Scilab Textbook Companion for Fundamentals of Electrical Drives by G. K. Dubey[1]

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July 31, 2019

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

Book Description

Title: Fundamentals of Electrical Drives

Author: G. K. Dubey

Publisher: Narosa, New Delhi

Edition: 2

Year: 2010

ISBN: 8173194289

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 2

Dynamics of Electric Drives

Scilab code Exa 2.1 Q1

```
//Chapter 2:Dynamics of Electric Drives
//Example 1
clc;

//Variable Initialization
Jo=0.2      // inertia of the motor in kg-m2
a1=0.1      // reduction gear
J1=10       // inertia of the load in kg-m2
Tl1=10      // load torque
v=1.5       // speed of the translational load
M1=1000     // mass of the translational load
N=1420      // speed of the motor
n1=.9       // efficiency of the reduction gear
n1_=0.85    // efficiency of the translational load
    and the motor
F1=M1*9.81 // force of the translational load

//Solution
Wm=N*%pi/30 //angular speed
J=Jo+a1**2*J1+ M1*(v/Wm)**2 // total equivalent
    moment of inertia
```

```
Tl= a1*Tl1/n1+F1/n1_*(v/Wm) // total equivalent
    torque

//Result
mprintf("\nEquivalent moment of inertia is : %.1f kg
    -m2",J)
mprintf("\nEquivalent load torque : %.2f N-m",Tl)
```

Scilab code Exa 2.2 Q2

```
//Chapter 2:Dynamics of Electric Drives
//Example 2
clc;

//Variable Initialization
J=10      //moment of inertia of the drive in kg-m2
mprintf("Passive load torque during steady state is
    : Tl=0.05*N in N-m")
mprintf("\nAnd load torque : T=100-0.1*N in N-m ")
mprintf("\nLoad torque when the direction is
    reversed T=-100-0.1*N  in N-m")

//Solution
mprintf("\nT-Tl=0")
mprintf("\n100-0.1*N-0.05*N=0\n")
N=100/0.15      //Required speed of the motor in rpm
    during steady state
N2=-100/0.15    //During reversal speed is in
    opposite direction
mprintf("\nJdWm/dt=-100-0.1*N-0.05*N during
    reversing")
mprintf("\ndN/dt=30/(J*pi)*(-100-0.15*N)")
mprintf("\ndN/dt=(-95.49-0.143*N)\n")
N1=N
N2=N2*0.95 //for speed reversal
```

```
deff('y=f(x)','y=1/(-95.49-0.143*x)')
t=intg(N1,N2,f)

//Result
mprintf("\nHence Time of reversal is : %.2f s",t)
```

Scilab code Exa 2.3 Q3

```
//Chapter 2:Dynamics of Electric Drives
//Example 3
clc;

//Variable Initialization
Tlh=1000      // load torque in N-m
Tmax=700      // maximum motor torque
Tll=200       // light load for the motor to regain its steady state
Tmin=Tll      // minimum torque
t_h=10        // period for which a load torque of 1000 N-m is apllied in sec
Jm=10         // moment of inertia of the motor in Kg-m2
No=500        // no load speed in rpm
Tr=500        // torque at a given no load speed in N-m

//Solution
Wmo=No*2*%pi/60 // angular no load speed in rad/sec
s=0.05              // slip at a torque of 500 N-m
Wmr=(1-s)*Wmo       // angular speed at a torque of 500 N-m in rad/sec

y=log((Tlh-Tmin)/(Tlh-Tmax))
x=Tr/(Wmo-Wmr)

```

```
J=x*t_h/y
Jf=J-Jm

//Result
//Answer Provided in the textbook is wrong
mprintf("\n\nMoment of inertia of the flywheel : %.1
    f Kg-m2",Jf)
```

Chapter 4

Selection of Motor Power Rating

Scilab code Exa 4.1 Q1

```
//Chapter 4: Selection of Motor Power Rating
//Example 1
clc;

//Variable Initialization
t_min=40        // Minimum Temperature Rise in degree
    Celsius
t_ri=15          // Temperature Rise in degree
   Celsius
t_cl=10          // Clutched Time in sec
t_de=20          // Declutched Time in sec
k= 60           // Heating and Cooling time constant

//Solution

x=exp(-t_de/k)
y=exp(-t_cl/k)

th2= (t_min-t_ri*(1-x))/x       //as t_min=t_ri(1-x)
```

```
    +th2*x
th_s=(th2-t_min*y)/(1-y)    //as th2=th_s(1-y)+t_min*
    y

mprintf("Maximum temperature during the duty cycle :
    %.1f  C ",th2)
mprintf("\n Temperature when the load is clutched
    continuously :%.1f  C ",th_s)
```

Scilab code Exa 4.2 Q2

```
//Chapter 4: Selection of Motor Power Rating
//Example 2
clc;

//Variable Initialization
N=200           //Speed in rpm
Tc=25000        //Constant Torque in N-m
J=10000         //Moment of inertia  in Kg-m2

//Given Duty Cycles
t1=10           //For full speed and at constant
    torque
t2=1            //For no load at full speed
t3=5            //For speed reversal from N to -N
t4=1            //For no load  at full speed
T5=20000        //Torque in N-m
t5=15           //At full speed and at a torque T1
t6=1            //For no operation at full speed
t7=5            //For speed reversal from -N to N
t8=1            //For no load operation


//Solution

```

```
Tr=J*(N-(-N))*2*%pi/60/5    //Reversal torque
x=Tc**2*t1+Tr**2*t3+T5**2*t5+Tr**2*t7
t=t1+t2+t3+t4+t5+t6+t7+t8       //Total Time
Trms=sqrt(x/t)              //rms torque

Trated=Trms                 //Rated torque is equal to
    the rms torque
Pr=Trated*2*%pi*200/60      //Power rating
r=Tr/Trms                   //Ratio of reversal torque to
    the rms torque
Pr=Pr*1e-3

mprintf("Torque of motor is :%d N-m",Trms)

if r < 2 then
disp("Trms is rated equal to the Motor")
mprintf(" Trms=%d N-m\n",Trms)
end

mprintf(" Power rating :%.3f kW",Pr)
//The answer provided in the textbook is wrong
```

Scilab code Exa 4.3 Q3

```
//Chapter 4: Selection of Motor Power Rating
//Example 3
clc;

//Variable Initialization
P1=400      //load in kW
P2=500      //load in KW
Pmax=P2

//Duty Cycles in minutes
t1=5        //load rising from 0 to P1
```

```
t2=5        //uniform load of P2
t3=4        //regenerative power equal to P1
t4=2        //motor remains idle

//Solution
deff('y=f(x)','y=(400/5*x)**2')
I=intg(0,5,f)
P11=sqrt(I/t1)
x=P11**2*t1+P2**2*t2+P1**2*t3
t=t1+t2+t3+t4     //total time
Prms=sqrt(x/t)

y=2*Prms
if P2<y then
    mprintf(" Hence Pmax:%d kW is less than twice
       Prms:%.1f kW",Pmax,2*Prms)
end
mprintf("\n Hence Motor rating is: %d kW\n",Prms)
```

Scilab code Exa 4.4 Q4

```
//Chapter 4: Selection of Motor Power Rating
//Example 4
clc;

//Variable Initialization
Cr=60       //Heating time constant in minutes
Cs=90       //Cooling time constant in minutes
P=20        //Full load in kW

//Solution

//Part-i
a=0
tr=10     //Time to deliver in minutes
```

```
x=exp(-tr/Cr)
K=sqrt(1/(1-x))
P1=K*P  //Permitted load

//Part-ii
a=0
tr=10   //Intermittent load period allowed in
   minutes
ts=10   //Shutdown time period in minutes
x=exp(-(tr/Cr+ts/Cs))
y=exp(-tr/Cr)
K=sqrt((1-x)/(1-y))
P2=K*P  //Permitted load


mprintf("\ni)Required permitted load:%d kW",P1)
mprintf("\nii)Required permitted load:%.2f kW",P2)
```

Scilab code Exa 4.5 Q5

```
//Chapter 4: Selection of Motor Power Rating
//Example 5
clc;

//Variable Initialization
P=100     //Half hour rating of the motor
Cr=80     //Heating time constant in minutes
n=0.7     //Maximum efficiency at full load

//Solution

Pcu=n**2   //Coppper loss
a=Pcu
K=sqrt((1+a)/(1-%e**(-30/Cr))-a)
Pco=P/K
```

```
mprintf("Therefore the continuous rating is:%.2f kW"
    ,Pco)
```

Scilab code Exa 4.6 Q6

```
//Chapter 4: Selection of Motor Power Rating
//Example 6
clc;

//Variable Initialization
I=500         //Eated Armature Current in A
Ra=0.01       //Armature Resistance in ohm
P=1000        //Core Loss in W
B=0.5

//Duty Cycles
tst=10         //Given Interval for accelaration at
    twice the rated current
tr=10          //Given Interval for running at full
    load
tb=10          //Given Interval for deceleration at
    twice the rated armature current

//Solution

Es=tst*(2*I)**2*Ra+P
Eb=Es
p1s_tr=(I**2*Ra+P)*tr
p1r=I**2*Ra+P
gamma=(1+B)/2
x=(Es+p1s_tr+Eb)/p1r
y=gamma*tst+tr+gamma*tb
ts=(x-y)/B                  //Idling interval

fmax=3600/(tst+tr+tb+ts) //Maximum Frequency of
```

```
    drive operation

mprintf("\nMaximum Frequency of drive operation = %
    .2f per hour",fmax)
//The answer provided in the textbook is wrong
```

Chapter 5

Dc Motor Drives

Scilab code Exa 5.1 Q1

```
//Chapter 5:DC Motor Drives
//Example 1
clc;

//Variable Initialization

//Motor ratings
V1=200      //rated voltage in V
Ia1=10.5    //rated current in A
N1=2000     //speed in rpm
Ra=0.5      //armature resistance in ohms
Rs=400      //field resistance in ohms
V2=175      //drop in source voltage in V

//Solution

flux2=V2/V1
Ia2=1/flux2*Ia1     //since load torque
E1=V1-Ia1*Ra
E2=V2-Ia2*Ra
N2=(E2/E1)*(1/flux2)*N1
```

```
//Result
mprintf("\nMotor speed is:%.1f rpm",N2)
//Answer provided in the book is incorrect
```

Scilab code Exa 5.2 Q2

```
//Chapter 5:DC Motor Drives
//Example 2
clc;

//Variable Initialization

V1=220      //rated voltage in V
Ia1=100     //rated current in A
N1=1000     //rated speed in rpm clockwise
Ra=0.05     //armature resistance in ohms
Rs=0.05     //field resistance in ohms

//Solution
//Turns is reduced to 80% then flux is also reduced by the same value and hence current is also reduced
T1=Ia1**2       //flux is directly proportional to current Ia
T2=0.8*1**2   //flux is directly proportional to current Ia
Ia2=-Ia1/sqrt(0.8)    //since T1=T2 and the direction is opposite

E1=V1-Ia1*(Ra+Rs)

Rs=.8*Rs        //Rs=80% of the field resistance 0.05 ohm since the flux is reduced to 80%
E2=-(V1+Ia2*(Ra+Rs))
```

```
N2=(E2/E1)*(Ia1/Ia2)*(N1/0.8)    //since E=Kn*flux*N

//Result
mprintf("\nMotor speed is:N2=%.1f rpm",N2)
```

Scilab code Exa 5.3 Q3

```
//Chapter 5:Dc Motor Drives
//Example 3
clc;

//Variable Initialization

//Motor ratings
V1=220      //rated voltage in V
Ia1=200     //rated current in A
Ra=0.06     //armature resistance in ohms
Rb=0.04     //internal resistance of the variable
   source in ohms
N1=800      //speed in rpm
N2=600      //speed when motor is operatingin
   regenerative braking in rpm

//Solution
Ia2=0.8*Ia1          //motor is opereting in
   regenerative braking at 80% of Ia1
E1=V1-Ia1*Ra         //back emf at rated operation
E2=(N2/N1)*E1        //back emf at the given speed N2
V2=E2-Ia2*(Ra+Rb)    //internal voltage of thevariable
    source

//Results
mprintf("\n Internal voltage of the variable source:
   %.1f V",V2)
```

Scilab code Exa 5.4 Q4

```
//Chapter 5:DC Motor Drives
//Example 4
clc;

//Variable Initialization

//The ratings of the motor are same as that of Ex
    -5.2
V1=220        //rated voltage in V
Ia1=100       //rated current in A
N1=1000       //speed in rpm clockwise
N2=800        //given speed during the dynamic braking
    in rpm
Ra=0.05       //armature resistance in ohms
Rs=0.05       //field resistance in ohms

//Solution

T2 = 2    //dynamic torque is twice the rated torque
Ia2=Ia1*sqrt(T2)    //since T=Kf*Ia**2
E1=V1-Ia1*(Ra+Rs)
E2=(Ia2/Ia1)*(N2/N1)*E1     //since E=Ke*Ia*N
Rb=E2/Ia2-(Ra+Rs)           //since E2=Ia2(Rb+Ra+Rs)
    during braking

//Results
mprintf("\n Braking current Ia2: %.1f A",Ia2)
mprintf("\n Required braking resistance Rb: %.2f ohm
    ",Rb)
```

Scilab code Exa 5.5 Q5

```
//Chapter 5:Dc Motor Drives
//Example 5
clc;

//Variable Initialization

//Ratings of the DC shunt motor which operated under dynamic braking
Rb=1        //braking resisance in ohms
Ra=0.04     //armature resistance in ohms
Rf=10       //field resistance in ohms
T=400       //load torque in N-m

//Magnetisation curve at N1
N1=600      //speed in rpm
If=[2.5,5,7.5,10,12.5,15,17.5,20,22.5,25]     //field current in A
E =[25,50,73.5,90,102.5,110,116,121,125,129]  //back emf in V

//Solution
disp(If,"Field current   If:in A")
x=(Rb+Rf)/Rb
Ia = If * x                            //armature current
Wm=2*%pi*N1/60
Ke_flux=E / Wm      //Ke*flux=constant
T=[]
for i=1:10
T($+1)=(Ke_flux(i))*(Ia(i))    //torque
end
disp(Ke_flux,"Ke_flux :")
disp(T,"Torque  :in N-m")


//Results
```

```

//Plotting the values of Ke*flux vs If
If=[2.5,5,7.5,10,12.5,15,17.5,20,22.5,25]     //field
    current in A
subplot(2,1,1)
plot(If,Ke_flux,'y')
xlabel('field current I_f')
ylabel('Ke*flux')
title('If  vs  Ke*flux')
xgrid(2)

//Plotting the values of  T vs If
If=[2.5,5,7.5,10,12.5,15,17.5,20,22.5,25]     //field
    current in A
subplot(2,1,2)
plot(T,If)
xlabel('Torque T')
ylabel('field current I_f')
title('T vs If')
xgrid(2)


mprintf("\nFrom the plot we can see that when the
   torque is 400 N-m, ")
mprintf("\nthe field current is If=19.3 A, and Ke*
   flux=1.898 when If=19.3 A")
T=400            // braking torque in N-m
If=19.13         // field current in A
Ke_flux=1.898   // Ke*flux
Ia=x*If
E=If*Rf+Ia*Ra     //since E=V+Ia*Ra
N2=(E/Ke_flux)*(60/(2*%pi))   //required speed
mprintf("\nHence the required speed in is :%.1f rpm"
   ,N2)
```

Scilab code Exa 5.6 Q6

```
//Chapter 5:Dc Motor Drives
//Example 6
clc;

//Variable Initialization

//The motor rating is same as that of Ex-5.5
N=600       //value of the speed given from the magnetization curve in Ex-5.5

Ra=0.04     //armature resistance in ohms
Rf=10       //field resistance in ohms
T=400       //load torque in N-m
N1=1200     //given speed in rpm to hold the overhauling torque

//Solution
Wm=2*%pi*N1/60    //angular speed at the given speed N1

//Magnetisation curve at N=600rpm
If=[2.5,5,7.5,10,12.5,15,17.5,20,22.5,25]        //field current in A
E =[25,50,73.5,90,102.5,110,116,121,125,129]     //value of the back emf as given in Ex-5.5 for the speed N in V

//Magnetisation curve at N=1200rpm
If=[2.5,5,7.5,10,12.5,15,17.5,20,22.5,25]        //field current in A
E1=N1/N*E                                  //back emf at the speed N1
mprintf("Hence the magnetization curve at 1200rpm is")
disp(If,"Field current    If:in A")
disp(E1,"Back emf is      E1 in V:")
```

```

Pd=T*Wm                                    //power developed
x=Pd*Ra
V=[]
for i=1:10
V($+1)=E1(i)-x/E1(i)
end
disp(V,"Terminal voltage V:in V")

//Results
//Plotting the values of V vs If
subplot(2,1,1)
plot(V,If)
xlabel('Terminal voltage V')
ylabel('Field current I_f')
title('V vs If')
xgrid(2)

//Plotting the values of E vs If
If=[2.5,5,7.5,10,12.5,15,17.5,20,22.5,25]        //field current in A
E =[25,50,73.5,90,102.5,110,116,121,125,129]     //value of the back emf as given in Ex-5.5 for the speed N in V
E1=N1/N*E                                  //back emf at the speed N1

subplot(2,1,2)
plot(E1,If,'y')
xlabel('E')
ylabel('Field current I_f')
title('E vs If')
xgrid(2)

mprintf("\nFrom the plot we can see that when the current If=25 A the terminal voltage is V=250 V with the back emf E=258V")
```

```
E=258              //value of the back emf in V at from the plot
V=250              //value of terminal voltage in V from the plot at E=258 V
If=25              //value of If in A from the plot at E=258 V
Ia=(E-V)/Ra        //armature current
If=V/Rf            //field current
Ir=Ia-If
Rb=V/Ir            //braking resistance

mprintf("\nHence the rquired braking resistance is %.3f ohm",Rb)
```

Scilab code Exa 5.7 Q7

```
//Chapter 5:Dc Motor Drives
//Example 7
clc;

//Variable Initialization

//Ratings of the DC series motor which operated under dynamic braking
Ra=0.5            //total resistance of armature and field windings in ohms
Rf=10             //field resistance in ohms
T=500             //overhauling load torque in N-m
N=600             //speed at the overhauling torque T in rpm

//Nagnetisation curve at a speed of 500 rpm
N1=500     //speed in rpm
Ia=[20, 30, 40, 50, 60, 70, 80]        //armature
```

```
    current in A
E =[215,310,381,437,482,519,550]      //back emf in V

//Solution
Wm1=2*%pi*N1/60
disp(Ia,"Armature current : in A")
Ke_flux=E / Wm1      //Ke*flux=constant
disp(Ke_flux,"Ke_flux :")
T=[]
for i=1:7
T($+1)=(Ke_flux(i))*(Ia(i))    //torque
end
disp(T,"Torque  :in N-m")


//Results
//Plotting the values of Ke*flux vs Ia and T vs Ia
subplot(2,1,1)
plot(Ia,Ke_flux,'y')
xlabel('Armature current I_a')
ylabel('Ke*flux')
title('Ke*flux vs Ia')
xgrid(2)

subplot(2,1,2)
plot(T,Ia)
xlabel('Torque T')
ylabel('Armature current I_a')
title('T vs Ia')
xgrid(2)

mprintf("\nFrom the plot we can see that at the
    given torque T=500 N-m the current Ia is 56 A,
    and Ke*flux is 8.9 at Ia=56 A")
Ke_flux=8.9     //value of Ke*flux at T=500 N-m from
    the plot
Ia=56           //value of Ia at at T=500 N-m from
    the plot
```

```
Wm=2*%pi*N/60
E=Ke_flux*Wm    //required emf
x=E/Ia          //x=Ra+Rb
Rb=x-Ra         //required braking resistance
mprintf("\nHence the rquired braking resistance is %
   .3f ohm",Rb)
```

Scilab code Exa 5.8 Q8

```
//Chapter 5:Dc Motor Drives
//Example 8
clc;

//Variable Initialization

//Ratings of the separately excited motor
V=220      // rated voltage in V
N=970      // rated speed in rpm
Ia=100     // rated current in A
Ra=0.05    // armature resistance in ohms
N1=1000    // initial speed of the motor in rpm

//Solution
E=V-Ia*Ra
E1=N1/N*E    //value of back emf at the speed N1

//(a)The resistance to be placed
Ia1=2*Ia           //value of the braking current is
   twice the rated current
Rb=(E1+V)/Ia1-Ra   //required resistance

//(b)The braking torque
Wm=(2*%pi*N1)/60
T=E1*Ia1/Wm

```

```
//(c)When the speed has fallen to zero the back emf
    is zero
E2=0
Ia2=V/(Ra+Rb)
T2=Ia2/Ia1*T    //since the torque is directly
    proportional to the current


//Results
mprintf("(a)Hence required resistance is :%.2f ohm",
    Rb)
//Answer given for the resistance in the book is
    wrong

mprintf("\n(b)Hence the required braking torque is :
    %.1f N-m",T)
mprintf("\n(c)Hence the required torque is :%.1f N-m
    ",T2)
```

Scilab code Exa 5.9 Q9

```
//Chapter 5:Dc Motor Drives
//Example 9
clc;

//Variable Initialization

//Ratings of the separately excited motor which
    operates under rheostatic braking
V=220      // rated voltage in V
N=1000     // rated speed in rpm
Ia=175     // rated current in A
Ra=0.08    // armature resistance in ohms
N1=1050    // initial speed of the motor in rpm
J=8        // moment of inertia of the motor load
```

```
system kg-m2
La=0.12   // armature curcuit inductance in H

//Solution
E=V-Ia*Ra
Wm=N*2*%pi/60     //rated speed in rad/s

//(a)When  the braking current is twice the rated current
Ia1=2*Ia
E1=N1/N*E
x=E1/Ia1   //x=Rb+Ra
Rb=x-Ra    //required braking resistance

//(b)To obtain the expression for the transient value of speed and current including the effect of armature inductance
Ra=x                      //total armature current
K1=N1*2*%pi/60     //initial speed in rad/s
K=E/Wm
B=0
ta=La/Ra                           //time constant in sec
Trated=E*Ia/Wm                     //rated torque
Tl=0.15*Trated                     //load torque is 15% of the rated torque
tm1= %inf             //tm1=J/B and B=0 which is equal to infinity
tm2=J*Ra/(B*Ra+K**2)

a = ta
b = -(1+ta/tm1)
c = 1/tm2

//Discriminant
d = (b**2) - (4*a*c)

alpha1 = (-b-sqrt(d))/(2*a)
alpha2 = (-b+sqrt(d))/(2*a)
```

```
K3=tm2*Tl/J
K4=tm2*K*Tl/J/Ra

//Transient value for speed
x1=((J*alpha2-B)*K1-(Tl-J*alpha2*K3))/(J*(alpha2-alpha1))
y1=((J*alpha1-B)*K1-(Tl-J*alpha1*K3))/(J*(alpha1-alpha2))

//Transient value for the current
x2=(K*K1+alpha2*La*K4)/(La*(alpha2-alpha1))
y2=(K*K1+alpha1*La*K4)/(La*(alpha1-alpha2))


//(c) To calculate the time taken by braking operation and the maximum value of the armature current
//now Wm=0 for the braking operation and hence 151.5 exp(-0.963*t1)- 8.247 = 0 from the previous answer in (b)
a=K3/x1     //a=exp(-0.963*t1)
t1=-alpha1*log(real(a))         //take log base e on both sides
//now d/dt(ia)=0 for themaximum current and hence d/dt(26.25-593.1exp(-0.963*t)+566.8exp(-4.19*t) = 0 from the previous answer in (b)
b=abs(alpha2*y2)/abs(alpha1*x2)     //b=exp(-0.963*t)/exp(-4.19*t)
t2=log(b)/(-alpha1+alpha2)     //take log base e on both sides
t2=abs(t2)
ia=K4-real(x2)*exp(real(-alpha1)*t2)-real(y2)*exp(real(-alpha2)*t2)


//Results
mprintf("(a)Hence the braking resistance is :%.3f
```

```
ohm",Rb)
mprintf("\nb)The value of alpha1 :%.3f and alpha2 :%.3f ",real(alpha1),real(alpha2))
mprintf("\nHence the expression for the transient value for the speed is")
mprintf("\nWm=%.1f exp( -%.3f *t)%.1f exp( -%.2f *t) - %.3f",real(x1),real(alpha1),real(y1),real(alpha2),K3)
mprintf("\nHence the expression for the transient value for the current is")
mprintf("\nia=%.2f -%.1f exp(-%.3f*t) +%.1f exp(%.2f*t)",K4,real(x2),real(alpha1),-real(y2),-real(alpha2))
mprintf("\n(c)Hence the time taken is :%.2f sec",t2)
mprintf("\nHence the maximum current is:%.2f A",ia)
//There is a slight difference in the answers because of rounding
```

Scilab code Exa 5.10 Q10

```
//Chapter 5:Dc Motor Drives
//Example 10
clc;

//Variable Initialization


V=220      // rated voltage in v
N=1000     // rated speed in rpm
Ia=175     // rated current in A
Ra=0.08    // armature resistance in ohms
N1=1050    // initial speed of the motor in rpm
J=8        // moment of inertia of the motor load system kg-m2
La=0.12    // armature curcuit inductance in H
```

```
//Solution
E=V-Ia*Ra
Wm=N*2*%pi/60      //rated speed in rad/s
//(a)When  the braking current is twice the rated current
Ia1=2*Ia
E1=N1/N*E
x=(V+E1)/Ia1    //x=Rb+Ra
Rb=x-Ra         //required braking resistance

//(b)To obtain the expression for the transient value of speed and current including the effect of armature inductance
//The values given below are taken from Ex-5.9
ta=0.194                        //time constant in sec
B=0
tm1= %inf             //tm1=J/B and B=0 which is equal to infinity
tm2=1.274
K=1.967
Trated=E*Ia/Wm                  //rated torque
Tl=0.5*Trated                   //load torque is 50% of the rated torque
Ra=Rb
K1=N1*2*%pi/60           //initial speed in rad/s
//Values of the coefficient of the quadratic equation for Wm
x1=(1+ta/tm1)/ta
x2=1/tm2/ta
x3=-(K*V+Ra*Tl)/J/Ra/ta
//Values of the coefficient of the quadratic equation ia
y1=(1+ta/tm1)/ta
y2=1/tm2/ta
y3=-B*V/J/Ra/ta+K*Tl/J/Ra/ta

//solving the quadratic equation
```

```
a = 1
b = x1
c = x2
//Discriminant
d = (b**2) - (4*a*c)

alpha1 = (-b+sqrt(d))/(2*a)
alpha2 = (-b-sqrt(d))/(2*a)

K3=x3/x2
K4=y3/y2

Wm_0=K1                            ;ia_0=0
d_Wm_dt_0=(K*ia_0-B*Wm-Tl)/J   ;d_ia_dt_0=(-V-Ra*ia_0-K*K1)/La     //Wm=K1 at t=0 and during braking rated voltage V is equal to -V

a = [1,1;real(alpha1),real(alpha2)]
b = [Wm_0;d_Wm_dt_0]
x = inv(a)*b
c = [1,1;real(alpha1),real(alpha2)]
d = [-K4;d_ia_dt_0]
y = inv(c)*d

//(c)To calculate the time taken for the speed to fall to zero value
a=-K3/x(1)                             //a=exp(-0.966*t1)
t1=alpha1*log(a)               //take log base e on both sides


//Results
mprintf("(a)Hence the braking resistance is :%.3f ohm",Rb)
mprintf("\n(b)The solutions for alpha are %.3f and %.3f",real(alpha1),real(alpha2))
mprintf("\nWm=%.2f + A*exp(%.3f*t) + B*exp(%.2f*t)",K3,real(alpha1),real(alpha2))
```

```
mprintf("\nia=%.2f+ C*exp(%.3f*t) + D*exp(%.2f*t)",K4,real(alpha1),real(alpha2))
mprintf("\nWe have to find the value of A,B,C and D in the linear equation using the initial condition")
mprintf("\nA=%.2f B=%.2f C=%.2f D=%.2f",x(1),x(2),y(1),y(2))
mprintf("\nHence the expression for the transient value for the speed is")
mprintf("\nWm=%.2f+%.2f*exp(%.3f*t)%.2f*exp(%.2f*t)",K3,x(1),real(alpha1),x(2),real(alpha2))
mprintf("\nHence the expression for the transient value for the current is")
mprintf("\nia=%.2f %.1f *exp(%.3f*t) +%.2f*exp(%.2f*t)",K4,y(1),real(alpha1),y(2),real(alpha2))
mprintf("\n(c)Hence the time taken is :%.2f sec",real(t1))
//There is slight difference in the answers due to accuracy
```

Scilab code Exa 5.11 Q11

```

//Chapter 5:Dc Motor Drives
//Example 11
clc;

//Variable Initialization

//Ratings of the separately excited motor
V=220      // rated voltage in V
N=600      // rated speed in rpm
Ia=500    // rated current in A
Ra=0.02    // armature resistance in ohms
Rf=10      // field resistance in ohms
```

```

//Solution
Ia1=2*Ia
E1=V-Ia*Ra              //rated back emf at rated operation
Wm1=2*%pi*N/60    //angular speed
Trated=E1*Ia1/Wm1      //rated torque

//(i) When the speed of the motor is 450rpm
N1=450              //given speed in rpm
Tl=2000-2*N1        //load torque is a function of the speed as given
Ia2=Tl/Trated*Ia1  //for a torque of  Tl as a function of current
E2=N1/N*E1          //for a given speed of 450rpm
V2=E2+Ia2*Ra        //terminal voltage for a given speed of 450 rpm

//(ii) when the speed of the motor is 750rpm
N1=750            //given speed in rpm
Tl=2000-2*N1     //load torque is a function of the speed as given
Wm_=2*%pi*N1/60
Ke_phi1=E1/Wm1

//Since we know that V=Ke*phi*Wm+Ia*Ra  by solving we get that  0.02*(Ia_)**2 -220*Ia_ + 39270 = 0"
a = 0.02
b = -220
c = 39270

//Discriminant
d = (b**2) - (4*a*c)

Ia_1 = (-b-sqrt(d))/(2*a)
Ia_2 = (-b+sqrt(d))/(2*a)

Ke_phi=Tl/abs(Ia_1)
```

```
V1=V*Ke_phi/Ke_phi1   //required field voltage

//Results
mprintf("(i)Hence motor terminal voltage is :%.1f V",V2)
mprintf("\nAnd the armature current is :%.1f A",Ia2)
mprintf("\n(ii)The solutions for Ia_ are %.1f A and %.1f A",abs(Ia_1),abs(Ia_2))
mprintf("\nWe ignore %d A since it is infeasible,\n Hence armature current is :%.1f A",abs(Ia_2),abs(Ia_1))
mprintf("\nHence the required field voltage is :%.1f V",V1)
```

Scilab code Exa 5.12 Q12

```

//Chapter 5:Dc Motor Drives
//Example 12
clc;

//Variable Initialization

//Ratings of the 2-pole separately excited DC motor with the fields coils connected in parallel
V=220       // rated voltage in V
N=750       // rated speed in rpm
Ia1=100     // rated current in A
Ra=0.1      // armature resistance in ohms

//Solution
E1=V-Ia1*Ra            //rated back emf at rated operation
Wm1=2*%pi*N/60     //angular speed
Trated=E1*Ia1/Wm1      //rated torque
```

```
Ke_phi1=E1/Wm1

//(i) When the armature voltage is reduced to 110V
Wm2=2*%pi*N/60     //angular speed
E2=Ke_phi1*Wm2
//Now there are two linear equations...that we have to solve
//They are given by 0.3*N2+2.674*Ia2=500 and 0.28*N2+0.1*Ia2=110
a = [0.3,2.674;0.28,0.1]
b = [500;110]
x = inv(a)*b
N2=x(1)         //let the motor speed be N2
Ia2=x(2)        //let the motor current be Ia2

//(ii)When the field coils are connected in series
K=Ke_phi1/2
Wm3=2*%pi*N/60     //angular speed
E3=K*Wm3
//Now there are two linear equations...that we have to solve"
//They are given by 0.3*N3+1.337*Ia3=500 and 0.14*N3+0.1*Ia3=220"
a = [0.3,1.337;0.14,0.1]
b = [500;220]
x = inv(a)*b
N3=x(1)              //let the motor speed be N3
Ia3=x(2)             //let the motor current be Ia3

//Results
mprintf("(i)Hence the motor armature current is Ia2 :%.1f A",Ia2)
mprintf("\nAnd the required speed is N2 :%.1f rpm",N2)
mprintf("\n(ii)Hence the motor armature current is Ia3 :%.1f A",Ia3)
mprintf("\nAnd the required speed is N3 :%.1f rpm",N3)
```

Scilab code Exa 5.13 Q13

```
//Chapter 5:Dc Motor Drives
//Example 13
clc;

//Variable Initialization

//Ratings of the separately excited motor
V=200     // rated voltage in V
N=875     // rated speed in rpm
Ia=150    // rated current in A
Ra=0.06   // armature resistance in ohms
Vs=220    // source voltage in V
f=50      // frequency of the source voltage in Hz

//Solution
E=V-Ia*Ra              //back emf
Vm=sqrt(2)*Vs    //peak voltage

//(i)When the speed is 750 rpm and at rated torque
N1=750          //given speed in rpm
E1=N1/N*E       //back emf at the given speed N1
Va=E1+Ia*Ra     //terminal voltage
cos_alpha=Va*%pi/2/Vm
alpha=acos(cos_alpha)    //required firing angle in
   radian
alpha1=alpha*180/%pi     //required firing angle in
   degrees

//(ii)When the speed is −500rpm and at rated torque
N1=-500          //given speed in rpm
E1=N1/N*E        //back emf at the given speed N1
Va=E1+Ia*Ra      //terminal voltage
```

```
cos_alpha=Va*%pi/2/Vm
alpha=acos(cos_alpha)    //required firing angle in radian
alpha2=alpha*180/%pi     //required firing angle in degrees

//(iii)When the firing angle is 160 degrees
alpha=160    //firing angle in degrees
alpha=alpha*%pi/180
Va=2*Vm/%pi*cos(alpha)
E1=Va-Ia*Ra     //since Va=E1+Ia*Ra
N1=E1/E*N       //the required speed at the given firing angle

//Results
mprintf("(i)Hence the required firing angle is :%.1f ",alpha1)
mprintf("\n(ii)Hence the required firing angle is :%.1f  ",alpha2)
mprintf("\n(iii)Hence the required speed is :%.1f rpm",N1)
```

Scilab code Exa 5.14 Q14

```
//Chapter 5:Dc Motor Drives
//Example 14
clc;

//Variable Initialization

//Ratings of the separately excited motor is same as that of Ex-5.13
V=200     // rated voltage in v
N=875     // rated speed in rpm
Ia=150    // rated current in A
```

```
Ra=0.06   // armature resistance in ohms
Vs=220    // source voltage in v
f=50      //frequency of the source voltage in hz
La=0.85e-3    // armature curcuit inductance in H

//Solution
E=V-Ia*Ra              //back emf
Vm=sqrt(2)*Vs    //peak voltage
Wm=2*%pi*N/60     //synchronous angular speed

//(i)When the speed is 400 rpm and firing angle is 60 degrees
N1=400          //given speed in rpm
alpha=60        //firing angle in degrees
W=2*%pi*f
x=W*La/Ra
phi=atan(x)
cot_phi=1/tan(phi)
Z=sqrt(Ra**2+(W*La)**2)
K=E/Wm

y=Ra*Vm/Z/K
a=(1+exp(-(%pi*cot_phi)))/(exp(-(%pi*cot_phi))-1)
alpha=alpha*%pi/180
Wmc=y*sin(alpha-phi)*a    //required angular speed in rps
Nmc=Wmc*60/2/%pi      //required angular speed in rpm

E1=N1/N*E

//The equation Vm/Z*sin(beta-phi)-E/Ra+(E/Ra-Vm/Z*sin(alpha-phi))*exp(-(beta-alpha)*cot_phi)=0
//can be solved using trial method such that beta=230 degrees
beta=230                     //in degrees
beta=beta*%pi/180//in radians

Va=(Vm*(cos(alpha)-cos(beta))+(%pi+alpha-beta)*E1)/
```

```
    %pi
Ia=(Va-E1)/Ra
T1=K*Ia

//(ii)When the speed is -400 rpm and firing angle is 120 degrees
Le=2e-3          //external inductance added to the armature
L=La+Le
N2=-400           //given speed in rpm
alpha=120         //firing angle in degrees
x=W*L/Ra
phi=atan(x)
cot_phi=1/tan(phi)
Z=sqrt(Ra**2+(W*L)**2)
K=E/Wm

y=Ra*Vm/Z/K
alpha=alpha*%pi/180
a=(1+exp(-(%pi*cot_phi)))/(exp(-(%pi*cot_phi))-1)
Wmc=y*sin(alpha-phi)*a    //required angular speed in rps
Nmc1=Wmc*60/2/%pi      //required angular speed in rpm
//The motor is operating under discontinous condition"
E2=N2/N*E

//The equation Vm/Z*sin(beta-phi)-E/Ra+(E/Ra-Vm/Z*sin(alpha-phi))*exp(-(beta-alpha)*cot_phi)=0
//can be solved using trial method such that beta=281 degrees
beta=281                       //in degrees
beta=beta*%pi/180//in radians

Va=(Vm*(cos(alpha)-cos(beta))+(%pi+alpha-beta)*E2)/%pi
Ia=(Va-E2)/Ra
```

```
T2=K*Ia

//(iii)When the speed is -600 rpm and firing angle
    is 120 degrees
N3=-600         //speed in rpm
alpha=120       //firing angle in degrees
alpha=alpha*%pi/180
Va=2*Vm/%pi*cos(alpha)
E3=N3/N*E     //since Va=E1+Ia*Ra
Ia=(Va-E3)/Ra
T3=K*Ia

//Results
mprintf("(i)Hence the required torque is :%.2f N-m",
    T1)
mprintf("\n(ii)Hence the required torque is :%.1f N-
    m",T2)
mprintf("\n(iii)Hence the required torque is :%.1f N
    -m",T3)
//There is a minor difference in the answers because
     of accuracy
```

Scilab code Exa 5.15 Q15

```
//Chapter 5:Dc Motor Drives
//Example 15
clc;

//Variable Initialization

V=200     // rated voltage in v
N=875     // rated speed in rpm
Ia=150    // rated current in A
Ra=0.06   // armature resistance in ohms
Vs=220    // source voltage in v
```

```
f=50      //frequency of the source voltage in hz
La=2.85e-3    // armature curcuit inductance in H

//Solution
E=V-Ia*Ra            //back emf
Vm=sqrt(2)*Vs    //peak voltage
Wm=2*%pi*N/60     //angular speed
W=2*%pi*f

alpha=120        //firing angle in degrees
x=W*La/Ra
phi=atan(x)
cot_phi=1/tan(phi)
Z=sqrt(Ra**2+(W*La)**2)
K=E/Wm

y=Ra*Vm/Z/K
a=(1+exp(-(%pi*cot_phi)))/(exp(-(%pi*cot_phi))-1)
alpha=alpha*%pi/180
Wmc=y*sin(alpha-phi)*a    //required angular speed in rps
Nmc=Wmc*60/2/%pi      //required angular speed in rpm

Va=2*Vm/%pi*cos(alpha)
E1=Nmc/N*E      //value of back emf at the critical speed of Nmc
Ia=(Va-E1)/Ra
Tc=K*Ia

//(i)When the torque is 1200 N-m and firing angle is 120 degrees
T2=1200          //given torque in N-m
Ia2=T2/K         //given terminal current for the given torque and the answer in the book is wrong
E2=Va-Ia*Ra
N2=E2/E*N

//(ii)When the torque is 300 N-m and firing angle is
```

```
120 degrees
T=300     //required torque in N-m
beta=233.492    //required angle in degrees
beta=beta*%pi/180     //in radians
x=beta-alpha
E1=(Vm*(cos(alpha)-cos(beta)))/x-(%pi*Ra*T)/(K*x)
N1=E1/E*N    //required speed


//Results
mprintf("\nThe motor is operating under continuous
    condition")
mprintf("\nThe torque Tc is :%.2f N-m",Tc)
//The answer for torque Tc in the book is wrong due
    to accuracy which leads to other incorrect
    answers
mprintf("\n(i)Hence the required speed is :%.1f rpm"
    ,N2)
mprintf("\n(ii)The equation Vm/Z*sin(beta-phi)-sin(
    alpha-phi))*exp(-(beta-alpha)*cot_phi)=")
mprintf("\n(Vm*(cos(alpha)-cos(beta))/Ra/(beta-alpha
    )-pi*T/K/(beta-alpha) )*(1-exp(-(beta-alpha)*
    cot_phi)")
mprintf("\ncan be solved using trial method such
    that beta=233.492 degrees")
mprintf("\n  Hence the required speed is :%.1f rpm",
    N1)
```

Scilab code Exa 5.16 Q16

```
//Chapter 5:Dc Motor Drives
//Example 16
clc;

//Variable Initialization
```

```
//Ratings of the separately excited motor
V=220         // rated voltage in v
N=960         // rated speed in rpm
Ia=12.8       // rated current in A
Ra=2          // armature resistance in ohms
Vs=230        // source voltage in v
f=50          //frequency of the source voltage in hz
La=150e-3     // armature curcuit inductance in H

//Solution
E=V-Ia*Ra              //back emf
Vm=sqrt(2)*Vs    //peak voltage
Wm=2*%pi*N/60     //angular speed
W=2*%pi*f

//(i)When speed is 600rpm and the firing angle is 60
    degrees
alpha=60        //firing angle in degrees
N1=600          //motor speed in rpm
x=W*La/Ra
phi=atan(x)
cot_phi=1/tan(phi)
Z=sqrt(Ra**2+(W*La)**2)
K=E/Wm

y=Ra*Vm/Z/K
alpha=alpha*%pi/180
b=sin(phi)*exp(-(alpha*cot_phi))
c=sin(alpha-phi)*exp(-(%pi*cot_phi))
a=1-exp(-(%pi*cot_phi))
Wmc=y*(b-c)/a    //required angular speed in rps
Nmc=Wmc*60/2/%pi      //required angular speed in rpm

Va=Vm/%pi*(1+cos(alpha))
E1=N1/N*E      //value of back emf at the speed of N1
Ia=(Va-E1)/Ra
T=K*Ia
```

```
//(ii)When the torque is 20 N-m and firing angle is 60 degrees
T1=20       //required torque in N-m
alpha=60    //required firing angle in degrees
Ec=Nmc/N*E //motor back emf at critical speed of Nmc
Tc=K*(Va-Ec)/Ra     //torque at the critical speed

Ia=T1/K
E1=Va-Ia*Ra
N1=E1/E*N    //required speed

//Results
//if N1<Nmc then
mprintf("(i)The motor is operating under continuous condition")
mprintf("\nHence the required torque is :%.2f N-m",T)
//end
//if Tc<T1 then
mprintf("\n(ii)The motor is operating under continuous condition")
mprintf("\nHence the required speed is :%.1f rpm",N1)
//end
```

Scilab code Exa 5.17 Q17

```
//Chapter 5:Dc Motor Drives
//Example 17
clc;

//Variable Initialization

//Ratings of the separately excited motor
```

```
V=220     // rated voltage in V
N=1500    // rated speed in rpm
Ia=50     // rated current in A
Ra=0.5    // armature resistance in ohms
Vl=440    // line  voltage inV with 3-phase ac supply
f=50      //frequency of the source voltage in Hz

//Solution
//(i) Tranformer ratio
alpha=0    //firing angle in degrees
Va=V       //motor terminal voltage is equal to the rated voltage when the firing angle is 0 degrees
Vm=%pi/3*Va/cos(alpha)
Vrms=Vm/sqrt(2)         //rms value of the converter input voltage
a=(Vl/sqrt(3))/Vrms     //required transformer ratio

//(ii)Value of the firing angle
E=V-Ia*Ra       //back emf at the rated speed

//(a)When the speed of the motor is 1200 rpm and rated torque
N1=1200         //speed of the motor i rpm
E1=N1/N*E       //back emf at the given speed N1
Va=E1+Ia*Ra     //terminal voltage at the given speed N1
alpha=acos(%pi/3*Va/Vm)  //required firing angle in radians
alpha1=alpha*180/%pi          //required firing angle in degrees

//(b)When the speed of the motor is -800 rpm and twice the rated torque
N1=-800         //speed of the motor in rpm
E1=N1/N*E       //back emf at the given speed N1
Ia=2*Ia         //torque is directly proportional to the current hence twice the rated current
Va=E1+Ia*Ra     //terminal voltage at the given speed
```

```
N1
alpha=acos(%pi/3*Va/Vm)  //required firing angle in radians
alpha2=alpha*180/%pi          //required firing angle in degrees


//Results
mprintf("(i)Hence the required transformer ratio is :%.3f",a)
mprintf("\n(ii)(a)Hence the required firing angle is :%.2f   ",alpha1)
mprintf("\n(b)Hence the required firing angle is :%.2f   ",alpha2)
```

Scilab code Exa 5.18 Q18

```
//Chapter 5:Dc Motor Drives
//Example 18
clc;

//Variable Initialization

//The separately excited motor  is fed from a circulating dual converter
V=220     // rated voltage in V
N=1500    // rated speed in rpm
Ia=50     // rated current in A
Ra=0.5    // armature resistance in ohms
Vl=165    // line  voltage in V
f=50      // frequency of the source voltage in Hz

//Solution
E=V-Ia*Ra              //back emf at the rated speed
Vm=Vl*sqrt(2)    //peak voltage
```

```

//(i)During motoring operation when the speed is 1000 rpm and at rated torque
N1=1000          //speed of the motor in rpm
E1=N1/N*E        //back emf at the given speed N1
Va=E1+Ia*Ra      //terminal voltage at the given speed N1
alpha_A=acos(%pi/3*Va/Vm)
alpha_A=alpha_A*180/%pi//required converter firing angle in degrees
alpha_B=180-alpha_A

//(ii)During braking operation when the speed is 1000 rpm and at rated torque
N1=1000          //speed of the motor in the book is given as 100 rpm which is wrong
E1=N1/N*E        //back emf at the given speed N1
Va=E1-Ia*Ra      //terminal voltage at the given speed N1
alpha_A1=acos(%pi/3*Va/Vm)
alpha_A1=alpha_A1*180/%pi//required converter firing angle in degrees
alpha_B1=180-alpha_A1

//(iii)During motoring operation when the speed is -1000 rpm and at rated torque
N1=-1000          //speed of the motor in rpm
E1=N1/N*E        //back emf at the given speed N1
Va=E1-Ia*Ra      //terminal voltage at the given speed N1
alpha_A2=acos(%pi/3*Va/Vm)
alpha_A2=alpha_A2*180/%pi//required converter firing angle in degrees
alpha_B2=180-alpha_A2

//(iv)During braking operation when the speed is -1000 rpm and at rated torque
N1=-1000         //speed of the motor in the book it
```

```
    is given as 100 rpm which is wrong
E1=N1/N*E       //back emf at the given speed N1
Va=E1+Ia*Ra     //terminal voltage at the given speed
     N1
alpha_A3=acos(%pi/3*Va/Vm)
alpha_A3=alpha_A3*180/%pi//required converter firing
     angle in degrees
alpha_B3=180-alpha_A3

//Results
mprintf("\n(i)Hence the required firing angle is :%
    .1f    ",alpha_B)
mprintf("\n(ii)Hence the required firing angle is :%
    .1f    ",alpha_B1)
mprintf("\n(iii)Hence for negative speed during
    motoring operation the required firing angles are
     :")
mprintf("\nalpha_A :%.1f     and alpha_B :%.1f    ",
    alpha_A2,alpha_B2)
mprintf("\n(iv)Hence for negative speed during
    braking operation the required firing angles are
    :")
mprintf("\nalpha_A :%.1f     and alpha_B :%.1f    ",
    alpha_A3,alpha_B3)
```

Scilab code Exa 5.19 Q19

```
//Chapter 5:Dc Motor Drives
//Example 19
clc;

//Variable Initialization

//Ratings of the separately excited motor
V=230     // rated voltage in V
```

```
N=960     // rated speed in rpm
Ia=200    // rated current in A
Ra=0.02   // armature resistance in ohms
Vs=230    // source voltage in V

//Solution
E=V-Ia*Ra     //back emf

//(i) When the speed of motor is 350 rpm with the rated torque during motoring operation
N1=350       //given speed in rpm
E1=N1/N*E    //given back emf at N1
Va=E1+Ia*Ra  //motor terminal voltage
delta=Va/V   //duty ratio

//(ii) When the speed of motor is 350 rpm with the rated torque during braking operation
Va=E1-Ia*Ra  //motor terminal voltage
delta1=Va/V   //duty ratio

//(iii)Maximum duty ratio is 0.95
delta2=0.95   //maximum duty ratio
Va=delta2*V   //terminal voltage
Ia1=2*Ia      //maximum permissable current
E1=Va+Ia1*Ra  //back emf
N1=E1/E*N     //maximum permissible speed
Pa=Va*Ia1     //power fed to the source

//(iv) If the speed of the motor is 1200 rpm and the field of the motor is also controlled
N2=1200       //given speed in rpm
//Now the field current is directly proportional to the speed of the motor
If=N/N2      //field current as a ratio of the rated current


//Results
```

```
mprintf("(i) Duty ratio is :%.3f",delta)
mprintf("\n(ii)Duty ratio is :%.2f",delta1)
mprintf("\n(iii)Maximum permissible speed is :%d rpm
   ",N1)
mprintf("\nPower fed to the source is :%.1f kW",Pa
   /1000)
mprintf("\n(iv)Field current as a ratio of the rated
    current is :%.1f",If)
```

Scilab code Exa 5.20 Q20

```
//Chapter 5:Dc Motor Drives
//Example 20
clc;

//Variable Initialization

//Ratings of the separately excited motor when it is
    operated in dynamic breaking
V=230    // rated voltage in V
N=960    // rated speed in rpm
Ia=200   // rated current in A
Ra=0.02  // armature resistance in ohms
Vs=230   // source voltage in V
Rb=2     // braking resistance in ohm

//Solution
//When the motor speed is 600 rpm and the braking
   torque is twice the rated value
Ia1=2*Ia      //torque is directly proportional to
   current
N1=600        //speed of the motor in rpm
E=V-Ia*Ra     //back emf
E1=N1/N*E
x=E1/Ia1-Ra   //x=(1-delta)*Rb
```

```
y=x/Rb        //y=1-delta
delta=1-y     //duty ratio

//(ii)If the duty ratio is 0.6 and and the braking
   torque is twice the rated value
delta1=0.6  //duty ratio
Ia1=2*Ia   //torque is directly proportional to
   current
E1=Ia1*((1-delta1)*Rb+Ra)   //back emf
N1=E1/E*N


//Results
mprintf("(i)Duty ratio is :%.2f",delta)
mprintf("\n(ii)Hence the motor speed is :%.1f rpm",
   N1)
```

Scilab code Exa 5.21 Q21

```
//Chapter 5:Dc Motor Drives
//Example 21
clc;

//Variable Initialization

//Ratings of the series motor
N=600      //speed in rpm
Vs=220     //source voltage in V
Ra_Rf=0.12    //combine armature resistance field
   resistance

//Magnetisation curve at N
If=[10, 20,30, 40, 50,  60, 70, 80]     //field
   current in A
E =[64,118,150,170,184,194,202,210]     //terminal
```

```
voltage in V

//Solution
//(i)When the duty ratio is 0.6 and motor current is 60 A
delta=0.6     //duty ratio
Ia1=60        //motor current in A
Va1=delta*Vs //terminal voltage for the given duty ratio
E1=Va1-Ia1*Ra_Rf       //back emf for the given duty ratio

//For Ia1=60 A the terminal voltage is 194 V as given in the magnetization curve
N1=E1/E(6)*N           //motor speed for the given duty ratio

//(ii)When the speed is 400rpm and the duty ratio is 0.65
delta=0.65     //duty ratio
N2=400         //speed in rpm
Va1=delta*Vs //terminal voltage for the given duty ratio

//From the magnetization characteristic for the speed of 400rpm the current Ia=70 A
E1=Va1-If(7)*Ra_Rf       //back emf for the given duty ratio
T=(E1*If(7))/N2/(2*%pi/60)     //required torque


//Results
mprintf("(i)Hence the motor speed is :%.1f rpm",N1)
mprintf("\n(ii)Hence the required torque is :%.1f N-m",T)
```

Scilab code Exa 5.22 Q22

```
//Chapter 5:Dc Motor Drives
//Example 22
clc;

//Variable Initialization

//The motor is operated using regenarative braking
   method
N=600      //speed in rpm
Vs=220     //source voltage in V
Ra_Rf=0.12     //combine armature resistance field
   resistance

//Magnetisation curve at N
If=[10, 20,30, 40, 50,  60, 70, 80]     //field
   current in A
E =[64,118,150,170,184,194,202,210]     //terminal
   voltage in V

//Solution
//(i)When  the duty ratio is 0.5 and the braking
   torque is equal to the motor torque
delta=0.5        //duty ratio
Va1=delta*Vs     //terminal voltage
Ia1=If(7)        //current at rated motor torque
E1=Va1+Ia1*Ra_Rf       //back emf for the given duty
   ratio
N1=E1/E(7)*N           //for a current of 70 A E=202
   V from the magnetization curve

//(ii)When maximum permisssible duty ratio is 0.95
   and current is 70A
```

```
delta_max=0.95        //maximum duty ratio
Va1=delta_max*Vs      //terminal voltage
Ia1=70                //maximum permissible current in A
E2=Va1+Ia1*Ra_Rf      //back emf for the given duty ratio
N2=E2/E(7)*N          //for a current of 70 A E=202 V

//(iii)When the motor speed is 1000rpm and maximum current is 70A with duty ratio in the range of 0.05 to 0.95
Ia1=70                //maximum permissible current in A
N3=1000               //given speed in rpm
delta_max=0.95        //maximum duty ratio
E3=N3/N*E(7)          //terminal voltage
x=(E3-delta_max*Vs)/Ia1     //x=R+Ra_Rf   where R is the required external resistance
R=x-Ra_Rf     //external resistance

//(iv)when the motor is running at 1000rpm with current at 70
Ia1=70                //maximum permissible current in A
N4=1000               //given speed in rpm
Ra=Ra_Rf              //total value of armature resistance is assumed to be the same
E4=Va1+Ia1*Ra         //back emf for the given speed N4
E_=N/N4*E4
ratio=E_/E(7)         //fraction of the requuired number of turns to be reduced

//Results
mprintf("(i)Hence the motor speed is :%.1f rpm",N1)
mprintf("\n(ii)Hence the motor speed is :%.1f rpm",N2)
mprintf("\n(iii)Hence the required external
```

```
resistance is :%.1f ohm",R)
mprintf("\n(iv)Hence fraction of the number of turns to be reduced is :%.3f",ratio)
```

Scilab code Exa 5.23 Q23

```
//Chapter 5:Dc Motor Drives
//Example 23
clc;

//Variable Initialization

//The motor is operated using dynamic braking method
N=600      //speed in rpm
Vs=220     //source voltage in v
Ra=0.12    // armature resistance in ohms
delta_min=0.1   //manimum value of duty ratio
delta_max=0.9   //maximum value of duty ratio

//Magnetisation curve at N
If=[10, 20,30, 40, 50,  60, 70, 80]     //field current in A
E =[64,118,150,170,184,194,202,210]     //terminal voltage in V

//Solution
//(i) Maximum braking speed is 800rpm with armature current of 70 A
N1=800    //maximum braking speed in rpm
Ia=70     //armature current in A
E1=N1/N*E(7)    //at 70A motor back emf is 202V
Rbe=E1/Ia-Ra    //effective value of braking resistance
Rb=Rbe/(1-delta_min)    //required braking resistance

```

```
//(ii)When the speed of the motor is 87 rpm
//now torque is maximum when the duty ratio is maximum
N1=87    //speed in rpm
R=Rb*(1-delta_max)+Ra

Ia=If(5)    //value of armature current for the given value of E=184V
Ke_phi=E(5)/(2*%pi*N)*60
T=Ke_phi*Ia    //required torque


//Results
mprintf("(i)Hence braking resistance is:%.2f ohm",Rb)
mprintf("\n(ii)Hence the required torque is :%.1f N-m",T)
```

Chapter 6

Induction Motor Drives

Scilab code Exa 6.1 Q1

```
//Chapter 6:Induction Motor Drives
//Example 1
clc;

//Variable Initialization

//Ratings of the Y−connected induction motor
f=50            // frequency in HZ
Vl=440          //line voltage in V
P=6             // number of poles
N=950           //speed in rpm

//Parameters referred to the stator
Xr_=1.2         // rotor winding reactance in ohm
Rr_=0.4         // resistance of the rotor windings
   in ohm
Rs=0.5          // resistance of the stator windings
   in ohm
Xs=Xr_          // stator winding reactance in ohm
Xm=50           // no load reactance in ohms

```

```
//Solution
Ns=120*f/P      //synchronous speed in rpm
s=(Ns-N)/Ns     //full load slip
x=sqrt((Rs+Rr_/s)**2+(Xs+Xr_)**2)    //total impedance
Ir_=(Vl/sqrt(3))/x                   //full load rotor current
angle=-atan((Xs+Xr_)/(Rs+Rr_/s))     //angle in radian

Ir_=Ir_*(cos(angle)+sin(angle)*%i)                //full load rotor current in rectangular form
Im=Vl/sqrt(3)/Xm*(-%i)               //magnetizing current
Is=Ir_+Im                                  //full load current

Zf=Rs+Xs*%i+%i*Xm*(Rr_/s+%i*Xr_)/(Rr_/s+%i*(Xr_+Xm))
Zb=Rs+Xs*%i+%i*Xm*(Rr_/(2-s)+%i*Xr_)/(Rr_/(2-s)+%i*(Xr_+Xm))
Z=Zf+Zb
I=(Vl/sqrt(3))/abs(Z)              //motor current
Wms=2*%pi*Ns/60

//Torque due to positive sequence
Tp=(1/Wms)*(3*I**2*Xm**2*Rr_/s)/((Rr_/s)**2+(Xr_+Xm)**2)

//Torque due to negative sequence
Tn=-(1/Wms)*(3*I**2*Xm**2*Rr_/(2-s))/((Rr_/(2-s))**2+(Xr_+Xm)**2)
T=Tp+Tn          //net torque
Wm=Wms*(1-s)     //rated speed in in rad/sec
Tl=0.0123*Wm**2 //required torque of the load

//Results
var=phasemag(Is)
mprintf("Full load motor current Is:%.1f %.1f    A",
```

```
abs(Is),var)
mprintf("\nTp:%.2f N-m",Tp)
mprintf("\nTn:%.3f N-m",Tn)
mprintf("\n\nSince I:%.2f A and N:%d rpm",I,N)
mprintf("\nAnd I:%.2f A< Is %.2f A, the motor will run safely",I,abs(Is))
```

Scilab code Exa 6.2 Q2

```
//Chapter 6:Induction Motor Drives
//Example 2
clc;

//Variable Initialization
//Ratings of the Delta connected Induction motor
f=50              //frequency in HZ
Vl=2200           //line voltage in V
P=8               //number of poles
N=735             //rated speed in rpm

//Parameters referred to the stator
Xr_=0.55           // rotor winding reactance in ohm
Xs=0.45            // stator winding reactance in ohm
Rr_=0.1            // resistance of the rotor windings in ohm
Rs=0.075           // resistance of the stator windings in ohm

//Solution
Ns=120*f/P        //synchronous speed in rpm
s=(Ns-N)/Ns       //full load slip
x=sqrt((Rs+Rr_/s)**2+(Xs+Xr_)**2)    //total impedance
Ip=(Vl)/x                        //full load phase current
Il=sqrt(3)*Ip             //full load line current
```

```
Wms=2*%pi*Ns/60
Tl=(1/Wms)*(3*Ip**2*Rr_/s) //full load torque

//(i)if the motor is started by star-delta switching
y=sqrt((Rs+Rr_)**2+(Xs+Xr_)**2)
Ist=(Vl/sqrt(3))/y                    //Maximum line current during starting
Tst=(1/Wms)*(3*Ist**2*Rr_)                 //Starting torque
ratio1=Tst/Tl                              //ratio of starting torque to full load torque
z=Rs+sqrt(Rs**2+(Xs+Xr_)**2)
Tmax=3/(2*Wms)*(Vl/sqrt(3))**2/z  //maximum torque
ratio2=Tmax/Tl                             //ratio of maximum torque to full load torque

//(ii) If the motor is started using auto transformer
y=sqrt((Rs+Rr_)**2+(Xs+Xr_)**2)
Ist1=Vl*sqrt(3)/y           //starting current direct online
aT=sqrt(2*Il/Ist1)          //transofrmation ratio
Ilst=2*Il/aT                     //starting motor line current
Ipst=Ilst/sqrt(3)           //starting motor phase current
Tst1=(1/Wms)*(3*Ipst**2*Rr_)     //starting torque

//(iii) If motor is started using part winding method
Rs_=2*Rs
Xs_=2*Xs
y=sqrt((Rs_+Rr_)**2+(Xs_+Xr_)**2)
Ist2=(Vl*sqrt(3))/y        //starting line current
Ip=Ist2/sqrt(3)            //starting phase current
Tst2=(1/Wms)*(3*Ip**2*Rr_)     //starting torque

//(iv) motor is started using series reactors in
```

```
line
Rs_=Rs/3  ;  Rr_=Rr_/3
Xs_=Xs/3  ;  Xr_=Xr_/3
Il=2*Il          //line current at start
x=(Vl/sqrt(3))**2/(Il**2)      //x=(Rs_+Rr_)**2+(Xs_+Xr_+Xe)**2
y=x-(Rs_+Rr_)**2                          //y=(Xs_+Xr_+Xe)**2
z=sqrt(y)                         //z=(Xs_+Xr_+Xe)
Xe=z-Xs_-Xr_


//Results

mprintf("(i)Maximum value of line current during starting Ist:%d A",Ist)
mprintf("\nRatio of starting torque to full load torque :%.3f",ratio1)
mprintf("\nRatio of maximum torque to full load torque :%.2f\n",ratio2)
mprintf("\n(ii)Transformation ratio aT:%.3f",aT)
mprintf("\nStarting torque :%d N-m\n",Tst1)
//Answer for the starting torque in the book is wrong due to accuracy

mprintf("\n(iii)Maximum line current during starting :%d A",Ist2)
mprintf("\nStarting torque :%d N-m\n",Tst2)
//Answer for the starting torque in the book is wrong due to accuracy

mprintf("\n(iv)Value of the reactor Xe:%.3f ohm",Xe)
```

Scilab code Exa 6.3 Q3

```
//Chapter 6:Induction Motor Drives
//Example 3
clc;

//Variable Initialization

//Ratings of the star connected Induction motor
f=50              // frequency in HZ
Vl=400            // line voltage in V
P=6               // number of poles

//Parameters referred to the stator
Xr_=2            // rotor winding reactance in ohm
Xs=Xr_           // stator winding reactance in ohm
Rr_=1            // resistance of the rotor windings in ohm
Rs=Rr_           // resistance of the stator windings in ohm

//Solution
Ns=120*f/P      //synchronous speed in rpm
Wms=2*%pi*Ns/60

//(i)
Sm=-Rr_/sqrt(Rs**2+(Xs+Xr_)**2)    //slip at maximum torque
x=sqrt((Rs+Rr_/Sm)**2+(Xs+Xr_)**2)
Ir_=(Vl/sqrt(3))/x          //current at maximum torque
Tmax=(1/Wms)*3*Ir_**2*Rr_/Sm    //maximum torque
N=(1-Sm)*Ns                     //range of speed

//(ii)an overhauling torque of 100Nm
Tl=100    //overhauling torque in Nm
// Tl=(3/Wms)*(Vl**2*Rr_/s)/y
// where y=(Rs+Rr_/s)**2+(Xs+Xr_)**2
a=(1/Wms)*(Vl**2*Rr_)/(-Tl)     //a=s*(Rs+Rr_/s)**2+(Xs+Xr_)**2
```

```
a = 17
b = 17.3
c = 1

//Discriminant
d = (b**2) - (4*a*c)

// find two solutions
s1 = (-b-sqrt(d))/(2*a)
s2 = (-b+sqrt(d))/(2*a)

N2=(1-s2)*Ns            //motor speed and we neglect s1

//slight difference in the answer due to accuracy

//(iii)when a capacitive reactance of 2 ohm is inserted in each phase stator
Xc=2      //reactance of the capacitor in ohms
Sm=-Rr_/sqrt(Rs**2+(Xs+Xr_-Xc)**2)   //slip at maximum torque
x=sqrt((Rs+Rr_/Sm)**2+(Xs+Xr_-Xc)**2)
Ir_=(Vl/sqrt(3))/x        //current at maximum torque
Tmax_=(1/Wms)*3*Ir_**2*Rr_/Sm   //maximum overhauling torque with capacitor
ratio=Tmax_/Tmax


//Results
mprintf("(i)Maximum overhauling torque that the motor can hold is:%.1f N-m",abs(Tmax))
mprintf("       \nRange of speed is from %d to %d rpm\n",Ns,abs(N))
mprintf("\n(ii)Now s*(1+1/s)**2+16s=%d",a)
mprintf("\n      Or 17s**s+17.3s+1=0")
mprintf("\nThe solutions for s are %.3f and %.3f\n",s1,s2)
```

```
mprintf("\nTherefore Motor speed is:%d rpm\n",N2)
//Note :There is a slight difference in the answer
    due to the decimal place"
mprintf("\n(iii) Ratio of maximum torque with
    capacitor and to maximum torque without capacitor
     is:%.2f",ratio)
```

Scilab code Exa 6.4 Q4

```
//Chapter 6:Induction Motor Drives
//Example 4
clc;

//Variable Initialization

//Ratings of the motor are same as that in Ex-6.3
f=50                // frequency in HZ
Vl=400              //line voltage in V
P=6                 // number of poles

//Parameters referred to the stator
Xr_=2             // rotor winding reactance in ohm
Xs=Xr_            // stator winding reactance in ohm
Rr_=1             // resistance of the rotor windings in
     ohm
Rs=Rr_            // resistance of the stator windings
    in ohm
N=950             //full load speed in rpm
SR=2.3            //stator to rotor turns ratio

//Solution
Ns=120*f/P          //synchronous speed in rpm
Wms=2*%pi*Ns/60
s=(Ns-N)/Ns         //full load slip
x=sqrt((Rs+Rr_/s)**2+(Xs+Xr_)**2)
```

```
Irf_=(Vl/sqrt(3))/x          //full load current
Tf=(1/Wms)*3*Irf_**2*Rr_/s         //full load  torque

//(i)initial braking current and torque
S=2-s      //during plugging at 950rpm
y=sqrt((Rs+Rr_/S)**2+(Xs+Xr_)**2)
Ir_=(Vl/sqrt(3))/y          //initial braking current
ratio1=Ir_/Irf_
T=(1/Wms)*3*Ir_**2*Rr_/S        //initial braking torque
ratio2=T/Tf

//(ii)when an external resistance is connected such
//that maximum braking current is 1.5 times the full load current
Ir_=1.5*Irf_
x=(Vl/sqrt(3))/Ir_     //x=sqrt((Rs+(Rr_+Re_)/S)**2+(Xs+Xr_)**2)
y=x**2                        //y=(Rs+(Rr_+Re_)/S)**2+(Xs+Xr_)**2
z=y-(Xs+Xr_)**2               //z=(Rs+(Rr_+Re_)/S)**2
a=sqrt(z)              //a=(Rs+(Rr_+Re_)/S)
b=(a-Rs)*S                    //b=(Rr_+Re_)
Re_=b-Rs
Re=Re_/SR**2
T=(1/Wms)*3*Ir_**2*(Rr_+Re_)/S        //initial braking  torque
ratio=T/Tf


//Results
mprintf("(i)Ratio of initial braking current to full load current is:%.1f",ratio1)
mprintf("\nRatio of initial braking torque to full load torque is:%.2f\n",ratio2)
mprintf("\n(ii)Ratio of initial braking torque to full load torque when the resistance is added is:%.3f",ratio)
```

Scilab code Exa 6.5 Q5

```
//Chapter 6:Induction Motor Drives
//Example 4
clc;

//Variable Initialization

//Ratings of the star connected Induction motor
f=50            // frequency in HZ
Vl=440          // line voltage in V
P=6             // number of poles
Vp=Vl/sqrt(3)   //phase voltage in V

//Parameters referred to the stator
Xr_=1.2         // rotor winding reactance in ohm
Xs=Xr_          // stator winding reactance in ohm
Rr_=0.4         // resistance of the rotor windings in ohm
Rs=0.5          // resistance of the stator windings in ohm
Xm=50           // no load reactance in ohms
N=950           // full load speed in rpm
Sm=2            // slip at maximum torque

//Solution
Rr_=Sm*sqrt(Rs**2+(Xs+Xr_)**2)    //Since Sm=Rr_/sqrt(Rs**2+(Xs+Xr_)**2)
Ns=120*f/P      //synchronous speed in rpm
Wms=2*%pi*Ns/60
s=(Ns-N)/Ns             //slip at 950 rpm

x=%i*Xm*(Rr_/s+%i*Xr_)
y=Rr_/s+%i*(Xr_+Xm)
```

```
Zp=Rs+%i*Xs+x/y
Ip=Vp/sqrt(3)/Zp
//The value of Ip is wrong which leads to other
    wrong answers

Irp_=Ip*(%i*Xm)/(Rr_/s+%i*(Xr_+Xm))
Tp=(1/Wms)*3*abs(Irp_)**2*Rr_/s
x=%i*Xm*(Rr_/(2-s)+%i*Xr_)
y=Rr_/(2-s)+%i*(Xr_+Xm)
Zn=Rs+%i*Xs+x/y
In=Vp/sqrt(3)/Zn
Irn_=In*(%i*Xm)/(Rr_/(2-s)+%i*(Xr_+Xm))
Tn=-(1/Wms)*3*abs(Irn_)**2*Rr_/(2-s)
//The value of In is wrong

T=Tp-Tn
I=abs(Ip)+abs(In)
Rr_=0.4     // from the parameters of the motor
    referred to the stator
x=sqrt((Rs+Rr_/s)**2+(Xs+Xr_)**2)
If=(Vl/sqrt(3))/x        //full load current
Tf=(1/Wms)*3*If**2*Rr_/s      //full load  torque

ratio1=I/If
ratio2=abs(T)/Tf

//Results
mprintf("Ratio of braking current to full load
    current  is:%.3f",ratio1)
mprintf("\nRatio of braking torque to full load
    torque  is:%.3f",ratio2)
//Answer provided in the book is wrong
```

Scilab code Exa 6.6 Q6

```

//Chapter 6:Induction Motor Drives
//Example 6
clc;

//Variable Initialization

//Ratings of the star connected Induction motor which operates under dynamic braking
f=50            // frequency in HZ
P=6             // number of poles

//Parameters referred to the stator
Xr_=3.01        // rotor winding reactance in ohm
Xs=Xr_          // stator winding reactance in ohm
Rr_=4.575       // resistance of the rotor windings in ohm
Rs=1.9          // resistance of the stator windings in ohm
J=0.1           // moment of inertia of the motor load system in kg-m2
Id=12           // given DC current

N=1500          //given asynchronous speed
//magnetization chacrateristic at the given asynchronous speed
Im=[0.13,0.37,0.6,0.9,1.2,1.7,2.24,2.9,3.9,4.9,6,8,9,9.5]       //magnetization current
E=[12.8,32,53.8,80,106,142,173,200,227,246,260,280,288,292]     //back emf

//Solution
Ns=120*f/P       //synchronous speed in rpm
torque=[]
speed=[]
temp=[]
```

```
Is=sqrt(2/3)*Id   //value of stator current for two
   lead connection
Wms=2*%pi*N/60
for i=2:14
x=(Is**2-Im(i)**2)/(1+2*Xr_*Im(i)/E(i))   //x=Ir_**2
Ir_=sqrt(x)       //required rotor current
y=(E(i)/Ir_)**2-Xr_**2
S=Rr_/sqrt(y)        //required slip
N=S*Ns                    //required speed
T=(3/Wms)*(Ir_)**2*Rr_/S  //required torque
speed($+1)=N
torque($+1)=T
temp($+1)=T
end
mprintf("Hence the magnetization curve is")
disp(speed,"Speed:in rpm")
for i=1:13
torque(i)=-1*torque(i)
end
disp(torque,"Braking torque :in N-m")

//Results

//Plot of of torque vs speed
subplot(2,1,1)
plot(torque,speed)
xlabel('Torque, N-m')
ylabel('Speed, rpm')
title('Torque vs Speed')
xgrid(2)

//Plot of Wm vs J/T
inertia_over_torque=[]
for i=3:13
J_T=1000*J/temp(i)
inertia_over_torque($+1)=J_T
end
disp(inertia_over_torque,"J/t :")
```

```
Wm=[1,4,8,12,16,20,25,55,95,125,160]
//the values of Wm are taken for the angular frequency with maximum value of Wms=50*pi rad/s
subplot(2,1,2)
plot(Wm,inertia_over_torque)
xlabel('$Angular speed \omega_m$')
ylabel(' J/T,1*10e-2')
title('$J/T   vs   \omega_m$')
xgrid(2)
x=[6.5,6.5]
y=[2,4.5]
plot(x,y,'blue')
str=["${A}$"]
str1=["${B}$"]
str2=["${C}$"]
str3=["${D}$"]
str4=["${E}$"]
xstring(6,2,str)
xstring(6,4.5,str1)
xstring(80,3.4,str2)
xstring(156,8.3,str3)
xstring(156,2,str4)

mprintf("Hence from the plot the area ABCDEA between the curve and the speed axis for speed change ")
mprintf("for synchronous to 0.02 times synchrnous speed is the stopping time which is equal to: 9.36 sec")
```

Scilab code Exa 6.7 Q7

```
//Chapter 6:Induction Motor Drives
//Example 7
clc;
```

```
//Variable Initialization

//Ratings of the Star connected Induction motor
f=50            // frequency in HZ
Vl=2200         // line voltage in V
P=6             // number of poles

//Parameters referred to the stator
Xr_=0.5         // rotor winding reactance in ohm
Xs=Xr_          // stator winding reactance in ohm
Rr_=0.12        // resistance of the rotor windings in ohm
Rs=0.075        // resistance of the stator windings in ohm
J=100           // combine inertia of motor and load in kg-m2

//Solution

//(i) During starting of the motor
Sm=Rr_/sqrt(Rs**2+(Xs+Xr_)**2)   //slip at maximum torque
Wms=4*%pi*f/P                       //angular frequency
x=Rs+sqrt(Rs**2+(Xs+Xr_)**2)
Tmax=(3/2/Wms)*(Vl/sqrt(3))**2/x  //maximum torque
tm=J*Wms/Tmax                          //mechanical time constant of the motor
ts=tm*(1/4/Sm+1.5*Sm)                  //time taken during starting
Es=1/2*J*Wms**2*(1+Rs/Rr_)             //energy disspated during starting

//(ii) When the motor is stopped by plugging method
tb=tm*(0.345*Sm+0.75/Sm)        //time required to stop by plugging
Eb=3/2*J*Wms**2*(1+Rs/Rr_)      //energy disspated
```

```
during braking

//(iii)Required resistance to be inserted during plugging
tb1=1.027*tm        //minimum value of stopping time during braking
x=1.47*(Xs+Xr_)     //x=Rr_+Re
Re=x-Rr_            //Re is the required external resistance to be connected
Ee=3/2*J*Wms**2*(Re/(Re+Rr_))       //energy disspated in the external resistor
Eb1=Eb-Ee                                  //total energy disspated during braking


//Results

mprintf("(i)Time taken during starting is ts:%.4f s",ts)
mprintf("   \nEnergy dissipated during starting is Es:%d kilo-watt-sec",Es/1000)
mprintf("\n\n(ii)Time taken to stop by plugging is tb:%.2f s",tb)
mprintf("    \nEnergy dissipated during braking is Eb:%d kilo-watt-sec",Eb/1000)
mprintf("\n\n(iii)Minimum Time taken to stop by plugging is tb:%.2f s",tb1)
mprintf("     \nRequired external resistance to be connected is Re:%.2f ohm",Re)
mprintf("     \nTotal Energy dissipated during braking is Eb:%.2f kilo-watt-sec",Eb1/1000)
```

Scilab code Exa 6.8 Q8

```
//Chapter 6:Induction Motor Drives
```

```
//Example 8
clc;

//Variable Initialization

//Ratings of the delta connected Induction motor
f=50             // frequency in HZ
Vl=400           // line voltage in V
P=4              // number of poles
Pm=2.8*1000      // rated mechanical power developed in W
N=1370           // rated speed in rpm

//Parameters referred to the stator
Xr_=5            // rotor winding reactance in ohm
Xs=Xr_           // stator winding reactance in ohm
Rr_=5            // resistance of the rotor windings in ohm
Rs=2             // resistance of the stator windings in ohm
Xm=80            // no load reactance in ohm

//Solution
Ns=120*f/P                      //synchronous speed in rpm
Wms=2*%pi*Ns/60               //synchronous speed in rad/s
s=(Ns-N)/Ns                     //full load slip
x=(Rs+Rr_/s)**2+(Xs+Xr_)**2     //total impedance
T=(3/Wms)*(Vl**2*Rr_/s)/x       //full load torque
Tl=T
K=Tl/(1-s)**2                   //since Tl=K*(1-s)**2

//(i) When the motor is running at 1200 rpm
N1=1200              //speed in rpm
s1=(Ns-N1)/Ns        //slip at the given speed N1
Tl=K*(1-s1)**2       //torque at the given speed N1

```

```
y=(Rs+Rr_/s1)**2+(Xs+Xr_)**2    //total impedance
a=Tl*(Wms/3)*y*(s1/Rr_)          //Since T=(3/Wms)*(Vl**2*Rr_/s)/x       and a=V**2
V=sqrt(a)                    //required voltage at the given speed N1
Ir_=V/((Rs+Rr_/s1)+%i*(Xs+Xr_))//rotor current
Im=V/(%i*Xm)                     //magnetizing current
Is=Ir_+Im                        //total current
Il=abs(Is)*sqrt(3)           //line current

//(ii)When the terminal voltage is 300 V
V1=300   //terminal voltage in V
x=(Rs+Rr_)**2+(Xs+Xr_)**2
T=(3/Wms)*(V1**2*Rr_)/x

//Now we have to solve for the value of slip 's' from the given equation 104s**4- 188s**3 + 89s**2 - 179s + 25=0"
coeff = [104,-188,89,-179,25]     //coeffcient of the polynomial equation
s=[]
s=roots(coeff)                      //roots of the polynomial equation

T=K*(1-real(s(4)))**2       //torque at the given terminal voltage of 300 V
N=Ns*(1-real(s(4)))         //speed at the given terminal voltage of 300 V
Ir_=V1/((Rs+Rr_/real(s(4)))+%i*(Xs+Xr_))//rotor current
Im=V1/(%i*Xm)                      //magnetizing current
Is=Ir_+Im                          //total current
Il1=abs(Is)*sqrt(3)          //line current


//Results
mprintf("(i)Required torque is Tl:%.1f N-m",Tl)
```

```
mprintf("\nRequired motor terminal voltage is V: %.1f V",V)
mprintf("\nRequired line current is Il:%.2f A",Il)
mprintf("\n(ii)The roots of the polynomial equation are s1:%.3f s2:%.3f s3:%.3f s4:%.3f",real(s(1)),real(s(2)),real(s(3)),real(s(4)))
mprintf("\nHence Only s4: %.3f is valid",real(s(4)))
mprintf("\nRequired torque is Tl:%.2f N-m",T)
mprintf("\nRequired speed is N:%.1f rpm",N)
mprintf("\nRequired line current is Il:%.2f A",Il1)
```

Scilab code Exa 6.9 Q9

```
//Chapter 6:Induction Motor Drives
//Example 9
clc;
clf();
//Variable Initialization

//Ratings of the star connected squirrel Induction motor
f=50              // frequency in HZ
Vl=400            // line voltage in V
P=4               // number of poles
N=1370            // rated speed

//Frequency variation is from 10 Hz to 50 Hz
fmin=10
fmax=50

//Parameters referred to the stator
Xr_=3.5           // rotor winding reactance in ohm
Xs=Xr_            // stator winding reactance in ohm
Rr_=3             // resistance of the rotor windings in ohm
```

```
Rs=2            // resistance of the stator windings in ohm

//Solution
Ns=120*f/P      //synchronous speed
N1=Ns-N         //increase in speed from no load to full torque rpm
Wms=2*%pi*Ns/60
s=(Ns-N)/Ns     //full load slip

//(i)to obtain the plot between the breakdown torque and the frequency
K=0.1
k=[]
frequency=[]
torque=[]
for i=0:8
K=K+0.1
f1=K*f
x=Rs/K+sqrt((Rs/K)**2+(Xs+Xr_)**2)
Tmax=(3/2/Wms)*(Vl/sqrt(3))**2/x
k($+1)=K
frequency($+1)=f1
torque($+1)=Tmax
end
disp(k,"K:")
disp(frequency,"f:in Hz")
disp(torque,"Tmax:in N-m")

//Plotting the values of Tmax vs f
plot(frequency,torque)
xgrid(2)
xlabel('f,Hz')
ylabel('Tmax,N-m')
title('Torque vs frequency characteristic')

//(ii) to obtain the starting torque and current at rated frequency and voltage
```

```
x=(Rs+Rr_)**2+(Xs+Xr_)**2
Tst=(3/Wms)*(Vl/sqrt(3))**2*Rr_/x      //starting
    torque at 50 Hz frequency
Ist=(Vl/sqrt(3))/sqrt(x)          //starting current
    at 50 Hz frequency

K=fmin/fmax      //minimum is available at 10 Hz
y=((Rs+Rr_)/K)**2+(Xs+Xr_)**2
Tst_=(3/Wms)*(Vl/sqrt(3))**2*Rr_/K/y      //starting
    torque at 10 Hz frequency
Ist_=(Vl/sqrt(3))/sqrt(y)          //starting
    current at 10 Hz frequency

ratio1=Tst_/Tst    //ratio of starting torque to the
     rated starting torque
ratio2=Ist_/Ist    //ratio of starting current to
    the rated starting current

//Results
mprintf("\n(i)Hence from the plot we can see that
    for a constant (V/f) ratio breakdown torque
    decreases with frequency")
mprintf("\n(ii)Hence the required ratio of starting
    torque to the rated starting torque is :%.3f",
    ratio1)
mprintf("\nHence the required ratio of starting
    current to the rated starting current is :%.2f",
    ratio2)
```

Scilab code Exa 6.10 Q10

```
//Chapter 6:Induction Motor Drives
//Example 10
clc;
clf();
```

```
//Variable Initialization
//ratings of the star connected squirrel Induction motor is same as that of Ex-6.9
f=50             // frequency in HZ
Vl=400           // line voltage in V
P=4              // number of poles
N=1370           // rated speed

//the frequency variation is from 5 Hz to 50 Hz
fmin=5
fmax=50
//parameters referred to the stator
Xr_=3.5          // rotor winding reactance in ohm
Xs=Xr_           // stator winding reactance in ohm
Rr_=3            // resistance of the rotor windings in ohm
Rs=2             // resistance of the stator windings in ohm

//calculation
Ns=120*f/P       //synchronous speed
N1=Ns-N          //increase in speed from no load to full torque rpm
Wms=2*%pi*Ns/60
s=(Ns-N)/Ns      //full load slip
Tmax=54.88    //maximum torque as obtain from Ex-6.9

//to obtain the plot between the voltage and the frequency
K=0
k=[]
frequency=[]
line_voltage=[]
for i=0:9
K=K+0.1
f1=K*f
x=2*K*Wms*Tmax/3
y=Rs+sqrt((Rs)**2+(K*(Xs+Xr_))**2)
```

```
Vl_square=3*x*y
Vl=sqrt(Vl_square)
k($+1)=K
frequency($+1)=f1
line_voltage($+1)=Vl
end
disp(k,"K:")
disp(frequency,"f:in Hz")
disp(line_voltage,"Vl:in V")

//Plotting the values of line voltage Vl vs f
plot(frequency,line_voltage,'b')
xlabel('f,Hz')
ylabel('Line voltage,volts')
xgrid(2)
title('Line voltage  vs Frequency characteristic')
//for constant V/f ratio
x=[0,10,20,30,40,50]
y=[0,80,160,240,320,400]
plot(x,y,'--')
str=["$\underleftarrow{\huge{Constant V/f  ratio}}$"
  ]
xstring(21,160,str)

mprintf("\nHence for a constant breakdown torque at
  all frequencies,")
mprintf("\nV/f ratio has to be progressively
  increased with increase in frequency")
```

Scilab code Exa 6.11 Q11

```
//Chapter 6:Induction Motor Drives
//Example 11
clc;

```

```
//Variable Initialization

//Ratings of the star connected squirrel Induction
   motor are same as that of Ex-6.9
f=50              // frequency in HZ
Vl=400            // line voltage in V
P=4               // number of poles
N=1370            // rated speed

//Parameters referred to the stator
Xr_=3.5           // rotor winding reactance in ohm
Xs=Xr_            // stator winding reactance in ohm
Rr_=3             // resistance of the rotor windings
   in ohm
Rs=2              // resistance of the stator windings
   in ohm

//Solution
Ns=120*f/P        //synchronous speed
N1=Ns-N           //increase in speed from no load to
   full torque rpm
Wms=2*%pi*Ns/60 //synchronous speed
s=(Ns-N)/Ns       //full load slip
D=Ns-N           //drop in speed from no load to full
   load torque at 50 Hz

//(i)When the frequency is 30 Hz and 80% of full
   load torque
f1=30             //given frequency in Hz
d=D*0.8           //drop in speed from no load to 80%
   full load torque
Ns1=120*f1/P      //synchronous speed at the given
   frequency f1=30 Hz
N1=Ns1-d          //required motor speed

//(ii)When the speed is 1000 rpm for a full load
   torque
N2=1000          //given speed in rpm
```

```
Ns2=N2+D        //synchronous speed
f2=P*Ns2/120    //required frequency

//When the speed is 1100 rpm and the frequency is 40 Hz
N3=1100         //given speed in rpm
f3=40           //given frequency in Hz
Ns3=120*f3/P    //synchronous speed at the given frequency f1=40 Hz
D1=Ns3-N3       //drop in speed from no load to N1=1100 rpm
x=(Rs+Rr_/s)**2+(Xs+Xr_)**2
Tf=(3/Wms)*(Vl/sqrt(3))**2*(Rr_/s)/x        //full load torque
T1=D1/D*Tf      //required torque


//results
mprintf("(i)Hence the required motor speed is :%d rpm",N1)
mprintf("\n(ii)Hence the required frequency is :%.2f Hz",f2)
mprintf("\n(iii)Hence the required torque is :%.2f N-m",T1)
```

Scilab code Exa 6.12 Q12

```
//Chapter 6:Induction Motor Drives
//Example 12
clc;

//Variable Initialization

//Ratings of the star connected Induction motor are same as that of Ex-6.9
```

```
f=50            // frequency in HZ
Vl=400          //line voltage in V
P=4             // number of poles
N=1370          //rated speed

//Parameters referred to the stator
Xr_=3.5         // rotor winding reactance in ohm
Xs=Xr_          // stator winding reactance in ohm
Rr_=3           // resistance of the rotor windings in ohm
Rs=2            // resistance of the stator windings in ohm

//Solution
Ns=120*f/P      //synchronous speed
N1=Ns-N         //increase in speed from no load to full torque rpm

//(i)When f1=30Hz and 80% of full load
Ns=120*f/P
f1=30           //frequency
N2=0.8*N1       //increase in speed from no load to 80% of full torque rpm
Ns1=f1/f*Ns
N=Ns1+N2        //machine speed

//(ii)At a speed of 1000rpm
N2=1000          //given speed in rpm
N3=N2-N1         //synchronous speed
f3=P*N3/120      //required frequency

//(iii)When frequency is 40Hz and speed is 1300 rpm
f4=40           //frequency in hz
N2=1300         //speed in rpm
Ns=120*f4/P     //required synchronous speed in rpm
N4=N2-Ns        //increase in speed from no load speed in rpm
Tf=25.37        //full load torque as calculated in
```

```
   Ex-6.11
Tm=-N4/N1*Tf    //motor torque

//(iv) when the motor is under dynamic braking


//Results

mprintf("(i)Required speed is :%d rpm",N)
mprintf("\n(ii)Required frequency is:%d Hz",f3)
mprintf("\n(iii)Required motor torque :%.2f N-m",Tm)
mprintf("\n(iv)The value of the frequency,speed and
   motor torque calculated in (i),(ii) and(iii)")
mprintf("     \nwill be the same when the motor is
   operated under dynamic braking")
```

Scilab code Exa 6.13 Q13

```
//Chapter 6:Induction Motor Drives
//Example 13
clc;

//Variable Initialization

//Ratings of the star connected Induction motor are
   same as that of Ex-6.9
f=50            // frequency in HZ
Vl=400          //line voltage in V
P=4             // number of poles
N=1370          //rated speed

//Parameters referred to the stator
Xr_=3.5         // rotor winding reactance in ohm
Xs=Xr_          // stator winding reactance in ohm
Rr_=3           // resistance of the rotor windings
```

```
    in ohm
Rs=2              // resistance of the stator windings in ohm

//Solution
Wms=4*%pi*f/P
f1=60             //frequency in Hz during speed control of the motor
K=f1/f            //the value of K at 60Hz
x=Rs+sqrt(Rs**2+K**2*(Xs+Xr_)**2)
Tmax_=3/(2*K*Wms)*(Vl/sqrt(3))**2/x        //torque at 60 Hz frequency
z=Rs+sqrt(Rs**2+(Xs+Xr_)**2)
Tmax=3/(2*Wms)*(Vl/sqrt(3))**2/z           //maximum torque
ratio=Tmax_/Tmax  //ratio

//Result
mprintf("Ratio of Motor breakdown torque at 60Hz to rated torque at 50Hz is:%.3f",ratio)
```

Scilab code Exa 6.14 Q14

```
//Chapter 6:Induction Motor Drives
//Example 14
clc;

mprintf("When operating at a frequency K times rated  frequency f then")
mprintf("\nIm**2=[((Rr_/Ksf)**2+(2*pi*Lr_)**2)/((Rr_/Ksf)**2+(2*pi*Lm+2*Pi*Lr_)**2)]*Is**2----(1)")
mprintf("\nSince Im is constant for constant flux,")
mprintf("\nK*s*f=constant--------(2)")
mprintf("\nK*Wms*s=constant-------(3) which is the slip speed")
```

```
mprintf("\ns*K=constant----------(4)")
mprintf("\nThereofre for a frequency K*f")
mprintf("\nT=(3/K/Wms)*[(Is*K*Xm)**2*(Rr_/s)/((Rr_/s
   )**2+K**2*(Xm+Xr_)**2]")
mprintf("\nT=(3/K/Wms*s)*[(Is*Xm)**2*(Rr_)/((Rr_/s/K
   )**2+(Xm+Xr_)**2]--------(5)")
mprintf("\nHence for a given slip speed (K*Wms*s),K*
   s is constant and from (1) for a given K*s*f and
   constant flux")
mprintf("\noperation Is is fixed. Now from (5) T is
   also fixed. Thus, motor develps a constant torque
    and draws a")
mprintf("\nconstant current from the inverter at all
    frequencies for a given slip speed")
```

Scilab code Exa 6.15 Q15

```
//Chapter 6:Induction Motor Drives
//Example 15
clc;

//Variable Initialization

//Ratings of the star connected Induction motor
f=50            // frequency in HZ
Vl=400          //line voltage in V
P=4             // number of poles
N=1370          //rated speed
//Parameters referred to the stator
Xr_=3.5         // rotor winding reactance in ohm
Xs=Xr_          // stator winding reactance in ohm
Rr_=3           // resistance of the rotor windings
   in ohm
Rs=2            // resistance of the stator windings
   in ohm
```

```
Xm=55           // magnetizing reactance in ohm

//Solution
Wms=4*%pi*f/P
Ns=120*f/P      //synchronous speed in rpm
s=(Ns-N)/Ns     //full load slip
x=%i*Xm*(Rr_/s+%i*Xr_)
y=Rr_/s+%i*(Xr_+Xm)
Z=Rs+%i*Xs+x/y        //total motor impedance
Isf=(Vl/sqrt(3))/abs(Z)                   //full load stator current
Irf_=Isf*(%i*Xm)/(Rr_/s+%i*(Xr_+Xm))          //full load rotor current
Tf=(3/Wms)*abs(Irf_)**2*Rr_/s                 //full load  torque
N1=Ns-N         //full load slip speed
//(i) When the motor is operating at 30Hz
f1=30           //given frequency in Hz
//At rated slep speedvalue of torque and stator current is same as the rated value
T=Tf
Is=abs(Isf)
Ns1=f1/f*Ns     //synchronous at f1=30Hz
N2=Ns1-N1       //required motor speed at 30Hz

//(ii)At a speed of 1200 rpm
N3=1200        //speed in rpm
Ns1=N3+N1      //required synchronous speed
f1=Ns1/Ns*f    //required frequency at N2=1200rpm

//(iii)When speed-torque curves are assumed to be straight lines at 30Hz at half the rated motor torque
f2=30           //frequency in Hz
N1_=N1/2        //slip at half the rated torque
Ns1=f2/f*Ns     //synchronous at f1=30Hz
N4=Ns1-N1_      //required motor speed

```

```
//(iv) When the motor is operating at 45hz  and
    braking torque is equal to rated torque
f3=45            //given frequency in Hz
N1_=-N1          //slip speed when braking at rated
    torque
Ns1=f3/f*Ns      //synchronous at f1=45Hz
N5=Ns1-N1_       //required motor speed


//results
mprintf("(i)At 30Hz the required value of Torque is
    T:%.2f N-m",T)
mprintf("\nStator current is Is:%.4f A",Is)
mprintf("\nMotor speed is :%d rpm",N2)
mprintf("\n(ii)Required inverter frequency is :%.2f
    Hz",f1)
mprintf("\n(iii)Required motor speed at 30Hz is:%d
    rpm",N4)
mprintf("\n(iv)Required motor speed at 45Hz is:%d
    rpm",N5)
```

Scilab code Exa 6.16 Q16

```
//Chapter 6:Induction Motor Drives
//Example 16
clc;

//Variable Initialization

//Ratings of the Delta connected slipring Induction
    motor
f=50             // frequency in HZ
Vl=400           //line voltage in V
P=6              // number of poles
SR=2.2           //ratio of stator to rotor
```

```

//Parameters referred to the stator
Xr_=1           // rotor winding reactance in ohm
Rr_=0.2         // resistance of the rotor windings in ohm
s=0.04          // given slip when motor runs at full load

//Solution
Ns=120*f/P      //synchronous speed
Wms=2*%pi*Ns/60
x=(Rr_/s)**2+Xr_**2
Tf=(3/Wms)*(Vl)**2*(Rr_/s)/x        //full load torque
K=Tf/(Ns*(1-s))**2
N=850                   //speed of the motor in rpm
Tl=K*N**2               //torque at the given speed N
s=(Ns-N)/Ns             //slip at the given speed N
y=Tl*(Wms/3)/Vl**2      //y=X/(X**2+Xr_**2) and X=(Re+Rr_)/s

mprintf("\nThe torque at the given speed of 850rpm is:%d N-m",Tl)
mprintf("\nWith a slip of s:%.2f",s)
mprintf("\nTo find the external resistance connected the given quadratic equation is X**2-6.633X+1=0")
mprintf("\nWith X=(Re-Rr_)/s where Re is the required external resistance")

a = 1
b = -1/y
c = 1

//Discriminant
d = (b**2) - (4*a*c)

X1 = (-b-sqrt(d))/(2*a)
```

```
X2 = (-b+sqrt(d))/(2*a)

//Results
mprintf("\nThe solutions for X are %.4f and %.4f",X1,X2)
Re1=X1*s-Rr_
Re2=X2*s-Rr_

if (Re1>0) then :
mprintf("\nThe number Re1:%.3f ohm is feasible",abs(Re1))
R=Re1/SR**2
mprintf("\nRotor referred value of the external resistance is:%.3f ohm",R)
end

if (Re2>0) then
mprintf("\nThen  Re2:%.3f ohm is feasible",abs(Re2))
R=Re2/SR**2
mprintf("\nHence Rotor referred value of the external resistance is:%.3f ohm",R)
end
```

Scilab code Exa 6.17 Q17

```
//Chapter 6:Induction Motor Drives
//Example 17
clc;

//Variable Initialization

//Ratings of the star connected Induction motor
f=50            // frequency in HZ
Vl=440          //line voltage in V
P=6             // number of poles
```

```
Ns=120*f/P      //synchronous speed

//Parameters referred to the stator
Xr_=1.2         // rotor winding reactance in ohm
Xs=Xr_          // stator winding reactance in ohm
Rr_=0.4         // resistance of the rotor windings in ohm
Rs=0.5          // resistance of the stator windings in ohm
Xm=50           // magnetizing reatance
a=3.5           // stator to rotor turns ratio
delta=0         // duty ratio  at the given breakdown torque
Sm=1            // slip at standstill

//Solution

//Slip at maximum torque without an external resistance is Sm=Rr_/sqrt(Rs**2+(Xs+Xr_)**2)
//When an external resistanc Re referred to the stator is connected
x=Sm*sqrt(Rs**2+(Xs+Xr_)**2)      //x=Re+Rr_
Re=x-Rr_
y=0.5*a**2*(1-delta)     // y=0.5*a**2*R*(1-delta)  //y=Re
R=Re/y

//(Ns-N)/Ns
//(Ns/Ns)-(N/Ns)
Sm=(Ns/Ns)-(1/Ns)
c=(x*Sm-Rr_)/(0.5*a**2*R)   //c=(1-delta)
delta=1-c                   //given duty ratio

//Results
mprintf("Variation of the duty ratio is:%.3f*N*10**(-3)",delta*1000)
mprintf("\nHence the duty ratio must change linearly with speed N")
```

Scilab code Exa 6.18 Q18

```
//Chapter 6:Induction Motor Drives
//Example 18
clc;

//Variable Initialization

//Ratings of the star connected Induction motor
f=50          // frequency in HZ
Vl=440        // line voltage in V
P=6           // number of poles
N=970         // rated speed
n=2           // ratio of stator to rotor
Sm=0.25       // it is given the speed range is 25%
   below the synchronous speed which is proportional
    to the Slip

//Parameters referred to the stator
Xr_=0.4       // rotor winding reactance in ohm
Xs=0.3        // stator winding reactance in ohm
Rr_=0.08      // resistance of the rotor windings in
   ohm
Rs=0.1        // resistance of the stator windings in
    ohm
alpha=165     // maximum value of the firing angle in
    degress

//Solution
Ns=120*f/P    // synchronous speed
Wms=2*%pi*Ns/60
//(i) transformer turns ratio
al=alpha*(%pi/180)
a=-Sm/cos(al)  //since  Sm=a*math.cos(alpha)
```

```
m=n/a          //since a=n/m where m is the transformer ratio

//(ii)When speed is 780 rpm and firing angle is 140 degrees
N1=780             //given speed
alpha1=140         //given firing angle
s1=(Ns-N1)/Ns      //slip at the given speed N1
Vd1=(3*sqrt(6)/%pi)*s1*(Vl/sqrt(3))/n
al1=alpha1*(%pi/180)
Vd2=(3*sqrt(6)/%pi)*(Vl/sqrt(3))/m*cos(al1)
Rs_=Rs*(1/n)**2    //stator resistance referred to the rotor
Rr=Rr_*(1/n)**2    //rotor resistance referred to the rotor
Rd=0.01            //equivalent resistance of the DC link inductor
Id=(Vd1+Vd2)/(2*(s1*Rs_+Rr)+Rd)
T1=abs(Vd2)*Id/s1/Wms      //required torque

//(iii)when speed is 800rpm and firing angle is half the rated motor torque
N1=800             //given speed
s=(Ns-N)/Ns        //rated slip
x=(Rs+Rr_/s)**2+(Xs+Xr_)**2
Trated=(3/Wms)*(Vl/sqrt(3))**2*(Rr_/s)/x           //rated torque
T_half=Trated/2          //half rated torque
s1=(Ns-N1)/Ns            //given slip at speed N1=800 rpm
Vd1=(3*sqrt(6)/%pi)*s1*(Vl/sqrt(3))/n
Vd2=(3*sqrt(6)/%pi)*(Vl/sqrt(3))/m
Id=(Vd1+Vd2)/(2*(s1*Rs_+Rr)+Rd)
T=abs(Vd2)*Id/s1/Wms      //required torque

//since the given torque is half of the rated value
//To find the find the firing angle we assumed cos(alpha1)=-X
```

```
//The given quadratic equation is X**2-0.772X
    +0.06425=0
a = 1
b = -0.772
c = 0.06425
//Discriminant
d = (b**2) - (4*a*c)

X1 = (-b-sqrt(d))/(2*a)
X2 = (-b+sqrt(d))/(2*a)
alpha1=-acos(X2)   //since cos(alpha1)=-X where
    alpha1 is radians
alpha1=alpha1*(180/%pi)
alpha1=180+alpha1              //required firing angle


//Results
mprintf("(i)Transformer ratio is:%.3f",m)
mprintf("\n(ii)Required torque is :%.2f N-m",T1)
//There is a slight difference in the answer for the
     torque due to accuracy
mprintf("\n(iii)The half rated torque at the given
    speed of %d rpm is:%.2f N-m",N1,T_half)
mprintf("\nWith a slip of s:%.1f",s1)
mprintf("\nThe solutions for X are %.4f and %.4f",X1
    ,X2)
mprintf("\nFor X1:%.4f the motor is unstable so we
    use X2:%.4f",X1,X2)
mprintf("\nHence the required firing angle is :%.1f
      ",alpha1)
```

Scilab code Exa 6.19 Q19

```
//Chapter 6:Induction Motor Drives
//Example 19
```

```
clc;

//Variable Initialization

//Ratings of the star connected Induction motor is same as that of Ex-6.17
f=50            // frequency in HZ
Vs=440          // line voltage in V
P=4             // number of poles
//Parameters referred to the stator
Xr_=1.2         // rotor winding reactance in ohm
Xs=Xr_          // stator winding reactance in ohm
Rr_=0.4         // resistance of the rotor windings in ohm
Rs=0.5          // resistance of the stator windings in ohm
Xm=50           // magnetizing reatance
a=3.5           // stator to rotor turns ratio

//Solution
Ns=120*f/P                // synchronous speed in rpm
Wms=2*%pi*Ns/60      // synchronous speed in rad/s

//(i)When motor speed is 1200rpm with a voltage of 15+0j V

V=15*(cos(0)+sin(0)*%i)
N1=1200  //speed in rpm
Vr_=a*V          //rotor voltage
s1=(Ns-N1)/Ns    //slip at the given speed N1=1200 rpm
Z=Rs+Rr_/s1+%i*(Xs+Xr_)                    //total impedance
Ir_=(Vs/sqrt(3)-Vr_/s1)/Z            //rotor current
phi_r=atan(imag(Vr_),real(Vr_))-atan(imag(Ir_),real(Ir_))//angle between Vr_ and Ir_
Pr=3*(abs(Ir_))**2*Rr_                     //rotor copper loss
```

```
P1=3*abs(Vr_)*abs(Ir_)*cos(phi_r)     //power absorbed by Vr_
Pg=(Pr+P1)/s1                         //gross power
T=Pg/Wms                              //required motor torque

//(ii)when motor speed is 1200rpm with a unity power factor
N1=1200  //speed in rpm
Ir_=abs(Ir_)
Ir_=Ir_*(cos(0)+sin(0)*%i)//machine is operating at unity power factor
x=Ir_*Z                                 //x=(Vs-Vr_/s1)*phi_r where phi_r is the angle between Vr_ and Ir_

//x=a+b
d=(Vs/sqrt(3)-Vr_/s1*cos(phi_r))**2
e=(Vr_/s1*sin(phi_r))**2
f=x/(d+e)
theta=atan(imag(f),real(f))//required angle in radian
theta=theta*180/%pi
//Now we should solve for the quadratice equation for the rotor current
//  0.9*Ir_**2 + 50.8*Ir_ + 90.12 = 0
a1 = 0.9
b1 = 50.8
c1 = 90.12

//Discriminant
d = (b1**2) - (4*a1*c1)

Ir_1 = (-b1-sqrt(d))/(2*a1)
Ir_2 = (-b1+sqrt(d))/(2*a1)

Ir_=Ir_2              //Ir_2 is chosen because for Ir_1 the motor is unstable
Vr_sin_phi_r=abs(Ir_)/2.083
Vr_cos_phi_r=s1*(Vs/sqrt(3)+2.5*Vr_sin_phi_r)
```

```
Vr_=Vr_cos_phi_r+%i*Vr_sin_phi_r    //total rotor
    voltage referred to the stator
Vr_=Vr_/a                           //total  rotor
    voltage referred to the rotor
var=atan(imag(Vr_),real(Vr_))
phase=var*180/%pi

//Results
mprintf("(i)The torque is :%.2f N-m and since it is
    negative the motor is operating in regenerative
    braking ",T)
mprintf("\n(ii)Now theta    :%.2f     ",theta)
mprintf("\nThe solution for Ir_ are %.3f and %.3f",
    Ir_1,Ir_2)
mprintf("\nWe choose Ir_:%.3f A since higher value
    corresponds to unstable region",Ir_2)
mprintf("\nHence the required voltage magnitude is
    Vr:%.2f V,phase:%.1f     ",Vr_,phase)
//There is a slight difference in the answers due to
     accuracy
```

Scilab code Exa 6.20 Q20

```
//Chapter 6:Induction Motor Drives
//Example 20
clc;

//Variable Initialization

//Ratings of the single phase Induction motor
f=50             // frequency in HZ
Vs=220           // supply voltage in V
P=4              // number of poles
N=1425           // rated speed in rpm

```

```
//Parameters referred to the stator
Xr_=6          // rotor winding reactance in ohm
Xs=Xr_         // stator winding reactance in ohm
Rr_=5          // resistance of the rotor windings in ohm
Rs=2           // resistance of the stator windings in ohm
Xm=60          // magnetizing reatance

//Solution
N1=1200      //when the motor is operating at the given speed in rpm
Ns=120*f/P   // synchronous speed
Wms=2*%pi*Ns/60
s=(Ns-N)/Ns   //rated slip

Zf=%i*(Xm)*(Rr_/s+%i*Xr_)/2/(Rr_/s+%i*(Xr_+Xm))
Rf=real(Zf)
Xf=imag(Zf)
Zb=%i*(Xm)*(Rr_/(2-s)+%i*Xr_)/2/(Rr_/(2-s)+%i*(Xr_+Xm))
Rb=real(Zb)
Xb=imag(Zb)
Zs=Rs+%i*Xs
Z=Zs+Zf+Zb
Is=(Vs)/Z
T=(abs(Is))**2/Wms*(Rf-Rb)
Tl=T
K=Tl/N**2

//Therefore for a speed of  of N1=1200 rpm we get
Tl=K*N1**2      //required load torque for the given speed N1
s1=(Ns-N1)/Ns   // slip for the given speed N1

Zf=%i*(Xm)*(Rr_/s1+%i*Xr_)/2/(Rr_/s1+%i*(Xm))
Rf=real(Zf)
Xf=imag(Zf)
```

```
Zb=%i*(Xm)*(Rr_/(2-s1)+%i*Xr_)/2/(Rr_/(2-s1)+%i*(Xr_
    +Xm))
Rb=real(Zb)
Xb=imag(Zb)
x=(Wms*Tl)/(Rf-Rb)      //since Tl=(abs(Is))**2/Wms*(
    Rf-Rb)    and x=Is**2
Is=sqrt(x)
Z=Zs+Zf+Zb
V=Is*abs(Z)

//Result
mprintf("Hence the motor terminal voltage at the
    speed of%d rpm is :%.1f V",N1,V)
```

Chapter 7

Synchronous Motor and Brushless Dc Motor Drives

Scilab code Exa 7.1 Q1

```
//Chapter 7:Synchronous Motor and Brushless DC Motor
    Drives
//Example 1
clc;

//Variable Initialization

//Ratings of the synchronous motor
Pm1=500*1000    // power rating in W
f=50            // frequency in HZ
Vl=3.3*1000     // line voltage in V
pf=0.8          // power factor lagging
P=4             // number of poles
I=10            // field current in A
Xs=15           // reactance of the windings in ohm
Rs=0            // resistance of the windings in ohm
Wms=50*%pi // synchronous speed in rad/sec
Pm=Pm1/2        // power at half the rated torque
   when the losses are neglected
```

```

//Solution
V=Vl/sqrt(3)  //phase voltage
Is=Pm1/(sqrt(3)*Vl*pf)   //rated current
rad=acos(pf)

Is=Is * (cos(-rad) + sin(-rad)*%i)   //rated current
    in vector form
V=V * (cos(0) + sin(0))       //rated phase voltage
   in rectangular form
E=V-Is*%i*Xs                  //back emf

//(i) When field current has not changed
sin_delta=Pm*Xs/(3*abs(V)*abs(E))
delta=asin(sin_delta)                  //angle delta
Is=(V-(abs(E) * (cos(-delta) + sin(-delta)*%i)))/(%i
   *Xs)   //armature current
Is1=[]
Is1(1)=abs(Is)
Isp=phasemag(Is)
x=Isp
n1=x*%pi/180
power_factor=cos(n1)    //power factor

//(ii) At unity power factor and rated torque
cos_phi=1
Is=Pm1/(3*V)         //since Pm1=3*V*Is
E1=V-Is*%i*Xs
If=abs(E1)/abs(E)*I  //field current

//(iii) At the field current of 12.5 A
If1=12.5      //field current
E2=If1/I*abs(E)
Is=sqrt(E2**2-abs(V)**2)/Xs  //since E2=abs(V-Is*1j*
   Xs)
Pm=3*abs(V)*Is*cos_phi             //power output at
   the given field current
T=Pm/Wms                           //required torque
```

```
//results
mprintf("i)Armature current :%.2f %.1f    A",abs(Is1
   ),x)
mprintf("\nPower factor:%.2f lagging",power_factor)
mprintf("\nii)Field current at unity power factor at
    rated torque:%.2f A",If)
mprintf("\niii)Required torque is:%.1f N-m",T)
//There is a slight difference in the answer
```

Scilab code Exa 7.2 Q2

```
//Chapter 7:Synchronous Motor and Brushless DC Motor
    Drives
//Example 2
clc;

//Variable Initialization

//Ratings of the synchronous motor is same as that
   of Example-7.1
Pm1=500*1000    // power rating in W
f=50            // frequency in HZ
Vl=3.3*1000     // line voltage in V
pf=0.8          // power factor lagging
P=4             // number of poles
I=10            // field current in A
Xs=15           // reactance of the windings in ohm
Rs=0            // resistance of the windings in ohm
Pm=Pm1/2        // power at half the rated torque
   when the losses are neglected

//Solution
Wms=50*%pi      // synchronous speed in rad/sec
V=Vl/sqrt(3)   // phase voltage
```

```
Is=Pm1/(sqrt(3)*Vl*pf)  //rated current
rad=acos(pf)

Is=Is * (cos(-rad) + sin(-rad)*%i) //rated current in vector form
V=V * (cos(0) + sin(0))        //rated phase voltage in rectangular form
E=V-Is*%i*Xs                          //back emf

//(i) at rated current and unity power factor
E1=V-abs(Is)*%i*Xs
delta=phasemag(E1)        //phase angle of E1
nd=delta*%pi/180
Pm=3*abs(V)*abs(E1)*sin(nd)/Xs    //mechanical power developed
T=Pm/Wms                    //braking torque
If=abs(E1)/abs(E)*I       //field current

//(ii) at field current of 15A and 500kW output
If1=15               //field current
Pm=-500*1000     //output power
E2=If1/I*abs(E)
sin_delta=Pm*Xs/(3*abs(V)*abs(E2))
delta=asin(sin_delta)                    //angle delta
Is=((E2*(cos(abs(delta))+sin(abs(delta))*%i))-V)/(%i*Xs) //armature current
Isn=phasemag(Is)
x=(Isn)*%pi/180          //phase angle of Is
power_factor=cos(x) //power factor


//Results
mprintf("i)Braking torque :%.1f N-m",T)
mprintf("\nField current:%.2f A",If)
mprintf("\nii)Armature current :%.2f %.2f    A",abs(Is),Isn)
mprintf("\nPower factor:%.3f lagging",power_factor)
//Note :There is a slight difference in the answers
```

Scilab code Exa 7.3 Q3

```
//Chapter 7:Synchronous Motor and Brushless DC Motor
    Drives
//Example 3
clc;

//Variable Initialization

//Ratings of the synchronous motor
Pm1=6*10**6      // power rating in W
f=50             // frequency in HZ
Vl=11*1000       // line voltage in V
pf=0.9           // power factor leading
P=6              // number of poles
I=10             // rated field current in A
Xs=9             // reactance of the windings in ohm
Rs=0             // resistance of the windings in ohm
N=120*f/P        // synchronous speed

//Solution
V=Vl/sqrt(3)             //phase voltage
Is=Pm1/(sqrt(3)*Vl*pf)   //rated current
rad=acos(pf)

//(i)To find torque and field current at rated
   armature current
//   at 750 rpm and 0.8 leading power factor
Is=Is * (cos(rad) + sin(rad)*%i)     //rated current
   in vector form
V=V *(cos(0)+sin(0)*%i)
E=V-Is*%i*Xs                      //back emf

N1=750           //speeed in rpm
```

```
pf1=0.8          //given leading power factor
f1=N1/N*f        //required frequency
V1=abs(V)*f1/f   //required voltage
Xs1=Xs*f1/f      //required field resistance
E1=V1-Xs1*%i*(abs(Is) * (cos(acos(pf1))+sin(acos(pf1))*%i))   //rated back emf  in complex form
E1_polar=abs(E1)                              //rated back emf in rectangular form

//At rated field current and 750 rpm
E2=abs(E)*N1/N                 //back emf at the given speed N1
If=abs(E1)/E2*f                //field current at the given speed N1
Pm=3*abs(V1)*abs(Is)*pf1       //power input at the given speed N1
Wm1=2*%pi*N1/60            //angular motor speed in rad/s
T=Pm/Wm1

//(ii) At half the rated motor torque and 1500 rpm and rated field current
Pm=6*10**6        //rated power rating in W
N1=1500           //speeed in rpm
f1=N1/N*f         //required frequency
Xs1=f1/f*Xs       //required field resistance
E1=abs(E)*f1/f    //back emf at rated field current


Wms=Pm
Wms_=N1/N*Wms
Pm_= (0.5)*Wms_          //required power developed at N1=1500 rpm

sin_delta=Pm_*Xs1/(3*abs(V)*abs(E1))        //since Pm=3*abs(V)*abs(E1)*sin(delta)/Xs
delta=asin(sin_delta)                       //angle delta
Is=(abs(V)-(E1 * (cos(-delta)+sin(-delta)*%i)))/(%i*
```

```
Xs1) //armature current
Is1=polar(Is)                                //aramture current in rectangular form
x1=phasemag(Is)
x1n=x1*%pi/180
power_factor1=cos(x1n)                       //power factor

//(iii) at 750 rpm and rated field current from part (i)
N1=750          //speeed in rpm
pf1=0.8         //given leading power factor
f1=N1/N*f       //required frequency at N1=750 rpm
V1=abs(V)*f1/f  //required voltage at N1=750 rpm
Xs1=Xs*f1/f     //required field resistance
E2=abs(E)*N1/N

Pm=-4.2*10**6 //braking power output
sin_delta=Pm*Xs1/(3*abs(V1)*abs(E2))        //since Pm=3*abs(V)*abs(E1)*math.sin(delta)/Xs
delta=asin(sin_delta)                        //angle delta
Is=(E2 * (cos(abs(delta))+sin(abs(delta))*%i)-V1)/(%i*Xs1) //armature current
Is2=polar(Is)                                //aramture current in rectangular form
x2=phasemag(Is)
x2n=x2*%pi/180
power_factor2=cos(x2n) //power factor

//(iv)from part (ii) at 1500 rpm and from part(iii) the armature current of 349.9 A is taken
Is=Pm1/(sqrt(3)*Vl*pf)          //armature current as given from (i)
N1=1500             //speeed in rpm
f1=N1/N*f           //required frequency at N1=1500 rpm
Xs1=f1/f*Xs         //required field resistance
E1=abs(E)*f1/f      //at rated field current
E2=V-%i*Xs1*Is
```

```
E2ph=abs(E2)
E2n=phasemag(E2)
E2na=E2n*%pi/180
If1=abs(E2ph)/abs(E1)*f    //required field current
Pm=3*abs(V)*(E2ph)*sin(abs(E2na))/Xs1    //power input
Wm1=2*%pi*N1/60    //motor speed in rad/sec
T1=Pm/Wm1

//Results
mprintf("\ni)Required torque is:%.1f N-m",T)
mprintf("\nField current :%.2f A",If)
mprintf("\nii)Armature current :%.1f %.2f    A",abs(Is1),x1)
mprintf(" \nPower factor :%.1f leading",power_factor1)
mprintf("\niii)Armature current :%.2f %.2f    A",abs(Is2),x2)
mprintf("\nPower factor :%.3f lagging",power_factor2)
mprintf("\niv)Field current :%.2f A",If1)
mprintf("\nRequired torque is:%.1f N-m",T1)
//There is a slight difference in the answers
```

Scilab code Exa 7.4 Q4

```
//Chapter 7:Synchronous Motor and Brushless DC Motor Drives
//Example 4
clc;

//Variable Initialization

//Ratings of the synchronous motor
Pm=8*10**6      // power rating in W
```

```
f=50             // frequency in HZ
Vl=6600          // line voltage in V
pf=1             // unity power factor
P=6              // number of poles
I=10             // rated field current in A
Xs=2.8           // reactance of the windings in ohm
Rs=0             // resistance of the windings in ohm
Rd=0.1           // Dc link inductor resistance in ohms
alpha=140        // constant firing angle in degrees

//Solution
N=120*f/P                         //synchronous speed
V=Vl/sqrt(3)            //phase voltage
Is=Pm/(sqrt(3)*Vl*pf)   //rated current

Id=%pi/sqrt(6)*Is   //Dc line current
phi=180-alpha  //phase angle between Is and V in degrees

//(i) When motor operates at rated current and 500 rpm
N1=500     //motor speed in rpm
f1=N1/N*f  //frequency at N1
V1=f1/f*V  //voltge at N1
phi=phi*%pi/180
Pm1=3*V1*Is*cos(phi) //power developed by the motor
//for the 3-phase load commutated inverter
alpha=alpha*%pi/180
Vdl=(3*sqrt(6)/%pi)*V1*cos(alpha)
Vds=-Vdl+Id*Rd
cos_alpha_s=Vds/(3*sqrt(6)/%pi*V)
alpha_s=acos(cos_alpha_s)  //in radian
alpha_s1=alpha_s*180/%pi


//(ii) Regenerative braking at 500rpm and at rated motor current
```

```
alpha=0  //firing angle
//When firng angle is zero then power factor is
   unity
pf=1

Pm2=3*V1*Is*pf   //power developed by the motor
Ps=Pm2-Id**2*Rd  //power supplied to the source
Vdl=(3*sqrt(6)/%pi)*V1*cos(alpha)
Vds=-Vdl+Id*Rd
cos_alpha_s=Vds/(3*sqrt(6)/%pi*V)
alpha_s=acos(cos_alpha_s)   //in radian
alpha_s2=alpha_s*180/%pi   //in degrees

//Results
disp('W',Pm1,"i)Power developed by the motor is:")
disp('  ',alpha_s1,"Source side converter firing
   angle is")
disp('W',Ps,"ii)Power supplied to the source is:")
disp("  ",alpha_s2,"Source side converter firing
   angle is")
//Answer given for firing angle in the book is wrong
```

Chapter 10

Traction Drives

Scilab code Exa 10.1 Q1

```
//Chapter 10:Traction Drives
//Example 1
clc;

//Variable Initialization
Ma=480     //mass of each motor armature in kg  0.48
   tonne=480kg
Da=0.5     //average diameter of each motor in m
m=450      //mass of each wheel in kg
R=0.54     //radius of each wheel tread in m
M=40       //combine wight of one motor and one
   trailer coach in ton
alpha=5    //accelaration in metres per second
N=4        //number of DC motors
a=0.4      //gear ratio
r=20       //train resistance in ohms

//Solution
Jw=1/2*m*R**2    //inertia of the each wheel in kg
   metre square
nw=2*(N*2)       //total number of wheels
```

```
J1=nw*Jw          //total inertia of all the wheels in
    kg metre square

Jm=N*(1/2*Ma*(Da/2)**2)   //approximate inertia of
   all the motors in kg metre square
J2=Jm/a**2                //approximate innertia of
   the motor referred to the wheels in kg metre
   square

Fa2=(J1+J2)*alpha*1000/3600/R    //Tractive efforts
   for driving rorating parts
Fa1=277.8*M*alpha                //tractive efforts
   to accelerate the train mass horizontally
Fr=r*M                           //Tractive efforts
   required to overcome train resistance
Ft=Fa1+Fa2+Fr                    //Tractive efforts
   required to move the train
Tm=a*R*Ft/N                      //torque per motor

//Result
mprintf("\nTorque per motor: %.1f N-m",Tm)
```

Scilab code Exa 10.2 Q2

```
//Chapter 10:Traction Drives
//Example 2
clc;

//Variable Initialization
M=100        //mass of each motor armature in tonne
Me=100
Tm=5000      //torque of each motor in N-m
Da=0.5       //average diameter of each motor in m
m=450        //mass of each wheel in kg
R=0.54       //radius of each wheel tread in m
```

```
N=4          //number of DC motors
r=25         //train resistance N/tonne
a=0.25       //gear ratio
nt=0.98      //gear transmission efficiency
G=50         //up gradient
Vm=100       //speed in kmph

//Solution
Ft=nt*Tm*N/a/R      //Tractive efforts required to
   move the train
alpha=(Ft-(9.81*M*G+M*r))/(277.8*1.1*Me)   //
   accelaration in metre per second
t=Vm/alpha          //time taken to attain speed of
   Vm in sec

//Result
mprintf("\n Time taken to reach a speed of 100kmph
   is : t=%.1f sec",t)
```

Scilab code Exa 10.3 Q3

```
//Chapter 10:Traction Drives
//Example 3
clc;

//Variable Initialization
G=8         //up gradient
r=25        //train resistance N/tonne
M=500       //mass of the electric train in tonne
n=0.8       //combine effiency of transmission and
   motor

//Speed-Time curve characteristics
t1=60         //characteristic for uniform
   accelaration at v1 in sec
```

```
alpha=2.5    //given accelaration in km/hr/sec at t1
t2=5*60      //characteristic for constant speed in sec
t3=3*60      //characteristic for coasting in sec
B=3          //dynamic braking deceleration in km/hr/sec

//Solution
Vm=alpha*t1   //peak voltage in V
Fg=9.81*M*G   //tractive effort required to overcome the force of gravity
Fr=M*r        //tractive effort required to overcome the train resistance
F_bc=Fg+Fr    //retarding force during coasting in N

Me=1.1*M
B_c=F_bc/(277.8*Me)    //deceleration during coasting in metre per second square
V=Vm-B_c*t3            //speed after coasting in m/s
t4=V/B                 //characteristic for a dynamic braking of 3km/hr/sec

d1=1/2*Vm*t1/3600      //distance covered during accelaration
d2=Vm*t2/3600          //distance covered during constant speed
d3=1/2*(Vm+V)*t3/3600  //distance covered coasting
d4=1/2*V*t4/3600       //distance covered during braking
D=d1+d2+d3+d4          //distance during stops
D1=d1+d2
x=D1/D
y=1-x
E=(0.01072*Vm**2/D)*(Me/M)+2.725*G*x+0.2778*r*x    //specific energy output in Whptpkm
Eo=E/n    //specific energy consumption in Whptpkm

//Result
```

```
mprintf("\n Specific energy consumption is : Eo= %.1
    f Whptpkm",Eo)
```

Scilab code Exa 10.4 Q4

```
//Chapter 10:Traction Drives
//Example 4
clc;

//Variable Initialization
G=20                  //up gradient
r=25                  //train resistance N/tonne
M=500                 //mass of the electric train in
    tonne
n=0.8                 //combine effiency of transmission
     and motor

//Speed-Time curve characteristics
t1=50           //characteristic for uniform
    accelaration at v1 in sec
alpha=3         //given accelaration in km/hr/sec at t1
t2=10*60        //characteristic for constant speed in
    sec
B=2.5           //uniform braking deceleration in kmphs
    to rest

//Solution
Vm=alpha*t1   //peak voltage in V
t3=Vm/B        //characteristic for a uniform braking
    of B=2.5 kmphs

//(i)during accelaration total tractive effort
Me=1.1*M
Fta=277.8*Me*alpha-9.81*M*G+M*r    //total tractive
    effort during accelaration
```

```
Da=1/2*Vm*t1/3600      //distance covered during accelaration ,and t1 is in seconds
Ea=Fta*Da*1000/3600    //energy output during accleration in Wh

//(ii)during uniform speed net tractive effort
Ftu=-9.81*M*G+M*r      //total tractive effort during uniform speed
//Ftu in the book is −105220 N  which is wrong, hence the other answers are incorrect

Du=Vm*t2/3600          //distance traveled ,and t2 is in seconds
Eu=Ftu*Du*1000/3600    //energy output in Wh

//(iii)during braking net tractive effort
Ftb=-277.8*Me*B-9.81*M*G+M*r  //total tractive effort for the net braking
Db=1/2*Vm*t3/3600      //distance covered during braking
Eb=Ftb*Db*1000/3600    //energy output during braking in Wh

E=Ea/n+n*(Eu+Eb)       //net energy consumption in Wh
D=Da+Du+Db             //total distance traveled in km
Eo=E/(M*D)             //specific energy consumption in Wh

//Results
mprintf("(i)Energy consumption during accelaration is :Ea : %.1f Wh",Ea)
mprintf("\n(ii)Energy consumption during uniform speed is :Eu : %d Wh",Eu)
mprintf("\n(iii)Energy consumption during braking is :Eb : %.1f Wh",Eb)
mprintf("\n Net Energy consumption  is E : %.1f Wh",E)
```

```
mprintf("\n Total Distance traveled is D : %.4f km",
    D)
mprintf("\n Specific Energy consumption  is Eo : %.2
    f Whptpkm",Eo),
//Answers provided in the textbook are incorrect
```

Scilab code Exa 10.5 Q5

```
//Chapter 10:Traction Drives
//Example 5
clc;

//Variable Initialization
Mm=40        //weight of the motor coach in tonne
Mt=35        //weight of the trailer in tonne
u=0.2        //co-efficient of adhesion
r=30         //train resistance N/tonne

//Solution
//(a)when the motor to trailer ratio is 1:2
M=Mm+2*Mt      //weight of one unit
Me=1.1*M
Md=40          //weight on the driving wheels
Fm=9810*u*Md   //total tractive effort without the
    wheel
Ft=Fm          //at maximum accelaration
alpha=(Ft-M*r)/(277.8*Me) //required accelaration
    since Ft=277.8*u*alpha*M*r

//(b)when the motor to trailer ratio is 1:1
M=Mm+Mt        //weight of one unit
Me=1.1*M
Md=40          //weight on the driving wheels
Fm=9810*u*Md   //total tractive effort wihout the
    wheel
```

```
Ft=Fm           //at maximum accelaration
alpha1=(Ft-M*r)/(277.8*Me) //required accelaration
   since Ft=277.8*u*alpha*M*r


//Results
mprintf("(a)Maximum accelaration on a level track
   is alpha : %.4f kmphps",alpha)
mprintf("\n(b)Maximum accelaration when motor to
   trailer coaches ratio is 1:1 is alpha : %.3f
   kmphps",alpha1)
```

Scilab code Exa 10.6 Q6

```
//Chapter 10:Traction Drives
//Example 6
clc;

//Variable Initialization
G=10          //up gradient of the locomotive
Ml=110        //weight of the locomotive coach in
   tonne
Mt=500        //weight of the train in tonne
r=35          //train resistance N/tonne
n=0.8         //80% of the locomotive weight is
   carried by the driving wheels
alpha=1       //acelaration in kmphps

//Solution
//when only the 110 tonne locomotive is present
Md=Ml*n       //weight of the motor
M=Mt+Ml       //total mass of the train
Me=1.1*M
Ft=277.8*Me*alpha+9.81*M*G+M*r   //total tractive
   effort required to move the train
```

```
Fm=Ft
u=Fm/(9810*Md)    //co-efficient of adhesion ,since Fm=9810*u*Md

//when another locomotive of 70 is added together
Md=Ml*n+70        // mass of the motor
M_=Mt+Ml+70       // mass of the train
Fm=9810*u*Md
Ft=Fm
M=Ft/(277.8*1.1*alpha+9.81*G+r)   //total mass of the train , since Ft=277.8*Me*alpha+9.81*M*G+M*r
W=M-M_            //weight of additional bogies to be attached


//Results
mprintf("\n Given co-efficient of adhesion is: %.2f",u)
mprintf("\n Weight of additional bogies to be attached is:%.1f T",W)
```

Scilab code Exa 10.7 Q7

```
//Chapter 10:Traction Drives
//Example 6
clc;

//Variable Initialization
Ml=1000        //weight of the empty train in tonne
Mt=5000        //weight of the fully loaded train in tonne
G=15           //gradient of the track
V=30           //maximum speed of the train
r=40           //train resistance in N/tonne
u=0.25         //co-efficient of adhesion
```

```
alpha=0.3     //acelaration in kmphps

W=100              //weight of each locomotive

//Solution
Md=W//Md=W*n
Fm=9810*u*Md
//By expanding and clubbing similar terms we get
//(G*9.81*Mt)+(9.81*W*n*G)-((r*Mt)+(r*W*n))
//(G*9.81*Mt)-(r*Mt)+(9.81*W*n*G)-(r*W*n)
Fb1=(9.81*Mt*G)-(r*Mt)            //By expanding we
   get
Fb2=(9.81*W*G)-(r*W)//By expanding we get Mt*r+W*n*r
mprintf("\nFm=%d*n",Fm)
mprintf("\nFb=%d*n+%d",Fb2,Fb1)
mprintf("\nEquating Fb and Fm we get")
n=535750/(245250-10715)
if (n>2) then
    n=3
end
mprintf("\nThe number of locomotives is n:%d",n)
Md=W*n
M=Ml+W*n
Ft=277.8*1.1*M*alpha+9.81*M*G+M*r
Fm=9810*0.3*Md
if (Fm>Ft) then
    mprintf("\nThe train can be accelarated with %d
       locomotives",n)
end
```