10 f=50 //frequency
11 Bm=1.3 //flux density
12 Ai=Et/(4.44*f*Bm)
13 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

```

1
2 //calculating currents in the main and teaser
    transformer
3 P2=600D+3 //output
4 V2=110 //applied voltage
5 pf=.707 //lagging power factor
6 I2=P2/(pf*V2)

```



```

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

```

Scilab code Exa 15.4 Example on three phase transformer

```

1
2 function [r, theta]=rect2pol(x,y)
3     r=sqrt(x^2+y^2)
4     theta=atand(y/x)
5 endfunction
6 Q=750 //total load to be shared
7 pf=.8 //lagging power factor
8 theta=-acosd(.8)
9 Q=rect2pol(Q*cos(theta),Q*sin(theta))
10 Zb=rect2pol(.35,3.3) //per phase impedance of
    transformer B
11 Za=rect2pol(.2,1.8) //per phase impedance of
    transformer A
12 Qa=Zb*Q/(Za+Zb)
13 Qb=Za*Q/(Za+Zb)
14 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

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

Scilab code Exa 16.3 Example on Electromechanical Energy Conversion Devices

```
1
2 mu_not=4D-7*%pi
3 i=120/6 //current flowing in coil
4 N=300 //no. of turns
5 x=.005 //length of air gap
6 Ag=36D-4 //cross-sectional area at gap
7 //calculating stored field energy
8 W_f=mu_not*N^2*Ag*i^2/(4*x)
9 mprintf("Stored field energy=%f watt-sec\n", W_f)
10 //calculating mechanical force developed
11 F_f=mu_not*N^2*i^2*Ag/(4*x^2)
12 mprintf("Mechanical force developed=%f N-m", F_f)
```

Chapter 17

Fundamentals of DC Machines

Scilab code Exa 17.1 Example on DC Winding

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

Scilab code Exa 17.2 Example on DC Winding

```
1
2 P=4//no. of poles
3 n=24//no. of slots
```

```

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

```

Scilab code Exa 17.3 Example on EMF Equation

```

1
2 P=6//no. of poles
3 A=P//no. of parallel paths
4 phi=.018//flux per pole
5 N=600//speed of rotation in rpm
6 Z=840//total no. of conductors
7 Eg=P*phi*N*Z/(60*A)
8 mprintf("Emf generated=%f V\n",Eg)

```

Scilab code Exa 17.4 Example on EMF Equation

```

1
2 P=6//no. of poles
3 A=2//no. of parallel paths
4 Z=300//no. of conductors on armature
5 N=1000//speed of rotation in rpm
6 Eg=400//emf generated on open circuit
7 phi=60*Eg*A/(P*N*Z)
8 mprintf("Flux per pole=%f Wb\n", phi)

```

Scilab code Exa 17.5 Example on EMF Equation

```
1
2 Eg=400//emf generated
3 n=80//no. of slots on armature
4 c=10//conductors per slot
5 Z=n*c//total no. of conductors on armature
6 N=1000//speed in rpm
7 phi=60*Eg/(N*Z)
8 Eg=220//desired value of generated voltage
9 N=60*Eg/(phi*Z)
10 mprintf("Speed of rotation to generate 220 V=%f rpm\
    n", round(N))
```

Scilab code Exa 17.6 Example on EMF Equation

```
1
2 n=60//no. of slots on armature
3 c=6//conductors per slot
4 Z=n*c//total no. of conductors
5 A=2//no. of parallel paths in armature winding
6 N=750//speed of rotation
7 P=4//no. of poles
8 Eg=230//emf generated on open circuit
9 phi=60*Eg*A/(P*N*Z)
10 mprintf(" Useful fux per pole=%f Wb\n",phi)
11 Eg=115//emf to be generated at no load
12 A=P*N*Z*phi/(60*Eg)//required no. of parallel paths
    in armature winding
13 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

```
1
2 //calculating terminal voltage
3 P=10D+3//load supplied
4 V1=220//voltage at load terminals
5 I1=P/V1
6 R=.1//resistance of feeders
7 Vd=I1*R//voltage drop on feeders
8 V=Vd+V1
9 mprintf("Terminal voltage across the armature
   terminals=%f V\n",V)
10 //Calculating shunt field current
11 Rsh=100//shunt resistance
12 Ish=V/Rsh
13 mprintf("Shunt field current=%f A\n",Ish)
14 //Calculating generated emf
15 Ra=.05//resistance of armature
16 Eg=V+I1*Ra
17 mprintf("Generated emf Eg=%f V",Eg)
```

Scilab code Exa 17.8 Example on Types of DC Machines

```
1
2 //calculating total armature current
3 V=200//terminal voltage across armature
4 Rsh=80//shunt field resistance
5 Ish=V/Rsh//shunt field current
6 I1=100//load current
7 Ia=I1+Ish
8 mprintf("Armature current=%f A\n",Ia)
9 //calculating current per armature path
```

```

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

```

Scilab code Exa 17.9 Example on Types of DC Machines

```

1
2 V=100//terminal voltage
3 I1=200//load current
4 Rse=.03//resistance of series field winding
5 Ra=.04//resistance of armature winding
6 Rsh=60//resistance of shunt
7 Vd=I1*Rse//voltage drop in series field winding
8 V_dash=V+I1*Rse//terminal voltage across armature
9 Ish=V_dash/Rsh
10 Ia=I1+Ish
11 Eg=V+I1*Rse+Ia*Ra
12 mprintf("Generated emf=%f V",Eg)

```

Scilab code Exa 17.10 Example on Types of DC Machines

```

1
2 V=250//terminal voltage
3 I1=450//load current
4 Rsh=50//shunt field resistance
5 Ish=V/Rsh
6 Ia=Ish+I1
7 Ra=.05//armature resistance
8 Eg=V+Ia*Ra

```



```

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

```

Scilab code Exa 17.11 Example on Types of DC Machines

```

1
2 //when the dc shunt machine works as a generator
3 V=250//terminal voltage
4 I1=80//load current
5 Rsh=100//field resistance
6 Ra=.12//armature resistance
7 Ish=V/Rsh
8 Ia=I1+Ish
9 Eg=V+Ia*Ra
10
11 //when the dc shunt machine works as a motor
12 V=250//applied voltage to motor
13 I1=80//line current drawn by the motor
14 Ia=I1-Ish
15 Eb=V-Ia*Ra
16 //for a machine, P*phi*Z/(60*A) is a constant
17 x=Eg/Eb
18 mprintf("speed as generator/speed as motor=%f",x)

```

Scilab code Exa 17.12 Example on Types of DC Machines

```

1

```

```

2 //calculating back emf
3 V=120//applied voltage
4 I1=200//line current
5 Rsh=30//shunt field resistance
6 Ra=.02//armature winding resistance
7 Ish=V/Rsh
8 Ia=I1-Ish
9 Eb=V-Ia*Ra
10 mprintf("Back emf=%f V\n",Eb)
11 n=90//no. of slots on armature
12 c=4//conductors per slot
13 Z=n*c//total no. of conductors on armature
14 phi=.04
15 N=60*Eb/(phi*Z)
16 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

```

1
2 //calculating load current
3 i=30//current drawn by each motor
4 I=5*i//current drawn by 5 motors
5 P=150*60//total lighting load
6 V=110//applied voltage
7 I1=P/V//current taken by lighting load
8 I=I1+I
9 mprintf("Total load current=%d A\n",round(I))
10 //calculating terminal voltage
11 V_dash=110//voltage at terminals of load
12 R=.04//resistance of feeders
13 Vd=I*R//voltage drop in feeders
14 V=V_dash+Vd
15 mprintf("Terminal voltage across the generator
      terminals=%f V\n",V)

```

```

16 //calculating emf generated
17 Rsh=55//resistance of shunt field
18 Ish=V/Rsh
19 Ia=I+Ish
20 Ise=Ia
21 Rse=.04//series field resistance
22 Ra=.03//armature resistance
23 Eg=V+Ia*(Ra+Rse)
24 mprintf("Generated emf, Eg=%f V",Eg)

```

Scilab code Exa 17.14 Example on Types of DC Machines

```

1
2 //when the machine is working as generator
3 V=240//terminal voltage across the load
4 P=40D+3//load on generator
5 I1=P/V//load current
6 Rsh=60//resistance of shunt field
7 Ish=V/Rsh
8 Ia=I1+Ish
9 Ra=.03//armature resistance
10 e=2*1//voltage drop at brushes
11 Eg=V+Ia*Ra+e
12 N=450//speed as a generator at this load
13 //let k=P*phi*Z/(60*A)
14 k=Eg/N
15 //when the machine is working as motor
16 Ia=I1-Ish
17 Eb=V-Ia*Ra-e
18 N=Eb/k
19 mprintf("Speed as a motor=%d rpm", round(N))

```

Chapter 18

DC Generators

Scilab code Exa 18.1 Example on Magnetization Characteristics

```
1
2 i=linspace(0,1.6,9)
3 V=[0 40 66 86 101 112 121 128 133]
4 plot(i,V,rect=[0 0 1.6 133])
5 xtitle("Magnetization curve for example 18.1","Field
        Current","Generated emf")
6
7 //refer Fig. 18.4 in the textbook
8 Rsh=94//resistance of shunt field winding
9 //OA is the field resistance line for this
  resistance
10 Voc=126//voltage corresponding to point A
11 mprintf("Open circuit voltage when the field circuit
        resistance is 94 ohm=%d V\n",Voc)
12 //D is point on OCC corresponding to 110 V. OD
  represents the field resistance line to generate
  this voltage
13 R=70/.6//total resistance of shunt field circuit
14 mprintf("Additional resistance in the shunt field
```

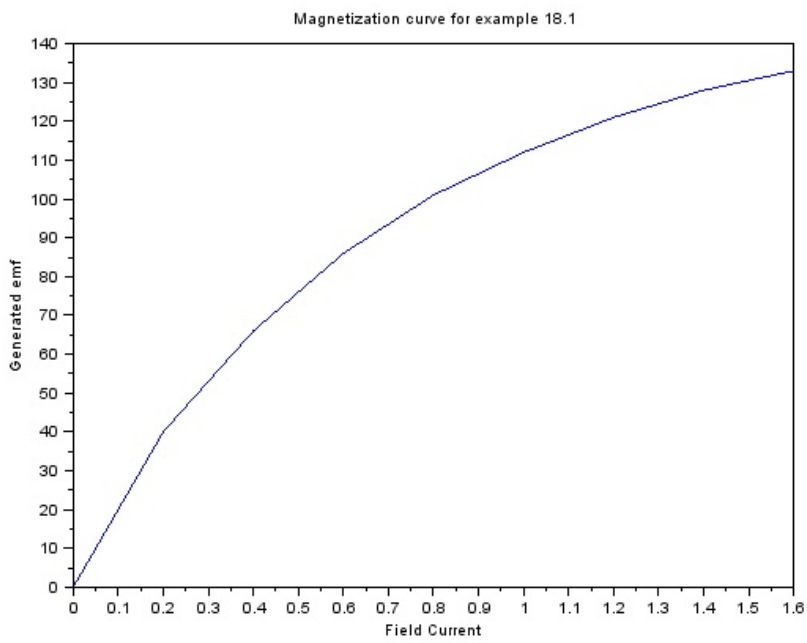


Figure 18.1: Example on Magnetization Characteristics

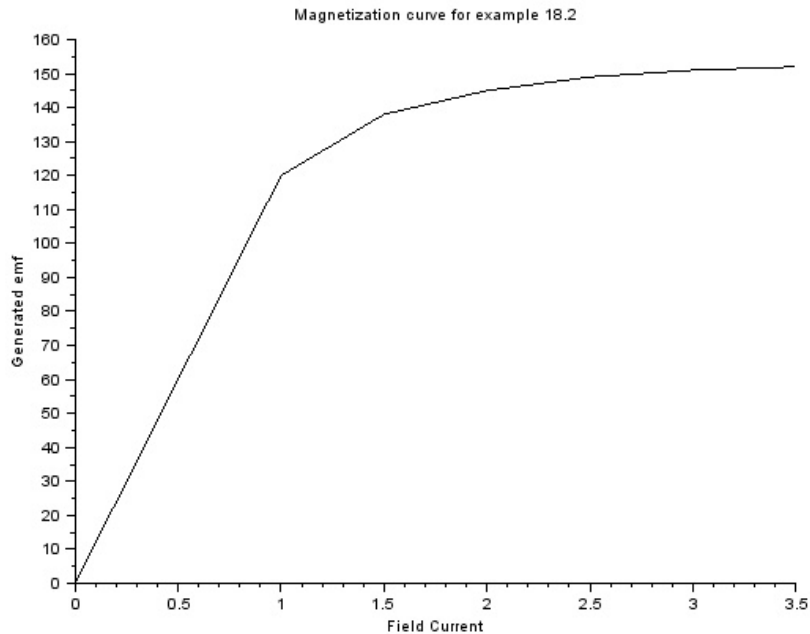


Figure 18.2: Example on Magnetization Characteristics

```

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

```

Scilab code Exa 18.2 Example on Magnetization Characteristics

```

1
2 i=linspace(0,3.5,8)
3 V=[0 60 120 138 145 149 151 152]

```

```

4 plot2d(i,V)
5 xtitle("Magnetization curve for example 18.2", "Field
    Current", "Generated emf")
6
7 //refer Fig. 18.5 in the textbook
8 Rsh=60//shunt field resistance
9 //line OA is field resistance line
10 Voc=149//voltage corresponding to point A
11 mprintf("Open circuit voltage=%d V\n",Voc)
12 //resistance represented by OE is critical
    resistance
13 Rc=120
14 mprintf("Critical resistance of shunt field=%d ohm\n
    ",Rc)
15 //when the load has a resistance of 4 ohm
16 R=4
17 //load current I=V/4
18 //Ish=V/60
19 //Ia=I+Ish
20 Eg=Voc
21 Ra=.1//armature resistance
22 //V=Eg-Ia*Ra
23 V=Eg/(1+(1/R+1/Rsh)*Ra)
24 mprintf("Terminal voltage , V=%f V\n",V)
25 //when the terminal voltage is 100 V
26 V=100//terminal voltage
27 Ia=(Eg-V)/Ra
28 Ish=V/Rsh
29 I=Ia-Ish
30 mprintf("Load current=%f A",I)

```

Scilab code Exa 18.3 Example on Magnetization Characteristics

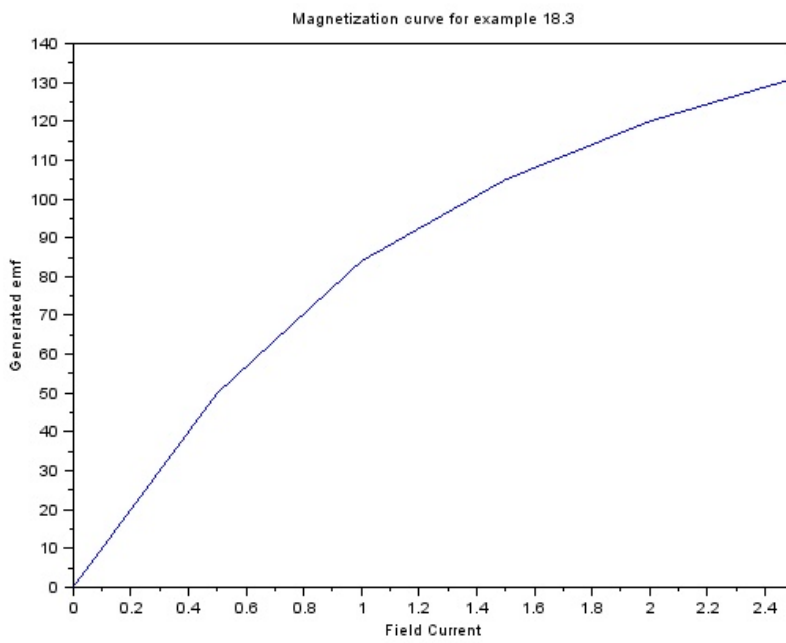


Figure 18.3: Example on Magnetization Characteristics


```

1
2 i=linspace(0,2.5,6)
3 V=[0 50 84 105 120 131]
4 plot(i,V)
5 xtitle("Magnetization curve for example 18.3", "Field
        Current", "Generated emf")
6
7 //refer Fig.18.6 in the textbook
8 //OE is the field resistance line of critical
    resistance
9 Rc=100
10 //solving (iii)
11 Rsh=70//field resistance
12 N=750//speed in rpm
13 Nc=Rsh/Rc*N
14 mprintf("When the field resistance is 70 ohm,
        critical speed=%d rpm\n", round(Nc))
15 //solving (iv)
16 Eg=100//open-circuit voltage
17 Rsh=55//shunt field resistance
18 //now, the operating point is M instead of A
19 //LM/LN=N1/N
20 //from the graph, LM/LN=100/115
21 N1=100/115*N//desired speed
22 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

```

1
2 //generated emf is directly proportional to speed
3 //readings for OCC at 1000 rpm are

```

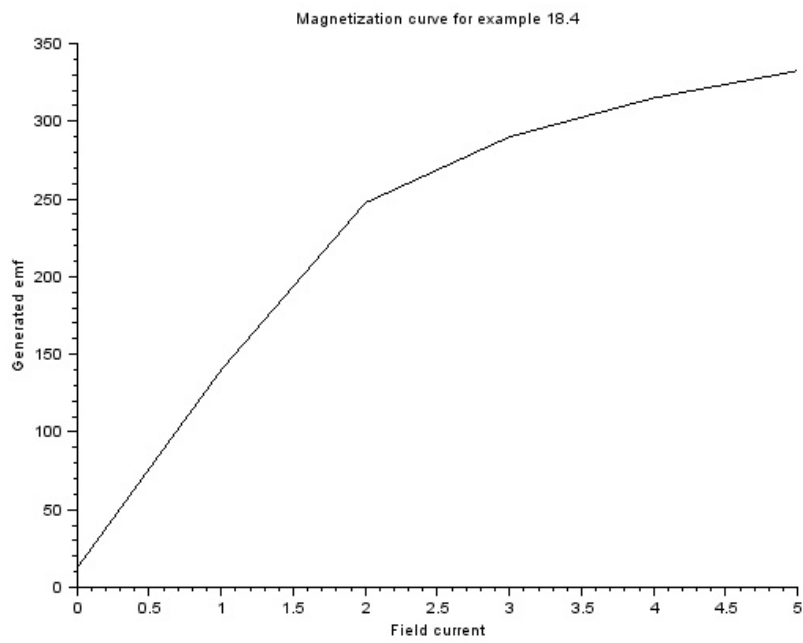


Figure 18.4: Example on Magnetization Characteristics

```

4 Eg2=[10*(1000/800) 112*(1000/800) 198*(1000/800)
      232*(1000/800) 252*(1000/800) 266*(1000/800)]
5 i=linspace(0,5,6)
6 plot2d(i,Eg2)
7 xtitle("Magnetization curve for example 18.4", "Field
      current", "Generated emf")
8
9 //refer Fig.18.7 in the textbook
10 Rsh=70//resistance of field circuit
11 //line OA is field resistance line
12 V=330//voltage corresponding to point A
13 mprintf("No load terminal voltage is %d V\n",V)
14 //now, no load terminal voltage is 270 V
15 V=270
16 //the operating point is D
17 //line OD is corresponding field resistance line
18 R=V/2.4//resistance represented by line OD
19 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

```

1
2 //for generator A
3 V1=240//initial terminal voltage
4 V2=225//final terminal voltage
5 Ia=120//armature current
6 Ra=(V1-V2)/Ia//armature resistance
7 //for generator B
8 V1=230//initial terminal voltage
9 V2=215//final terminal voltage
10 Ib=100//armature current
11 Rb=(V1-V2)/Ib//armature resistance
12 I=200//total load current

```

```

13 //I1+I2=I , V=240-I1*Ra, V=230-I2*Rb
14 //solving for V, I1 and I2
15 a=[1 1 0;Ra 0 1;0 Rb 1]
16 b=[200;240;230]
17 x=inv(a)*b
18 I1=x(1,1)
19 I2=x(2,1)
20 V=x(3,1)
21 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

```

1
2 Ra=.03//armature resistance of each generator
3 Rsh=60//field resistance of each generator
4 I=4500//total load current
5 //I1+I2=4500, Ish=V/60
6 //Ia1=I1+V/60
7 //Ia2=I2+V/60
8 Ea1=500//induced emf in generator 1
9 //500=V+Ia1*.03
10 Ea2=510//induced emf in generator 2
11 //510=V+Ia2*.03
12 //solving for V,I1 and I2
13 a=[1 1 0;.03 0 1+.03/60;0 .03 1+.03/60]
14 b=[4500;500;510]
15 x=inv(a)*b
16 I1=x(1,1)
17 I2=x(2,1)
18 V=x(3,1)
19 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

```
1
2 //Let V be bus-bar voltage and I1, I2 be the
   currents supplied by generators 1 and 2
   respectively
3 I1=3000//total load current
4 //I1+I2=I1
5 //for generator 1
6 Rsh1=30//field resistance
7 Ra1=.05//armature resistance
8 Eg1=400//induced emf
9 //for generator 2
10 Rsh2=25//field resistance
11 Ra2=.03//armature resistance
12 Eg2=380//induced emf
13 //Ish1=V/Rsh1
14 //Ish2=V/Rsh2
15 //Ia1=I1+Ish1
16 //Ia2=I2+Ish2
17 //Eg1=V+Ia1*Ra1;Eg2=V+Ia2*Ra2
18 //solving for I1, I2 and V
19 a=[1 1 0;Ra1 0 1+Ra1/Rsh1;0 Ra2 1+Ra2/Rsh2]
20 b=[I1;Eg1;Eg2]
21 x=inv(a)*b
22 I1=x(1,1)
23 I2=x(2,1)
24 V=x(3,1)
25 P1=V*I1
26 P2=V*I2
27 mprintf("Output of generator 1=%f kW\nOutput of
   generator 2=%f kW", P1/1000,P2/1000)
28 //answers vary from the textbook due to round off
   error
```

Chapter 19

DC Motors

Scilab code Exa 19.1 Example on Torque and Speed

```
1
2 //calculating torque deveoped
3 P=6//no. of poles
4 A=6//no. of parallel circuits
5 Ia=300//armature current
6 n=500//no. of armature turns
7 Z=2*500//total no. of conductors
8 phi=75D-3//flux per pole
9 Ta=.159*P*phi*Ia*Z/A
10 mprintf("Torque developed=%f N-m\n",Ta)
11 //calculating shaft torque
12 T=2.5*Ta/100//torque lost in windage, friction and
    iron losses
13 Tsh=Ta-T
14 mprintf("Shaft torque=%f N-m\n",Tsh)
15 //calculating shaft power
16 N=400//speed in rpm
17 Psh=2*%pi*N*Tsh/60
18 mprintf("Shaft power=%f kW",Psh/1000)
19 //answer vary from the textbook due to round off
    error
```

Scilab code Exa 19.2 Example on Torque and Speed

```
1
2 //calculating torque developed by armature
3 V=200//voltage applied across the motor
4 Rsh=40//resistance of shunt field winding
5 Ish=V/Rsh
6 I=100//total current drawn by motor
7 Ia=I-Ish
8 Ra=.1//armature resistance
9 Eb=V-Ia*Ra
10 P=Eb*Ia//mechanical power developed
11 N=750//speed in rpm
12 Ta=60*P/(2*pi*N)
13 mprintf("Torque developed by armature=%f N-m\n",Ta)
14 //calculating copper losses
15 Wcu1=V*Ia-Eb*Ia//armature copper losses
16 Wcu2=Ish^2*Rsh//field copper losses
17 mprintf("Total copper losses=%f W\n",Wcu1+Wcu2)
18 //calculating shaft power
19 Wc=1500//friction and iron losses
20 Pi=200*100//input to motor
21 Psh=Pi-(Wc+Wcu1+Wcu2)
22 mprintf("Shaft power=%f kW\n",Psh/1000)
23 //calculating shaft torque
24 Tsh=60*Psh/(2*pi*N)
25 mprintf("Shaft torque=%f N-m\n",Tsh)
26 //calculating efficiency
27 e=Psh/Pi*100
28 mprintf("Efficiency=%f percent",e)
```

Scilab code Exa 19.3 Example on Torque and Speed

```

1
2 Po=60D+3//full load output of the motor
3 e=0.905//efficiency of the motor
4 Pin=Po/e
5 V=400//applied voltage
6 I=Pin/V//line current drawn by the motor
7 Rsh=200//resistance of the shunt field winding
8 Ish=V/Rsh
9 Ia=I-Ish
10 Ra=0.1//armature resistance
11 Eb=V-Ia*Ra
12 A=2//no. of parallel paths in armature winding
13 P=4//no. of poles
14 phi=45D-3//flux per pole
15 Z=450//total number of conductors
16 N=round(60*Eb*A/(P*phi*Z))
17 mprintf(" Full load speed=%d rpm\n",N)
18 //calculating armature torque
19 Ta=0.159*P*phi*Ia*Z/A
20 mprintf(" Torque developed by the armature of the DC
    motor=%f N-m\n",Ta)
21 //calculating useful torque
22 Psh=60D+3//shaft power
23 Tsh=60*Psh/(2*pi*N)
24 mprintf(" Useful torque=%f N-m",Tsh)
25 //error in the textbook answer for useful torque

```

Scilab code Exa 19.4 Example on Torque and Speed

```

1
2 V=220//voltage applied to motor
3 Rsh=157//shunt field resistance
4 Ra=0.3//armature resistance
5 Ish=V/Rsh
6 IO=4.5//current drawn by the motor at no load

```



```

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

```

Scilab code Exa 19.5 Example on Torque and Speed

```

1
2 //calculating shaft power
3 V=100//voltage applied to series motor
4 Ra=.22//armature resistance
5 Rse=.13//series field resistance
6 Rm=Ra+Rse//total resistance
7 Ia=45//current in armature circuit
8 Eb=V-Ia*Rm
9 Pm=Eb*Ia//mechanical power developed
10 Wc=750//iron and friction losses
11 Psh=Pm-Wc
12 mprintf(" Shaft power=%f kW\n",Psh/1000)
13 //calculating torque developed
14 N=750//speed in rpm
15 Ta=60*Pm/(2*pi*N)
16 mprintf(" Total torque=%f N-m\n",Ta)
17 //calculating shaft torque
18 Tsh=60*Psh/(2*pi*N)
19 mprintf(" Shaft torque=%f N-m",Tsh)

```

Scilab code Exa 19.6 Example on Torque and Speed

```
1
2 //calculating speed
3 P=4//no. of poles
4 V=220//applied voltage
5 Ia=46//current in armature circuit
6 Ra=.25//field resistance
7 Rse=.15//series field resistance
8 Rm=Ra+Rse
9 Eb=V-Ia*Rm
10 A=2//no. of parallel circuits
11 phi=20D-3//flux per pole
12 Z=1200//total conductors on armature
13 N=round(60*Eb*A/(P*phi*Z))
14 mprintf("Speed, N=%d rpm\n", N)
15 //calculating total torque
16 Ta=.159*P*phi*Ia*Z/A
17 mprintf("Total torque=%f N-m\n", Ta)
18 //calculating shaft power
19 Pm=Eb*Ia//mechanical power developed
20 Wc=900//iron and friction losses
21 Po=Pm-Wc
22 mprintf("Shaft power=%f kW\n", Po/1000)
23 //calculating shaft torque
24 Tsh=60*Po/(2*pi*N)
25 mprintf("Shaft torque Tsh=%f N-m\n", Tsh)
26 //calculating efficiency
27 Pin=V*Ia//input to motor
28 e=Po/Pin*100
29 mprintf("Efficiency=%f percent", e)
```

Scilab code Exa 19.7 Example on Torque and Speed

```
1
2 //working as motor
3 V1=110//applied voltage to motor
4 Rsh=45//shunt field resistance
5 Ish1=V1/Rsh//shunt field current
6 I1=230
7 Ia1=I1-Ish1
8 Ra=.03//armature resistance
9 Eb1=V1-Ia1*Ra
10 N1=450//speed in rpm
11 V2=210//changed value of applied voltage
12 Ish2=V2/Rsh
13 I1=85//current drawn by the motor from the main
14 Ia2=I1-Ish2
15 Eb2=V2-Ia2*Ra
16 //back emf is directly proportional to shunt field
    current and speed
17 N2=(Eb2/Eb1)*(Ish1/Ish2)*N1
18 mprintf("Speed of the motor=%d rpm\n",N2)
19 //working as generator
20 V=200//terminal voltage across the load
21 Ish3=V/Rsh
22 I1=140//load current on the generator
23 Ia3=I1+Ish3
24 Eg=V+Ia3*Ra
25 N3=(Eg/Eb1)*(Ish1/Ish3)*N1
26 mprintf("Speed at which generator would have to run=
    %d rpm",N3)
27 //answers vary from the textbook due to round off
    error
```

Scilab code Exa 19.8 Example on Speed Control of DC Motors

```

1
2 V=230//voltage applied to motor
3 N1=1000//initial speed
4 Ia=35//armature current
5 Ra=.3//resistance of armature circuit
6 Eb1=V-Ia*Ra
7 N1=1000//speed in rpm
8 Ia=25//armature current in new situation
9 N2=750//changed speed in rpm
10 //back emf is directly proportional to speed
11 R=((V-Ia*Ra)*N1-N2*Eb1)/(Ia*N1)
12 mprintf("Additional resistance in armature circuit=
    %f ohm",R)

```

Scilab code Exa 19.9 Example on Speed Control of DC Motors

```

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

```

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

Scilab code Exa 19.10 Example on Speed Control of DC Motors

```
1
2 V=500 //applied voltage
3 N1=700 //initial speed of motor
4 Ia1=50 //armature current
5 Ra=.4 //effective armature resistance
6 Eb1=V-Ia1*Ra
7 N2=600 //reduced speed of motor
8 Ia2=Ia1 //as torque and flux remains same
9 //back emf is directly proportional to speed
10 R=((V-Ia2*Ra)*N1-Eb1*N2)/(Ia2*N1)
11 mprintf(" Additional resistance in the armature
    circuit is %f ohm" ,R)
```

Scilab code Exa 19.11 Example on Speed Control of DC Motors

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

```

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

```

Scilab code Exa 19.12 Example on Speed Control of DC Motors

```

1
2 //solving (i)
3 I1=70//current drawn by the motor
4 V=200//applied voltage
5 Rsh=100//shunt field resistance
6 Ish=V/Rsh//shunt field current
7 Ia1=I1-Ish
8 N1=500//initial speed
9 Ra1=.2//armature resistance
10 Eb1=200-Ia1*Ra1
11 N2=350//reduced speed of motor
12 Ia2=Ia1//armature current remains same
13 //Eb2=200-68*(R+.2)
14 //back emf is proportional to speed
15 R=((V-Ia2*Ra1)*N1-Eb1*N2)/(Ia2*N1)
16 mprintf("Additional resistance in the armature
    circuit=%f ohm\n", R)
17 //solving (ii)
18 Ra2=R+Ra1//armature resistance
19 Ia3=35//armature current
20 Eb3=V-Ia3*Ra2
21 N3=N1*Eb3/Eb1
22 mprintf("Speed=%d rpm", N3)
23 //answer vary from the textbook due to round off

```

error

Scilab code Exa 19.13 Example on Speed Control of DC Motors

```
1
2 V=250//voltage applied to the motor
3 Eb1=V//Ra is negligible
4 N1=500//speed in rpm
5 Ia1=40//armature current
6 R=25//additional resistance
7 //as flux remains same, back emf is directly
  proportional to speed; and torque is directly
  proportional to armature current
8 //Eb2=250-Ia2*25, N2=500-50*Ia2
9 //also, torque varies as cube of speed
10 //from these conditions, we get,  $Ia2^3 - 30*Ia2^2 + 325*Ia2 - 1000 = 0$ 
11 //solving this equation, we get
12 Ia2=5
13 N2=(Ia2/Ia1)^(1/3)*N1
14 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

```
1
2 E1=400//eddy current losses
3 //for a machine, eddy current losses is directly
  proportional to Bmax^2 and f^2
4 //Bmax is proportional to flux
5 //f is proportional to speed
6 //when speed and flux increased by 10%
7 E2=1.1^2*1.1^2*E1 //Eddy current losses under
  changed condition
8 mprintf("Increase in eddy current losses=%f W", E2-
  E1)
```

Scilab code Exa 20.2 Example on losses in DC Machine

```
1
2 N=1500//speed in rpm
3 E1=300//hysteresis losses
4 //E1=k1*N
```



```

5 k1=E1/N
6 E2=150//eddy current losses
7 //E2=k2*N^2
8 k2=E2/N^2
9 E=E1+E2//total iron losses
10 //when iron losses are reduced to half
11 //k1*N1+k2*N1^2=.5*E
12 //solving for N1
13 N1=(-k1+sqrt(k1^2-4*k2*(-.5*E)))/(2*k2)
14 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

```

1
2 //calculating efficiency at full load
3 I1=200 //current supplied
4 Rsh=100 //shunt field resistance
5 V=500 //terminal voltage
6 Ish=V/Rsh
7 Ia=I1+Ish
8 Wcu=Ia^2*.1 //armature copper losses
9 Wc=4000 //constant losses including field copper
    losses
10 Wt=Wcu+Wc //total losses
11 Po=V*I1 //output power
12 e=Po*100/(Po+Wt)
13 mprintf("Efficiency at full load=%f percent\n", e)
14 //Calculating efficiency at half load
15 I1=200/2
16 Ia=I1+Ish
17 Wcu=Ia^2*.1
18 Wt=Wc+Wcu
19 Po=V*I1
20 e=Po*100/(Po+Wt)

```

```

21 mprintf(" Efficiency at half load=%f percent\n", e)
22 //Calculating efficiency at 1.5 times the full load
23 I1=1.5*200
24 Ia=I1+Ish
25 Wcu=Ia^2*.1
26 Wt=Wc+Wcu
27 Po=V*I1
28 e=Po*100/(Po+Wt)
29 mprintf(" Efficiency at 1.5 times the full load=%f
    percent", e)

```

Scilab code Exa 20.4 Example on losses in DC Machine

```

1
2 Po=10D+3 //output power of each motor at full load
3 e=.85 //efficiency at full load
4 Pi=Po/e
5 W=Pi-Po //total losses at full load for each motor
6 //calculating half load efficiency for motor A
7 Wc=500 //constant losses
8 Wcu1=(W-Wc)/2^2 //copper losses
9 W1=Wc+Wcu1 //total losses
10 P1=Po/2 //output
11 e1=P1/(P1+W1)*100
12 mprintf(" Efficiency at half load for motor A=%f
    percent\n", e1)
13 //calculating half load efficiency for motor B
14 Wc=600 //constant losses
15 Wcu2=(W-Wc)/2^2 //copper losses
16 W2=Wc+Wcu2 //total losses
17 P2=Po/2 //output
18 e2=P2/(P2+W2)*100
19 mprintf(" Efficiency at half load for motor B=%f
    percent", e2)

```

Scilab code Exa 20.5 Example on losses in DC Machine

```
1
2 //calculating power required at the driving shaft at
   full load
3 Po=30D+3 //output power of dc shunt generator
4 Wi=1300 //mechanical and iron losses
5 Rsh=125 //shunt field resistance
6 V=250 //terminal voltage
7 Ra=.13 //armature resistance
8 Ish=V/Rsh
9 Wcu=V*Ish //shunt field copper losses
10 Wc=Wi+Wcu //constant losses of generator
11 Il=Po/V
12 Ia=Il+Ish
13 Wcu=Ia^2*Ra //armature copper loss
14 Wt=Wc+Wcu //total losses
15 Pi=Po+Wt
16 mprintf("Power required at the driving shaft at full
   load=%f kW\n", Pi/10^3)
17 //calculating efficiency at full load
18 e=Po/Pi*100
19 mprintf("Efficiency at full load=%f percent\n", e)
20 //calculating efficiency at half load
21 Il=(Po/2)/V
22 Ia=Il+Ish
23 Wcu=Ia^2*Ra //copper losses
24 Wt=Wc+Wcu //total losses
25 e=(Po/2)/(Po/2+Wt)*100
26 mprintf("Efficiency at half load=%f percent\n", e)
27 //at maximum efficiency
28 Wcu=Wc //copper losses
29 Ia=sqrt(Wcu/Ra)
30 Il=Ia-Ish
```

```

31 mprintf("Power output at max efficiency=%f kW\n", I1*
    V/10^3)
32 //calculating max efficiency
33 e_max=I1*V/(I1*V+2*Wc)*100
34 mprintf("Max efficiency=%f percent", e_max)
35 //answer vary from the textbook due to round off
    error

```

Scilab code Exa 20.6 Example on losses in DC Machine

```

1
2 V=500 //voltage applied to motor
3 Ra=.2 //armature resistance
4 I10=4 //no load current taken by motor
5 Ish=1 //shunt current
6 Pi=V*I10 //power input at no load
7 Ia0=I10-Ish
8 Wcu=Ia0^2*Ra //armature copper losses at no load
9 Wc=Pi-Wcu //constant losses
10 //when input current=20 A
11 I1=20
12 Ia=I1-Ish
13 Wcu=Ia^2*Ra //armature copper losses
14 Wt=Wc+Wcu //total losses
15 Pi=V*I1 //power input to motor
16 Po=Pi-Wt
17 e=Po/Pi*100
18 mprintf("When input current=20 A, output is %f W and
    efficiency of motor is %f percent\n", Po, e)
19 //when input current =100 A
20 I1=100
21 Ia=I1-Ish
22 Wcu=Ia^2*Ra //armature copper losses
23 Wt=Wc+Wcu //total losses
24 Pi=V*I1 //power input to motor

```

```

25 Po=Pi-Wt
26 e=Po/Pi*100
27 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

```

1
2 //shunt generator was run as a shunt motor at no
  load
3 I0=5 //current drawn
4 Ish=1.5 //shunt field current
5 Ia0=I0-Ish
6 Ra=.15 //armature circuit resistance
7 V=440 //terminal voltage
8 Wcu=Ia0^2*Ra //armature copper loss
9 Pi=V*I0 //power input
10 Wc=Pi-Wcu //constant losses
11 //calculating efficiency of shunt generator at full
  load
12 Po=50D+3 //output of generator
13 I1=Po/V //load current
14 Ia=I1+Ish
15 Wcu=Ia^2*Ra //copper losses
16 Wt=Wc+Wcu //total losses
17 e=Po/(Po+Wt)*100
18 mprintf("Efficiency of shunt generator at full load=
    %f percent\n", e)
19 //calculating efficiency at 3/4th load
20 I1=3/4*I1 //load current
21 Ia=I1+Ish
22 Wcu=Ia^2*Ra //copper losses
23 Wt=Wc+Wcu //total losses
24 e=(3/4*Po)/(3/4*Po+Wt)*100
25 mprintf("Efficiency at 3/4th load=%f percent\n", e)

```

```

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

```

Scilab code Exa 20.8 Example on losses in DC Machine

```

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

```

Chapter 21

Three Phase Alternators

Scilab code Exa 21.1 Example on emf Equation

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

```

19 Eph=round(4.44*Kw*f*phi*T)
20 mprintf("Generated emf per phase=%d V\n", Eph)
21 //calculating line emf
22 E1=sqrt(3)*round(Eph)
23 mprintf("Line emf=%d V", round(E1))
24 //answer vary from the textbook due to round off
    error

```

Scilab code Exa 21.2 Example on emf Equation

```

1
2 funcprot(0)
3 m=2//no. of slots per pole per phase
4 x=m*3//no. of slots per pole
5 alpha=180/x//phase displacement between adjacent
    slots in degrees
6 Kd=sin((m*alpha/2)*%pi/180)/(m*sin((alpha/2)*%pi
    /180))//distribution factor
7 beta=180-150//in degrees
8 Kc=cos((beta/2)*%pi/180)//coil span factor
9 Kw=Kd*Kc//winding factor
10 P=10//no. of poles
11 n=m*P//no. of slots per phase
12 Zph=n*10//no. of conductors per phase
13 Tph=100//no. of turns per phase
14 N=600//speed of the alternator in rpm
15 f=P*N/120//frequency
16 phi=.05//useful flux per pole in Wb
17 Eph=4.44*Kw*f*phi*Tph
18 mprintf("Stator emf per phase at no load=%d V",
    round(Eph))

```

Scilab code Exa 21.3 Example on emf Equation


```

1
2 funcprot(0)
3 //calculating pitch factor
4 beta=0//full pitch coil
5 Kc=cos((beta/2)*%pi/180)
6 mprintf("Pitch factor , Kc=%d\n", Kc)
7 //calculating distribution factor
8 m=4//no. of slots per pole per phase
9 x=m*3//no. of slots per pole
10 alpha=180/x//phase displacement between adjacent
    slots in degrees
11 Kd=sin((m*alpha/2)*%pi/180)/(m*sin((alpha/2)*%pi
    /180))
12 mprintf("Distribution factor of stator winding=%f\n"
    , Kd)
13 //calculating emf generated per phase
14 Kw=Kd*Kc
15 y=m*8//no. of slots per phase
16 n=y*10//no. of conductors per phase
17 Tph=160//no. of turns per phase
18 f=50//frequency
19 phi=.04//flux per pole
20 Eph=round(4.44*f*Kw*Tph*phi)
21 mprintf("Emf per phase at no load=%d V\n", Eph)
22 //calculating line emf
23 E1=sqrt(3)*Eph
24 mprintf("Line emf=%d V", round(E1))
25 //answer vary from the textbook due to round off
    error

```

Scilab code Exa 21.4 Example on emf Equation

```

1
2 funcprot(0)
3 //calculating distribution factor of stator winding

```

```

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

```

Scilab code Exa 21.5 Example on emf Equation

```

1
2 funcprot(0)
3 m=5//no. of slots per pole per phase
4 x=m*3//no. of slots per pole
5 alpha=180/x//in degrees
6 Kd=sin((m*alpha/2)*%pi/180)/(m*sin((alpha/2)*%pi
    /180))//distribution factor
7 beta=3*12//in degrees
8 Kc=cos((beta/2)*%pi/180)//pitch factor of stator
    winding
9 Tph=5*2*4/2//no. of turns per phase

```

```

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

```

Scilab code Exa 21.6 Example on Regulation

```

1
2 //calculating regulation at full load at unity pf
3 V=3300//line voltage
4 Vph=V/sqrt(3)
5 P=500D+3//output
6 Ia=P/(sqrt(3)*V)
7 Ra=.4//resistance per phase
8 Xs=3.8//reactance per phase
9 pf=1//power factor
10 Ef=[(Vph*1+Ia*Ra)^2+(Vph*0+Ia*Xs)^2]^0.5//open
    circuit voltage per phase
11 VR=(Ef-Vph)/Vph*100
12 mprintf("Regulation at full load at unity pf=%f
    percent\n", VR)
13 //calculating regulation at full load at .8 pf
    lagging
14 Ef=[(Vph*.8+Ia*Ra)^2+(Vph*0.6+Ia*Xs)^2]^0.5
15 VR=(Ef-Vph)/Vph*100
16 mprintf("Regulation full load at .8 pf lagging=%f
    percent\n", VR)
17 //answers vary from the textbook due to round off
    error

```

Scilab code Exa 21.7 Example on emf Equation

```
1
2 //calculating synchronous impedance
3 Voc=90//open circuit voltage per phase
4 Isc=15//short circuit current
5 Zs=Voc/Isc
6 mprintf("Synchronous impedance=%d ohm\n", Zs)
7 //calculating synchronous reactance
8 Ra=1//armature resistance per phase
9 Xs=sqrt(Zs^2-Ra^2)
10 mprintf("Synchronous reactance=%f ohm\n", Xs)
11 //Solving part (iii)
12 V=400//line voltage
13 Vt=round(V/sqrt(3))//phase voltage at the terminals
    of load
14 Ia=15//load current
15 Ef=round([(Vt*.8+Ia*Ra)^2+(Vt*.6+Ia*Xs)^2]^0.5)
16 mprintf("Voltage rises from %d V to %d V, when the
    load is thrown off\n", Vt, Ef)
17 //solving part (iv)
18 //at 0.8 pf lagging
19 VR=(Ef-Vt)/Vt*100
20 mprintf("Regulation at .8 pf lagging=%f percent\n",
    VR)
21 //at unity pf
22 Ef=[(Vt*1+Ia*Ra)^2+(Vt*0+Ia*Xs)^2]^0.5
23 VR=(Ef-Vt)/Vt*100
24 mprintf("Regulation at unity pf=%f percent", VR)
25 //answers vary from the textbook due to round off
    error
```

Scilab code Exa 21.8 Example on Regulation

```
1
2 //refer Fig. 21.19 in the textbook
3 AT=15D+3//PE represents the armature reaction ampere
  turns
4 mprintf("Armature reaction ampere turns=%d\n", AT)
5 Pout=15D+6//output of the alternator
6 V1=10.2D+3//line voltage
7 I1=Pout/(sqrt(3)*V1)
8 Iph=I1
9 Ia=I1
10 //line DE represents the leakage reactance drop in
  terms of line values
11 Es=1.3D+3
12 Eph=Es/sqrt(3)
13 Xl=Eph/Ia
14 mprintf("Leakage reactance per phase, Xl=%f ohm\n",
  Xl)
15 //calculating regulation for full load at .8 pf
  lagging
16 Rt=.53//resistance of the stator winding between
  terminals
17 Ra=Rt/2//resistance per phase
18 Rd1=Ia*Ra//resistance drop in terms of phase value
19 Rd2=sqrt(3)*Rd1//resistance drop in terms of line
  value
20 //refer Fig.21.20(a) in the textbook
21 Ifg=21.67D+3
22 Ifs=1.67D+3
23 Ifsc=18D+3
24 //refer Fig.21.20(b) in the textbook
25 If1=40.67D+3//total field ampere turns
26 Ef=12.85D+3//no load voltage
27 Vt=10.2D+3//full load rated voltage
28 VR=(Ef-Vt)/Vt*100
29 mprintf("Regulation at full load, 0.8 pf lagging=%d
  percent", round(VR))
```

Scilab code Exa 21.9 Example on Regulation

```
1
2 function [z]=pol2rect(r,theta)
3     x=r*cos(theta*%pi/180)
4     y=r*sin(theta*%pi/180)
5     z=x+y*%i
6 endfunction
7 function [r]=mag(A)
8     x=real(A)
9     y=imag(A)
10    r=sqrt(x^2+y^2)
11 endfunction
12 j=%i
13 Vt=1100/sqrt(3)//terminal voltage,taken as reference
    phasor
14 Vt=pol2rect(Vt,0)
15 Ia=1200*1000/(3*Vt)//armature current
16 pf=.8//lagging power factor
17 phi=acosd(pf)
18 Ia=pol2rect(Ia,-phi)
19 Xq=1.2*j
20 Xd=1.8*j
21 //refer Fig.21.24 in the textbook, phasor OB in the
    direction of Ef is given as
22 OB=Vt+Ia*Xq
23 delta=29//power angle
24 Id=Ia*sin((delta+phi)*%pi/180)
25 Ef=mag(OB)+mag(Id)*mag(Xd-Xq)
26 mprintf("Excitation voltage Ef=%d V", round(Ef))
```

Scilab code Exa 21.10 Example on Regulation

```

1
2 function [z]=pol2rect(r,theta)
3     x=r*cos(theta*pi/180)
4     y=r*sin(theta*pi/180)
5     z=x+y*i
6 endfunction
7 function [r]=mag(A)
8     x=real(A)
9     y=imag(A)
10    r=sqrt(x^2+y^2)
11 endfunction
12 j=%i
13 //terminal voltage is taken as reference phasor and
14    the rated quantities are taken as 1 p.u.
14 Vt=pol2rect(1,0)//terminal voltage
15 pf=.8//lagging power factor
16 phi=acosd(pf)
17 Ia=pol2rect(1,-phi)//armature current
18 Xd=.8*j
19 Xq=.4*j
20 //refer to Fig.21.24 in the textbook
21 OB=Vt+Ia*Xq
22 delta=14.47//power angle
23 Id=Ia*sin((delta+phi)*pi/180)
24 Ef=mag(OB)+mag(Id)*mag(Xd-Xq)
25 mprintf("Excitation voltage per phase is %f p.u.",
26    Ef)

```

Chapter 22

Synchronous Motors

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

```
1
2 function [r, theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r, theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)
11    z=x+y*%i
12 endfunction
13 Va=400/sqrt(3)//per phase applied voltage
14 Ef=Va//per phase excitation voltage
15 delta=4*2//equivalent electrical degrees by which
    the rotor is retarded
16 Xs=2//per phase synchronous reactance
17 Vt=pol2rect(Va,0)
18 Ef=pol2rect(Ef,-8)
19 Xs=pol2rect(2,90)
20 Ia=(Vt-Ef)/Xs
```



```

21 [Ia theta]=rect2pol(Ia)
22 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

```

1
2 //calculating armature current
3 Pout=7.46D+3//output power
4 Wc=500//iron amd mechanical losses
5 P=Pout+Wc//total mechanical power developed
6 Pm=P/3
7 Va=440/sqrt(3)//applied voltage per phase
8 pf=.75//lagging power factor
9 Ra=.5//effective resistance per phase
10 //Pm=Va*Ia*pf-Ia^2*Ra
11 //solving this quadratic equation
12 Ia=(Va*pf-sqrt((Va*pf)^2-4*Ra*Pm))/(2*Ra)
13 mprintf("Armature current=%f A\n", Ia)
14 //calculating total power supplied
15 Pin=Va*Ia*pf
16 Pi=3*Pin//total input to stator
17 Pe=650//excitation loss
18 Pt=Pi+Pe
19 mprintf("Total power supplied=%f W\n", Pt)
20 //calculating efficiency
21 e=Pout/Pt*100
22 mprintf("Efficiency=%f percent", e)
23 //answers vary from the textbook due to round off
    error

```

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

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r,theta)
9     x=r*cos(theta*pi/180)
10    y=r*sin(theta*pi/180)
11    z=x+y*i
12 endfunction
13 function [r]=mag(A)
14     x=real(A)
15     y=imag(A)
16     r=sqrt(x^2+y^2)
17 endfunction
18 f=50
19 P=4
20 Ns=120*f/P
21 //calculating excitation voltage and power angle
22 Va=400/sqrt(3)
23 Va=pol2rect(Va,0)
24 pf=1//power factor
25 Pin=3000//input to motor
26 Ia=Pin/(3*mag(Va))
27 Xs=8
28 Ef=mag(Va)-%i*Ia*Xs
29 [Ef theta]=rect2pol(Ef)
30 mprintf("Excitation voltage Ef=%f V, power angle=%f
        degrees\n", Ef,-theta)
31 //calculating torque developed
32 omega_s=2*pi*Ns/60
33 T=3*mag(Va)*Ef/(Xs*omega_s)*sin(-theta*pi/180)
34 mprintf("Mechanical torque developed T=%f N-m\n",T)
35 //calculating max torque developed
36 Tmax=3*mag(Va)*Ef/(Xs*omega_s)
37 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

```
1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r,theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)
11    z=x+y*%i
12 endfunction
13 function [r]=mag(A)
14    x=real(A)
15    y=imag(A)
16    r=sqrt(x^2+y^2)
17 endfunction
18 j=%i
19 //calculating per phase current drawn from the
    supply
20 Pout=100*746//output power
21 Va=500/sqrt(3)//per phase applied voltage
22 Zs=.06+j*.6//synchronous impedance per phase
23 e=.89//efficiency of motor at full load
24 Pin=Pout/e//input to the motor
25 pf=.8//leading power factor
26 Ia=Pin/(3*Va*pf)
27 theta=acosd(.8)
28 mprintf("Current drawn from the supply is %f A
    leading the applied voltage by %f degrees\n", Ia,
    theta)
```

```

29 //calculating excitation voltage per phase
30 Va=pol2rect(Va,0)
31 Ia=pol2rect(Ia,theta)
32 Ef=Va-Ia*Zs
33 [Ef delta]=rect2pol(Ef)
34 mprintf("Excitation voltage per phase is %f V\nPower
        angle=%f degrees\n", mag(Ef),-delta)
35 //calculating mechanical power developed Pm
36 Ra=.06//stator winding resistance per phase
37 Pm=Pin-3*mag(Ia)^2*Ra
38 mprintf("Mechanical power developed=%f W\n", Pm)

```

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

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r,theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)
11    z=x+y*%i
12 endfunction
13
14 j=%i
15 Pout=10D+3//output of the motor at full load
16 e=.85//efficiency at full load
17 Pin=Pout/e//input at full load
18 Zs=.4+j*3//synchronous impedance per phase
19 Va=400/sqrt(3)//per phase applied voltage
20 pf=.8//leading power factor
21 Ia=Pin/(3*Va*pf)

```

```

22 Ia=pol2rect(Ia,acosd(pf))
23 Ef=Va-Ia*Zs
24 [Ef delta]=rect2pol(Ef)
25 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

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8
9
10 j=%i
11 Va=400/sqrt(3)//applied voltage per phase
12 Zs=.5+j*4//synchronous impedance per phase
13 pf=1//power factor
14 Ia=15
15 Ef=Va-Ia*Zs
16 [Ef delta]=rect2pol(Ef)
17 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

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)

```

```

4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7     endfunction
8     function [z]=pol2rect(r,theta)
9         x=r*cos(theta*pi/180)
10        y=r*sin(theta*pi/180)
11        z=x+y*i
12    endfunction
13    function [r]=mag(A)
14        x=real(A)
15        y=imag(A)
16        r=sqrt(x^2+y^2)
17    endfunction
18
19    j=%i
20    //applied voltage per phase is taken as the
        reference phasor
21    Va=1//applied voltage per phase in p.u.
22    pf=.8//lagging power factor
23    theta=acosd(pf)
24    Ia=pol2rect(1,-theta)//armature current per phase
25    Xq=.4*j
26    Xd=.8*j
27    OC=Va-Ia*Xq
28    [OC alpha]=rect2pol(OC)
29    delta=-alpha//power angle
30    Id=Ia*sin((theta-delta)*pi/180)
31    Ef=OC-mag(Id)*mag(Xd-Xq)//armature resistance is
        neglected
32    mprintf("Excitation voltage per phase is %f p.u.
        lagging the applied voltage by %f degrees\n",Ef,
        delta)
33    //calculating power due to excitation
34    Pf=Va*Ef*sin(delta*pi/180)/mag(Xd)
35    mprintf("Per phase power developed due to field
        excitation is %f p.u.\n",Pf)
36    //calculating power due to saliency

```

```

37 Pr=Va^2*mag((Xd-Xq)/(2*Xd*Xq))*sin(2*delta*%pi/180)
38 mprintf("Per phase power developed due to saliency
    of the motor is %f p.u.\n",Pr)
39 //answers vary from the textbook due to round off
    error

```

Scilab code Exa 22.8 Example on Variation of Excitation

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r,theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)
11    z=x+y*%i
12 endfunction
13 j=%i
14 //calculating new power angle
15 Va=400/sqrt(3)//applied voltage per phase
16 Pin=8.5D+3/3//power input per phase
17 pf=.8//lagging power factor
18 Ia=Pin/(Va*pf)//armature current per phase
19 theta=acosd(pf)
20 Ia=pol2rect(Ia,-theta)
21 Zs=4*j
22 Ef=Va-Ia*Zs
23 [Ef theta]=rect2pol(Ef)
24 delta=-theta
25 //the excitation voltage is increased by 50%
26 Ef_dash=1.5*Ef
27 //as the power developed remains same

```

```
28 delta_dash=asind(Ef*sin(delta*pi/180)/Ef_dash)
29 mprintf("The new power angle is %f degrees\n",
    delta_dash)
30 //calculating new armature current and power factor
31 Ef_dash=pol2rect(Ef_dash,-delta_dash)
32 Ia_dash=(Va-Ef_dash)/Zs
33 [Ia_dash theta]=rect2pol(Ia_dash)
34 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))
35 //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

```
1
2
3 //calculating full load speed of induction motor
4 P1=8//no. of poles of alternator
5 N=750//speed at which alternator runs
6 f=P1*N/120//frequency of alternator
7 P2=6//no. of poles of induction motor
8 Ns=120*f/P2//synchronous speed
9 s=.03//full load slip
10 Nr=Ns*(1-s)
11 mprintf("Full load speed of induction motor=%d rpm\n
    ", round(Nr))
12 //calculating frequency of rotor emf
13 fr=s*f
14 mprintf("Frequency of rotor emf=%f Hz", fr)
```

Scilab code Exa 23.2 Example on Slip and Rotor Frequency

```

1
2 //calculating no. of poles
3 Ns=1200//synchronous speed of rotating magnetic
   field
4 f=60//frequency of the supply to the stator
5 P=120*f/Ns
6 mprintf("No. of poles=%d\n", P)
7 //calculating slip at full load
8 Nr=1140//full load speed
9 s=(Ns-Nr)/Ns
10 mprintf("Percentage slip at full load=%f percent\n",
   s*100)
11 //calculating frequency of rotor voltage
12 fr=s*f
13 mprintf("Frequency of rotor voltage=%d Hz\n", fr)
14 //calculating speed of rotor field w.r.t. rotor
15 N1=120*fr/P//speed
16 mprintf("Speed of rotor field w.r.t. rotor=%d rpm\n"
   ,N1)
17 //calculating speed of rotor field w.r.t. stator
18 N2=1140//speed of the rotor w.r.t. stator
19 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)
20 s=.1
21 N1=(1-s)*Ns
22 mprintf("Speed of the rotor at 10 percent slip=%d
   rpm\nRotor frequency at 10 percent slip=%d Hz\n",
   N1, s*f)
23 Eph=230//applied voltage per phase
24 E1ph=Eph//induced emf per phase in the stator
   winding
25 E2ph=E1ph*.5//rotor induced emf at standstill
26 E2ph_dash=s*E2ph
27 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

```
1
2 //calculating synchronous speed
3 f=50//frequency
4 P=4//no. of poles
5 Ns=120*f/P
6 mprintf("Synchronous speed=%f rpm\n",Ns)
7 //calculating speed of rotating air gap field
8 mprintf("Rotating field in air gap rotates at
   synchronous speed,hence its speed=%f rpm\n",Ns)
9 //calculating speed of induction motor
10 s=.04//slip
11 Nr=(1-s)*Ns
12 mprintf("Speed of induction motor=%f rpm\n",Nr)
13 //calculating slip in rpm
14 mprintf("Slip of the motor in rpm=%f rpm\n",s*Ns)
15 mprintf("The rotor field rotates at synchronous
   speed w.r.t. stator , hence relative speed=%f rpm\
n",Ns)
16 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"
   )
17 mprintf("Speed of the rotor field w.r.t. rotor=%f
   rpm\n",s*Ns)
18 //calculating frequency of rotor induced emf
19 fr=s*f
20 mprintf("Frequency of rotor induced emf=%f Hz\n",fr)
21 //calculating rotor induced emf per phase
22 k=.6//turns ratio
23 E1ph=400/sqrt(3)//induced emf in stator winding
24 E2ph=E1ph*k//rotor induced emf per phase at the
   instant of starting
```

```

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

```

Scilab code Exa 23.4 Example on Equivalent Circuit

```

1
2 R2=.5//rotor resistance per phase
3 //at standstill
4 E=40//induced emf
5 E2=E/sqrt(3)//induced emf per phase
6 X2=3//rotor reactance per phase
7 R=4//additional resistance per phase in the rotor
  circuit
8 Rt=R2+R//total resistance per phase in the rotor
  circuit
9 Z2=sqrt(Rt^2+X2^2)//rotor impedance per phase
10 I2=E2/Z2
11 mprintf("Rotor current per phase at standstill=%f A\
    n", I2)
12 //calculating rotor current per phase at 5% slip
13 s=.05//slip
14 X2=s*X2
15 Z2=sqrt(R2^2+X2^2)
16 E2=s*E2//induced emf per phase
17 I2=E2/Z2
18 mprintf("Rotor current per phase at 5 percent slip=
    %f A",I2)

```

Scilab code Exa 23.5 Example on Equivalent Circuit

```

1

```

```

2 //calculating rotor starting current per phase on
   normal voltage with slip ring short-circuited
3 V=400//voltage applied to the stator winding
4 V1=V/sqrt(3)//phase voltage
5 k=2.5//transformation ratio
6 R2=.02//rotor resistance per phase
7 //at standstill
8 s=1//slip
9 E2=V1/k//induced phase voltage in the rotor winding
10 X2=2*%pi*50*.6D-3//rotor reactance per phase
11 Z2=sqrt(R2^2+X2^2)
12 I2=E2/Z2
13 mprintf("Rotor starting current per phase on normal
   voltage with slip ring short-circuited=%f A\n",I2
   )
14 //calculating rotor power factor at starting
15 pf=R2/Z2
16 mprintf("Rotor power factor at starting=%f\n",pf)
17 //calculating rotor current per phase at 3 % slip
18 s=.03//slip
19 E2=s*E2
20 X2=s*X2
21 Z2=sqrt(R2^2+X2^2)
22 I2=E2/Z2
23 mprintf("Rotor current per phase at 3 percent slip=
   %f A\n",I2)
24 //calculating rotor power factor at 3% slip
25 pf=R2/Z2
26 mprintf("Rotor power factor at 3 percent slip=%f",pf
   )
27 //answers vary from the textbook due to round off
   error

```

Scilab code Exa 23.6 Example on Equivalent Circuit

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [r]=mag(A)
9     x=real(A)
10    y=imag(A)
11    r=sqrt(x^2+y^2)
12 endfunction
13 j=%i
14 R2_dash=.16
15 s=.03
16 X2=.4
17 Z2_dash=R2_dash/s+X2*j//effective rotor impedance
    referred to stator
18 R0=200
19 Xm=20*j
20 Z=1/(1/R0+1/Xm+1/Z2_dash)//equivalent impedance
21 Z1=.15+.4*j//stator impedance
22 Zin=Z1+Z//total input impedance
23 V=400//applied voltage
24 //calculating stator current
25 V1=V/sqrt(3)//per phase stator voltage
26 I1=V1/Zin
27 [I1 theta1]=rect2pol(I1)
28 mprintf("Stator current=%f A at %f power factor
    lagging\n",I1,cos(theta1*pi/180))
29 //calculating rotor current
30 I1=V1/Zin
31 E1=V1-I1*Z1
32 Iw=E1/R0//per phase core loss component of no load
    current
33 Im=E1/Xm//per phase magnetising current
34 IO=Iw+Im//no load current
35 I2_dash=I1-IO

```

```

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

```

Scilab code Exa 23.7 Example on Equivalent Circuit

```

1
2
3 function [r,theta]=rect2pol(A)
4     x=real(A)
5     y=imag(A)
6     r=sqrt(x^2+y^2)
7     theta=atand(y/x)
8 endfunction
9 function [r]=mag(A)
10    x=real(A)
11    y=imag(A)
12    r=sqrt(x^2+y^2)
13 endfunction
14 j=%i
15 R2_dash=.16
16 s=3/100//slip
17 Rl=R2_dash*(1-s)/s//load resistance

```

```

18 Z1=.15+.4*j//stator impedance
19 Z2_dash=.16+.4*j//equivalent rotor impedance
20 Z=R1+Z1+Z2_dash//total impedance per phase
21 Vph=400/sqrt(3)//applied voltage per phase
22 I2_dash=Vph/Z
23 R0=200
24 Xm=20
25 Iw=Vph/R0
26 Im=Vph/Xm
27 I0=Iw-Im*j
28 I1=I0+I2_dash
29 [I1 theta]=rect2pol(I1)
30 pf=cos(theta*%pi/180)
31 p=mag(I2_dash)^2*R1//output power per phase
32 Pout=3*p
33 Pin=3*Vph*I1*pf
34 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)
35 //refer Fig. 23.16 in the textbook
36 Z2_dash=5.3+j*0.4
37 Z=(j*Xm)*Z2_dash/(j*Xm+Z2_dash)//equivalent
    impedance
38 Zin=Z1+Z//total input impedance
39 I1=Vph/Zin
40 I2_dash=I1*j*Xm/(j*Xm+Z2_dash)
41 [I1 theta]=rect2pol(I1)
42 pf=cos(theta*%pi/180)
43 Pout=3*(mag(I2_dash))^2*R2_dash*(1-s)/s
44 Pin=3*Vph*I1*pf
45 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

```
1
2 Pin=60D+3//power input
3 p=1D+3//stator losses
4 Pg=Pin-p//air gap power
5 s=3/100//slip
6 Pm=Pg*(1-s)
7 Prcu=s*Pg
8 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

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

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

Scilab code Exa 23.10 Example on Losses in Induction Motor

```
1
2 f=50//frequency
3 P=6//no. of poles
4 Ns=120*f/P//synchronous speed in rpm
5 Nr=950//speed at which the motor is running in rpm
6 s=(Ns-Nr)/Ns//slip
7 Pm=3.73D+3//mechanical power developed by the motor
8 //iron losses in the rotor are neglected
9 Prcu=s*Pm/(1-s)//rotor copper loss
10 P1=Pm+Prcu//rotor input
11 P=.25D+3//stator losses
12 P2=P1+P
13 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

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

```

12 //calculating line current
13 pf=.86//power factor of load
14 V1=500//line voltage
15 I1=P/(sqrt(3)*V1*pf)
16 mprintf("Line current=%f A\n",I1)
17 //calculating no of complete cycles of the rotor
    electromotive force per minute
18 f=50//supply frequency
19 f_r=s*f//frequency of rotor emf
20 n=f_r*60
21 mprintf("No of complete cycles of the rotor
    electromotive force per minute=%d\n",n)
22 //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

```

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

```

```

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

```

Scilab code Exa 23.13 Example on Torque

```

1
2
3 //calculating ratio of maximum to full load torque
4 Nr=970//speed at full load torque in rpm
5 Ns=50*120/6//synchronous speed in rpm
6 s=(Ns-Nr)/Ns//slip at full load
7 R2=.02//rotor resistance per phase
8 X2=.3//rotor reactance per phase at standstill
9 alpha=R2/X2
10 //Full load torque Tf=k1*Kt
11 k1=s*alpha/(s^2+alpha^2)
12 //maximum torque Tmax=Kt/2
13 x=1/(2*k1)
14 mprintf("Ratio of maximum to full load torque=%f\n",
    x)
15 //calculating speed at maximum torque
16 s_m=R2/X2//slip at maximum torque
17 Nm=(1-s_m)*Ns
18 mprintf("Speed at maximum torque=%d rpm\n",round(Nm)
    )
19 //calculating ratio of starting torque to full load

```

```

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

```

Scilab code Exa 23.14 Example on Torque

```

1
2 function [r]=mag(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6 endfunction
7 j=%i
8 V1=220//line voltage
9 Vph=V1/sqrt(3)//stator phase voltage
10 n=.65//ratio of no. of rotor winding turns to no. of
    stator winding turns
11 E2=n*Vph//phase voltage induced in the rotor winding
    at standstill
12 R2=.1//rotor resistance per phase
13 X2=.8//standstill reactance per phase
14 //at 5 % slip
15 s=5/100
16 X=s*X2//reactance per phase
17 Z2=R2+X*j//rotor impedance
18 e2=s*E2//rotor phase voltage
19 I2=e2/mag(Z2)
20 mprintf("Rotor current at 5 percent slip=%f A\n",I2)
21 //calculating rotor input
22 Prcu=3*I2^2*R2//total rotor copper losses
23 Pg=Prcu/s

```

```

24 mprintf(" Rotor input=%f W\n",Pg)
25 //calculating total torque at 5% slip
26 Pm=Pg-3*I2^2*R2//mechanical power developed by the
    rotor
27 Ns=120*50/4//synchronous speed
28 Nr=Ns*(1-s)//speed of the rotor
29 T=60*Pm/(2*pi*round(Nr))
30 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)
31 //calculating rotor current at maximum torque
32 s_m=R2/X2//slip for maximum torque
33 I2m=s_m*E2/sqrt(R2^2+(s_m*X2)^2)
34 mprintf(" Rotor current at maximum torque=%d A\n",
    round(I2m))
35 //calculating rotor input corresponding to maximum
    torque
36 Sm=3*round(I2m)^2*R2//total rotor copper losses
37 Pg=Sm/s_m
38 mprintf(" Rotor input corresponding to maximum torque
    =%f W\n",Pg)
39 //calculating maximum torque
40 Pm=Pg-Sm
41 Nm=Ns*(1-s_m)
42 T=60*Pm/(2*pi*round(Nm))
43 mprintf(" Maximum torque=%f N-m\nSpeed at maximum
    torque=%d rpm\nMaximum mechanical power=%f kW",T,
    Nm,Pm/1000)
44 //answers vary from the textbook due to round off
    error

```

Scilab code Exa 23.15 Example on Torque

```

1
2 Ns=120*50/4//synchronous speed

```

```

3 R2=.03//rotor resistance
4 X2=.15//rotor reactance
5 alpha=R2/X2
6 s_m=alpha//slip at maximum torque
7 Nr=(1-s_m)*Ns//speed at maximum torque
8 //alpha=(.03+r)/.15
9 //Tst=Kt*alpha/(1+alpha^2)
10 //Tmax=Kt/2
11 //Tst/Tmax=3/4-->3*alpha^2-8*alpha+3=0
12 //solving for alpha
13 alpha=(8-sqrt(8^2-4*3*3))/(2*3)
14 r=.15*alpha-.03
15 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

```

1
2 R2=1.1//rotor resistance per phase
3 //at 60 Hz supply
4 f=60//frequency of supply
5 P=6//no. of poles
6 Ns1=120*f/P//synchronous speed
7 Nr=1000//speed of rotor
8 s_m1=(Ns1-Nr)/Ns1//slip at maximum torque
9 X2=R2/s_m1
10 L2=X2/(2*%pi*60)
11 //at 50 Hz supply
12 X2=2*%pi*50*L2
13 s_m2=R2/X2//slip at maximum torque
14 Ns2=120*50/6//synchronous speed
15 Nr2=(1-s_m2)*Ns2
16 mprintf(" Rotor speed at maximum torque=%d rpm",round
    (Nr2))

```

Scilab code Exa 23.17 No load and Block Rotor Test

```
1
2 function [z]=pol2rect(r,theta)
3     x=r*cos(theta)
4     y=r*sin(theta)
5     z=x+y%i
6 endfunction
7 function [r]=mag(A)
8     x=real(A)
9     y=imag(A)
10    r=sqrt(x^2+y^2)
11 endfunction
12
13 j=%i
14 R1=.15//per phase stator winding resistance
15 //block rotor test
16 Vb=133/sqrt(3)//per phase voltage
17 Ib=100//per phase current
18 Wb=8085/3//per phase power
19 Zb=Vb/Ib//per phase impedance
20 Rb=Wb/Ib^2//per phase resistance
21 Xb=sqrt(Zb^2-Rb^2)//per phase reactance
22 R2_dash=Rb-R1//per phase rotor resistance referred
    to stator
23 X2_dash=Xb/2//per phase rotor reactance referred to
    stator
24 X1=X2_dash//per phase stator leakage reactance
25 //no load test
26 Vo=400/sqrt(3)//per phase voltage
27 Io=20//per phase current
28 Wo=2080/3//per phase power
29 pf=Wo/(Vo*Io)//power factor
30 phi0=acos(pf)
```



```

31 Iw=Io*cos(phi0)
32 Im=-Io*sin(phi0)*j
33 Io=pol2rect(Io,-phi0)
34 Z1=R1+X1*j
35 Ro=(Vo-Io*Z1)/Iw
36 Xm=(Vo-Io*Z1)/Im
37 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

```

1
2 //refer Fig. 23.25 in the textbook
3 k1=40//current scale
4 Vph=400/sqrt(3)//voltage per phase
5 P=k1*Vph//power per phase
6 k2=3*P//power scale
7 //calculating full load stator current
8 P=33.6D+3//output of motor
9 P1=P/k2//ouput of motor to scale
10 //P is the corresponding operating point
11 OP=1.55
12 I1=OP*k1
13 phi1=28.5
14 mprintf("Full load stator current=%f A with %f power
           factor lagging\n",I1,cos(phi1*%pi/180))
15 //calculating efficiency at full load
16 PL=2.35
17 PX=2.75
18 e=PL/PX*100
19 mprintf("Efficiency at full load=%f percent\n",e)
20 //calculating max power output
21 NPm=2.6

```

```

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

```

Scilab code Exa 23.19 Example on starting

```

1
2 //at short circuit
3 Vsc=100//applied voltage
4 Isc=15//line value of current
5 Iph=Isc/sqrt(3)//phase value of current
6 //calculating starting current drawn by the motor
7 V=400//line voltage
8 Vph=V/sqrt(3)//phase voltage
9 I=Iph*Vph/Vsc//phase value of starting current
10 I1=I
11 mprintf("Starting current drawn by the motor=%d A\n",
    ,I1)
12 //calculating ratio of starting to full load current
13 Pout=5D+3//output
14 e=.84//full load efficiency
15 pf=.82//power factor
16 I=Pout/(sqrt(3)*V*pf*e)//full load current
17 r=I1/I
18 mprintf("Ratio of starting to full load current=%f",
    r)

```

Scilab code Exa 23.20 Example on starting

```

1
2 V=400//phase voltage applied to motor
3 //when started directly on line
4 Iph=25//phase current
5 I1=sqrt(3)*Iph
6 mprintf("Line current drawn by the motor when
   started directly on line=%f A\n",I1)
7 //when started with auto-transformer starter with a
   tapping percent of 60 percent
8 V1=.6*V//line voltage
9 Vph=V1//phase voltage
10 Iph=25//phase current
11 Ist=Iph*Vph/V
12 I1=sqrt(3)*Ist
13 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,
   I1)
14 //when started with star-delta starter
15 Vph=V/sqrt(3)//phase voltage
16 I=Iph*Vph/V
17 I1=I
18 mprintf("When started with star-delta starter\nPhase
   starting current =%f A\nLine starting current=%f
   A",I,I1)

```

Chapter 24

Single Phase Induction Motor

Scilab code Exa 24.1 Example on Equivalent Circuit

```
1
2 f=50//frequency in Hz
3 P=4//no. of poles
4 Ns=120*f/P//synchronous speed
5 Nr=1420
6 //calculating forward slip
7 s=(Ns-Nr)/Ns
8 mprintf("Forward slip=%f p.u.\n",s)
9 //calculating backward slip
10 s1=2-s
11 mprintf("Backward slip s_b=%f p.u.\n",s1)
12 //calculating effective rotor resistance in forward
    branch
13 R2_dash=4.5
14 Rf=R2_dash/(2*s)
15 mprintf("Effective rotor resistance in forward
    branch=%f ohm\n", Rf)
16 //calculating effective rotor resistance in backward
    branch
17 Rb=R2_dash/(2*(2-s))
18 mprintf("Effective rotor resistance in backward
```

```

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

```

Scilab code Exa 24.2 Example on Equivalent Circuit

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r,theta)
9     x=r*cos(theta*pi/180)
10    y=r*sin(theta*pi/180)
11    z=x+y*i
12 endfunction
13 function [r]=mag(A)
14    x=real(A)
15    y=imag(A)
16    r=sqrt(x^2+y^2)
17 endfunction
18 f=50//frequency
19 P=4//no. of poles
20 Ns=120*f/P//synchronous speed
21 Nr=1420
22 s=(Ns-Nr)/Ns
23 Xm=70
24 R2_dash=3.75
25 X2_dash=1.75
26 Zf=(Xm*i/2)*(R2_dash/(2*s)+i*X2_dash/2)/(R2_dash
    /(2*s)+i*(Xm+X2_dash)/2)//forward impedance
27 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
28 Z1=2.5+%i*1.5
29 Zin=Z1+Zf+Zb//input impedance
30 //calculating input current
31 V1=pol2rect(230,0)
32 I1=V1/Zin
33 [I1 theta]=rect2pol(I1)
34 mprintf("Input current drawn by the motor is %f A,
        lagging the applied voltage by %f degrees\n", I1
        ,-theta)
35 //calculating input power
36 Pin=mag(V1)*I1*cos(theta*%pi/180)
37 mprintf("Power input=%f W\n", Pin)
38 //calculating mechanical power developed
39 Pgf=I1^2*real(Zf)
40 Pgb=I1^2*real(Zb)
41 Pm=(Pgf-Pgb)*(1-s)
42 mprintf("Mechanical power developed=%f W\n", Pm)
43 //calculating resultant torque developed
44 omega_s=2*%pi*Ns/60
45 T=(Pgf-Pgb)/omega_s
46 mprintf("Resultant torque developed=%f N-m\n",T)
47 //calculating efficiency
48 Prot=35+60
49 Pout=Pm-Prot
50 e=Pout/Pin*100
51 mprintf("Efficiency=%f percent", e)
52 //answers vary from the textbook due to round off
        error

```

Scilab code Exa 24.3 Example on Equivalent Circuit

```

1
2 function [r,theta]=rect2pol(A)
3     x=real(A)

```

```

4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atan(y/x)
7     endfunction
8     function [z]=pol2rect(r,theta)
9         x=r*cos(theta)
10        y=r*sin(theta)
11        z=x+y*i
12    endfunction
13    function [r]=mag(A)
14        x=real(A)
15        y=imag(A)
16        r=sqrt(x^2+y^2)
17    endfunction
18    f=50//frequency
19    P=4//no. of poles
20    Ns=120*f/P//synchronous speed
21    Nr=1425
22    s=(Ns-Nr)/Ns//slip
23    R2_dash=7.5
24    X2_dash=4.5
25    Xm=150
26    Zf=(Xm*i/2)*(R2_dash/(2*s)+i*X2_dash/2)/(R2_dash
        /(2*s)+i*(Xm+X2_dash)/2)//forward impedance
27    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
28    Z1=2.5+4.5*i
29    Zin=Z1+Zf+Zb//input impedance
30    //calculating input current
31    V1=pol2rect(230,0)
32    I1=V1/Zin
33    [I1 theta]=rect2pol(I1)
34    mprintf("Input current drawn by the motor is %f A at
        %f pf lagging\n", I1,cos(theta))
35    //calculating air gap power
36    Pgf=I1^2*real(Zf)//air gap power due to forward
        field

```

```

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

```

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

```

1
2 //under block rotor condition
3 Vb=82.5
4 Ib=9.3
5 Zb=Vb/Ib
6 P=500//power consumed
7 Rb=P/Ib^2
8 Xb=sqrt(Zb^2-Rb^2)
9 R1=2.5//main resistance winding
10 R2_dash=Rb-R1//rotor resistance referred to stator
11 X1=Xb/2
12 X2_dash=X1//rotor reactance referred to stator
13 //under no load
14 I0=6.4
15 V0=230
16 Z0=V0/I0
17 P0=220//power consumed
18 R0=P0/I0^2
19 X0=sqrt(Z0^2-R0^2)
20 Xm=2*X0-3/2*Xb
21 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

```
1
2 function [r, theta]=rect2pol(A)
3     x=real(A)
4     y=imag(A)
5     r=sqrt(x^2+y^2)
6     theta=atand(y/x)
7 endfunction
8 function [z]=pol2rect(r, theta)
9     x=r*cos(theta*%pi/180)
10    y=r*sin(theta*%pi/180)
11    z=x+y*%i
12 endfunction
13 function [r]=mag(A)
14    x=real(A)
15    y=imag(A)
16    r=sqrt(x^2+y^2)
17 endfunction
18 f=50//frequency
19 P=4//no. of poles
20 Ns=120*f/P//synchronous speed
21 Nr=1420//motor speed
22 s=(Ns-Nr)/Ns
23 R1=2.5
24 X1=3.365
25 Xm=60.945
26 R2_dash=3.28
27 X2_dash=3.365
28 Zf=(Xm*%i/2)*(R2_dash/(2*s)+%i*X2_dash/2)/(R2_dash
    /(2*s)+%i*(Xm+X2_dash)/2)//forward impedance
29 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
30 Z1=R1+%i*X1
31 Zin=Z1+Zf+Zb//input impedance
32 //calculating input current and power factor
33 V1=pol2rect(230,0)
34 I1=V1/Zin
35 [I1 theta]=rect2pol(I1)
36 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))
37 //calculating input power
38 Pin=mag(V1)*I1*cos(theta*pi/180)
39 mprintf("Power input=%f W\n", Pin)
40 //calculating torque developed
41 Pgf=I1^2*real(Zf)
42 Pgb=I1^2*real(Zb)
43 omega_s=2*pi*Ns/60
44 T=(Pgf-Pgb)/omega_s
45 mprintf("Resultant torque developed=%f N-m\n",T)
46 //calculating output power
47 Pm=(Pgf-Pgb)*(1-s)//mechanical power developed
48 W0=220//power consumed under no load
49 I0=6.4//no load current
50 Prot=W0-I0^2*(R1+R2_dash/4)//rotational losses
51 Pout=Pm-Prot
52 mprintf("Output power developed=%f W\n", Pout)
53 //calculating efficiency
54 e=Pout/Pin*100
55 mprintf("Efficiency=%f percent\n", e)
56 //calculating air gap power
57 Pg=Pgf+Pgb
58 mprintf("Air gap power=%f W\n",Pg)
59 //calculating rotor copper losses
60 Prc=s*Pgf+(2-s)*Pgb
61 mprintf("Rotor copper losses=%f W",Prc)
62 //answers vary from the textbook due to round off
        error

```

