Scilab Textbook Companion for A Course In Power Plant Engineering by S. C. Arora, S. Domkundwar, A. V. Domkundwar[1]

Created by
Praveenkumar C
B.E
Mechanical Engineering
SURYA ENGINEERING COLLEGE
College Teacher
None
Cross-Checked by
None

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Book Description

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Author: S. C. Arora, S. Domkundwar, A. V. Domkundwar

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 2

HYDROLOGY

Scilab code Exa 2.1 Volume of Rainfall

```
// Example 2_1
clc;funcprot(0);
//Given data
R=6.2;//Rainfall in  cm
A=2346;// Area in km^2

//Calculation
Tr=A*10^6*(R/100);// Total rainfall in m^2
V=(A*R*10^4)/86400;// Rainfall in day-sec-metre
R_k=(A*R*10^4)/10^6;// Rainfall in km^2-m
printf('\n Total rainfall=%0.4e m^3 \nVolume of
    rainfall=%0.0f day-sec-metre \nRainfall in km^2-m
    =%0.2f km^2-m',Tr,V,R_k);
// The answer provided in the textbook is wrong
```

Scilab code Exa 2.2 Number of days water supplied

```
//Example 2_2
```

```
clc;funcprot(0);
// Given data
Pdr=400*10^6; // Per day requirement in L
Pdr=Pdr/10^3;// convert L to m^3
Aw=30000*10^6;// Available water in the dam in m^3

//Calculation
n=(Aw)/(Pdr);// days
printf('No.of days water supplied,N=%0.0f days\n',n)
    ;
```

Scilab code Exa 2.3 `Total flow volume`

```
// Example 2_3
clc;funcprot(0);
//Given data
D=[1 2 3 4 5 6 7];// Days
F=[100 320 210 120 50 30 25];//Mean daily flow in m
    ^3/sec

//Calculation
Tf=F(1)+F(2)+F(3)+F(4)+F(5)+F(6)+F(7);
Tfv=24*3600*(Tf);// Total flow volume in m^3
Tfv_1=Tfv/(10^6);// million-m^3
Tfv_2=Tfv/86400;// day-sec-metre
Tfv_3=Tfv/(3350*10^4);// cm
Tfv_4=Tfv_1;// km^2-m as 1 km^2-m =1 million of cu-m
    .
printf('\nTotal flow volume=%0.1f million-m^3 \
    nTotal flow volume =%0.1f day-sec-metre \nTotal
    flow volume=%0.1f cm \nTotal flow volum=%0.1f km
    ^2-m',Tfv_1,Tfv_2,Tfv_3,Tfv_4);
// The answer provided in the textbook is wrong
```

Scilab code Exa 2.4 The output of the generating station

```
// Example 2_4
clc;funcprot(0);
//Given data
m_1=20;// The steam discharge during the monsoon
   season of four months in m^3/sec
m_2=2.5;// The steam discharge during the remaining
   year in m^3/sec
h_l=3;//The head loss in the pipe in %
n_o=90;//Over all efficiency of the generation in %
Tn=365;// Total number of days in a year
H=80;// metres
g=9.81;// m/s^2
//Calculation
N_m=30+31+31+30;//The number of days during which
   the discharge of 20 m^3/sec is available
N_r=Tn-N_m;//The number of days during which the
   discharge of 2.5 m^3/sec is available
Tf=(m_1*3600*24*N_m)+(m_2*3600*24*N_r);// Total flow
    during the year in m^3
m_avg=(Tf)/(3600*24*Tn);//Average discharge in m^3/
   sec
gradm=m_1-m_avg;// The difference between the
   maximum and average discharge in  m^3/sec
Rc=(gradm*3600*24*N_m)/86400;// Reservoir capacity
   to store the excess water in day-sec-metre
H_net=H*(1-(h_l/100));// metres
P_avg=(m_avg*1000*g*H_net*(n_o/100))/(1000);//
   Average kW generated in kW
P_avg=P_avg/1000;// MW
printf('\nReservoir capacity to store the excess
   water=%0.0f day-sec-metre \nAverage kW generated=
   %0.2f MW',Rc,P_avg);
```

```
// The answer provided in the textbook is wrong
```

Scilab code Exa 2.5 Power developed

```
// Example 2_5
clc;funcprot(0);
//Given data
A=2260;// The catchment area in km^2
AAR=154;// The average annual rainfall in cm
H=120;// The head drop in m
n_t=85;// Turbine efficiency in %
n_g=90;// Generation efficiency in %
F_l=1;// Load factor
N=240;// The speed of the runner in rpm
PEL=20;// Percoalation and evaporation losses in %
g=9.81;// m/s^2

//Calculation
V=A*10^6*(AAR/100)*(1-((PEL/100)));// The quantity of water available for power generation per year in cu.m
Q=V/(365*24*3600);// Quantity of water available per second in m^3/sec
m=Q*1000;// Discharge in kg/sec
P=((m*g*H)/1000)*(n_t/100)*(n_g/100);// Power developed in kW
P=P/1000;// MW
N_a=(N*sqrt(P))/(H)^(5/4);
printf('\nPower developed,P=%0.2f MW \nSingle pelton wheel with 4 jets can be used.',P)
//The answer seems different due to calculation error occur in the book
```

Scilab code Exa 2.6 The energy generated in kWh per year

```
// Example 2_6
clc;funcprot(0);
//Given data
A=200;// The catchment area in km^2
AAR=100;// The average annual rainfall in cm
Tro=80;//Total run off in%
H=80;// the mean head available in m
n_g=75;// Over all efficiency of generation in %
Apw=16;// The average period of working in hours
g=9.81;// m/s^2
F_l=1;// Load factor

//Calculation
V=A*10^6*(Tro/100);//Total water available in m^3/
    year
Q=V/(365*24*3600);// m^3/sec
m=Q*1000;// Discharge in kg/sec
P=((m*g*H)/1000)*(n_g/100);// Capacity of the plant
    in kW
E=(P/1000)*Apw*365*10^3;//Energy generated per year
    in kWh
printf('\nThe energy generated per year =%0.3e kWh',
    E );
// The answer vary due to round off error
```

Scilab code Exa 2.7 The average power developed by the power plant

```
// Example 2_7
clc;funcprot(0);
// Given data
A=1200;// The catchment area in km^2
AR=160;// The annual rainfall in cm
H=360;// The head available in m
```

```
n_o=75;// Over all efficiency of the plant in %
F_l=0.5;// Load factor
PEL=25;// Percoalation and evaporation losses in %
g=9.81;// m/s^2

// Calculation
V=A*10^6*(AR/100)*(1-((PEL/100)));// The quantity of water available for power generation per year in cu.m
Q=V/(365*24*3600);// Average flow per second in m^3/sec
m=Q*1000;// Discharge in kg/sec
P_avg=((m*g*H)/1000)*(n_o/100);// Average power developed in kW
P_avg=P_avg/1000;// MW
MD=(P_avg/F_l);// Maximum demand in MW
printf('\nThe average power developed=%0.2f MW \nMaximum demand=%0.1f MW',P_avg,MD);
// The answer vary due to round off error
```

Scilab code Exa 2.8 Fall in water height

```
// Example 2_8
clc;funcprot(0);
//Given data
A=50;// Area in sq.km
H_1=100;// Head in m
E=13.5*10^6;// The energy utilised by the customer in kWh
n_g=0.75;// The over all generation efficiency
rho_w=1000;// kg/m^3
g=9.81;// m/s^2

//Calculation
// V=A*H;// Water used during 5 hours in m^3
```

```
// Q=(A*H)/(5*3600);(discharge/sec)
function[X]=head(y)
    X(1)=E-(5*(rho_w*((A*10^6*y(1))/(5*3600))*g*(H_1/1000)*n_g));
endfunction
y=[10];
z=fsolve(y,head);
H=z(1);// metres
printf('\nThe fall in the height of water in the reservoir=%0.2f metres',H);
// The answer provided in the textbook is wrong
```

Scilab code Exa 2.9 The capacity of the power plant

```
//Example 2_9
clc;funcprot(0);
// Given values
A=250*10^6;// Catchment area in m^2
Ar=1.25;// Annual rainfall in m
H=60;// Average head in m
P_w=70;// Percentage of water in the dam
n_t=0.9// Turbine efficiency
n_g=0.95// Generator efficiency
g=9.81;// The acceleration due to gravity in m/s^2

//Calculation
V=(A*Ar*(P_w/100));// Total water used for power generation in m^3
printf('Total water used for power generation=%0.3e m^3\n',V);
q=(V/(365*24*3600));
printf('Water flow rate =%0.2f m^3/sec\n',q);
P=((q*1000*9.81*60)/1000)*n_t*n_g*(1/1000);
printf('The capacity of the power plant,P=%0.1f MW\n',P);
```

```
// The answer vary due to round off error
```

Scilab code Exa 2.10 The rate at which the water fall in the reservoir

```
// Example 2_10
clc;funcprot(0);
//Given data
H=40;// Head in m
A=1.8;// Area of the reservoir in km^2
P=24;// MW
n_o=80/100;// The over all efficiency
rho_w=1000;// kg/m^3
g=9.81;// m/s^2

//Calculation
q=(P*1000*1000)/(rho_w*g*H*n_o);// m^3/sec
x=(q*3600)/(A*10^6);// m/hr
printf('\nThe rate of fall in height of reservoir=%0
    .3f m/hr',x);
```

Scilab code Exa 2.11 Energy produced in kWh

```
// Example 2_11
clc;funcprot(0);
//Given data
V=6*10^6;// m^3
H=75;// m
F_l=0.6;// Load factor
n_g=72/100;// The over all generation efficiency
rho_w=1000;// kg/m^3
g=9.81;// m/s^2

//Calculation
```

```
P=((V)/(365*24*3600))*(((rho_w)*g*H*n_g)/(1000));//
    The power capacity of the plant in kW
E=P*F_l*365*24;// Energy produced in kWh
printf('\nEnergy produced=%0.0f kW',E);
// The answer provided in the textbook is wrong
```

Scilab code Exa 2.12 Generator capacity

```
// Example 2_12
clc;funcprot(0);
//Given data
H=30;// m
A=250;// sq.km
Ar=125;// Annual rainfall in cm
Tr=70/100;// Total rainfall
F_l=50/100;// Load factor
h_l=8/100;// Head loss
n_m=90/100;// Mechanical efficiency of the turbine
n_g=95/100;// Generator efficiency
rho_w=1000;// kg/m^3
g=9.81;// m/s^2

//Calculation
V=A*10^6*(Ar/100)*Tr;//Water available during the
    year in m^3
Q=(V)/(8760*3600);// Water flow per second in m^3/
    sec
Q=Q*1000;// kg/sec
n_h=(1-h_l);// Hydraulic efficiency
n_o=n_h*n_m*n_g;//The over all efficiency
P=(Q*9.81*H*n_o)/(1000);// kW
//With 50% load factor
Gc=P/F_l;// Generator capacity in kW
printf('\nThe power=%0.0f kW \nGenerator capacity=%0
    .1f kW',P,Gc);
```

```
// The answer provided in the textbook is wrong
```

Scilab code Exa 2.13 Average kW available

```
// Example 2_13
clc;funcprot(0);
//Given data
m=[1 2 3 4 5 6 7 8 9 10 11 12];// Month
D=[500 200 1500 2500 3000 2400 2000 1500 1500 1000
   800 600];// Discharge in millions of m^3 per
   month
H=80;// Available head in m
n_o=80/100;// Overall efficiency of the generation
g=9.81;// The acceleration due to gravity in m/s^2

// Calculation
// (a)
Q_a1=(D(1)+D(2)+D(3)+D(4)+D(5)+D(6)+D(7)+D(8)+D(9)+D
   (10)+D(11)+D(12))/12;// The average monthly flow
   in millions of m^3/month
m_1=[0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 10 10 11
   11 12 12];
D_1=[500 500 200 200 1500 1500 2500 2500 3000 3000
   2400 2400 2000 2000 1500 1500 1500 1500 1000 1000
    800 800 600 600 3200];
Q_a=[Q_a1,Q_a1];
m=[0,12];
xlabel('Month');
ylabel('Discharge in millions of m^3 per month');
subplot(2,1,1);
plot(m_1',D_1','b',m',Q_a','r-');
a=gca();
a.x_ticks.labels=["0","J","F","M","A","M","J","J","A
   ","S","O","N","D"];
a.x_ticks.locations=[0;1;2;3;4;5;6;7;8;9;10;11;12];
```

```
legend('Hydrograph','Mean flow');
D=[200 500 600 800 1000 1500 2000 2400 2500 3000];
M=[12 11 10 9 8 7 4 3 2 1];// Total number of months
    during which flow is available
for(i=1:10)
    T(i)=(M(i)/12)*100;
end
subplot(2,1,2);
xlabel('Percentage of time');
ylabel('Discharge in millions of cu.m.month');
plot(T,D','b');
legend('Flow duration curve');

m=(Q_a1*10^6/(30*24*3600));// The average flow
    available in m^3/sec
P=(((m*1000*g*H)/1000)*(n_o/1000));// Average kW
    available in MW
printf('\nAverage kW available at the site=%0.3f MW'
    ,P);
// The answer provided in the textbook is wrong
```

Scilab code Exa 2.14 Average MW energy available

```
// Example 2_14
clc;funcprot(0);
//Given data
m=[1 2 3 4 5 6 7 8 9 10 11 12];// Month
D=[80 50 40 20 0 100 150 200 250 120 100 80];//
    Discharge in millions of m^3 per month
H=100;// Available head in m
n_o=80/100;// Overall efficiency of the generation
g=9.81;// The acceleration due to gravity in m/s^2

// Calculation
// (a)
```

```
Q_a1=(D(1)+D(2)+D(3)+D(4)+D(5)+D(6)+D(7)+D(8)+D(9)+D(10)+D(11)+D(12))/12;// The average monthly flow in millions of m^3/month
m_1=[0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 10 10 11 11 12 12];// Month for hydrograph
D_1=[80 80 50 50 40 40 20 20 0 0 100 100 150 150 200 200 250 250 120 120 100 100 80 80 260];// Discharge in millions of m^3 per month
Q_a=[Q_a1,Q_a1];// Mean flow
m=[0,12];// month
xlabel('Month');
ylabel('Discharge in millions of m^3 per month');
subplot(2,1,1);
plot(m_1',D_1','b',m',Q_a','r-');
a=gca();
a.x_ticks.labels=["0","J","F","M","A","M","J","J","A","S","O","N","D"];
a.x_ticks.locations=[0;1;2;3;4;5;6;7;8;9;10;11;12];
legend('Hydrograph','Mean flow');
D=[0 20 40 50 80 100 120 150 200 220];// Discharge in millions of m^3 per month
M=[12 11 10 9 8 7 4 3 2 1];// Total number of months during which flow is available
for(i=1:10)
    T(i)=(M(i)/12)*100;
end
subplot(2,1,2);
xlabel('Percentage of time');
ylabel('Discharge in millions of cu.m.month');
plot(T,D','b');
legend('Flow duration curve');
m=((Q_a1*10^6)/(30*24*3600));// The average flow available in m^3/sec
P=(((Q_a1*10^6*1000*g*H)/(30*24*3600*1000))*(n_o/1000));// Average kW available in MW
printf('\nAverage kW available at the site=%0.3f MW',P);
// The answer provided in the textbook is wrong
```

Scilab code Exa 2.15 Flow rate available

```
// Example 2_15
clc;funcprot(0);
//Given data
w=[1 2 3 4 5 6 7 8 9 10 11 12];// Week
b=[6000 4000 5400 2000 1500 1000 1200 4500 8000 4000 3000 2000];// Weekly flow in m^3/sec

//Calculation
for(i=1:12)
    c(i)=b(i)*7;
end
Cv(1)=c(1);// day-sec-metres
Cv(2)=Cv(1)+c(2);// day-sec-metres
Cv(3)=Cv(2)+c(3);// day-sec-metres
Cv(4)=Cv(3)+c(4);// day-sec-metres
Cv(5)=Cv(4)+c(5);// day-sec-metres
Cv(6)=Cv(5)+c(6);// day-sec-metres
Cv(7)=Cv(6)+c(7);// day-sec-metres
Cv(8)=Cv(7)+c(8);// day-sec-metres
Cv(9)=Cv(8)+c(9);// day-sec-metres
Cv(10)=Cv(9)+c(10);// day-sec-metres
Cv(11)=Cv(10)+c(11);// day-sec-metres
Cv(12)=Cv(11)+c(12);// day-sec-metres
w=[0 1 2 3 4 5 6 7 8 9 10 11 12];// Week for plot
CV=[0 Cv(1) Cv(2) Cv(3) Cv(4) Cv(5) Cv(6) Cv(7) Cv(8) Cv(9) Cv(10) Cv(11) Cv(12)];// Cumulative volume in day-sec-metres for plot
ylabel('Flow in thousands & day-sec-meter');
plot(w,CV/1000)
// The total flow in the week,Q=7*day-sec-metres.
// From fig.prob.2.15
C=42*10^3;// The capacity of the reservoir in day-
```

```
sec-metre
bc=5.7*20*10^3;// day-sec-metre
ac=5.5;// day
Q=bc/(ac*7);// Flow rate available in m^3/sec
printf('\n The capacity of the reservoir=%0.1e day-sec-metre \nFlow rate available=%0.0f m^3/sec',C,Q);
// The answer vary due to round off error
```

Scilab code Exa 2.16 Storage capacity of the reservoir

```
// Example 2_16
clc;funcprot(0);
//Given data
m=[1 2 3 4 5 6 7 8 9 10 11 12];// Month
F=[100 50 20 80 10 10 190 40 30 200 170 80];// Flow in millions of cu-m-per month

// Calculation
Cv(1)=F(1);
Cv(2)=Cv(1)+F(2);// Millions of cu-m
Cv(3)=Cv(2)+F(3);// Millions of cu-m
Cv(4)=Cv(3)+F(4);// Millions of cu-m
Cv(5)=Cv(4)+F(5);// Millions of cu-m
Cv(6)=Cv(5)+F(6);// Millions of cu-m
Cv(7)=Cv(6)+F(7);// Millions of cu-m
Cv(8)=Cv(7)+F(8);// Millions of cu-m
Cv(9)=Cv(8)+F(9);// Millions of cu-m
Cv(10)=Cv(9)+F(10);// Millions of cu-m
Cv(11)=Cv(10)+F(11);// Millions of cu-m
Cv(12)=Cv(11)+F(12);// Millions of cu-m
m=[0 1 2 3 4 5 6 7 8 9 10 11 12];// Month
CV=[0 Cv(1) Cv(2) Cv(3) Cv(4) Cv(5) Cv(6) Cv(7) Cv(8) Cv(9) Cv(10) Cv(11) Cv(12)];// Cumulative volume in millions of cu-m
```

```
xlabel('Month');
ylabel('Millions of cu.m')
plot(m,CV,'b');
// From Fig.Prob(2.16),from the mass curve
Sc=80*10^6;// Storage capacity in m^3
sc=85*10^6;// Spill way capacity required in m^3
i=13;
j=1;
Q=((CV(i)-CV(j))/(m(i)-m(j)))*10^6;// The uniform
    discharge in m^3/month
// The required storage capacity for the uniform
    supply Q,
SC_u=233*10^6;// cu-m.
printf('\nThe required reservoir capacity=%0.0e m^3
    \nSpill way capacity=%0.1e m^3 \nAverage flow
    capacity=%0.2e m^3/month \nRequired capacity of
    the reservoir fo the uniform supply=%0.2e cu-m',
    Sc,sc,Q,SC_u);
```

Scilab code Exa 2.17 The maximum flow available

```
// Example 2_17
clc;funcprot(0);
//Given data
m=[1 2 3 4 5 6 7 8 9 10];// Month
D=[200 100 20 20 260 180 40 280 60 120];// Discharge
     in millions of cu-m-per month
Q=100;// millions of cu.m

// Calculation
Cv(1)=D(1);
Cv(2)=Cv(1)+D(2);// Millions of cu-m
Cv(3)=Cv(2)+D(3);// Millions of cu-m
Cv(4)=Cv(3)+D(4);// Millions of cu-m
Cv(5)=Cv(4)+D(5);// Millions of cu-m
```

```
Cv(6)=Cv(5)+D(6);// Millions of cu-m
Cv(7)=Cv(6)+D(7);// Millions of cu-m
Cv(8)=Cv(7)+D(8);// Millions of cu-m
Cv(9)=Cv(8)+D(9);// Millions of cu-m
Cv(10)=Cv(9)+D(10);// Millions of cu-m
m=[0 1 2 3 4 5 6 7 8 9 10];// Month
CV=[0 Cv(1) Cv(2) Cv(3) Cv(4) Cv(5) Cv(6) Cv(7) Cv
    (8) Cv(9) Cv(10)];// Cumulative volume in
    millions of cu-m
xlabel('Discharge in millions of cu-m  month');
ylabel('Millions of cu.m');
plot(m,CV);
// From the mass curve
Q_a=72.6;// Flow rate at point a in millions of cu-m
    /month
Q_b=166.4;// Flow rate at point b in millions of cu-
   m/month
Q_c=137.6;// Flow rate at point c in millions of cu-
   m/month
printf('\nThe maximum flow available=%0.1f millions
    of cu-m/month \nThe minimum flow available=%0.1f
    millions of cu-m/month',Q_b,Q_a);
```

Chapter 3

DIFFERENT HYDRO ELECTRIC POWER PLANT

Scilab code Exa 3.1 `Which river is more suitable`

```
// Example 3_1
clc;funcprot(0);
// Given data
m=[1 2 3 4 5 6 7 8 9 10 11 12];// Month for load curve
R_a=[40 30 30 20 20 160 180 180 100 80 50 50];// The run off for river A is  given in millions of cu-m per month
R_b=[50 50 60 80 100 100 90 90 70 60 60 60];// The run off for river B is  given in millions of cu-m per month
H_a=80;// The head available for river A in m
H_b=82;// The head available for river B in m

// Calculation
m=[0 0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 10 10 11 11 12 12];// Month for load curve
R_a=[0 40 40 30 30 30 30 20 20 20 20 160 160 180 180 180 180 100 100 80 80 50 50 50 50 190];//The run
```

```
off for river A is given in millions of cu-m per month for load curve
R_b=[0 50 50 50 50 60 60 80 80 100 100 100 100 90 90 90 90 70 70 60 60 60 60 60 60 190];//The run off for river B is given in millions of cu-m per month for load curve
subplot(2,1,1);
xtitle('Fig.Prob.3.1.(a)');
plot(m',R_a','b',m',R_b','r');
a=gca();
a.x_ticks.labels=["0","J","F","M","A","M","J","J","A","S","O","N","D"];
a.x_ticks.locations=[0;1;2;3;4;5;6;7;8;9;10;11;12];
legend('Hydrograph of river A','Hydrograph of river B');
D_a=[20 30 40 50 80 100 160 180];// Discharge in millions of cu-m. per month
M_a=[12 10 8 7 5 4 3 2];// No.of months during which flow is available
D_b=[50 60 70 80 90 100];// Discharge in millions of cu-m. per month
M_b=[12 10 6 5 4 2];// No.of months during which flow is available
for(i=1:8)
    T_a(i)=(M_a(i)/12)*100;
end
for(j=1:6)
    T_b(j)=(M_b(j)/12)*100;
end
subplot(2,1,2);
xtitle('Fig.Prob.3.1.(b)');
plot(T_a,D_a','b',T_b,D_b','g');
legend('Flow duration curve for river A','Flow duration curve for river B');

//(a)
Q_a=(R_a(1)+R_a(2)+R_a(3)+R_a(4)+R_a(5)+R_a(6)+R_a(7)+R_a(8)+R_a(9)+R_a(10)+R_a(11)+R_a(12))/12;//
```

```
The average flow per month of river A in millions of cu-m. per month
Q_b=(R_b(1)+R_b(2)+R_b(3)+R_b(4)+R_b(5)+R_b(6)+R_b(7)+R_b(8)+R_b(9)+R_b(10)+R_b(11)+R_b(12))/12;// The average flow per month of river A in millions of cu-m. per month
P_a=Q_a*H_a;// The power developed
P_b=Q_b*H_b;// The power developed
P_r=P_a/P_b;// Power ratio
if(P_a>P_b)
    printf('\n(a)As P_a>P_b,the river A is more suitable for storage type power plant');
else
    printf('\n(a)As P_b>P_a,the river B is more suitable for storage type power plant');
end
//(b)From Fig.Prob.3.1(a),The flow available for 85% of the time in year
Q_b=59.5;// millions of cu-m per month
Q_a=29;// millions of cu-m per month
P_b=Q_b*H_b;
P_a=Q_a*H_a;
if(P_b>P_a)
    printf('\n(b)The site of river B is more suitable than the site of river A for run-off river power plant');
else
    printf('\n(b)The river A is more suitable than the site of river B for run-off river power plant');
end
//(c)when 60% time of the year,the run off is required from both the rivers,thenfrom Fig.Prob.3.1(b),
Q_a=47;// millions of cu-m per month
Q_b=66;// millions of cu-m per month
Q_r=Q_a/Q_b;// Flow ratio
P_a=Q_a*H_a;// The power developed
```

```
P_b=Q_b*H_b;// The power developed
P_r=P_a/P_b;// Power ratio
printf('\n(c)Flow ratio=%0.3f \n    Power ratio=%0.3f',Q_r,P_r);
printf('\n(d)From Fig.Prob.3.1(b),At 43 percentage of time,the run off rate of both sites is same');
// The answer vary due to round off error
```

Scilab code Exa 3.2 At what percentage of time the run off rate of both rivers is

```
// Example 3_2
clc;funcprot(0);
// Given data
m=[1 2 3 4 5 6 7 8 9 10 11 12];// Month for load curve
R_a=[40 30 20 15 10 80 140 120 100 60 50 40];// The run off for river A is  given in millions of cu-m per month
R_b=[50 50 40 40 40 90 100 100 80 70 60 70];// The run off for river B is  given in millions of cu-m per month

// Calculation
Q_a1=R_a(1)+R_a(2)+R_a(3)+R_a(4)+R_a(5)+R_a(6)+R_a(7)+R_a(8)+R_a(9)+R_a(10)+R_a(11)+R_a(12);// Total flow from the river A  in millions of cu-cm/month
Q_a=Q_a1/12;// Average flow of the river A in cu-cm/month
Q_b1=R_b(1)+R_b(2)+R_b(3)+R_b(4)+R_b(5)+R_b(6)+R_b(7)+R_b(8)+R_b(9)+R_b(10)+R_b(11)+R_b(12);// Total flow from the river B  in millions of cu-cm/month
Q_b=Q_b1/12;// Average flow of the river B in cu-cm/month
```

```
m=[0 0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 10 10 11 11 12];// Month for load curve
R_a=[0 40 40 30 30 20 20 15 15 10 10 80 80 140 140 120 120 100 100 60 60 50 50 40 40];//The run off for river A is given in millions of cu-m per month for load curve
R_b=[0 50 50 50 50 40 40 40 40 40 40 90 90 100 100 100 100 80 80 70 70 60 60 70 70];//The run off for river B is given in millions of cu-m per month for load curve
Q_A=[Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a Q_a];// Average flow of the river A in cu-cm/month for plot
Q_B=[Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b Q_b];// Average flow of the river B in cu-cm/month for plot
subplot(2,1,1);
xtitle('Fig.Prob.3.1.(a)');
ylabel('Millions of Cu.m/month')
plot(m',R_a','b',m',R_b','g',m',Q_A','r-.',m',Q_B','b-.');
a=gca();
a.x_ticks.labels=["0","J","F","M","A","M","J","J","A","S","O","N","D"];
a.x_ticks.locations=[0;1;2;3;4;5;6;7;8;9;10;11;12];
legend(['Hydrograph of river A','Hydrograph of river B','Average flow for River A','Average flow for River B'],"in_upper_left");
//(a)
// From Fig.Prob.3.2(a)
Q_B=72;// At 40% of time,the flow of river B in in millions of cu-m per month
Q_A=61;// At 40% of time,the flow of river A in in millions of cu-m per month
Q_r=(Q_B/Q_A);// Flow ratio
dQ_r=(Q_r-1)*100;// %
```

```

D_a=[10 15 20 30 40 50 60 70 80 90 100 110 120 140];// Discharge in millions of cu-m. per month
M_a=[12 11 10 9 8 6 5 4 4 2 3 2 2 1];// No.of months during which flow is available
for(i=1:14)
    T_a(i)=(M_a(i)/12)*100;
end
D_b=[40 50 60 70 80 90 100];// Discharge in millions of cu-m. per month
M_b=[12 9 6 5 4 3 2];// No.of months during which flow is available
for(j=1:7)
    T_b(j)=(M_b(j)/12)*100;
end
Q_a=[Q_a Q_a];// Average flow of the river A in cu-cm/month
Q_b=[Q_b Q_b];// Average flow of the river B in cu-cm/month
T=[0 100];// Time in percentage for plot
subplot(2,1,2);
xtitle('Fig.Prob.3.1.(b)');
plot(T_a,D_a','b',T_b,D_b','g',T',Q_a','r-.',T',Q_b','g-.');
legend('Flow duration curve for river A','Flow duration curve for river B','Average flow for River A','Average flow for River B');
printf('\n(a)The ratio of run off of river A and river B is %0.2f.',Q_r);
//(b)
// From Fig.Prob.3.2(b)
Q_A=23;// At 80% of time,the flow of river A in in millions of cu-cm per month
Q_B=48;// At 80% of time,the flow of river B in in millions of cu-cm per month
if(Q_B>Q_A)
    printf('\n(b)River B is preferable for runoff type plant.');
```

```
else
    printf('\n(b)River A is preferable for runoff
       type plant.');
end
//(c)
if(Q_b>Q_a)
    printf('\n(c)River B is preferable for storage
       type plant also.');
else
    printf('\n(c)River A is preferable for storage
       type plant also.');
end
//(d)
// From Fig.Prob.3.2(b)
disp('(d)The run off rate is same at 25%(90 cu-m/
   month) and 33.33% (80 cu-m/month) of the year.');
```

Scilab code Exa 3.3 The over all efficiencies in both cases

```
// Example 3_3
clc;funcprot(0);
//Given data
L=[100 160 80 40 20];// Load in MW
T_1=[6,10];// Time in hours
T_2=[10,18];// Time in hours
T_3=[18,20];// Time in hours
T_4=[20,24];// Time in hours
T_5=[0,6];// Time in hours
n_th=[30 35 25 15 10]/100;// The thermal
   efficiencies of the plant
n_p=80;// The efficiency of the pump in %
n_t=90;// The efficiency of the turbine in %

// Calculation
//(a)
```

```
T_p=[0 0 4 4 12 12 14 14 18 18 24 24];// Time in hours for load curve
L_p=[0 100 100 160 160 80 80 40 40 20 20 100];// Load in MW for load curve
plot(T_p',L_p','b');
a=gca();
a.x_ticks.labels=["6 A.M","","","12 P.M","","","6 A.M","","","12 P.M","","","6 A.M"];
a.x_ticks.locations=[0;2;4;6;8;10;12;14;16;18;20;22;24];
O=(L(1)*(T_1(2)-T_1(1)))+(L(2)*(T_2(2)-T_2(1)))+(L(3)*(T_3(2)-T_3(1)))+(L(4)*(T_4(2)-T_4(1)))+(L(5)*(T_5(2)-T_5(1)));// Total output per day in MW-hrs
I_1= ((L(1)*(T_1(2)-T_1(1)))/(n_th(1)))+((L(2)*(T_2(2)-T_2(1)))/(n_th(2)))+((L(3)*(T_3(2)-T_3(1)))/(n_th(3)))+((L(4)*(T_4(2)-T_4(1)))/(n_th(4)))+((L(5)*(T_5(2)-T_5(1)))/(n_th(5)));// The input to the thermal plant in MW-hrs
n_o1=(O/I_1)*100;// Over all efficiency in %

//(b)
n_op=(n_p/100)*(n_t/100)*100;// The over all efficiency of the pump storage plant in %
// From the Fig.Prob.3.3
function[X]=baseload(y)
    X(1)=((((y(1)-L(3))*(T_3(2)-T_3(1)))+((y(1)-L(4))*(T_4(2)-T_4(1)))+((y(1)-L(5))*(T_5(2)-T_5(1))))*(n_op/100))-(((L(1)-y(1))*(T_1(2)-T_1(1)))+((L(2)-y(1))*(T_2(2)-T_2(1))));
endfunction
y=[10];
z=fsolve(y,baseload);
x=(z(1));// The capacity of the thermal plant in MW
X=[x x x x x x x x x x x x];//The capacity of the thermal plant in MW for plot
xlabel('Time in hrs');
ylabel('Load in MW');
```

```
plot(T_p',L_p','b',T_p',X','b-.');
legend('Load curve','Base load thermal plant');
I_2=(x*24)/(n_th(2));// The energy supplied in the second case in MW-hrs
n_o2=(O/I_2)*100;// The over all efficiency of the combined plant in %
PI=((I_1-I_2)/I_1)*100;// The percentage saving in input in %
printf('\n(a)The total input to the thermal plant=%0.0f MW-hrs \n(b)The percentage saving in input to the plant=%0.2f percentage \n(c)The over all efficiency of the thermal plant=%0.1f percentage \n   The over all efficiency of the combined plant=%0.0f percentage',I_1,PI,n_o1,n_o2);
// The answer vary due to round off error
```

Scilab code Exa 3.4 The capacity of the thermal plant

```
// Example 3_4
clc;funcprot(0);
//Given data
L=[60 120 40 10];// Load in MW
T_1=[6,10];// Time in hours
T_2=[10,18];// Time in hours
T_3=[18,24];// Time in hours
T_4=[0,6];// Time in hours
Er=1.5;// Rs/kW-hr
c=2.2;// Cost of input in rupees
n_th=[35 40 30 20]/100;
Q=20000;// kJ
n_thb=40/100;// Thermal efficiency
n_o=80/100;// Over all efficiency of pump storage plant

// Calculation
```

```
//(a)
T_p=[0 0 4 4 12 12 18 18 24 24];// Time in hours
L_p=[0 60 60 120 120 40 40 10 10 130];// Load in MW
plot(T_p',L_p','b');
a=gca();
a.x_ticks.labels=["6 P.M","","","12 P.M","","","6 P.
   M","","","12 P.M","","","6 P.M"];
a.x_ticks.locations
   =[0;2;4;6;8;10;12;14;16;18;20;22;24];
O=((L(1)*(T_1(2)-T_1(1)))+(L(2)*(T_2(2)-T_2(1)))+(L
   (3)*(T_3(2)-T_3(1)))+(L(4)*(T_4(2)-T_4(1))))
   *10^3;// Total energy generated by the thermal
   plant
Tc_s=Er*O;// Total cost of selling the power in
   rupees
I= (((L(1)*(T_1(2)-T_1(1)))/(n_th(1)))+((L(2)*(T_2
   (2)-T_2(1)))/(n_th(2)))+((L(3)*(T_3(2)-T_3(1)))/(
   n_th(3)))+((L(4)*(T_4(2)-T_4(1)))/(n_th(4))))
   *10^3;// Total input to the thermal plant in kWh
Tc_i=c*(1/(Q))*(I*3600);// Total cost of input
   energy in rupees
Nr_1=Tc_s-Tc_i;// Net revenue earned in Rs./day

//(b)
function[Y]=baseload(x)
    Y(1)=((((x(1)-L(3))*(T_3(2)-T_3(1)))+((x(1)-L(4)
       )*(T_4(2)-T_4(1)))+((x(1)-L(1))*(T_1(2)-T_1
       (1))))*(n_o))-((L(2)-x(1))*(T_2(2)-T_2(1)));
   endfunction
x=[10];
z=fsolve(x,baseload);
x=(z(1));// The capacity of the thermal plant in MW
X=[x x x x x x x x x x];// // The capacity of the
   thermal plant in MW for plot
xlabel('Time in hrs');
ylabel('Load in MW');
plot(T_p',L_p','b',T_p',X','b-.');
legend('Load curve','Base load thermal plant');
```

```
Ti=((x*24)/n_thb)*3600;// Total input to the thermal
     plant in 24 hours in MJ
Tc_i=Er*(1/Q)*Ti*10^3;// Total cost of input energy
    during 24 hours in rupees
Nr_2=Tc_s-Tc_i;// // Net revenue earned from the
    combined plant in Rs./day
P=((Nr_2-Nr_1)/(Nr_1))*100;// Percentage increase in
     the profit
printf('\n(a)The net revenue earned if the load is
    taken by the single thermal power plant=%0.3e
    rupees per day \n(b)The capacity of the thermal
    plant=%0.0f MW \n    Percentage increase in the
    revenue earned=%0.1f percentage',Nr_1,x,P);
```

Chapter 4

DESIGN CONSTRUCTION AND OPERATION OF DIFFERENT COMPONENTS OF HYDRO ELECTRIC POWER STATIONS

Scilab code Exa 4.1 The power and rpm of actual turbine

```
//Example 4_1
clc;funcprot(0);
//Given data
p=25;// kW
n=480;// rpm
h=5;// m
// d_r=D/d
d_r=10;
H=40;// m

//Calculation
N=n*(1/d_r)*(sqrt(H/h));// rpm
P=p*(d_r)^2*(H/h)^(3/2);// kW
```

```
n_s=(n*sqrt(p))/h^(5/4);
N_s=(N*sqrt(P))/(H)^(5/4);
printf('\n N=%0.0f r.p.m\nP=%0.0f kW\nN_s=%0.0f',N,P
    ,N_s);
printf('\nThe runner is of propeller type');
// The answer vary due to round off error
```

Scilab code Exa 4.2 The speed and power of the prototype

```
//Example 4_2
clc;funcprot(0);
//Given data
p=4.1;// kW
n=360;// r.p.m
h=1.8;// m
H=6;// m
// d_r=D/d
d_r=5

//Calculation
N=n*(1/d_r)*sqrt(H/h);// r.p.m
P=p*(d_r)^2*(H/h)^(3/2);// kW
//Q/q=q_r
q_r=(d_r)^2*sqrt(H/h);
n_s=(n*sqrt(p))/h^(5/4);
N_s=(N*sqrt(P))/(H)^(5/4);
printf('\nN=%0.0f r.p.m\nP=%0.0f kW\nQ/q=%0.1f',N,P,
    q_r);
printf('\nThe runner must be of propeller type');
// The answer vary due to round off error
```

Scilab code Exa 4.3 The running speed of the model

```
//Example 4_3
clc;funcprot(0);
//Given data
P=10000;// kW
H=12;// m
N=100;// r.p.m
// d_r=D/d;
d_r=10;
h=8;// m
n_m=0.8;

//Calculation
n=N*d_r*sqrt(h/H);// r.p.m
p=P/((d_r^2*(H/h)^(3/2)));// kW
w=1000*9.81;// N
q=(p*1000)/(w*h*n_m);// m^3/sec
n_s=(n*sqrt(p))/h^(5/4);
N_s=(N*sqrt(P))/(H)^(5/4);
printf('\n(a)The running speed of the model,n=%0.0f
    r.p.m \n(b)B.P,p=%0.1f kW \n    The flow quantity
    required,q=%0.2f m^3/sec \n    The specific speed
    of the runner,N_s=%0.0f',n,p,q,N_s );
// The answer vary due to round off error
```

Scilab code Exa 4.4 `What is the type of runner`

```
//Example 4_4
clc;funcprot(0);
//Given data
P=40000;//kW
N=500;//r.p.m
H=240;// m
h=30;// m
SG=1.1;// Specific gravity of water
q=150;// litres/sec
```

```
q=q*SG;// kg/sec
n_m=0.88;// The over all efficiency

//Calculation
w=1000*9.81;// N
p=(q*w*h*n_m)/(1000*1000);// kW
//d_r=D/d;
d_r=sqrt(P/p)*(h/H)^0.75;
n=N*d_r*sqrt(h/H);// r.p.m
n_s=(n*sqrt(p))/h^(5/4);
N_s=(N*sqrt(P))/(H)^(5/4);
printf('\n(a)The design speed for a turbie,n=%0.0f r
    .p.m',n);
printf('\nThe runner is of Francis type');
// The answer provided in the textbook is wrong
```

Scilab code Exa 4.5 Power developed by the model

```
//Example 4_5
clc;funcprot(0);
//Given data
P=50000;// kW
H=225;// m
N=600;// r.p.m
h=36;// m
q=170;// litres/sec
n_p=0.9;// Over all efficency
n_m=n_p;

//Calculation
w=1000*9.81;// N
Q=(P*1000)/(w*H*n_m);// m^3/s
// D_r= d/D
D_r=sqrt(sqrt(h/H)*((Q/q)));
D=1/D_r;
```

```
p=P*(D_r^2*(h/H)^(3/2));// kW
n=N*((1/D_r)*(sqrt(h/H)));// r.p.m
printf('\n(a)The model size is (1/%0.2f)^th of prototype. \n(b)Power developed by the model=%0.1f kW \n(c)Model runner speed=%0.0f r.p.m',D,p,n);
// The answer provided in the textbook is wrong
```

Scilab code Exa 4.6 The number of turbine units required

```
//Example 4_6
clc;funcprot(0);
//Given data
Q=260;//m^3/s
H=1.7;//m
n_p=0.825;
N_s=890;// r.p.m
N=50;//r.p.m

//Calculation
w=1000*9.81;// N
P_t=(Q*w*H*n_p)/(1000);// Total power to be developed in kW
P=((N_s*H^(5/4))/N)^2;// kW
n_k=P_t/P;// Number of kaplan turbine required
printf('Number of Kaplan turbine required=%0.0f\n',n_k);
// The answer vary due to round off error
```

Scilab code Exa 4.7 The least number of machines

```
//Example 4_7
clc;funcprot(0);
//Given data
```

```
Q=400;// m^3/sec
H=45;// m
n_t=0.90;// The turbine efficiency
N=250;// r.p.m

//Calculation
w=1000*9.81;// N
P_t=(w*Q*H*n_t)/(1000);// kW
//(a)
N_sf=200;// Specific speed
P=((N_sf*H^(5/4))/N)^2;// kW
f_n=(P_t/P);// Number of francis turbine required
// (b)
N_sk=600;// Specific speed
P=((N_sk*H^(5/4))/N)^2;// kW
k_n=(P_t/P);// Number of kaplan turbine required
printf('\n Number of francis turbines=%0.0f \n
   Number of kaplan turbine used=%0.0f',f_n,k_n);
if(f_n>k_n)
    printf('\n The installation of kaplan turbine is
        more economical than francis turbine as
        number of units required is less.');
else(k_n>f_n)
    printf('\n The installation of francis turbine
        is more economical than kaplan turbine as
        number of units required is less.');
end
// The answer provided in the textbook is wrong
```

Scilab code Exa 4.8 The least number of machines

```
//Example 4_8
clc;funcprot(0);
//Given data
Q=350;// m^3/sec
```

```
H=30;// m
n_t=0.88;//// The turbine efficiency
f=50;// The frequency of generation in cycles/sec
no_p=24;// Number of poles used
N_sf=300;// Specific speed
N_sk=800;// Specific speed

//Calculation
N=(120*f)/(no_p);// r.p.m
w=1000*9.81;
P_t=(w*Q*H*n_t)/(1000);// kW
P=((N_sf*H^(5/4))/N)^2;// kW
f_n=(P_t/P);// Number of francis turbine required
P=((N_sk*H^(5/4))/N)^2;// kW
k_n=(P_t/P);// Number of kaplan turbine required
printf('\n Number of francis turbines=%0.0f \n
    Number of kaplan turbine used=%0.0f',f_n,k_n);
// The answer vary due to round off error
```

Scilab code Exa 4.9 Diameter of the runner

```
//Example 4_9
clc;funcprot(0);
//Given data
Q=30;//m^/sec
H=7.5;// m
n_t=0.85;
N=50;///r.p.m
Sr=0.85;//Speed ratio
g=9.81;//The acceleration due to gravity in m/s^2

//Calculation
w=1000*9.81;// N
P_t=(w*Q*H*n_t)/1000;// kW
N_s=(N*sqrt(P_t))/(H)^(5/4);//Specific speed
```

```
if(N_s>=174)
    printf('\n (a)As N_s=340,two turbine units can
       be used.\n (b)The runner is of Francis type.'
       );
else
    printf('\n Wrong');
end
D=Sr*60*(sqrt(2*g*H))*(1/(%pi*N));//The diameter of
   the runner in m
printf('\n (c)The diameter of the runner,D=%0.2f m',
   D);
// The answer vary due to round off error
```

Scilab code Exa 4.10 The power developed by the prototype

```
//Example 4_10
clc;funcprot(0);
//Given data
h=36;// m
p=135;// kW
q=0.44;// m^3/sec
H=100;// m
N=428;// r.p.m
d_r=4;// d_r=D/d

// Calculation
w=1000*9.81;// N
n=N*d_r*sqrt(h/H);// r.p.m
n_m=(p*1000)/(1000*9.81*q*h);// The efficiency of
   the model
n_p=n_m+0.03;//The efficiency of the prototype
P=p*(n_p/n_m)*(d_r)^2*(H/h)^(3/2);// kW
printf('\n The power developed by the prototype,P=%0
   .0f kW',P);
n_s=(n*sqrt(p))/h^(5/4);
```

```
N_s=(N*sqrt(P))/(H)^(5/4);
if(N_s~=n_s)
    printf('\n The runner is of Francis type.');
else
    printf('\n Wrong');
end
// The answer vary due to round off error
```

Scilab code Exa 4.11 Diameter of the runner

```
//Example 4_11
clc;funcprot(0);
//Given data
Q=70;// m^3/sec
H=15;// m
N=200;// r.p.m
N_s=340;// Specific speed
n_t=0.90;// The efficiency of the turbine
rho=1000;// Density in kg/m^3
g=9.81;// m/s^2
D=[143 151 158.5 165 172.5];// Diamter of runner in
    cm
kW=[66.7 74 82.5 87 92];// (Unit)
rpm=[53 51 48.5 45.4 42.5];// (Unit)

// Calculation
//(a)
printf('\n (a)The type of the runner is Kaplan as
    the specific speed is 340.');
//(b)
w=rho*g;
P_t=(w*Q*H*n_t)/(1000);// kW
P=((N_s*H^(5/4))/N)^2;// kW
T_n=P_t/P;// Number of turbine units required
printf('\n (b)Number of turbine units required=%0.0f
```

```
',T_n);
//(c)
P_u=P/(H^(3/2));//The unit Power in kW
N_u=N/(H^(1/2));//The unit speed in r.p.m.m^-1/2
// For unit power of 43.35 and unit speed of 51.7, the required diameter can be calculated by interploation from the given data
D=D(1)+(((rpm(1)-N_u)/(rpm(1)-rpm(2)))*((D(2)-D(1)))); // The diameter of the runner in cm
printf('\n(c)The diameter of the runner=%0.2f cm',D);
// The answer provided in the textbook is wrong
```

Scilab code Exa 4.12 The maximum height of the francis turbine

```
//Example 4_12
clc;funcprot(0);
//Given data
p_a=1.30;// Atmospheric pressure in bar
p_c=0.5;// bar
V_c=5;// m/sec
V_d=2;// m/sec
h_f=0.2;// m
g=9.81;// m/s^2

//Calculation
w=1000*9.81;// N
h=(((p_a-p_c)*1.03*10^5)/w)-((V_c^2)/(2*g))+(((V_d^2)/(2*g))+h_f);// m
printf('\n The maximum height of the turbine above tail race,h=%0.3f m',h);
// The answer provided in the textbook is wrong
```

Scilab code Exa 4.13 The position of kaplan turbine

```
//Example 4_13
clc;funcprot(0);
//Given data
p_a=750;// mm of Hg
p_v=400;// mm of Hg
p_d=p_a-p_v;// mm of Hg
V_c=13; // m/sec
// Assume Friction loss and exit velocity of water
   head (V_a^2/(2*g))+h_f=V
V=1.5;//m
rho=1000;// kg/m^3
g=9.81;// m/s^2

//Calculation
w=rho*g;// N
h=(((p_a-p_d)*1.03*10^5)/(w*760))-((V_c^2)/(2*g))+V;
   // m
printf('\nThe position of the kaplan turbine with
   respect to tail race,h=%0.2f m',h);
// The answer vary due to round off error
```

Scilab code Exa 4.14 The maximum possible height of the turbine

```
//Example 4_14
clc;funcprot(0);
//Given data
p_a=755;// mm of Hg
V_c=8;// m/sec
V_d=3;// m/sec
T_a=20;//  C
g=9.81;// m/s^2

//Calculation
```

```
// The minimum value of p_c corresponds to the saturation pressure of water vapour at 20 C .
//From steam table ,
p_c=17.6;// mm of Hg
h_f=0.0;// m
p_b=760;// mm of Hg
h=(((p_a-p_c)*13.6)/p_b)-((V_c^2)/(2*g))+(((V_d^2)/(2*g))+h_f);// m
printf('\n The maximum possible height of the turbine ,h=%0.1f meters above tailrace level.',h);
```

Scilab code Exa 4.15 Power Generated

```
//Example 4_15
clc;funcprot(0);
//Given data
N_1=200;// r.p.m
H_1=25;// m
Q=9;// m^3/sec
n_t=0.90;// The turbine efficiency
g=9.81;// m/s^2
rho=1000;// kg/m^3

// Calculation
//(a)
N_s=(2*%pi*N_1*sqrt(Q))*(sqrt(n_t))/(60*(g*H_1)^(3/4));
//(b)
P_1=(rho*g*H_1*Q*n_t)/(1000);// kW
//(c)
H_2=15;// m
N_2=N_1*sqrt(H_2/H_1);// r.p.m
P_2=P_1*(H_2/H_1)^(3/2);// kW
printf('\n(a)The specific speed ,N_s=%0.3f \n(b)Power generated ,P=%0.1f kW \n(c)Speed and Power if the
```

```
head is reduced to 15m, N_2=%0.1f rpm & P_2=%0.0f kW',N_s,P_1,N_2,P_2);
printf('\nFrom the range of specific speed it is seen that the turbine to be selected is Francis type');
```

Scilab code Exa 4.16 Diameter

```
//Example 4_16
clc;funcprot(0);
//Given data
P=5400;// kW
N=200;// r.p.m
D=3;// m
H=240;// m
n_t=0.82;
rho=1000;// kg/m^3
g=9.81;// m/s^2

//Calculation
//(a)
Q=(P*1000)/(rho*g*H*n_t);// m^3/sec
N_u=(N*D/sqrt(H));// Unit speed
P_u=(P/(D^2*H^(3/2)));// Unit power
Q_u=(Q/(D^2*(sqrt(H))));// Unit flow
N_s=(2*%pi*N*sqrt(Q)*sqrt(n_t))/(60*(g*H)^(3/4));// Specific speed
printf('\n(a)The flow rate,Q=%0.1f m^3/sec \n    The unit speed,N_u=%0.1f \n    The unit power,P_u=%0.3f \n    The unit flow,Q_u=%0.2f \n    The specific speed,N_s=%0.3f',Q,N_u,P_u,Q_u,N_s);
//(b)
// When the head is changed to 160 m,the diameter remains same.
H=160;// m
```

```
N=(N_u*sqrt(H))/D;// rpm
P_1=(P_u*D^2*H^(3/2));// kW
Q=(Q_u*D^2*sqrt(H));// m^3/sec
printf('\n(b)Speed,N=%0.0f r.p.m\n    Power,P=%0.0f
    kW\n    The flow rate,Q=%0.2f m^3/sec ',N,P_1,Q);
//(c)
H=183;// m
P=2850;// kW
D_1=sqrt((P/(P_u*H^(3/2))));// m
N_1=(N_u*sqrt(H))/(D_1);// r.p.m
Q=Q_u*D_1^2*sqrt(H);// m^3/sec
printf('\n(c)Diameter,D_1=%0.2f m\n    Speed,N=%0.0f
    r.p.m\n    The flow rate,Q=%0.2f m^3/sec ',D_1,N_1
    ,Q);
// The answer vary due to round off error
```

Scilab code Exa 4.17 The power developed

```
//Example 4_17
clc;funcprot(0);
//Given data
P_1=93;// kW
H_1=64;// m
H_2=88;// m

//Calculation
//(i)For the same size,the speed is proportional to
    the square root of head and so
// N=N_2/N_1
N=sqrt(H_2/H_1);
// By solving N, it gives the relation N_2=1.173 N_2
N_i=((N*100)-100);//The speed increases in %
//(ii)For the same wheel,power varies as H^3/2 and
    so
P_2=P_1*(H_2/H_1)^(3/2);// kW
```

```
printf('\n The speed increases by %0.1f percentage.\n The power developed,P=%0.0f kW',N_i,P_2);
```

Scilab code Exa 4.18 The specific speed

```
//Example 4_18
clc;funcprot(0);
//Given data
P=86000;// kW
N=180;// r.p.m
H=148;// m
D=3.4;// m
Q=66.5;// m^3/sec
rho=1000;// kg/m^3
g=9.81;// m/s^2

//Calculation
N_u=(N*D/sqrt(H));// r.p.m
P_u=(P/(D^2*H^(3/2)));// kW
Q_u=(Q/(D^2*(sqrt(H))));// m^3/s
n_t=((P*1000)/(rho*g*Q*H));// The turbine efficiency
N_s=((%pi*D*N)/60)*((sqrt(Q*n_t)/(g*H)^(3/4)));// Specific speed
printf('\nThe unit speed,N_u=%0.0f r.p.m\nThe unit power,P_u=%0.2f kW\nThe unit flow,Q_u=%0.3f m^3/sec\nThe specific speed,N_s=%0.3f',N_u,P_u,Q_u,N_s);
printf('\nFor this range of specific speed in the SI system,turbine must be francis type');
```

Scilab code Exa 4.19 Diameter

```
//Example 4_19
```

```
clc;funcprot(0);
//Given data
P_1=36000;// kW
P_2=27000;// kW
N_1=81.8;// r.p.m
H_1=13;// m
H_2=11;// m
D_1=7.82;// m

//Calculation
//As the specific speeds are the same,using the definition of specific speed in terms of power,
N_2=((N_1*sqrt(P_1)/(H_1^(5/4)))*((H_2^(5/4))/sqrt(P_2)));// rpm
// As the unit speeds are same,
D_2=(D_1*N_1*sqrt(H_2))/(sqrt(H_1)*N_2);// m
// As the unit flow is same,Q=Q_2/Q_1
Q=(D_2^2*H_2^(1/2))/((D_1^2*H_1^(1/2)));
// By solving Q, it gives the relation ,Q_2=0.886*Q_1;
Q_r=(1-Q)*100;
printf('\n Speed,N_2=%0.1f rpm \n Diameter,D_2=%0.2f m \n There is a reduction in flow by about %0.2f percentage.',N_2,D_2,Q_r);
// The answer vary due to round off error
```

Chapter 5

INTRODUCTION TO THERMAL POWER PLANT

Scilab code Exa 5.1 The coal required per hour

```
// Example 5_1
clc;clear;funcprot(0);
// Given data
P=100;// Plant capacity in Mw
CV=25600;// Calorific value in kJ/kg
n_th=30;// The thermal efficiency of the plant in %
n_eg=92;// Electrical generation efficiency in %

// Calculation
// Mechanical energy available=W*CV*(n_th/100) in kJ/hr
// Electrical energy available=W*CV*(n_th/100)*(n_eg/100) in kJ/hr
q_e=P*10^3*3600;// Heat equivalent in kJ/hr
W=(q_e/(CV*(n_th/100)*(n_eg/100)));// The coal required per hour in kg/hr
W=(W/1000);// The coal required per hour in tons/hr
printf('\nThe coal required per hour,W=%0.2f tons/hr',W);
```

Scilab code Exa 5.2 The capacity of the power plant

```
// Example 5_2
clc;clear;funcprot(0);
// Given data
CV=28900;//kJ/kg
n_b=83;// The boiler efficiency in %
n_t=32;// The turbine efficiency in %
n_g=97;// The generator efficiency in %
W=30;// The coal consumption of the station in tons/
    hr

// Calculation
P=((W*1000*CV)*(n_b/100)*(n_t/100)*(n_g/100))
    /(3600*1000);// The capacity of the power plant
    in MW
printf('\n The capacity of the power plant,P=%0.0f
   MW',P);
```

Scilab code Exa 5.3 The volume of gas required

```
//Example 5_3
clc;funcprot(0);
// Given values
P=100;// Power in kW
CV=4000;// Calorific value in kJ/m^3
n_o=0.20;// Over all efficiency of the plant

// Calculation
V=(3600*P)/(CV*n_o);// m^3/hr
printf('The volume of gas required per hour,V=%0.0f
   m^3/hr\n',V);
```

Chapter 14

BOILER ACCESSORIES

Scilab code Exa 14.1 Desuperheater

```
// Example 14_1
clc;funcprot(0);
//Given data
P=35;// bar
T_1=400;//Temperature of steam in  C
m_s=200;// Flow rate of steam in Tonnes/hr
T_2=450;// C
T_sp=60;// The temperature of spray water in  C
C_pw=4.2;// kJ/kg. C
//Calculation
//From steam tables,
//At 35 bar and 450 C
h_1=3337;// kJ/kg
//At 35 bar and 400 C
h_2=3222;// kJ/kg
h_w=C_pw*(T_sp-0);// kJ/kg
m_w=m_s*((h_1-h_2)/(h_2-h_w));//The mass of water
    supplied to the super heater in tons/hr
m_w=(m_w*1000)/3600;// kg/hr
printf('\nThe mass of water supplied to the super
    heater=%0.2f kg/sec',m_w);
```

Scilab code Exa 14.2 `Scale deposition in the super heater tube`

```
// Example 14_2
clc;funcprot(0);
//Given data
m_s=65;// Flow rate of steam in kg/sec
p=60;// Pressure in bar
m_fw=63;// Flow rate of feed water in kg/sec
m_mw=2;// Flow rate of make up water in kg/sec
moisture=2;//%
m_dsalt=3;// Mass of dissolved salt in ppm
m_dsolid=5;// Mass of dissolved salt in ppm
m_sc=1000;// ppm
m_bd=5;// ppm
m_c=8;// kg/sec
T=30;// Room temperature in  C
CV=20000;// Calorific value in kJ/kg
C_pw=4.2;// kJ/kg. C
m_w=1;// kg (Assumption)

//Calculation
//(a)
// Making the mass balance of the impurities
   entering and leaving the drum,
m_b=((m_fw*m_dsalt*10^-6)+(m_mw*m_dsolid*10^-6)-((
   moisture/100)*m_w*m_bd*10^-6))/(m_sc*10^-6);//The
    blow down rate in kg/sec

//(b)
//From Steam tables,at p=60bar
h_fp=1213.35;// kJ/kg
h_fT=m_w*(T-0)*C_pw;// kJ/kg
Q_loss=((m_b*(h_fp-h_fT))/(m_c*CV))*100;//The heat
   loss in the blow down as the percentage of heat
```

```
release in the furnace in %

//(c)
m_sd=((moisture/100)*m_w*m_dsolid*10^-6)*3600;// kg/hr
printf('\n(a)The blow down rate=%0.4f kg/sec \n(b)The heat loss in the blow down as the percentage of heat release in the furnace,Q_loss=%0.3f percentage \n(c)Deposition rate in super heater=%0.4f kg/hr',m_b,Q_loss,m_sd);
// The answer provided in the textbook is wrong
```

Scilab code Exa 14.3 The vertical height of the economiser coils

```
// Example 14_3
clc;funcprot(0);
//Given data
T_1=170;//  C
P_1=140;// bar
m_w=600;// The flow rate in the economiser in kg/sec
m_g=1250;// The flow rate of hot gases in kg/sec
T_go=450;//  C
v_g=12;// m/s
V_w=1.2;//The optimum velocity of water in  m/s
d_o=70;// mm
d_i=60;// mm
C_pg=1.12;// kJ/kg C
P_v=8;// The vertical pitch of the coil in cm
C=5;// Clearance in mm
B=4.8;// Duct width in m
// (LMTD)_cross=(LMTD)_counter*1.12;
C_pw=4.2;// kJ/kg. C
m=1;// kg
U_o=80;// Over all heat transfer coefficient in W/m^2 C
```

```
//Calculation
//From steam tables, at p=140 bar
T_s=336.75;// C
h_f1=1571.2;// kJ/kg
v_w=0.00161;// m^3/kg
//At 170 C ,
h_f2=m*C_pw*(T_1-0);// kJ/kg
Q=m_w*(h_f1-h_f2);// kJ/sec
T_gi=T_go+(Q/(C_pg*m_g));// C
Theta_i=(T_gi-T_s);// C
Theta_o=(T_go-T_1);// C
LMTD_counter=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));// Logrithemic mean temperature difference in C
LMTD_cross=LMTD_counter*1.12;// C
A_s=(Q*10^3)/(U_o*LMTD_cross);// m^2
n=m_w/(((%pi/4)*(d_i/1000)^2*(V_w/v_w)));
L=(A_s/(%pi*(d_o/1000)*n));// meters
N=L/(B-(2*C/100));// The number of the turns of the coil
printf('\nLength,L=%0.0f meters \nThe number of the turns of the coil=%0.0f',L,N);
// The answer provided in the textbook is wrong
```

Scilab code Exa 14.4 The length and number of tubes used in the air heater

```
// Example 14_4
clc;funcprot(0);
//Given data
m_g=1250;// The mass flow in the gases in kg/sec
m_a=1170;//The air flow rate in kg/sec
T_gi=450;//
T_go=160;// Temperature of hot gases at inlet and outlet in C
```

```
T_ai=35;//  C
d_i=60;// mm
d_o=65;// mm
U_o=30;//Over all heat transfer coefficient in W/m^2 C
V_g=13;// Gas velocity in m/sec
C_pg=1.1;// kJ/kg- C
C_pa=1;// kJ/kg- C
R_g=287;// J/kg-K
p=101.325;// kPa

//Calculation
v_gi=((R_g/1000)*(T_gi+273))/(p);//Specific volume of gas at entry in m^3/kg
T_ao=((m_g*C_pg*(T_gi-T_go))/(m_a*C_pa))+T_ai;// C
Theta_i=(T_gi-T_ao);//  C
Theta_o=(T_go-T_ai);//  C
LMTD_counter=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));//Logrithemic mean temperature difference in C
LMTD_actual=LMTD_counter*1.2;//  C
A=(m_g*C_pg*(T_gi-T_go)*10^3)/(U_o*LMTD_actual);// m^2
n=m_g/((%pi/4)*(d_i/1000)^2*(V_g/v_gi));// Number of tubes used in air heater
L=(A/(%pi*(d_o/1000)*n));// meters
printf('\nThe length,L=%0.0f m \nThe number of tubes used in air heater=%0.0f',L,n);
// The answer vary due to round off error
```

Scilab code Exa 14.5 The length and number of super heater coils required

```
// Example 14_5
clc;funcprot(0);
//Given data
```

```
p=60;// bar
T=500;//  C
V_s=10;// m/sec
d_i=50;// mm
d_o=60;// mm
m_s=100;// kg/sec
q=150;// The amount of heat given in the super heater to the steam in kW/m^2
C_pg=1.2;// kJ/kg- C
gradT_g=100;// C

//Calculation
//From steam tables ,
// At p=60 bar(saturated)
h_1=2784.3;// kJ/kg
// At p=60 bar and T=500 C
h_2=3422.3;// kJ/kg
v_s2=0.0567;// m^3/kg
Q=m_s*(h_2-h_1);// kJ/sec
A_s=Q/q;// m^2
n=m_s/((((%pi/4)*(d_i/1000)^2*(V_s/v_s2)));
L=(A_s/(%pi*(d_o/1000)*n));// m

//(b)
m_g=(Q)/(C_pg*gradT_g);// kg/sec
printf('\nThe number of super heat coils required=%0.0f \nLength of super heat coils ,L=%0.1f m \nThe gas flow rate through rhe super heater=%0.1f kg/sec',n,L,m_g);
```

Chapter 17

CONSENSERS

Scilab code Exa 17.1 The cooling water required per hour

```
// Example 17_1
clc;funcprot(0);
// Given data
P_1=100;// bar
T_1=400;//  C
n_t=80;// The isentropic efficiency of the turbine
   in %
P_2=0.1;// Pressure in the condenser in bar
SSC=4;// The specific steam consumption in kg/kWh
T_c=5;// Under cooling temperature in the condenser
   in  C
//gradT=(T_wo-T_wi)
gradT=10;// Rise in temperature of the cooling water
    in  C
P=120;// Plant capacity in kW
C_pw=4.2;// kJ/kg. C

//Calculation
//(a)
m_s=SSC*P*10^3;// The steam to be condensed in the
   condenser in kg/hr
```

```
// For condenser,Heat gained by water= Heatlost by steam
// From h-s chart,
h_3=1970;// kJ/kg
//From steam table at 0.1 bar
h_f3=191.8;// kJ/kg
m_w=(m_s*(h_3-h_f3))/(C_pw*gradT);// Mass flow rate of water in kg/hr
m_w=(m_w/(1000*60));// tons/min
printf('\n(a)The cooling water required per minute in the condenser=%0.1f tons/min',m_w);
// The answer provided in the textbook is wrong
```

Scilab code Exa 17.2 `The heat transfer area of condenser`

```
// Example 17_2
clc;funcprot(0);
//Given data
P_1=100;// bar
T_1=400;// C
T_wi=20;// C
P_v=71;// cm of Hg
P_b=76;//cm of Hg
gradT=10;// Rise in temperature of the cooling water in C
rho_w=1080;// kg/m^3
C_pw=4.6;//kJ/kg. C
U=400;// The over all heat transfer coefficient in W/m^2. C
P=30;// kW

//Calculation
P_2=(P_b-P_v)*0.01359;// The pressure in the condenser in bar
// From h-s chart,
```

```
h_1=3389;// kJ/kg
h_2=2054;//kJ/kg
m_s=(P*1000)/(h_1-h_2);// Mass of steam in kg/sec
x_2=0.782;// dryness fraction from h-s chart
// Heat lost by steam in condenser = Heat gained by
   water
h_f2=159.6;//kJ/kg
m_w=((h_2-h_f2)*m_s)/(C_pw*gradT);// kg/sec
CP=m_w;// Capacity of the pump in kg/sec
Theta_i=(38-20);// C
Theta_o=(38-30);// C
LMTD=(Theta_i-Theta_o)/log(Theta_i/Theta_o);// C
A=((h_2-h_f2)*m_w)/(U*LMTD);// The heat transfer
   area of the condenser in m^2
printf('\n(a)The mass of steam supplied to the
   turbine,m_s=%0.1f kg/sec \n(b)Capacity of the
   pump=%0.1f kg/sec \n(c) The heat transfer area of
    the condenser=%0.1f m^2',m_s,m_w,A);
// The answer vary due to round off error
```

Scilab code Exa 17.3 The thermal efficiency of the plant

```
// Example 17_3
clc;funcprot(0);
//Given data
P=3000;// kW
P_1=10;// bar
T_1=250;//  C
P_c=65;// cm of Hg
P_b=75.2;// cm of Hg
gradT=15;//  C
T_c=35;// The temperature of the condensate in  C
C_pw=4.2;// kJ/kg. C

//Calculation
```

```
//(a)
p_t=(P_b-P_c)*0.1359;// bar
p_s=p_t;// bar (as p_a=0)
// From h-s chart
x=0.846;// Dryness fraction from h-s chart
h_1=2984;// kJ/kg
h_2=2234;// kJ/kg
h_f2=147;//kJ/kg
gradh=(h_1-h_2);//  kJ/kg
m_s=P/gradh;// kg/sec
m_s=m_s*3600;// kg/hr
SSC=m_s/P;// Specific steam consumption in kg/kW-hr
//(b)
n_th=(gradh/(h_1-h_f2))*100;// Thermal efficiency in %
//(c)
m_w=(m_s*(h_2-h_f2))/(gradT*C_pw*1000);//Cooling water supplied in tons/hr.
printf('\n(a)Specific steam consumption=%0.1f kg/kW-hr \n(b)Thermal efficiency of the plant=%0.1f percentage \n(c)Cooling water supplied=%0.0f tons/hr',SSC,n_th,m_w);
```

Scilab code Exa 17.4 Quantity of cooling water

```
// Example 17_4
clc;funcprot(0);
//Given data
m_s=50000;// Steam condensed in kg/hr
T_s=40;// Temperature of steam in a condenser in  C
x=0.85;// Dryness of steam entering into condenser
m_a=150;// The air leakage in the condenser in kg/hr
T_c=35;// Temperature of the condensate in  C
T_suction=32;//Temperature at the suction of the air pump in  C
```

```
gradT=10;//The rise in cooling water temperature in C
R=287;// Gas constant in J/kg k
p_b=1.013;// bar
C_pw=4.2;// kJ/kg.k

//Calculation
//From steam tables
//(a)
//At 40 C  saturation temperature
p_s=0.0752;// Pressure in bar
v_s=19.5;// Specific volume in m^3/kg
V=m_s*x*v_s;// Volume in m^3
p_a=(m_a*R*(T_s+273))/(V*10^5);// The pressure of air in the condenser in bar
p_t=p_a+p_s;// The total pressure in the condenser in bar
P_v=(p_b-p_t)/0.013959;// Vacuum in condenser in cm of Hg

//(b)
// From steam tables ,At 32 C
p_s1=0.0485;// Partial pressure of steam in bar
p_a1=p_t-p_s1;// bar
V_1=(m_a*R*(T_suction+273))/(p_a1*10^5);// Volume of air at 32 C  in m^3/hr
Apc=V_1;// Air pump capacity in m^3/hr

//(c)
v_s1=29.6;// Specific volume of steam at 32 C saturation temperature in m^3/hr
Ls=V_1/v_s1;// Loss of steam in kg/hour

//(d)
// From steam tables ,At 40 C  saturation temperature and 0.85 dry
h_f1=168;// kJ/kg
h_fg1=2414;// kJ/kg
```

```
h_1=h_f1+(x*h_fg1);// kJ/kg
h_f2=147;// kJ/kg
m_w=(m_s*(h_1-h_f2))/(C_pw*gradT*1000);// Quality of cooling water passed through the condenser in tons/hr
printf('\n(a)Vacuum in condenser=%0.2f cm of Hg \n(b)Capacity of dry air pump=%0.1f m^3/hr \n(c)Loss of steam in kg per hour=%0.1f kg/hr \n(d)Quality of cooling water passed through the condenser=%0.0f tons/hr',P_v,Apc,Ls,m_w);
// The answer provided in the textbook is wrong
```

Scilab code Exa 17.5 Loss of condensate per hour

```
// Example 17_5
clc;funcprot(0);
//Given data
T_s=56;// Temperature of steam entering the condenser in C
T_a=46;// Temperature at the air pump suction in C
P_b=76;// The barometer reading in cm of Hg
Q=90;// The discharge of dry air pump in m^3/min
R=287;// J/kg.k

//Calculation
//(a)
//From steam tables,at saturation temperature of 56 C
p_s=0.1684;//Pressure of steam in bar
p_s=p_s/0.01359// cm of Hg
p_a=0;// Partial pressureair at the inlet of condenser in cm of Hg
p_t=p_s+p_a;
p_v=P_b-p_t;//Vacuum in the condenser in cm of Hg

```

```
//(b)
//From steam tables ,at saturation temperature of 46 C
p_s1=0.1028;// bar
v_s=14.56;// m^3/kg
p_a1=(p_t*0.01359)-p_s1;// bar
m_a=(p_a1*10^5*Q*60)/(R*(T_a+273));//The air leakage in the condenser per hour in kg/hr
//(c)
Ls=(Q*60)/v_s;// Loss of condensate in kg/hr
printf('\n(a)The vacuum in the condenser=%0.1f cm of Hg \n(b)The air leakage in the condenser=%0.1f kg/hr \n(c)Loss of condensate=%0.0f kg/hr',p_v,m_a,Ls);
// The answer vary due to round off error
```

Scilab code Exa 17.6 Minimum capacity of the air pump

```
// Example 17_6
clc;funcprot(0);
//Given data
m_a=84;// kg/hr
p_v=70;// cm of Hg
p_b=76;// cm of Hg
T_i=20;// The temperature at the inlet of the vacuum pump in C
n_v=80;// Volumetric efficiency in %
N=200;// rpm
LbyD=3/2;// L/D ratio
R=287;// J/kg.k

//Calculation
//(a)
p_t=((p_b-p_v)/p_b)*1.013;// bar
//From steam table , a saturation temperature at 20
```

```
    C
p_s=0.0238;// bar
v_s=57.63;//The specific volume of saturated steam
   in m^3/kg
p_a=p_t-p_s;// Partial pressure of air at point A in
    bar
V=(m_a*R*(T_i+273))/(p_a*10^5);// Total volume in m
   ^3/hr

//(b)
D=(((V/60)*100^2*100*4)/(%pi*1.5*N*(n_v/100)))^(1/3)
   ;// cm
L=1.5*D;// Stroke of air pump in cm

//(c)
m_s=V/v_s;// kg/hr
printf('\n(a)Capacity of air pump=%0.1f m^3/hr \n(
   bThe dimensions of the reciprocating air pump D=
   %0.0f cm & L=%0.1f cm \n(c)The mass of water
   vapour extracted per minute=%0.2f kg/hr',V,D,L,
   m_s);
// The answer vary due to round off error
```

Scilab code Exa 17.7 The capacity of wet air pump

```
// Example 17_7
clc;funcprot(0);
//Given data
m_s=12500;// kg/hr
m_a=5;// kg/hr
p_v=70;// cm of Hg
p_b=76;// cm of Hg
T=34;// C
n_v=80;// Volumetric efficiency in %
N=100;// rpm
```

```
LbyD=1.5;// L/D ratio
R=287;// J/kg.k

//Calculation
//From steam table, a saturation temperature at 34 C
p_s=0.0542;// bar
p_t=(p_b-p_v)*0.01359;// Pressure in condenser in bar
p_a=p_t-p_s;// Partial pressure of air in bar
V=(m_a*R*(T+273))/(p_a*10^5);// Volume of air in the condenser in m^3/hr
V=V/60;// m^3/min
V_s=m_s/(60*1000);// Volume of condensate formed m^3/min
T_v=V+V_s;// Total volume of air and condensate removed by the pump m^3/min
D=((T_v*100^2*100*4)/(%pi*1.5*N*(n_v/100)))^(1/3);// Diameter in cm
L=1.5*D;// Stroke of air pump in cm
printf('\n The capacity of wet air pump=%0.3f m^3/min \nThe dimensions of pump D=%0.1fcm & L=%0.0fcm',T_v,D,L);
// The answer vary due to round off error
```

Scilab code Exa 17.8 Percentage increase in air pump capacity and Percentage incre

```
// Example 17_8
clc;funcprot(0);
//Given data
T_s=38;// The temperature of the steam entering the condenser in C
T_a=34;// The temperature of the air entering the air pump in C
T_c=36;// The temperature of the air of the
```

```
    condensate in  C
m_a=3;// kg/hr
m_c=8000;//The condensate removed in kg/hr
R=287;// J/kg.k

//Calculation
//(a)
//From steam table , a saturation temperature at 38
     C
p_s1=0.0676;// bar
p_a1=0.0;// bar
p_t=p_a1+p_s1;// bar
//From steam table , a saturation temperature at 34
     C
v_s1=26.5;// kg/hr
p_s=0.0542;// bar
p_a=p_t-p_s;// Partial pressure of air at the entry
    of air pump in bar
V_1=(m_a*R*(T_a+273))/(p_a*10^5);// m^2/hr

//(b)
// From steam table , a saturation temperature at 36
     C
v_s2=24;// kg/hr
p_s=0.0606;// bar
p_a=p_t-p_s;// bar
V_2=(m_a*R*(T_c+273))/(p_a*10^5);// m^2/hr
V=m_c*0.001006;// m^3/hr
Tv=V_2+V;// Total volume removed by wet air pump in
   m^3/hr
Pi_apc=((Tv-V_1)/V_1)*100;// Percentage increase in
    air-pump capacity in %
m_wd=(V_1/v_s1);// Mass of water vapour carried with
     air when dry air-pump is used to remove the air
    in kg/hr
m_ww=(Tv/v_s2);// Mass of water vapour carried with
    air when wet air-pump is used to remove the air
    in kg/hr
```

```
Pi_lwv=((m_ww-m_wd)/m_wd)*100;// Percentage increase in loss of water vapour
printf('\n(a)The Capacity of the air pump=%0.0f m^3/hr \n(b)Percentage increase in air-pump capacity=%0.0f percentage \n   Percentage increase in air-pump capacity=%0.1f percentage',Tv,Pi_apc,Pi_lwv);
// The answer vary due to round off error
```

Scilab code Exa 17.9 The quantity of cooling water required

```
// Example 17_9
clc;funcprot(0);
//Given data
P=12500;// Steam turbine capacity in kW
M_a=1/1000;//kg per kg of steam
M_s=5;// kg/hr/kW
p_v=70;// cm of Hg
p_b=76;// cm of Hg
T_s=30;// The temperature at the suction of the air pump in  C
gradT=8;// Rise in temperature of the water in  C
x_1=0.9;// Dryness fraction
R=287;// J/kg k
C_pw=4.2;// kJ/kg. C

//Calculation
//From Steam tables, At 30 C
p_s=0.04325;// Partial pressure of steam in bar
v_s=32.8;// Specific volume of steam in m^3/kg
h_fg1=2438;// kJ/kg
//(a)
p_t=((p_b-p_v)/p_b*1.013);//bar
p_a=p_t-p_s;//Partial pressure of air in bar
m_a=P*M_s*M_a*(1/60);//Air leakage into the
```

```
condenser in kg/min
V=(m_a*R*(T_s+273))/(p_a*10^5);//Volume of air in m^3/min

//(b)
m_s=(V*60)/v_s;//The mass of water vapour carried with air in kg/hr

//(c)
m_s1=(P*M_s)/60;// kg/min
m_w=((m_s1*x_1*h_fg1)/(C_pw*gradT*1000));// tons/min
printf('\n(a)Capacity of air pump=%0.1f m^3/min\n(b)The mass of water vapour carried with air=%0.2f kg/hr\n(c)The quantity of cooling water required per minute=%0.1f tons/min',V,m_s,m_w);
// The answer provided in the textbook is wrong
```

Scilab code Exa 17.10 The mass of water required

```
// Example 17_10
clc;funcprot(0);
//Given data
x=0.9;// Dryness fraction
T_wi=15;//Cooling water inlet temperature C
R_air=287;// Nm/kg.K
R_steam=462.8;// Nm/kg.K
p_v=61.3;// cm of Hg
p_b=76;// cm of Hg
// p_a=0.3*p_t(given)
C_pw=4.2;// kJ/kg C


// Calculation
p_t=(p_b-p_v)*0.01359;// bar
p_a=0.3*p_t;// bar
```

```
p_s=p_t-p_a;// bar
// From steam tables ,Saturation temperature of steam
    at 0.14 bar
T_s=52;//  C
T_m=T_s;// Mixture temperature coming out of
   condenser in  C
// From steam tables ,At steam pressure of 0.14 bar ,
h_f1=218.4;// kJ/kg
h_fg1=2381.4;// kJ/kg
// m=m_w/m_s;
T_wo=T_s;//  C
m=((h_f1+(x*h_fg1))-(C_pw*T_s))/(C_pw*(T_wo-T_wi));
printf('\n(a)Mixture temperature coming out of
   condenser=%0.0f  C \n(b)Minimum quantity of
   cooling water required per kg of steam=%0.1f kg',
   T_m,m);
```

Scilab code Exa 17.11 The number of tube in each pass and the Length of each tube

```
// Example 17_11
clc;funcprot(0);
//Given data
m_s=30*10^3;// kg/hr
x=90/100;// Dryness fraction
v=1.5;// Water speed in m/s
d_o=2;// cm
t=1.2;// mm
T_wi=15;//  C
T_wo=25;//  C
U_o=3000;// W/m^2 C
P_abs=0.04;//bar
C_pw=4.2;// kJ/kg.k

//Calculation
T_s=28.6// The saturation temperature of steam at
```

```
   0.04 bar in  C
h_fg=2440;// kJ/kg (from steam tables)
//Total heat lost by steam power=Total heat gained
   by water
m_w=(m_s*h_fg*x)/(C_pw*(T_wo-T_wi));// kg/hour
Theta_i=T_s-T_wi;//  C
Theta_o=T_s-T_wo;//  C
LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));//
   Logrithemic mean temperature difference in  C
A=((m_w*h_fg*x)/3600)/(U_o*LMTD);// m^2
d_i=(d_o*10)-(2*t);// mm
T_a=(T_wi+T_wo)/2;
// For T_a=20 C ,
rho=998.2;// Density in kg/m^3
n=(m_w/((%pi/4)*(d_i/(10*100))^2*rho*3600));// The
   number tubes of tubes in one pass
Tn=2*n;// Total number of tubes in both passes
L=A/(%pi*(d_o/100)*Tn);// The length of each tube in
    m
printf('\nThe surface area required ,A=%0.1f m^2\nThe
    number of tubes in each pass ,n=%0.0f\nThe length
    of each tube ,L=%0.2f m',A,n,L);
// The answer provided in the textbook is wrong
```

Scilab code Exa 17.12 The area of the condenser required

```
// Example 17_12
clc;funcprot(0);
//Given data
m_s=10;// Tonnes
U=4;// KW/m^2. C
P=0.2;// bar

//Calculation
h_fg=2358.3;// Latent heat of steam at 0.2 bar
```

```
pressure in kJ/kg
Q=(m_s*1000*h_fg)/3600;//kW
//The given data is T_s-T_wo=10 C ; T_wo-T_wi=20 C ; Using this two equations,we get
Theta_i=30;// C
Theta_o=10;// C
LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));// Logrithemic mean temperature difference in  C
A=Q/(U*LMTD);// m^2
printf('\nThe area of the condenser required=%0.0f m^2',A);
```

Scilab code Exa 17.13 Number of tubes

```
// Example 17_13
clc;funcprot(0);
//Given data
m_s=5000;// kg
T_s=50;//  C
d_i=15;// mm
d_o=18;// mm
Theta_o=20;//  C
T_r=10;// C
Theta_i=Theta_o+T_r;//  C
L=3;// Length in m
v=2;// Velocity in m/s
h_o=5000;// J/m^2-s- C
h_i=3200;// J/m^2-s- C
f_i=0.0002;// m^2- C /W
K=80;// W/m- C

//Calculation
// At 50 C  saturated temperature
h_fg=2383;// kJ/kg
Q=(m_s*h_fg)/3600;//kW
```

```
LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));//  C
U_o=1/(((((1/h_i)+f_i)*(d_o/d_i))+(1/h_o)+(((d_o-d_i)
    /(d_o+d_i))*(d_o/(1000*K))));// W/m^2 C
A=((Q*10^3)/(U_o*LMTD));// m^2
n=(A/(%pi*(d_o/1000)*L));
printf('\nThe number of tubes required=%0.0f',n);
// The answer vary due to round off error
```

Scilab code Exa 17.14 The number of tubes required

```
// Example 17_14
clc;funcprot(0);
//Given data
P=120;//Plant capacity in MW
p_1=150;// bar
T_1=600;//  C
p_2=0.08;// bar
h_i=1000;// Heat transfer coefficient of water side
    in W/m^2  C
h_o=5000;// Heat transfer coefficient of steam side
    in W/m^2  C
T_wi=25;// The inlet temperature of water in  C
T_wo=35;//The outlet temperature of water in  C
d_i=2.5;// cm
d_o=2.9;// cm
L=5;// Length of the tube in m'

//Calculation
// From steam tables,the saturation temperature of
    the steam at 0.08 bar
T_c=41.5;//The condensate temperature in  C
h_f2=174;// kJ/kg
//From h-s chart,
h_1=3580;// kJ/kg
h_2=2080;// kJ/kg
```

```
m_s=((P*1000)/(h_1-h_2));// The mass of steam flowing through the turbine in kg/sec
Q=m_s*(h_2-h_f2);
U_o=1/(((1/h_i)*(d_o/d_i))+(1/h_o));// Overall heat transfer coefficient referred to outer surface of the tubes in W/m^2 C
Theta_i=(T_c-T_wi);// C
Theta_o=(T_c-T_wo);// C
LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));// Logrithemic mean temperature difference in C
A_s=(Q/(U_o*LMTD));//m^2
n=(A_s/(%pi*(d_o/100)*L));
printf('The number of tubes required=%0.0f tubes',n);
// The answer provided in the textbook is wrong
```

Scilab code Exa 17.15 The number of tube in each pass and the Length of each tube

```
// Example 17_15
clc;funcprot(0);
//Given data
m_s=300;// tons/hour
P_c=0.04;// bar
x=0.9;// Dryness fraction
U=3;// KJ/m^2- C
T_wi=15;// The inlet temperature of water in C
T_wo=25;//The outlet temperature of water in C
d_i=17.6;// mm
d_o=20;// mm
v=2.5;// The water speed in the condenser in m/sec
rho=1000;// Density of water in kg/m^3
C_pw=4.2;// kJ/kg. C

//Calculation
//From steam tables at 0.04bar,
```

```
T_s=28.6;// C
h_fg=2433;// kJ/kg
m_s=(m_s*1000)/3600;// kg/sec
m_w=(m_s*h_fg*x)/(C_pw*(T_wo-T_wi));// kg/sec
Theta_i=(T_s-T_wi);//  C
Theta_o=(T_s-T_wo);//  C
LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));// Logrithemic mean temperature difference in  C
Q=m_s*h_fg*x;// kJ/sec
A=(Q/(U*LMTD));//m^2
n_1=m_w/((%pi/4)*(d_i/1000)^2*v*rho);// Number of tubes in each pass
n=n_1*2;// Total number of tubes in both passes
L=A/(%pi*(d_o/1000)*n);// Length of each tube in m
printf('\nThe number of tubes in one pass=%0.0f\nLength of each tube =%0.2f m',n_1,L);// The answer provided in the textbook is wrong
// The answer vary due to round off error
```

Scilab code Exa 17.16 Percentage reduction in air pump capacity

```
// Example 17_16
clc;funcprot(0);
// Given data
m_s1=20;// tons/hr
m_s1=20*10^3;// kg/hr
m_a1=6;// kg/hr
T_1=39;//  C
T_2=28;//  C
T_3=36;//  C
gradT=15;//  C
R=287;// J/kg. C
C_pa=1.005;// kJ/kg. C
C_pw=4.18;//kJ/kg. C

```

```
// Calculation
// Considering section 1-1
// From steam tables , at T_1=39 C
p_s1=0.06991;// bar
v_s1=20.56;// m^3/kg
h_s1=2572.6;// kJ/kg
V_s1=(m_s1*10^3*v_s1);// m^3/hr
// By Dalton's law ,
V_a1=V_s1;// m^3/hr
p_a1=(m_a1*R*(T_1+273))/(V_a1);// N/m^2
p_a1=p_a1/10^5;// bar
p_t=p_s1+p_a1;// bar

//Considering section 2-2
//From steam tables , at T_2=28 C
p_s2=0.0378;// bar
v_s2=36.728;// m^3/kg
h_s2=2552.7;// kJ/kg
p_a2=p_t-p_s2;// bar
V_a2=(m_a1*R*(T_2+273))/(p_a2*10^5);// m^3/hr
//As per Dalton's law ,
V_s2=V_a2;// m^3/hr
m_s2=V_a2/v_s2;// kg/hr

// Considering section 3-3
// From steam tables , at T_3=36 C
p_s3=0.0594;// bar
v_s3=23.967;// m^3/kg
p_a3=p_t-p_s3;// bar
V_s3=(m_a1*R*(T_3+273))/(p_a3*10^5);// m^3/hr
V_a3=V_s3;// m^3/hr
m_s3=V_a3/v_s3;// kg/hr
Pr=((V_a3-V_a2)/V_a3)*100;// %

// Determination of cooling water requirement
// Assume
m_a2=m_a1;
m_c=m_s1;// (assumed))
```

```
m_w=(((m_s1*h_s1)-(m_s2*h_s2))+((m_a1*C_pa*T_1)-(
    m_a2*C_pa*T_2))-(m_c*C_pw*T_3))/(C_pw*gradT);//
    kg/hr
m_w=m_w/10^3;// tons/hr
m_w=(m_w*10^3)/3600;// kg/sec
m_sc=m_s3-m_s2;// Saving in condensate in kg/hr
Q=m_sc*C_pw*(T_3-gradT);//kJ/hr
printf('\nPercentage reduction in air pump capacity=
    %0.1f percentage \nMinimum quantity of cooling
    water=%0.1f kg/sec \nSaving in the condensate=%0
    .2f kg/hr \nSaving in heat supplied,Q=%0.2f kJ/hr
    ',Pr,m_w,m_sc,Q);
// The answer vary due to round off error
```

Scilab code Exa 17.17 The length and number of condenser tubes

```
// Example 17_17
clc;funcprot(0);
//Given data
m_s=250;// tons/hr
T_s=40;//  C
T_wi=30;// C
T_wo=36;// C
U_o=2.5;//kW/m^2 C
P_t=0.078;// bar
v=1.8;// m/s
d_i=23;// mm
d_o=25;// mm
rho_w=1000;// kg/m^3
moisture=12;// Percentage
x_2=(100-12)/100;// Dryness fraction
p_t=0.078;// bar
C_pw=4.2;// kJ/kg. C
R=287;// J/kg C
v=1.8;// m/s
```

```
//Calculation
//From steam tables ,at 40 C \
p_sat=0.074;//bar
h_fg2=2407;// kJ/kg
v_g2=19.54;// m^3/kg
//gradh=H_2-h_3
gradh=x_2*h_fg2;// kJ/kg
m_s=(250*1000)/3600;// kg/sec
m_w=(m_s*gradh)/(C_pw*(T_wo-T_wi));// kg/sec
p_air=p_t-p_sat;// bar
v_s2=x_2*v_g2;// m^3/kg
m_a=(m_s*v_s2*p_air*10^5)/(R*(T_s+273));// kg/sec
Theta_i=(T_s-T_wi);//  C
Theta_o=(T_s-T_wo);//  C
LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));//
    Logrithemic mean temperature difference in  C
A_s=(m_s*gradh)/(U_o*LMTD);// m^2
n=(m_w)/((%pi/4)*(d_i/1000)^2*rho_w*v);// Number of
    tubes
L=A_s/(%pi*(d_o/1000)*n);// Length in m
printf('\nQuantity of water circulation=%0.0f kg/sec
     \nAir leakage in the condenser=%0.2f kg/sec \
    nThe length of each tube,L=%0.1f m \nNumber of
    condenser tubes,n=%0.0f',m_w,m_a,L,n);
// The answer vary due to round off error
```

Chapter 18

COOLING PONDS AND COOLING TOWERS

Scilab code Exa 18.1 The quantity of air and make up water

```
// Example 18_1
clc;funcprot(0);
//Given data
n=10;// Number of fans used
T_1=35;//  C
T_2=30;//  C
m_w1=1000;// The quantity of cooling tower
    circulated through the tower in kg/min
DBT=35;// Dry bulb temperature in  C
WBT=25;//Wet bulb temperature in  C
C_pw=4.2;// kJ/kg C
RH=90;// Relative humidity in %

//Calculation
//The conditions of air at inlet and outlet are
    represented on psychrometric chart as shown in
    Fig.Prob.18.1(b)
// From psychrometric chart ,
H_a1=76.4;// kJ/kg
```

```
H_a2=94.5;// kJ/kg
w_1=19;// grams/kg
w_2=24.4;// grams/kg
v_s1=0.895;// m^3/kg
V=(v_s1*m_w1*C_pw*(T_1-T_2))/((H_a2-H_a1)-(((w_2-w_1
    )/1000)*C_pw*T_2));// m^3/min
C=V/n;// Capacity of each fan in  m^3/min
m_m=(V/v_s1)*((w_2-w_1)/1000)*60;// The quantity of
    make up in kg/hr
printf('\nThe quantity of air handled=%0.1f m^3/min
    \nThe quantity of make up water=%0.0f kg/hr',C,
    m_m);
// The answers provided in the textbook is wrong
```

Scilab code Exa 18.2 Make up required per hour

```
// Example 18_2
clc;funcprot(0);
//Given data
m_w1=400;// Quantity of cooling water in kg/min
T_1=43.5;// The temperature of water at inlet in  C
T_a1=18.5;//  C
RH=60;// Relative humidity in %
T_a2=27;//  C
V=600;// Volume of air per minute in m^3/min
P=4;// Power absorbed in kW
C_pw=4.2;// kJ/kg C

//Calculation
//The conditions of air at inlet and outlet are
    represented on psychrometric chart as shown in
    Fig.Prob.18.2
// Total heat of air at inlet + Total heat of water
    at inlet + heat dissipatedby motor = Total heat
    of air at outlet + Total heat of water at outlet
```

```
// From psychrometric chart,
H_a1=38.87;// kJ/kg
H_a2=84.85;// kJ/kg
w_1=7.8;// grams/kg
w_2=22.6;// grams/kg
v_s1=0.836;// m^3/kg
m_a=V/v_s1;// kg/min
Q=P*60;// kJ/min
//T_2=y(1)
function[X]=Temperature(y);
    X(1)=((m_w1*C_pw*(T_1-y(1)))+Q)-(m_a*((H_a2-H_a1)-(((w_2-w_1)/1000)*C_pw*y(1))));
endfunction
y=[10]
z=fsolve(y,Temperature);
T_2=z(1);// The temperature of water coming out of the tower in  C
m_m=m_a*((w_2-w_1)/1000);// The make up water required per hour in kg/min
printf('\nThe temperature of water coming out of the tower=%0.2f  C \nThe make up water required per hour=%0.1f kg/min',T_2,m_m);
// The answers provided in the textbook is wrong
```

Scilab code Exa 18.3 Amount of make up water required

```
// Example 18_3
clc;funcprot(0);
//Given data
T_1=45;//The temperature of water at inlet in  C
m_w1=360;// kg/min
V=10;// The air circulated in the tower in m^3/sec
Q=4900;// The amount of heat absorbed by the air in watts
DBT=20;// Dry bulb temperature in  C
```

```
RH=60;// Relative humidity in %
T_a2=26;// The temperature of air leaves the tower at saturated condition in C
C_pw=4.2;// kJ/kg C

//Calculation
// The condtions of air entering and leaving the tower are represented onn psychrometric chart as shown in Fig.Prob.18.3
// From psychrometric chart,
H_a1=45;// kJ/kg
H_a2=81;// kJ/kg
w_1=9.6;// grams/kg
w_2=21.6;// grams/kg
v_s1=0.848;// m^3/kg
m_a=V/v_s1;// kg/sec
Q=Q/1000;// kW=kJ/sec
//T_2=y(1)
function[X]=Temperature(y);
    X(1)=(((m_w1*C_pw*(T_1-y(1)))/60)+Q)-(m_a*((H_a2-H_a1)-(((w_2-w_1)/1000)*C_pw*y(1))));
endfunction
y=[10]
z=fsolve(y,Temperature);
T_2=z(1);// The temperature of water coming out of the tower in C
m_m=m_a*((w_2-w_1)/1000);// The make up water required per hour in kg/min
printf('\nThe temperature of water coming out of the tower=%0.0f C \nThe make up water required per hour=%0.3f kg/min',T_2,m_m);
```

Scilab code Exa 18.4 The make up required per hour

```
// Example 18_4
```

```
clc;funcprot(0);
//Given data
V=5000;//Circulation of cooling water in m^3/hr
C=3;// Allowable concentration ratio
Cr=12;// The cooling range in  C
El=2;// Evaporation losses in %
Wl=0.2;// Windage losses in %

//Calculation
E=(El/100)*V;// Evaporation losses in m^3/hr
W=(Wl/100)*V;// Windage losses in m^3/hr
B=(E/(C-1))-W;// Blow down rate in m^3/hr
M=E+W+B;// The make up water in m^3/hr
printf('\nThe make up water required=%0.0f m^3/hr',M
    );
```

Chapter 22

THERMODYNAMIC CYCLES FOR STEAM POWER PLANTS

Scilab code Exa 22.1 The thermal efficiency of the cycle

```
// Example 22_1
clc;funcprot(0);
//Given data
p_1=30;// The boiler pressure in bar
p_2=1;// The condenser pressure in bar

//Calculation
//(a)
// From steam tables, at pressure P_b=30 bar
h_1=2796;// kJ/kg
//For finding the dryness-fraction of steam at the
    point 'c',we can equate  the entropies.
// At pressure 30 bar=At pressure 1 bar
// From steam tables, at pressure P_1=30 bar and P_2
    =1 bar
T_s1=232.8;// C
T_s2=99.1;// C
```

```
h_f2=414.6;// kJ/kg
h_fg1=1797;// kJ/kg
h_fg2=2253;// kJ/kg
v_f2=0.001043;// m^3/kg
// Assume x_2=y(1)
function[X]=drynessfraction(y)
    X(1)=((2.3026*log10((T_s2+273)/273))+((y(1)*h_fg2)/(T_s2+273)))-((2.3026*log10((T_s1+273)/273))+(h_fg1/(T_s1+273)));
endfunction
y=[0.1];
z=fsolve(y,drynessfraction);
x_2=z(1);
//x_2=z(1);// Dryness fraction
h_2=h_f2+(x_2*h_fg2);// kJ/kg
n_r1=((h_1-h_2)/(h_1-h_f2))*100;// The thermal efficiency of the cycle without feed pump work in %
//(b)
W_p=(v_f2*(p_1-p_2)*10^5)/1000;// kJ
n_r2=(((h_1-h_2)-W_p)/(h_1-(h_f2+W_p)))*100;// The thermal efficiency of the plant feed pump work in %
printf('\nThe thermal efficiency of the cycle without feed pump work=%0.2f percentage \nThe thermal efficiency of the cycle with feed pump work=%0.2f percentage',n_r1,n_r2);
// The answer vary due to round off error
```

Scilab code Exa 22.2 The cycle efficiency

```
// Example 22_2
clc;funcprot(0);
//Given data
p_a=10;// bar
```

```
p_b=0.08;// bar
T_1=450;//  C
p_1=30;// bar
p_3=25;// bar
T_4=33;//  C
p_4=0.04;// bar


//Calculation
//From tables of mercury the following enthalpy values and entropy values are taken
h_1=359.11;// kJ/kg
h_f2=33.21;// kJ/kg
h_3=h_f2;// kJ/kg
s_1=0.5089;// kJ/kg.K
s_f2=0.087;// kJ/kg.K
Q_fg2=0.5721;// kJ/kg
h_g2=294.7;// kJ/kg
x_2=(s_1-s_f2)/(Q_fg2);
h_2=h_f2+(x_2*h_g2);// kJ/kg
// From steam tables and chart(For steam cycle)
h_4=3348.6;// kJ/kg
h_5=2183;// kJ/kg
h_6=138;// kJ/kg
h_7=972;// kJ/kg
h_8=2803;// kJ/kg
// Assume m_r=m_hg/m_H2O
m_r=(h_8-h_7)/(h_2-h_3);
// For each kg of steam generated,8.42 kg of mercury is to be used
n=((m_r*(h_1-h_2))+(h_4-h_5))/((m_r*(h_1-h_f2))+(h_7-h_6)+(h_4-h_8));// The cycle efficiency
printf('\nCycle efficiency=%0.3f',n);
```

Scilab code Exa 22.3 `The cycle efficiency and dryness`

```
// Example 22_3
clc;funcprot(0);
//Given data
p_1=30;// bar
p_3=0.04;// bar
x_1=0.841;// Dryness fraction

//Calculation
//From h-s chart:
h_1=2803;// kJ/kg
h_2=2370;// kJ/kg
h_3=2717;// kJ/kg
h_4=2124;// kJ/kg
x_2=0.824;// kJ/kg
p_7=2.5// bar
p_2=p_7;// bar
//From steam tables at p=2.5bar & p=0.04 bar
v_s1=0.00106;// kJ/kg
v_s2=0.00104;// kJ/kg
h_f5=121;// kJ/kg
h_f2=535;// kJ/kg

W_ph=(p_1-p_2)*10^2*v_s1;// Pump work for higher
    pressure stage in kJ/kg
W_pl=(p_1-p_2)*10^2*v_s2;// Pump work for lower
    pressure side in kJ/kg
m_s=x_1;// mass flow inkg
m_f=0.159;// Mass flow through first feed pump in kg
n_ws=(((h_1-h_2)+(m_s*(h_3-h_4))-(m_s*W_ph)-(m_f*
    W_pl))/((m_s*(h_1-h_f5))+(m_f*(h_1-h_f2))))*100;
    // Efficiency of the cycle
W_p=(p_1-p_2)*10^2*v_s2;// Pump work in kJ/kg
n_wos=(((h_1-h_4)-W_p)/(h_1-h_f5))*100;// Efficiency
     of the cycle without seperation
//From steam table,at p=0.04 bar
h_fg4=2433.1;// kJ/kg
h_f4=121.4;// kJ/kg
x_4=(h_4-h_f4)/(h_fg4);// Dryness at exit
```

```
printf('\n Efficiency of the cycle with seperation=
    %0.1f percentage \n Efficiency of the cycle
    without seperation=%0.1f percentage \n Dryness at
     exit ,x_4=%0.3f',n_ws,n_wos,x_4 );
// The answer vary due to round off error
```

Scilab code Exa 22.4 The efficiency of the reheat cycle

```
// Example 22_4
clc;funcprot(0);
//Given data
p_1=90;// bar
T_1=480;//  C
p_2=12;// bar
p_3=0.07;// bar
m=1;// Steam flow rate in kg/sec

//Calculation
//From h-s chart:
h_1=3333.5;// kJ/kg
h_2=2815;// kJ/kg
h_3=3425.5;// kJ/kg
h_4=2364;// kJ/kg
//From steam tables at p=0.07 bar
h_f5=161.8;// kJ/kg
v_sw1=0.001013;// m^3/kg
h_6=h_f5+((v_sw1*(p_1-p_3)*10^5)/(1000*m));// kJ/kg
W_p=(h_6-h_f5);// Pump work in kJ/kg
W_net=(h_1-h_2)+((h_3-h_4))-W_p;// Net Work done in
    kJ/kg
P=W_net*m;// Power generating capacity of the plant
    in kW
H_s=(h_1-h_6)+(h_3-h_2);// Heat supplied per kg of
    steam in kJ/kg
n=(W_net/H_s)*100;// Efficiency of the cycle
```

```
printf('\nEfficiency of the cycle=%0.1f percentage \nNet work done per kg steam=%0.1f kJ/kg',n,W_net);
// The answer vary due to round off error
```

Scilab code Exa 22.5 The thermal efficiency of the cycle

```
// Example 22_5
clc;funcprot(0);
//Given data
p_1=100;// bar
T_1=500;// C
p_2=8.5;// bar
p_3=p_2-0.5;// bar
p_4=0.05;// bar
n_t=80;// The isentropic efficiency of the turbine in %
n_lt=85;// The isentropic efficiency of lower stage of the turbine in %

//Calculation
//From h-s chart:
h_1=3377;// kJ/kg
h_2a=2750;// kJ/kg
h_3=3478;// kJ/kg
h_4a=2738;// kJ/kg
// The isentropic efficiency of the expansion 1-2 is 80% as given in problem
h_2=h_1-((n_t/100)*(h_1-h_2a));// kJ/kg
// The isentropic efficiency of the expansion 3-4 is 85% as given in problem
h_4=h_3-((n_lt/100)*(h_3-h_4a));// kJ/kg
//From steam tables ,
h_f5=137;// kJ/kg
n_th1=(((h_1-h_2)+(h_3-h_4))/((h_1-h_f5)+(h_3-h_2)))
```

```
*100;// The efficiency of the cycle in %
// From h-s diagram
h_6a=2305;// kJ/kg
// The isentropic efficiency of the expansion 2-6 is
    75% as given in problem
n_lt=75;//The isentropic efficiency of the turbine
   in %
h_6=h_2-((n_lt/100)*(h_2-h_6a));// kJ/kg
n_th2=(((h_1-h_2)+(h_2-h_6))/(h_1-h_f5))*100;// The
   thermal efficiency of the cycle without reheating
    in %
printf('\nThe thermal efficiency of the cycle with
   reheating=%0.1f percentage \nThe thermal
   efficiency of the cycle without reheating=%0.1f
   percentage',n_th1,n_th2);
// The answer is bit different due to calculation
   error in the book
```

Scilab code Exa 22.6 The isentropic efficiencies of the expansion stages

```
// Example 22_6
clc;funcprot(0);
//Given data
p_1=215;// bar
T_1=500;//  C
p_2=40;// bar
T_2=280;//  C
p_3=p_2-1;// bar
p_4=8;// bar
T_4=270;// C
p_5=p_4-0.5;// bar
p_6=0.07;// bar
m=10;// The flow of steam in kg/sec

//Calculation
```

```
// From h-s diagram
h_1=3234;// kJ/kg
h_2a=2822;// kJ/kg
h_2=2910;// kJ/kg
h_3=3435;// kJ/kg
h_4a=2977;// kJ/kg
h_4=2998;// kJ/kg
h_5=3473;// kJ/kg
h_6a=2444;// kJ/kg
h_6=2578;// kJ/kg
//From steam tables ,
h_f7=162;// kJ/kg
W=(h_1-h_2)+(h_3-h_4)+(h_5-h_6);// Work done per kg of steam kJ/kg
Q=(h_1-h_f7)+(h_3-h_2)+(h_5-h_4);// Heat supplied per kg of steam kJ/kg
n_th=(W/Q)*100;//The thermal efficiency of the cycle in %
P=(W*m);// Power developed by the plant in kW
n_i1=((h_1-h_2)/(h_1-h_2a))*100;//Isentropic efficiency of the first stage in %
n_i2=((h_3-h_4)/(h_3-h_4a))*100;//Isentropic efficiency of the second stage in %
n_i3=((h_5-h_6)/(h_5-h_6a))*100;//Isentropic efficiency of the third stage in %
printf('\n(a)The thermal efficiency of the cycle=%0.1f percentage \n   Power developed by the plant=%0.0f kW \n(b)Isentropic efficiency of the first stage=%0.1f percentage \n   Isentropic efficiency of the second stage=%0.1f percentage \n   Isentropic efficiency of the third stage=%0.0f percentage',n_th,P,n_i1,n_i2,n_i3);
```

Scilab code Exa 22.7 The quantity of steam circulated per hour

```
// Example 22_7
clc;funcprot(0);
//Given data
p_1=100;// bar
T_1=400;//  C
p_2=20;// bar
p_l=1;// bar
p_3=p_2-p_l;// bar
T_3=380;// C
n_i=80;// Isentropic efficiency of both the
   expansions in %
n_t=98;//The transmission efficiency in %
n_g=95;// The generator efficiency in %
P=60;// The generator output in MW

//Calculation
// From h-s diagram
h_1=3093;// kJ/kg
h_2a=2734;// kJ/kg
h_3=3203;// kJ/kg
h_4a=2157;// kJ/kg
// The isentropic efficiency of the expansion 1-2
   and 3-4 is 80% as given in problem
h_2=h_1-((n_i/100)*(h_1-h_2a));// kJ/kg
h_4=h_3-((n_i/100)*(h_3-h_4a));// kJ/kg
W=(h_1-h_2)+(h_3-h_4);//Work done per kg of steam kJ
   /kg
m_s=(P*1000)/(W*(n_t/100)*(n_g/100));// Mass of
   steam passing through the turbine in kg/sec
m_s=(m_s*3600)/1000;// tons/hr
printf('\nThe quantity of steam circulated per hour=
   %0.1f tons/hr',m_s)
```

Scilab code Exa 22.8 `The mass of steam generated by the boiler`

```
// Example 22_8
clc;funcprot(0);
//Given data
p_1=50;// bar
T_1=400;//  C
x=0.96;// Dryness
p_2=5;// bar
p_3=0.03;// bar
T_3=250;//  C
n_i=80;// Isentropic efficiency of both the expansions in %
n_m=99;//The mechanical efficiency in %
n_g=96;// The generator efficiency in %

//Calculation
//From h-s chart:
h_1=3198;// kJ/kg
h_2a=2675;// kJ/kg
h_3=2955;// kJ/kg
h_4a=2153;// kJ/kg
dh_1=((n_i/100)*(h_1-h_2a));//(h_1-h_2) kJ/kg
h_2=h_1-((n_i/100)*(h_1-h_2a));// kJ/kg
dh_2=((n_i/100)*(h_3-h_4a));//(h_3-h_4) in kJ/kg
W=dh_1+dh_2;//Work done per kg of steam kJ/kg
W_e=W*(n_m/100)*(n_g/100);// The work used out of 1060 kJ for the generation of electricity in kJ/kg
m_g=(1000/W_e)*3.6;// The steam generated in the boiler per 1 kW power generation in kg/kW-hr
//From steam tables,
h_fg=1643.5;// kJ/kg
Lh=x*h_fg;// The latent heat of steam lost per kg
m_s=(m_g*(h_3-h_2))/Lh;// The steam used in the reheater in kg
m=m_g+m_s;// Steam generated by the boiler per kW-hr output from the generator in kg
printf('\nThe mass of steam generated by the boiler per kW-hr=%0.3f kg',m);
```

```
// The answer vary due to round off error
```

Scilab code Exa 22.9 The efficiency of the cycle

```
// Example 22_9
clc;funcprot(0);
//Given data
p_1=100;// bar
p_4=0.035;// bar
T_1=500;// bar

//Calculation
// From the (Mollier) chart:
h_1=3373;// kJ/kg
h_2=2778;// kJ/kg
h_3=3478;// kJ/kg
h_4=2322;// kJ/kg
x_4=0.907;
// From steam tables
h_f5=112;// kJ/kg
W_p=10;// Pump work as calculated in kJ/kg
n=(((h_1-h_2)+(h_3-h_4)-W_p)/((h_1-h_f5)+(h_3-h_2)))
    ;// Efficiency of the cycle
printf('\n The efficiency of the cycle=%0.2f(or)%0.0
    f percentage',n,n*100);
```

Scilab code Exa 22.10 The efficiency of the plant and the steam required per hour

```
// Example 22_10
clc;funcprot(0);
//Given data
p_2=100;// bar
T_1=500;//  C
```

```
p_3=11.5;// bar
p_5=0.05// bar
n_i1=85;// Isentropic efficiency of each stage
   expansion in %
n_i2=80;//Isentropic efficiency of one stage
   expansion with no reheat in %
P=100;// The capacity of the plant in MW

//Calculation
//(a)
// In this case the processes are shown in Fig.Prob
   .22.10(b)
// From h-s chart:
h_2=3370;// kJ/kg
h_3aa=2860;// kJ/kg
h_4=3500;// kJ/kg
h_5aa=2530;// kJ/kg
// From steam tables, at 0.06 bar
h_f6=137.6;// kJ/kg
W_t1=h_2-h_3aa;// (H.P turbine) kJ/kg
W_t2=h_4-h_5aa;// (L.P turbine) kJ/kg
Q_b=h_2-h_f6;// Heat supplied in the boiler in kJ/kg
Q_r=h_4-h_3aa;// Heat supplied in the reheater in kJ
   /kg
n_a=((W_t1+W_t2)/(Q_b+Q_r))*100;// Efficiency of the
    cycle iin %
m_s=(P*10^3)/(W_t1+W_t2);// The mass flow of steam
   per scond in kJ/sec
m_sa=(m_s*3600)/1000;// tons/hr

//(b)
// In this case the processes are shown in Fig.Prob
   .22.10(c)
h_2=3370;// kJ/kg
h_3a=2300;// kJ/kg
h_f4=137.8;// kJ/kg
n_b=((h_2-h_3a)/(h_2-h_f4))*100;//Efficiency of the
   cycle in %
```

```
m_sb=(((P*10^3*3600))/((h_2-h_3a)*1000));// tons/hr
printf('\n(a)Efficiency of the plant with reheating=%0.1f percentage \n    The steam required per hour=%0.2f kJ/sec \n(b)Efficiency of the plant with no reheating=%0.1f percentage \n    The steam consumption per hour=%0.2f kJ/sec',n_a,m_sa,n_b,m_sb);
```

Scilab code Exa 22.11 The over all efficiency of the plant

```
// Example 22_11
clc;funcprot(0);
//Given data
P=27000;// kW
p_1=60;// bar
T_1=450;// C
p_v=707.5;// The condenser vaccum in mm of Hg
p_2=3;//bar
n_t=87;// The turbine efficiency
n_b=90;// The boiler efficiency in %
n_a=95;//The alternator efficiency in %
n_m=98;//The mechanical efficiency in %
p_b=760;// cm of Hg

//Calculation
p_3=((p_b-p_v)/p_b)*1.013;//The condenser pressure bar
// From h-s chart:
h_1=3296;// kJ/kg
h_2a=2606;// kJ/kg
h_3a=2163;// kJ/kg
h_2=h_1-((n_t/100)*(h_1-h_2a));// kJ/kg
h_3=h_2-((n_t/100)*(h_2-h_3a));// kJ/kg
//From steam tables
h_f4=162;// kJ/kg (at 0.07 bar)
```

```
h_f5=558;// kJ/kg (at 3 bar)
//Assume m=y(1)
function[X]=bled(y)
    X(1)=((1-y(1))*(h_f5-h_f4))-(y(1)*(h_2-h_f5));
endfunction
y=[0.1]
z=fsolve(y,bled);
m=z(1);// kg/kg of steam generated
W=(h_1-h_2)+((1-m)*(h_2-h_3));//Work developed per
   kg of steam in kJ/kg
W_act=(P/((n_a/100)*(n_m/100)));//Actual work
   developed by the turbine kW
m_s=(W_act/W)*(3600/1000);// Steam generated per
   second in tons/hr
P_p=P*(10/100);// Pump power in kW
P_net=P*(1-(10/100));// Net power available in kW
Q_s=((m_s*1000*(h_1-h_f5))/((n_b/100)*3600));// Heat
    supplied in the boiler in kW
n_o=(P_net/Q_s)*100;// The overall efficiency of the
    plant in %
printf('\n(a)The steam bled per kg of steam supplied
    to the turbine=%0.3f kg/kg of steam generated \n
   (b)Steam generated per hour=%0.1f tons/hr \n(c)
   The overall efficiency of the plant=%0.1f
   percentage',m,m_s,n_o);
// The answer vary due to round off error
```

Scilab code Exa 22.12 The thermal efficiency of the plant

```
// Example 22_12
clc;funcprot(0);
//Given data
T_1=300;// C
p_1=35;// bar
p_2=25;// bar
```

```
p_2a=1.5;// bar
p_3=0.1;// bar
n_t=80/100;// The isentropic efficiency for both
    sections of the turbine
gradT=10;//  C
m_w=1;// kg
C_p=4.2;// kJ/kg. C

// Calculation
// From h-s chart:
h_1=2970;// kJ/kg
h_2=2504;// kJ/kg
h_3=2197;// kJ/kg
h_f2=264;// kJ/kg (at 1.5 bar)
h_f2a=h_f2-(m_w*C_p*gradT);// kJ/kg
h_f3=190;// kJ/kg (at 0.1 bar)
m=(h_f2a-h_f3)/(h_2-h_f3);// kg/kg of steam
W=(h_1-h_2)+((1-m)*(h_2-h_3));// kJ/kg
Q_s=h_1-h_f2a;// kJ/kg
n_th=(W/Q_s)*100;// Thermal efficiency of the plant
printf('\n(a)Bleed steam per kg of steam supplied to
     the steam turbine=%0.3f kg/kg of steam \n(b)The
    thermal efficiency of the plant=%0.1f percentage'
    ,m,n_th);
// The answer provided in the textbook is wrong
```

Scilab code Exa 22.13 The cycle efficiency

```
// Example 22_13
clc;funcprot(0);
//Given data
T_1=300;//  C
p_1=40;// bar
p_2=14;// bar
p_3=3.4;// bar
```

```
p_4=0.07;// bar
n_t=80/100;// The turbine efficiency of each portion
    of the expansion

//Calculation
//(a)
// From h-s chart:
h_1=2953;// kJ/kg
h_2a=2738;// kJ/kg
h_2=h_1-((n_t)*(h_1-h_2a));// kJ/kg
// From h-s chart:
h_3a=2529;// kJ/kg
h_3=h_2-((n_t)*(h_2-h_3a));// kJ/kg
// From h-s chart:
h_4a=2040;// kJ/kg
h_4=h_3-((n_t)*(h_3-h_4a));// kJ/kg
// From steam tables
h_f5=162;// kJ/kg
h_f7=575;// kJ/kg
h_f8=825;// kJ/kg
m_1=(h_f8-h_f7)/(h_2-h_f8);// kJ/kg of steam
//Assume m_2=y(1);h_f6=y(2)
function[X]=mass(y)
    X(1)=(y(1)*(h_3-h_f7))-(1*(h_f7-y(2)));
    X(2)=(((m_1+y(1))*h_f7)+((1-m_1-y(1))*h_f5))-(1*
       y(2));
endfunction
y=[0.1 100];
z=fsolve(y,mass)
m_2=z(1);// kJ/kg of steam supplied to turbine
h_f6=z(2);// kJ/kg
//(b)
n=(((h_1-h_2)+((1-m_1)*(h_2-h_3))+((1-m_1-m_2)*(h_3-
   h_4)))/(h_1-h_f8))*100;//The efficiency of the
   cycle in %
printf('\n(a)The optimum mass of bled steam=%0.2f kJ
   /kg \n(b)The cycle efficiency=%0.1f percentage',
   m_2,n);
```

```
// The answer vary due to round off error
```

Scilab code Exa 22.14 The quantity of steam extracted

```
// Example 22_14
clc;funcprot(0);
//Given data
T_1=350;//  C
p_1=30;// bar
p_2=6;// bar
p_3=1;// bar
p_4=0.07;// bar
P=10;// Power developed by the turbine in MW
n_t=80/100;// Isentropic efficiency of each stage

// Calculation
// From h-s chart:
h_1=3106;// kJ/kg
h_2=2811;// kJ/kg
h_3=2560;// kJ/kg
h_4=2259;// kJ/kg
// From steam tables
h_f2=777;// kJ/kg (at 6 bar)
h_f3=415;// kJ/kg (at 1 bar)
h_f5=162;//kJ/kg (at 0.07 bar)
h_f8=h_f2;// kJ/kg
h_f6=h_f3;// kJ/kg
//Assume m_1=y(1);m_2=y(2)
function[X]=mass(y)
    X(1)=(y(1)*(h_2-h_f2))-(1*(h_f8-h_f6));
    X(2)=((y(2)*(h_3-h_f3))+(y(1)*(h_f2-h_f3)))-((1-
        y(1)-y(2))*(h_f6-h_f5));
    X(3)=(((1-y(1)-y(2)))*h_f6)+((y(1)+y(2))*h_f3)-(
        y(3));
endfunction
```

```
y=[0.1 0.01 100];
z=fsolve(y,mass);
m_1=z(1);// kg/kg of steam generated
m_2=z(2);// kg/kg of steam generated
W_t=(h_1-h_2)+((1-m_1)*(h_2-h_3))+((1-m_1-m_2)*(h_3-h_4));// kJ/kg
m_s=((P*10^3)/W_t)*60;// kg/sec
m_s6=(m_s*m_1);// Quantity of steam extracted per minute at 6 bar pressure in kg/min
m_s1=(m_s*m_2);// Quantity of steam extracted per minute at 1 bar pressure in kg/min
C=m_s6+m_s1;// Capacity of feed pump extraction pump in kg/min
printf('\nQuantity of steam extracted per minute at 6 bar pressure=%0.1f kg/min \nQuantity of steam extracted per minute at 1 bar pressure=%0.1f kg/min \nCapacity of feed pump extraction pump=%0.1f kg/min',m_s6,m_s1,C);
// The answer provided in the textbook is wrong
```

Scilab code Exa 22.15 The thermal efficiency of the cycle

```
// Example 22_15
clc;funcprot(0);
//Given data
T_1=400;// C
p_1=40;// bar
p_2=2;// bar
p_3=0.5;// bar
p_4=0.05;// bar
n_t1=75/100;// The isentropic efficiency of the first stage of the turbine
n_t2=80/100;// The isentropic efficiency of the second stage of the turbine
n_t3=85/100;// The isentropic efficiency of the
```

```
    third stage of the turbine
m_s=10;// The steam flow in kg/sec

// Calculation
// From h-s chart:
h_1=3210;// kJ/kg
h_2a=2562;// kJ/kg
h_2=h_1-((n_t1)*(h_1-h_2a));// kJ/kg
h_3a=2508;// kJ/kg
h_3=h_2-((n_t2)*(h_2-h_3a));// kJ/kg
h_4a=2232;// kJ/kg
h_4=h_3-((n_t3)*(h_3-h_4a));// kJ/kg
// From steam tables
h_f8=502;// kJ/kg(2 bar)
h_f10=h_f8;// kJ/kg
h_f6=339;// kJ/kg(0.5 bar)
h_f7=h_f6;// kJ/kg
h_f9=h_f6;// kJ/kg
h_f5=136;// kJ/kg(0.05 bar)
//Assume m_1=y(1);m_2=y(2)
function[X]=mass(y)
    X(1)=(y(1)*(h_2-h_f10))-((1-y(1))*(h_f8-h_f7));
    X(2)=(y(2)*(h_3-h_f9))-((1-y(1)-y(2))*(h_f6-h_f5
       ));
endfunction
y=[0.01 0.01];
z=fsolve(y,mass);
m_1=z(1);// kJ/kg
m_2=z(2);// kJ/kg
W=(h_1-h_2)+((1-m_1)*(h_2-h_3))+((1-m_1-m_2)*(h_3-
   h_4));// kJ/kg
P=W*m_s;// Power developed by the turbine in kW
Q_s=h_1-h_f10;// Heat supplied per kg of steam in kJ
   /kg
n_th=(W/Q_s)*100;// Thermal efficiency of the cycle
   in %
printf('\n(a)Steam bled for regenerative heaters per
    kg of steam to turbine,m_1=%0.4f kJ/kg & m_2=%0
```

```
.4f kJ/kg \n(b)Power developed by the turbine=%0.0f kW \n(c)Thermal efficiency of the cycle=%0.2f percentage',m_1,m_2,P,n_th);
// The answer provided in the textbook is wrong
```

Scilab code Exa 22.16 `Over all efficiency of the plant`

```
// Example 22_16
clc;funcprot(0);
//Given data
T_1=459;// C
T_3=420;// C
p_1=70;// bar
p_2=25;// bar
p_3=10;// bar
p_4=0.07;// bar
n_t1=78.5/100;// The isentropic efficiency of the H.P turbine
n_t2=83/100;// The isentropic efficiency of the L.P turbine 1
n_t3=83/100;// The isentropic efficiency of the L.P turbine 2
T_7=179;// C
P=20;// MW
n_m=85/100;// Mechanical efficiency of the turbine
n_t=95/100;// Transmission efficiency
n_g=95/100;// Generation efficiency

// Calculation
// From h-s chart:
h_1=3280;// kJ/kg
h_2a=2997;// kJ/kg
h_2=h_1-((n_t1)*(h_1-h_2a));// kJ/kg
h_3=3277;// kJ/kg
h_4a=3020;// kJ/kg
```

```
h_4=h_3-((n_t2)*(h_3-h_4a));// kJ/kg
h_5a=2220;// kJ/kg
h_5=h_4-((n_t3)*(h_4-h_5a));// kJ/kg
// From steam tables
h_f6=162;// kJ/kg(at 0.07 bar)
h_f7=758;// kJ/kg(at 10 bar)
function[X]=mass(y)
    X(1)=(y(1)*(h_4-h_f7))-((1-y(1))*(h_f7-h_f6));
endfunction
y=[0.1];// kg
z=fsolve(y,mass);
m=z(1);// kg
W=(h_1-h_2)+(h_3-h_4)+((1-m)*(h_4-h_5));// kJ/kg
E_g=W*n_m*n_t*n_g;// Energy coverted for generating the electrical energy in kJ
m_s=((P*10^3)/E_g)*60;// Steam generated in kg/min
Q_s=(h_1-h_f7)+(h_3-h_2);// Heat supplied per kg of steam in kJ/kg
n_th=(W/Q_s)*100;// Thermal efficiency of the cycle in %
printf('\n(a)Thermal efficiency of the cycle=%0.1f percentage \n(b)Quantity of steam supplied per minute=%0.0f kg/min',n_th,m_s);
```

Scilab code Exa 22.17 The amount of cooling water

```
// Example 22_17
clc;funcprot(0);
//Given data
P=500;// Plant capacity in kW
T_1=300;//  C
p_4=30;// bar
p_5=7;// bar
p_6=0.04;// bar
dT=5;// The rise in cooling water temperature in  C
```

```
C_pw=4.2;// kJ/kg. C

// Calculation
// From h-s chart:
h_4=3000;// kJ/kg
h_5=2700;// kJ/kg
h_6=1970;// kJ/kg
// From steam tables
h_f1=121.4;// kJ/kg(at 0.04 bar)
h_f2=697;// kJ/kg(at 7 bar)
function[X]=mass(y)
    X(1)=((y(1)*h_5)+((1-y(1))*h_f1))-(1*h_f2);
endfunction
y=[0.1];
z=fsolve(y,mass);
m=z(1);// kg
W=(1*(h_4-h_5))+((1-m)*(h_5-h_6));// kJ/kg
Q_s=h_4-h_f2;// Heat supplied in kJ/kg
n_s=(W/Q_s)*100;// Efficiency in %
m_s=(P/W)*3600;//Steam generated per second in kg/hr
m_w=((h_6-h_f1)*(m_s/3600)*(1-m))/(C_pw*dT);// kg/sec
// If there ie no feed water,then
W_1=h_4-h_6;// kJ/kg
Q_s=h_4-h_f1;// kJ/kg
n=(W_1/Q_s)*100;// Efficiency in %
m_s1=(P/W_1)*3600;//Steam generated per second in kg/hr
m_w1=((m_s/3600)*(h_6-h_f1))/(C_pw*dT);// The amount of cooling water in kg/sec
printf('\n(a)The rankine efficiency=%0.1f percentage \n    Steam generation rate of boiler=%0.1f kg/hr \n    The amount of cooling water=%0.2f kg/sec \n(b)The rankine efficiency=%0.1f percentage \nSteam generation rate of boiler=%0.1f kg/hr \nThe amount of cooling water=%0.2f kg/sec',n_s,m_s,m_w,n,m_s1,m_w1);
// The answer vary due to round off error
```

Scilab code Exa 22.18 The thermal efficiency of the plant and power generating cap

```
// Example 22_18
clc;funcprot(0);
//Given data
T_1=500;//  C
p_1=40;// bar
p_2=10;// bar
p_3=0.04;// bar
m_b=50;// The boiler generation rate in tons/hour
n_m=85/100;// Mechanical efficiency
n_g=95/100;// Electrical generation efficiency

// Calculation
// From h-s chart:
h_1=3400;// kJ/kg
h_2=3050;// kJ/kg
h_3=2150;// kJ/kg
// From steam tables
h_f4=121.4;// kJ/kg(at 0.04 bar)
h_f5=762.6;// kJ/kg(at 10 bar)
h_f6=h_f5;// kJ/kg
//Assume m_1=y(1);h_fm=y(2)
function[X]=mass(y)
    X(1)=((y(1)*h_f6)+((1-y(1))*h_f4))-(y(1)*y(2));
    X(2)=(y(1)*(h_2-h_f5))-(1*(h_f5-y(2)));
endfunction
y=[0.1 100];
z=fsolve(y,mass);
m=z(1);// kg/kg of steam generated
h_fm=z(2);// kJ/kg
W=(h_1-h_2)+((1-m)*(h_2-h_3));// kJ/kg
m_b=m*100;// Bled steam in %
Q_s=h_1-h_f5;// Heat supplied per kg of steam in kJ/
```

```
kg
n=(W/Q_s)*100;// Efficiency in %
P=(((m_b*10^3)*W*n_m*n_g)/3600)/1000;// Power developed in MW
printf('\nThe percentage of bled steam=%0.0f percentage \nThe thermal efficiency of the plant=%0.1f percentage \nThe generating capacity of the plant=%0.1f MW',m_b,n,P);
// The answer provided in the textbook is wrong
```

Scilab code Exa 22.19 Boiler generating rate per hour in tons of steam

```
// Example 22_19
clc;funcprot(0);
//Given data
P=100;// MW
p_2=80;// bar
p_3=7;// bar
p_5=0.05;// bar
T_4=350;//  C

// Calculation
// From h-s chart:
h_2=2990;// kJ/kg
h_3=2350;// kJ/kg
h_4=3170;// kJ/kg
h_5=2180;// kJ/kg
// From steam tables
h_f6=138;// kJ/kg
h_f7=697;// kJ/kg
function[X]=mass(y)
    X(1)= (y(1)*(h_3-h_f7))-((1-y(1))*(h_f7-h_f6));
endfunction
y=[0.1];
z=fsolve(y,mass);
```

```
m=z(1);
m_p=m*100;// Percentage of bled steam in %
W=(h_2-h_3)+((1-m)*(h_4-h_5));// kJ/kg
Q_s=(h_2-h_f7)+((1-m)*(h_4-h_3));// kJ/kg
n=(W/Q_s)*100;// The efficiency of the power plant in %
m_b=((P*10^3)/((h_2-h_3)+((1-m)*(h_4-h_5))));// tons/hr
printf('\nThe percentage of bled steam=%0.1f percentage \nThe thermal efficiency of the cycle=%0.0f percentage \nBoiler generating rate=%0.0f tons/hr',m_p,n,m_b);
// The answer provided in the textbook is wrong
```

Scilab code Exa 22.20 The Theoretical over all efficiency of the plant

```
// Example 22_20
clc;funcprot(0);
//Given data
T_1=556;// C
T_2=222;// C
m_s=20;// kg/sec
n_m=80/100;// Mechanical efficiency
n_t=95/100;// Transmission efficiency
n_g=85/100;// Generator efficiency
W_act=50/100;
h_f1=76;// kJ/kg
h_f2=29;// kJ/kg
h_fg1=290;// kJ/kg
h_fg2=302;// kJ/kg
h_g1=366;// kJ/kg
h_g2=331;// kJ/kg
s_f1=0.152;// kJ/kg-K
s_f2=0.08;// kJ/kg-K
s_fg1=0.359;// kJ/kg-K
```

```
s_fg2=0.626;// kJ/kg-K
s_g1=0.511;// kJ/kg-K
s_g2=0.706;// kJ/kg-K
p_a=17;// bar
p_b=0.035;// bar
h_fa=874;// kJ/kg
h_fb=111;// kJ/kg
h_fga=1932;// kJ/kg
h_fgb=2453;// kJ/kg
h_ga=2806;// kJ/kg
h_gb=2564;// kJ/kg
s_fa=2.37;// kJ/kg-K
s_fb=0.388;// kJ/kg-K
s_ga=6.42;// kJ/kg-K
s_gb=0.388;// kJ/kg-K

// Calculation
//(a)
x_2=(s_g1-s_f2)/s_fg2;// The condition of the mercury vapour at point2
m_hg=h_fga/(x_2*h_fg2);// kg
//(b)
W=h_g1-(h_f2+(x_2*h_fg2));// kJ/kg
W_m=W*m_hg;//Work done per kg of Hg vapour in kJ
//(c)
// From steam tables ,
T_sup=380+273;// K
T_sa=203.4+273;// K
T_b=26.5+273;// K
x_b=(((s_ga+(2*2.303*log(T_sup/T_sa)))*(T_b))-s_fb)/(T_b/h_fga);
T_sup=383+273;// K
x_2=0.72;
W_s=(h_ga+(2*(T_sup-T_sa)))-(h_fb+(x_2*h_fgb));// Work done per kg of steam in  kJ/kg
//(d)
W=W_m+W_s;// Total work done in kJ
Q_s=(m_hg*(h_g1-h_f2))+(1*(h_fa-h_fb))+(2*(T_sup-
```

```
T_sa));// Heat supplied in kJ
n_o=(W/Q_s)*100;// Overall efficiency of the cycle in %
E=((m_s*W*W_act)*n_m*n_t*n_g)/1000;// Total energy generated per sec in MW
printf('\n(a)Mass of Hg required per kg of steam used=%0.1f kg \n(b)Work done per kg of Hg vapour=%0.1f kJ/kg \n(c)Work done per kg of steam=%0.0f kJ/kg \n(d)Overall efficiency of the cycle=%0.1f percentage \n(e)Total energy generated per sec=%0.3f MW',m_hg,W_m,W_s,n_o,E);
// The answer provided in the textbook is wrong
```

Scilab code Exa 22.21 The Power generating capacity of the plant

```
// Example 22_21
clc;funcprot(0);
//Given data
p_1=30;// bar
T_1=550;//  C
p_2=2.6;// bar
p_3=0.2;// bar
m_s=30;// kg/sec

//Calculation
//From h-s chart:
h_1=3580;// kJ/kg
h_2=2870;// kJ/kg
h_3=2440;// kJ/kg
// From steam tables
h_f2=541;// kJ/kg
h_f3=251.5;// kJ/kg
function[X]=mass(y)
    X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f3));
endfunction
```

```
y=[0.1];
z=fsolve(y,mass);
m=z(1);// kg
P=m_s*((h_1-h_2)+((1-m)*(h_2-h_3)))/1000;// MW
n_r=((h_1-h_3)/(h_1-h_f3))*100;// The efficiency of
    the rankine cycle in %
n_b=(((h_1-h_2)+((1-m)*(h_2-h_3)))/(h_1-h_f2))*100;
printf('\nThe power generating capacityof the plant=
    %0.2f MW \nThe efficiency of the rankine cycle=%0
    .0f percentage \nThe efficiency of the cycle with
     bled heating=%0.0f percentage',P,n_r,n_b);
// The answer vary due to round off error
```

Scilab code Exa 22.22 Boiler generating capacity

```
// Example 22_22
clc;funcprot(0);
//Given data
P=30;// MW
p_1=0.04;// bar
p_2=7;// bar
p_3=60;// bar
T_1=550;// C
p_c=730;// mm of Hg
p_v=760;// mm of Hg
n_t=90/100;// The isentropic efficiency of the
    turbine

//Calculation
p_1=((p_v-p_c)*133.3)/10^5;// bar
//From h-s chart:
h_1=3420;// kJ/kg
h_2a=2860;// kJ/kg
h_2=2900;// kJ/kg
h_3=2410;// kJ/kg
```

```
h_3a=2190;// kJ/kg
// From steam tables
h_f3=121.5;// kJ/kg(liquid heat at 0.04 bar)
h_f2=697;// kJ/kg(liquid heat at 7 bar)
function[X]=mass(y)
    X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f3));
endfunction
y=[0.1];
z=fsolve(y,mass);
m=z(1);// kg
m_s=(P*10^3)/((h_1-h_2)+((1-m)*(h_2-h_3a)));// kg/
    sec
printf('\n(a)Fraction of steam bled for feed heating
    =%0.3f kg \n(b)Boiler generating capacity=%0.1f
    kg/sec',m,m_s);
```

Scilab code Exa 22.23 The boiler generating capacity in tons of steam per hour

```
// Example 22_23
clc;funcprot(0);
//Given data
P=120;// MW
p_1=86;// bar
p_2=7;// bar
p_3=0.35;// bar
T_1=350;//  C

//Calculation
//From h-s chart:
h_1=2980;// kJ/kg
h_2=2520;// kJ/kg
h_3=3170;// kJ/kg
h_4=2550;// kJ/kg
// From steam tables
h_f1=304.3;// kJ/kg(liquid heat at 0.35 bar)
```

```
T_s1=72.7;//  C
h_f2=697;// kJ/kg(liquid heat at 7 bar)
T_s2=165;//  C
h_f4=h_f1;// kJ/kg
function[X]=mass(y)
    X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f4));
endfunction
y=[0.1];
z=fsolve(y,mass);
m=z(1);// tons/hr
S=(1/m);// The ratio of steam bled to steam
   generated
m_s=((P*10^3)/((h_1-h_2)+((1-m)*(h_3-h_4))))
   *(3600/1000);// kg/sec
n_th=(((h_1-h_2)+((1-m)*(h_3-h_4)))/((h_1-h_f1)+((1-
   m)*(h_3-h_2))))*100;
printf('\n(a)The ratio of steam bled to steam
   generated=%0.2f \n(b)The boiler generating
   capacity=%0.1f tons/hr \n(c)The thermal
   efficiency of the cycle=%0.1f percentage',S,m_s,
   n_th);
// The answer vary due to round off error
```

Scilab code Exa 22.24 The Power output capacity of the plant

```
// Example 22_24
clc;funcprot(0);
//Given data
T_1=300;//  C
p_1=30;// bar
p_2=10;// bar
p_4=5;// bar
T_4=270;//  C
p_6=0.07;// bar
m_s=20;// tons/hr
```

```
C_pw=4.2;// kJ/kg. C
T_9=180;//  C
T_8=38;//  C

//Calculation
//From h-s chart:
h_1=3000;// kJ/kg
h_2=2780;// kJ/kg
h_3=2640;// kJ/kg
// From steam tables
h_f2=762.5;// kJ/kg
function[X]=mass(y)
    X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*C_pw*(T_9-T_8)
       );
endfunction
y=[0.1];
z=fsolve(y,mass);
m=z(1);// kg
//From h-s chart:
h_4=3000;// kJ/kg
h_5=(((1/3)*h_4)+(((2/3)-m)*h_3))/(1-m);// kJ/kg
//From h-s chart:
h_6=2150;// kJ/kg
// From steam tables
h_f7=h_f2;// kJ/kg
W=(((2/3)*(h_1-h_2))+(((2/3)-m)*(h_2-h_3))+((1-m)*(
   h_5-h_6)));// kJ/kg
n=((((2/3)*(h_1-h_2)+((2/3)-m)*(h_2-h_3))+((1-m)*(
   h_5-h_6)))/(((2/3)*h_1)+((1/3)*h_4)-h_f7))*100;//
    Efficiency of the cycle in %
m_s=(m_s*1000)/3600;// Steam generated per second in
    kg/sec
P=m_s*W;// Power generating capacity of the plant in
    kW
printf('\nFraction of steam bled=%0.4f \nEfficiency
   of the plant=%0.1f percentage \nPower generating
   capacity of the plant=%0.0f kW',m,n,P);
// The answer provided in the textbook is wrong
```

Scilab code Exa 22.25 `Steam supplied by the boiler`

```
// Example 22_25
clc;funcprot(0);
//Given data
P=30;// MW
p_1=60;// bar
p_2=3;// bar
T_1=500;// C
p_v=73;// mm of Hg
p_b=76;// mm of Hg
n_t=90/100;// The isentropic efficiency of the turbine

//Calculation
p_3=(((p_b-p_v)/p_b)*1.013);// bar
//From h-s chart:
h_1=3410;// kJ/kg
h_2=2720;// kJ/kg
h_3=2220;// kJ/kg
// From steam tables
h_f2=361.4;// kJ/kg(liquid heat at 0.04 bar)
h_f3=121.4;// kJ/kg(liquid heat at 7 bar)
function[X]=mass(y)
    X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f3));
endfunction
y=[0.1];
z=fsolve(y,mass);
m=z(1);// kg/kg of steam
m_s=(P*10^3)/((h_1-h_2)+((1-m)*(h_2-h_3)));// kg/sec
m_s=m_s*(3600/1000);// tons/hr
printf('\n(a)Fraction of steam bled for feed heating =%0.3f kg/kg of steam \n(b)Steam supplied by the boiler=%0.1f tons/hr',m,m_s);
```

Scilab code Exa 22.26 `Cycle efficiency`

```
// Example 22_26
clc;funcprot(0);
//Given data
p_1=80;// bar
T_1=470;// C
p_2=7;// bar
T_1=350;// C
p_3=0.35;// bar
m_s=50;// kg/sec

//Calculation
//From h-s chart:
h_1=3310;// kJ/kg
h_2=2780;// kJ/kg
h_3=3170;// kJ/kg
h_4=2220;// kJ/kg
// From steam tables
h_f2=697;// kJ/kg
h_6=h_f2;// kJ/kg
h_5=111.85;// kJ/kg
h_f4=h_5;// kJ/kg
function[X]=mass(y)
    X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f4));
endfunction
y=[0.1];
z=fsolve(y,mass);
m=z(1);// kg
m_b=m*100;// Amount of steam bled off in %
m_l=(100-m_b);// Amount of steam supplied to L.P turbine in %
Q_b=h_1-h_6;// kJ/kg
Q_r=(1-m)*(h_3-h_2);// kJ
```

```
Q_s=Q_b+Q_r;// Total amount of heat supplied by the boiler and reheater in kJ/kg
W=(h_1-h_2)+((1-m)*(h_3-h_4));// kJ/kg
n=(W/Q_s)*100;
P=(m_s*W)/1000;// Power developed by the steam in MW
printf('\n(a)Amount of steam bled off for feed heating=%0.0f percentage \n(b)Amount of steam in LP turbine=%0.0f percentage \n(c)Heat supplied in the boiler and reheater=%0.1f kJ/kg \n(d)Cycle efficiency=%0.1f percentage \n(e)Power developed by the steam=%0.1f MW',m_b,m_l,Q_s,n,P);
// The answer provided in the textbook is wrong
```

Scilab code Exa 22.27 `Thermal efficiency`

```
// Example 22_27
clc;funcprot(0);
//Given data
T_1=600;//  C
p_1=150;// bar
T_3=600;//  C
p_3=40;// bar
p_4=5;// bar
p_5=0.1;// bar

//Calculation
//From h-s chart:
h_1=3570;// kJ/kg
h_2=3280;// kJ/kg
h_3=3650;// kJ/kg
h_4=2920;// kJ/kg
h_5=2280;// kJ/kg
// From steam tables
h_f1=1610;// kJ/kg(at 150 bar)
h_f2=1087;// kJ/kg(at 40 bar)
```

```
h_f4=640;// kJ/kg(at 5 bar)
h_f5=192;// kJ/kg(at 0.1 bar)
function[X]=mass(y)
    X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f4));
    X(2)=(y(2)*(h_4-h_f4))-((1-y(1)-y(2))*(h_f4-h_f5
       ));
endfunction
y=[0.1 0.1];
z=fsolve(y,mass);
m_1=z(1);// kg/kg of steam supplied by the boiler
m_2=z(2);// kg/kg of steam supplied by the boiler
W_t=(h_1-h_2)+((1-m_1)*(h_3-h_4))+((1-m_1-m_2)*(h_4-
   h_5));// Total workdone per kg of steam supplied
   by the boiler in kJ/kg
v_w1=1/1000;// m^3/kg
v_w2=v_w1;// m^3/kg
v_w3=v_w1;// m^3/kg
W_p1=(v_w1*(1-m_1-m_2)*(p_4-p_5*10^5))/1000;// kJ/kg
W_p2=(v_w2*(1-m_1)*(p_1-p_4)*10^5)/1000;// kJ/kg
W_p3=(v_w3*(m_1)*(p_1-p_3)*10^5)/1000;// kJ/kg
W_pt=W_p1+W_p2+W_p3;// kJ/kg
W_n=W_t-W_pt;// Net work done by the turbine per kg
   of steam supplied by the boiler in kJ
Q_f=((1-m_1)*h_f1)+(m_1*h_f1);// Heat of feed water
   entering the boiler in kJ
Q_s1=h_1-Q_f;// Heat supplied by the boiler per kg
   of steam in kJ
Q_s2=(1-m_1)*(h_3-h_2);// Heat supplied in the
   reheater in kJ/kg
Q_st=Q_s1+Q_s2;// Total heat supplied in kJ/kg
n=(W_n/Q_st)*100;// Thermal efficiency in %
printf('\nm_1=%0.2f kg/kg of steam \nm_2=%0.3f kg/kg
    of steam \nThermal efficiency=%0.1f percentage',
   m_1,m_2,n);
```

Scilab code Exa 22.28 The thermal efficiency of the plant

```
// Example 22_28
clc;funcprot(0);
//Given data
p_1=80;// bar
T_1=470;//  C
p_2=7;// bar
T_1=350;//  C
p_3=0.035;// bar
m_s=100;// kg/sec

//Calculation
//From h-s chart:
h_1=3350;// kJ/kg
h_2=2770;// kJ/kg
h_3=3170;// kJ/kg
h_4=2220;// kJ/kg
// From steam tables
h_f5=112;// kJ/kg
h_f6=697;// kJ/kg
function[X]=mass(y)
    X(1)= (y(1)*(h_2-h_f6))-((1-y(1))*(h_f6-h_f5));
endfunction
y=[0.1];
z=fsolve(y,mass);
m=z(1);// kg
m_b=m*100;// The fraction of steam bled for reheating in %
Q_s=(h_1-h_f6)+((1-m)*(h_3-h_2));// Heat supplied in the boiler and reheater in kJ/kg
W=(h_1-h_2)+((1-m)*(h_3-h_4));// Power output in kJ/kg
P=(W*100)/1000;// Capacity of the plant in MW
n=(W/Q_s)*100;// The efficiency of the plant in %
printf('\n(a)Fraction of steam bled for feed heating=%0.0f percentage \n(b)Heat supplied per kg of steam in boiler and turbine=%0.0f kJ/kg \n(c)
```

```
Power output of the plant=%0.0f MW \n(d)Thermal efficiency of the plant=%0.1f percentage',m_b,Q_s,P,n);
// The answer vary due to round off error
```

Scilab code Exa 22.29 Over all efficiency of the plant

```
// Example 22_29
clc;funcprot(0);
//Given data
p_a=4.5;// bar
p_b=0.04;// bar
p_1=15;// bar
p_2=0.04;// bar
m_s=48000;// kg/hr
T_a=450;// C
T_b=217;// C
h_fa=62.9// kJ/kg
h_fb=30.0;// kJ/kg
h_ga=356;// kJ/kg
h_gb=330;// kJ/kg
s_fa=0.135;// kJ/kg-K
s_fb=0.081;// kJ/kg-K
s_ga=0.539;// kJ/kg-K
s_gb=0.693;// kJ/kg-K
v_sfa=80*10^-6;// m^3/kg
v_sfb=76.5*10^-6;// m^3/kg
v_sga=0.068;// m^3/kg
v_sgb=5.178;// m^3/kg

//Calculation
m_h2o=(m_s/3600);// kg/sec
// s_a=s_b
x_b=(s_ga-s_fb)/(s_gb-s_fb);
h_b=h_fb+(x_b*(h_gb-h_fb));// kJ/kg
```

```
h_c=30;// kJ/kg
h_fc=h_c;// kJ/kg
//From h-s chart:
h_1=2800;// kJ/kg
h_2=1920;// kJ/kg
// From steam tables
h_f3=121.4;// kJ/kg
h_f4=844.6;// kJ/kg
m_hg=(m_h2o*(h_1-h_f3))/(h_b-h_fc);// kg/sec
m=m_hg/m_h2o;
W_Hg=m_hg*(h_ga-h_b);// kW
W_H2o=m_h2o*(h_1-h_2);// kW
W_t=(W_Hg+W_H2o)/1000;//Total work done per second
    in MW
Q_s=m_hg*(h_ga-h_fc);// The total heat supplied in
    kJ/sec
n_o=((W_t*1000)/Q_s)*100;// Overall efficiency in %
printf('\nThe overall efficiency of the cycle=%0.1f
    percentage \nThe flow of mercury through mercury
    turbine=%0.1f kg/sec \nTotal work done per second
    =%0.1f MW',n_o,m_hg,W_t);
// The answer vary due to round off error
```

Scilab code Exa 22.30 The Power generating capacity of the plant

```
// Example 22_30
clc;funcprot(0);
//Given data
p_a=10;// bar
p_b=0.2;// bar
p_1=40;// bar
T_1=400;// C
T_2=40;// C
m_s=500;// kg/sec
T_sa=515.5;// C
```

```
T_sb=277.3;//  C
h_fa=72.33// kJ/kg
h_fb=38.35;// kJ/kg
h_ga=363.0;// kJ/kg
h_gb=336.55;// kJ/kg
s_fa=0.1478;// kJ/kg-K
s_fb=0.0967;// kJ/kg-K
s_ga=0.5167;// kJ/kg-K
s_gb=0.6385;// kJ/kg-K
v_fa=80.9*10^-6;// m^3/kg
v_fb=77.4*10^-6;// m^3/kg
v_ga=0.0333;// m^3/kg
v_gb=1.163;// m^3/kg

//Calculation
//From h-s chart:
h_1=3230;// kJ/kg
h_2=2120;// kJ/kg
// From steam tables
h_3=167.5;// kJ/kg
h_4=h_3;// kJ/kg
// s_a=s_b
x_b=(s_ga-s_fb)/(s_gb-s_fb);
h_b=h_fb+(x_b*(h_gb-h_fb));// kJ/kg
h_c=38.35;// kJ/kg
h_d=h_c;// kJ/kg
//(a)
h_a=h_ga;// kJ/kg
m_Hg=(h_1-h_4)/(h_b-h_c);// kg/kg of steam
n_Hg=((h_a-h_b)/(h_a-h_d))*100;// The efficiency of
   the mercury cycle in %
n_H2o=((h_1-h_2)/(h_1-h_3))*100;// The efficiency of
    the steam cycle in %
n_o=(((m_Hg*(h_a-h_b))+(1*(h_1-h_2)))/(m_Hg*(h_a-h_c
   )))*100;// The over all efficiency of the plant
   in %
P=((m_s/60)*((m_Hg*(h_a-h_b))+(1*(h_1-h_2))))/1000;
   // Total power generated in the system in MW
```

```
printf('\nMass of mercury required to generate one
   kg of steam=%0.2f kg/kg of steam \nThe efficiency
    of the mercury cycle=%0.1f percentage \nThe
   efficiency of the steam cycle=%0.2f percentage \
   nThe over all efficiency of the plant=%0.1f
   percentage \nThe power generating capacity of the
    plant=%0.2f MW',m_Hg,n_Hg,n_H2o,n_o,P);
// The answer vary due to round off error
```

Chapter 24

GAS TURBINE POWER PLANTS

Scilab code Exa 24.1 The Power generating capacity of the plant

```
// Example 24_1
clc;funcprot(0);
//Given data
P_1=1;// bar
P_2=5;// bar
T_1=27+273// K
T_3=650+273;// K
C_p=1;// kJ/kg. C
//C_p=C_pg=C_pa;
r=1.4;//The specific heat ratio
m=5;//kg/s
//Air-fuel ratio,AF_r=m_air/m_fuel
AF_r=60/1;
n_c=0.80;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of turbine

//Calculation
//T'2=T_2a;T'4=T_4a;
T_2a=T_1*(P_2/P_1)^((r-1)/r);// K
```

```
T_2=((T_2a-T_1)/n_c)+T_1;// Modified equation in K
T_4a=T_3*(P_1/P_2)^((r-1)/r);// K
T_4=T_3-(n_t*(T_3-T_4a));// Modified equation in K
n_th=(((AF_r+1)*(T_3-T_4))-(AF_r*(T_2-T_1)))/((AF_r
   +1)*(T_3-T_2));
n_th=n_th*100;// %
printf('The thermal efficiency of the cycle,n_th=%0
   .0f percentage\n',n_th);
W=(C_p*(1+60)*(T_3-T_4))-(C_p*60*(T_2-T_1));//kJ/kg
   of fuel
P=(W*m)/1000;// MW
printf('The power generating capacity of the plant,P
   =%0.1f MW\n',P);
// The answer vary due to round off error
```

Scilab code Exa 24.2 Air Fuel ratio

```
// Example 24_2
clc;funcprot(0);
//Given data
T_1=300;// K
P_r=8;// P_r=(p1/p2)
p_1=1;// bar
T_4=1080;// K
m=500;// kg/min
n_c=0.8;
n_t=n_c;//Isentropic efficiency of the compressor
   and turbine
CV=42000;// kJ/kg
e=0.6;// The effectiveness of the heat exchanger
r=1.4;// Specific heat ratio
C_p=1;// kJ/kg.C
//C_p=C_pg=C_pa;

//Calculation
```

```
T_2a=T_1*(P_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// Modified equation in K
T_5a=T_4*(1/P_r)^((r-1)/r);// K
T_5=T_4-(n_t*(T_4-T_5a));// K
T_3=(e*(T_5-T_2))+T_2;// K
//m_f=y(1)
function[X]=Mass(y);
    X(1)=(y(1)*CV)-(C_p*(1+y(1))*(T_4-T_3));
endfunction
y=[0.01]
z=fsolve(y,Mass);
m_f=z(1);// kJ/kg of air
m_a=1;// kg
q=m_a*(T_3-T_2);//Heat saved in kJ/kg of air
M=(m*60*q)/CV;// Fuel saved per hour in kg/hr
W_net=(C_p*(1+m_f)*(T_4-T_5))-(C_p*m_a*(T_2-T_1));// kJ/kg
P=(m/60)*W_net;// The capacity of the plant in kW
printf('\nFuel saved per hour=%0.2f kg/hr\nThe capacity of the plant=%0.1f kW',M,P);
// The answer vary due to round off error
```

Scilab code Exa 24.3 Efficiency and specific work output of the plant

```
// Example 24_3
clc;funcprot(0);
//Given data
T_1=288;// K
P_r=6;// P_r=p1/p2
T_3=1000;// K
m=2;// tonnes/hr
n_c=0.85;
n_t=0.90;//Isentropic efficiencies of the compressor and turbine
CV=46500;// kJ/kg
```

```
e=0.6;// The effectiveness of the heat exchanger
r=1.4;// Specific heat ratio
C_p=1;// kJ/kg. C
//C_p=C_pg=C_pa

//Calculation
T_2a=T_1*(P_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_4a=T_3/(P_r)^((r-1)/r);// K
T_4=T_3-(n_t*(T_3-T_4a));// K
W_c=C_p*(T_2-T_1);// kJ/kg
W_t=C_p*(T_3-T_4);// kJ/kg
Q_a=C_p*(T_3-T_2);// kJ/kg
n_th=((W_t-W_c)/Q_a)*100;//Cycle efficiency
W_s=W_t-W_c;// kJ/kg
P=((m*1000)/3600)*CV*n_th/100*n_t*n_c;// kW
P=P/1000;//MW
printf('\n Cycle efficiency=%0.1f percentage \nThe
    specific work output=%0.0f kJ/kg',n_th,W_s);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.4 The thermal efficiency of the plant

```
// Example 24_4
clc;funcprot(0);
//Given data
p_1=101;//kN/m^2
p_2=606;//kN/m^2
e=0.65;//Effectiveness of regenerative heat
    exchanger
T_1=15+273;// K
n_c=0.85;// The compressor efficiency
n_t=0.80;// The turbine efficiency
m=4;// Air flow rate in kg/s
T_3=870+273;// K
```

```
// P_r=(P_1/P_2)=(P_3/P_4)
P_r=6;// Pressure ratio
C_p=1.005;// kJ/kg K
r=1.4;// Specific heat ratio

//Calculation
T_2a=T_1*(P_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_4a=T_3/(P_r)^((r-1)/r);// K
T_4=T_3-(n_t*(T_3-T_4a));// K
P=m*C_p*((T_3-T_4)-(T_2-T_1));// kW
T_5=(e*(T_4-T_2))+T_2;// K
// T_4-T_6=T_5-T_2, neglecting,the weight of the
   fuel
T_6=T_4+T_2-T_5;// K
n_th1=(((T_3-T_4)-(T_2-T_1))/(T_3-T_5))*100;//%
n_th2=(((T_3-T_4)-(T_2-T_1))/(T_3-T_2))*100;// %
printf('\nEfficiency of the plant with regeneration=
   %0.1f percentage \nEfficiency without heat
   exchanger=%0.1f percentage',n_th1,n_th2);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.5 The thermal efficiency of the plant

```
// Example 24_5
clc;funcprot(0);
//Given data
T_1=19+273;// K
p_1=100;//kN/m^2
p_2=800;// kN/m^2
n_c=0.85;// The isentropic efficiency of compressor
n_t=0.88;// The isentropic efficiency of turbine
n_pt=0.86;// The isentropic efficiency of power
   turbine
m=7;//Air flow rate in kg/s
```

```
T_3=980+273;// K
C_p=1.006;// kJ/kg.K
r=1.4;// Specific heat ratio

//Calculation
T_2a=T_1*(p_2/p_1)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
//(1)For the first turbine
// Compressor work= Turbine work
T_4=T_3-(T_2-T_1);// Turbine exit temperature in K
T_4a=T_3-((T_3-T_4)/(n_t));// K
p_3=p_2;// bar
p_4a=(p_3)/((T_3/T_4a)^(r/(r-1)));// kN/m^2
p_4=p_4a;//kN/m^2
//(2)For the power turbine
p_5=p_1;// bar
T_5a=T_4*(p_5/p_4)^((r-1)/r);// K
T_5=T_4-(n_pt*(T_4-T_5a));// K
P=(m*C_p*(T_4-T_5));// kW
n_th=(C_p*(T_4-T_5))/(C_p*(T_3-T_2));// Thermal efficiency
printf('\n1.The condition of air at the exit of the first turbine:T_4=%0.0f K & p_4=%0.0f kN/m^2 \n2.The power output of the turbine=%0.0f kW\nThe thermal efficiency of the plant=%0.3f or %0.1f percentage',T_4,p_4,P,n_th,n_th*100 );
// The answer vary due to round off error
```

Scilab code Exa 24.6 Thermal efficiency of the plant

```
// Example 24_6
clc;funcprot(0);
//Given data
T_1=288;// K
p_1=1.03;// bar
```

```
p_2=6;// bar
p_3=p_2-0.1;// bar
n_c=80/100;// The isentropic efficiency of compressor
n_t=n_c;// The isentropic efficiency of turbine
n_com=90/100;// Combustion efficiency
W=1.1*1000;// kW
m=7;//Air flow rate in kg/s
T_3=750+273;// K
//C_p=C_pa=C_pg
C_p=1.0;// kJ/kg.K
r=1.4;// Specific heat ratio
CV=20000;// kJ/kg

//Calculation
//Applying isentropic law to the process 1-2
T_2a=T_1*(p_2/p_1)^((r-1)/r);// K
T_2=T_1+((T_2a-T_1)/n_c);// K
// m=m_a/m_f
m=((CV*n_com)/(T_3-T_2))-1;
//Applying isentropic law to the process 3-4'
T_4a=T_3/((p_3/p_1)^((r-1)/r));// K
T_4=T_3-(n_t*(T_3-T_4a));//K
m_a=W/((((1+(1/m))*C_p*(T_3-T_4))-(C_p*(T_2-T_1)));// kg/sec
m_f=m_a/37;// kg/sec
m_g=m_a+m_f;// kg/sec
W_t=m_g*C_p*(T_3-T_4);// kW
W_r=W/W_t;// Work ratio
n_th=W/(m_g*C_p*(T_3-T_2));// Thermal efficiency of the plant
printf('\n(i)Flow of air and flow of gases per second,m_a=%0.1f kg/sec & m_g=%0.2f kg/sec \n(ii) Work ratio=%0.4f \n(iii) Thermal efficiency of the plant=%0.3f (or)%0.1f percentage',m_a,m_g,W_r,n_th,n_th*100);
// The answer vary due to round off error
```

Scilab code Exa 24.7 Thermal efficiency of the plant and Work saved per hour due t

```
// Example 24_7
clc;funcprot(0);
//Given data
p_r=6.5// Pressure ratio
T_1=300;// K
p_1=1;// bar
T_5=850;// K
P=10;//The power plant capacity in MW
CV=45000;// kJ/kg
r=1.4;// Spcific heat ratio for air and gases
C_p=1;// kJ/kg-k for air and gases
C_pg=C_p;

//Calculation
p_2=p_1*p_r;// bar
p_i=sqrt(p_1*p_2);//The required intermediate pressure in bar
T_2=T_1*(p_i/p_1)^((r-1)/r);// K
T_7=T_1*(p_2/p_1)^((r-1)/r);// K
T_3=T_1;// K
T_4=T_1*(p_2/p_i)^((r-1)/r);// K
W_wi=2*C_p*(T_2-T_1);//The workdone per kg of air with perfect inter cooling in kJ/kg
W_woi=C_p*(T_7-T_1);//The workdone per kg of air without inter cooling in kJ/kg
W_s=W_woi-W_wi;// Work saved per kg of air compressed due to intercooling in kJ/kg
// Assume m=m_a/m_f
m=(CV/(C_pg*(T_5-T_4)))-1;
T_6=T_5*(p_1/p_2)^((r-1)/r);// K
W_e=C_pg*(T_5-T_6);// Work done per kg of exhaust gases in turbine in kJ/kg
```

```
//When 1 kg of fuel used,m_f=1
m_a=m*1;// The mass of air supplied in kg
W_net=((1+m_a)*W_e)-(m_a*W_wi);// Net work available
    in kJ/kg of fuel
m_f=(P*10^3)/W_net;// kg /sec
m_f=m_f*3600;// kg/hr
W_si=W_s*m_f*m_a;// kJ/hr
W_si=W_si/3600;// kJ/hr
P_woi=P-(W_si/1000);// MW
n_th=((((m+1)*(T_5-T_6))-(2*m*(T_2-T_1)))/((m+1)*(
   T_5-T_4)))*100;// Thermal efficiency of the plant
printf('\n Thermal efficiency of the plant=%0.1f
   percentage \n Fuel consumption per hour=%0.1f kg/
   hr \n Work saved per hour due to inter cooling=%0
   .0f kW',n_th,m_f,W_si);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.8 The thermal efficiency and the capacity of the plant

```
// Example 24_8
clc;funcprot(0);
//Given data
p_1=1;// bar
p_2=5;// bar
p_i=2.5;// bar
T_1=27+273;// K
T_3=900;// K
T_5=T_3;// K
r=1.4;// Specific heat ratio
CV=40000;// kJ/kg
r=1.4;// Spcific heat ratio for air and gases
C_p=1;// kJ/kg-k for air and gases
m_a=10;// kg/sec
C_pg=C_p;
C_pa=C_p
```

```
//Calculation
T_2=T_1*(p_2/p_1)^((r-1)/r);// K
T_4=T_3*(p_i/p_2)^((r-1)/r);// K
T_6=T_5*(p_1/p_i)^((r-1)/r);// K
m_f1=1/((CV/(T_3-T_2))-1);// kg/kg of air
m_f2=1/((CV/(T_5-T_4))-(1+m_f1));// kg/kg of air
W_net=(C_pg*(1+m_f1)*(T_3-T_4))+(C_pg*(1+m_f1+m_f2)*(T_5-T_6))-(C_pa*(T_2-T_1));//Net work done per kg of air flow in kJ/kg of air
Q_net=(m_f1+m_f2)*CV;// Net heat supplied per kg of air passing through the system in kJ.
n_th=(W_net/Q_net)*100;// Thermal efficiency in %
P=m_a*W_net;// Capacity of the plant in kW
printf('\nThermal efficiency=%0.1f percentage \nPlant capacity=%0.1f MW',n_th,P/10^3);
// The answer vary due to round off error
```

Scilab code Exa 24.9 The thermal efficiency of the plant and the fuel consumption

```
// Example 24_9
clc;funcprot(0);
//Given data
W=2;// Work done in MW
p_1=1;// bar
p_r=5;// Pressure ratio in bar
p_i=2.5;// bar
T_1=27+273;// K
r=1.4;// Specific heat ratio
CV=40000;// kJ/kg
n_c=85/100;// The isentropic efficiency of the compressor
n_t=85/100;//  The isentropic efficiency of the turbine
Q_a=80;// Heat absorbed in kJ/kg of air
```

```
m_f=0.01;// kg per kg of air
m_a=1;// kg
r=1.4;// Spcific heat ratio for air and gases
C_p=1;// kJ/kg-k for air and gases
C_pg=C_p;
C_pa=C_p

//Calculation
T_2a=T_1*(p_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_3=T_2+(Q_a/(C_pa*m_a));// K
T_4=((m_f*CV)/((1+m_f)*C_p))+T_3;// K
T_5a=T_4*(1/p_r)^((r-1)/r);// K
T_5=T_4-(n_t*(T_4-T_5a));// K
n_th=(((T_4-T_5)-(T_2-T_1))/(T_4-T_3))*100;// Thermal efficiency in %
Q=(W*10^3)/(n_th/100);//Heat supplied in kJ/sec
F=(Q/CV)*3600;// Fuel required per hour in kg/hr
n_cp=(1-(1/(p_r)^((r-1)/r)))*100;//Efficiency of normal constant pressure cycle
printf('\nThe thermal efficiency of the plant=%0.1f percentage \nEfficiency of normal constant pressure cycle=%0.0f percentage \nFuel consumption per hour=%0.0f kg/hr',n_th,n_cp,F);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.10 The thermal efficiency of the plant and the specific fuel co

```
// Example 24_10
clc;funcprot(0);
//Given data
T_1=20+273;// K
p_1=1;// bar
T_6=700+273;// K
p_r=6;// Pressure ratio
```

```
e=0.7;// The effectiveness of regenerator
m_air=200;//Air flow through the plant in kg/sec
n_c=0.82;// Isentropic efficiency of both
    compressors
n_t=0.92;// Isentropic efficiency of turbine
n_com=0.96;// Combustion efficiency
n_m=0.96;// Mechanical efficiency
n_g=0.95;// Generation efficiency
CV=35000;// kJ/kg
C_p=1;// kJ/kg.K
r=1.4;// Specific heat ratio

//Calculation
p_2=p_r*p_1;// bar
p_i=sqrt(p_1*p_2);// bar
T_2a=T_1*(p_i/p_1)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_3=T_1;// K
T_4a=T_3*(p_2/p_i)^((r-1)/r);// K
T_4=T_2;// K (as n_c1=n_c2)
T_7a=T_6*((p_1/p_2)^((r-1)/r));// K
T_7=T_6-(n_t*(T_6-T_7a));// K
T_5=(e*(T_7-T_4))+T_4;// K
function[X]=m_f(y)
    X(1)=(C_p*(1+y(1))*(T_6-T_5))-(y(1)*CV*n_com);
endfunction
y=[0.01]
z=fsolve(y,m_f);
m_fuel=z(1);
m_a=1;// kg/kg of air
m=(m_a/m_fuel);//Air fuel ratio
n_th=(((T_6-T_7)-(2*(T_2-T_1)))/(T_6-T_5))*100;//
    Thermal efficiency
W=(m_a*(T_6-T_5)*(n_th/100));// Work done per kg of
    air in kJ
W_s=W*m_air;// Work done per sec in kJ/sec
P=W_s/10^3;// Capacity of the plant in MW
P_a=W_s*n_m*n_t;// Power available at generation
```

```
terminals in kW
F=m_air*3600*m_fuel;// Fuel consumption per hour in
   kg/hr
Sfc=F/(P_a);// Specific fuel consumption in kg/kW.hr
printf('\nAir fuel ratio used=%0.0f:1 \nThermal
   efficiency of the cycle=%0.1f percentage \nFuel
   consumption per hour=%0.0f kg/hr \nSpecific fuel
   consumption=%0.3f kg/kW.hr',m,n_th,F,Sfc);
// The answers provided in the textbook is wrong
```

Scilab code Exa 24.11 The mass of air flow and the charges of energy

```
// Example 24_11
clc;funcprot(0);
//Given data
P=5;// Power plant capacity in MW
T_1=27+273;// K
p_1=1;// bar
T_4=1000;// K
p_r=5;// Pressure ratio
n_c=0.85;// Isentropic efficiency of compressor
n_t=0.90;// Isentropic efficiency of turbine
n_com=0.95;// Combustion efficiency
n_m=0.95;// Mechanical efficiency
n_g=0.92;// Generation efficiency
Tl=10;// Transmission losses
CV=40000;// kJ/kg
C_pa=1;// kJ/kg.K
C_pg=1.1;// kJ/kg.K
r=1.4;// Specific heat ratio
m=80;// Air fuel ratio
Cf_t=5000;// Cost of fuel in Rs./tonne
Oc=5000;// All other charges in rupees

//Calculation
```

```
n_tt=(1-(Tl/100));// Transmission efficiency
p_2=p_1*p_r;// bar
T_2a=T_1*(p_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_5a=T_4*(p_1/p_2)^((r-1)/r);// K
T_5=T_4-(n_t*(T_4-T_5a));// K
e_g=P*1000;// The energy generated per second in kJ/sec
m_a=(e_g)/((((1+(1/m))*C_pg*(T_4-T_5))-(C_pa*(T_2-T_1)))*n_m*n_g*n_tt);// kg/sec
T_3=T_4-((CV*n_com)/(C_pg*(m+1)));// K
e=(C_pa*(T_3-T_2))/(C_pg*(1+(1/m))*(T_5-T_2));// Effectiveness of regenerator
Fc=(m_a*3600*(1/m));// The fuel consumption per hour in kg/hr
Cf=(Fc/1000)*Cf_t;// Cost of fuel per hour in Rs.
Tc=Cf+Oc;// Total cost to be charged per hour in Rs.
E_g=e_g*1;// Energy generated in kW-hr
Ce=Tc/E_g;// Charges of energy per kW-hr in Rs./kWh
printf('\nThe mass of air flow through the compressor per second=%0.2f kg/sec \nThe effectiveness of regenerator=%0.3f \nThe charges of energy per kW-hr=Rs.%0.2f/kWh',m_a,e,Ce);
// The answers provided in the textbook is wrong
```

Scilab code Exa 24.12 The cost of energy generated

```
// Example 24_12
clc;funcprot(0);
//Given data
P=10;// Power plant capacity in MW
T_1=300;// K
T_4=960;// K
e=0.7;// The effectiveness of regenerator
n_c=0.8;// Isentropic efficiency of compressor
```

```
n_t=0.90;// Isentropic efficiency of turbine
n_com=0.96;// Combustion efficiency
n_m=0.95;// Mechanical efficiency
n_g=0.95;// Generation efficiency
CV=40000;// kJ/kg
C_pa=1;// kJ/kg.K
r=1.4;// Specific heat ratio
Cf_t=4000;// Cost of fuel in Rs./tonne
Oc=3000;// All other charges in rupees
Q=90;// Heat developed in combustion chamber in %

//Calculation
p_r=(n_c*n_t*(T_4/T_1))^(r/(2*(r-1)));// Pressure
    ratio
T_2a=T_1*(p_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_5a=T_4*(1/p_r)^((r-1)/r);// K
T_5=T_4-(n_t*(T_4-T_5a));// K
m_a=(P*1000)/((C_pa*((T_4-T_5)-(T_2-T_1)))*n_com*n_g
    );
T_3=T_2+(e*(T_5-T_2));// K
m_f=(m_a*C_pa*(T_4-T_3))/(CV*n_com*(Q/100));// kg/
    sec
Cf=((m_f*3600)/1000)*Cf_t;// Cost of fuel in Rs./hr
Tc=Cf+Oc;// Total cost in Rs/hr
Ce=Tc/(P*1000);// Cost of energy generated in Rs/kWh
m=m_a/m_f;// Air-fuel ratio
printf('\nThe cost of energy generated=Rs.%0.2f/kWh'
    ,Ce);
// The answer vary due to round off error
```

Scilab code Exa 24.13 The power available at the generator terminals

```
// Example 24_13
clc;funcprot(0);
```

```
//Given data
T_1=27+273;// K
p_1=1;// bar
p_2=4;// bar
n_c=0.80;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of turbine
e=0.75;// The effectiveness of regenerator
p_lr=0.1;// Pressure loss in regenerator along air
   side in bar
p_lcc=0.05;//  Pressure loss in the combustion
   chamber in bar
n_com=0.90;// Combustion efficiency
n_m=0.90;// Mechanical efficiency
n_g=0.95;// Generation efficiency
m_a=25;// kg/sec
CV=40000;// kJ/kg
C_pa=1;// kJ/kg.K
C_pg=1.1;// kJ/kg.K
r=1.4;// Specific heat ratio
T_4=700+273;// K
p_atm=1.03;// bar

// Calculation
p_i=p_2-(p_lr+p_lcc);// Pressure at the inlet of the
    turbine in bar
p_e=p_atm+p_lr;// Pressure at the exit of the
   turbine in bar
T_2a=T_1*(p_2/p_1)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_5a=T_4*(p_e/p_i)^((r-1)/r);// K
T_5=T_4-(n_t*(T_4-T_5a));// K
// Assume m=(m_a/m_f)
// m=y(1),T_3=y(2)
function[X]=airfuelratio(y)
    X(1)=((y(1)+1)*C_pg*(T_4-y(2)))-(CV*n_com);
    X(2)=((C_pa*(y(2)-T_2))/(e*C_pg*(T_5-T_2)))
       -(1+(1/y(1)));
endfunction
```

```
y=[10 100];
z=fsolve(y,airfuelratio);
m=z(1);
T_3=z(2);// K
W_c=C_pa*(T_2-T_1);// kJ/kg of air
W_t=C_pg*(1+(m_a/m))*(T_4-T_5);// kJ/kg of air
W_a=W_t-W_c;// kJ/kg of air
W=W_a*n_m*n_g;// Work available per kg of air at the terminals of generator in kJ/kg
P=(m_a*W)/1000;// Power available at the terminals of generator in kJ/kg
n_o=((W)/((1/m)*CV))*100;// Over all efficiency
Fr=m_a*3600*(1/m);// Fuel required per hour in kg/hr
Sfc=Fr/(P*1000);// Specific fuel consumption in kg/kW.hr
printf('\nThe over all efficiency of the plant=%0.3f percentage \nSpecific fuel consumption=%0.2f kg/kW.hr',n_o,Sfc);
// The answers provided in the textbook is wrong
```

Scilab code Exa 24.14 Thermal efficiency of the plant

```
// Example 24_14
clc;funcprot(0);
//Given data
P=800;// Plant capacity in kW
T_1=15+273;// K
p_1=1.01;// bar
T_4=700+273;// K
p_r=6;// Pressure ratio
e=0.75;// The effectiveness of regenerator
p_lr=0.15;// Pressure drop in regenerator in bar
p_lcc=0.15;// Pressure drop in the combustion chamber in bar
n_c=0.80;// Isentropic efficiency of compressor
```

```
n_t=0.85;// Isentropic efficiency of turbine
C_p=1;// kJ/kg.K
r=1.4;// Specific heat ratio

//Calculation
p_2=p_r*p_1;// bar
p_3=p_2-p_lcc;// Pressure at point 4 in bar
T_2a=T_1*(p_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
p_4=p_1+p_lr;// bar
T_5a=T_4/(p_3/p_4)^((r-1)/r);// K
T_5=T_4-(n_t*(T_4-T_5a));// K
T_3=T_2+(e*(T_5-T_2));// K
W_c=C_p*(T_2-T_1);// kJ/kg
W_t=C_p*(T_4-T_5);// kJ/kg
W_n=W_t-W_c;// kJ/kg
Q_s=C_p*(T_4-T_3);// kJ/kg
n_th=(W_n/Q_s)*100;// Thermal Efficiency in
   percentage
printf('\nThe thermal efficiency of the plant=%0.1f
   percentage',n_th);
```

Scilab code Exa 24.15 The thermal efficiency of the plant

```
// Example 24_15
clc;funcprot(0);
//Given data
m_a=10;// kg/sec
p_r=6;// Pressure ratio
T_1=300;// K
p_1=1;// bar
T_6=1073;// K
e=0.75;// The effectiveness of regenerator
n_c=0.80;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of turbine
```

```
C_pa=1;// kJ/kg.K
r=1.4;// Specific heat ratio
m=1;// kg

//Calculation
p_3=p_1*p_r;// bar
p_2=sqrt(p_1*p_3);// bar
T_2a=T_1*(p_2/p_1)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
//W_c=W_c1+W_c2=2*W_c1 (as intercooling is perfect)
W_c=2*m*C_pa*(T_2-T_1);// kJ/kg
// As T_3=T_1 and p_r=(p_2/p_1)=(p_3/p_2)
T_4=T_2;// K
T_7a=T_6/(p_3/p_1)^((r-1)/r);// K
T_7=T_6-(n_t*(T_6-T_7a));// K
W_t=C_pa*(T_6-T_7);// kJ/kg
T_5=T_4+(e*(T_7-T_4));// K
Q_s=m*C_pa*(T_6-T_5);// kJ/kg
W_n=W_t-W_c;// kJ/kg
P=m_a*W_n;//Power capacity of the plant in kW
n_th=(W_n/Q_s)*100;// Thermal Efficiency in percentage
printf('\nPower capacity of the plant=%0.0f kW\nThe thermal efficiency of the plant=%0.1f percentage',P,n_th);
// The answer vary due to round off error
```

Scilab code Exa 24.16 Specific fuel consumption and overall efficiency of the plan

```
// Example 24_16
clc;funcprot(0);
//Given data
P=5;// Power plant capacity in MW
T_1=300;// K
p_1=1;// bar
```

```
T_5=650+273;// K
p_r=5;// Pressure ratio
e=0.7;// The effectiveness of regenerator
n_c=0.8;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of both turbines
n_t1=n_t;
n_t2=n_t;
n_com=0.97;// Combustion efficiency
n_m=0.98;// Mechanical efficiency of both turbines
CV=40000;// kJ/kg
C_pa=1;// kJ/kg. C
C_pg=1.145;// kJ/kg. C
r_a=1.4;// Specific heat ratio for air
r_g=1.35;// Specific heat ratio for gases

//Calculation
p_2=p_1*p_r;// bar
p_i=sqrt(p_1*p_2);// The intermediate pressure
    between two compressors
T_2a=T_1*(p_i)^((r_a-1)/r_a);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_3=T_1;// K
T_4=T_2;// K
T_7=T_5;// K
// Work developed by the compressor turbine = Work
    required to run the compressor
T_6=T_5-((2*C_pa*(T_2-T_1))/(C_pg*n_m));// K
T_6a=T_5-((T_5-T_6)/n_t1);// K
p_3=p_2/((T_5/T_6a)^(r_g/(r_g-1)));// K
T_8a=T_7*(p_1/p_3)^((r_g-1)/r_g);// K
T_8=T_7-(n_t2*(T_7-T_8a));// K
T_x=T_4+((e*C_pg*(T_8-T_4))/C_pa);// K
W_net=C_pg*(T_7-T_8)*n_m;//Net Work available per kg
     of air in kJ/kg of air
Q_s=C_pg*((T_5-T_x)+(T_7-T_6));// Heat supplied per
    kg of air kJ/kg of air
m_f=Q_s/(CV*n_com);// The total mass of fuel in per
    kg of air flow
```

```
m=1/m_f;// Air fuel ratio
n_o=(W_net/(m_f*CV))*100;// Over all efficiency
m_a=(P*1000)/(W_net);// kg/sec
M_f=m_a*3600*m_f;// Mass of fuel used per hour in kg/hr
Sfc=M_f/(P*1000*1);// Specific fuel consumption in kg/kW-hr
printf('\nOver all efficiency of the plant=%0.1f percentage \nMass flow of air through the plant per second=%0.2f kg/sec \nSpecific fuel consumption=%0.3f kg/kW-hr',n_o,m_a,Sfc);
// The answer vary due to round off error
```

Scilab code Exa 24.17 Plant efficiency and Specific fuel consumption

```
// Example 24_17
clc;funcprot(0);
//Given data
P=1600;// Power plant capacity in kW
T_1=300;// K
T_3=1050;// K
p_1=1;// bar
T_5=1100;// K
p_2=5;// bar
e=0.7;// The effectiveness of regenerator
n_c=0.8;// Isentropic efficiency of compressor
n_t1=0.85;// Efficiency of compressor turbine
n_t2=0.90;// Efficiency of power turbine
n_com=0.95;// Combustion efficiency
n_m=0.90;// Mechanical efficiency of both turbines
n_g=1;// Generation efficiency
CV=40000;// kJ/kg
C_pa=1;// kJ/kg.K
C_pg=1.1;// kJ/kg.K
r_a=1.4;// Specific heat ratio for air
```

```
r_g=1.35;// Specific heat ratio for gases

//Calculation
T_2a=T_1*(p_2/p_1)^((r_a-1)/r_a);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_4a=T_3*(p_1/p_2)^((r_g-1)/r_g);// K
T_4=T_3-(n_t1*(T_3-T_4a));// K
T_6a=T_5*(p_1/p_2)^((r_g-1)/r_g);// K
T_6=T_5-(n_t2*(T_5-T_6a));// K
m_a2=P/(C_pg*(T_5-T_6)*n_m*n_g);// kg/sec
//Power developed by compressor turbine = Power
    absorbed by compressor
//m_a1=y(1)
function[X]=mass(y);
    X(1)=((y(1)+m_a2)*C_pa*(T_2-T_1))-(y(1)*C_pg*(
        T_3-T_4)*n_m);
endfunction
y=[10];
z=fsolve(y,mass);
m_a1=z(1);// kg/sec
T_y=((m_a1/(m_a1+m_a2))*T_4)+((m_a2/(m_a1+m_a2))*T_6
    );// The temperature after mixing in C
T_x=T_2+((e*C_pg*(T_y-T_2))/C_pa);// K
m_f=((C_pg*m_a1*(T_3-T_x))+(C_pg*m_a2*(T_5-T_x)))/(
    CV*n_com);// kg/sec
n_th=(P/(m_f*CV))*100;// Plant efficiency in
    percentage
Sfc=(m_f*3600)/P;// kg/kWh
Afr=(m_a1+m_a2)/m_f;// Air fuel ratio
printf('\n(a)Plant efficiency=%0.1f percentage \n(b)
    Specific fuel consumption=%0.3f kg/kW-hr \n(c)Air
     fuel ratio=%0.0f:1',n_th,Sfc,Afr);
// The answer vary due to round off error
```

Scilab code Exa 24.18 Compressor turbine capacity

```
// Example 24_18
clc;funcprot(0);
//Given data
P=200;// Power plant capacity in MW
T_6=1000;// K
T_8=900;// K
p_1=1;// bar
T_1=27+273;// K
p_r=5;// bar
e=0.7;// The effectiveness of heat exchanger
n_c=1;// Isentropic efficiency of  both compressors
n_t=0.9;// Efficiency of both turbines
n_com=0.95;// Combustion efficiency
n_m=0.92;// Mechanical efficiency of compressor and
    generator shafts
CV=40000;// kJ/kg
C_p=1;// kJ/kg. C
r=1.4;// Specific heat ratio for air and gases

//Calculation
p_2=p_1*p_r;// bar
p_i=sqrt(p_1*p_2);// bar
T_7a=T_6*(p_1/p_2)^((r-1)/r);// K
n_t2=n_t;
T_7=T_6-(n_t2*(T_6-T_7a));// K
W_g=C_p*(T_6-T_7)*n_m;//Work done per kg of air in
    generator-turbine in kJ/kg
m_2=CV/W_g;// The mass of exhaust gases in kg/sec
T_2=T_1*(p_i)^((r-1)/r);// K
W_c=2*C_p*(T_2-T_1);//Work done per kg of air in
    both compressors in kJ/kg
T_4=T_2;// K
// Assume m_1=y(1);T_5=y(2)
function[X]=massflow(y);
     X(1)=(m_2*C_p*(y(2)-T_8))-(y(1)*C_p*(T_8-T_4));
     X(2)=((y(1)*C_p*(T_8-T_4))/(m_2*C_p*(y(2)-T_4)))
         -(e);
endfunction
```

```
y=[100 1000];
z=fsolve(y,massflow);
T_5=z(2);// K
m_1=z(1);// kg/sec
T_9a=T_8/(p_i)^((r-1)/r);// K
n_t1=n_t;
T_9=T_8-(n_t1*(T_8-T_9a));// K
m_c1=(((m_1*(T_8-T_9))/((T_2-T_1)*n_m))-m_1)/2;// Air taken from atmosphere in kg/sec
m_c2=m_c1+m_1;// kg/sec
//Assume m_f=y(1)
function[X]=massoffuel(z);
    X(1)=((m_c2+z(1))*C_p*(T_5-T_4))/(CV*n_com)-z(1);
endfunction
z=[10];
y=fsolve(z,massoffuel);
m_f=y(1);// Mass of fuel used per second
n_o=((P*10^3)/(CV*m_f))*100;// Over all efficiency of the plant in %
Ctc=(m_1*C_p*(T_8-T_9))/1000;// Compressor-turbine capacity in MW
printf('\n(a)Air taken from atmosphere per second=%0.0f kg/sec \n(b)Fuel required per second=%0.2f kg/sec \n(c)Over all efficiency of the plant=%0.1f percentage \n(d) Compressor-turbine capacity=%0.0f kW',m_c1,m_f,n_o,Ctc*1000);
// The answer vary due to round off error
```

Scilab code Exa 24.19 The over all efficiency of the plant

```
// Example 24_19
clc;funcprot(0);
//Given data
P=5;// Power plant capacity in MW
```

```
T_1=30+273;// K
p_1=1;// bar
T_3=550+273;// K
p_r=5;// Pressure ratio
p_3=2.24;// bar
n_c=0.8;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of both turbines
n_t1=n_t;
n_t2=n_t;
C_pa=1;// kJ/kg.C
C_pg=1.15;// kJ/kg.C
r_a=1.4;// Specific heat ratio for air
r_g=1.33;// Specific heat ratio for gases

//Calculation
p_2=p_1*p_r;// bar
T_5=T_3;// K
T_2a=T_1*(p_2/p_1)^((r_a-1)/r_a);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
W_c=C_pa*(T_2-T_1);// kJ/kg
T_4a=T_3/(p_2/p_3)^((r_g-1)/r_g);// K
T_4=T_3-(n_t1*(T_3-T_4a));// K
T_6a=T_5/(p_3/p_1)^((r_g-1)/r_g);// K
T_6=T_5-(n_t2*(T_5-T_6a));// K
W_t=2*C_pg*(T_3-T_4);// kJ/kg
W_n=W_t-W_c;// kJ/kg
m_a=((P*10^3)/W_n);// kg/sec
Q_s=(C_pg*(T_3-T_2))+(C_pg*(T_5-T_4));// kJ/kg
n_o=(W_n/Q_s)*100;// Over all efficiency in %
printf('\nThe over all efficiency=%0.0f percentage \nThe mass flow rate=%0.1f kg/sec',n_o,m_a);
// The answers provided in the textbook is wrong
```

Scilab code Exa 24.20 Fuel consumption of the plant per hour

```
// Example 24_20
clc;funcprot(0);
//Given data
P=5;// Power plant capacity in MW
T_1=15+273;// K
p_1=1;// bar
T_4=750+273;// K
p_r=6;// Pressure ratio
p_3=2.24;// bar
e=0.75;// The effectiveness of heat exchanger
n_c=0.8;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of both turbines
n_t1=n_t;
n_t2=n_t;
C_pa=1;// kJ/kg.K
C_pg=1.15;// kJ/kg.K
r_a=1.4;// Specific heat ratio for air
r_g=1.33;// Specific heat ratio for gases
CV=18500;// kJ/kg

//Calculation
p_2=p_1*p_r;// bar
p_re=sqrt(p_1*p_2);//Pressure ratio for each turbine
    in bar
T_2a=T_1*(p_2/p_1)^((r_a-1)/r_a);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_6=T_4;// K
T_5a=T_4/((p_re)^((r_g-1)/r_g));// K
T_5=T_4-(n_t1*(T_4-T_5a));// K
T_7=T_5;// K
T_3=T_2+(e*(T_7-T_2));// K
//(i)
function[X]=massoffuel(y)
    X(1)=((1+y(1))*C_pg*(T_4-T_3))-(y(1)*CV);
endfunction
y=[0.01];
z=fsolve(y,massoffuel);
m_f1=z(1);// kg/kg of air
```

```
AF=1/m_f1;// Air fuel ratio
function[X]=massoffuel1(x)
    X(1)=(C_pg*((1+m_f1+x(1))*(T_6-T_5)))-(x(1)*CV);
endfunction
x=[0.001];
y=fsolve(x,massoffuel1);
m_f2=y(1);// kg/kg of air
W_c=C_pg*(T_2-T_1);// kJ/kg of air
W_t1=C_pg*(1+(m_f1))*(T_4-T_5);// kJ/kg of air
W_t2=C_pg*(1+m_f1+m_f2)*(T_6-T_7);// kJ/kg of air
W_t=W_t1+W_t2;// kJ/kg of air
W_n=W_t-W_c;// kJ/kg of air
//(ii)
Q_s=(m_f1+m_f2)*CV;// kJ/kg of air
n_th=(W_n/Q_s)*100;// Thermal efficiency of the cycle
//(iii)
m_a=((P*10^3)/W_n);// kg/sec
//(iv)
F=m_a*(m_f1+m_f2)*3600;// Fuel required per hour in kg/hr
printf('\n(i)Cycle efficiency=%0.1f percentage \n(ii)Air supplied to the plant=%0.1f kg/sec \n(iii)A:F ratio=%0.1f:1 \n(iv)Fuel consumption of the plant=%0.0f kg/hr',n_th,AF,m_a,F);
// The answers provided in the textbook is wrong
```

Scilab code Exa 24.21 Power develpoed by the plant

```
// Example 24_21
clc;funcprot(0);
//Given data
T_1=25+273;// K
p_1=1;// bar
T_6=1250+273;// K
```

```
p_3=9;// bar
n_c=0.83;// Isentropic efficiency of both
    compressors
n_c1=n_c;
n_c2=n_c;
n_t=0.83;// Isentropic efficiency of both turbines
n_t1=n_t;
n_t2=n_t;
C_pa=1;// kJ/kg.K
r=1.4;// Specific heat ratio
m_a=16.5;// kg/sec

//Calculation
p_2=sqrt(p_1*p_3);// bar
T_2a=T_1*(p_2/p_1)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c1)+T_1;// K
T_8=T_6;// K
T_4=T_2;// K
T_7a=T_6/(p_3/p_2)^((r-1)/r);// K
T_7=T_6-(n_t1*(T_6-T_7a));// K
T_9=T_7;// K
W_c=2*C_pa*(T_2-T_1);// kJ/kg
W_t=2*C_pa*(T_6-T_7);// kJ/kg
W_n=W_t-W_c;// kJ/kg
T_5=T_7;
//When the ideal regeneration is given,then
e=1;// Effectiveness
Q_s=2*C_pa*(T_6-T_5);// kJ/kg
//(i)
n_th=(W_n/Q_s)*100;//The thermal efficiency in %
//(ii)
P=W_n*m_a;// Power developed by the plant in kW
printf('\n(i)The thermal efficiency of the plant=%0
    .1f percentage \n(ii)Power developed by the plant
    =%0.2f kW',n_th,P);
// The answer vary due to round off error
```

Scilab code Exa 24.22 The thermal efficiency and work ratio of the plant

```
// Example 24_22
clc;funcprot(0);
//Given data
T_1=290;// K
p_1=1.01;// bar
T_3=650+273;// K
p_r=8;// Pressure ratio
n_c=0.8;// Isentropic efficiency of compressor
n_t1=0.85;// Isentropic efficiency of H.P turbine
n_t2=0.83;// Isentropic efficiency of L.P turbine
C_pa=1;// kJ/kg.K
C_pg=1.15;// kJ/kg.K
r_a=1.4;// Specific heat ratio for air
r_g=1.33;// Specific heat ratio for gases
m_a=10;// The  air flow through the compressor in kg
    /sec

//Calculation
p_2=p_1*p_r;// bar
T_2a=T_1*(p_r)^((r_a-1)/r_a);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
W_c=1*C_pa*(T_2-T_1);//Work input to the compressor
    in kJ/kg
W_t1=W_c;// kJ/kg
T_4=T_3-(W_t1/C_pg);// K
T_4a=T_3-((T_3-T_4)/n_t1);// K
p_3=p_2/((T_3/T_4a)^(r_g/(r_g-1)));// bar
p_re=p_3/p_1;// The pressure ratio of expansion in
    the power turbine
T_5a=T_4/(p_3/p_1)^((r_g-1)/r_g);// K
dT_45=n_t2*(T_4-T_5a);// (dT_45=T_4-T_5) K
W_t2=C_pg*(dT_45);//Work developed by power turbine
```

```
    in kJ/kg
W_net=W_t2;// The net work done per kg of air in kJ/kg
W_t=W_t1+W_t2;// Total work done per in kJ/kg
W_r=W_t2/W_t;// Work ratio
Q_s=C_pa*(T_3-T_2);// kJ/kg
n_th=(W_t2/Q_s)*100;// Thermal efficiency in %
P=W_t2*m_a;// Power capacity of the plant in kW
printf('\nThe power developed by the unit=%0.0f kW \nThe thermal efficiency=%0.0f percentage \nWork ratio=%0.1f',P,n_th,W_r);
// The answer vary due to round off error
```

Scilab code Exa 24.23 The thermal efficiency of the plant and power generating cap

```
// Example 24_23
clc;funcprot(0);
//Given data
p_1=1;// bar
p_2=5;// bar
p_3=2.5;// bar
T_1=300;// K
T_3=900;// K
T_5=T_3;// K
m_a=10;// kg/sec
CV=33500;// kJ/kg
C_p=1;// kJ/kg.C
r=1.4;// Specific heat ratio for air and gases

//Calculation
T_2=T_1*(p_2/p_1)^((r-1)/r);// K
T_4=T_3/(p_2/p_3)^((r-1)/r);// K
T_6=T_5/(p_2/p_3)^((r-1)/r);// K
function[X]=massoffuel(y)
    X(1)=((1+y(1))*C_p*(T_3-T_2))-(y(1)*CV);
```

```
endfunction
y=[0.01];
z=fsolve(y,massoffuel);
m_f1=z(1);// kg/kg of air
function[X]=massoffuel1(x)
    X(1)=(C_p*((1+m_f1+x(1))*(T_5-T_4)))-(x(1)*CV);
endfunction
x=[0.001];
y=fsolve(x,massoffuel1);
m_f2=y(1);// kg/kg of air
W_n=((m_a*(1+m_f1)*C_p*(T_3-T_4)))+((m_a*(1+m_f1+
   m_f2)*C_p*(T_5-T_6)))-(m_a*C_p*(T_2-T_1));// kW
n_g=100;//The generator efficiency is considered 100
   %
n_th=(W_n/(m_a*(m_f1+m_f2)*CV))*100;// The
   efficiency of the plant in %
printf('\nThe thermal efficiency of the plant=%0.1f
   percentage \nPower generating capacity=%0.0f kW',
   n_th,W_n);
// The answers provided in the textbook is wrong
```

Scilab code Exa 24.24 Heat carried away by the exhaust gases

```
// Example 24_24
clc;funcprot(0);
//Given data
T_1=300;// K
p_1=1;// bar
T_4=870+273;// K
p_r=6;// Pressure ratio
e=0.65;// The effectiveness of heat exchanger
n_c=0.8;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of turbine
n_g=0.95// Generator efficiency
m_a=5;// kg/sec
```

```
C_p=1;// kJ/kg.K
r=1.4;// Specific heat ratio

//Calculation
//(a)
T_2a=T_1*(p_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_5a=T_4/(p_r)^((r-1)/r);// K
T_5=T_4-(n_t*(T_4-T_5a));// K
W_n=m_a*C_p*((T_4-T_5)-(T_2-T_1))*n_g;// kW
//(b)
T_3=T_2+(e*(T_5-T_2));// K
n_th=((C_p*((T_4-T_5)-(T_2-T_1)))/(C_p*(T_4-T_3)))
    *100;// Thermal efficiency of the plant in %
T_6=T_5-(T_3-T_2);// K
//(c)
Q=(m_a*60)*C_p*(T_6-T_1);// KJ/min
printf('\n(a)Power output of the plant=%0.2f kW \n(b
    )Thermal efficiency of the plant=%0.1f percentage
     \n(c)Heat carried by the exhaust gases=%0.0f kJ/
    min',W_n,n_th,Q);
// The answer vary due to round off error
```

Scilab code Exa 24.25 Over all efficiency of the plant

```
// Example 24_25
clc;funcprot(0);
//Given data
p_r=4.5;// Pressure ratio
m_a=82;// kg/min
m_f=1.4;// kg/min
W_o=200;// kW
W_c=230// kW
p_1=1;// bar
T_1=15+273;// K
```

```
T_3=765+273;// K
r_c=1.4;// The index of compression
r_e=1.34;// The index of expansion
C_pa=1;// kJ/kg.K
C_pg=1.13;// kJ/kg.K
n_m=0.98;// Mechanical efficiency of the compressor

//Calculation
W_t=(W_o+W_c)/n_m;// kW
m_a=(m_a)/60;// kg/sec
m_f=(m_f)/60;// kg/sec
AF=m_a/m_f;// Air fuel ratio
//(a)
T_2a=T_1*(p_r)^((r_c-1)/r_c);// K
n_c=(m_a*C_pa*((T_2a-T_1)/W_c))*100;// Isentropic
    efficiency of compressor in %
//(b)
T_4a=T_3/(p_r)^((r_e-1)/r_e);// K
n_t=(W_t/((m_a+m_f)*C_pg*(T_3-T_4a)))*100;//
    Isentropic efficiency of turbine in %
//(c)
T_2=T_1+((T_2a-T_1)/(n_c/100));// K
n_o=(W_o/((m_a+m_f)*C_pg*(T_3-T_2)))*100;// The over
     all efficiency of the plant in %
printf('\n(a)Isentropic efficiency of compressor=%0
    .0f percentage \n(b)Isentropic efficiency of
    turbine=%0.1f percentage \n(c) The over all
    efficiency of the plant=%0.1f percentage',n_c,n_t
    ,n_o);
// The answers provided in the textbook is wrong
```

Scilab code Exa 24.26 The power developing capacity of the system

```
// Example 24_26
clc;funcprot(0);
```

```
//Given data
T_1=303;// K
p_1=0.9;// bar
p_2=4.5;// bar
T_3=1000+273;// K
p_3=1.1;// bar
e=0.8;// Effectiveness of heat exchanger
n_c=0.85;// Isentropic efficiency of compressor
n_t=0.80;// Isentropic efficiency of turbine
m_a=5;// kg/sec
C_p=1.005;// kJ/kg.K
r=1.4;// Specific heat ratio

//Calculation
T_2a=T_1*(p_2/p_1)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_4a=T_3/(p_2/p_3)^((r-1)/r);// K
T_4=T_3-(n_t*(T_3-T_4a));// K
T_5=T_2+(e*(T_4-T_2));// K
n_th=(((T_3-T_4)-(T_2-T_1))/(T_3-T_5))*100;// The
    thermal efficiency of the system in %
P=m_a*C_p*((T_3-T_4)-(T_2-T_1));// The power
    developed by the system in kW
printf('\nThe thermal efficiency of the system=%0.0f
     percentage \nThe power developing capacity of
    the system=%0.1f kW',n_th,P);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.27 The thermal efficiency of the plant

```
// Example 24_27
clc;funcprot(0);
//Given data
T_1=21+273;// K
T_4=925+273;// K
```

```
n_c=0.86;// Isentropic efficiency of compressor
n_t1=0.85;// Isentropic efficiency of H.P turbine
n_t2=0.87;// Isentropic efficiency of L.P turbine
e=0.75;// Effectiveness of heat exchanger
n_com=0.98;// Combustion efficiency
n_m=0.99;// Mechanical efficiency of compressor and
    H.P turbine assembly
P=2040;// kW
C_pa=1.005;// kJ/kg.K
r=1.4;// Specific heat ratio for air
m=1;// kg

//Calculation
// p_r=p_1/p_2;
p_r1=7;// Pressure ratio
T_2a=T_1*(p_r1)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
W_c=1*C_pa*(T_2-T_1);//Work input to the compressor
    in kJ/kg
W_t1=W_c/n_m;// kJ/kg
T_5=T_4-(W_t1/(m*C_pa))// K
T_5a=T_4-((T_4-T_5)/n_t1);// K
p_r2=(T_4/T_5a)^(r/(r-1));// Pressure ratio(p_2/p_3)
p_r3=(1/p_r1)*(p_r2);// Pressure ratio(p_3/p_1)
T_6a=T_5*(p_r3)^((r-1)/r);// K
T_6=T_5-((T_5-T_6a)*n_t2);// K
T_3=T_2+(e*(T_6-T_2));// K
m_a=(P/(C_pa*(T_5-T_6)));// kg/sec
n_th=(P)/(m_a*C_pa*(T_4-T_3)*n_com)*100;// The
    thermal efficiency of the plant in %
printf('\nThe air flow rate=%0.2f kg/sec \nThe
    thermal efficiency of the plant=%0.1f percentage'
    ,m_a,n_th);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.28 The power output of the plant and the thermal efficiency

```
// Example 24_28
clc;funcprot(0);
//Given data
T_1=15+273;// K
p_1=1;// bar
T_3=680+273;// K
p_2=5;// bar
n_c=0.76;// Isentropic efficiency of compressor
n_t=0.86;// Isentropic efficiency of both turbines
m_a=23;// kg/sec
C_pa=1.005;// kJ/kg.K
C_pg=1.128;// kJ/kg.K
r_a=1.4;// Specific heat ratio for air
r_g=1.34;// Specific heat ratio for gases
CV=42000;// kJ/kg

//Calculation
//First considering C-TB_1
T_2a=T_1*(p_2/p_1)^((r_a-1)/r_a);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
// Assume m_r1=m_a1/m_f1
m_r1=(CV/(C_pg*(T_3-T_2)))-1;
T_4a=T_3/(p_2/p_1)^((r_g-1)/r_g);// K
T_4=T_3-((T_3-T_4a)*n_t);// K
m_f1=(m_a*C_pa*(T_2-T_1))/((m_r1+1)*C_pg*(T_3-T_4));// kg/sec
m_a1=m_r1*m_f1;// kg/sec
m_a2=m_a-m_a1;// kg/sec
// Now considering G-TB_2
//m_f2=y(1)
function[X]=massoffuel(y)
    X(1)=((m_a2+y(1))*C_pg*(T_3-T_2))-(y(1)*CV);
endfunction
y=[0.01];
z=fsolve(y,massoffuel);
m_f2=z(1);// kg/kg of air
```

```
m_r2=m_a2/m_f2;
W_2=(m_a2+m_f2)*C_pg*(T_3-T_4);//Work developed by TB_2 kW
W_1=m_a1*C_pa*(T_2-T_1);// The capacity of TB_1 to run the compressor in kW
m_f=(m_f1+m_f2)*60;// kg/min
n_th=(W_2/((m_f/60)*CV))*100;// The thermal efficiency of the plant in %
printf('\n\The power output of the plant=%0.0f kW \nThe thermal efficiency of the plant=%0.1f percentage',W_2,n_th);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.29 Specific fuel consumption and Over all efficiency of the pla

```
// Example 24_29
clc;funcprot(0);
//Given data
T_1=15+273;// K
p_1=1;// bar
T_5=1000;// K
dp_in=0.07;// bar
dp_re=0.1;// bar
R_c1=2;// Compression ratio
n_c=0.80;//  Efficiency of compressor
n_c1=n_c;
n_c2=n_c;
dp_com=0.15;// bar
dp_rh=0.1;// bar
n_t1=0.87;// Efficiency of turbine 1
n_t2=0.7;// Efficiency of turbine 2
e=0.75;// Effectiveness of heat exchanger
n_com=0.98;// Combustion efficiency
n_m=0.99;// Mechanical efficiency of compressor-turbine
```

```
m_a=20;// kg/sec
C_pa=1;// kJ/kg.K
C_pg=1.1;// kJ/kg.K
r_a=1.4;// Specific heat ratio for air
r_g=1.33;// Specific heat ratio for gases
CV=43.5;// MJ/kg

//Calculation
p_2=p_1*R_c1;// bar
p_3=p_2-dp_in;// bar
p_4=2*p_3;// bar
p_5=p_4-dp_in-dp_re;// bar
p_8=1+dp_rh;// bar
T_2=T_1+((T_1/n_c1)*(((R_c1)^((r_a-1)/r_a))-1));// K
T_3=T_1;// K
T_4=T_3+((T_3/n_c2)*(((R_c1)^((r_a-1)/r_a))-1));// K
// as T_4-T_3=T_2-T_1
W_1=2*m_a*C_pa*(T_2-T_1);// Power required to run the compressor in kW
W_t1=W_1/n_m;// Power developed by compressor turbine in kW
W_t1=W_t1/m_a;// The work developed by the turbine per kg of air in kJ/kg
dT_56=W_t1/C_pg;//(dT_56=T_5-T_6) K
R_t1=1/(1-((dT_56/(T_5*n_t1))))^(r_a/(r_a-1));
p_6=p_5/R_t1;// bar
p_7=p_6-dp_rh;// bar
R_t2=p_7/p_8;// bar
T_7=T_5;// K
dT_78=T_7*n_t2*(1-((1/R_t2)^((r_a-1)/r_a)));// K
T_8=T_7-dT_78;// K
W=m_a*C_pa*(T_7-T_8);// Net output of the plant in kW
T_9=T_4+(e*(T_8-T_4));// K
Q_s=C_pa*((T_5-T_9)+(dT_56));// The total heat supplied in the plant per kg of air in kJ/kg
m_f=((m_a*Q_s)/(CV*10^3*n_com))*3600;// The mass of fuel supplied in kg/hr
```

```
Sfc=m_f/W;// Specific fuel consumption in kg/kWh
n_th=(W/(Q_s*m_a))*100;// Thermal efficiency in %
printf('\nThe specific fuel consumption of the plant
   =%0.2f kg/kWh \nPlant capacity=%0.0f kW \nOver
   all efficiency of the plant=%0.1f',Sfc,W,n_th);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.30 The over all efficiency of the plant

```
// Example 24_30
clc;funcprot(0);
//Given data
T_1=15+273;// K
p_1=1;// bar
R_c=5;//Compression ratio
T_3=800+273;// K
T_9=265+273;// K
W=625;// kW
e=0.75;// Effectiveness of heat exchanger
n_c=0.86;// Isentropic efficiency of compressor
n_t=0.86;// Isentropic efficiency of both turbine
n_t1=n_t;
n_t2=n_t;
m_a=5.85;// kg/sec
C_p=1;// kJ/kg.K
C_pa=C_p;
C_pg=C_p;
r=1.4;// Specific heat ratio

//Calculation
R_t1=R_c;
R_t2=R_c;
dT_21=(T_1/n_c)*(((R_c)^((r-1)/r))-1);// K
T_2=T_1+dT_21;// K
W_c=m_a*C_pa*(T_2-T_1);// The work done in the
```

```
compressor in kW
dT_34=T_3*n_t1*(1-((1/R_t1)^((r-1)/r)));//(T_3-T_4) K
m_a1=W_c/(dT_34);// kg/sec
P_ta=(m_a1/m_a)*100;// Percentage of total air supplied to turbine 1 in %
m_a2=m_a-m_a1;// kg/sec
// Assume T_7=y(1); T_8=y(2);
function[X]=Temperature8(y)
    X(1)=(m_a*C_pg*(y(1)-T_2))-(m_a*C_pg*(y(2)-T_9));
    X(2)=((y(1)-T_2)/(y(2)-T_2))-e;
endfunction
y=[100 100];
z=fsolve(y,Temperature8);
T_8=z(2);// K
T_7=z(1);// K
// Assume T_5=x(1); T_6=x(2);
function[Y]=Temperature5(x)
    Y(1)=(x(1)*n_t2*(1-((1/R_t2)^((r-1)/r))))-(x(1)-x(2));
    Y(2)=(m_a2*C_pa*(x(1)-x(2)))-W;
endfunction
x=[100 100];
q=fsolve(x,Temperature5);
T_5=q(1);// K
T_6=q(2);// K
n_th=(W/(((m_a1*C_pa*(T_3-T_7))+(m_a2*C_pa*(T_5-T_6)))))*100;//The over all efficiency of the plant in %
printf('\nPercentage of total air passed to the compressor turbine=%0.1f percentage \nThe combined temperature of of the exhaust gases entering into the heat exchanger,T_8=%0.0f K \nThe temperature of gases entering into the power turbine,T_5=%0.0f K \nThe over all efficiency of the plant=%0.1f percentage',P_ta,T_8,T_5,n_th);
// The answer vary due to round off error
```

Scilab code Exa 24.31 The effectiveness of the heat exchanger

```
// Example 24_31
clc;funcprot(0);
//Given data
T_1=288;// K
p_1=1;// bar
R_c=2.5;// Pressure ratio of each compressor stage
R_c1=R_c;
R_c2=R_c;
T_3=300// K
T_5=1000;// K
W_2=100;// kW/kg of air
p_l1=0.2;// Pressure loss in air side of H.P and
    main combustion chamber in bar
p_l2=0.1;// Pressure loss in reheat combustion
    chamber in bar
p_l3=0.05;// Pressure loss in intercooler in bar
n_c=0.85;// Isentropic efficiency of compressor
n_c1=n_c;
n_c2=n_c;
n_t1=0.88;// Isentropic efficiency of turbine 1
n_t2=0.85;// Isentropic efficiency of turbine 2
m_a=5.85;// kg/sec
C_p=1;// kJ/kg.K
n_o=0.30;// The over all efficiency of the plant
r=1.4;// Specific heat ratio

//Calculation
T_2=T_1+(T_1/n_c1)*(((R_c1)^((r-1)/r))-1);// K
p_2=R_c*p_1;// bar
p_3=p_2-p_l3;// bar
T_4=T_3+(T_3/n_c2)*(((R_c1)^((r-1)/r))-1);// K
p_4=p_3*p_2;// ba
```

```
T_1=T_3;
W_1=C_p*((T_2-T_1)+(T_4-T_3));//The work required to
    compress one kg of air in kJ/kg
n_m=1;// Mechanical efficiency (Assumed)
T_6=T_5-(W_1/C_p);// K
R_t1=1/(1-(((T_5-T_6)/(T_5*n_t1))))^(r/(r-1));//
   Pressure ratio in turbine 1
p_5=p_4-p_l1;// bar
p_6=p_5/R_t1;// bar
p_7=p_6-p_l2;// bar
T_7=T_5;// K
T_8=T_7-(W_2/C_p);// K
R_t2=1/(1-(((T_7-T_8)/(T_7*n_t2))))^(r/(r-1));//
   Pressure ratio in turbine 2
p_8=p_7/R_t2;// bar
p_m=p_8-p_1;// Maximum pressure loss in H.E towards
   gas side in bar
T_9=T_5-(((T_7-T_8)/(n_o))-(T_7-T_6));// K
e=(T_9-T_4)/(T_8-T_4);// The effectiveness of heat
   exchanger
printf('\nThe effectiveness of heat exchanger=%0.3f
   \nMaximum pressure loss in H.E towards gas side=
   %0.2f bar',e,p_m);
// The answer vary due to round off error
```

Scilab code Exa 24.32 The plant efficiency

```
// Example 24_32
clc;funcprot(0);
//Given data
T_1=15+273;// K
p_1=1;// bar
p_r=6;// Pressure ratio
T_4=750+273;// K
e=0.75;// Effectiveness of heat exchanger
```

```
n_c=0.80;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of turbine
C_pa=1;// kJ/kg.K
C_pg=1;// kJ/kg.K
r=1.4;// Specific heat ratio

//Calculation
T_2a=T_1*(p_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
p_2=p_1*p_r;// bar
p_3=sqrt(p_1*p_2);// bar
p_r1=p_2/p_3;// Pressure ratio
p_r2=p_r1;
T_5a=T_4/(p_r1)^((r-1)/r);// K
T_5=T_4-(n_t*(T_4-T_5a));// K
T_6=T_4;// K
T_7=T_5;// K
T_3=T_2+(e*(T_7-T_2));// K
W_c=C_pa*(T_2-T_1);// The work of compression in kJ/kg
W_t=2*C_pg*(T_4-T_5);// The work developed by both turbines in kJ/kg
W_n=W_t-W_c;// Net work in kJ/kg
Q_1=C_pg*(T_4-T_3);// kJ/kg
Q_2=C_pa*(T_6-T_5);// kJ/kg
Q_s=Q_1+Q_2;// The total heat supplied in kJ/kg
W_r=W_n/W_t;// Work ratio
n_p=(W_n/Q_s)*100;// The plant efficiency in %
printf('\nEfficiency of the plant=%0.1f percentage \nWork ratio=%0.4f',n_p,W_r);
// The answer vary due to round off error
```

Scilab code Exa 24.33 Thermal efficiency and Work ratio

```
// Example 24_33
```

```
clc;funcprot(0);
//Given data
p_1=1;// bar
p_2=9;// bar
T_1=25+273;// K
T_6=1250+273;// K
e=0.83;// The effectiveness of regenerator
n_c=0.83;// Isentropic efficiency of  both
    compressors
n_t=0.83;// Isentropic efficiency of both turbines
n_com=0.95;// Combustion efficiency
CV=42;// MJ/kg
C_p=1;// kJ/kg.K
r=1.4;// Specific heat ratio for air and gases

//Calculation
T_8=T_6;// K
n_c1=n_c;
n_c2=n_c;
n_t1=n_t;
n_t2=n_t;
p_i=sqrt(p_1*p_2);// bar
T_2a=T_1*(p_i/p_1)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_3=T_1;// K
T_4=T_2;// K
T_7a=T_6/(p_2/p_i)^((r-1)/r);// K
T_7=T_6-(n_t1*(T_6-T_7a));// K
T_8=T_6;// K
T_9=T_7;// K
T_5=T_2+(e*(T_9-T_4));// K
W_c=2*C_p*(T_2-T_1);// The work developed by  both
    compressors in kJ/kg
W_t=2*C_p*(T_6-T_7);// The work developed by both
    turbines in kJ/kg
W_n=W_t-W_c;// Net work in kJ/kg
W_r=W_n/W_t;// Work ratio
Q_1=C_p*(T_6-T_5);// kJ/kg
```

```
Q_2=C_p*(T_8-T_7);// kJ/kg
Q_s=Q_1+Q_2;// The total heat supplied in kJ/kg
n=(W_n/Q_s)*100;// The plant efficiency in %
printf('\nThermal efficiency of the plant=%0.0f percentage \nWork ratio=%0.2f',n,W_r);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.34 Specific fuel consumption and Thermal efficiency of the plan

```
// Example 24_34
clc;funcprot(0);
//Given data
p_1=1;// bar
p_2=8;// bar
T_1=300;// K
T_3=1000;// K
CV=40;// MJ/kg
W_2=500;// kW
C_pa=1;// kJ/kg. C
C_pg=1;// kJ/kg. C
r=1.4;// Specific heat ratio for air and gases

//Calculation
p_r=(p_2/p_1);// Pressure ratio
T_2=T_1*(p_r)^((r-1)/r);// K
T_4=T_3/(p_r)^((r-1)/r);// K
// Assume m_a=y(1);m_f=y(2);// m_g1=y(3);m_g2=y(4)
function[X]=mass(y)
    X(1)=(y(1)+y(2))-(y(3)+y(4));
    X(2)=(y(4)*C_pg*(T_3-T_4))-(W_2);
    X(3)=(y(1)*C_pa*(T_2-T_1))-(y(3)*C_pg*(T_3-T_4));
    X(4)=(y(2)*CV*10^3)-((y(1)+y(2))*C_pg*(T_3-T_2));
endfunction
```

```
y=[1 0.1 1 1];
z=fsolve(y,mass);
m_a=z(1)*60;// kg/min
m_f=z(2)*3600;// kg/hr
m_g1=z(3);// kg/sec
m_g2=z(4);// kg/sec
Sfc=(m_f/W_2);// kg/kWh
AF=(m_a/60)/(m_f/3600);// Air fuel ratio
n_th=(W_2/((m_f/3600)*CV*10^3))*100;// Thermal efficiency in %
printf('\nThe mass of air consumed by the plant=%0.1f kg/min \nA:F ratio used=%0.0f \nSpecific fuel consumption=%0.2f kg/kWh \nThermal efficiency of the plant=%0.1f percentage',m_a,AF,Sfc,n_th);
// The answer vary due to round off error
```

Scilab code Exa 24.35 Mass of air compressed

```
// Example 24_35
clc;funcprot(0);
//Given data
P=2000;// kW
p_r=8;// Pressure ratio
T_1=300;// K
T_3=1000;// K
T_3a=900;// K
CV=42*10^3;// kJ/kg
n_com=0.95;// Combustion efficiency
C_pa=1;// kJ/kg.K
C_pg=1;// kJ/kg.K
r=1.4;// Specific heat ratio for air and gases

// Calculation
T_2=T_1*(p_r)^((r-1)/r);// K
T_4=T_3/(p_r)^((r-1)/r);// K
```

```
T_4a=T_3a/(p_r)^((r-1)/r);// K
// Assume m_a=y(1);m_a1=y(2); m_a2=y(3);m_f1=y(4);m_f2=y(5);
function[X]=mass(y)
    X(1)=(y(1)*C_pa*(T_2-T_1))-((y(2)+y(4))*C_pa*(T_3-T_4));
    X(2)=y(1)-(y(2)+y(3));
    X(3)=P-((y(3)+y(5))*C_pg*(T_3a-T_4a));
    X(4)=(y(4)*CV*n_com)-((y(2)+y(4))*C_pg*(T_3-T_2));
    X(5)=(y(5)*CV*n_com)-((y(3)+y(5))*C_pg*(T_3-T_2));
endfunction
y=[1 1 1 0.01 0.01];
z=fsolve(y,mass);
m_a=z(1)*60;// kg/min
m_a1=z(2)*3600;// kg/hr
m_a2=z(3)*3600;// kg/hr
m_f1=z(4)*3600;// kg/hr
m_f2=z(5)*3600;// kg/hr
m_f=m_f1+m_f2;// kg/hr
Sfc=m_f/P;// kg/kW-hr
n_th=(3600/(Sfc*CV))*100;// Thermal efficiency of the plant in %
printf('\nFuel consumed by the plant=%0.1f kg/hr \nSpecific fuel consumption=%0.3f kg/kW-hr \nThermal efficiency of the plant=%0.1f percentage \nMass of air compressed=%0.0f kg/min',m_f,Sfc,n_th,m_a);
// The answer provided in the textbook is wrong
```

Scilab code Exa 24.36 Specific fuel consumption and Thermal efficiency of the plan

```
// Example 24_36
clc;funcprot(0);
```

```
//Given data
P=25;// MW
p_r=8;// Pressure ratio
T_1=300;// K
p_1=1;// bar
T_8=700;// K
AF_1=80;// Air fuel ratio
AF_2=70;// Air fuel ratio
e=0.7;// Effectiveness of heat exchanger
CV=40*10^3;// kJ/kg
C_pa=1;// kJ/kg.K
C_pg=1;// kJ/kg.K
r=1.4;// Specific heat ratio for air and gases

//Calculation
p_2=p_1*p_r;// bar
T_2=T_1*(p_r)^((r-1)/r);// K
function[Y]=temperature(x)
    Y(1)=(e*(x(1)-T_2))-(x(1)-T_8);
endfunction
x=[100];
T=fsolve(x,temperature);
T_7=T(1);// K
T_2a=(T_7-T_8)+T_2;// K
//Assume m_f1=y(1);T_3=y(2);m_f2=y(3);T_5=y(4);T_6=y(5);T_4=y(6)
function[X]=massoffuel(y)
    X(1)=(((80*y(1))+y(1))*C_pg*(y(2)-T_2a))-(y(1)*CV);
    X(2)=(((70*y(3))+y(3))*C_pg*(y(4)-T_2a))-(y(3)*CV);
    X(3)=(((70*y(3))+y(3))*C_pg*(y(4)-y(5)))-(P*10^3);
    X(4)=y(5)-((y(4))/((p_r)^((r-1)/r)));
    X(5)=(((80*y(1))+y(1))*((y(2))-y(6)))-(((80*y(1))+(70*y(3)))*(T_2-T_1));
    X(6)=y(6)-((y(2))/((p_r)^((r-1)/r)));
endfunction
```

```
y=[0.1 1000 0.1 1000 100 100 ];
z=fsolve(y,massoffuel);
m_f1=z(1);// kg/sec
m_f2=z(3);// kg/sec
T_3=z(2);// K
T_4=z(6);// K
T_5=z(4);// K
T_6=z(5);// K
m_f=(m_f1+m_f2)*3600;// Total mass of fuel consumed
    per hour in kg/hr
m_a=((m_f1*AF_1)+(m_f2*AF_2))*60;// Mass of air
    compressed per minute in kg/hr
Sfc=(m_f)/(P*10^3);// Specific fuel consumption in
    kg/kW-hr
n_th=((P*10^3)/((m_f1+m_f2)*CV))*100;// Thermal
    efficiency in %
printf('\n(a)Total mass of fuel consumed per hour=%0
    .0f kg/hr \n(b)Mass of air compressed per minute=
    %0.0f kg/hr \n(c)Specific fuel consumption=%0.3f
    kg/kW-hr \n(d)Thermal efficiency=%0.0f percentage
    ',m_f,m_a,Sfc,n_th);
// The answers provided in the textbook is wrong
```

Chapter 25

GAS AND STEAM TURBINES COMBINED CYCLE PLANTS

Scilab code Exa 25.1 Total power generating capacity of the plant

```
// Example 25_1
clc;funcprot(0);
//Given data
m_a=2000;// tons/hr
T_1=20+273;// K
p_1=1;// bar
T_3=1000+273;// K
p_r=7;// Pressure ratio
n_c=0.80;// Isentropic efficiency of compressor
n_t=0.85;// Isentropic efficiency of both turbines
T_5=1200+273;// K
T_6=200+273;// K
p_8=0.1;// bar
C_pa=1;// kJ/kg.K
C_pg=1.1;// kJ/kg.K
r_a=1.4;// Specific heat ratio for air
r_g=1.33;// Specific heat ratio for gases
```

```
CV=45*10^3;// kJ/kg

// Calculation
p_2=p_1*p_r;// bar
T_2a=T_1*(p_r)^((r_a-1)/r_a);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_4a=T_3/(p_r)^((r_g-1)/r_g);// K
T_4=T_3-((T_3-T_4a)*n_t);// K
m_a1=(m_a*1000)/3600;// kg/sec
function[X]=mass(y)
    X(1)=(y(1)*CV)-((m_a1+y(1))*C_pg*(T_3-T_2));
endfunction
y=[10];
z=fsolve(y,mass);
m_f1=z(1);
AF=(m_a1)/(m_f1);
W_g=(((m_a1+m_f1)*C_pg*(T_3-T_4))-(m_a1*C_pa*(T_2-T_1)))/1000;
function[Y]=mass2(x)
    Y(1)= (x(1)*CV)-((m_a1+m_f1+(x(1)))*C_pg*(T_5-T_4));
endfunction
x=[1];
m=fsolve(x,mass2);
m_f2=m(1);// kg/sec
// From h-s chart:
h_7=3400;// kJ/kg
h_8=2220;// kJ/kg
// From steam table
h_9=45.5;// kJ/kg
m_s=((m_a1+m_f1+m_f2)*C_pg*(T_3-T_6))/(h_7-h_9);// kg/sec
W_s=(m_s*(h_7-h_8))/1000;// Power developed in steam turbine in MW
W_t=W_g+W_s;// Total power generated in MW
Q_s=(m_f1+m_f2)*CV;// kW
n=((W_t*10^3)/Q_s)*100;// Overall efficiency of the plant
```

```
m_f=((m_f1+m_f2)*3600)/1000;// Mass of fuel supplied
    in tons/hr
Sfc=(m_f*10^3)/(W_t*10^3);// Specific fuel
   consumption in kg/kWh
printf('\n(i)Total power generating capacity of the
   plant=%0.0f MW \n(ii)Overall efficiency of the
   plant=%0.0f percentage \n(iii)Mass of fuel
   supplied per hour=%0.2f tons/hr \n(iv)Specific
   fuel consumption=%0.3f kg/kWh',W_t,n,m_f,Sfc);
// The answers provided in the textbook is wrong
```

Scilab code Exa 25.2 Power generating capacity of the plant

```
// Example 25_2
clc;funcprot(0);
//Given data
T_1=20+273;// K
T_3=1100+273;// K
T_5=1000+273;// K
T_11=150;//  C
p_r=8;// Pressure ratio
p_7=80;// bar
T_6a=300+273;// K
T_7=600+273;// K
n_c=100/100;// Isentropic efficiency of compressor
n_t=100/100;// Isentropic efficiency of both
   turbines
p_8=0.05;// bar
C_p=1;// kJ/kg
C_pa=C_p;
C_pg=C_p;
r=1.4;// Specific heat ratio
CV=61600;// kJ/kg
C_pw=4.2;// kJ/kg C

```

```
// Calculation
// The combustion reaction taking place in CC-I is given by CH_4+2O_2=CO_2+2H_2O
// 16+64=44+36;
m_o=64/16;// Amount of O_2 required in per kg of CH_4
m_a=(100/23)*4;// Amount of air required in kg/kg of fuel
m_act=m_a*5;// Actual air supplied in kg/kg of fuel
m_f1=(1/m_act);// Amount of fuel supplied per kg of air flow through CC-I in kg
T_2a=T_1*(p_r)^((r-1)/r);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
T_4=T_3/(p_r)^((r-1)/r);// K
// In CC-II
m_a1=1;// kg/sec
m_f2=(m_a1*C_pa*(T_5-T_4))/CV;// kg/kg of air flow
// From h-s chart:
h_7=3510;// kJ/kg
h_11=C_pw*T_11;// kJ/kg
m_s1=(m_a1*C_pg*(T_5-T_6a))/(h_7-h_11);// kg/kg of air
AF=(m_a1/m_s1);
m_a=1.5;// kg/sec(given)
W_g=(m_a*C_pa*((T_3-T_4)-(T_2-T_1)));
m_s=m_a*m_s1;// kg/sec
// From h-s chart:
h_g=2080;// kJ/kg
W_s=(m_s*(h_7-h_g));// kW
W_t=W_g+W_s;// Total power generated in MW
Q_s=(m_f1+m_f2)*m_a*CV;// kW
n=(W_t/Q_s)*100;// Overall efficiency of the plant
m_f=((m_f1+m_f2)*m_a*3600);// Mass of fuel supplied in kg/hr
Sfc=(m_f)/(W_t);// Specific fuel consumption in kg/kWh
printf('\n(i)Total power generating capacity of the plant=%0.0f MW \n(ii)Overall efficiency of the
```

```
    plant=%0.1f percentage \n(iii)Mass of fuel
    supplied per hour=%0.2f kg/hr \n(iv)Specific fuel
     consumption=%0.3f kg/kWh',W_t,n,m_f,Sfc);
// The answer vary due to round off error
```

Scilab code Exa 25.3 Mass of fuel supplied

```
// Example 25_3
clc;funcprot(0);
//Given data
T_1=15+273;// K
T_3=800+273;// K
p_r=8;// Pressure ratio
T_6=200+273;// K
p_9=0.05;// bar
W_t=190;// MW
C_pa=1;// kJ/kg.K
C_pg=1.1;// kJ/kg.K
r=1.33;// Specific heat ratio
CV=40*10^3;// kJ/kg

// Calculation
T_2=T_1*(p_r)^((r-1)/r);// K
T_4=T_3/(p_r)^((r-1)/r);// K
function[X]=mass(y);
    X(1)=(y(5)+y(6))-(W_t*10^3);
    X(2)=y(7)-((W_t*10^3)/(y(8)*CV));
    X(3)=y(5)-(y(1)*C_pa*((T_3-T_4)-(T_2-T_1)));
    // From Moiller chart:
    h_7=3370;// kJ/kg
    h_8=2080;// kJ/kg
    // From steam tables
    h_9=32.6;// kJ/kg
    h_10=h_9;// kJ/kg
    X(4)=y(6)-(y(4)*(h_7-h_8));
```

```
    X(5)=(y(1)*C_pa*(T_3-T_2))-(y(2)*CV);
    T_5=T_3;// K
    X(6)=(y(1)*C_pa*(T_5-T_6))-(y(4)*(h_7-h_9));
    X(7)=(y(3)*CV)-((y(1)*C_pa*(T_5-T_4)));
    X(8)=y(8)-(y(2)+y(3));
endfunction
y=[100 1 1 10 10 10 .1 1];
z=fsolve(y,mass);
m_a=z(1);// kg/sec
m_f1=z(2);// kg/sec
m_f2=z(3);// kg/sec
m_s=z(4);// kg/sec
W_g=z(5)/1000;// MW
W_s=z(6)/1000;// MW
n=z(7)*100;// %
m_ft=z(8)*(3600/1000);// kg/sec
printf('\n(a)Thermal efficiency of the combined
   cycle=%0.1f percentage \n(b)Power generated in
   each unit of the cycle,W_g=%0.1f MW & W_s=%0.1f
   MW \n(c)The generating rate=%0.1f kg/sec \n(d)
   Mass of fuel supplied=%0.2f tons/hr',n,W_g,W_s,
   m_s,m_ft);
// The answers provided in the textbook is wrong
```

Scilab code Exa 25.4 Quantity of cooling water required

```
// Example 25_4
clc;funcprot(0);
//Given data
W_t=100*10^3;// kW
W_g=(60/100)*W_t;// kW
T_1=300;// K
p_1=1;// bar
T_3=1000+273;// K
p_r=8;// Pressure ratio
```

```
n_c=0.85;// Isentropic efficiency of compressor
n_t=0.90;// Isentropic efficiency of both turbines
n_com=0.95;// Combustion efficiency
Gc=2500;// Rs./ton
T_7=600+273;// K
T_6=200+273;// K
p_9=0.05;// bar
C_pa=1;// kJ/kg.K
C_pg=1.1;// kJ/kg.K
r_a=1.4;// Specific heat ratio for air
r_g=1.33;// Specific heat ratio for gases
CV=40*10^3;// kJ/kg
dT=10;//  C
C_pw=4.2;// kJ/kg C

// Calculation
// Considering compressor
p_2=p_1*p_r;// bar
T_2a=T_1*(p_r)^((r_a-1)/r_a);// K
T_2=((T_2a-T_1)/n_c)+T_1;// K
// Considering turbine
T_4a=T_3/(p_r)^((r_g-1)/r_g);// K
T_4=T_3-((T_3-T_4a)*n_t);// K
T_5=T_3;// K
// Considering heat balance in CC-I
function[X]=mass(y);
    X(1)=(y(1)*CV*n_com)-((y(2)+y(1))*C_pg*(T_3-T_2));
    X(2)=(W_g)-((((y(2)+y(1))*C_pg*(T_3-T_4))-(y(2)*C_pa*(T_2-T_1)));
    X(3)=(y(3)*CV*n_com)-((y(2)+y(1)+y(3))*C_pg*(T_5-T_4));
endfunction
y=[1 100 1];
z=fsolve(y,mass);
m_a1=z(2);// kg/sec
m_f1=z(1);// kg/sec
m_f2=z(3);// kg/sec
```

```
AF_1=m_a1/m_f1;
m_f=m_f1+m_f2;// kg/sec
Q_s=(m_f*CV);// kW
n=(W_t/Q_s)*100;// Efficiency of the plant in %
// From h-s chart:
h_7=3610;// kJ/kg
// From steam table
h_9=32.6;// kJ/kg
m_s=((m_a1+m_f1+m_f2)*C_pg*(T_5-T_6))/(h_7-h_9);// kg/sec
Afsf=m_a1/m_s;// Air flow to steam flow ratio
Cf=((m_f*3600)/1000)*Gc;// Cost of fuel per hour in rupees
E_g=W_t;// Energy generated per hour kWh
Cg=Cf/E_g;// Cost of generation in rupees/kWh
// From h-s chart:
h_8=2220;// kJ/kg
m_w=(m_s*3600*(h_8-h_9))/(C_pw*dT*1000);// Quantity of cooling water required in tons/hr
printf('\n(i)Overall efficiency of the plant=%0.1f percentage \n(ii)Air flow to steam flow ratio=%0.2f \n(iii)Cost of generation=%0.2f rupees/kWh \n(iv)Quantity of cooling water required=%0.0f tons/hr',n,Afsf,Cg,m_w);
// The answer provided in the textbook is wrong
```

Scilab code Exa 25.5 The thermal efficiency of the each plant and the combined pln

```
// Example 25_5
clc;funcprot(0);
//Given data
W_t=200*10^3;// kW
T_1=300;// K
p_1=1;// bar
T_3=800+273;// K
```

```
T_5=800+273;// K
T_6=200;//  C
p_r=8;// Pressure ratio
p_7=50;// bar
T_7=600+273;// K
n_c=100/100;// Isentropic efficiency of compressor
n_t=100/100;// Isentropic efficiency of both
    turbines
p_8=0.05;// bar
C_p=1;// kJ/kg
C_pa=C_p;
C_pg=C_p;
r=1.4;// Specific heat ratio
CV=42*10^3;// kJ/kg

// Calculation
p_2=p_1*p_r;// bar
T_2=T_1*(p_r)^((r-1)/r);// K
T_4=T_3/(p_r)^((r-1)/r);// K
function[X]=mass(y);
    X(1)=(y(2)*CV)-((y(1)+y(2))*C_pg*(T_3-T_2));
    X(2)=(y(5))-(((y(1)+y(2))*C_pg*(T_3-T_4))-(y(1)*
        C_pa*(T_2-T_1)));
    X(3)=(y(3)*CV)-((y(1)+y(2)+y(3))*C_pg*(T_5-T_4))
        ;
    // From h-s chart:
    h_7=3620;// kJ/kg
    h_9=32.6;// kJ/kg
    h_8=2220;// kJ/kg
    T_5=800;//  C
    X(4)=(y(4)*(h_7-h_9))-((y(1)+y(2)+y(3))*C_pg*(
        T_5-T_6));
    X(5)=y(6)-(y(4)*(h_7-h_8));
    X(6)=(y(5)+y(6))-W_t;
endfunction
y=[100 1 1 1 100000 10000];
z=fsolve(y,mass);
m_a1=z(1);// kg/sec
```

```
m_f1=z(2);// kg/sec
m_f2=z(3);// kg/sec
m_s=z(4);// kg/sec
W_g=z(5);// kW
W_s=z(6);// kW
m_f=m_f1+m_f2;// kg/sec
R_a=m_a1/m_s;// Ratio of air supplied
//(a)
n_o=((W_t)/(m_f*CV))*100;
//(b)
n_g=((W_g)/(m_f1*CV))*100;
//(a)
n_s=((W_s)/(m_f2*CV))*100;
printf('\nOverall efficiency of the plant=%0.0f
   percentage \nThermal efficiency of gas turbine
   plant=%0.0f percentage \nThermal efficiency of
   steam turbine plant=%0.0f percentage \nRatio of
   air supplied=%0.2f',n_o,n_g,n_s,R_a);
```

Scilab code Exa 25.6 AF ratio used in gas turbine plant

```
// Example 25_6
clc;funcprot(0);
//Given data
W_t=200;// MW
T_a=15+273;// K
T_c=750+273;// K
p_r=7.5;// Pressure ratio
T_e=750+273;// K
T_f=100+273;// K
C_pg=1.11;// kJ/kg.C
C_pa=1.005;// kJ/kg.C
r_a=1.4;// Specific heat ratio for air
r_g=1.33;// Specific heat ratio for gases
CV=43300;// kJ/kg
```

```
// Calculation
T_b=T_a*(p_r)^((r_a-1)/r_a);// K
T_d=T_c/(p_r)^((r_g-1)/r_g);// K
function[X]=mass(y)
    X(1)=y(3)-(y(1)*((C_pg*(T_c-T_d))-(C_pa*(T_b-T_a))));
    // From Moiller chart:
    h_1=3670;// kJ/kg
    h_2=2305;// kJ/kg
    // From steam tables
    h_3=192;// kJ/kg
    h_4=h_3;// kJ/kg
    X(2)=y(4)-(y(2)*(h_1-h_2));
    X(3)=(y(3)+y(4))-(W_t*10^3);
    X(4)=(y(1)*C_pg*(T_e-T_f))-(y(2)*(h_1-h_4));
endfunction
y=[100 10 10000 10000];
z=fsolve(y,mass);
m_a=z(1);// kg/sec
m_s=z(2);// kg/sec
W_g=z(3)/1000;// MW
W_s=z(4)/1000;// MW
Q_s=m_a*((C_pa*(T_c-T_b))+(C_pg*(T_e-T_d)));
n_th=((W_t*10^3)/Q_s)*100;// Thermal efficiency of the cycle
AF=CV/((C_pa*(T_c-T_b))+(C_pg*(T_e-T_d)));
printf('\nThe mass of air supplied per second=%0.1f kg/sec \nThe mass of steam supplied per second=%0.1f kg/sec \nPower output by gas turbine=%0.1f MW \nPower output by steam turbine=%0.1f MW \nOver all efficiency of the plant=%0.1f percentage \nA:F ratio used in the gas turbine plant=%0.1f',m_a,m_s,W_g,W_s,n_th,AF);
// The answers vary due to round off error
```

Chapter 32

FLUCTUATING LOADS ON POWER PLANTS

Scilab code Exa 32.1 The load factor and the energy consumed during 24 hours

```
// Example 32_1
clc;funcprot(0);
//Given data
T_1=[0,5];// Time in hours
T_2=[5,6];// Time in hours
T_3=[6,9];// Time in hours
T_4=[9,18];// Time in hours
T_5=[18,21];// Time in hours
T_6=[21,24];// Time in hours
L=[2,6,20,0,12,8];// Load in kW
L_p=20;// Peak load in kW

//Calculation
E_t=(L(1)*(T_1(2)-T_1(1)))+(L(2)*(T_2(2)-T_2(1)))+(L
   (3)*(T_3(2)-T_3(1)))+(L(4)*(T_4(2)-T_4(1)))+(L(5)
   *(T_5(2)-T_5(1)))+(L(6)*(T_6(2)-T_6(1)));//Total
   energy consumed during 24 hours in kW-hrs.
L_a=E_t/24;// Average load in kW
F_l=L_a/L_p;// Load factor
```

```
T=[0 5 5 6 6 9 9 18 18 21 21 24 24];//Time in hours
    for load curve
L=[2 2 6 6 20 20 0 0 12 12 8 8 22];// Load in kW for
     load curve
xlabel('TIME IN HOURS');
ylabel('LOAD IN kW');
title('Fig.32.1.Load curve');
plot(T,L,'b');
x=[0 24];// Time in hours
y=[L_a L_a];// Load in kW
plot(x,y,'r-.');
legend('LOAD CURVE','AVERAGE LOAD');
printf('\nLoad factor=%0.3f \nTotal energy consumed
    during 24 hours=%0.0f kW-hrs',F_l,E_t);
// The answer vary due to round off error
```

Scilab code Exa 32.2 Load Factor of the plant

```
// Example 32_2
clc;funcprot(0);
//Given data
T_1=[0,6];// Time in hours
T_2=[6,10];// Time in hours
T_3=[10,12];// Time in hours
T_4=[12,16];// Time in hours
T_5=[16,20];// Time in hours
T_6=[20,22];// Time in hours
T_7=[22,24];// Time in hours
L=[20,50,60,40,80,70,40];//load in kW

//Calculation
//(a)
L_p=80;// Peak load in kW
E_g=(L(1)*(T_1(2)-T_1(1)))+(L(2)*(T_2(2)-T_2(1)))+(L
    (3)*(T_3(2)-T_3(1)))+(L(4)*(T_4(2)-T_4(1)))+(L(5)
```

```
*(T_5(2)-T_5(1)))+(L(6)*(T_6(2)-T_6(1)))+(L(7)*(
    T_7(2)-T_7(1)));//Energy generated in MW-hrs
L_a=E_g/24;// Average load in kW
F_l=L_a/L_p;// Load factor
T=[0 0 6 6 10 10 12 12 16 16 20 20 22 22 24 24];//
    Time in hours for load curve
L=[0 20 20 50 50 60 60 40 40 80 80 70 70 40 40 100];
    // Load in kW for load curve
xlabel('TIME IN HOURS');
ylabel('LOAD IN kW');
title('Fig.32.2 Load curve');
plot(T,L,'b');
printf('\n(a)Load factor=%0.3f',F_l);
//(b)
L_p=20;// Peak load in kW
E_g=(20*4)+(10*2);//MW-hrs
T_s=6;//Time during which stand by unit remains in
    operation hours (from the load curve)
L_a=E_g/T_s;
F_l=L_a/L_p;// Load factor
printf('\n(b)Load factor=%0.3f',F_l);
x=[16 22];// Time n hours
L=[60 60];// Load in MW
plot(x,L,'r-.');
legend('LOAD CURVE');
// The answer vary due to round off error
```

Scilab code Exa 32.3 Diversity factor

```
// Example 32_3
clc;funcprot(0);
//Given data
L_p=30;// The peak load on a power station in MW
L=[25 10 5 7];// Connected load in MW
F_l=50;// Load factor in %
```

```
//Calculation
//(a)
L_a=(L_p*(F_l/100));// Average load in MW
//(b)
E=L_a*10^3*8760;// Energy supplied per year in kW-hrs
//(c)
L_c=L(1)+L(2)+L(3)+L(4);// MW
F_d=L_p/L_c;// Demand factor
//(d)
F_div=L_c/L_p;// Diversity factor
printf('\n(a)Average load on the power station=%0.0f MW \n(b)Energy supplied per year=%0.3e kW-hrs \n(c)Demand factor=%0.2f \n(d)Diversity factor=%0.2f',L_a,E,F_d,F_div);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.4 The capacity of the plant

```
// Example 32_4
clc;funcprot(0);
//Given data
L_p=50;// Peak load in MW
F_l=60;// Load factor in %
Cc=1;// The coal consumption kg per kWh
CC=600;// The cost of coal in RS./ton of coal
E_s=1;// The energy is sold at Rs./kW-hr

//Calculation
L_a=(L_p*(F_l/100));// Average load in MW
E=L_a*10^3*8760;// Energy generated per year in kW-hrs
C_py=(E*Cc)/1000;// Coal required per year in tons
CC_py=C_py*CC;// Cost of coal per year in rupees
```

```
C_e=(E*Cc)/E_s;//Cost of energy sold in rupees
R=E-CC_py;// Revenue earned by the power plant per
    year in rupees
printf('\n(a)Revenue earned by the power plant per
    year=%0.4e rupees \n(b)The energy generated per
    year=%0.3e kW-hr',R,E);
```

Scilab code Exa 32.5 The plant load factor and the plant use factor

```
// Example 32_5
clc;funcprot(0);
//Given data
L_1=60;// Load in MW
L_2=60;// Load in MW
L_3=30;// Load in MW
T_12=8000;// Running time in hours
T_3=2000;// Running time in hours
E=876*10^6;// kWh per year

//Calculation
P=L_1+L_2+L_3;// Plant capacity in MW
L_a=(E/8760)/1000;// MW
F_l=(L_a/P)*100;// Load factor in %
L=60;// L_1=L_2=L in MW
ME=(2*L*T_12)+(1*L_3*T_3);// Maximum possile energy
    which can be produced by the plant in MEWh
Puf=(E/(ME*10^3));// Plant use factor
printf('\nLoad factor=%0.0f percentage \nPlant use
    factor=%0.2f',F_l,Puf);
```

Scilab code Exa 32.6 Annual energy supplied by the power plant

```
// Example 32_6
```

```
clc;funcprot(0);
//Given data
MD_1=40;// MW
MD_2=50;// MW
MD_3=30;// MW
F_l=60;// Load factor in percentage
DF=1.2;// Diversity factor

// Calculation
MD_s=MD_1+MD_2+MD_3;// Sum of individual maximum demands in MW
SMD=MD_s/DF;// Simultaneous maximum demand in MW
P=MD_s;// The capacity of the plant in MW
L_a=(F_l/100)*SMD;// Average load in MW
E=L_a*10^3*8760;// Energy supplied per year in kWh
printf('\n(a)The maximum load on the power plant=%0.0f MW \n(bThe capacity of the power plant=%0.0f MW \n(c)Annual energy supplied per year=%0.3e kWh',SMD,P,E );
```

Scilab code Exa 32.7 Number of hours the plant remained in operation during the ye

```
// Example 32_7
clc;funcprot(0);
//Given data
UF=0.5;// Use factor
CF=0.4;// Capacity factor

//Calculation
// Use factor=E/(P_c*t);.... (1)
// Capacity factor=(average load/P_c)=(E/(P_c*8760));....(2)
// Dividing euations (1) and (2) we get,
T=(8760*CF)/(UF);// hours
printf('\nThe number of hours of its operation
```

```
during the year=%0.0f hours',T);
```

Scilab code Exa 32.8 The over all efficiency of the plant

```
// Example 32_8
clc;funcprot(0);
//Given data
L_12=500;// Load in kW
L_3=200;// Load in kW
CV=40000;//Calorific value in kJ/kg
Fc=0.25;// Fuel consumption in kg/kWh
CF=4000;// Cost of fuel in rupees
Cf=50;// Plant capacity factor in %
d=30;// Number of days

//Calculation
P_c=(2*L_12)+L_3;// Plant capacity in kW
t=d*24;// Time in hours during the month
E=(Cf/100)*P_c*t;// Energy generated during the
   month in kWh/month
Fc_p=(Fc*E);//Fuel cost per month in kg
Fc_p=(Fc_p)/1000;// tonnes
FC=CF*Fc_p;// rupees/month
Ce=FC/E;// Cost of energy in Rs./kWhr
O=E*3600;// Output
I=Fc_p*1000*CV;// Input
n_o=(O/I)*100;// Over all efficiency
printf('\nThe over all efficiency of the plant=%0.0f
    percentage',n_o);
```

Scilab code Exa 32.9 Capacity factor of the plant

```
// Example 32_9
```

```
clc;funcprot(0);
//Given data
L_1=45000;// kW
L_2=5000;//kW
L_34=20000;// Load in kW
L_5=10000;// Load in kW
L_p=5000;

//Calculation
// The energy generated per year by the plant= Area under the load curve
E_g=(8760*L_2)+((1/2)*8760*(L_1-L_2));// kWh/year
L_a=(E_g)/8760;// Average load in kW
MD=L_1;// Maximum demand in kW
F_l=L_a/MD;// Load factor
P=(2*L_34)+(1*L_5);// Plant capacity in kW
CF=(E_g)/(P*8760);
printf('\nLoad factor=%0.2f \nCapacity factor of the plant=%0.1f',F_l,CF);
// The answer vary due to round off error
```

Scilab code Exa 32.10 The capacities of the hydel and the steam plant

```
// Example 32_10
clc;funcprot(0);
//Given data
ML=30;// Maximum load in MW
ml=10;// Minimum load in MW
L_p=72;// Peak load in MWh/day

// Calculation
// From Fig.Prob.32.10
// Area BGFA=(1/2)*xy-72;
// FED=(1/2)*(20-x)*(24-y);
function[X]=capacity(y)
```

```
    X(1)=(y(1)*y(2)-144)-(0.45*(20-y(1))*(24-y(2)));
    X(2)=(y(1)/y(2))-(20/24);
endfunction
y=[1 1];
z=fsolve(y,capacity);
x=z(1);// Hydel capacity in MW
Spc=ML-x;// Steam plant capacity in MW
printf('\nHydel plant capacity=%0.0f MW \nSteam
   plant capacity=%0.0f MW',x,Spc);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.11 Load factor of the system

```
// Example 32_11
clc;funcprot(0);
//Given data
T=[0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
    20 21 22 23 24];// Time in hours
Rl=[80 80 80 80 80  100 120 120 120 120 40 40 40 40
   40 40 40 140 160 160 160 160 80 80];//
   Residential load in kW
Sll=[60 60 60 60 60 60 0 0 0 0 0 0 0 0 0 0 0 0 60 60
    60 60 60 60];// Street lighting load in kW
Il=[400 400 400 400 400 300 200 200 1000 1000 1000
   1000 400 1000 1000 1000 1000 400 200 400 400 400
   400 400];// Industrial load in kW
Tl=[540 540 540 540 540 460 320 320 1120 1120 1040
   1040 440 1040 1040 1040 1040 540 320 620 620 620
   540 540];// Total load in kW

// Calculation
T_p=[0 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 10 10 11
   11 12 12 13 13 14 14 15 15 16 16 17 17 18 18 19
   19 20 20 21 21 22 22 23 23 24];// Time in hours
   for load curve
```

```
Rl_p=[80 80 80 80 80 80 80 80 80 80 100 100 120 120 120 120 120 120 120 120 40 40 40 40 40 40 40 40 40 40 40 40 40 40 140 140 160 160 160 160 160 160 160 160 80 80 80 80];// Residential load in kW for load curve
Sll_p=[60 60 60 60 60 60 60 60 60 60 60 60 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 60 60 60 60 60 60 60 60 60 60 60 60];// Street lighting load in kW for load curve
Il_p=[400 400 400 400 400 400 400 400 400 400 300 300 200 200 200 200 1000 1000 1000 1000 1000 1000 1000 1000 400 400 1000 1000 1000 1000 1000 1000 1000 1000 400 400 200 200 400 400 400 400 400 400 400 400 400 400];// Industrial load in kW for load curve
Tl_p=[540 540 540 540 540 540 540 540 540 540 460 460 320 320 320 320 1120 1120 1120 1120 1040 1040 1040 1040 440 440 1040 1040 1040 1040 1040 1040 1040 1040 540 540 320 320 620 620 620 620 620 620 540 540 540 540];// Total load in kW for load curve
xlabel('TIME IN HOURS');
ylabel('LOAD IN kW');
title('Fig.Prob.32.11.Load curve');
plot(T_p',Rl_p','r',T_p',Sll_p','b-.',T_p',Il_p','g',T_p',Tl_p');
legend(['COMMERCIAL LOAD','STREET LIGHTING LOAD','INDUSTRIAL LOAD','TOTAL CURVE LOAD']);
E_1=(Rl(1)*5)+(Rl(6)*1)+(Rl(7)*4)+(Rl(11)*7)+(Rl(18)*1)+(Rl(19)*4)+(Rl(23)*2);// Total energy consumed by the residential load in kW-hrs
L_a1=E_1/24;// Average load of residential consumers in kW
ML_1=Rl(19);// Maximum load in kW
F_l1=L_a1/ML_1;// Load factor
E_2=(Sll(1)*12);// Total energy consumed by the Street lighting load in kW-hrs
ML_2=Sll(1);// Maximum load in kW
```

```
F_l2=(E_2/24)*(1/ML_2);//Load factor
E_3=(Il(1)*5)+(Il(6)*1)+(Il(7)*2)+(Il(9)*4)+(Il(13)
    *1)+(Il(14)*4)+(Il(18)*1)+(Il(19)*1)+(Il(20)*5);
    // Total energy consumed by the Industrial load
    in kW-hrs
ML_3=Il(9);// Maximum load in kW
F_l3=(E_3/24)*(1/ML_3);//Load factor
ML_s=Tl(11);// Simultaneous maximum demand in kW
ML_si=ML_1+ML_2+ML_3;// Sum of individual maximum
    load in kW
F_d=ML_si/ML_s;// Diversity factor
F_l=(E_1+E_2+E_3)/(ML_s*24);// Load factor of the
    system
printf('\n(a)Load factor of Residential load=%0.3f \
    n   Load factor of street lighting load=%0.1f \n
      Load factor of industrial load load=%0.2f \n(b)
    Diversity factor of the system=%0.3f \n(c)Load
    factor of the system=%0.3f',F_l1,F_l2,F_l3,F_d,
    F_l);
// The answer vary due to round off error
```

Scilab code Exa 32.12 Hours not in service

```
// Example 32_12
clc;funcprot(0);
//Given data
F_l=70/100;// Load factor
F_c=50/100;// Capacity factor
F_u=60/100;// Use factor
MD=20;// Maximum demand in MW

// Calculation
//(a)
L_a=(MD*F_l)*10^3;// Average load in kW
E=L_a*365*24;// Annual energy produced in kW-hrs
```

```
//(b)
Pc=(L_a/1000)/F_c;// Plant capacity in MW
Rc=Pc-MD;// Reserve capacity in MW
//(c)
t_1=E/(Pc*10^3*F_u);// hours
T=8760-t_1;// Hours not in service in hrs in a year
printf('\n(a)Annual energy production=%0.3e kW-hrs \n(b)Reserve capacity over and above peak load=%0.0f MW \n(c)Hours not in service=%0.0f hrs in a year',E,Rc,T);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.13 Load factor and the monthly bill

```
// Example 32_13
clc;funcprot(0);
//Given data
L_i=1500;// Installed load in MW
L=[50 0 1200 1000 500];// kW
T=[0 5 8 12 16 24];// hrs
Tp_1=40;// kW
Tp_2=1.5;// kWh
MD=1200;// Maximum load in kW

//Calculation
L_p=[0 50 50 0 0 1200 1200 1000 1000 500 500 2000];//Load in MW
T_p=[0 0 5 5 8 8 12 12 16 16 24 24];// Time in hours
L_I=[L_i L_i L_i L_i L_i L_i L_i L_i L_i L_i L_i L_i];// Installed load in MW for plot
plot(T_p',L_p','b',T_p',L_I','r');
a=gca();
a.x_ticks.labels=["","","5am","","8 am","","12noon","","4pm","","8 pm","","12pm"];
a.x_ticks.locations
```

```
    =[0;2;5;6;8;10;12;14;16;18;20;22;24];
xlabel('Time in hours');
ylabel('Load in kW');
xtitle('Fig.Prob.32.13');
legend('Load curve','Installed load');
E=(L(1)*(T(2)-T(1)))+(L(3)*(T(4)-T(3)))+(L(4)*(T(5)-
    T(4)))+(L(5)*(T(6)-T(5)));
F_l=(E/(MD*24));// Load factor
Fa=L_i*Tp_1;// Fixed amount in rupees
C=(E)*30*Tp_2;// Cost of energy consumed
Mb=Fa+C;// Monthly bill in rupees
printf('\nLoad factor=%0.3f \nMonthly bill=Rs.%0.0f'
    ,F_l,Mb);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.14 Reserve capacity

```
// Example 32_14
clc;funcprot(0);
//Given data
F_l=0.6;// Load factor
F_c=0.4;// Capacity factor
F_u=0.45;// Use factor
MD=20;// Maximum demand in MW

// Calculation
//(a)
L_a=(MD*F_l)*10^3;// Average load in kW
E=L_a*365*24;// Annual energy produced in kWh
//(b)
Pc=(L_a/1000)/F_c;// Plant capacity in MW
Rc=Pc-MD;// Reserve capacity in MW
//(c)
t=(8760*(F_c/F_u));// hours
T=8760-t;// Number of hours during which plant
```

```
    remains in operation during the year
printf('\n(a)Annual energy production=%0.4e kW-hrs \
    n(b)Reserve capacity over and above peak load=%0
    .0f MW \n(c)Number of hours during which plant
    remains in operation during the year=%0.0f hours'
    ,E,Rc,T);
```

Scilab code Exa 32.15 Connected load of each type

```
// Example 32_15
clc;funcprot(0);
//Given data
MD_1=15;// Maximum demand in MW
MD_2=25;// Maximum demand in MW
MD_3=50;// Maximum demand in MW
F_di1=1.25;// Diversity factor
F_di2=1.20;// Diversity factor
F_di3=1.30;// Diversity factor
F_d1=0.70;// Demand factor
F_d2=0.90;// Demand factor
F_d3=0.98;// Demand factor
F_dio=1.5;// Diversity factor

// Calculation
//(a)
MD_s=MD_1+MD_2+MD_3;// The sum of maximum demands
    from all customers in MW
MD=MD_s/F_dio;// Maximum demand of the plant in MW
//(b)
Mdl=MD_1*F_di1;// Maximum domestic load demand in MW
Cdl=Mdl/F_d1;// Connected domestic load in MW
Ccl=(MD_2*F_di2)/F_d2;// Connected commercial load
    in MW
Cil=(MD_3*F_di3)/F_d3;// Connected industrial load
    in MW
```

```
Tcl=Cdl+Ccl+Cil;// Total connected load to the plant
    in MW
printf('\n(a)Maximum demand of the plant=%0.0f MW \n
   (b)Connected commercial load=%0.2f MW \n
   Connected industrial load=%0.2f MW \n   Connected
    industrial load=%0.2f MW \n   Total connected
   load to the plant=%0.2f MW',MD,Cdl,Ccl,Cil,Tcl);
// The answer vary due to round off error
```

Scilab code Exa 32.16 Reserve capacity of the plant

```
// Example 32_16
clc;funcprot(0);
//Given data
MD=500;// Maximum demand in MW
F_l=0.5;// Load factor
F_c=0.4;// Capacity factor

// Calculation
E=MD*F_l*8760;// Energy generated per year in MWh
Pc=E/(F_c*8760);// Plant capacity in MW
Rc=Pc-MD;// Reserve capacity of the plant in MW
printf('\nReserve capacity of the plant=%0.0f MW',Rc
   );
```

Scilab code Exa 32.16A The annual load factor of the plant

```
// Example 32_16A
clc;funcprot(0);
//Given data
P=1000;// Plant capacity in MW
P_1=1000;// MW
t_1=2;// hours
```

```
P_2=500;// MW
t_2=6;// hours
n=60;// Number of days plant should shut down
    annualy

// Calculation
E_d=((P_1*t_1))+((P_2*t_2));//The amount of energy
    generated per day in Mwh/day
N=365-n;// No. of days (the plant is working)
E_y=E_d*N;//The amount of energy generated per year
    in Mwh
L_f=E_y/(P*(N*24));// Annual load factor
printf('\n Annual load factor=%0.3f',L_f);
```

Scilab code Exa 32.17 The annual load factor of the plant

```
// Example 32_17
clc;funcprot(0);
//Given data
P=1000;// Plant capacity in MW
P_1=1000;// MW
t_1=2;// hours
P_2=500;// MW
t_2=6;// hours
P_3=300;// MW
t_3=8;// hours
n=50;// Number of days plant should shut down
    completely

// Calculation
E_g=((P_1*t_1))+((P_2*t_2)+((P_3*t_3)));//Eenergy
    generated per working day in Mwh
N=365-n;// Working days/year of the plant
E_s=E_g*N;// Energy supplied per year in MWh
F_l=E_s/(P*(N*24));// Annual load factor
```

```
printf('\n Annual load factor=%0.3f',F_l);
```

Scilab code Exa 32.17A Diversity factor and the annual load factor

```
// Example 32_17A
clc;funcprot(0);
//Given data
L_i=720;// Industrial load in MW
L_c=350;// Commercial load in MW
L_d=10;// Domestic power in MW
L_dl=50;// Domestic load in MW
MD=1000;// MW
E_g=50*10^5;// Energy generated in MWh/year

// Calculation
//(a)
F_d=(L_i+L_c+L_d+L_dl)/MD;// Diversity factor
AD=E_g/8760;// Average demand in MW
//(b)
F_l=AD/MD;// Annual load factor
printf('\n Annual load factor=%0.4f',F_l);
```

Scilab code Exa 32.18 Plant capacity factor

```
// Example 32_18
clc;funcprot(0);
//Given data
L_max=6000;// MW
L_min=2000;// MW
P_cap=7000;// MW

// Calculation
```

```
t=[0 1 2 3 4 5  6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24];// Time in hours
for(i=1:25)
    L(i)=(2000+(4000*sin((%pi*t(i))/24)));
end
t_1=[0 12 24 24];// Time in hours
L_cap=[7000 7000 7000 8000];// Plant capacity in MW
xlabel('t(time in hrs)');
ylabel('Load in kW');
xtitle('Fig.Prob.32.18');
plot(t,L,'g', t_1,L_cap,'b-.');
a=gca();
a.x_ticks.labels=["0","","","","","","12","","","","","","24"];
a.x_ticks.locations=[0;2;4;6;8;10;12;14;16;18;20;22;24];
legend('Load curve','L_cap')
t_1=0;
t_2=24;// Limits of integration
L_av=(1/24)*integrate('(2000+(4000*(sin((%pi*t)/(24)))))','t',t_1,t_2);// Average load on the plant in MW
PLF=(L_av/L_max);// Plant load factor
PCF=(L_av/P_cap);// Plant Capacity factor
printf('\nAverage load on the plant=%0.1f MW \nPlant load factor=%0.3f \nPlant Capacity factor=%0.2f',L_av,PLF,PCF);
```

Scilab code Exa 32.19 Plant capacity factor

```
// Example 32_19
clc;funcprot(0);
//Given data
L_max=5;// MW
P=7;// Plant capacity in MW
```

```

// Calculation
//(a)
t=[0 12 6];// Time in hours
x=[6 12 6];
a=[6 6 6];
b=[5 5 5];// MW
for(i=1:3)
L=(b(i)/a(i))*sqrt((2*a(i)*x(i))-((x(i))^2));
end
b=5;// MW
L_av=(%pi*b)/4;// Average load in MW
// (i)
F_l=L_av/L_max;// Load factor
E=L_av*12;// Energy used during 12-hrs period MW hr
CF=L_av/P;// Capacity factor
printf('\n(a)The average load of the factory=%0.3f
    MW \n    Load factor of the factory=%0.3f MW \n
    Energy consumed by the factory during 12 hours=%0
    .1f MW-hr \n    Capacity factor=%0.3f',L_av,F_l,E,
    CF);
//(b)
b=5;
a=4;
t=[0 8 4];// Time in hours
for(i=1:3)
    L(i)=2+((b/a)*sqrt((2*a*t(i))-(t(i))^2));
end
L_av=(L(1)+L(2)+L(3))/3;// Average load in MW
printf('\n(b)The average load of the factory=%0.2f
    MW',L_av);
// The answer vary due to round off error
```

Scilab code Exa 32.19a Electrical charges to be paid

```
// Example 32_19a
clc;funcprot(0);
//Given data
L_min=1;// MW
L_max=sqrt(3);// MW
P=2;// Plant capacity in MW
N=26;// Number of working days per month
h=8;// Number of working hours per day
c=50;// Charges in Rs./kW
c_d=2.5;//  Charges in Rs./kW-hr

// Calculation
x_0=4;
x_1=12;// Limits of integration
L_av=(1/8)*integrate('(((1/2)*sqrt(x)))','x',x_0,x_1)*1000;// Average load on the plant in kW
F_l=L_av/(L_max*1000);// Load factor
CF=L_max/P;// Capacity factor
E=L_av*N*h;// Energy consumption per month in kWhr
Ec=(L_max*1000*c)+(E*c_d);// Electrical charges to be paid by the factory
printf('\nLoad factor=%0.3f \nCapacity factor=%0.3f \nEnergy consumption per month=%0.0f kWhr \nElectrical charges to be paid by the factory=Rs.%0.0f',F_l,CF,E,Ec);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.20 The cost of per kWh generated

```
// Example 32_20
clc;funcprot(0);
//Given data
P=500;// MW
F_c=0.45;// Capacity factor
F_l=0.6;// Annual load factor
```

```
Cf=1000*10^6;// Cost of fuel used/year in rupees
CC=10000*10^6// Capital cost plant in rupees
ID=15/100;// Interest and depriciation

// Calculation
//(a)
MD=(F_c/F_l)*P;// Maximum demand in MW
Rc=P-MD;// Reserve capacity in MW
//(b)
E=MD*10^3*F_l*8760;// Number of units generated in
    kW-hrs
Afc=CC*ID;// Annual fixed charges in rupees
Arc=Cf;//  Annualrunning charges in rupees
Tc=Afc+Arc;// Total annual charges in rupees
C=Tc/E;// Cost of generation (Rs./kW-hr) in rupees
printf('\n(a)Minimum reserve capacity of the station
    =%0.0f MW \n(b)The cost per kWh generated=Rs.%0.2
    f',Rc,C);
```

Scilab code Exa 32.21 Capacity factor of the plant

```
// Example 32_21
clc;funcprot(0);
//Given data
// L=350+10t-t^2;

// Calculation
// Differentiating L with respect to t, we get 10-2t
    =0
t=10/2;// hrs
L_max=350+(10*t)-t^2;// The maximum load occurs at 5
     th hour during the day in MW
t_0=0;
t_1=24;// Limits of integration
L_av=(1/24)*integrate('(350+(10*t)-t^2)','t',t_0,t_1
```

```
    );
F_l=L_av/L_max;// Load factor
printf('\nMaximum load,L_max=%0.0f MW \nLoad factor
    of the plant=%0.4f',L_max,F_l);
// Load duration curve is the representation of load
     with respect to time
t=[0 1 2 3 4 5  6 7 8 9 10 11 12 13 14 15 16 17 18
    19 20 21 22 23 24];// Time in hours
for(i=1:25)
    L(i)=((350+(10*t(i))-t(i)^2));
end
T=[0 12 24];
L_max=[L_max L_max L_max];
subplot(2,1,1);
plot(t',L,'g',T',L_max','--');
xlabel('t');
ylabel('L');
xtitle('Load curve');
// Load duration curve is the representation of load
     with respect to time is decending order.
T=[24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8
    7 6 5 4 3 2 1 0];// Time in hours
for(j=1:25)
    L(j)=((350+(10*T(j))-T(j)^2));
end
subplot(2,1,2);
plot(t',L,'r');
xtitle('Load duration curve');
xlabel('t');
ylabel('L');
```

Scilab code Exa 32.22 Capacity factor of the plant

```
// Example 32_22
clc;funcprot(0);
```

```
//Given data
PC_a=32;// Plant capacity in MW
PC_b=20;// MW
E_a=135*10^6;// The energy output in kWh
E_b=9.5*10^6;// kWh
MD_b=15;// MW
t_b=2900;// Time in hours
MD_a=25;// MW

// Calculation
// (a)Base load plant
ALF_a=E_a/((MD_a*10^3)*8760);// Annual load factor
PUF_a=MD_a/PC_a;// Plant use factor
CF_a=E_a/((PC_a*10^3)*8760);// Capacity factor
//(b)Peak load plant
ALF_b=E_b/((MD_b*10^3)*8760);// Annual load factor
PUF_b=MD_b/PC_b;// Plant use factor
CF_b=E_b/((PC_b*10^3)*t_b);// Capacity factor
printf('\n(a)Annual load factor=%0.3f \n    Plant use
    factor=%0.2f \n    Capacity factor=%0.2f \n(b)
    Annual load factor=%0.3f \n    Plant use factor=%0
    .2f \n    Capacity factor=%0.3f',ALF_a,PUF_a,CF_a,
    ALF_b,PUF_b,CF_b);
// The answer vary due to round off error
```

Scilab code Exa 32.23 `Total maximum demand`

```
// Example 32_23
clc;funcprot(0);
//Given data
CL=5;// kW
n=1000;// No. of apartments
No=[2 2 2 1 4 2 1 2 2 2 2 1];
Cl=[20 10 60 5 8 10 2 5 120 4 7 5];// Connected load
    of each in kW
```

```
F_d=[0.68 0.56 0.54 0.68 0.75 0.82 0.71 0.55 0.60 0.72 0.65 0.88];// Demand factors
F_da=40/100;// Demand factor of the apartments
F_dir=3.2;// Group diversity factor of the residential system
F_dirp=1.5;// Peak diversity factor of the residential system
F_dic=1.6;// Group diversity factor of the commercial system
F_dicp=1.2;// Peak diversity factor of the commercial system
E_l=5/100;// Losses of delievered energy

// Calculation
D=n*CL*F_da;// Demand of power from 1000 apartments in kW
MD_r=D/F_dir;// Maximum demand of 1000 apartments in kW
D_p1=MD_r/F_dirp;// Demand at the time of system peak in kW
for (i=1:12)
    Tl(i)=Cl(i)*No(i);
    MD_c(i)=Tl(i)*F_d(i);
end
MD=MD_c(1)+MD_c(2)+MD_c(3)+MD_c(4)+MD_c(5)+MD_c(6)+MD_c(7)+MD_c(8)+MD_c(9)+MD_c(10)+MD_c(11)+MD_c(12);
MD_c=(MD)/F_dic;// Maximum demand of 1000 commercial group in kW
D_p2=MD_c/F_dicp;// Demand at the time of system peak in kW
TMD=(D_p1+D_p2)*(1+E_l);// Total maximum demand in kW
printf('\nThe increase in peak demand=%0.2f kW',TMD);
// The answer vary due to round off error
```

Scilab code Exa 32.24 The consumption of coal

```
// Example 32_24
clc;funcprot(0);
//Given data
P=60;// MW
n_o=25/100;// The over all efficiency
CV=30000;// The calorific value of value in kJ/kg
F_l=30/100;// Load factor

// Calculation
I=(1/n_o)*3600;// Input in kJ
Cc=(I/CV);// Consumption of coal per kW-hr in kg
E=F_l*P*10^3*24;// kW-hr
Cc_d=(E*Cc)/1000;// Consumption of coal per day in
    tons
printf('\nConsumption of coal per kW-hr=%0.2f kg \
    nConsumption of coal per day=%0.1f tons',Cc,Cc_d)
    ;
```

Scilab code Exa 32.25 Total revenue earned

```
// Example 32_25
clc;funcprot(0);
//Given data
T_1=[0,4];// Time in hours
T_2=[4,6];// Time in hours
T_3=[6,8];// Time in hours
T_4=[8,12];// Time in hours
T_5=[12,13];// Time in hours
T_6=[13,17];// Time in hours
T_7=[17,19];// Time in hours
```

```
T_8=[19,20];// Time in hours
T_9=[20,24];// Time in hours
L_a=[50 150 300 50 50 50 300 200 100];// Group A(
    Load in kW)
L_b=[20 20 100 600 100 600 50 20 20];// Group B(Load
     in kW)
// Load factor=[1-0.8 0.8-0.6 0.6-0.4 0.4-0.2
    below0.2]
C=[1 1.6 2.4 5 8];// Charge in Rs.per kW-hr
MD_A=300;// kW
MD_B=600;// kW

// Calculation
E_tA=L_a(1)*(T_1(2)-T_1(1))+L_a(2)*(T_2(2)-T_2(1))+
    L_a(3)*(T_3(2)-T_3(1))+L_a(4)*(T_4(2)-T_4(1))+L_a
    (5)*(T_5(2)-T_5(1))+L_a(6)*(T_6(2)-T_6(1))+L_a(7)
    *(T_7(2)-T_7(1))+L_a(8)*(T_8(2)-T_8(1))+L_a(9)*(
    T_9(2)-T_9(1));// Total energy consumed by group
    A in kW-hrs
F_lA=(E_tA/24)*(1/MD_A);// Load factor of group A
R_A=E_tA*C(3);// Revenue earned by from group A
E_tB=L_b(1)*(T_1(2)-T_1(1))+L_b(2)*(T_2(2)-T_2(1))+
    L_b(3)*(T_3(2)-T_3(1))+L_b(4)*(T_4(2)-T_4(1))+L_b
    (5)*(T_5(2)-T_5(1))+L_b(6)*(T_6(2)-T_6(1))+L_b(7)
    *(T_7(2)-T_7(1))+L_b(8)*(T_8(2)-T_8(1))+L_b(9)*(
    T_9(2)-T_9(1));// Total energy consumed by group
    A in kW-hrs
F_lB=(E_tB/24)*(1/MD_B);// Load factor of group A
R_B=E_tB*C(4);// Revenue earned by from group A
Tr=R_A+R_B;// Total revenue earned per day from both
     groups in Rs./day
printf('\nTotal revenue earned per day from both
    groups=Rs.%0.0f/day',Tr);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.26 FLUCTUATING LOADS ON POWER PLANTS

```
// Example 32_26
clc;funcprot(0);
//Given data
P=25;// The capacity of the plant in MW
T_1=[6,8];// Time in hours(A.M)
T_2=[8,9];// Time in hours(A.M)
T_3=[9,11];// Time in hours(A.M)
T_4=[11,2];// Time in hours(A.M,P.M)
T_5=[2,5];// Time in hours(P.M)
T_6=[5,8];// Time in hours(P.M)
T_7=[8,12];// Time in hours(P.M)
T_8=[12,5];// Time in hours(A.M)
T_9=[5,6];// Time in hours(A.M)
T_g=[0 2 3 5 8 11 14 18 23 24];// Time in hours for
    load curve(time in 24 hours format for the given
    problem)
L_g=[800 600 2000 1200 1400 2000 1000 500 600]/100;
    // Load in MW

// Calculation
T=[0 0 2 2 3 3 5 5 8 8 11 11 14 14 18 18 23 23 24
    24];// Time in hours for load curve
L=[0 800 800 600 600 2000 2000 1200 1200 1400 1400
    2000 2000 1000 1000 500 500 600 600 2200]/100;//
    Load in MW
P_b=15;// Base load plant capacity in MW
P_b=[P_b P_b P_b P_b P_b P_b P_b P_b P_b P_b P_b P_b
     P_b P_b P_b P_b P_b P_b P_b P_b];// Base load
    plant capacity in MW for plot
subplot(2,1,1);
xlabel('TIME');
ylabel('LOAD IN MW');
xtitle('Fig.32.26(a)');
plot(T',L','b',T',P_b','r-.');
legend('LOAD CURVE','B');
a=gca();
```

```
a.x_ticks.labels=["6 A.M","8","10","12 NOON","2","4","6","8","10","12 NIGHT","2","4","6 A.M "];
a.x_ticks.locations=[0;2;4;6;8;10;12;14;16;18;20;22;24];
// From the table
t=[24 19 18 16 12 9 6 5];
for(i=1:8)
    T_p(i)=(t(i)/24)*100;
end
l=[0 0 500 500 600 600 800 800 1000 1000 1200 1200 1400 1400 1600 1600 2000]/100;// Load in MW
T_p=[0 T_p(1) T_p(1) T_p(2) T_p(2) T_p(3) T_p(3) T_p(4) T_p(4) T_p(5) T_p(5) T_p(6) T_p(6) T_p(7) T_p(7) T_p(8) T_p(8)];// Percentage of time
subplot(2,1,2);
xlabel('PERCENTAGE OF TIME');
ylabel('LOAD IN MW');
xtitle('Fig.32.26(b)');
plot(T_p',l','b');
legend('LOAD DURATION CURVE');
E_t=(L_g(1)*(T_g(2)-T_g(1)))+(L_g(2)*(T_g(3)-T_g(2)))+(L_g(3)*(T_g(4)-T_g(3)))+(L_g(4)*(T_g(5)-T_g(4)))+(L_g(5)*(T_g(6)-T_g(5)))+(L_g(6)*(T_g(7)-T_g(6)))+(L_g(7)*(T_g(8)-T_g(7)))+(L_g(8)*(T_g(9)-T_g(8)))+(L_g(9)*(T_g(10)-T_g(9)));// The total energy generated in MW-hrs
CF=(E_t/(P*24))*100;// Capacity factor in %
// The base load plant(15 MW capacity) works for 100 % of the time
// From load curve
P_b=15;// MW
T=[0 2 5 8 11 14 18 23 24];// hours
L=[800 1500 1200 1400 1500 1000 500 600]/100;// MW
P_act1=(L(1)*(T(2)-T(1)))+(L(2)*(T(3)-T(2)))+(L(3)*(T(4)-T(3)))+(L(4)*(T(5)-T(4)))+(L(5)*(T(6)-T(5)))+(L(6)*(T(7)-T(6)))+(L(7)*(T(8)-T(7)))+(L(8)*(T(9)-T(8)));// The actual energy generated by the base load plant from load curve in MW-hrs
```

```
LF_b=(P_act1/(P_b*24))*100;// Load factor in %
CF_b=LF_b;// Capacity factor in %
UF_b=LF_b;// Use factor in %
// The load above 15 MW capacity is supplied by a 10 MW capacity peak load plant
P_p=10;// Peak load plant capacity in MW
L_p=5;// Peak load in MW
P_act2=(1*1)+(L_p*5);// (From load curve)The actual energy generated by the peak load plant in MW-hrs
LF_p=(P_act2/(L_p*24))*100;// Load factor in %
CF_p=(P_act2/(P_p*24))*100;// Capacity factor in %
UF_p=(P_act2/(P_p*6))*100;// Use factor in %
printf('\nThe capacity factor of the plant=%0.1f percentage\nFor base load plant:Load factor=%0.1f percentage\n                    Capacity factor=%0.1f percentage\n                    Use factor=%0.1f percentage\nFor peak load plant:Load factor=%0.1f percentage\n                    Capacity factor=%0.2f percentage\n                    Use factor=%0.1f percentage',CF,LF_b,CF_b,UF_b,LF_p,CF_p,UF_p);
// The answer vary due to round off error
```

Scilab code Exa 32.27 Capacity factor and Use factor

```
// Example 32_27
clc;funcprot(0);
//Given data
T=[0 2 3 6 8 12 14 15 17 23 24];// Time in hours
L=[1200 2000 3000 1500 2500 1800 2000 1000 500 800];//  Load in kW

//Calculation
T_p=[0 0 2 2 3 3 6 6 8 8 12 12 14 14 15 15 17 17 23 23 24 24];// Time in hours for load curve
```

```
L_p=[3200 1200 1200 2000 2000 3000 3000 1500 1500 2500 2500 1800 1800 2000 2000 1000 1000 500 500 800 800 200];//  Load in kW for load curve
xlabel('Time (hours)');
ylabel('LOAD (kW)');
xtitle('Fig.32.27 Load curve');
plot(T_p,L_p,'b')
a=gca();
a.x_ticks.labels=["6 A.M","8","10","12 NOON","2","4","6","8","10","12 NIGHT","2","4","6 A.M "];
a.x_ticks.locations=[0;2;4;6;8;10;12;14;16;18;20;22;24];
//(a)
E_t=(L(1)*(T(2)-T(1)))+(L(2)*(T(3)-T(2)))+(L(3)*(T(4)-T(3)))+(L(4)*(T(5)-T(4)))+(L(5)*(T(6)-T(5)))+(L(6)*(T(7)-T(6)))+(L(7)*(T(8)-T(7)))+(L(8)*(T(9)-T(8)))+(L(9)*(T(10)-T(9)))+(L(10)*(T(11)-T(10)));// Total power generated in kW-hrs
L_max=L(3);// Maximum load in kW
LF=E_t/(L_max*24);// Load factor
//(b)
L_1=1200;// kW
L_2=800;// kW
L_3=2*500;// kW
L_4=300;// kW
//(c)
Rc=1200;// Reserve capacity in MW
Ic=L_1+L_2+L_3+L_4+Rc;// Installed capacity in kW
CF=(E_t/(Ic*24))*100;// Plant capacity factor
//(d)
L_1=1200;// kW
L_2=800;// kW
L_3=500;// kW
L_4=300;// kW
E=(L_1*17)+(L_2*11)+(L_3*3)+(L_3*7)+(L_3*7)+(L_4*3);// The energy generated by the capacity of the plant in kW-hrs;
UF=(E_t/E)*100;// Plant use factor
```

```
printf('\n(a)Load factor=%0.3f \n(b)It is obvious
    from the load curve that the numberof sets
    required are 5 in number \n  One set of 1200 kW
    \n  One set of 800 kW \n  Two sets of 500 kW \n
       One set of 300 kW \n(c)The reserve capacity of
     the plant=%0.0f kW \n   Capacity factor=%0.0f
    percentage \n(d)Plant use factor=%0.0f percentage
    ',LF,Rc,CF,UF);
```

Scilab code Exa 32.28 Average load and load factor

```
// Example 32_28
clc;funcprot(0);
//Given data
T=[0 6 10 12 16 20 22 24];// Time in hours
L=[30 100 110 60 120 100 60];// Load in MW

// Calculation
t=[0 6 6 10 10 12 12 16 16 20 20 22 22 24];// Time
    in hours for load curve
l=[30 30 100 100 110 110 60 60 120 120 100 100 60
    60];// Load in MW for load curve
subplot(2,1,1);
xlabel('Time in hrs');
ylabel('Load(MW)');
plot(t',l','b');
xtitle('(a)Load curve');
L_a=((L(1)*(T(2)-T(1)))+(L(2)*(T(3)-T(2)))+(L(3)*(T
    (4)-T(3)))+(L(4)*(T(5)-T(4)))+(L(5)*(T(6)-T(5)))
    +(L(6)*(T(7)-T(6)))+(L(7)*(T(8)-T(7))))/24;//
    Averge load in MW
L_max=L(5);// Maximum load in MW
LF=L_a/L_max;// Load factor
T_p1=((T(6)-T(5))/24)*100;// % Time
T_p2=T_p1+((T(4)-T(3))/24)*100;// % Time
```

```
T_p3=T_p2+(((T(3)-T(2))+(T(7)-T(6)))/24)*100;// % Time
T_p4=T_p3+(((T(8)-T(7))+(T(5)-T(4)))/24)*100;// % Time
T_p5=T_p4+((T(2)-T(1))/24)*100;// % Time
T_p=[0 0 T_p1 T_p1 T_p2 T_p2 T_p3 T_p3 T_p4 T_p4 T_p5];// % Time for load duration curve
L=[0 120 120 110 110 100 100 60 60 30 30];// Load in MW for load duration curve
L_avg=[L_a L_a L_a L_a L_a L_a L_a L_a L_a L_a];// Averge load in MW for plot
subplot(2,1,2);
xlabel('% Time');
ylabel('Load(MW)');
plot(T_p',L','b',T_p',L_avg','r');
xtitle('(b)Load duration curve');
legend('Load curve','AL');
printf('\nAverage load=%0.2f MW \nLoad factor=%0.3f',L_a,LF);
```

Scilab code Exa 32.29 Diversity factor and the load factor

```
// Example 32_29
clc;funcprot(0);
//Given data
L_cap=1200;// MW
T=[0 4 8 12 16 20 22];// hours
C_1=[200 600 1000 400 200 100];// MW
C_2=[800 400 200 200 600 400];// MW
Tl=[1000 1000 1200 600 800 500];// MW

// Calculation
E_1=((C_1(1)*(T(2)-T(1)))+(C_1(2)*(T(3)-T(2)))+(C_1(3)*(T(4)-T(3)))+(C_1(4)*(T(5)-T(4)))+(C_1(5)*(T(6)-T(5)))+(C_1(6)*(T(7)-T(6))));// MW
```

```
L_a1=E_1/24;// Average load in MW
L_max1=C_1(3);// Maximum load in MW
LF_1=L_a1/L_max1;// Load factor of the consumer 1
E_2=((C_2(1)*(T(2)-T(1)))+(C_2(2)*(T(3)-T(2)))+(C_2(3)*(T(4)-T(3)))+(C_2(4)*(T(5)-T(4)))+(C_2(5)*(T(6)-T(5)))+(C_2(6)*(T(7)-T(6))));// MW
L_a2=E_2/24;// Average load in MW
L_max2=C_2(5);// Maximum load in MW
LF_2=L_a2/L_max2;// Load factor of the consumer 1
E_t=E_1+E_2;// Total energy consumed by both consumers in MW
AL_p=E_t/24;// Average load of the plant  in MW
LF_p=AL_p/L_cap;// Load factor of the plant
DF_p=(L_max1+L_max2)/L_cap;// Diversity factor of the plant
t_p=[0 0 4 4 8 8 12 12 16 16 20 20 22];// hours
C_1p=[0 200 200 600 600 1000 1000 400 400 200 200 100 100];// MW
C_2p=[0 800 800 400 400 200 200 200 200 600 600 400 400];// MW
T_p=[0 1000 1000 1000 1000 1200 1200 600 600 800 800 500 500];// MW
L_avg1=[L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1];
L_avg2=[L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2];
AL_p=[AL_p AL_p AL_p AL_p AL_p AL_p AL_p AL_p AL_p AL_p AL_p AL_p AL_p];
subplot(3,1,1);
xlabel('Time in hrs');
ylabel('Load (mw)');
xtitle('Consumes-I 1200 MW');
plot(t_p',C_1p','b',t_p',L_avg1','r-.');
legend('Load curve','AL_1');
subplot(3,1,2);
xlabel('Time in hrs');
ylabel('Load (mw)');
xtitle('Consumes-II 1200 MW');
```

```
plot(t_p',C_2p','b',t_p',L_avg2','r-.');
legend('Load curve','AL_2');
subplot(3,1,3);
xlabel('Time in hrs');
ylabel('Load (mw)');
plot(t_p',T_p','b',t_p',AL_p','r-.');
legend('Load curve of the generating plant','AL_p');
//(d)
n_g=40/100;// Overall efficiency of generation
CV=20000;// kJ/kg
E=E_t/n_g;// Thermal energy generated in the plant in MWh
E=E*10^3*3600;// kJ/hr
C_u=(E/(CV*10^3));// Coal used per hour in tons/hr
C=C_u*30;// tons/day
C=C_u/L_cap;// tons/MW-hr
cc=50/100;// Rs./kg
Cc=(C*10^3*cc)/10^3;// Cost of coal per kWh in rupees
L_am=74.2;// Average load in MW
L_max=120;// Maximum demand in MW
CF=L_am/L_max;// Capacity factor of the plant
printf('\n(a)Load factor of the consumer I=%0.3f \n Load factor of the consumer II=%0.2f \n(b)Load factor of the plant=%0.2f \n(c)Diversity factor of the plant=%0.1f \n(d)The amount of coal required per day=%0.2f tons/MW-hr',LF_1,LF_2,LF_p,DF_p,C);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.32 Percentage change in profit

```
// Example 32_32
clc;funcprot(0);
//Given data
```

```
P=100;// MW
T=[0 4 8 12 16 20 24];// Time in hr
L_a=[20 20 80 80 20 20];// Load A in MW
L_b=[30 60 60 60 60 10];// Load B in MW
CV=45000;// kJ/kg
C=10;// Cost in Rs./kg
Sc=10;// Sale cost in Rs./kWh

// Calculation
t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24];// Time in
    hrs for load curve
L_A=[0 20 20 20 20 80 80 80 80 20 20 20 20 100];//
    Load A in MW
subplot(2,1,1);
xlabel('Time(hrs)');
ylabel('Load(MW)');
xtitle('Consumer-A');
plot(t,L_A,'b');
L_B=[0 30 30 60 60 60 60 60 60 60 60 10 10 100];
subplot(2,1,2);
xlabel('Time(hrs)');
ylabel('Load(MW)');
xtitle('Consumer-B');
plot(t,L_B,'b');
L_a1=((L_a(1)*(T(3)-T(1)))+(L_a(3)*(T(5)-T(3)))+(L_a
    (5)*(T(7)-T(5))))/24;// MW
L_max1=80;// MW
LF_1=L_a1/L_max1;
L_a2=((L_b(1)*(T(2)-T(1)))+(L_b(2)*(T(6)-T(2)))+(L_b
    (6)*(T(7)-T(6))))/24;// MW
L_max2=60;// MW
LF_2=L_a2/L_max2;
//Consider Consumer-A
// Outputs
O_a1=(L_a(1)*(T(3)-T(1)));// MWh
O_a2=(L_a(3)*(T(5)-T(3)));// MWh
O_a3=(L_a(5)*(T(7)-T(5)));// MWh
O_a=O_a1+O_a2+O_a3;// Total output of A in MWh
```

```
// n=0.4*L;(given)
n_a1=0.4*(L_a(1)/100);
n_a2=0.4*(L_a(3)/100);
n_a3=0.4*(L_a(5)/100);
// Inputs
I_a1=O_a1/n_a1;// MWh
I_a2=O_a2/n_a2;// MWh
I_a3=O_a3/n_a3;// MWh
I=I_a1+I_a2+I_a3;// Total input in MWh
TI=I*10^3*3600;// kJ/day
m_fa=(TI)/(CV*1000);// Fuel used in tonnes for
   consumer A in tons/day
//Consider Consumer-B
// Outputs
O_b1=(L_b(1)*(T(2)-T(1)));// MWh
O_b2=(L_b(2)*(T(6)-T(2)));// MWh
O_b3=(L_b(6)*(T(7)-T(6)));// MWh
O_b=O_b1+O_b2+O_b3;// Total output of A in MWh
// n=0.4*L;(given)
n_b1=0.4*(L_b(1)/100);
n_b2=0.4*(L_b(2)/100);
n_b3=0.4*(L_b(6)/100);
// Inputs
I_b1=O_b1/n_b1;// MWh
I_b2=O_b2/n_b2;// MWh
I_b3=O_b3/n_b3;// MWh
I=I_b1+I_b2+I_b3;// Total input in MWh
TI=I*10^3*3600;// kJ/day
m_fb=(TI)/(CV*1000);// Fuel used in tonnes for
   consumer B in tons/day
A_b=m_fb*10^3*C;// The amount spent towards the fuel
    B in rupees
C_e=O_b*10^3*Sc;// The charges of energy received
   from B in rupees
N_p=C_e-A_b;// Net profit in Rs./day
pc=((C_e-A_b)/A_b)*100;// Percentage change in
   revenue in %
printf('\n(a)Load factor:LF_1=%0.1f \n    Load factor
```

```
    :LF_2=%0.3f \n(b)Fuel used in tonnes for consumer
     A=%0.0f tons/day \n    Fuel used in tonnes for
    consumer B=%0.0f tons/day \n(c)Net profit=Rs.%0.1
    e/day \n(d)Percentage change in revenue=%0.1f
    percentage',LF_1,LF_2,m_fa,m_fb,N_p,pc);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.33 Over all efficiency of the plant

```
// Example 32_33
clc;funcprot(0);
//Given data
L_cap=100;// MW
// n=0.4*L;(given)
L=[20 80 30];// MW
T=[0 8 16 24];// Time in hours
CV=35;// MJ/kg
C=2;// Coal cost in Rs./kg
Sc=2.5;// Rs./kWh
n_com=95/100;// Combustion efficiency

// Calculation
E=(L(1)*(T(2)-T(1)))+(L(2)*(T(3)-T(2)))+(L(3)*(T(4)-
    T(3)));// Total energy consumed a day in MWh
L_a=E/24;// Average load of the plant in MW
L_max=80;// MW
LF=L_a/L_max;
CF=L_a/L_cap;
// Outputs
O_1=(L(1)*(T(2)-T(1)));// MWh
n_1=0.4*(L(1)/100);
I_1=O_1/n_1;// MWh
O_2=(L(2)*(T(3)-T(2)));// MWh
n_2=0.4*(L(2)/100);
I_2=O_2/n_2;// MWh
```

```
O_3=(L(3)*(T(4)-T(3)));// MWh
n_3=0.4*(L(3)/100);
I_3=O_3/n_3;// MWh
I=(I_1+I_2+I_3)*10^3;// Total input in MWh
m_f=(I*3600)/(CV*10^3*n_com*24);//  kg/hr
m_f=(m_f*24)/10^3;// tons/day
Cf=m_f*10^3*C;// The cost of fuel in Rs./day
Mg=E*10^3*Sc;// The money gained by selling the
    energy generated in rupees
Pr=(Mg-Cf);// Profit gained during the day in rupees
    /day
n_o=(E/(I/10^3))*100;// The overall efficiency of
    the plant in %
printf('\n(a)The load factor of the plant=%0.2f \n
      The capacity factor of the plant=%0.3f \n(b)The
     fuel consumed in tonnes per day=%0.1f tons/day \
    n(c)Profit gained by the plant=%0.0e rupees/day \
    n(d)The overall efficiency of the plant=%0.2f
    percentage',LF,CF,m_f,Pr,n_o);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.34 The cost of saling the energy

```
// Example 32_34
clc;funcprot(0);
//Given data
L_cap=1500;// kW
// n=0.43*(L)^0.48;(given)
T=[0 4 8 12 16 20 24];// Time in hours
L_a=[200 600 1000 400 200 100];// Load in kW
L_b=[800 400 200 200 600 400];// Load in kW
L_t=[1000 1000 1200 600 800 500];// Load in kW
CV=45*10^3;// MJ/kg
Dc=30;// The cost of diesel in Rs./liter
SG=0.85;// Specific gravity
```

```
pr=15/100;// The profit required
oc=30/100;// The other costs
n_com=92/100;// Combustion efficiency

// Calculation
t=[0 4 4 8 8 12 12 16 16 20 20 24 24];// Time in hrs for load curve
L_A=[200 200 600 600 1000 1000 400 400 200 200 100 100 1500];// Load A in kW for load curve
subplot(3,1,1);
xlabel('Time in hours');
ylabel('Load in kW');
xtitle('Load of consumer−A');
plot(t,L_A,'b');
legend('Load curve for (A)');
t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24];// Time in hrs for load curve
L_B=[0 800 800 400 400 200 200 200 200 600 600 400 400 1500];// Load B in kW for load curve
subplot(3,1,2);
xlabel('Time in hours');
ylabel('Load in kW');
xtitle('Load of consumer−B');
plot(t,L_B,'b');
legend('Load curve for (B)');
t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24];// Time in hrs for load curve
L_AB=[0 1000 1000 1000 1000 1200 1200 600 600 800 800 500 500 1500];// Load A+B in kW for load curve
subplot(3,1,3);
xlabel('Time in hours');
ylabel('Load in kW');
xtitle('Load of on plant for consumerA and B');
plot(t,L_AB,'b');
legend('Load curve for (A+B)');
//(i)
E=(L_a(1)*(T(2)-T(1)))+(L_a(2)*(T(3)-T(2)))+(L_a(3)
```

```
*(T(4)-T(3)))+(L_a(4)*(T(5)-T(4)))+(L_a(5)*(T(6)-T(5)))+(L_a(6)*(T(7)-T(6)));// Total energy consumed a day in kWh
L_a1=E/24;// kW
L_max1=1000;// kW
LF_A=L_a1/L_max1;
E=(L_b(1)*(T(2)-T(1)))+(L_b(2)*(T(3)-T(2)))+(L_b(3)*(T(4)-T(3)))+(L_b(4)*(T(5)-T(4)))+(L_b(5)*(T(6)-T(5)))+(L_b(6)*(T(7)-T(6)));// Total energy consumed a day in kWh
L_b1=E/24;// kW
L_max2=800;// kW
LF_B=L_b1/L_max2;
E=(L_t(1)*(T(2)-T(1)))+(L_t(2)*(T(3)-T(2)))+(L_t(3)*(T(4)-T(3)))+(L_t(4)*(T(5)-T(4)))+(L_t(5)*(T(6)-T(5)))+(L_t(6)*(T(7)-T(6)));// Total energy consumed a day in kWh
L_ab=E/24;// kW
L_max=1200;
LF_AB=L_ab/L_max;
PL=((LF_AB-LF_A)/LF_A)*100;// Maximum percentage increase in load factor
DF=(L_max1+L_max2)/L_max;// Diversity factor
O_1=(L_t(1)*(T(3)-T(1)));// kWh
n_1=0.43*(L_t(1)/L_cap)^0.48;
I_1=O_1/n_1;// kWh
O_2=(L_t(3)*(T(4)-T(3)));// kWh
n_2=0.43*(L_t(3)/L_cap)^0.48;
I_2=O_2/n_2;// kWh
O_3=(L_t(4)*(T(5)-T(4)));// kWh
n_3=0.43*(L_t(4)/L_cap)^0.48;
I_3=O_3/n_3;// kWh
O_4=(L_t(5)*(T(6)-T(5)));// kWh
n_4=0.43*(L_t(5)/L_cap)^0.48;
I_4=O_4/n_4;// kWh
O_5=(L_t(6)*(T(7)-T(6)));// kWh
n_5=0.43*(L_t(6)/L_cap)^0.48;
I_5=O_5/n_5;// kWh
```

```
I_t=(I_1+I_2+I_3+I_4+I_5)*3600;// Total input in kJ
m_f=I_t/(CV*n_com*24);// kg/hr
V_f=m_f/0.85;// liters/hr
V_f=V_f*24;// liters
C_f=V_f*Dc;// Cost of fuel in Rs./day
Oc=C_f*oc;// The other cost running the plants in Rs
    ./day
Tc=C_f+Oc;// The total cost running the plants in Rs
    ./day
Pr=Tc*pr;// The profit required in Rs./day
Tcs=Tc+Pr;// Total cost of saling the energy
    generated/day in rupees
O_t=O_1+O_2+O_3+O_4+O_5;// Total energy generated in
     kWh
Cs=Tcs/O_t;// The cost of sailing the energy in Rs./
    kWh
printf('\n(i)The individual load factor of consumer
    A=%0.3f \n    The individual load factor of
    consumer B=%0.3f \n(ii)Load factor of the system=
    %0.3f \n     Diversity factor of the system=%0.1f
    \n(iii)The cost of selling the power=Rs.%0.2f/kWh
    ',LF_A,LF_B,LF_AB,DF,Cs);
// The answer vary due to round off error
```

Scilab code Exa 32.35 Capacity factor of the plant

```
// Example 32_35
clc;funcprot(0);
//Given data
L_cap=1500;// MW
// n=0.43*(L)^0.95;(given)
T=[0 4 8 12 16 20 24];// Time in hours
C_1=[200 600 1000 400 200 100];// Load in MW
C_2=[800 400 200 200 600 400];// Load in MW
C_t=[1000 1000 1200 600 800 500];// Load in MW
```

```
// Calculation
E=(C_1(1)*(T(2)-T(1)))+(C_1(2)*(T(3)-T(2)))+(C_1(3)*(T(4)-T(3)))+(C_1(4)*(T(5)-T(4)))+(C_1(5)*(T(6)-T(5)))+(C_1(6)*(T(7)-T(6)));// Total energy consumed a day in MWh
L_a1=E/24;// MW
L_max1=1000;// MW
LF_1=L_a1/L_max1;// Load factor
t=[0 4 4 8 8 12 12 16 16 20 20 24 24];// Time in hrs for load curve
c_1=[200 200 600 600 1000 1000 400 400 200 200 100 100 1600];// Load C_1 in MW for load curve
L_a1=[L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1 L_a1];// Average load in MW for plot
subplot(3,1,1);
xlabel('hrs');
ylabel('MW');
xtitle('Load curve for C_1');
plot(t',c_1','b',t',L_a1','r');
legend('Load curve','Average');
E=(C_2(1)*(T(2)-T(1)))+(C_2(2)*(T(3)-T(2)))+(C_2(3)*(T(4)-T(3)))+(C_2(4)*(T(5)-T(4)))+(C_2(5)*(T(6)-T(5)))+(C_2(6)*(T(7)-T(6)));// Total energy consumed a day in kWh
L_a2=E/24;// MW
L_max2=800;// MW
LF_2=L_a2/L_max2;
t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24];// Time in hrs for load curve
c_2=[0 800 800 400 400 200 200 200 200 600 600 400 400 1600];// Load C_2 in MW for load curve
L_a2=[L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2 L_a2];// Average load in MW for plot
subplot(3,1,3);
subplot(3,1,2);
```

```
xlabel('hrs');
ylabel('MW');
xtitle('Load curve for C_2');
plot(t',c_2','b',t',L_a2','r');
legend('Load curve','Average');
E=(C_t(1)*(T(2)-T(1)))+(C_t(2)*(T(3)-T(2)))+(C_t(3)
   *(T(4)-T(3)))+(C_t(4)*(T(5)-T(4)))+(C_t(5)*(T(6)-
   T(5)))+(C_t(6)*(T(7)-T(6)));// Total energy
   consumed a day in kWh
L_p=E/24;// MW
L_max=1200;// Maximum load in MW
LF_p=L_p/L_max;// Load factor of the plant
t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24];// Time in
   hrs for load curve
c_t=[0 1000 1000 1000 1000 1200 1200 600 600 800 800
    500 500 1600];// Load C_1+C_2 in MW for load
   curve
L_a_p=[L_p L_p L_p L_p L_p L_p L_p L_p L_p L_p L_p
   L_p L_p L_p];// Average load of the plant in MW
   for plot
subplot(3,1,3);
xlabel('hrs');
ylabel('MW');
xtitle('Load curve of the plant');
plot(t',c_t','b',t',L_a_p','r');
legend('Load curve','Average');
DF=(L_max1+L_max2)/L_max;// Diversity factor
L_min=C_t(6);// MW
n_min=(0.43*(L_min/L_cap)^0.95)*100;// Minimum
   thermal efficiency
L_max=C_t(3);// MW
n_max=(0.43*(L_max/L_cap)^0.95)*100;// Maximum
   thermal efficiency
CF=L_p/L_cap;// Capacity factor of the plant
printf('\n(a)Load factor of customer A=%0.4f \n
   Load factor of customer B=%0.3f \n(b)Diversity
   factor of the system=%0.1f \n(c)Minimum thermal
   efficiency of the plant=%0.0f percentage\n
```

```
Maximum thermal efficiency of the plant=%0.1f
percentage\n    Capacity factor of the plant=%0.3f
',LF_1,LF_2,DF,n_min,n_max,CF);
```

Scilab code Exa 32.36 The capacity of the fuel tank required

```
// Example 32_36
clc;funcprot(0);
//Given data
L_cap=150;// MW
// n=0.435*(L)^0.925;(given)
T_1=[0 8 18 24];// Time in hours
T_2=[0 6 20 24];// Time in hours
L_a=[20 80 40];// Load in MW
L_b=[30 70 20];// Load in MW
SG=0.88;// Specific gravity
CV=40.5;// MJ/kg

// Calculation
E_a=(L_a(1)*(T_1(2)-T_1(1)))+(L_a(2)*(T_1(3)-T_1(2))
   )+(L_a(3)*(T_1(4)-T_1(3)));// MWh
L_avga=E_a/24;// MW
L_max1=L_a(2);// MW
LF_a=(L_avga/L_max1);// Load factor
E_b=(L_b(1)*(T_2(2)-T_2(1)))+(L_b(2)*(T_2(3)-T_2(2))
   )+(L_b(3)*(T_2(4)-T_2(3)));// MWh
L_avgb=E_b/24;// MW
L_max2=L_b(2);// MW
LF_b=(L_avgb/L_max2);// Load factor
E_t=E_a+E_b;// The total energy supplied by the
   plant in MWh
L_p=E_t/24;// The average load on the plant in MW
L_max=L_max1+L_max2;// MW
LF_p=L_p/L_max;// Load factor of the plant
E_1=(L_a(1)+L_b(1));// MW
```

```
E_2=(L_a(1)+L_b(2));// MW
E_3=(L_a(2)+L_b(2));// MW
E_4=(L_a(3)+L_b(2));// MW
E_5=(L_a(3)+L_b(3));// MW
E_t=[0 E_1 E_1 E_2 E_2 E_3 E_3 E_4 E_4 E_5 E_5];//
   MW
T=[0 0 6 6 8 8 18 18 20 20 24];// Time in hrs
L_avgp=[L_p L_p L_p L_p L_p L_p L_p L_p L_p L_p L_p
   ];// The average load on the plant in MW for plot
plot(T',E_t','b',T',L_avgp','r-.');
xlabel('Time in hrs');
ylabel('Load in MW');
legend('Load curve','Average load');
n_com=1;// Combustion efficiency
O_1=E_1*6;// Output in MWh
n_1=0.435*(E_1/L_cap)^0.925;// Efficiency
I_1=O_1/n_1;// Input in MWh
m_f1=(I_1*10^3*3600)/(CV*10^3);// The mass of fuel
   supplied in kg
O_2=E_2*2;// Output in MWh
n_2=0.435*(E_2/L_cap)^0.925;// Efficiency
I_2=O_2/n_2;// Input in MWh
m_f2=(I_2*10^3*3600)/(CV*10^3);// The mass of fuel
   supplied in kg
O_3=E_3*10;// Output in MWh
n_3=0.435*(E_3/L_cap)^0.925;// Efficiency
I_3=O_3/n_3;// Input in MWh
m_f3=(I_3*10^3*3600)/(CV*10^3);// The mass of fuel
   supplied in kg
O_4=E_4*2;// Output in MWh
n_4=0.435*(E_4/L_cap)^0.925;// Efficiency
I_4=O_4/n_4;// Input in MWh
m_f4=(I_4*10^3*3600)/(CV*10^3);// The mass of fuel
   supplied in kg
O_5=E_5*4;// Output in MWh
n_5=0.435*(E_5/L_cap)^0.925;// Efficiency
I_5=O_5/n_5;// Input in MWh
m_f5=(I_5*10^3*3600)/(CV*10^3);// The mass of fuel
```

```
    supplied in kg
m_fta=m_f1+m_f2+m_f3+m_f4+m_f5;// The total fuel consumed during 24 hrs in kg per day
T_fa=m_fta;// Total fuel required for 10 days in kg
V_fa=T_fa/SG;// Volume of the fuel in litres/day
V=(V_fa*10)/1000;// The capacity of the tank required for 10 days in m^3
//(b)
n=0.435*(L_p/L_cap)^0.925;// Efficiency
E_t=E_a+E_b;// MWh
I_t=E_t/n;// MWh
m_ftb=(I_t*10^3*3600)/(CV*10^3);// Mass of fuel required per day
T_f=m_ftb*10;// kg
V_fb=(T_f/SG)/1000;// Volume of fuel in m^3
m_f=m_ftb/24;// kg/hr
bsfc=m_f/(L_p*10^3);// kg/kWh
printf('\n(a)The capacity of the fuel tank required=%0.2f m^3 \n(b)Load factor of the plant=%0.3f \n(c)Volume of fuel=%0.0f m^3 \n(d)bsfc=%0.3f kg/kWh',V,LF_p,V_fb,bsfc);
// The answer is varied due to round off error
```

Scilab code Exa 32.37 Over all efficiency of the plant

```
// Example 32_37
clc;funcprot(0);
//Given data
L_cap=80;// MW
// n=0.91*(L)^0.49;(given)
T_1=[0 10 18 24];// Time in hours
L_1=[60 40 20];// Load in MW
H=60;// m
g=9.81;// m/s^2

```

```
// Calculation
//(i)
E_a=(L_1(1)*(T_1(2)-T_1(1)))+(L_1(2)*(T_1(3)-T_1(2)))+(L_1(3)*(T_1(4)-T_1(3)));// MW-hrs
L_a=E_a/24;// Average load on the plant in MW
L_max=L_1(1);// Maximum load in MW
LF=(L_a/L_max);// Load factor of the plant
CF=(L_a/L_cap);// Capacity factor of the plant
//(ii)
O_1=L_1(1)*(T_1(2)-T_1(1));// Output in MWh
n_1=0.91*(L_1(1)/L_cap)^0.49;// Efficiency
I_1=O_1/n_1;// Input in MW
O_2=L_1(2)*(T_1(3)-T_1(2));// Output in MWh
n_2=0.91*(L_1(2)/L_cap)^0.49;// Efficiency
I_2=O_2/n_2;// Input in MW
O_3=L_1(3)*(T_1(4)-T_1(3));// Output in MWh
n_3=0.91*(L_1(3)/L_cap)^0.49;// Efficiency
I_3=O_3/n_3;// Input in MW
// 1MWh=3.6*10^6 kJ
E_1=I_1*3.6*10^6;// kJ
E_2=I_2*3.6*10^6;// kJ
E_3=I_3*3.6*10^6;// kJ
m_w1=(E_1*1000)/(9.81*H*(T_1(2)-T_1(1))*3600);// Water flow in kg/sec
M_w1=(m_w1*(T_1(3)-T_1(2))*3600)/1000;// m^3
m_w2=(E_2*1000)/(9.81*H*(T_1(3)-T_1(2))*3600);// Water flow in kg/sec
M_w2=(m_w2*(T_1(3)-T_1(2))*3600)/1000;// m^3
m_w3=(E_3*1000)/(9.81*H*(T_1(4)-T_1(3))*3600);// Water flow in kg/sec
M_w3=(m_w3*(T_1(4)-T_1(3))*3600)/1000;// m^3
V=M_w1+M_w2+M_w3;// The water supplied during the day in m^3/day
n_o=(E_a/(I_1+I_2+I_3))*100;// Over all efficiency of the plant
printf('\nThe quantity of water required=%0.4e m^3/day \nThe load factor=%0.3f \nThe capacity factor=%0.2f \nOver all efficiency of the plant=%0.1f
```

```
    percentage',V,LF,CF,n_o);
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.38 The total quantity of water required

```
// Example 32_38
clc;funcprot(0);
//Given data
L_cap=100;// MW
H=50;// m
// n=0.91*(L)^0.49;(given)
L_a1=60;// Load in MW
L_a2=30;// Load in MW
T_a1=16;// Time in hours
T_a2=8;// Time in hours
L_b1=100;// Load in MW
L_b2=33.33;// Load in MW
T_b1=6;// Time in hours
T_b2=18;// Time in hours
g=9.81;// m/s^2

// Calculation
// Consider the Consumer A
t_a1=T_a1*3600;// sec
P_a1=L_a1*10^6;// Watts
n_a1=0.91*(L_a1/L_cap)^0.49;// Efficiency
m_wa1=(P_a1/(n_a1*g*H));// Mass of water in liters/
    sec
V_wa1=(m_wa1/1000)*t_a1;// Volume of water supllied
    in m^3
t_a2=T_a2*3600;// sec
P_a2=L_a2*10^6;// Watts
n_a2=0.91*(L_a2/L_cap)^0.49;// Efficiency
m_wa2=(P_a2/(n_a2*g*H));// Mass of water in liters/
    sec
```

```
V_wa2=(m_wa2/1000)*t_a2;// Volume of water supllied in m^3
V_wta=V_wa1+V_wa2;// Total water supplied to the power plant in m^/day
// Consider the Consumer B
t_b1=T_b1*3600;// sec
P_b1=L_b1*10^6;// Watts
n_b1=0.91*(L_b1/L_cap)^0.49;// Efficiency
m_wb1=(P_b1/(n_b1*g*H));// Mass of water in liters/sec
V_wb1=(m_wb1/1000)*t_b1;// Volume of water supllied in m^3
t_b2=T_b2*3600;// sec
P_b2=L_b2*10^6;// Watts
n_b2=0.91*(L_b2/L_cap)^0.49;// Efficiency
m_wb2=(P_b2/(n_b2*g*H));// Mass of water in liters/sec
V_wb2=(m_wb2/1000)*t_b2;// Volume of water supllied in m^3
V_wtb=V_wb1+V_wb2;// Total volume of water supplied in m^3
E_tA=(L_a1*T_a1)+(L_a2*T_a2);// Total energy generated in MWh
Uw1=V_wta/24;// m^3/hr
W_a=Uw1/E_tA;// m^3/ MW
E_tB=(L_b1*T_b1)+(L_b2*T_b2);// Total energy generated in MWh
Uw2=V_wtb/24;// m^3/hr
W_b=Uw2/E_tB;// m^3/ MW
printf('\nWater used by A=%0.0f m^3/MW \nWater used by B=%0.1f m^3/MW',W_a,W_b)
// The answer provided in the textbook is wrong
```

Scilab code Exa 32.40 The power supplied by the plant

```
// Example 32_40
clc;funcprot(0);
//Given data
L_cap=150;// MW
L=[20 60 30];// Load in MW
T=[0 8 16 24];// Time in hours
n_1=0.9;
n_2=2.7;

// Calculation
// Considering the Consumer C_1
E_1=(L(1)*(T(2)-T(1)))+(L(2)*(T(3)-T(2)))+(L(3)*(T
    (4)-T(3)));// MWh
L_a1=E_1/24;// Average load in MW
L_max1=L(2);// Maximum load in MW
LF_1=L_a1/L_max1;// Load factor
// Considering the Consumer C_1
T=[0 4 12 20 24];// Time in hours
L_4=30;// Load in MW
t_4=4;// Time in hours
L_12=80;// Load in MW
t_12=12;// Time in hours
L_20=20;// Load in MW
t_20=20;// Time in hours
E_2=(L_4*(T(2)-T(1)))+(((L_12*t_12)-(L_4*t_4))/(n_1
    +1))+(((L_12*t_12)-(L_20*t_20))/(n_2-1))+(L_20*(T
    (5)-T(4)));
L_a2=E_1/24;// Average load in MW
L_max2=L_12;// Maximum load in MW
LF_2=L_a2/L_max2;// Load factor
E_t=E_1+E_2;// Total energy supplied in MW
L_ap=E_t/24;// Average load on the plant in MW
L_pmax=L_max1+L_max2;// Maximum load in MW
LF_p=L_ap/L_pmax;// Load factor
t=[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
    20 21 22 23 24];// Time in hours
L_5=(L_4*(t(5)/t(4))^n_1);// MW
L_6=(L_5*(t(6)/t(5))^n_1);// MW
```

```
L_7=(L_6*(t(7)/t(6))^n_1);// MW
L_8=(L_7*(t(8)/t(7))^n_1);// MW
L_9=(L_8*(t(9)/t(8))^n_1);// MW
L_10=(L_9*(t(10)/t(9))^n_1);// MW
L_11=(L_10*(t(11)/t(10))^n_1);// MW
L_12=(L_11*(t(12)/t(11))^n_1);// MW
L_12=80;// MW
L_13=(L_12*((t(12)/t(13))^n_2));// MW
L_14=(L_13*(t(13)/t(14))^n_2);// MW
L_15=(L_14*(t(14)/t(15))^n_2);// MW
L_16=(L_15*(t(15)/t(16))^n_2);// MW
L_17=(L_16*(t(16)/t(17))^n_2);// MW
L_18=(L_17*(t(17)/t(18))^n_2);// MW
L_19=(L_18*(t(18)/t(19))^n_2);// MW
L_20=(L_19*(t(19)/t(20))^n_2);// MW
P_8=L(1)+L_8;// MW
P_6=L(2)+L_16;// MW
printf('\nPower supplied at 8th hour=%0.2f MW \
   nPower supplied at 16th hour=%0.2f MW',P_8,P_6);
```

Chapter 34

ECONOMIC ANALYSIS OF POWER PLANTS AND TARIFFS

Scilab code Exa 34.1 The annual cost of the plant

```
// Example 34_1
clc;funcprot(0);
//Given data
P=120000;// The cost of the water softner plant in
    rupees
S=(8/100)*P;// The salvage value of the plant in
    rupees
r=8/100;//Interest on sinking fund
n=12;//The life of the plant in years
RMLc=8000;//Repair,maintainence and labour costs
Cc=5000;// Chemical cost

//Calculation
A=(P-S)*(r/(((1+r)^n)-1));// Annual sinking fund
    payment for the plant in rupees
Ac=A+RMLc+Cc;// Annual cost of the plant in rupees
printf('\nAnnual cost of the plant=Rs.%0.0f',Ac);
```

```
// The answer vary due to round off error
```

Scilab code Exa 34.2 The salvage value of the preheater

```
// Example 34_2
clc;funcprot(0);
//Given data
P=12000;//The cost of a small preheater in rupees
r=5/100;// Interest
n=16;// Expected life in years
A=425;//The cost of  the equipment in rupees

//Calculation
S=round(P-((A)/(r/(((1+r)^n)-1))));// The salvage
    value of the preheater in rupees
printf('\nThe salvage value of the preheater after
    16 years of service,S=Rs.%0.0f',S);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.3 Value of the plant at end of 10 years

```
// Example 34_3
clc;funcprot(0);
//Given data
C=40000;//Capital cost in Rupees
V_1=4000;// Salvage value in Rupees
n=20;// Useful life in years
r=6/100;//Interest rate

//Calculation
//(a)
TD=C-V_1;//Total depreciation in rupees
D=TD/2;//Depreciation in 10 years in rupees
```

```
V_2a=C-D;//Plant value at the end of 10 years in
    rupees
//(b)
// Assume  p_d=(1-p)
p_d=(V_1/C)^(1/n);
n=10;// Plant life in years
V_2b=C*(p_d)^(n);// Plant value at the end of 10
    years in rupees
//(c)
n=20;// Plant life in years
Q=C-V_1;// Replacement cost  in rupees
q=(Q*r)/(((1+r)^n)-1);//The amonut set aside per
    year
n=10;// Plant life in years
Q=(q*(((1+r)^n)-1))/(r);// The amount deposited in
    sinking fund in rupees
V_2c=C-Q;// Plant value at the end of 10 years in
    rupees
printf('\n(a)Plant value at the end of 10 year,V_2=
    Rs.%0.0f\n(b)Plant value at the end of 10 year,
    V_2=Rs.%0.0f\n(c)Plant value at the end of 10
    year,V_2=Rs.%0.0f',V_2a,V_2b,V_2c)
// The answer vary due to round off error
```

Scilab code Exa 34.4 The cost of coal

```
// Example 34_4
clc;funcprot(0);
//Given data
PC=30;// Plant capacity in MW
F_l=0.4;// Load factor
Cc=650;// Caoal costs in Rupees
t=24;// hours
n_o=25;// Over all efficiency in %
CV=25000;// kJ/kg
```

```
//Calculation
E_g=PC*F_l*24;// Energy generated in the form of
    electricity per day in kWh
E_i=E_g/(n_o/100);// Input energy per day in kWh
E_i=E_i*10^3*3600;// kJ
m_f=E_i/CV;// Mass of fuel consumed per day in kg/
    day
m_f=m_f/1000;// tonnes/day
Cc_d=Cc*m_f;// Cost of coal/day in rupees
printf('\nCost of coal/day=Rs.%0.0f',Cc_d);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.5 Unit energy charge

```
// Example 34_5
clc;funcprot(0);
//Given data
//Demand rates
DR_1=200;//0-5kW:Rs./kW
DR_2=150;// 6-10kW:Rs./kW
DR_3=120;//11-15kW:Rs./kW
//Energy rates
Er_1=2;//First -100 kW-hr:Rs. kW-hr
Er_2=1.5;//Next -500 kW-hr:Rs. kW-hr
Er_3=1;//Next -2000 kW-hr:Rs. kW-hr
Er_4=0.8;///Excess over -2000 kW-hr:Rs./kW-hr
Ecpm=2300;// Energy consumption per month in kW-hr

//Calculation
//(a)
DC=(5*DR_1)+(5*DR_2)+(2*DR_3);// Demand charges per
    month in rupees
EC=(100*Er_1)+(500*Er_2)+(1700*Er_3);// Energy
    charge in rupees
```

```
Mb=DC+EC;// Monthly bill in rupees
Auec=Mb/Ecpm;//Average unit energy cost in Rs./kWh
//(b)
d=30;// Number of days in a month
ML=Ecpm/(d*24);// Maximum load = Average load in kW
DC=ML*200;// Demand charges in Rupees
MMb=DC+EC;// Mininmum monthly bill in Rupees
Uec=MMb/Ecpm;// Unit energy charge in this condition
    in Rs./kWh
printf('\n(a)Monthly bill of the consumer=Rs.%0.0f \
   n    Average unit energy cost=Rs.%0.2f kW/h \n(b)
   Mininmum monthly bill=Rs.%0.0f \n    Unit energy
   cost for the given  energy consumption condition=
   Rs.%0.2f /kWh ',Mb,Auec,MMb,Uec);
// The answer vary due to round off error
```

Scilab code Exa 34.6 The average rate of heat supplied

```
// Example 34_6
clc;funcprot(0);
//Given data
t_25=10;// Operating time at 25 MW load in hours
t_z=14;//Remaining period at zero load in hours
// I=5*10^6*(7+0.2L+0.1L^3) where I is in kJ/hr and
   L is in MW

//Calculation
//(a)
L_0=0;// Zero load
I_0=((5*10^6)*(7+0.2*L_0+0.1*L_0^2));// The input
   per hour at zero load in kJ/hr
L_1=25;// Load in MW
I_1=((5*10^6)*(7+0.2*L_1+0.1*L_1^2));// The input
   per hour at 25 MW load in kJ/hr
T_e=(L_1*t_25)+(L_0*t_z);// Total energy generated
```

```
with in 24 hours in MW-hrs.
T_p=(I_1*t_25)+(I_0*t_z);//Total energy input to the plant within 24 hours
H_i1=T_p/T_e;//Average rate of heat input in kJ/MW-hr.

//(b)
A_l=T_e/24;// The average load on the plant MW
L=A_l;// Load in MW
I=5*10^6*(7+0.2*L+0.1*L^2);// The input per hour at L=10.41 MW in kJ/hr
H_i2=I/L;// The heat rate in kJ/MW-hr
H_rs=H_i1-H_i2;//Saving in heat rate in  kJ/MW-hr
printf('\n(a)Average rate of heat input=%0.3e kJ/MW-hr \n(b)Saving in heat rate=%0.3e kJ/MW-hr',H_i1,H_rs);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.7 `Total increase in input`

```
// Example 34_7
clc;funcprot(0);
//Given data
L_p=10;// MW
// I=5*10^6(18+12L+0.5L^2)
L_1=5;// MW
L_2=7;// MW

// Calculation
//(a)
// n=(L/I)=(1/(5*10^6((18/L)+12+0.5L)));
// The efficiency will be maximum when ((18/L)+12+0.5L)),differentiating we get
L_m=sqrt((-18)/(-0.5));// MW
L=L_m*10^3*3600;// kJ/hr
```

```
I_6=5*10^6*(18+(12*L_m)+(0.5*L_m^2));// kJ/hr
n_max=(L/I_6)*100;// Maximum efficiency in %
printf('\n(a)The load at which the efficiency of the
    plant will be maximum=%0.0f MW \n   The maximum
   efficiency=%0.0f percentage',L_m,n_max);
//(b)
I_5=5*10^6*(18+(12*L_1)+(0.5*L_1^2));// kJ/hr
I_7=5*10^6*(18+(12*L_2)+(0.5*L_2^2));// kJ/hr
dI=I_7-I_5;// Increase in output to the plant per
   hour in  kJ/hr
L=(L_1+L_2)/2;// MW
IR=5*10^6*(12+L);// kJ/hr
Ti=IR*(L_2-L_1);// Total increase in input in kJ/hr
printf('\n(b)Total increase in input=%0.2e kJ/hr',Ti
   );
```

Scilab code Exa 34.8 `Which plant should be preferable`

```
// Example 34_8
clc;funcprot(0);
//Given data
a=[5 4 2 1 0.5];// Load in kW
b=[200 4000 2000 1000 1560];// No of hours at load
CV_c=28000;// kJ/kg
Cc=350;// Cost of coal in Rs./ton
CV_d=36000;// kJ/kg
Cd=1200;// Cost of diesel oil in Rs./ton
Ci_s=18500;// Capital investment for  steam plant in
    Rs/kW
Ci_d=17000;// Capital investment for diesel plant in
    Rs/kW
Es=320000;// Extra annual salary for steam plant in
   rupees

// Calculation
```

```
Cce=(10^6*Cc)/(CV_c*1000);// The cost of coal energy
     per 10^6 kJ
Cde=(10^6*Cd)/(CV_d*1000);// The cost of diesel oil
    energy per 10^6 kJ
for (i=1:5)
    c(i)=a(i)*b(i);// MW-hrs
    d(i)=5*10^6*(1.5+(2*a(i))+(0.025*(a(i))^3));//
       Input rate in kJ per hour for steam plant
    e(i)=b(i)*d(i);// Total input in kJ
    f(i)=5*10^6*(2.25+a(i)+(0.12*(a(i))^2)-(0.004*(a
       (i))^3));// Input rate in kJ per hour for
       diesel plant
    g(i)=b(i)*f(i);// Total input in kJ
end
N=b(1)+b(2)+b(3)+b(4)+b(5);// Total no. of hours at
    load
MW_hrs=c(1)+c(2)+c(3)+c(4)+c(5);// Total MW-hrs
T_s=e(1)+e(2)+e(3)+e(4)+e(5);// Total input in kJ
    for steam plant
T_d=g(1)+g(2)+g(3)+g(4)+g(5);// Total input in kJ
    for diesel plant
Ahr_s=(T_s)/(MW_hrs*1000);// Average heat rate in kJ
     per kW hour (for steam plant)
Ahr_d=(T_d)/(MW_hrs*1000);// Average heat rate in kJ
     per kW hour (for diesel plant)
// Steam plant
Fc_s=a(1)*10^3*Ci_s*(12/100);// Fixed cost in Rs./
    year
Oc_s=((T_s/10^6)*Cce)+(Es);// Operating cost in Rs./
    year
Tc_s=Fc_s+Oc_s;// Total cost in rupees
// Diesel plant
Fc_d=a(1)*10^3*Ci_d*(12/100);// Fixed cost in Rs./
    year
Oc_d=((T_d/10^6)*Cde);// Operating cost in Rs./year
Tc_d=Fc_d+Oc_d;// Total cost in rupees
printf('\nTotal cost of steam plant=Rs.%0.4e \nTotal
     cost of diesel plant=Rs.%0.4e',Tc_s,Tc_d)
```

```
if(Tc_s<Tc_d)
    printf('\nThe steam plant would be the choice
       under the given circumstances despite the
       higher investment and the greater relative
       labour cost.');
else
    printf('\nThe diesel plant would be the choice
       under the given circumstances.');
end
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.9 Saving per kWh energy produced

```
// Example 34_9
clc;funcprot(0);
//Given data
L=60;// MW
L_0=0;// Zero load in MW
// I=5*10^6*(8+8*L+0.4L^2)
T_f=20;// Time in hours
T_0=4;// Time in hours

// Calculation
E_g=(T_f*L)+(T_0*0);// Total energy generated by the
    power plant during 24 hoursbin MWh
I_60=5*10^6*(8+(8*L)+(0.4*L^2))*20;// Input to the
   plant when the plant is running at full load in
   kJ
I_0=5*10^6*(8+(8*L_0)+(0.4*L_0^2))*20;// Input at no
    load in kJ
Ti=I_60+I_0;// Total input to the plant during 24
   hours in kJ/day
Q=Ti/(E_g*10^3);// Average heat supplied per kWh
   generated in kJ/kWh
L_a=E_g/24;// Average load in MW
```

```
I_50=5*10^6*(8+(8*L_a)+(0.4*L_a^2))*24;// Heat supplied during 24 hours in kJ/day
Ns=Ti-I_50;// Net saving per day in kJ/day
S=Ns/(E_g*10^3);// Saving per kWh
printf('\nThe heat input per day to the power station=%0.5e kJ/day \nSaving per kWh=%0.0f kJ/kWh',I_50,S);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.10 The loss in fuel cost per hour

```
// Example 34_10
clc;funcprot(0);
//Given data
// dF_a/dP_a=0.065*P_a+25;
// dF_b/dP_b=0.08*P_b+20;
L=160;// Total load in MW

// Calculation
//(a)
function[X]=power(y)
    X(1)=(y(1)+y(2))-L;
    X(2)=((0.065*y(1))+25)-((0.08*y(2))+20);
endfunction
y=[10 100];
z=fsolve(y,power);
P_a=z(1);// MW
P_b=z(2);// MW
//(b)
L=160/2;//If the load is equally shared by both the units
p_a1=P_a;
p_a2=L;// Limits of integration
Ic_A=integrate('((0.065*p_a)+25)','p_a',p_a1,p_a2);// Increase in cost for unit A in Rs/hr.
```

```
p_b1=P_b;
p_b2=L;// Limits of integration
Ic_B=integrate('((0.08*p_b)+20)','p_b',p_b1,p_b2);// Increase in cost for unit B in Rs/hr.
dC=Ic_A+Ic_B;
printf('\n(a)P_a=%0.1f MW \n    P_b=%0.1f MW \n(b)The loss in fuel cost per hour=Rs.%0.0f/hr',P_a,P_b,dC);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.11 The most economical loading

```
// Example 34_11
clc;funcprot(0);
//Given data
L=30;// Total load in MW
L_12=20;//Capacity of two steam turbines in MW
// S_1=2000+10*L_1-0.0001*L_1^2
// S_2=1000+7*L_1-0.00005*L_2^2

//Calculation
//L_1+L_2=L*10^3;
// For the most loading,the required condition is (dS_1/dL_1=dS_2/dL_2)
function[X]=Load(y)
    X(1)=(y(1)+y(2))-(L*10^3);
    X(2)=(10-(0.0002*y(1)))-(7-(0.0001*y(2)));
endfunction
y=[10 10];
z=fsolve(y,Load);
L_1=z(1)/1000;// MW
L_2=z(2)/1000;// MW
printf('\nL_1=%0.0f MW \nL_2=%0.0f MW',L_1,L_2);
```

Scilab code Exa 34.12 Which unit will prove economical

```
// Example 34_12
clc;funcprot(0);
//Given data
C_1=5000;//Cost of first unit in Rupees
MD_1=100;// Maximum demand in kW
C_2=14000;//Cost of second unit in Rupees
MD_2=60;// Maximum demand in kW
n=40000;// Useful life in hours
C_e=80;//Energy charge per kW in Rupees/year
C_kwh=5/100;//Energy charge per kW-hr in Rupees

//Calculation
//(a)First unit
Cc=C_1/n;// Capital cost of unit per hour in Rupees
C_MD=((MD_1*C_e)/8760);// Charge for maximum demand
    per hour in Rupees
C_eh=MD_1*1*C_kwh;// Energy charge per hour in
    Rupees
TC_1=Cc+C_MD+C_eh;// Total charges per hour for the
    operation of first unit in Rupees
//(b)Second unit
Cc=C_2/n;// Capital cost of unit per hour in Rupees
C_MD=((MD_2*C_e)/8760);// Charge for maximum demand
    per hour in Rupees
C_eh=MD_2*1*C_kwh;// Energy charge per hour in Rupee
TC_2=Cc+C_MD+C_eh;// Total charges per hour for the
    operation of second unit in Rupees
printf('\n(a)Total charges per hour for the
    operation of first unit=Rs.%0.3f\n(b)Total
    charges per hour for the operation of second unit
    =Rs.%0.3f',TC_1,TC_2);
if(TC_1>TC_2)
```

```
    printf('\n The second unit is more economical than first unit in this case.');
else
    printf('\n The first unit is more economical than second unit in this case.');
    end
```

Scilab code Exa 34.13 Which supply will be more economical

```
// Example 34_13
clc;funcprot(0);
//Given data
C_kw=500;// Charges in Rs./kW
MD=800;// Maximum demand in kW
Cc_1=8*10^5;// Capital cost of Public supply in Rupees
F_l=30/100;// Load factor
ID_1=10;// Interest and decpreciation charges on capital of public supply in %
Cc_2=3*10^6;// Capital cost of private supply in Rupees
ID_2=12;// Interest and decpreciation charges on capital of private supply in %
Fc=0.35;// Fuel consumption in kg/kW-hr
Cf=80;// Percentage per kg
C_e=40;//  Percentage per kW-hr
C_ml=10;//The maintainence and labour charges in percentage per kW-hr

//Calculation
L_a=MD*F_l;// Average load in kW
ERPY=240*8760;// Energy required per year in kW-hrs

//(a)Public supply
C_MD=C_kw*MD;//Charge for maximum demand per year in
```

```
    Rupees
ID=(ID_1/100)*Cc_1;// Interest and decpreciation in
    Rupees
C_ey=(C_e/100)*ERPY;// Energy cost per year in
    Rupees
TC=C_MD+ID+C_ey;// Total cost in Rupees
AEC_1=TC/ERPY;// Average energy cost in Rs./kWh

//(b)Private supply
Fc_y=(Fc*ERPY)/1000;// Fuel consumption per year in
    tons
C_f=Fc_y*1000*(Cf/100);// Cost of fuel in Rupees
MLC=(C_ml/100)*ERPY;// The maintainence and labour
    charges per year
ID=(ID_2/100)*Cc_2;// Interest and decpreciation in
    Rupees
TC=C_f+MLC+ID;// Total cost in Rupees
AEC_2=TC/ERPY;// Average energy cost in Rs./kWh
printf('\n(a)Public supply:Average energy cost=Rs.%0
    .2f/kWh \n(b)Private supply:Average energy cost=
    Rs.%0.2f/kWh',AEC_1,AEC_2);
if(AEC_1>AEC_2)
    printf('\n As the average energy cost for oil
        engine is less than the public supply,the oil
         engine generation is more preferable.');
else(AEC_1<AEC_2)
    printf('\nPublic supply is preferable');
end
```

Scilab code Exa 34.14 The cost of energy per unit

```
// Example 34_14
clc;funcprot(0);
//Given data
MD=80;// MW
```

```
F_l=40/100;// Load factor
E=120*10^6;// kW-hr
MO=30;// Maximum output in MW
CC_ss=18000;// Capital cost of steam station in Rs./
    kW of installed capacity
CC_psp=12000;// Capital cost of pump storage plant
    in Rs./kW of installed capacity
Oc_s=0.80;// Operating cost of steam plant in Rs./kW
    -hr
Oc_psp=0.05;// Operating cost of pump storage plant
    in Rs./kW-hr
ID_s=12/100;// Interest and depriciation

// Calculation
//(a)
CC_s=MD*1000*CC_ss;// Capital cost of steam station
    in rupees
ID=ID_s*CC_s;// Interest and depriciation in rupees
L_a=MD*1000*F_l;// Average load in kW
E_s=L_a*8760;// Energy supplied per year in kW-hrs
IDc=(ID/E_s)*100;// Interest and depriciation
    charges per unit of energy in paise/kWh
Tc_a=(Oc_s*100)+IDc;// Total cost per unit in paise/
    unit
Tc_a=Tc_a/100;// Rs./kWh
//(b)
L=MD-MO;// The load supplied by the steam plant in
    MW
CC_s=L*1000*CC_ss;// Capital cost of steam plant in
    rupees
CC_psp=CC_psp*MO*1000;// Capital cost of pump
    storage plant in rupees
Tc_cs=CC_s+CC_psp;// Total capital costof combined
    station in rupees
IDc=ID_s*Tc_cs;// Interest and depriciation charges
    on capital investment in rupees
Oc_psp=(Oc_psp*E);// Operating cost of pump storage
    plant in rupees
```

```
e_s=E_s-E;// The energy units supplied by steam
    station in kW-hr
Oc_s=Oc_s*e_s;// Operating cost of steam station in
    rupees
Tcpy=IDc+Oc_psp+Oc_s;// Total cost per year in
    rupees
Tc_b=Tcpy/E_s;// The cost per unit in Rs./kWh
printf('\n(a)Total cost per unit=Rs.%0.3f/kWh \n(b)
    Total cost per unit=Rs.%0.2f/kWh',Tc_a,Tc_b);
```

Scilab code Exa 34.15 The cost of generation per kW hr

```
// Example 34_15
clc;funcprot(0);
//Given data
CP=120*1000;// Capacity of the plant in kW
Cc=12000;//Capital cost in per kW installed in
    rupees
Swrm=600000;// Salaries,wages,repairs and
    maintainence per year in rupees
MD=80;// MW
F_l=40/100;// Load factor
Fc=400;// Fuel cost per tonne in rupees
F_c=1.2;// kg/kW-hr

//Calculation
Ci=CP*Cc;// Capital investment in rupees
ID=(10/100)*Ci;// Interest and Depriciation in
    rupees
L_a=MD*10^6*F_l;//Average Load in MW
L_a=L_a/1000;// kW
E_t=L_a*8760;// kW-hr
F_c=F_c*E_t;// Fuel consumption in kg
Fc=(Fc/1000)*F_c;// Fuel cost in rupees
TAC=ID+Fc+Swrm;
```

```
C_g=TAC/E_t;//The cost of generation in rupees per kWh.
printf('\nThe cost of generation=Rs.%0.3f kWh',C_g);
```

Scilab code Exa 34.16 `The cost of generation`

```
// Example 34_16
clc;funcprot(0);
//Given data
CC_kw=15000;// Capital cost/kW installed
TP=2200;// Total power of the diesel power plant in kW
AOC=600000;//Annual operating costs in rupees
FC=100000;// Fixed cost in rupees
VC=200000;// Variable cost in rupees
AMC=FC+VC;// Annual maintainence costs in rupees
Cf=0.8;// Cost of fuel per kg in rupees
Clo=40;// Cost of lubricating oil per kg in rupees
CV=40000;// kJ/kg
cf=0.5;// Consumption of fuel in kg/kWh
clo=1/400;// Consumption of lubricant oil in kg/kWh
MD=1600;// Maximum demand in kW
F_l=45/100;//Load factor

//Calculation
CC=ceil (TP*CC_kw);// Capital costof the plant in rupees/ year;
I=ceil(CC*(15/100));// Interest on capital
AE=ceil(MD*F_l*8760);// Annual energy generated in kWh/year
F_c=ceil(cf*AE);// kg/year
Fc=ceil(F_c*Cf);// Cost of fuel in rupees per year
Lc=ceil(clo*AE);// Lubrication consumption in kg / year
CLO=ceil(Clo*Lc);//Cost of lubricant oil Rs/year
```

```
TFC=ceil(I+FC);// Total fixed cost in kg/year
TRC=ceil(Fc+Lc+VC+AOC);// Total running cost in Rs/
    year
Tc=ceil(TFC+TRC);// Total cost in Rs/year
Gc=(Tc/AE);// Generation cost in Rs/kWh.
printf('\nThe annual energy generated=%0.1e kWh/year
     \nThe cost of generation=Rs.%0.2f/kWh',AE,Gc);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.17 Over all cost of generation

```
// Example 34_17
clc;funcprot(0);
//Given data
L=120;// Steam power station capacity in MW
Ac=1000;// Annual cost towards the interest and
    depriciation in Rs./kW
MD=100;// Peak demand in MW
OC=1200*10^4;// Operating costs in Rs./ year
Mc_f=200*10^4;// Maintainence costs (fixed) in Rs./
    year
Mc_v=400*10^4;/// Maintainence costs (vaiable) in Rs
    ./ year
Mic=100*10^4;// Miscellaneous costs in Rs./ year
C_c=320;// Cost of coal used in Rs./ton
CV=25000;// Calorific value in kJ/kg
n_o=20;// Over all efficiency of the plant in %
F_l=80/100;// Load factor


//Calculation
E_g=MD*10^3*F_l*8760;// Energy generated in kWh/year
SC=(0.8+3.5*F_l);//Steam consumption per kW load in
    kg
//1 kW load generates 0.8 kWh energy as load factor
```

```
   is 0.8.
SC_kW=SC/F_l;// Steam consumption per kWh in kg
// If W_c is the weight of the coal in tons used per
    year,
W_c=(E_g*3600)/(10^3*CV*(n_o/100));// tons/year
CC=W_c*C_c;// Cost of coal in Rs./year
Tfc=(Ac*L*10^3)+Mc_f;//Total fixed costs in Rs./
   year
Tvc=OC+Mc_v+Mic+CC;//Total variable costs in Rupees
Tac=Tfc+Tvc;// Total annual cost in Rupees
Gc=Tac/E_g;//Generation cost in Rs./kWh
printf('\n(a)Coal cost per year=Rs%0.3e/year \n(b)
   Over all cost of generation=Rs%0.2f/kWh',CC,Gc);
```

Scilab code Exa 34.18 The annual cost and cost per kWh for each plant

```
// Example 34_18
clc;funcprot(0);
//Given data
MD=80;// Maximum demand in MW
F_l=35/100;// Load factor
E_s=120*10^6;// Energy supplied by steam plant in
   kWh/year
MD_s=50;// Maximum load in MW
CC_s=18000;// Capital cost of steam plant in Rs./ kW
    installed
CC_h=30000;// Capital cost of hydro plant in Rs./ kW
    installed
CC_n=25000;// Capital cost of nuclear plant in Rs./
   kW installed
OC_s=0.5;// Operating cost of steam plant in Rs./
   kWh
OC_h=0.1;// Operating cost in hydro plant Rs./ kWh
T_h=0.05;// Transmission cost of hydro plant in Rs./
    kWh
```

```
ID_s=(12/100)*CC_s;// Interest and decpreciation for
    steam plant
ID_h=(10/100)*CC_h;// Interest and decpreciation for
    hydro plant
Rc_n=0.25;// Running cost of nuclear plant in Rs./
   kWh
ID_n=10;// Interest and decpreciation for nuclear
   plant in % per annum

//Calculation
E=MD*10^3*F_l*8760;// Energy required per year in
   kWh
//(a)Steam plant
ID_1=ID_s*MD*10^3;// Interest and decpreciation(
   fixed plant)in Rs./year
OC_1=OC_s*E;// Operating cost Rs./year
Tc_1=ID_1+OC_1;// Total cost in Rs./year
Oc_kWh1=Tc_1/E;// Over all cost per kWh in Rs./kWh

//(b(i))Hydel Plant
ID_2=ID_h*(MD-MD_s)*10^3;// Interest and
   decpreciation(fixed cost)in Rs./year
E_h=(E-E_s);// Energy supplied by the hydro plant in
    kWh/year
OC_2=(E_h*OC_h)+T_h;// Operating or running cost
   including transmission in Rs./year
//(b(ii)) Steam station
L_t=E_s/8760;// Load taken in kW
MD_m=L_t/F_l;// Maximum load (Minimum plant capacity
   ) in kW
ID_3=ID_s*MD_m;//Interest and decpreciation in Rs./
   year
OC_3=E_s*OC_s;// Operating cost Rs./year
Tc_2=ID_2+OC_2+ID_3+OC_3;// Total cost of both the
   plants in Rs./year
Oc_kWh2=Tc_2/E;// Over all cost per kWh in Rs./kWh

//(c)Nuclear plant
```

```
ID_4=MD*10^3*CC_n*(ID_n/100);// Interest and
    decpreciation in Rs./year
Rc=E*Rc_n;// Running cost in Rs./year
Tc_3=(ID_4+Rc);// Total cost in Rs./year
Oc_kWh3=Tc_3/E;// Over all cost per kWh in Rs./kWh
printf('\n(a)The annual cost=Rs.%0.2e /year \n   The
     over all cost=Rs.%0.2f/kWh \n(b)The annual cost=
    Rs.%0.2e /year \n   The over all cost=Rs.%0.3f/
    kWh \n(c)The annual cost=Rs.%0.2e /year \n   The
    over all cost=Rs.%0.2f/kWh',Tc_1,Oc_kWh1,Tc_2,
    Oc_kWh2,Tc_3,Oc_kWh3);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.19 Energy cost

```
// Example 34_19
clc;funcprot(0);
//Given data
//(i)A private diesel generating plant
MD=900;// kW
F_l=30;// Load factor in %
Cc=90*10^5;// Capital cost in rupees
Cf=800;// Fuel cost in Rs./ton
Fc=0.3;//Fuel consumption in kg/kWh-generated
Mc=2.5;// Cost of maintainence in paise/kWh-
    generated
Oc=0.3;// Cost of lubricating oil,water,store,etc in
     paise/kWh-generated
W=180000;// Wages in Rs./year
ID_1=10;//Interest and decpreciation in % per year
//(ii)Public supply
MD_pub=1500;// Maximum demand per year in Rs./kW
Mc_pub=80;// paise/kWh

//Calculation
```

```
//(i)Private plant
ID=ID_1*Cc;//Interest and decpreciation in rupees
Nu=MD*(F_l/100)*8760;//Number of units required per
    year in kWh/year
Fr=(F_l/100)*(Nu);// Fuel required in kg/year
CF=Fr*(Mc_pub/100);// Fuel cost in Rs./year
Cmo=((0.3+2.5)/100)*Nu;//Cost of maintainence,oil
    and water in Rs./year
Tc=ID+CF+Cmo+W;// Total cost of running the plant
    per year in rupees
Ec_1=(Tc/Nu);//The energy cost in Rs./kWh
//(ii)Public supply
Tc=(MD_pub*MD)+((Mc_pub/100)*Nu);// Total cost in Rs
    ./year
Ec_2=Tc/Nu;// Energy cost in Rs./kWh
if(Ec_1>Ec_2)
    printf('\nThe public supply set is preferable as
         its cost is less than diesel set.');
else
    printf('\nThe private supply set is preferable
        as its cost is less than diesel set.');
end
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.20 The reserve capacity and the cost of generation per kWh

```
// Example 34_20
clc;funcprot(0);
//Given data
P=120;// Plant capacity in MW
CC=15000;// The Capital cost in Rs/kW
Arc=20*10^6;// Annual running charges in rupees
F_al=0.6;// The annual load factor
F_ac=0.5;// Annual capacity factor

```

```
//Calculation
MD=(P*F_ac)/F_al;// Maximum demand in MW
Rc=P-MD;// Reserve capacity in MW
L_a=F_al*MD;// Average load in MW
E_py=L_a*10^3*8760;//Energy produced/year in kWh
E_a=E_py*0.95;// kWh
TCC=CC*P*10^3;// Total capital cost of the plant in
    rupees
ID=.10*TCC;// Interest and decpreciation in rupees
p=.10*TCC;// Profit to be gained in rupees
TC=ID+p+Arc;// Total charges to be recovered in
    rupees
C_eg=(TC/E_a);// Cost of energy generated in Rs./kWh
printf('\n(a)The reserve capacity=%0.0f MW \n(b)Cost
     of energy generated=Rs.%0.2f/kWh',Rc,C_eg);
```

Scilab code Exa 34.21 Over all cost of generation

```
// Example 34_21
clc;funcprot(0);
//Given data
P=142.5;// Plant capacity in MW
CC=130*10^7;// The Capital cost in rupees
Ac_o=18.8*10^7;// Annual cost of coal,oil,tax and
    salaries in rupees
R_i=5;// Rate of interest in % of capital
R_d=5;// Rate of depreciation in % of capital
U_e=6;// Unit of energy used in % of the total units
     supplied
F_l=0.6;// The annual load factor
F_c=0.5;// Annual capacity factor

//Calculation
MD=(P*F_c)/F_l;// Maximum demand in MW
Rc=P-MD;// Reserve capacity in MW
```

```
E_s=MD*10^3*F_l*8760;// Yearly energy supplied by
    the plant in kWh
E_g=(1+(U_e/100))*E_s;// Yearly energy generated in
    kWh
ID=((R_i+R_d)/100)*CC;//Interest and decpreciation
    in Rs./year
TC=(ID+Ac_o);// Total cost in Rs./year
Oc=(TC/E_g);// Overall cost of generation in Rs./kWh
printf('\nReserve capacity=%0.2f MW \nOverall cost
    of generation=Rs.%0.3f/kWh',Rc,Oc);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.22 Three charge rate

```
// Example 34_22
clc;funcprot(0);
//Given data
N=50000;// Number of domestic customers
Fc=2.5*10^7;// Fixed charges in rupees
Ec=2*10^7;// Energy charges in rupees
Cc=0.5*10^7;// Customer charges in rupees
p=20*10^5;// Profit in rupees
MD=5000;// kW
F_d=4;// Diversity factor
F_l=0.3;// Load factor

//Calculation
FC=Fc+((25/100)*p);// Fixed cost in rupees
EC=Ec+((50/100)*p);// Energy cost in rupees
CC=Cc+((25/100)*p);// Customer charges in rupees
MD_i=MD*F_d;// kW
E=MD*F_l*8760;// kW-hrs
Fc_kW=FC/(MD_i);// Fixed cost per kW per year in Rs
    ./kW
C=CC/N;// Changes per customer per year in rupees
```

```
Er=EC/E;// Energy rate in Rs./kWh
printf('\nFixed cost per kW per year=Rs.%0.0f/kW \
    nEnergy rate=Rs.%0.1f/kWh \nThree charge rate=Rs.
    %0.0f+%0.0f kW+%0.1f/kWh',Fc_kW,Er,C,Fc_kW,Er);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.23 The generation charge in two part tariff

```
// Example 34_23
clc;funcprot(0);
//Given data
P=100;// MW
CC=10000;// Rs./kW
R=2;// Royalty in Rs./kW
C_e=0.3;//Rs./kWh
MD=70;// MW
F_l=0.6;// Annual load factor
S_a=10^7;// Salaries and maintainence in rupees

//Calculation
E=(MD*10^3)*F_l*8760;// kWh
CC=P*10^3*CC;// Capital cost of the plant in rupees

// Annual fixed charges
D=(15/100)*CC;// Depriciation in rupees
S=(20/100)*S_a;// Salaries and maintainence in
    rupees
Tfc=D+S;// Total fixed charges in rupees
C_kw=(Tfc/(MD*10^3));// Cost per kW

// Annual fixed charges
S=(80/100)*S_a;// Salaries and maintainence in
    rupees
Tc=(S/E)+C_e;// Total cost in rupees
Tc=(Tc*100);// paise/kWh
```

```
printf('\nTwo part tariff=Rs.%0.0f/kW+%0.3f/kWh',
   C_kw,Tc/100);
```

Scilab code Exa 34.24 The average cost kW hr

```
// Example 34_24
clc;funcprot(0);
//Given data
P=25;// MW
CC=12000;// Rs/kW
CC_ps=15*10^6;// Capital cost of primary and
   secondary distribution in rupees
Mc=80*10^4;// Plant maintainence cost in Rs./year
Mc_ps=2*10^6;// Maintainence cost of primary and
   secondary equipments in Rs./year
Sw=6*10^6;// Salaries and wages in Rs./year
Cc=80*10^3;// Consumption of coal in tonnes/year
cc=800;// Cost of coal Rs./tonne
Di=12*10^6;// Rs./year
E_l=10/100;// Energy loss in transmission
F_d=1.5;// Diversity factor
F_l=80/100;// Load factor
MD=14;// MW

//Calculation
L_a=MD*10^3*F_l;// kW
E_g=L_a*8760;// kW-hr
CC=P*10^3*CC;// Rs.
IiD=(10/100)*CC;// Interest,insurance,depriciation
   charges of plant in rupees
IiD_ps=(80/100)*CC;// Interest,insurance,
   depriciation charges of primary and secondary
   equipments in rupees
Tfc=IiD+IiD_ps+Di;// Total fixed cost in rupees
MD_i=MD*10^3*F_d;
```

```
FC=Tfc/MD_i;// Fixed cost per kW in rupees
Fc=Cc*cc;// Rs./year
Tvc=Mc+Mc_ps+Sw+Fc;// Total variable charges in rupees
E_t=E_g*(1-E_l);// Energy generated in kW-hr
Cec=Tvc/E_t;// Charges for energy consumption in Rs./kW-hr
Tc=Tfc+Tvc;// Total charges in rupees
Ac=Tc/E_t;// Average cost of supply in Rs./kWh
printf('\nAverage cost of supply=Rs.%0.2f/kWh',Ac);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.25 Over all cost of generation

```
// Example 34_25
clc;funcprot(0);
//Given data
P=12;// MW
MD=10;// MW
F_l=0.7;// load factor
CC=17000;// Rs./kW
C_td=3*10^6;// Cost of transmission and distribution system in rupees
ID=5;// Interest,depriciation on distribution system in %
Oc=3*10^6;// Operating cost in rupees
Cc=800;// Cost of coal in Rs./ton
Mc_f=0.3*10^6;// Plant maintainence costs in Rs./year (fixed)
Mc_r=350000;//Plant maintainence costs in Rs./year (running)
c=30*10^3;// Coal used in tons/year


//Calculation
```

```
ID_f=(10/100)*CC*P*10^3;//  Interest,depriciation etc. of the plant in Rs./year
ID_ftd=(5/100)*C_td;// Interest,depriciation etc.of the transmission and distribution in Rs./year
Ac_r=c*Cc;//Annual cost of coal in Rs./year
FC=ID_f+ID_ftd+Mc_f;// Fixed cost in Rs./year
RC=Ac_r+Oc+Mc_r;// Running cost in Rs./year
Gtc=FC+RC;// Grand total cost in Rs./year
E_g=MD*10^3*F_l*8760;// Energy generated per year in kWh
Tpt_1=(FC/(MD*10^3));// Rs./kW
Tpt_2=(RC/(E_g));// Rs./kWh
Oac=(FC+RC)/(E_g);// Over all cost/kWh
printf('\nTwo part tariff=Rs.%0.0f/kW+Rs.%0.3f/kWh \nOver all cost/kWh=Rs.%0.2f',Tpt_1,Tpt_2,Oac);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.26 Over all cost per unit

```
// Example 34_26
clc;funcprot(0);
//Given data
P=5000;// kW
MD_d=3000;// kW
F_ld=20/100;// Load factor
MD_s=1800;// kW
F_ls=50/100;// Load factor
MD_st=200;// kW
F_lst=30/100;// Load factor
CC=18000;// Rs./kW
Trc=6.2*10^6;//Total running cost in Rs./year
ID=10/100;// Annual rate of depriciation and interest in capital

//Calculation
```

```
E_s=((MD_d*F_ld)+(MD_s*F_ls)+(MD_st*F_lst))*8760;// The energy supplied per year to all three consumers in kW-hrs
Oc=Trc/E_s;// Operating charges per kW-hr in rupees
CC=P*CC;// Capital cost of the plant in rupees
Fcpy=CC*ID;// Fixed cost per year in rupees
Fc=Fcpy/P;// Fixed cost per kW in rupees
//(a)
Tc_d=(MD_d*Fc)+((MD_d*F_ld)*8760*Oc);// The total charges in rupees
Oac_d=Tc_d/((MD_d*F_ld)*8760);// Over all cost per unit in rupees
//(b)
Tc_s=(MD_s*Fc)+((MD_s*F_ls)*8760*Oc);// The total charges in rupees
Oac_s=Tc_s/((MD_s*F_ls)*8760);// Over all cost per unit in rupees
//(c)
Tc_st=(MD_st*Fc)+((MD_st*F_lst)*8760*Oc);// The total charges in rupees
Oac_st=((Tc_st)/((MD_st*F_lst)*8760));// Over all cost per unit in rupees
printf('\n(a)Over all cost per unit=Rs.%0.2f/kW-hr \n(b)Over all cost per unit=Rs.%0.3f/kW-hr \n(c)Over all cost per unit=Rs.%0.2f/kW-hr',Oac_d,Oac_s,Oac_st);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.27 Load factor and the generation cost

```
// Example 34_27
clc;funcprot(0);
//Given data
// Annual fixed and running charges
// Diesel Rs.(300/kW + 0.5/kWh)
```

```
// Steam Rs.(1200/kW + 0.125/kWh)
E=500*10^6;//kWh
// Calculation
//(a)
// P=Maximum load in kW
// K=Load factor
// C_1=(300*P + (0.5*P*K*8760))
// C_2=(1200*P + (0.125*P*K*8760))
// Unit energy cost by Diesel=Unit energy cost by steam
function[X]=loadfactor(y)
    X(1)=((300)+(0.5*y(1)*8760))-((1200)+(0.125*y(1)*8760))
endfunction
y=[0.1];
z=fsolve(y,loadfactor)
K=z(1);

//(b)
P=(E/(8760*K));// kW
C_1=((300*P)+(0.5*P*K*8760));// Rupees
GC=C_1/E;// Generation cost in Rs./kWh
printf('\nLoad factor=%0.1f percentage \nThe generation cost=Rs.%0.3f/kWh',K*100,GC);
// The answer vary due to round off error
```

Scilab code Exa 34.28 Which motor will be economical

```
// Example 34_28
clc;funcprot(0);
//Given data
P=30;// kW
C_a=60000;// Cost of motor A in rupees
C_b=40000;// Cost of motor B in rupees
n_a=90;// Efficiency of motor A at full load
```

```
n_b=85;//  Efficiency of motor B at full load
n_50a=86;// Efficiency of motor A at 50% load
n_50b=82;// Efficiency of motor B at 50% load
N=20;// Life of each motor
I=5/100;// Interest
T=25;// Time in %
Mc_a=4200;// The annual maintainence cost of motor A
    in rupees
Mc_b=2400;// The annual maintainence cost of motor B
    in rupees
Er=1;// Energy rate in Re./kWh

//Calculation
//(a)
SV=(10/100)*C_a;// Salary value in rupees
D=(C_a-SV)/N;// Depriciation in Rs./year
I=(5/100)*C_a;// Interest in  Rs./year
E=((P/1)*(8760*(T/100)*(1/(n_a/100))))+((P/2)
   *(8760*((100-T)/100)*(1/(n_50a/100))));// Energy
   cost in rupees
Tc_a=D+I+Mc_a+E;// Total cost of motor A
//(b)
SV=(10/100)*C_b;// Salary value in rupees
D=(C_b-SV)/N;// Depriciation in Rs./year
I=(5/100)*C_b;// Interest in  Rs./year
E=((P/1)*(8760*(T/100)*(1/(n_b/100))))+((P/2)
   *(8760*((100-T)/100)*(1/(n_50b/100))));// Energy
   cost in rupees
Tc_b=D+I+Mc_b+E;// Total cost of motor B
printf('\nTotal cost of motor A=Rs.%0.0f/year \
   nTotal cost of motor B=Rs.%0.0f/year',Tc_a,Tc_b);
if(Tc_a<Tc_b)
    printf('\nMotor A is recommended as its annual
       cost is less than motor B.');
else(Tc_b<Tc_a)
    printf('\nMotor B is recommended as its annual
       cost is less than motor A.');
end
```

```
// The answer vary due to round off error
```

Scilab code Exa 34.29 The price of coal

```
// Example 34_29
clc;funcprot(0);
//Given data
P=50;// MW
F_l=40/100;// Load factor
CC_s=15000;// Initial cost of steam plant in Rs./kW
Mc_s=20;// Maintainence cost in paise/kWh
n_os=25/100;// The over all efficiency of the steam plant
CV=25000;// kJ/kg
CC_h=30000;// Capital cost of hydel plant in Rs./kW
Rc=5;// Running cost in paise/kWh
ID_s=12/100;// Interest and depriciation for steam plant
ID_h=9/100;// Interest and depriciation for hydel plant

//Calculation
E=P*10^3*F_l*8760;// Energy required per year in kWh/year
//(a)Steam plant
ID_s=P*10^3*CC_s*ID_s;//Interest and depriciation in Rs./year
Mc_s=(Mc_s/100)*E;//Maintainence cost in Rs./year
m_c=E/(10^3*CV*n_os)*3600;// The mass of coal in tons/year
//(b)Hydel plant
ID_h=P*10^3*CC_h*ID_h;//Interest and depriciation in Rs./year
Rc_h=(Rc/100)*E;// Running cost in Rs./year
Tc_h=ID_h+Rc_h;// Total cost of hydel plant in
```

```
    rupees
// Tc_s=ID_s+Mc_s+(m_c*C); where C is the cost of
    coal
function[X]=costofcoal(y)
    X(1)=(ID_s+Mc_s+(m_c*y(1)))-Tc_h;
endfunction
y=[0.1];
z=fsolve(y,costofcoal);
C=z(1);// Rs./ton
printf('\nThe cost of coal=Rs.%0.0f/ton',C);
```

Scilab code Exa 34.30 The number of working hours per week

```
// Example 34_30
clc;funcprot(0);
//Given data
// High voltage-Rs.450/kW per year + paise 35/kWh
// Low voltage-Rs.470/kW per year + paise 40/kWh
CC=1000;// Rs./kW
T_l=3/100;// Losses in the transformer
N=50;// Working weeks per year
P=1;// MW

//Calculation
Cl=1000;// Consumer load in kW
Rr=Cl/(1-T_l);// Required rating of transformer in
    kW
Ct=Cl*Rr;// Cost of transformer to the consumer in
    rupees
ID=(Ct/P)*(10/100);// Annual Interest and
    depriciation in rupees
// P=50*h; Power used during the year in hours
// N_l=Cl*P; Number of units consumed from low
    voltage side in kWh/year
// N_h=Rr*P; Number of units consumed from high
```

```
    voltage side in hours
function[X]=hours(y)
    X(1)=((Cl*470)+(((Cl*50*y(1))/P)*(40/100)))-((Rr
        *450)+(((Rr*50*y(1))/P)*(35/100))+ID);
endfunction
y=[10];
z=fsolve(y,hours);
h=z(1);// The number of working hours per week (hrs/
    week)
printf('\nThe number of working hours per week=%0.2f
    hrs/week',h);
// The answer vary due to round off error
```

Scilab code Exa 34.31 The cost of generation

```
// Example 34_31
clc;funcprot(0);
//Given data
P=2500;// kW
MD=1600;// Maximum load in kW
F_l=0.48;// Load factor
CC_s=15000;// Initial cost of
Ic=18000;// Installation cost in Rs./kW
I=15/100;// Interest on capital
Mc=200000;// Maintainence cost in Rs./year
Tlo=850000;// Total labour and other consumables in
    Rs./year
Fc=7;// Fuel cost in Rs./kg
Lc=30;// Lubricating oil cost in Rs./kg
F=0.25;// Fuel consumed in kg/kWh
O=0.025;// Oil consumed in kg/kWh

//Calculation
CC=P*Ic;// Capital cost of the plant in rupees
I=CC*I;// Interest on capital in rupees
```

```
E_g=MD*F_l*8760;// Energy generated per year in kWh
Cf=F*E_g*Fc;// Cost of fuel in Rs./year
Cl=O*E_g*Lc;// Cost of Lubricating oil in rupees
Tfc=I+Mc;// Total fixed cost in rupees
Trc=Cf+Cl+Tlo;// Total running cost in rupees
Tc=Tfc+Trc;// Total cost in rupees
Gc=Tc/E_g;// Generation cost in Rs./kWh
printf('\nThe cost of generation=Rs.%0.2f/kWh',Gc);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.32 The generating cost per kWh

```
// Example 34_32
clc;funcprot(0);
//Given data
P=200;// MW
Fc=24*10^6;// Fixed cost Rs./year
Cf=1800;// Cost of fuel in Rs./ton
CV=20000;// Calorific value in kJ/kg
Oe=280;// Other expanses in Rs./kW
Q_1=18000;// Plant heat rate at 100% capacity factor
    in kJ/kWh
F_c1=100/100;// Capacity factor
Q_2=10500;// Plant heat rate at 50% capacity factor
   in kJ/kWh
F_c2=50/100;// Capacity factor

//Calculation
Fc=Oe+(Fc/(P*10^3));// Fixed cost per kW capacity
   per year in Rs./kW

//(a)At 100% C.F
AD=P*10^3*F_c1;// The average demand in kW
E_g=AD*8760;// Energy generated per year in kWh
Fc_1=((Fc*AD)/(E_g))*100;// Fixed cost per kWh in
```

```
paise
C=Q_1/CV;// Coal burned per kWh in kg
Cc=(C*Cf)/1000;// Cost of coal per kWh energy generated in rupees
Tc_1=(Fc_1/100)+Cc;// Total cost of generation per kWh in rupees

//(b)At 50% C.F
AD=P*10^3*F_c2;// The average demand in kW
E_g=AD*8760;// Energy generated per year in kWh
Fc_2=((Fc*AD)/(E_g))*100;// Fixed cost per kWh in paise
C=Q_2/CV;// Coal burned per kWh in kg
Cc=(C*Cf)/1000;// Cost of coal per kWh energy generated in rupees
Tc_2=(Fc_2/100)+Cc;// Total cost of generation per kWh in rupees
printf('\n(a)Total cost of generation per kWh=Rs.%0.3f \n(b)Total cost of generation per kWh=Rs.%0.3f',Tc_1,Tc_2);
// The answer provided in the textbook is wrong
```

Scilab code Exa 34.33 The generating cost

```
// Example 34_33
clc;funcprot(0);
//Given data
P=210*10^3;// kW
CC=10000;// Rs./kW

//Calculation
CC=CC*P;// Capital cost of the plant in rupees
//(a)When the plant is operating at full load
F_l=1;// Load factor
Fc=CC*(13/100);// Fixed cost in rupees
```

```
Vc=Fc*1.3;// Variable cost in rupees
Tc=Fc+Vc;// Total cost in rupees
E_t=(P*F_l*8760);//Total units generated per year in
    kWh
Gc_1=(Tc/E_t)*100;// Generating cost in paise/kWh

//(b)When the plant is running at 50% load
F_l=50/100;
E_t=E_t*F_l;// Total units generated per year in kWh
Vc=Vc/2;// Variable cost in rupees
Tc=Fc+Vc;// Total operating cost in rupees
Gc_2=(Tc/E_t)*100;// Generating cost in paise/kWh
printf('\n(a)Generating cost when the plant is
   operating at full load=%0.1f paise/kWh \n(b)
   Generating cost when the plant is operating at 50
    percentage load=%0.0f paise/kWh',Gc_1,Gc_2);
// The answer vary due to round off error
```

Scilab code Exa 34.34 Over all efficiency of the plant

```
// Example 34_34
clc;funcprot(0);
//Given data
P=[600 600 600 400];// Capacity of 4-generating sets
    in kW
MD=1600;// kW
F_l=0.45;// Load factor
CC=10000;// Capital cost in Rs./kW
Mc=60000;// Annual maintainence cost in rupees
Oc=100000;// Operation cost in rupees
Fc=7;// Fuel cost in Rs./kg
Lc=40;// Lubricating oil cost in Rs./kg
F=0.5;// Fuel consumed in kg/kWh
O=0.0025;// Lubricating oil consumed in kg/kWh
CV=42000;// kJ/kg
```

```
n_g=0.92;// Generator efficiency

//Calculation
//(a)
R_f3=P(1)/n_g;// Rating of first 3 sets in kW
R_4=P(4)/n_g;// Rating of last set in kW
//(b)
AD=MD*F_l;// Average demand in kW
E_g=AD*8760;// Energy generated/year in kWh
//(c)(i)Fixed costs per year
CC=((3*P(1))+(1*P(4)))*CC;
Afc=.15*CC;// Annual fixed cost in rupees
Tfc=Afc+Mc;// Total fixed cost in rupees
//(i)Variable costs per year
Fc=(E_g*F)*Fc;// Fuel cost in rupees
Lc=(E_g*O)*Lc;// Lubricating oil cost in rupees
Tvc=Fc+Lc+Oc;// Total variable cost in rupees
Tc=Tfc+Tvc;// Total cost in rupees
C=Tc/E_g;// Cost per kWh generated
//(d)
n_o=((E_g*3600)/(E_g*F*CV))*100;// Over all efficiency of the plant in %
printf('\n(a)Rating of first 3 sets=%0.0f kW \n Rating of last set=%0.0f kW \n(b)Energy generated /year=%0.1e kWh \n(c)Cost of generation=Rs.%0.2f \n(d) Over all efficiency of the plant=%0.2f percentage',R_f3,R_4,E_g,C,n_o);
// The answer vary due to round off error
```

Scilab code Exa 34.35 The cost of energy generated

```
// Example 34_35
clc;funcprot(0);
//Given data
P=30;// MW
```

```
Pc=10*10^7;// Plant cost in rupees
Ii=13/100;// Interest and insurance
D=5/100;// Depriciation
Mc=50*10^5;// Plant maintainence cost in rupees
Fc=700*10^5;// Fuel cost in rupees
Lc=25*10^5;// Lubricating cost in rupees
LC=75*10^5;// Labour cost in rupees
MD=25;// MW
F_l=0.75;// Load factor
p=5;// Profit expected in paise/kWh

//Calculation
L_a=(MD*F_l);// Average load in MW
E_g=L_a*10^3*24*365;// Energy generated/year in kWh
Iic=Ii*Pc;// Interest and insurance cost in rupees
D=D*Pc;// Depriciation in rupees
Pr=(p/100)*E_g;// Profit required in rupees
Tc=Iic+D+Mc+Fc+Lc+LC+Pr;// Total cost in rupees
Ce=(Tc*100)/(E_g);// Cost of energy generated in
    paise/kWh
printf('\nCost of energy generated=%0.1f paise/kWh',
    Ce);
```

Chapter 35

COMBINED OPERATION OF DIFFERENT POWER PLANTS

Scilab code Exa 35.1 Annual Load factor for both stations

```
// Example 35_1
clc;funcprot(0);
//Given data
MD=100;// Maximum demand in MW
md=20;// Minimum demand in MW
A_1=200;// Rs./kW-year
A_2=50;// Rs./kW-year
B_1=0.05;// Rs./kWh
B_2=0.1;// Rs./kWh

// Calculation
L=(A_1-A_2)/(B_2-B_1);// Time in hours
P_b=MD-((L/8760)*(MD-md));// MW
P_p=100-P_b;// MW
// (b)
Area_STbcS=(1/2)*(1000+8760)*(P_p-md);
Area_bb1c1cb=(8760*md);
```

```
LF_b=((Area_STbcS+Area_bb1c1cb)/(P_p*8760))*100;// Load factor
A_aTSa=(1/2)*(3000*P_b);
LF_p=(A_aTSa/(P_p*8760))*100;// Load factor
printf('\nThe load shared by peak load plant=%0.1f MW \nLoad factor(base load)=%0.0f percentage \nLoad factor(peak load plant)=%0.0f percentage',P_p,LF_b,LF_p);
// The answer provided in the textbook is wrong
```

Scilab code Exa 35.2 Average cost

```
// Example 35_2
clc;funcprot(0);
//Given data
// C_1=2500 kW+0.550 kWh
// C_2=2400 kW+0.6 kWh
A_1=2500;
A_2=2400;
B_1=0.55;
B_2=0.6;
MD=100;// Maximum demand in MW
md=10;// Minimum demand in MW
t=8760;// hours

// Calculation
L=(A_1-A_2)/(B_2-B_1);// Time in hours
P_b=MD-((L/t)*(MD-md));// MW
P_p=100-P_b;// MW
// (a)
Ic_b=P_b;// MW
Ic_p=P_p*1.2;// MW
// (b)
// For base load plant
E_g1=((1/2)*(L+t)*(P_b-md))+(md*t);// MW-hrs
```

```
LF_b=(E_g1/(P_b*t))*100;// Load factor
CF_b=LF_b;// Capacity factor
UF_b=CF_b/LF_b;// Use factor
// For peak load plant
E_g2=((1/2)*(L)*(MD-P_b));// MW-hrs
LF_p=(E_g2/(P_p*t))*100;// Load factor
CF_p=(E_g2/(24*t))*100;// Capacity factor
UF_p=(CF_p/LF_p)*100;// Use factor
// (c)For I-plant(base)
E_g1=(((1/2)*(L+t)*(P_b-md))+(md*t))*1000;// kW-hrs
C_1=(P_b*10^3*A_1)+(E_g1*B_1);// rupees
// (c)For I-plant(peak)
E_g2=((1/2)*(L)*(P_b-md))*1000;// kWh
C_2=(P_p*10^3*A_2)+(E_g2*B_2);// rupees
E_t=E_g1+E_g2;// kWh
C=C_1+C_2;// Total generating cost in rupees
C_a=C/E_t;// Average cost in Rs./kWh
printf('\nAverage cost=Rs.%0.3f/kWh \nLoad shared by
    peak load plant=%0.0f MW \nLoad factor(base load
    plant)=%0.0f percentage \nLoad factor(peak load
   plant)=%0.1f percentage',C_a,P_p,LF_b,LF_p);
// The answer vary due to round off error
```

Scilab code Exa 35.3 The minimum cost of generation

```
// Example 35_3
clc;funcprot(0);
//Given data
// C_1=840000+840 kW+0.116 kWh
// C_2=500000+440 kW+0.2985 kWh
A_1=840;
A_2=440;
B_1=0.116;
B_2=0.2985;
MD=64000;// kW
```

```
t=8760;// hours

// Calculation
L=(A_1-A_2)/(B_2-B_1);// Time in hours
P_p=(MD/t)*L;// kW
P_b=MD-P_p;// kW
E_b=((1/2)*(L+t)*(P_b));// The kWh generated by base
    load plant
E_p=((1/2)*L*P_p);// The kWh generated by peak load
   plant
E_t=E_b+E_p;// // Total energy generated in kWh
C_1=840000+(A_1*P_b)+(B_1*E_b);// rupees
C_2=500000+(A_2*P_p)+(B_2*E_p);// rupees
C=C_1+C_2;// Total cost in rupees
Gc=C/E_t;// Generating cost in rupees
printf('\nGenerating cost=Rs.%0.2f/kWh',Gc);
// The answer vary due to round off error
```

Scilab code Exa 35.4 Over all cost of generation

```
// Example 35_4
clc;funcprot(0);
//Given data
// C_1=100*10^4+ 600 kW+0.1 kWh
// C_2=60*10^4+ 350 kW+0.2 kWh
A_1=600;
A_2=350;
B_1=0.1;
B_2=0.2;
t=8760;// hours

// Calculation
// C=[100*10^4+600x+0.1S_a]+[60*10^4+350*(P-x)+0.2*(
   S_t-S_a)];
//  The required condition is dC/dx=0;
```

```
// dS_a=2500dx;....(a)
// From Fig.Prob.35.4(b)
// dS=H.dx;....(b)
H=2500;// hrs
// From similar triangles oab and dcb
ob=50000;// kW
L_b=ob;// kW
db=(H*ob)/t;// Installed capacity for station B in kW
S_b=(1/2)*db*H;// Units generated by station B
oa=t;// hours
S_t=(1/2)*ob*oa;// Total units generated in kWh
S_a=S_t-S_b;// Units generated by station A
L_a=ob-db;// kW
C_a=100*10^4+(A_1*L_a)+(0.1*S_a);// rupees
C_b=60*10^4+(A_2*ob)+(0.1*S_b);// rupees
C=C_a+C_b;// rupees
Gc=(C/S_t)*100;// Overall cost of generation in paise/kWh
printf('\nOverall cost of generation=%0.1f paise/kWh',Gc);
// The answer vary due to round off error
```

Scilab code Exa 35.5 Load factor Capacity factor and Use factor

```
// Example 35_5
clc;funcprot(0);
//Given data
T=[0 10 20 30 40 50 60 70 80 90 100];// Percentage time of a year
L=[36.0 33.2 33 29.8 29.6 29.2 28.5 28.0 22.0 12.0 8.0];// Load in MW
// C_1=48 kW+0.03 kWh
// C_2=36 kW+0.035 kWh
L_b=32;// MW
```

```
L_p=7;// MW
A_1=48;
A_2=36;
B_1=0.030;
B_2=0.035;
t=8760;// hours
MD=L(1);// MW

// Calculation
xlabel('TIME IN PERCENT OF YEAR');
ylabel('LOAD IN MW');
xtitle('Fig.Prob.35.5');
plot(T,L,'r');
legend('Load duration curve');
L=(A_1-A_2)/(B_2-B_1);// Time in hours
T=(L/t)*100;// % of a year
// From Fig.Prob.35.5,
P_b=30;// MW
P_p=MD-P_b;// MW
A_b=12.38;// cm^2
A_p=0.38;// cm^2
x=20;// Percentage of time
y=10*10^3;// kW
// For base load plant
Q_b=A_b*((x/100)*t)*y;// kWh
LF_b=(Q_b/(P_b*10^3*t))*100;// Load factor
CF_b=(Q_b/(L_b*10^3*t))*100;// Capacity factor
UF_b=(CF_b/LF_b)*100;// Use factor
// For peak load plant
Q_p=A_p*((x/100)*t)*y;// kWh
LF_p=(Q_p/(P_p*10^3*t))*100;// Load factor
CF_p=(Q_p/(L_p*10^3*t))*100;// Capacity factor
UF_p=(CF_p/LF_p)*100;// Use factor
printf('\nFor Base load plant:Load factor=%0.1f
   percentage \n                              Capacity factor=
   %0.0f percentage \n                              Use
   factorr=%0.1f percentage \nFor peak load plant:
   Load factor=%0.2f percentage \n
```

```
                         Capacity  factor=%0.3f
    percentage \n                          Use  factor=%0.2f
    percentage',LF_b,CF_b,UF_b,LF_p,CF_p,UF_p);
// The answer vary due to round off error
```

Scilab code Exa 35.6 Capacity of hydel plant and steam plant

```
// Example 35_6
clc;funcprot(0);
//Given data
MD=50;// MW
md=10;// MW
n_o=60/100;// Over all efficiency of the plant
L_h=60;// MWh

// Calculation
// From Fig.Prob.35.6
// Area DEGHD=0.6*Area EFBE;
// xy-120*10^3=(24-x)*(40*10^3-y)0.6;.....(a)
// y/40000=x/24;.....(b)
// Solving (a) and (b),we get
// x^2+72x-1044=0
coeff=[1,72,-1044];
y=roots(coeff);
x=y(2);// hours
y=(40000/24)*x*(1/1000);// Total capacity of hydel
    plant in MW
L_s=MD-y;// Capacity of steam plant in MW
printf('\nTotal capacity of hydel plant=%0.3f MW \
    nCapacity of steam plant=%0.3f MW',y,L_s);
// The answer vary due to round off error
```