

Scilab Textbook Companion for  
A Course In Power Plant Engineering  
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# Book Description

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

**Exa** Example (Solved example)

**Eqn** Equation (Particular equation of the above book)

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

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

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# Chapter 2

## HYDROLOGY

Scilab code Exa 2.1 Volume of Rainfall

```
1 // Example 2_1
2 clc;funcprot(0);
3 //Given data
4 R=6.2;//Rainfall in cm
5 A=2346;// Area in km^2
6
7 //Calculation
8 Tr=A*10^6*(R/100);// Total rainfall in m^2
9 V=(A*R*10^4)/86400;// Rainfall in day-sec-metre
10 R_k=(A*R*10^4)/10^6;// Rainfall in km^2-m
11 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);
12 // The answer provided in the textbook is wrong
```

---

Scilab code Exa 2.2 Number of days water supplied

```
1 //Example 2_2
```

```

2  clc; funcprot(0);
3  // Given data
4  Pdr=400*106; // Per day requirement in L
5  Pdr=Pdr/103; // convert L to m3
6  Aw=30000*106; // Available water in the dam in m3
7
8  // Calculation
9  n=(Aw)/(Pdr); // days
10 printf('No. of days water supplied ,N=%0.0f days\n',n)
    ;

```

---

### Scilab code Exa 2.3 Total flow volume

```

1  // Example 2_3
2  clc; funcprot(0);
3  // Given data
4  D=[1 2 3 4 5 6 7]; // Days
5  F=[100 320 210 120 50 30 25]; // Mean daily flow in m
    ^3/sec
6
7  // Calculation
8  Tf=F(1)+F(2)+F(3)+F(4)+F(5)+F(6)+F(7);
9  Tfv=24*3600*(Tf); // Total flow volume in m3
10 Tfv_1=Tfv/(106); // million-m3
11 Tfv_2=Tfv/86400; // day-sec-metre
12 Tfv_3=Tfv/(3350*104); // cm
13 Tfv_4=Tfv_1; // km2-m as 1 km2-m =1 million of cu-m
    .
14 printf(' \nTotal flow volume=%0.1f million-m3 \
    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);
15 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 2.4 The output of the generating station

```
1 // Example 2_4
2 clc; funcprot(0);
3 //Given data
4 m_1=20; // The steam discharge during the monsoon
   season of four months in m3/sec
5 m_2=2.5; // The steam discharge during the remaining
   year in m3/sec
6 h_1=3; //The head loss in the pipe in %
7 n_o=90; //Over all efficiency of the generation in %
8 Tn=365; // Total number of days in a year
9 H=80; // metres
10 g=9.81; // m/s2
11 //Calculation
12 N_m=30+31+31+30; //The number of days during which
   the discharge of 20 m3/sec is available
13 N_r=Tn-N_m; //The number of days during which the
   discharge of 2.5 m3/sec is available
14 Tf=(m_1*3600*24*N_m)+(m_2*3600*24*N_r); // Total flow
   during the year in m3
15 m_avg=(Tf)/(3600*24*Tn); //Average discharge in m3/
   sec
16 gradm=m_1-m_avg; // The difference between the
   maximum and average discharge in m3/sec
17 Rc=(gradm*3600*24*N_m)/86400; // Reservoir capacity
   to store the excess water in day-sec-metre
18 H_net=H*(1-(h_1/100)); // metres
19 P_avg=(m_avg*1000*g*H_net*(n_o/100))/(1000); //
   Average kW generated in kW
20 P_avg=P_avg/1000; // MW
21 printf(' \nReservoir capacity to store the excess
   water=%0.0 f day-sec-metre \nAverage kW generated=
   %0.2 f MW', Rc, P_avg);
```

22 // The answer provided in the textbook is wrong

---

**Scilab code Exa 2.5** Power developed

```
1 // Example 2_5
2 clc;funcprot(0);
3 //Given data
4 A=2260;// The catchment area in km^2
5 AAR=154;// The average annual rainfall in cm
6 H=120;// The head drop in m
7 n_t=85;// Turbine efficiency in %
8 n_g=90;// Generation efficiency in %
9 F_l=1;// Load factor
10 N=240;// The speed of the runner in rpm
11 PEL=20;// Percolation and evaporation losses in %
12 g=9.81;// m/s^2
13
14 //Calculation
15 V=A*10^6*(AAR/100)*(1-((PEL/100)));// The quantity
    of water available for power generation per year
    in cu.m
16 Q=V/(365*24*3600);// Quantity of water available per
    second in m^3/sec
17 m=Q*1000;// Discharge in kg/sec
18 P=((m*g*H)/1000)*(n_t/100)*(n_g/100);// Power
    developed in kW
19 P=P/1000;// MW
20 N_a=(N*sqrt(P))/(H)^(5/4);
21 printf('\nPower developed ,P=%0.2f MW \nSingle pelton
    wheel with 4 jets can be used.',P)
22 //The answer seems different due to calculation
    error occur in the book
```

---

**Scilab code Exa 2.6** The energy generated in kWh per year

```
1 // Example 2_6
2 clc; funcprot(0);
3 // Given data
4 A=200; // The catchment area in km2
5 AAR=100; // The average annual rainfall in cm
6 Tro=80; // Total run off in%
7 H=80; // the mean head available in m
8 n_g=75; // Over all efficiency of generation in %
9 Apw=16; // The average period of working in hours
10 g=9.81; // m/s2
11 F_l=1; // Load factor
12
13 // Calculation
14 V=A*106*(Tro/100); // Total water available in m3/
    year
15 Q=V/(365*24*3600); // m3/sec
16 m=Q*1000; // Discharge in kg/sec
17 P=((m*g*H)/1000)*(n_g/100); // Capacity of the plant
    in kW
18 E=(P/1000)*Apw*365*103; // Energy generated per year
    in kWh
19 printf('\\nThe energy generated per year =%0.3e kWh',
    E );
20 // The answer vary due to round off error
```

---

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

```
1 // Example 2_7
2 clc; funcprot(0);
3 // Given data
4 A=1200; // The catchment area in km2
5 AR=160; // The annual rainfall in cm
6 H=360; // The head available in m
```



```

7 n_o=75; // Over all efficiency of the plant in %
8 F_1=0.5; // Load factor
9 PEL=25; // Percolation and evaporation losses in %
10 g=9.81; // m/s^2
11
12 // Calculation
13 V=A*10^6*(AR/100)*(1-((PEL/100))); // The quantity of
    water available for power generation per year in
    cu.m
14 Q=V/(365*24*3600); // Average flow per second in m^3/
    sec
15 m=Q*1000; // Discharge in kg/sec
16 P_avg=((m*g*H)/1000)*(n_o/100); // Average power
    developed in kW
17 P_avg=P_avg/1000; // MW
18 MD=(P_avg/F_1); // Maximum demand in MW
19 printf('\nThe average power developed=%0.2 f MW \
    nMaximum demand=%0.1 f MW',P_avg,MD);
20 // The answer vary due to round off error

```

---

### Scilab code Exa 2.8 Fall in water height

```

1 // Example 2_8
2 clc;funcprot(0);
3 //Given data
4 A=50; // Area in sq.km
5 H_1=100; // Head in m
6 E=13.5*10^6; // The energy utilised by the customer
    in kWh
7 n_g=0.75; // The over all generation efficiency
8 rho_w=1000; // kg/m^3
9 g=9.81; // m/s^2
10
11 //Calculation
12 // V=A*H; // Water used during 5 hours in m^3

```

```

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

```

---

### Scilab code Exa 2.9 The capacity of the power plant

```

1 //Example 2_9
2 clc;funcprot(0);
3 // Given values
4 A=250*10^6; // Catchment area in m^2
5 Ar=1.25; // Annual rainfall in m
6 H=60; // Average head in m
7 P_w=70; // Percentage of water in the dam
8 n_t=0.9 // Turbine efficiency
9 n_g=0.95 // Generator efficiency
10 g=9.81; // The acceleration due to gravity in m/s^2
11
12 // Calculation
13 V=(A*Ar*(P_w/100)); // Total water used for power
        generation in m^3
14 printf('Total water used for power generation=%0.3e
        m^3\n',V);
15 q=(V/(365*24*3600));
16 printf('Water flow rate =%0.2f m^3/sec\n',q);
17 P=((q*1000*9.81*60)/1000)*n_t*n_g*(1/1000);
18 printf('The capacity of the power plant ,P=%0.1f MW\n
        ',P);

```

19 // The answer vary due to round off error

---

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

```
1 // Example 2_10
2 clc;funcprot(0);
3 //Given data
4 H=40; // Head in m
5 A=1.8; // Area of the reservoir in km^2
6 P=24; // MW
7 n_o=80/100; // The over all efficiency
8 rho_w=1000; // kg/m^3
9 g=9.81; // m/s^2
10
11 // Calculation
12 q=(P*1000*1000)/(rho_w*g*H*n_o); // m^3/sec
13 x=(q*3600)/(A*10^6); // m/hr
14 printf('\nThe rate of fall in height of reservoir=%0
    .3f m/hr',x);
```

---

**Scilab code Exa 2.11** Energy produced in kWh

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

```

12 P=((V)/(365*24*3600))*(((rho_w)*g*H*n_g)/(1000)); //
    The power capacity of the plant in kW
13 E=P*F_1*365*24; // Energy produced in kWh
14 printf('\nEnergy produced=%0.0f kW',E);
15 // The answer provided in the textbook is wrong

```

---

### Scilab code Exa 2.12 Generator capacity

```

1 // Example 2_12
2 clc;funcprot(0);
3 //Given data
4 H=30; // m
5 A=250; // sq.km
6 Ar=125; // Annual rainfall in cm
7 Tr=70/100; // Total rainfall
8 F_1=50/100; // Load factor
9 h_1=8/100; // Head loss
10 n_m=90/100; // Mechanical efficiency of the turbine
11 n_g=95/100; // Generator efficiency
12 rho_w=1000; // kg/m^3
13 g=9.81; // m/s^2
14
15 // Calculation
16 V=A*10^6*(Ar/100)*Tr; // Water available during the
    year in m^3
17 Q=(V)/(8760*3600); // Water flow per second in m^3/
    sec
18 Q=Q*1000; // kg/sec
19 n_h=(1-h_1); // Hydraulic efficiency
20 n_o=n_h*n_m*n_g; // The over all efficiency
21 P=(Q*9.81*H*n_o)/(1000); // kW
22 //With 50% load factor
23 Gc=P/F_1; // Generator capacity in kW
24 printf('\nThe power=%0.0f kW \nGenerator capacity=%0
    .1f kW',P,Gc);

```

25 // The answer provided in the textbook is wrong

---

**Scilab code Exa 2.13** Average kW available

```
1 // Example 2_13
2 clc;funcprot(0);
3 //Given data
4 m=[1 2 3 4 5 6 7 8 9 10 11 12];// Month
5 D=[500 200 1500 2500 3000 2400 2000 1500 1500 1000
    800 600];// Discharge in millions of m3 per
    month
6 H=80;// Available head in m
7 n_o=80/100;// Overall efficiency of the generation
8 g=9.81;// The acceleration due to gravity in m/s2
9
10 // Calculation
11 // (a)
12 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 m3/month
13 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];
14 D_1=[500 500 200 200 1500 1500 2500 2500 3000 3000
    2400 2400 2000 2000 1500 1500 1500 1500 1500 1000 1000
    800 800 600 600 3200];
15 Q_a=[Q_a1,Q_a1];
16 m=[0,12];
17 xlabel('Month');
18 ylabel('Discharge in millions of m3 per month');
19 subplot(2,1,1);
20 plot(m_1',D_1', 'b',m',Q_a', 'r-');
21 a=gca();
22 a.x_ticks.labels=["0","J","F","M","A","M","J","J","A",
    "","S","O","N","D"];
23 a.x_ticks.locations=[0;1;2;3;4;5;6;7;8;9;10;11;12];
```

```

24 legend('Hydrograph','Mean flow');
25 D=[200 500 600 800 1000 1500 2000 2400 2500 3000];
26 M=[12 11 10 9 8 7 4 3 2 1]; // Total number of months
    during which flow is available
27 for(i=1:10)
28     T(i)=(M(i)/12)*100;
29 end
30 subplot(2,1,2);
31 xlabel('Percentage of time');
32 ylabel('Discharge in millions of cu.m.month');
33 plot(T,D','b');
34 legend('Flow duration curve');
35
36 m=(Q_a1*10^6/(30*24*3600)); // The average flow
    available in m^3/sec
37 P=((m*1000*g*H)/1000)*(n_o/1000); // Average kW
    available in MW
38 printf('\nAverage kW available at the site=%0.3f MW'
    ,P);
39 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 2.14 Average MW energy available

```

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

```

```

12 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
13 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
14 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
15 Q_a=[Q_a1,Q_a1]; // Mean flow
16 m=[0,12]; // month
17 xlabel('Month');
18 ylabel('Discharge in millions of m^3 per month');
19 subplot(2,1,1);
20 plot(m_1',D_1', 'b',m',Q_a', 'r-');
21 a=gca();
22 a.x_ticks.labels=["0","J","F","M","A","M","J","J","A",
    "","S","O","N","D"];
23 a.x_ticks.locations=[0;1;2;3;4;5;6;7;8;9;10;11;12];
24 legend('Hydrograph','Mean flow');
25 D=[0 20 40 50 80 100 120 150 200 220]; // Discharge
    in millions of m^3 per month
26 M=[12 11 10 9 8 7 4 3 2 1]; // Total number of months
    during which flow is available
27 for(i=1:10)
28     T(i)=(M(i)/12)*100;
29 end
30 subplot(2,1,2);
31 xlabel('Percentage of time');
32 ylabel('Discharge in millions of cu.m.month');
33 plot(T,D', 'b');
34 legend('Flow duration curve');
35 m=((Q_a1*10^6)/(30*24*3600)); // The average flow
    available in m^3/sec
36 P=((((Q_a1*10^6*1000*g*H)/(30*24*3600*1000))*(n_o
    /1000)); // Average kW available in MW
37 printf('\nAverage kW available at the site=%0.3f MW'
    ,P);
38 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 2.15** Flow rate available

```
1 // Example 2_15
2 clc;funcprot(0);
3 //Given data
4 w=[1 2 3 4 5 6 7 8 9 10 11 12];// Week
5 b=[6000 4000 5400 2000 1500 1000 1200 4500 8000 4000
    3000 2000];// Weekly flow in m^3/sec
6
7 //Calculation
8 for(i=1:12)
9     c(i)=b(i)*7;
10 end
11 Cv(1)=c(1);// day-sec-metres
12 Cv(2)=Cv(1)+c(2);// day-sec-metres
13 Cv(3)=Cv(2)+c(3);// day-sec-metres
14 Cv(4)=Cv(3)+c(4);// day-sec-metres
15 Cv(5)=Cv(4)+c(5);// day-sec-metres
16 Cv(6)=Cv(5)+c(6);// day-sec-metres
17 Cv(7)=Cv(6)+c(7);// day-sec-metres
18 Cv(8)=Cv(7)+c(8);// day-sec-metres
19 Cv(9)=Cv(8)+c(9);// day-sec-metres
20 Cv(10)=Cv(9)+c(10);// day-sec-metres
21 Cv(11)=Cv(10)+c(11);// day-sec-metres
22 Cv(12)=Cv(11)+c(12);// day-sec-metres
23 w=[0 1 2 3 4 5 6 7 8 9 10 11 12];// Week for plot
24 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
25 ylabel('Flow in thousands & day-sec-meter');
26 plot(w,CV/1000)
27 // The total flow in the week,Q=7*day-sec-metres.
28 // From fig.prob.2.15
29 C=42*10^3;// The capacity of the reservoir in day-
```



```

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

```

---

### Scilab code Exa 2.16 Storage capacity of the reservoir

```

1 // Example 2_16
2 clc; funcprot(0);
3 // Given data
4 m=[1 2 3 4 5 6 7 8 9 10 11 12]; // Month
5 F=[100 50 20 80 10 10 190 40 30 200 170 80]; // Flow
    in millions of cu-m-per month
6
7 // Calculation
8 Cv(1)=F(1);
9 Cv(2)=Cv(1)+F(2); // Millions of cu-m
10 Cv(3)=Cv(2)+F(3); // Millions of cu-m
11 Cv(4)=Cv(3)+F(4); // Millions of cu-m
12 Cv(5)=Cv(4)+F(5); // Millions of cu-m
13 Cv(6)=Cv(5)+F(6); // Millions of cu-m
14 Cv(7)=Cv(6)+F(7); // Millions of cu-m
15 Cv(8)=Cv(7)+F(8); // Millions of cu-m
16 Cv(9)=Cv(8)+F(9); // Millions of cu-m
17 Cv(10)=Cv(9)+F(10); // Millions of cu-m
18 Cv(11)=Cv(10)+F(11); // Millions of cu-m
19 Cv(12)=Cv(11)+F(12); // Millions of cu-m
20 m=[0 1 2 3 4 5 6 7 8 9 10 11 12]; // Month
21 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

```

```

22 xlabel('Month');
23 ylabel('Millions of cu.m');
24 plot(m,CV,'b');
25 // From Fig.Prob(2.16),from the mass curve
26 Sc=80*10^6;// Storage capacity in m^3
27 sc=85*10^6;// Spill way capacity required in m^3
28 i=13;
29 j=1;
30 Q=((CV(i)-CV(j))/(m(i)-m(j)))*10^6;// The uniform
    discharge in m^3/month
31 // The required storage capacity for the uniform
    supply Q,
32 SC_u=233*10^6;// cu-m.
33 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

```

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

```

```

14 Cv(6)=Cv(5)+D(6); // Millions of cu-m
15 Cv(7)=Cv(6)+D(7); // Millions of cu-m
16 Cv(8)=Cv(7)+D(8); // Millions of cu-m
17 Cv(9)=Cv(8)+D(9); // Millions of cu-m
18 Cv(10)=Cv(9)+D(10); // Millions of cu-m
19 m=[0 1 2 3 4 5 6 7 8 9 10]; // Month
20 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
21 xlabel('Discharge in millions of cu-m month');
22 ylabel('Millions of cu.m');
23 plot(m,CV);
24 // From the mass curve
25 Q_a=72.6; // Flow rate at point a in millions of cu-m
      /month
26 Q_b=166.4; // Flow rate at point b in millions of cu-
      m/month
27 Q_c=137.6; // Flow rate at point c in millions of cu-
      m/month
28 printf('\n\nThe maximum flow available=%0.1f millions
      of cu-m/month \n\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

```
1 // Example 3_1
2 clc; funcprot(0);
3 // Given data
4 m=[1 2 3 4 5 6 7 8 9 10 11 12]; // Month for load
   curve
5 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
6 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
7 H_a=80; // The head available for river A in m
8 H_b=82; // The head available for river B in m
9
10 // Calculation
11 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
12 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
13 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
14 subplot(2,1,1);
15 xtitle('Fig.Prob.3.1.(a)');
16 plot(m',R_a', 'b',m',R_b', 'r');
17 a=gca();
18 a.x_ticks.labels=["0", "J", "F", "M", "A", "M", "J", "J", "A",
    ", "S", "O", "N", "D"];
19 a.x_ticks.locations=[0;1;2;3;4;5;6;7;8;9;10;11;12];
20 legend('Hydrograph of river A', 'Hydrograph of river
    B');
21 D_a=[20 30 40 50 80 100 160 180]; // Discharge in
    millions of cu-m. per month
22 M_a=[12 10 8 7 5 4 3 2]; // No.of months during which
    flow is available
23 D_b=[50 60 70 80 90 100]; // Discharge in millions of
    cu-m. per month
24 M_b=[12 10 6 5 4 2]; // No.of months during which
    flow is available
25 for(i=1:8)
26     T_a(i)=(M_a(i)/12)*100;
27 end
28 for(j=1:6)
29     T_b(j)=(M_b(j)/12)*100;
30 end
31 subplot(2,1,2);
32 xtitle('Fig.Prob.3.1.(b)');
33 plot(T_a,D_a', 'b',T_b,D_b', 'g');
34 legend('Flow duration curve for river A', 'Flow
    duration curve for river B');
35
36 //(a)
37 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
38 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
39 P_a=Q_a*H_a; // The power developed
40 P_b=Q_b*H_b; // The power developed
41 P_r=P_a/P_b; // Power ratio
42 if(P_a>P_b)
43     printf('\n(a)As P_a>P_b,the river A is more
        suitable for storage type power plant');
44 else
45     printf('\n(a)As P_b>P_a,the river B is more
        suitable for storage type power plant');
46 end
47 //(b)From Fig.Prob.3.1(a),The flow available for 85%
    of the time in year
48 Q_b=59.5; // millions of cu-m per month
49 Q_a=29; // millions of cu-m per month
50 P_b=Q_b*H_b;
51 P_a=Q_a*H_a;
52 if(P_b>P_a)
53     printf('\n(b)The site of river B is more
        suitable than the site of river A for run-off
        river power plant');
54 else
55     printf('\n(b)The river A is more suitable than
        the site of river B for run-off river power
        plant');
56 end
57 //(c)when 60% time of the year,the run off is
    required from both the rivers ,thenfrom Fig.Prob
    .3.1(b) ,
58 Q_a=47; // millions of cu-m per month
59 Q_b=66; // millions of cu-m per month
60 Q_r=Q_a/Q_b; // Flow ratio
61 P_a=Q_a*H_a; // The power developed

```

```

62 P_b=Q_b*H_b;// The power developed
63 P_r=P_a/P_b;// Power ratio
64 printf('\n(c)Flow ratio=%0.3f \n    Power ratio=%0.3f
    ',Q_r,P_r);
65 printf('\n(d)From Fig.Prob.3.1(b),At 43 percentage
    of time,the run off rate of both sites is same');
66 // 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 same

```

1 // Example 3_2
2 clc;funcprot(0);
3 // Given data
4 m=[1 2 3 4 5 6 7 8 9 10 11 12];// Month for load
    curve
5 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
6 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
7
8 // Calculation
9 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
10 Q_a=Q_a1/12;// Average flow of the river A in cu-cm/
    month
11 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
12 Q_b=Q_b1/12;// Average flow of the river B in cu-cm/

```

```

month
13 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
14 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
15 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
16 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
    Q_a]; // Average flow of the river A in cu-cm/
    month for plot
17 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
    Q_b]; // Average flow of the river B in cu-cm/
    month for plot
18 subplot(2,1,1);
19 xtitle('Fig.Prob.3.1.(a)');
20 ylabel('Millions of Cu.m/month')
21 plot(m',R_a', 'b',m',R_b', 'g',m',Q_A', 'r-',m',Q_B', '
    b-.');
22 a=gca();
23 a.x_ticks.labels=["0","J","F","M","A","M","J","J","A
    ","S","O","N","D"];
24 a.x_ticks.locations=[0;1;2;3;4;5;6;7;8;9;10;11;12];
25 legend(['Hydrograph of river A','Hydrograph of river
    B','Average flow for River A','Average flow for
    River B'],'in_upper_left');
26 //(a)
27 // From Fig.Prob.3.2(a)
28 Q_B=72; // At 40% of time ,the flow of river B in in
    millions of cu-m per month
29 Q_A=61; // At 40% of time ,the flow of river A in in
    millions of cu-m per month
30 Q_r=(Q_B/Q_A); // Flow ratio

```



```

31 dQ_r=(Q_r-1)*100; // %
32
33 D_a=[10 15 20 30 40 50 60 70 80 90 100 110 120 140];
    // Discharge in millions of cu-m. per month
34 M_a=[12 11 10 9 8 6 5 4 4 2 3 2 2 1]; // No. of months
    during which flow is available
35 for(i=1:14)
36     T_a(i)=(M_a(i)/12)*100;
37 end
38 D_b=[40 50 60 70 80 90 100]; // Discharge in millions
    of cu-m. per month
39 M_b=[12 9 6 5 4 3 2]; // No. of months during which
    flow is available
40 for(j=1:7)
41     T_b(j)=(M_b(j)/12)*100;
42 end
43 Q_a=[Q_a Q_a]; // Average flow of the river A in cu-
    cm/month
44 Q_b=[Q_b Q_b]; // Average flow of the river B in cu-
    cm/month
45 T=[0 100]; // Time in percentage for plot
46 subplot(2,1,2);
47 xtitle('Fig.Prob.3.1.(b)');
48 plot(T_a,D_a','b',T_b,D_b','g',T',Q_a','r-.','T',Q_b
    ','g-.'');
49 legend('Flow duration curve for river A','Flow
    duration curve for river B','Average flow for
    River A','Average flow for River B');
50 printf('\n(a)The ratio of run off of river A and
    river B is %0.2f.',Q_r);
51 //(b)
52 // From Fig.Prob.3.2(b)
53 Q_A=23; // At 80% of time,the flow of river A in in
    millions of cu-cm per month
54 Q_B=48; // At 80% of time,the flow of river B in in
    millions of cu-cm per month
55 if(Q_B>Q_A)
56     printf('\n(b)River B is preferable for runoff

```

```

        type plant. ');
57 else
58     printf('\n(b) River A is preferable for runoff
        type plant. ');
59 end
60 //(c)
61 if(Q_b>Q_a)
62     printf('\n(c) River B is preferable for storage
        type plant also. ');
63 else
64     printf('\n(c) River A is preferable for storage
        type plant also. ');
65 end
66 //(d)
67 // From Fig.Prob.3.2(b)
68 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

```

1 // Example 3_3
2 clc;funcprot(0);
3 //Given data
4 L=[100 160 80 40 20]; // Load in MW
5 T_1=[6,10]; // Time in hours
6 T_2=[10,18]; // Time in hours
7 T_3=[18,20]; // Time in hours
8 T_4=[20,24]; // Time in hours
9 T_5=[0,6]; // Time in hours
10 n_th=[30 35 25 15 10]/100; // The thermal
    efficiencies of the plant
11 n_p=80; // The efficiency of the pump in %
12 n_t=90; // The efficiency of the turbine in %
13
14 // Calculation

```

```

15 //(a)
16 T_p=[0 0 4 4 12 12 14 14 18 18 24 24];// Time in
    hours for load curve
17 L_p=[0 100 100 160 160 80 80 40 40 20 20 100];//
    Load in MW for load curve
18 plot(T_p',L_p', 'b');
19 a=gca();
20 a.x_ticks.labels=["6 A.M", "", "", "12 P.M", "", "", "6 A.
    M", "", "", "12 P.M", "", "", "6 A.M"];
21 a.x_ticks.locations
    =[0;2;4;6;8;10;12;14;16;18;20;22;24];
22 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
23 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
24 n_o1=(O/I_1)*100;// Over all efficiency in %
25
26 //(b)
27 n_op=(n_p/100)*(n_t/100)*100;// The over all
    efficiency of the pump storage plant in %
28 // From the Fig.Prob.3.3
29 function [X]=baseload(y)
30     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))));
31 endfunction
32 y=[10];
33 z=fsolve(y,baseload);
34 x=(z(1));// The capacity of the thermal plant in MW
35 X=[x x x x x x x x x x x];//The capacity of the
    thermal plant in MW for plot
36 xlabel('Time in hrs');

```

```

37 ylabel('Load in MW');
38 plot(T_p',L_p', 'b',T_p',X', 'b-.');
39 legend('Load curve', 'Base load thermal plant');
40 I_2=(x*24)/(n_th(2)); // The energy supplied in the
    second case in MW-hrs
41 n_o2=(O/I_2)*100; // The over all efficiency of the
    combined plant in %
42 PI=((I_1-I_2)/I_1)*100; // The percentage saving in
    input in %
43 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);
44 // The answer vary due to round off error

```

---

### Scilab code Exa 3.4 The capacity of the thermal plant

```

1 // Example 3_4
2 clc;funcprot(0);
3 //Given data
4 L=[60 120 40 10]; // Load in MW
5 T_1=[6,10]; // Time in hours
6 T_2=[10,18]; // Time in hours
7 T_3=[18,24]; // Time in hours
8 T_4=[0,6]; // Time in hours
9 Er=1.5; // Rs/kW-hr
10 c=2.2; // Cost of input in rupees
11 n_th=[35 40 30 20]/100;
12 Q=20000; // kJ
13 n_thb=40/100; // Thermal efficiency
14 n_o=80/100; // Over all efficiency of pump storage
    plant
15

```

```

16 // Calculation
17 //(a)
18 T_p=[0 0 4 4 12 12 18 18 24 24]; // Time in hours
19 L_p=[0 60 60 120 120 40 40 10 10 130]; // Load in MW
20 plot(T_p',L_p', 'b');
21 a=gca();
22 a.x_ticks.labels=["6 P.M", "", "", "12 P.M", "", "", "6 P.
    M", "", "", "12 P.M", "", "", "6 P.M"];
23 a.x_ticks.locations
    =[0;2;4;6;8;10;12;14;16;18;20;22;24];
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
25 Tc_s=Er*O; // Total cost of selling the power in
    rupees
26 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
27 Tc_i=c*(1/(Q))*(I*3600); // Total cost of input
    energy in rupees
28 Nr_1=Tc_s-Tc_i; // Net revenue earned in Rs./day
29
30 //(b)
31 function [Y]=baseload(x)
32     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)));
33     endfunction
34 x=[10];
35 z=fsolve(x,baseload);
36 x=(z(1)); // The capacity of the thermal plant in MW
37 X=[x x x x x x x x x]; // // The capacity of the
    thermal plant in MW for plot
38 xlabel('Time in hrs');
39 ylabel('Load in MW');
40 plot(T_p',L_p', 'b',T_p',X', 'b-.');

```

```

41 legend('Load curve','Base load thermal plant');
42 Ti=((x*24)/n_thb)*3600; // Total input to the thermal
    plant in 24 hours in MJ
43 Tc_i=Er*(1/Q)*Ti*10^3; // Total cost of input energy
    during 24 hours in rupees
44 Nr_2=Tc_s-Tc_i; // // Net revenue earned from the
    combined plant in Rs./day
45 P=((Nr_2-Nr_1)/(Nr_1))*100; // Percentage increase in
    the profit
46 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

```
1 //Example 4_1
2 clc;funcprot(0);
3 //Given data
4 p=25; // kW
5 n=480; // rpm
6 h=5; // m
7 // d_r=D/d
8 d_r=10;
9 H=40; // m
10
11 // Calculation
12 N=n*(1/d_r)*(sqrt(H/h)); // rpm
13 P=p*(d_r)^2*(H/h)^(3/2); // kW
```

```

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

```

---

**Scilab code Exa 4.2** The speed and power of the prototype

```

1 //Example 4_2
2 clc;funcprot(0);
3 //Given data
4 p=4.1; // kW
5 n=360; // r.p.m
6 h=1.8; // m
7 H=6; // m
8 // d_r=D/d
9 d_r=5
10
11 // Calculation
12 N=n*(1/d_r)*sqrt(H/h); // r.p.m
13 P=p*(d_r)^2*(H/h)^(3/2); // kW
14 //Q/q=q_r
15 q_r=(d_r)^2*sqrt(H/h);
16 n_s=(n*sqrt(p))/h^(5/4);
17 N_s=(N*sqrt(P))/(H)^(5/4);
18 printf('\nN=%0.0 f r.p.m\nP=%0.0 f kW\nQ/q=%0.1 f ',N,P,
    q_r);
19 printf('\nThe runner must be of propeller type');
20 // The answer vary due to round off error

```

---

**Scilab code Exa 4.3** The running speed of the model



```

1 //Example 4_3
2 clc; funcprot(0);
3 //Given data
4 P=10000; // kW
5 H=12; // m
6 N=100; // r.p.m
7 // d_r=D/d;
8 d_r=10;
9 h=8; // m
10 n_m=0.8;
11
12 // Calculation
13 n=N*d_r*sqrt(h/H); // r.p.m
14 p=P/((d_r^2*(H/h)^(3/2))); // kW
15 w=1000*9.81; // N
16 q=(p*1000)/(w*h*n_m); // m^3/sec
17 n_s=(n*sqrt(p))/h^(5/4);
18 N_s=(N*sqrt(P))/(H)^(5/4);
19 printf(' \n(a)The running speed of the model, n=%0.0 f
      r.p.m \n(b)B.P, p=%0.1 f kW \n The flow quantity
      required, q=%0.2 f m^3/sec \n The specific speed
      of the runner, N_s=%0.0 f ', n, p, q, N_s );
20 // The answer vary due to round off error

```

---

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

```

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

```

```

10 q=q*SG; // kg/sec
11 n_m=0.88; // The over all efficiency
12
13 // Calculation
14 w=1000*9.81; // N
15 p=(q*w*h*n_m)/(1000*1000); // kW
16 // d_r=D/d;
17 d_r=sqrt(P/p)*(h/H)^0.75;
18 n=N*d_r*sqrt(h/H); // r.p.m
19 n_s=(n*sqrt(p))/h^(5/4);
20 N_s=(N*sqrt(P))/(H)^(5/4);
21 printf('\n(a)The design speed for a turbie ,n=%0.0f r
    .p.m',n);
22 printf('\nThe runner is of Francis type');
23 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 4.5 Power developed by the model

```

1 //Example 4_5
2 clc;funcprot(0);
3 //Given data
4 P=50000; // kW
5 H=225; // m
6 N=600; // r.p.m
7 h=36; // m
8 q=170; // litres/sec
9 n_p=0.9; // Over all efficiency
10 n_m=n_p;
11
12 // Calculation
13 w=1000*9.81; // N
14 Q=(P*1000)/(w*H*n_m); // m^3/s
15 // D_r= d/D
16 D_r=sqrt(sqrt(h/H)*((Q/q)));
17 D=1/D_r;

```

```

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

```

---

**Scilab code Exa 4.6** The number of turbine units required

```

1 //Example 4_6
2 clc;funcprot(0);
3 //Given data
4 Q=260; //m^3/s
5 H=1.7; //m
6 n_p=0.825;
7 N_s=890; // r.p.m
8 N=50; //r.p.m
9
10 //Calculation
11 w=1000*9.81; // N
12 P_t=(Q*w*H*n_p)/(1000); // Total power to be
        developed in kW
13 P=((N_s*H^(5/4))/N)^2; // kW
14 n_k=P_t/P; // Number of kaplan turbine required
15 printf('Number of Kaplan turbine required=%0.0f\n',
        n_k);
16 // The answer vary due to round off error

```

---

**Scilab code Exa 4.7** The least number of machines

```

1 //Example 4_7
2 clc;funcprot(0);
3 //Given data

```

```

4 Q=400; // m^3/sec
5 H=45; // m
6 n_t=0.90; // The turbine efficiency
7 N=250; // r.p.m
8
9 //Calculation
10 w=1000*9.81; // N
11 P_t=(w*Q*H*n_t)/(1000); // kW
12 // (a)
13 N_sf=200; // Specific speed
14 P=((N_sf*H^(5/4))/N)^2; // kW
15 f_n=(P_t/P); // Number of francis turbine required
16 // (b)
17 N_sk=600; // Specific speed
18 P=((N_sk*H^(5/4))/N)^2; // kW
19 k_n=(P_t/P); // Number of kaplan turbine required
20 printf('\n Number of francis turbines=%0.0f \n
        Number of kaplan turbine used=%0.0f',f_n,k_n);
21 if(f_n>k_n)
22     printf('\n The installation of kaplan turbine is
        more economical than francis turbine as
        number of units required is less. ');
23 else(k_n>f_n)
24     printf('\n The installation of francis turbine
        is more economical than kaplan turbine as
        number of units required is less. ');
25 end
26 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 4.8** The least number of machines

```

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

```

```

5 H=30; // m
6 n_t=0.88; // The turbine efficiency
7 f=50; // The frequency of generation in cycles/sec
8 no_p=24; // Number of poles used
9 N_sf=300; // Specific speed
10 N_sk=800; // Specific speed
11
12 // Calculation
13 N=(120*f)/(no_p); // r.p.m
14 w=1000*9.81;
15 P_t=(w*Q*H*n_t)/(1000); // kW
16 P=((N_sf*H^(5/4))/N)^2; // kW
17 f_n=(P_t/P); // Number of francis turbine required
18 P=((N_sk*H^(5/4))/N)^2; // kW
19 k_n=(P_t/P); // Number of kaplan turbine required
20 printf('\n Number of francis turbines=%0.0f \n
        Number of kaplan turbine used=%0.0f',f_n,k_n);
21 // The answer vary due to round off error

```

---

#### Scilab code Exa 4.9 Diameter of the runner

```

1 //Example 4_9
2 clc; funcprot(0);
3 //Given data
4 Q=30; //m^3/sec
5 H=7.5; // m
6 n_t=0.85;
7 N=50; //r.p.m
8 Sr=0.85; //Speed ratio
9 g=9.81; //The acceleration due to gravity in m/s^2
10
11 // Calculation
12 w=1000*9.81; // N
13 P_t=(w*Q*H*n_t)/1000; // kW
14 N_s=(N*sqrt(P_t))/(H)^(5/4); // Specific speed

```

```

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

```

---

**Scilab code Exa 4.10** The power developed by the prototype

```

1 //Example 4_10
2 clc;funcprot(0);
3 //Given data
4 h=36; // m
5 p=135; // kW
6 q=0.44; // m^3/sec
7 H=100; // m
8 N=428; // r.p.m
9 d_r=4; // d_r=D/d
10
11 // Calculation
12 w=1000*9.81; // N
13 n=N*d_r*sqrt(h/H); // r.p.m
14 n_m=(p*1000)/(1000*9.81*q*h); // The efficiency of
    the model
15 n_p=n_m+0.03; //The efficiency of the prototype
16 P=p*(n_p/n_m)*(d_r)^2*(H/h)^(3/2); // kW
17 printf('\n The power developed by the prototype ,P=%0
    .0 f kW',P);
18 n_s=(n*sqrt(p))/h^(5/4);

```

```

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

```

---

#### Scilab code Exa 4.11 Diameter of the runner

```

1 //Example 4_11
2 clc;funcprot(0);
3 //Given data
4 Q=70; // m^3/sec
5 H=15; // m
6 N=200; // r.p.m
7 N_s=340; // Specific speed
8 n_t=0.90; // The efficiency of the turbine
9 rho=1000; // Density in kg/m^3
10 g=9.81; // m/s^2
11 D=[143 151 158.5 165 172.5]; // Diamter of runner in
    cm
12 kW=[66.7 74 82.5 87 92]; // (Unit)
13 rpm=[53 51 48.5 45.4 42.5]; // (Unit)
14
15 // Calculation
16 //(a)
17 printf('\n (a)The type of the runner is Kaplan as
    the specific speed is 340. ');
18 //(b)
19 w=rho*g;
20 P_t=(w*Q*H*n_t)/(1000); // kW
21 P=((N_s*H^(5/4))/N)^2; // kW
22 T_n=P_t/P; // Number of turbine units required
23 printf('\n (b)Number of turbine units required=%0.0f

```

```

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

```

---

**Scilab code Exa 4.12** The maximum height of the francis turbine

```

1 //Example 4_12
2 clc;funcprot(0);
3 //Given data
4 p_a=1.30; // Atmospheric pressure in bar
5 p_c=0.5; // bar
6 V_c=5; // m/sec
7 V_d=2; // m/sec
8 h_f=0.2; // m
9 g=9.81; // m/s^2
10
11 //Calculation
12 w=1000*9.81; // N
13 h=(((p_a-p_c)*1.03*10^5)/w)-((V_c^2)/(2*g))+(((V_d
    ^2)/(2*g))+h_f); // m
14 printf('\n The maximum height of the turbine above
    tail race ,h=%0.3f m',h);
15 // The answer provided in the textbook is wrong

```

---



**Scilab code Exa 4.13** The position of kaplan turbine

```
1 //Example 4_13
2 clc;funcprot(0);
3 //Given data
4 p_a=750;// mm of Hg
5 p_v=400;// mm of Hg
6 p_d=p_a-p_v;// mm of Hg
7 V_c=13; // m/sec
8 // Assume Friction loss and exit velocity of water
   head (V_a^2/(2*g))+h_f=V
9 V=1.5;//m
10 rho=1000;// kg/m^3
11 g=9.81;// m/s^2
12
13 //Calculation
14 w=rho*g;// N
15 h=((p_a-p_d)*1.03*10^5)/(w*760))-((V_c^2)/(2*g))+V;
   // m
16 printf('\n\nThe position of the kaplan turbine with
   respect to tail race ,h=%0.2f m',h);
17 // The answer vary due to round off error
```

---

**Scilab code Exa 4.14** The maximum possible height of the turbine

```
1 //Example 4_14
2 clc;funcprot(0);
3 //Given data
4 p_a=755;// mm of Hg
5 V_c=8;// m/sec
6 V_d=3;// m/sec
7 T_a=20;// C
8 g=9.81;// m/s^2
9
10 //Calculation
```

```

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

```

---

#### Scilab code Exa 4.15 Power Generated

```

1 //Example 4_15
2 clc;funcprot(0);
3 //Given data
4 N_1=200; // r.p.m
5 H_1=25; // m
6 Q=9; // m^3/sec
7 n_t=0.90; // The turbine efficiency
8 g=9.81; // m/s^2
9 rho=1000; // kg/m^3
10
11 // Calculation
12 //(a)
13 N_s=(2*%pi*N_1*sqrt(Q))*(sqrt(n_t))/(60*(g*H_1)
    ^(3/4));
14 //(b)
15 P_1=(rho*g*H_1*Q*n_t)/(1000); // kW
16 //(c)
17 H_2=15; // m
18 N_2=N_1*sqrt(H_2/H_1); // r.p.m
19 P_2=P_1*(H_2/H_1)^(3/2); // kW
20 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);
21 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

```

1 //Example 4_16
2 clc;funcprot(0);
3 //Given data
4 P=5400; // kW
5 N=200; // r.p.m
6 D=3; // m
7 H=240; // m
8 n_t=0.82;
9 rho=1000; // kg/m^3
10 g=9.81; // m/s^2
11
12 //Calculation
13 //(a)
14 Q=(P*1000)/(rho*g*H*n_t); // m^3/sec
15 N_u=(N*D/sqrt(H)); // Unit speed
16 P_u=(P/(D^2*H^(3/2))); // Unit power
17 Q_u=(Q/(D^2*(sqrt(H)))); // Unit flow
18 N_s=(2*pi*N*sqrt(Q)*sqrt(n_t))/(60*(g*H)^(3/4)); //
        Specific speed
19 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=%0.3
        f \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);
20 //(b)
21 // When the head is changed to 160 m,the diameter
        remains same.
22 H=160; // m

```

```

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

```

---

#### Scilab code Exa 4.17 The power developed

```

1 //Example 4_17
2 clc;funcprot(0);
3 //Given data
4 P_1=93; // kW
5 H_1=64; // m
6 H_2=88; // m
7
8 //Calculation
9 //(i)For the same size ,the speed is proportional to
    the square root of head and so
10 // N=N_2/N_1
11 N=sqrt(H_2/H_1);
12 // By solving N, it gives the relation N_2=1.173 N_1
13 N_i=((N*100)-100); //The speed increases in %
14 //(ii)For the same wheel, power varies as H^3/2 and
    so
15 P_2=P_1*(H_2/H_1)^(3/2); // kW

```

```

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

```

---

#### Scilab code Exa 4.18 The specific speed

```

1 //Example 4_18
2 clc;funcprot(0);
3 //Given data
4 P=86000;// kW
5 N=180;// r.p.m
6 H=148;// m
7 D=3.4;// m
8 Q=66.5;// m^3/sec
9 rho=1000;// kg/m^3
10 g=9.81;// m/s^2
11
12 //Calculation
13 N_u=(N*D/sqrt(H));// r.p.m
14 P_u=(P/(D^2*H^(3/2)));// kW
15 Q_u=(Q/(D^2*(sqrt(H))));// m^3/s
16 n_t=((P*1000)/(rho*g*Q*H));// The turbine efficiency
17 N_s=((%pi*D*N)/60)*((sqrt(Q*n_t)/(g*H)^(3/4)));//
    Specific speed
18 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);
19 printf('\nFor this range of specific speed in the SI
    system ,turbine must be francis type');

```

---

#### Scilab code Exa 4.19 Diameter

```

1 //Example 4_19

```

```

2  clc; funcprot(0);
3  //Given data
4  P_1=36000; // kW
5  P_2=27000; // kW
6  N_1=81.8; // r.p.m
7  H_1=13; // m
8  H_2=11; // m
9  D_1=7.82; // m
10
11 //Calculation
12 //As the specific speeds are the same, using the
    definition of specific speed in terms of power,
13 N_2=((N_1*sqrt(P_1)/(H_1^(5/4)))*((H_2^(5/4))/sqrt(
    P_2))); // rpm
14 // As the unit speeds are same,
15 D_2=(D_1*N_1*sqrt(H_2))/(sqrt(H_1)*N_2); // m
16 // As the unit flow is same, Q=Q_2/Q_1
17 Q=(D_2^2*H_2^(1/2))/((D_1^2*H_1^(1/2)));
18 // By solving Q, it gives the relation ,Q_2=0.886*Q_1
    ;
19 Q_r=(1-Q)*100;
20 printf(' \n Speed ,N_2=%0.1 f rpm \n Diameter ,D_2=%0.2 f
    m \n There is a reduction in flow by about %0.2 f
    percentage. ',N_2,D_2,Q_r);
21 // 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

```
1 // Example 5_1
2 clc;clear;funcprot(0);
3 // Given data
4 P=100;// Plant capacity in Mw
5 CV=25600;// Calorific value in kJ/kg
6 n_th=30;// The thermal efficiency of the plant in %
7 n_eg=92;// Electrical generation efficiency in %
8
9 // Calculation
10 // Mechanical energy available=W*CV*(n_th/100) in kJ
    /hr
11 // Electrical energy available=W*CV*(n_th/100)*(n_eg
    /100) in kJ/hr
12 q_e=P*10^3*3600;// Heat equivalent in kJ/hr
13 W=(q_e/(CV*(n_th/100)*(n_eg/100)));// The coal
    required per hour in kg/hr
14 W=(W/1000);// The coal required per hour in tons/hr
15 printf('\nThe coal required per hour,W=%0.2f tons/hr
    ',W);
```

---

**Scilab code Exa 5.2** The capacity of the power plant

```
1 // Example 5_2
2 clc;clear;funcprot(0);
3 // Given data
4 CV=28900; //kJ/kg
5 n_b=83; // The boiler efficiency in %
6 n_t=32; // The turbine efficiency in %
7 n_g=97; // The generator efficiency in %
8 W=30; // The coal consumption of the station in tons/
   hr
9
10 // Calculation
11 P=((W*1000*CV)*(n_b/100)*(n_t/100)*(n_g/100))
   /(3600*1000); // The capacity of the power plant
   in MW
12 printf('\n The capacity of the power plant ,P=%0.0 f
   MW',P);
```

---

**Scilab code Exa 5.3** The volume of gas required

```
1 //Example 5_3
2 clc;funcprot(0);
3 // Given values
4 P=100; // Power in kW
5 CV=4000; // Calorific value in kJ/m^3
6 n_o=0.20; // Over all efficiency of the plant
7
8 // Calculation
9 V=(3600*P)/(CV*n_o); // m^3/hr
10 printf('The volume of gas required per hour ,V=%0.0 f
   m^3/hr\n',V);
```





# Chapter 14

## BOILER ACCESSORIES

Scilab code Exa 14.1 Desuperheater

```
1 // Example 14_1
2 clc; funcprot(0);
3 //Given data
4 P=35; // bar
5 T_1=400; //Temperature of steam in C
6 m_s=200; // Flow rate of steam in Tonnes/hr
7 T_2=450; // C
8 T_sp=60; // The temperature of spray water in C
9 C_pw=4.2; // kJ/kg. C
10 //Calculation
11 //From steam tables,
12 //At 35 bar and 450 C
13 h_1=3337; // kJ/kg
14 //At 35 bar and 400 C
15 h_2=3222; // kJ/kg
16 h_w=C_pw*(T_sp-0); // kJ/kg
17 m_w=m_s*((h_1-h_2)/(h_2-h_w)); //The mass of water
    supplied to the super heater in tons/hr
18 m_w=(m_w*1000)/3600; // kg/hr
19 printf('\n\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

```
1 // Example 14_2
2 clc; funcprot(0);
3 //Given data
4 m_s=65; // Flow rate of steam in kg/sec
5 p=60; // Pressure in bar
6 m_fw=63; // Flow rate of feed water in kg/sec
7 m_mw=2; // Flow rate of make up water in kg/sec
8 moisture=2; // %
9 m_dsalt=3; // Mass of dissolved salt in ppm
10 m_dsolid=5; // Mass of dissolved salt in ppm
11 m_sc=1000; // ppm
12 m_bd=5; // ppm
13 m_c=8; // kg/sec
14 T=30; // Room temperature in C
15 CV=20000; // Calorific value in kJ/kg
16 C_pw=4.2; // kJ/kg. C
17 m_w=1; // kg (Assumption)
18
19 //Calculation
20 //(a)
21 // Making the mass balance of the impurities
   entering and leaving the drum,
22 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
23
24 //(b)
25 //From Steam tables ,at p=60bar
26 h_fp=1213.35; // kJ/kg
27 h_fT=m_w*(T-0)*C_pw; // kJ/kg
28 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 %
29
30 //(c)
31 m_sd=((moisture/100)*m_w*m_dsolid*10^-6)*3600; // kg/
    hr
32 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);
33 // The answer provided in the textbook is wrong

```

---

### Scilab code Exa 14.3 The vertical height of the economiser coils

```

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

```

```

21
22 // Calculation
23 //From steam tables , at p=140 bar
24 T_s=336.75; // C
25 h_f1=1571.2; // kJ/kg
26 v_w=0.00161; // m^3/kg
27 //At 170 C ,
28 h_f2=m*C_pw*(T_1-0); // kJ/kg
29 Q=m_w*(h_f1-h_f2); // kJ/sec
30 T_gi=T_go+(Q/(C_pg*m_g)); // C
31 Theta_i=(T_gi-T_s); // C
32 Theta_o=(T_go-T_1); // C
33 LMTD_counter=(Theta_i-Theta_o)/(log(Theta_i/Theta_o)
    ); // Logrithemic mean temperature difference in
    C
34 LMTD_cross=LMTD_counter*1.12; // C
35 A_s=(Q*10^3)/(U_o*LMTD_cross); // m^2
36 n=m_w/(((%pi/4)*(d_i/1000)^2*(V_w/v_w)));
37 L=(A_s/(%pi*(d_o/1000)*n)); // meters
38 N=L/(B-(2*C/100)); // The number of the turns of the
    coil
39 printf('\nLength, L=%0.0f meters \nThe number of the
    turns of the coil=%0.0f', L, N);
40 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 14_4
2 clc; funcprot(0);
3 //Given data
4 m_g=1250; // The mass flow in the gases in kg/sec
5 m_a=1170; //The air flow rate in kg/sec
6 T_gi=450; //
7 T_go=160; // Temperature of hot gases at inlet and

```

```

    outlet in C
8 T_ai=35; // C
9 d_i=60; // mm
10 d_o=65; // mm
11 U_o=30; //Over all heat transfer coefficient in W/m^2
    C
12 V_g=13; // Gas velocity in m/sec
13 C_pg=1.1; // kJ/kg- C
14 C_pa=1; // kJ/kg- C
15 R_g=287; // J/kg-K
16 p=101.325; // kPa
17
18 //Calculation
19 v_gi=((R_g/1000)*(T_gi+273))/(p); //Specific volume
    of gas at entry in m^3/kg
20 T_ao=((m_g*C_pg*(T_gi-T_go))/(m_a*C_pa))+T_ai; // C
21 Theta_i=(T_gi-T_ao); // C
22 Theta_o=(T_go-T_ai); // C
23 LMTD_counter=(Theta_i-Theta_o)/(log(Theta_i/Theta_o)
    ); //Logrithemic mean temperature difference in
    C
24 LMTD_actual=LMTD_counter*1.2; // C
25 A=(m_g*C_pg*(T_gi-T_go)*10^3)/(U_o*LMTD_actual); // m
    ^2
26 n=m_g/((%pi/4)*(d_i/1000)^2*(V_g/v_gi)); // Number of
    tubes used in air heater
27 L=(A/(%pi*(d_o/1000)*n)); // meters
28 printf('\nThe length ,L=%0.0f m \n\nThe number of tubes
    used in air heater=%0.0f',L,n);
29 // The answer vary due to round off error

```

---

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

```
1 // Example 14_5
```

```

2  clc; funcprot(0);
3  //Given data
4  p=60; // bar
5  T=500; // C
6  V_s=10; // m/sec
7  d_i=50; // mm
8  d_o=60; // mm
9  m_s=100; // kg/sec
10 q=150; // The amount of heat given in the super
    heater to the steam in kW/m^2
11 C_pg=1.2; // kJ/kg- C
12 gradT_g=100; // C
13
14 //Calculation
15 //From steam tables ,
16 // At p=60 bar(saturated)
17 h_1=2784.3; // kJ/kg
18 // At p=60 bar and T=500 C
19 h_2=3422.3; // kJ/kg
20 v_s2=0.0567; // m^3/kg
21 Q=m_s*(h_2-h_1); // kJ/sec
22 A_s=Q/q; // m^2
23 n=m_s/(((%pi/4)*(d_i/1000)^2*(V_s/v_s2)));
24 L=(A_s/(%pi*(d_o/1000)*n)); // m
25
26 //(b)
27 m_g=(Q)/(C_pg*gradT_g); // kg/sec
28 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

## CONDENSERS

Scilab code Exa 17.1 The cooling water required per hour

```
1 // Example 17_1
2 clc; funcprot(0);
3 // Given data
4 P_1=100; // bar
5 T_1=400; // C
6 n_t=80; // The isentropic efficiency of the turbine
   in %
7 P_2=0.1; // Pressure in the condenser in bar
8 SSC=4; // The specific steam consumption in kg/kWh
9 T_c=5; // Under cooling temperature in the condenser
   in C
10 //gradT=(T_wo-T_wi)
11 gradT=10; // Rise in temperature of the cooling water
   in C
12 P=120; // Plant capacity in kW
13 C_pw=4.2; // kJ/kg. C
14
15 // Calculation
16 //(a)
17 m_s=SSC*P*10^3; // The steam to be condensed in the
   condenser in kg/hr
```



```

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

```

---

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

```

1 // Example 17_2
2 clc;funcprot(0);
3 //Given data
4 P_1=100;// bar
5 T_1=400;// C
6 T_wi=20;// C
7 P_v=71;// cm of Hg
8 P_b=76;//cm of Hg
9 gradT=10;// Rise in temperature of the cooling water
    in C
10 rho_w=1080;// kg/m^3
11 C_pw=4.6;//kJ/kg. C
12 U=400;// The over all heat transfer coefficient in W
    /m^2. C
13 P=30;// kW
14
15 //Calculation
16 P_2=(P_b-P_v)*0.01359;// The pressure in the
    condenser in bar
17 // From h-s chart ,

```

```

18 h_1=3389; // kJ/kg
19 h_2=2054; //kJ/kg
20 m_s=(P*1000)/(h_1-h_2); // Mass of steam in kg/sec
21 x_2=0.782; // dryness fraction from h-s chart
22 // Heat lost by steam in condenser = Heat gained by
    water
23 h_f2=159.6; //kJ/kg
24 m_w=((h_2-h_f2)*m_s)/(C_pw*gradT); // kg/sec
25 CP=m_w; // Capacity of the pump in kg/sec
26 Theta_i=(38-20); // C
27 Theta_o=(38-30); // C
28 LMTD=(Theta_i-Theta_o)/log(Theta_i/Theta_o); // C
29 A=((h_2-h_f2)*m_w)/(U*LMTD); // The heat transfer
    area of the condenser in m^2
30 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);
31 // The answer vary due to round off error

```

---

### Scilab code Exa 17.3 The thermal efficiency of the plant

```

1 // Example 17_3
2 clc;funcprot(0);
3 //Given data
4 P=3000; // kW
5 P_1=10; // bar
6 T_1=250; // C
7 P_c=65; // cm of Hg
8 P_b=75.2; // cm of Hg
9 gradT=15; // C
10 T_c=35; // The temperature of the condensate in C
11 C_pw=4.2; // kJ/kg. C
12
13 //Calculation

```

```

14 //(a)
15 p_t=(P_b-P_c)*0.1359;// bar
16 p_s=p_t;// bar (as p_a=0)
17 // From h-s chart
18 x=0.846;// Dryness fraction from h-s chart
19 h_1=2984;// kJ/kg
20 h_2=2234;// kJ/kg
21 h_f2=147;//kJ/kg
22 gradh=(h_1-h_2);// kJ/kg
23 m_s=P/gradh;// kg/sec
24 m_s=m_s*3600;// kg/hr
25 SSC=m_s/P;// Specific steam consumption in kg/kW-hr
26 //(b)
27 n_th=(gradh/(h_1-h_f2))*100;// Thermal efficiency in
    %
28 //(c)
29 m_w=(m_s*(h_2-h_f2))/(gradT*C_pw*1000);// Cooling
    water supplied in tons/hr.
30 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

```

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

```

```

10 gradT=10; //The rise in cooling water temperature in
    C
11 R=287; // Gas constant in J/kg k
12 p_b=1.013; // bar
13 C_pw=4.2; // kJ/kg.k
14
15 //Calculation
16 //From steam tables
17 //(a)
18 //At 40 C saturation temperature
19 p_s=0.0752; // Pressure in bar
20 v_s=19.5; // Specific volume in m^3/kg
21 V=m_a*x*v_s; // Volume in m^3
22 p_a=(m_a*R*(T_s+273))/(V*10^5); // The pressure of
    air in the condenser in bar
23 p_t=p_a+p_s; // The total pressure in the condenser
    in bar
24 P_v=(p_b-p_t)/0.013959; // Vacuum in condenser in cm
    of Hg
25
26 //(b)
27 // From steam tables ,At 32 C
28 p_s1=0.0485; // Partial pressure of steam in bar
29 p_a1=p_t-p_s1; // bar
30 V_1=(m_a*R*(T_suction+273))/(p_a1*10^5); // Volume of
    air at 32 C in m^3/hr
31 Apc=V_1; // Air pump capacity in m^3/hr
32
33 //(c)
34 v_s1=29.6; // Specific volume of steam at 32 C
    saturation temperature in m^3/hr
35 Ls=V_1/v_s1; // Loss of steam in kg/hour
36
37 //(d)
38 // From steam tables ,At 40 C saturation
    temperature and 0.85 dry
39 h_f1=168; // kJ/kg
40 h_fg1=2414; // kJ/kg

```

```

41 h_1=h_f1+(x*h_fg1); // kJ/kg
42 h_f2=147; // kJ/kg
43 m_w=(m_s*(h_1-h_f2))/(C_pw*gradT*1000); // Quality of
    cooling water passed through the condenser in
    tons/hr
44 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,Ap_c,Ls,m_w);
45 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 17.5 Loss of condensate per hour

```

1 // Example 17_5
2 clc; funcprot(0);
3 // Given data
4 T_s=56; // Temperature of steam entering the
    condenser in C
5 T_a=46; // Temperature at the air pump suction in C
6 P_b=76; // The barometer reading in cm of Hg
7 Q=90; // The discharge of dry air pump in m^3/min
8 R=287; // J/kg.k
9
10 // Calculation
11 // (a)
12 // From steam tables, at saturation temperature of 56
    C
13 p_s=0.1684; // Pressure of steam in bar
14 p_s=p_s/0.01359 // cm of Hg
15 p_a=0; // Partial pressure air at the inlet of
    condenser in cm of Hg
16 p_t=p_s+p_a;
17 p_v=P_b-p_t; // Vacuum in the condenser in cm of Hg
18

```

```

19 // (b)
20 // From steam tables, at saturation temperature of 46
    C
21 p_s1=0.1028; // bar
22 v_s=14.56; // m^3/kg
23 p_a1=(p_t*0.01359)-p_s1; // bar
24 m_a=(p_a1*10^5*Q*60)/(R*(T_a+273)); // The air leakage
    in the condenser per hour in kg/hr
25 // (c)
26 Ls=(Q*60)/v_s; // Loss of condensate in kg/hr
27 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);
28 // The answer vary due to round off error

```

---

#### Scilab code Exa 17.6 Minimum capacity of the air pump

```

1 // Example 17_6
2 clc; funcprot(0);
3 // Given data
4 m_a=84; // kg/hr
5 p_v=70; // cm of Hg
6 p_b=76; // cm of Hg
7 T_i=20; // The temperature at the inlet of the vacuum
    pump in C
8 n_v=80; // Volumetric efficiency in %
9 N=200; // rpm
10 LbyD=3/2; // L/D ratio
11 R=287; // J/kg.k
12
13 // Calculation
14 // (a)
15 p_t=((p_b-p_v)/p_b)*1.013; // bar
16 // From steam table, a saturation temperature at 20

```

```

      C
17  p_s=0.0238; // bar
18  v_s=57.63; //The specific volume of saturated steam
      in m^3/kg
19  p_a=p_t-p_s; // Partial pressure of air at point A in
      bar
20  V=(m_a*R*(T_i+273))/(p_a*10^5); // Total volume in m
      ^3/hr
21
22  //(b)
23  D=(((V/60)*100^2*100*4)/(%pi*1.5*N*(n_v/100)))^(1/3)
      ; // cm
24  L=1.5*D; // Stroke of air pump in cm
25
26  //(c)
27  m_s=V/v_s; // kg/hr
28  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);
29  // The answer vary due to round off error

```

---

### Scilab code Exa 17.7 The capacity of wet air pump

```

1  // Example 17_7
2  clc; funcprot(0);
3  //Given data
4  m_s=12500; // kg/hr
5  m_a=5; // kg/hr
6  p_v=70; // cm of Hg
7  p_b=76; // cm of Hg
8  T=34; // C
9  n_v=80; // Volumetric efficiency in %
10 N=100; // rpm

```

```

11 LbyD=1.5; // L/D ratio
12 R=287; // J/kg.k
13
14 // Calculation
15 // From steam table, a saturation temperature at 34
    C
16 p_s=0.0542; // bar
17 p_t=(p_b-p_v)*0.01359; // Pressure in condenser in
    bar
18 p_a=p_t-p_s; // Partial pressure of air in bar
19 V=(m_a*R*(T+273))/(p_a*10^5); // Volume of air in the
    condenser in m^3/hr
20 V=V/60; // m^3/min
21 V_s=m_s/(60*1000); // Volume of condensate formed m
    ^3/min
22 T_v=V+V_s; // Total volume of air and condensate
    removed by the pump m^3/min
23 D=((T_v*100^2*100*4)/(pi*1.5*N*(n_v/100)))^(1/3); //
    Diameter in cm
24 L=1.5*D; // Stroke of air pump in cm
25 printf('\n The capacity of wet air pump=%0.3f m^3/
    min \n The dimensions of pump D=%0.1fcm & L=%0.0
    fcm ',T_v,D,L);
26 // The answer vary due to round off error

```

---

**Scilab code Exa 17.8** Percentage increase in air pump capacity and Percentage increase in loss of water vapour

```

1 // Example 17_8
2 clc; funcprot(0);
3 // Given data
4 T_s=38; // The temperature of the steam entering the
    condenser in C
5 T_a=34; // The temperature of the air entering the
    air pump in C

```



```

6 T_c=36; // The temperature of the air of the
   condensate in C
7 m_a=3; // kg/hr
8 m_c=8000; //The condensate removed in kg/hr
9 R=287; // J/kg.k
10
11 // Calculation
12 //(a)
13 //From steam table , a saturation temperature at 38
   C
14 p_s1=0.0676; // bar
15 p_a1=0.0; // bar
16 p_t=p_a1+p_s1; // bar
17 //From steam table , a saturation temperature at 34
   C
18 v_s1=26.5; // kg/hr
19 p_s=0.0542; // bar
20 p_a=p_t-p_s; // Partial pressure of air at the entry
   of air pump in bar
21 V_1=(m_a*R*(T_a+273))/(p_a*10^5); // m^2/hr
22
23 //(b)
24 // From steam table , a saturation temperature at 36
   C
25 v_s2=24; // kg/hr
26 p_s=0.0606; // bar
27 p_a=p_t-p_s; // bar
28 V_2=(m_a*R*(T_c+273))/(p_a*10^5); // m^2/hr
29 V=m_c*0.001006; // m^3/hr
30 Tv=V_2+V; // Total volume removed by wet air pump in
   m^3/hr
31 Pi_apc=((Tv-V_1)/V_1)*100; // Percentage increase in
   air-pump capacity in %
32 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
33 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
34 Pi_lwv=((m_wv-m_wd)/m_wd)*100; // Percentage increase
    in loss of water vapour
35 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)
    ;
36 // The answer vary due to round off error

```

---

**Scilab code Exa 17.9** The quantity of cooling water required

```

1 // Example 17_9
2 clc;funcprot(0);
3 //Given data
4 P=12500; // Steam turbine capacity in kW
5 M_a=1/1000; //kg per kg of steam
6 M_s=5; // kg/hr/kW
7 p_v=70; // cm of Hg
8 p_b=76; // cm of Hg
9 T_s=30; // The temperature at the suction of the air
    pump in C
10 gradT=8; // Rise in temperature of the water in C
11 x_1=0.9; // Dryness fraction
12 R=287; // J/kg k
13 C_pw=4.2; // kJ/kg. C
14
15 //Calculation
16 //From Steam tables , At 30 C
17 p_s=0.04325; // Partial pressure of steam in bar
18 v_s=32.8; // Specific volume of steam in m^3/kg
19 h_fg1=2438; // kJ/kg
20 //(a)
21 p_t=((p_b-p_v)/p_b*1.013); //bar
22 p_a=p_t-p_s; //Partial pressure of air in bar

```

```

23 m_a=P*M_s*M_a*(1/60); //Air leakage into the
    condenser in kg/min
24 V=(m_a*R*(T_s+273))/(p_a*10^5); //Volume of air in m
    ^3/min
25
26 //(b)
27 m_s=(V*60)/v_s; //The mass of water vapour carried
    with air in kg/hr
28
29 //(c)
30 m_s1=(P*M_s)/60; // kg/min
31 m_w=((m_s1*x_1*h_fg1)/(C_pw*gradT*1000)); // tons/min
32 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);
33 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 17.10 The mass of water required

```

1 // Example 17_10
2 clc; funcprot(0);
3 //Given data
4 x=0.9; // Dryness fraction
5 T_wi=15; //Cooling water inlet temperature C
6 R_air=287; // Nm/kg.K
7 R_steam=462.8; // Nm/kg.K
8 p_v=61.3; // cm of Hg
9 p_b=76; // cm of Hg
10 // p_a=0.3*p_t(given)
11 C_pw=4.2; // kJ/kg C
12
13
14 // Calculation
15 p_t=(p_b-p_v)*0.01359; // bar

```

```

16 p_a=0.3*p_t;// bar
17 p_s=p_t-p_a;// bar
18 // From steam tables , Saturation temperature of steam
    at 0.14 bar
19 T_s=52;// C
20 T_m=T_s;// Mixture temperature coming out of
    condenser in C
21 // From steam tables , At steam pressure of 0.14 bar ,
22 h_f1=218.4;// kJ/kg
23 h_fg1=2381.4;// kJ/kg
24 // m=m_w/m_s;
25 T_wo=T_s;// C
26 m=((h_f1+(x*h_fg1))-(C_pw*T_s))/(C_pw*(T_wo-T_wi));
27 printf('\n(a) Mixture temperature coming out of
    condenser=%0.0 f 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

```

1 // Example 17_11
2 clc; funcprot(0);
3 // Given data
4 m_s=30*10^3;// kg/hr
5 x=90/100;// Dryness fraction
6 v=1.5;// Water speed in m/s
7 d_o=2;// cm
8 t=1.2;// mm
9 T_wi=15;// C
10 T_wo=25;// C
11 U_o=3000;// W/m^2 C
12 P_abs=0.04;// bar
13 C_pw=4.2;// kJ/kg.k
14

```

```

15 //Calculation
16 T_s=28.6// The saturation temperature of steam at
    0.04 bar in C
17 h_fg=2440;// kJ/kg (from steam tables)
18 //Total heat lost by steam power=Total heat gained
    by water
19 m_w=(m_s*h_fg*x)/(C_pw*(T_wo-T_wi));// kg/hour
20 Theta_i=T_s-T_wi;// C
21 Theta_o=T_s-T_wo;// C
22 LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));//
    Logrithemic mean temperature difference in C
23 A=((m_w*h_fg*x)/3600)/(U_o*LMTD);// m^2
24 d_i=(d_o*10)-(2*t);// mm
25 T_a=(T_wi+T_wo)/2;
26 // For T_a=20 C ,
27 rho=998.2;// Density in kg/m^3
28 n=(m_w/((%pi/4)*(d_i/(10*100))^2*rho*3600));// The
    number tubes of tubes in one pass
29 Tn=2*n;// Total number of tubes in both passes
30 L=A/(%pi*(d_o/100)*Tn);// The length of each tube in
    m
31 printf('\n\nThe surface area required ,A=%0.1f m^2\n\nThe
    number of tubes in each pass ,n=%0.0f\n\nThe length
    of each tube ,L=%0.2f m',A,n,L);
32 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 17.12** The area of the condenser required

```

1 // Example 17_12
2 clc;funcprot(0);
3 //Given data
4 m_s=10;// Tonnes
5 U=4;// KW/m^2. C
6 P=0.2;// bar
7

```

```

8 //Calculation
9 h_fg=2358.3;// Latent heat of steam at 0.2 bar
   pressure in kJ/kg
10 Q=(m_s*1000*h_fg)/3600;//kW
11 //The given data is T_s-T_wo=10 C ; T_wo-T_wi=20 C ;
   Using this two equations ,we get
12 Theta_i=30;// C
13 Theta_o=10;// C
14 LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o));//
   Logrithemic mean temperature difference in C
15 A=Q/(U*LMTD);// m^2
16 printf('\n\nThe area of the condenser required=%0.0f m
   ^2',A);

```

---

#### Scilab code Exa 17.13 Number of tubes

```

1 // Example 17_13
2 clc;funcprot(0);
3 //Given data
4 m_s=5000;// kg
5 T_s=50;// C
6 d_i=15;// mm
7 d_o=18;// mm
8 Theta_o=20;// C
9 T_r=10;// C
10 Theta_i=Theta_o+T_r;// C
11 L=3;// Length in m
12 v=2;// Velocity in m/s
13 h_o=5000;// J/m^2-s- C
14 h_i=3200;// J/m^2-s- C
15 f_i=0.0002;// m^2- C/W
16 K=80;// W/m- C
17
18 //Calculation
19 // At 50 C saturated temperature

```

```

20 h_fg=2383; // kJ/kg
21 Q=(m_s*h_fg)/3600; //kW
22 LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o)); // C
23 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
24 A=((Q*10^3)/(U_o*LMTD)); // m^2
25 n=(A/(%pi*(d_o/1000)*L));
26 printf('\n\nThe number of tubes required=%0.0f',n);
27 // The answer vary due to round off error

```

---

**Scilab code Exa 17.14** The number of tubes required

```

1 // Example 17_14
2 clc;funcprot(0);
3 //Given data
4 P=120; //Plant capacity in MW
5 p_1=150; // bar
6 T_1=600; // C
7 p_2=0.08; // bar
8 h_i=1000; // Heat transfer coefficient of water side
    in W/m^2 C
9 h_o=5000; // Heat transfer coefficient of steam side
    in W/m^2 C
10 T_wi=25; // The inlet temperature of water in C
11 T_wo=35; //The outlet temperature of water in C
12 d_i=2.5; // cm
13 d_o=2.9; // cm
14 L=5; // Length of the tube in m'
15
16 //Calculation
17 // From steam tables ,the saturation temperature of
    the steam at 0.08 bar
18 T_c=41.5; //The condensate temperature in C
19 h_f2=174; // kJ/kg
20 //From h-s chart ,

```

```

21 h_1=3580; // kJ/kg
22 h_2=2080; // kJ/kg
23 m_s=((P*1000)/(h_1-h_2)); // The mass of steam
    flowing through the turbine in kg/sec
24 Q=m_s*(h_2-h_f2);
25 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
26 Theta_i=(T_c-T_wi); // C
27 Theta_o=(T_c-T_wo); // C
28 LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o)); //
    Logrithemic mean temperature difference in C
29 A_s=(Q/(U_o*LMTD)); //m^2
30 n=(A_s/(%pi*(d_o/100)*L));
31 printf('The number of tubes required=%0.0f tubes',n)
    ;
32 // 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

```

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

```



```

15
16 // Calculation
17 // From steam tables at 0.04 bar,
18 T_s=28.6; // C
19 h_fg=2433; // kJ/kg
20 m_s=(m_s*1000)/3600; // kg/sec
21 m_w=(m_s*h_fg*x)/(C_pw*(T_wo-T_wi)); // kg/sec
22 Theta_i=(T_s-T_wi); // C
23 Theta_o=(T_s-T_wo); // C
24 LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o)); //
    Logarithmic mean temperature difference in C
25 Q=m_s*h_fg*x; // kJ/sec
26 A=(Q/(U*LMTD)); // m^2
27 n_1=m_w/((%pi/4)*(d_i/1000)^2*v*rho); // Number of
    tubes in each pass
28 n=n_1*2; // Total number of tubes in both passes
29 L=A/(%pi*(d_o/1000)*n); // Length of each tube in m
30 printf('\n The 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
31 // The answer vary due to round off error

```

---

**Scilab code Exa 17.16** Percentage reduction in air pump capacity

```

1 // Example 17_16
2 clc; funcprot(0);
3 // Given data
4 m_s1=20; // tons/hr
5 m_s1=20*10^3; // kg/hr
6 m_a1=6; // kg/hr
7 T_1=39; // C
8 T_2=28; // C
9 T_3=36; // C
10 gradT=15; // C
11 R=287; // J/kg. C

```

```

12 C_pa=1.005; // kJ/kg. C
13 C_pw=4.18; //kJ/kg. C
14
15 // Calculation
16 // Considering section 1-1
17 // From steam tables ,at T_1=39 C
18 p_s1=0.06991; // bar
19 v_s1=20.56; // m^3/kg
20 h_s1=2572.6; // kJ/kg
21 V_s1=(m_s1*10^3*v_s1); // m^3/hr
22 // By Dalton 's law ,
23 V_a1=V_s1; // m^3/hr
24 p_a1=(m_a1*R*(T_1+273))/(V_a1); // N/m^2
25 p_a1=p_a1/10^5; // bar
26 p_t=p_s1+p_a1; // bar
27
28 //Considering section 2-2
29 //From steam tables ,at T_2=28 C
30 p_s2=0.0378; // bar
31 v_s2=36.728; // m^3/kg
32 h_s2=2552.7; // kJ/kg
33 p_a2=p_t-p_s2; // bar
34 V_a2=(m_a1*R*(T_2+273))/(p_a2*10^5); // m^3/hr
35 //As per Dalton 's law ,
36 V_s2=V_a2; // m^3/hr
37 m_s2=V_a2/v_s2; // kg/hr
38
39 // Considering section 3-3
40 // From steam tables ,at T_3=36 C
41 p_s3=0.0594; // bar
42 v_s3=23.967; // m^3/kg
43 p_a3=p_t-p_s3; // bar
44 V_s3=(m_a1*R*(T_3+273))/(p_a3*10^5); // m^3/hr
45 V_a3=V_s3; // m^3/hr
46 m_s3=V_a3/v_s3; // kg/hr
47 Pr=((V_a3-V_a2)/V_a3)*100; // %
48
49 // Determination of cooling water requirement

```

```

50 // Assume
51 m_a2=m_a1;
52 m_c=m_s1; // (assumed)
53 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
54 m_w=m_w/10^3; // tons/hr
55 m_w=(m_w*10^3)/3600; // kg/sec
56 m_sc=m_s3-m_s2; // Saving in condensate in kg/hr
57 Q=m_sc*C_pw*(T_3-gradT); //kJ/hr
58 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);
59 // The answer vary due to round off error

```

---

**Scilab code Exa 17.17** The length and number of condenser tubes

```

1 // Example 17_17
2 clc; funcprot(0);
3 //Given data
4 m_s=250; // tons/hr
5 T_s=40; // C
6 T_wi=30; // C
7 T_wo=36; // C
8 U_o=2.5; //kW/m^2 C
9 P_t=0.078; // bar
10 v=1.8; // m/s
11 d_i=23; // mm
12 d_o=25; // mm
13 rho_w=1000; // kg/m^3
14 moisture=12; // Percentage
15 x_2=(100-12)/100; // Dryness fraction
16 p_t=0.078; // bar

```

```

17 C_pw=4.2; // kJ/kg. C
18 R=287; // J/kg C
19 v=1.8; // m/s
20
21 // Calculation
22 // From steam tables, at 40 C \
23 p_sat=0.074; // bar
24 h_fg2=2407; // kJ/kg
25 v_g2=19.54; // m^3/kg
26 // gradh=H_2-h_3
27 gradh=x_2*h_fg2; // kJ/kg
28 m_s=(250*1000)/3600; // kg/sec
29 m_w=(m_s*gradh)/(C_pw*(T_wo-T_wi)); // kg/sec
30 p_air=p_t-p_sat; // bar
31 v_s2=x_2*v_g2; // m^3/kg
32 m_a=(m_s*v_s2*p_air*10^5)/(R*(T_s+273)); // kg/sec
33 Theta_i=(T_s-T_wi); // C
34 Theta_o=(T_s-T_wo); // C
35 LMTD=(Theta_i-Theta_o)/(log(Theta_i/Theta_o)); //
    Logrithemic mean temperature difference in C
36 A_s=(m_s*gradh)/(U_o*LMTD); // m^2
37 n=(m_w)/((%pi/4)*(d_i/1000)^2*rho_w*v); // Number of
    tubes
38 L=A_s/(%pi*(d_o/1000)*n); // Length in m
39 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);
40 // 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

```
1 // Example 18_1
2 clc; funcprot(0);
3 //Given data
4 n=10; // Number of fans used
5 T_1=35; // C
6 T_2=30; // C
7 m_w1=1000; // The quantity of cooling tower
   circulated through the tower in kg/min
8 DBT=35; // Dry bulb temperature in C
9 WBT=25; //Wet bulb temperature in C
10 C_pw=4.2; // kJ/kg C
11 RH=90; // Relative humidity in %
12
13 //Calculation
14 //The conditions of air at inlet and outlet are
   represented on psychrometric chart as shown in
   Fig.Prob.18.1(b)
15 // From psychrometric chart ,
16 H_a1=76.4; // kJ/kg
```

```

17 H_a2=94.5; // kJ/kg
18 w_1=19; // grams/kg
19 w_2=24.4; // grams/kg
20 v_s1=0.895; // m^3/kg
21 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
22 C=V/n; // Capacity of each fan in m^3/min
23 m_m=(V/v_s1)*((w_2-w_1)/1000)*60; // The quantity of
    make up in kg/hr
24 printf('\nThe quantity of air handled=%0.1f m^3/min
    \nThe quantity of make up water=%0.0f kg/hr',C,
    m_m);
25 // The answers provided in the textbook is wrong

```

---

### Scilab code Exa 18.2 Make up required per hour

```

1 // Example 18_2
2 clc; funcprot(0);
3 //Given data
4 m_w1=400; // Quantity of cooling water in kg/min
5 T_1=43.5; // The temperature of water at inlet in C
6 T_a1=18.5; // C
7 RH=60; // Relative humidity in %
8 T_a2=27; // C
9 V=600; // Volume of air per minute in m^3/min
10 P=4; // Power absorbed in kW
11 C_pw=4.2; // kJ/kg C
12
13 //Calculation
14 //The conditions of air at inlet and outlet are
    represented on psychrometric chart as shown in
    Fig.Prob.18.2
15 // Total heat of air at inlet + Total heat of water
    at inlet + heat dissipated by motor = Total heat
    of air at outlet + Total heat of water at outlet

```

```

16 // From psychrometric chart ,
17 H_a1=38.87; // kJ/kg
18 H_a2=84.85; // kJ/kg
19 w_1=7.8; // grams/kg
20 w_2=22.6; // grams/kg
21 v_s1=0.836; // m^3/kg
22 m_a=V/v_s1; // kg/min
23 Q=P*60; // kJ/min
24 //T_2=y(1)
25 function [X]=Temperature(y);
26     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))));
27 endfunction
28 y=[10]
29 z=fsolve(y, Temperature);
30 T_2=z(1); // The temperature of water coming out of
           the tower in C
31 m_m=m_a*((w_2-w_1)/1000); // The make up water
           required per hour in kg/min
32 printf('\nThe temperature of water coming out of the
           tower=%0.2f C \n\nThe make up water required per
           hour=%0.1f kg/min', T_2, m_m);
33 // The answers provided in the textbook is wrong

```

---

**Scilab code Exa 18.3** Amount of make up water required

```

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

```

```

9 RH=60; // Relative humidity in %
10 T_a2=26; // The temperature of air leaves the tower
    at saturated condition in C
11 C_pw=4.2; // kJ/kg C
12
13 // Calculation
14 // The condtions of air entering and leaving the
    tower are represented onn psychrometric chart as
    shown in Fig.Prob.18.3
15 // From psychrometric chart ,
16 H_a1=45; // kJ/kg
17 H_a2=81; // kJ/kg
18 w_1=9.6; // grams/kg
19 w_2=21.6; // grams/kg
20 v_s1=0.848; // m^3/kg
21 m_a=V/v_s1; // kg/sec
22 Q=Q/1000; // kW=kJ/sec
23 //T_2=y(1)
24 function [X]=Temperature(y);
25     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))));
26 endfunction
27 y=[10]
28 z=fsolve(y, Temperature);
29 T_2=z(1); // The temperature of water coming out of
    the tower in C
30 m_m=m_a*((w_2-w_1)/1000); // The make up water
    required per hour in kg/min
31 printf('\nThe temperature of water coming out of the
    tower=%0.0 f C \n\nThe make up water required per
    hour=%0.3 f kg/min', T_2, m_m);

```

---

**Scilab code Exa 18.4** The make up required per hour

```
1 // Example 18_4
```



```

2  clc;funcprot(0);
3  //Given data
4  V=5000;//Circulation of cooling water in m3/hr
5  C=3;// Allowable concentration ratio
6  Cr=12;// The cooling range in C
7  E1=2;// Evaporation losses in %
8  W1=0.2;// Windage losses in %
9
10 //Calculation
11 E=(E1/100)*V;// Evaporation losses in m3/hr
12 W=(W1/100)*V;// Windage losses in m3/hr
13 B=(E/(C-1))-W;// Blow down rate in m3/hr
14 M=E+W+B;// The make up water in m3/hr
15 printf('\\nThe make up water required=%0.0f m3/hr',M
    );

```

---

## Chapter 22

# THERMODYNAMIC CYCLES FOR STEAM POWER PLANTS

Scilab code Exa 22.1 The thermal efficiency of the cycle

```
1 // Example 22_1
2 clc; funcprot(0);
3 //Given data
4 p_1=30; // The boiler pressure in bar
5 p_2=1; // The condenser pressure in bar
6
7 //Calculation
8 //(a)
9 // From steam tables , at pressure P_b=30 bar
10 h_1=2796; // kJ/kg
11 //For finding the dryness-fraction of steam at the
    point 'c', we can equate the entropies.
12 // At pressure 30 bar=At pressure 1 bar
13 // From steam tables , at pressure P_1=30 bar and P_2
    =1 bar
14 T_s1=232.8; // C
15 T_s2=99.1; // C
```

```

16 h_f2=414.6; // kJ/kg
17 h_fg1=1797; // kJ/kg
18 h_fg2=2253; // kJ/kg
19 v_f2=0.001043; // m^3/kg
20 // Assume x_2=y(1)
21 function [X]=drynessfraction(y)
22     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)));
23 endfunction
24 y=[0.1];
25 z=fsolve(y,drynessfraction);
26 x_2=z(1);
27 //x_2=z(1); // Dryness fraction
28 h_2=h_f2+(x_2*h_fg2); // kJ/kg
29 n_r1=((h_1-h_2)/(h_1-h_f2))*100; // The thermal
           efficiency of the cycle without feed pump work in
           %
30 // (b)
31 W_p=(v_f2*(p_1-p_2)*10^5)/1000; // kJ
32 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
           %
33 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);
34 // The answer vary due to round off error

```

---

### Scilab code Exa 22.2 The cycle efficiency

```

1 // Example 22_2
2 clc; funcprot(0);
3 // Given data
4 p_a=10; // bar

```

```

5 p_b=0.08; // bar
6 T_1=450; // C
7 p_1=30; // bar
8 p_3=25; // bar
9 T_4=33; // C
10 p_4=0.04; // bar
11
12
13 // Calculation
14 // From tables of mercury the following enthalpy
    values and entropy values are taken
15 h_1=359.11; // kJ/kg
16 h_f2=33.21; // kJ/kg
17 h_3=h_f2; // kJ/kg
18 s_1=0.5089; // kJ/kg.K
19 s_f2=0.087; // kJ/kg.K
20 Q_fg2=0.5721; // kJ/kg
21 h_g2=294.7; // kJ/kg
22 x_2=(s_1-s_f2)/(Q_fg2);
23 h_2=h_f2+(x_2*h_g2); // kJ/kg
24 // From steam tables and chart (For steam cycle)
25 h_4=3348.6; // kJ/kg
26 h_5=2183; // kJ/kg
27 h_6=138; // kJ/kg
28 h_7=972; // kJ/kg
29 h_8=2803; // kJ/kg
30 // Assume m_r=m_hg/m_H2O
31 m_r=(h_8-h_7)/(h_2-h_3);
32 // For each kg of steam generated ,8.42 kg of mercury
    is to be used
33 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
34 printf( '\nCycle efficiency=%0.3f ',n);

```

---

**Scilab code Exa 22.3** The cycle efficiency and dryness

```

1 // Example 22_3
2 clc; funcprot(0);
3 // Given data
4 p_1=30; // bar
5 p_3=0.04; // bar
6 x_1=0.841; // Dryness fraction
7
8 // Calculation
9 // From h-s chart:
10 h_1=2803; // kJ/kg
11 h_2=2370; // kJ/kg
12 h_3=2717; // kJ/kg
13 h_4=2124; // kJ/kg
14 x_2=0.824; // kJ/kg
15 p_7=2.5 // bar
16 p_2=p_7; // bar
17 // From steam tables at p=2.5 bar & p=0.04 bar
18 v_s1=0.00106; // kJ/kg
19 v_s2=0.00104; // kJ/kg
20 h_f5=121; // kJ/kg
21 h_f2=535; // kJ/kg
22
23 W_ph=(p_1-p_2)*10^2*v_s1; // Pump work for higher
    pressure stage in kJ/kg
24 W_pl=(p_1-p_2)*10^2*v_s2; // Pump work for lower
    pressure side in kJ/kg
25 m_s=x_1; // mass flow in kg
26 m_f=0.159; // Mass flow through first feed pump in kg
27 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
28 W_p=(p_1-p_2)*10^2*v_s2; // Pump work in kJ/kg
29 n_wos=((h_1-h_4)-W_p)/(h_1-h_f5)*100; // Efficiency
    of the cycle without separation
30 // From steam table, at p=0.04 bar
31 h_fg4=2433.1; // kJ/kg
32 h_f4=121.4; // kJ/kg
33 x_4=(h_4-h_f4)/(h_fg4); // Dryness at exit

```

```

34 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 );
35 // The answer vary due to round off error

```

---

**Scilab code Exa 22.4** The efficiency of the reheat cycle

```

1 // Example 22_4
2 clc; funcprot(0);
3 // Given data
4 p_1=90; // bar
5 T_1=480; // C
6 p_2=12; // bar
7 p_3=0.07; // bar
8 m=1; // Steam flow rate in kg/sec
9
10 // Calculation
11 // From h-s chart:
12 h_1=3333.5; // kJ/kg
13 h_2=2815; // kJ/kg
14 h_3=3425.5; // kJ/kg
15 h_4=2364; // kJ/kg
16 // From steam tables at p=0.07 bar
17 h_f5=161.8; // kJ/kg
18 v_sw1=0.001013; // m^3/kg
19 h_6=h_f5+((v_sw1*(p_1-p_3)*10^5)/(1000*m)); // kJ/kg
20 W_p=(h_6-h_f5); // Pump work in kJ/kg
21 W_net=(h_1-h_2)+((h_3-h_4))-W_p; // Net Work done in
    kJ/kg
22 P=W_net*m; // Power generating capacity of the plant
    in kW
23 H_s=(h_1-h_6)+(h_3-h_2); // Heat supplied per kg of
    steam in kJ/kg
24 n=(W_net/H_s)*100; // Efficiency of the cycle

```

```

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

```

---

**Scilab code Exa 22.5** The thermal efficiency of the cycle

```

1 // Example 22_5
2 clc;funcprot(0);
3 //Given data
4 p_1=100;// bar
5 T_1=500;// C
6 p_2=8.5;// bar
7 p_3=p_2-0.5;// bar
8 p_4=0.05;// bar
9 n_t=80;// The isentropic efficiency of the turbine
    in %
10 n_lt=85;// The isentropic efficiency of lower stage
    of the turbine in %
11
12 //Calculation
13 //From h-s chart:
14 h_1=3377;// kJ/kg
15 h_2a=2750;// kJ/kg
16 h_3=3478;// kJ/kg
17 h_4a=2738;// kJ/kg
18 // The isentropic efficiency of the expansion 1-2 is
    80% as given in problem
19 h_2=h_1-((n_t/100)*(h_1-h_2a));// kJ/kg
20 // The isentropic efficiency of the expansion 3-4 is
    85% as given in problem
21 h_4=h_3-((n_lt/100)*(h_3-h_4a));// kJ/kg
22 //From steam tables ,
23 h_f5=137;// kJ/kg
24 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 %
25 // From h-s diagram
26 h_6a=2305; // kJ/kg
27 // The isentropic efficiency of the expansion 2-6 is
    75% as given in problem
28 n_1t=75; //The isentropic efficiency of the turbine
    in %
29 h_6=h_2-((n_1t/100)*(h_2-h_6a)); // kJ/kg
30 n_th2=(((h_1-h_2)+(h_2-h_6))/(h_1-h_f5))*100; // The
    thermal efficiency of the cycle without reheating
    in %
31 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);
32 // The answer is bit different due to calculation
    error in the book

```

---

**Scilab code Exa 22.6** The isentropic efficiencies of the expansion stages

```

1 // Example 22_6
2 clc; funcprot(0);
3 //Given data
4 p_1=215; // bar
5 T_1=500; // C
6 p_2=40; // bar
7 T_2=280; // C
8 p_3=p_2-1; // bar
9 p_4=8; // bar
10 T_4=270; // C
11 p_5=p_4-0.5; // bar
12 p_6=0.07; // bar
13 m=10; // The flow of steam in kg/sec
14
15 // Calculation

```



```

16 // From h-s diagram
17 h_1=3234; // kJ/kg
18 h_2a=2822; // kJ/kg
19 h_2=2910; // kJ/kg
20 h_3=3435; // kJ/kg
21 h_4a=2977; // kJ/kg
22 h_4=2998; // kJ/kg
23 h_5=3473; // kJ/kg
24 h_6a=2444; // kJ/kg
25 h_6=2578; // kJ/kg
26 //From steam tables ,
27 h_f7=162; // kJ/kg
28 W=(h_1-h_2)+(h_3-h_4)+(h_5-h_6); // Work done per kg
    of steam kJ/kg
29 Q=(h_1-h_f7)+(h_3-h_2)+(h_5-h_4); // Heat supplied
    per kg of steam kJ/kg
30 n_th=(W/Q)*100; //The thermal efficiency of the cycle
    in %
31 P=(W*m); // Power developed by the plant in kW
32 n_i1=((h_1-h_2)/(h_1-h_2a))*100; //Isentropic
    efficiency of the first stage in %
33 n_i2=((h_3-h_4)/(h_3-h_4a))*100; //Isentropic
    efficiency of the second stage in %
34 n_i3=((h_5-h_6)/(h_5-h_6a))*100; //Isentropic
    efficiency of the third stage in %
35 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

```

1 // Example 22_7
2 clc; funcprot(0);
3 //Given data
4 p_1=100; // bar
5 T_1=400; // C
6 p_2=20; // bar
7 p_1=1; // bar
8 p_3=p_2-p_1; // bar
9 T_3=380; // C
10 n_i=80; // Isentropic efficiency of both the
    expansions in %
11 n_t=98; //The transmission efficiency in %
12 n_g=95; // The generator efficiency in %
13 P=60; // The generator output in MW
14
15 // Calculation
16 // From h-s diagram
17 h_1=3093; // kJ/kg
18 h_2a=2734; // kJ/kg
19 h_3=3203; // kJ/kg
20 h_4a=2157; // kJ/kg
21 // The isentropic efficiency of the expansion 1-2
    and 3-4 is 80% as given in problem
22 h_2=h_1-((n_i/100)*(h_1-h_2a)); // kJ/kg
23 h_4=h_3-((n_i/100)*(h_3-h_4a)); // kJ/kg
24 W=(h_1-h_2)+(h_3-h_4); //Work done per kg of steam kJ
    /kg
25 m_s=(P*1000)/(W*(n_t/100)*(n_g/100)); // Mass of
    steam passing through the turbine in kg/sec
26 m_s=(m_s*3600)/1000; // tons/hr
27 printf(' \n The 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

```

1 // Example 22_8
2 clc;funcprot(0);
3 //Given data
4 p_1=50;// bar
5 T_1=400;// C
6 x=0.96;// Dryness
7 p_2=5;// bar
8 p_3=0.03;// bar
9 T_3=250;// C
10 n_i=80;// Isentropic efficiency of both the
    expansions in %
11 n_m=99;//The mechanical efficiency in %
12 n_g=96;// The generator efficiency in %
13
14 //Calculation
15 //From h-s chart:
16 h_1=3198;// kJ/kg
17 h_2a=2675;// kJ/kg
18 h_3=2955;// kJ/kg
19 h_4a=2153;// kJ/kg
20 dh_1=((n_i/100)*(h_1-h_2a));//(h_1-h_2) kJ/kg
21 h_2=h_1-((n_i/100)*(h_1-h_2a));// kJ/kg
22 dh_2=((n_i/100)*(h_3-h_4a));//(h_3-h_4) in kJ/kg
23 W=dh_1+dh_2;//Work done per kg of steam kJ/kg
24 W_e=W*(n_m/100)*(n_g/100);// The work used out of
    1060 kJ for the generation of electricity in kJ/
    kg
25 m_g=(1000/W_e)*3.6;// The steam generated in the
    boiler per 1 kW power generation in kg/kW-hr
26 //From steam tables ,
27 h_fg=1643.5;// kJ/kg
28 Lh=x*h_fg;// The latent heat of steam lost per kg
29 m_s=(m_g*(h_3-h_2))/Lh;// The steam used in the
    reheater in kg
30 m=m_g+m_s;// Steam generated by the boiler per kW-hr
    output from the generator in kg
31 printf('\nThe mass of steam generated by the boiler
    per kW-hr=%0.3 f kg ',m);

```

32 // The answer vary due to round off error

---

**Scilab code Exa 22.9** The efficiency of the cycle

```
1 // Example 22_9
2 clc;funcprot(0);
3 //Given data
4 p_1=100;// bar
5 p_4=0.035;// bar
6 T_1=500;// bar
7
8 //Calculation
9 // From the (Mollier) chart:
10 h_1=3373;// kJ/kg
11 h_2=2778;// kJ/kg
12 h_3=3478;// kJ/kg
13 h_4=2322;// kJ/kg
14 x_4=0.907;
15 // From steam tables
16 h_f5=112;// kJ/kg
17 W_p=10;// Pump work as calculated in kJ/kg
18 n=((h_1-h_2)+(h_3-h_4)-W_p)/((h_1-h_f5)+(h_3-h_2))
    ;// Efficiency of the cycle
19 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

```
1 // Example 22_10
2 clc;funcprot(0);
3 //Given data
4 p_2=100;// bar
```

```

5 T_1=500; // C
6 p_3=11.5; // bar
7 p_5=0.05 // bar
8 n_i1=85; // Isentropic efficiency of each stage
   expansion in %
9 n_i2=80; // Isentropic efficiency of one stage
   expansion with no reheat in %
10 P=100; // The capacity of the plant in MW
11
12 // Calculation
13 //(a)
14 // In this case the processes are shown in Fig.Prob
   .22.10(b)
15 // From h-s chart:
16 h_2=3370; // kJ/kg
17 h_3aa=2860; // kJ/kg
18 h_4=3500; // kJ/kg
19 h_5aa=2530; // kJ/kg
20 // From steam tables , at 0.06 bar
21 h_f6=137.6; // kJ/kg
22 W_t1=h_2-h_3aa; // (H.P turbine) kJ/kg
23 W_t2=h_4-h_5aa; // (L.P turbine) kJ/kg
24 Q_b=h_2-h_f6; // Heat supplied in the boiler in kJ/kg
25 Q_r=h_4-h_3aa; // Heat supplied in the reheater in kJ
   /kg
26 n_a=((W_t1+W_t2)/(Q_b+Q_r))*100; // Efficiency of the
   cycle iin %
27 m_s=(P*10^3)/(W_t1+W_t2); // The mass flow of steam
   per scond in kJ/sec
28 m_sa=(m_s*3600)/1000; // tons/hr
29
30 //(b)
31 // In this case the processes are shown in Fig.Prob
   .22.10(c)
32 h_2=3370; // kJ/kg
33 h_3a=2300; // kJ/kg
34 h_f4=137.8; // kJ/kg
35 n_b=((h_2-h_3a)/(h_2-h_f4))*100; // Efficiency of the

```

```

    cycle in %
36 m_sb=((P*103*3600)/((h_2-h_3a)*1000)); // tons/hr
37 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

```

1 // Example 22_11
2 clc;funcprot(0);
3 //Given data
4 P=27000; // kW
5 p_1=60; // bar
6 T_1=450; // C
7 p_v=707.5; // The condenser vaccum in mm of Hg
8 p_2=3; //bar
9 n_t=87; // The turbine efficiency
10 n_b=90; // The boiler efficiency in %
11 n_a=95; //The alternator efficiency in %
12 n_m=98; //The mechanical efficiency in %
13 p_b=760; // cm of Hg
14
15 //Calculation
16 p_3=((p_b-p_v)/p_b)*1.013; //The condenser pressure
    bar
17 // From h-s chart:
18 h_1=3296; // kJ/kg
19 h_2a=2606; // kJ/kg
20 h_3a=2163; // kJ/kg
21 h_2=h_1-((n_t/100)*(h_1-h_2a)); // kJ/kg
22 h_3=h_2-((n_t/100)*(h_2-h_3a)); // kJ/kg
23 //From steam tables

```

```

24 h_f4=162; // kJ/kg (at 0.07 bar)
25 h_f5=558; // kJ/kg (at 3 bar)
26 // Assume m=y(1)
27 function [X]=bled(y)
28     X(1)=((1-y(1))*(h_f5-h_f4))-(y(1)*(h_2-h_f5));
29 endfunction
30 y=[0.1]
31 z=fsolve(y,bled);
32 m=z(1); // kg/kg of steam generated
33 W=(h_1-h_2)+((1-m)*(h_2-h_3)); // Work developed per
    kg of steam in kJ/kg
34 W_act=(P/((n_a/100)*(n_m/100))); // Actual work
    developed by the turbine kW
35 m_s=(W_act/W)*(3600/1000); // Steam generated per
    second in tons/hr
36 P_p=P*(10/100); // Pump power in kW
37 P_net=P*(1-(10/100)); // Net power available in kW
38 Q_s=((m_s*1000*(h_1-h_f5))/((n_b/100)*3600)); // Heat
    supplied in the boiler in kW
39 n_o=(P_net/Q_s)*100; // The overall efficiency of the
    plant in %
40 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);
41 // The answer vary due to round off error

```

---

**Scilab code Exa 22.12** The thermal efficiency of the plant

```

1 // Example 22_12
2 clc; funcprot(0);
3 // Given data
4 T_1=300; // C
5 p_1=35; // bar

```

```

6 p_2=25; // bar
7 p_2a=1.5; // bar
8 p_3=0.1; // bar
9 n_t=80/100; // The isentropic efficiency for both
    sections of the turbine
10 gradT=10; // C
11 m_w=1; // kg
12 C_p=4.2; // kJ/kg. C
13
14 // Calculation
15 // From h-s chart:
16 h_1=2970; // kJ/kg
17 h_2=2504; // kJ/kg
18 h_3=2197; // kJ/kg
19 h_f2=264; // kJ/kg (at 1.5 bar)
20 h_f2a=h_f2-(m_w*C_p*gradT); // kJ/kg
21 h_f3=190; // kJ/kg (at 0.1 bar)
22 m=(h_f2a-h_f3)/(h_2-h_f3); // kg/kg of steam
23 W=(h_1-h_2)+((1-m)*(h_2-h_3)); // kJ/kg
24 Q_s=h_1-h_f2a; // kJ/kg
25 n_th=(W/Q_s)*100; // Thermal efficiency of the plant
26 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);
27 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 22.13** The cycle efficiency

```

1 // Example 22_13
2 clc; funcprot(0);
3 //Given data
4 T_1=300; // C
5 p_1=40; // bar
6 p_2=14; // bar

```



```

7 p_3=3.4; // bar
8 p_4=0.07; // bar
9 n_t=80/100; // The turbine efficiency of each portion
    of the expansion
10
11 // Calculation
12 //(a)
13 // From h-s chart:
14 h_1=2953; // kJ/kg
15 h_2a=2738; // kJ/kg
16 h_2=h_1-((n_t)*(h_1-h_2a)); // kJ/kg
17 // From h-s chart:
18 h_3a=2529; // kJ/kg
19 h_3=h_2-((n_t)*(h_2-h_3a)); // kJ/kg
20 // From h-s chart:
21 h_4a=2040; // kJ/kg
22 h_4=h_3-((n_t)*(h_3-h_4a)); // kJ/kg
23 // From steam tables
24 h_f5=162; // kJ/kg
25 h_f7=575; // kJ/kg
26 h_f8=825; // kJ/kg
27 m_1=(h_f8-h_f7)/(h_2-h_f8); // kJ/kg of steam
28 // Assume m_2=y(1); h_f6=y(2)
29 function [X]=mass(y)
30     X(1)=(y(1)*(h_3-h_f7))-(1*(h_f7-y(2)));
31     X(2)=(((m_1+y(1))*h_f7)+((1-m_1-y(1))*h_f5))-(1*
        y(2));
32 endfunction
33 y=[0.1 100];
34 z=fsolve(y,mass)
35 m_2=z(1); // kJ/kg of steam supplied to turbine
36 h_f6=z(2); // kJ/kg
37 //(b)
38 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 %
39 printf('\n(a)The optimum mass of bled steam=%0.2f kJ
        /kg \n(b)The cycle efficiency=%0.1f percentage',

```

```

    m_2,n);
40 // The answer vary due to round off error

```

---

**Scilab code Exa 22.14** The quantity of steam extracted

```

1 // Example 22_14
2 clc; funcprot(0);
3 //Given data
4 T_1=350; // C
5 p_1=30; // bar
6 p_2=6; // bar
7 p_3=1; // bar
8 p_4=0.07; // bar
9 P=10; // Power developed by the turbine in MW
10 n_t=80/100; // Isentropic efficiency of each stage
11
12 // Calculation
13 // From h-s chart:
14 h_1=3106; // kJ/kg
15 h_2=2811; // kJ/kg
16 h_3=2560; // kJ/kg
17 h_4=2259; // kJ/kg
18 // From steam tables
19 h_f2=777; // kJ/kg (at 6 bar)
20 h_f3=415; // kJ/kg (at 1 bar)
21 h_f5=162; //kJ/kg (at 0.07 bar)
22 h_f8=h_f2; // kJ/kg
23 h_f6=h_f3; // kJ/kg
24 //Assume m_1=y(1);m_2=y(2)
25 function [X]=mass(y)
26     X(1)=(y(1)*(h_2-h_f2))-(1*(h_f8-h_f6));
27     X(2)=((y(2)*(h_3-h_f3))+(y(1)*(h_f2-h_f3)))-((1-y(1)-y(2))*(h_f6-h_f5));
28     X(3)=(((1-y(1)-y(2))*h_f6)+((y(1)+y(2))*h_f3)-(y(3)));

```

```

29 endfunction
30 y=[0.1 0.01 100];
31 z=fsolve(y, mass);
32 m_1=z(1); // kg/kg of steam generated
33 m_2=z(2); // kg/kg of steam generated
34 W_t=(h_1-h_2)+((1-m_1)*(h_2-h_3))+((1-m_1-m_2)*(h_3-
    h_4)); // kJ/kg
35 m_s=((P*10^3)/W_t)*60; // kg/sec
36 m_s6=(m_s*m_1); // Quantity of steam extracted per
    minute at 6 bar pressure in kg/min
37 m_s1=(m_s*m_2); // Quantity of steam extracted per
    minute at 1 bar pressure in kg/min
38 C=m_s6+m_s1; // Capacity of feed pump extraction pump
    in kg/min
39 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);
40 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 22.15** The thermal efficiency of the cycle

```

1 // Example 22_15
2 clc; funcprot(0);
3 // Given data
4 T_1=400; // C
5 p_1=40; // bar
6 p_2=2; // bar
7 p_3=0.5; // bar
8 p_4=0.05; // bar
9 n_t1=75/100; // The isentropic efficiency of the
    first stage of the turbine
10 n_t2=80/100; // The isentropic efficiency of the
    second stage of the turbine

```

```

11 n_t3=85/100; // The isentropic efficiency of the
    third stage of the turbine
12 m_s=10; // The steam flow in kg/sec
13
14 // Calculation
15 // From h-s chart:
16 h_1=3210; // kJ/kg
17 h_2a=2562; // kJ/kg
18 h_2=h_1-((n_t1)*(h_1-h_2a)); // kJ/kg
19 h_3a=2508; // kJ/kg
20 h_3=h_2-((n_t2)*(h_2-h_3a)); // kJ/kg
21 h_4a=2232; // kJ/kg
22 h_4=h_3-((n_t3)*(h_3-h_4a)); // kJ/kg
23 // From steam tables
24 h_f8=502; // kJ/kg (2 bar)
25 h_f10=h_f8; // kJ/kg
26 h_f6=339; // kJ/kg (0.5 bar)
27 h_f7=h_f6; // kJ/kg
28 h_f9=h_f6; // kJ/kg
29 h_f5=136; // kJ/kg (0.05 bar)
30 // Assume m_1=y(1); m_2=y(2)
31 function [X]=mass(y)
32     X(1)=(y(1)*(h_2-h_f10))-((1-y(1))*(h_f8-h_f7));
33     X(2)=(y(2)*(h_3-h_f9))-((1-y(1)-y(2))*(h_f6-h_f5
    ));
34 endfunction
35 y=[0.01 0.01];
36 z=fsolve(y,mass);
37 m_1=z(1); // kJ/kg
38 m_2=z(2); // kJ/kg
39 W=(h_1-h_2)+((1-m_1)*(h_2-h_3))+((1-m_1-m_2)*(h_3-
    h_4)); // kJ/kg
40 P=W*m_s; // Power developed by the turbine in kW
41 Q_s=h_1-h_f10; // Heat supplied per kg of steam in kJ
    /kg
42 n_th=(W/Q_s)*100; // Thermal efficiency of the cycle
    in %
43 printf('\n(a) Steam bled for regenerative heaters per

```

```

    kg of steam to turbine ,m_1=%0.4 f kJ/kg & m_2=%0
    .4 f kJ/kg \n(b)Power developed by the turbine=%0
    .0 f kW \n(c)Thermal efficiency of the cycle=%0.2 f
    percentage ',m_1,m_2,P,n_th);
44 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 22_16
2 clc;funcprot(0);
3 //Given data
4 T_1=459; // C
5 T_3=420; // C
6 p_1=70; // bar
7 p_2=25; // bar
8 p_3=10; // bar
9 p_4=0.07; // bar
10 n_t1=78.5/100; // The isentropic efficiency of the H.
    P turbine
11 n_t2=83/100; // The isentropic efficiency of the L.P
    turbine 1
12 n_t3=83/100; // The isentropic efficiency of the L.P
    turbine 2
13 T_7=179; // C
14 P=20; // MW
15 n_m=85/100; // Mechanical efficiency of the turbine
16 n_t=95/100; // Transmission efficiency
17 n_g=95/100; // Generation efficiency
18
19 // Calculation
20 // From h-s chart:
21 h_1=3280; // kJ/kg
22 h_2a=2997; // kJ/kg
23 h_2=h_1-((n_t1)*(h_1-h_2a)); // kJ/kg
24 h_3=3277; // kJ/kg

```

```

25 h_4a=3020; // kJ/kg
26 h_4=h_3-((n_t2)*(h_3-h_4a)); // kJ/kg
27 h_5a=2220; // kJ/kg
28 h_5=h_4-((n_t3)*(h_4-h_5a)); // kJ/kg
29 // From steam tables
30 h_f6=162; // kJ/kg(at 0.07 bar)
31 h_f7=758; // kJ/kg(at 10 bar)
32 function [X]=mass(y)
33     X(1)=(y(1)*(h_4-h_f7))-((1-y(1))*(h_f7-h_f6));
34 endfunction
35 y=[0.1]; // kg
36 z=fsolve(y,mass);
37 m=z(1); // kg
38 W=(h_1-h_2)+(h_3-h_4)+((1-m)*(h_4-h_5)); // kJ/kg
39 E_g=W*n_m*n_t*n_g; // Energy converted for generating
    the electrical energy in kJ
40 m_s=((P*10^3)/E_g)*60; // Steam generated in kg/min
41 Q_s=(h_1-h_f7)+(h_3-h_2); // Heat supplied per kg of
    steam in kJ/kg
42 n_th=(W/Q_s)*100; // Thermal efficiency of the cycle
    in %
43 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

```

1 // Example 22_17
2 clc;funcprot(0);
3 //Given data
4 P=500; // Plant capacity in kW
5 T_1=300; // C
6 p_4=30; // bar
7 p_5=7; // bar
8 p_6=0.04; // bar

```

```

9 dT=5; // The rise in cooling water temperature in C
10 C_pw=4.2; // kJ/kg. C
11
12 // Calculation
13 // From h-s chart:
14 h_4=3000; // kJ/kg
15 h_5=2700; // kJ/kg
16 h_6=1970; // kJ/kg
17 // From steam tables
18 h_f1=121.4; // kJ/kg(at 0.04 bar)
19 h_f2=697; // kJ/kg(at 7 bar)
20 function [X]=mass(y)
21     X(1)=((y(1)*h_5)+((1-y(1))*h_f1))-(1*h_f2);
22 endfunction
23 y=[0.1];
24 z=fsolve(y,mass);
25 m=z(1); // kg
26 W=(1*(h_4-h_5))+((1-m)*(h_5-h_6)); // kJ/kg
27 Q_s=h_4-h_f2; // Heat supplied in kJ/kg
28 n_s=(W/Q_s)*100; // Efficiency in %
29 m_s=(P/W)*3600; //Steam generated per second in kg/hr
30 m_w=((h_6-h_f1)*(m_s/3600)*(1-m))/(C_pw*dT); // kg/
    sec
31 // If there is no feed water, then
32 W_1=h_4-h_6; // kJ/kg
33 Q_s=h_4-h_f1; // kJ/kg
34 n=(W_1/Q_s)*100; // Efficiency in %
35 m_s1=(P/W_1)*3600; //Steam generated per second in kg
    /hr
36 m_w1=((m_s/3600)*(h_6-h_f1))/(C_pw*dT); // The amount
    of cooling water in kg/sec
37 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 \n
    Steam generation rate of boiler=%0.1f kg/hr \n
    The amount of cooling water=%0.2f kg/sec ',n_s,m_s
    ,m_w,n,m_s1,m_w1);

```

38 // The answer vary due to round off error

---

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

```
1 // Example 22_18
2 clc;funcprot(0);
3 //Given data
4 T_1=500; // C
5 p_1=40; // bar
6 p_2=10; // bar
7 p_3=0.04; // bar
8 m_b=50; // The boiler generation rate in tons/hour
9 n_m=85/100; // Mechanical efficiency
10 n_g=95/100; // Electrical generation efficiency
11
12 // Calculation
13 // From h-s chart:
14 h_1=3400; // kJ/kg
15 h_2=3050; // kJ/kg
16 h_3=2150; // kJ/kg
17 // From steam tables
18 h_f4=121.4; // kJ/kg(at 0.04 bar)
19 h_f5=762.6; // kJ/kg(at 10 bar)
20 h_f6=h_f5; // kJ/kg
21 //Assume m_1=y(1); h_fm=y(2)
22 function [X]=mass(y)
23     X(1)=((y(1)*h_f6)+((1-y(1))*h_f4))-(y(1)*y(2));
24     X(2)=(y(1)*(h_2-h_f5))-(1*(h_f5-y(2)));
25 endfunction
26 y=[0.1 100];
27 z=fsolve(y,mass);
28 m=z(1); // kg/kg of steam generated
29 h_fm=z(2); // kJ/kg
30 W=(h_1-h_2)+((1-m)*(h_2-h_3)); // kJ/kg
```



```

31 m_b=m*100; // Bled steam in %
32 Q_s=h_1-h_f5; // Heat supplied per kg of steam in kJ/
    kg
33 n=(W/Q_s)*100; // Efficiency in %
34 P=((m_b*10^3)*W*n_m*n_g)/3600)/1000; // Power
    developed in MW
35 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);
36 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 22_19
2 clc; funcprot(0);
3 //Given data
4 P=100; // MW
5 p_2=80; // bar
6 p_3=7; // bar
7 p_5=0.05; // bar
8 T_4=350; // C
9
10 // Calculation
11 // From h-s chart:
12 h_2=2990; // kJ/kg
13 h_3=2350; // kJ/kg
14 h_4=3170; // kJ/kg
15 h_5=2180; // kJ/kg
16 // From steam tables
17 h_f6=138; // kJ/kg
18 h_f7=697; // kJ/kg
19 function [X]=mass(y)
20     X(1)=(y(1)*(h_3-h_f7))-((1-y(1))*(h_f7-h_f6));
21 endfunction

```

```

22 y=[0.1];
23 z=fsolve(y,mass);
24 m=z(1);
25 m_p=m*100; // Percentage of bled steam in %
26 W=(h_2-h_3)+((1-m)*(h_4-h_5)); // kJ/kg
27 Q_s=(h_2-h_f7)+((1-m)*(h_4-h_3)); // kJ/kg
28 n=(W/Q_s)*100; // The efficiency of the power plant
    in %
29 m_b=((P*10^3)/((h_2-h_3)+((1-m)*(h_4-h_5)))); // tons
    /hr
30 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);
31 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 22_20
2 clc;funcprot(0);
3 //Given data
4 T_1=556; // C
5 T_2=222; // C
6 m_s=20; // kg/sec
7 n_m=80/100; // Mechanical efficiency
8 n_t=95/100; // Transmission efficiency
9 n_g=85/100; // Generator efficiency
10 W_act=50/100;
11 h_f1=76; // kJ/kg
12 h_f2=29; // kJ/kg
13 h_fg1=290; // kJ/kg
14 h_fg2=302; // kJ/kg
15 h_g1=366; // kJ/kg
16 h_g2=331; // kJ/kg
17 s_f1=0.152; // kJ/kg-K

```

```

18 s_f2=0.08; // kJ/kg-K
19 s_fg1=0.359; // kJ/kg-K
20 s_fg2=0.626; // kJ/kg-K
21 s_g1=0.511; // kJ/kg-K
22 s_g2=0.706; // kJ/kg-K
23 p_a=17; // bar
24 p_b=0.035; // bar
25 h_fa=874; // kJ/kg
26 h_fb=111; // kJ/kg
27 h_fga=1932; // kJ/kg
28 h_fgb=2453; // kJ/kg
29 h_ga=2806; // kJ/kg
30 h_gb=2564; // kJ/kg
31 s_fa=2.37; // kJ/kg-K
32 s_fb=0.388; // kJ/kg-K
33 s_ga=6.42; // kJ/kg-K
34 s_gb=0.388; // kJ/kg-K
35
36 // Calculation
37 //(a)
38 x_2=(s_g1-s_f2)/s_fg2; // The condition of the
    mercury vapour at point2
39 m_hg=h_fga/(x_2*h_fg2); // kg
40 //(b)
41 W=h_g1-(h_f2+(x_2*h_fg2)); // kJ/kg
42 W_m=W*m_hg; //Work done per kg of Hg vapour in kJ
43 //(c)
44 // From steam tables ,
45 T_sup=380+273; // K
46 T_sa=203.4+273; // K
47 T_b=26.5+273; // K
48 x_b=((s_ga+(2*2.303*log(T_sup/T_sa)))*(T_b))-s_fb)
    /(T_b/h_fga);
49 T_sup=383+273; // K
50 x_2=0.72;
51 W_s=(h_ga+(2*(T_sup-T_sa)))-(h_fb+(x_2*h_fgb)); //
    Work done per kg of steam in kJ/kg
52 //(d)

```

```

53 W=W_m+W_s; // Total work done in kJ
54 Q_s=(m_hg*(h_g1-h_f2))+(1*(h_fa-h_fb))+(2*(T_sup-
    T_sa)); // Heat supplied in kJ
55 n_o=(W/Q_s)*100; // Overall efficiency of the cycle
    in %
56 E=((m_s*W*W_act)*n_m*n_t*n_g)/1000; // Total energy
    generated per sec in MW
57 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);
58 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 22.21** The Power generating capacity of the plant

```

1 // Example 22_21
2 clc;funcprot(0);
3 //Given data
4 p_1=30; // bar
5 T_1=550; // C
6 p_2=2.6; // bar
7 p_3=0.2; // bar
8 m_s=30; // kg/sec
9
10 //Calculation
11 //From h-s chart:
12 h_1=3580; // kJ/kg
13 h_2=2870; // kJ/kg
14 h_3=2440; // kJ/kg
15 // From steam tables
16 h_f2=541; // kJ/kg
17 h_f3=251.5; // kJ/kg
18 function [X]=mass(y)

```

```

19     X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f3));
20 endfunction
21 y=[0.1];
22 z=fsolve(y,mass);
23 m=z(1); // kg
24 P=m_s*((h_1-h_2)+((1-m)*(h_2-h_3)))/1000; // MW
25 n_r=((h_1-h_3)/(h_1-h_f3))*100; // The efficiency of
    the rankine cycle in %
26 n_b=(((h_1-h_2)+((1-m)*(h_2-h_3)))/(h_1-h_f2))*100;
27 printf('\nThe power generating capacity of 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);
28 // The answer vary due to round off error

```

---

#### Scilab code Exa 22.22 Boiler generating capacity

```

1 // Example 22_22
2 clc; funcprot(0);
3 // Given data
4 P=30; // MW
5 p_1=0.04; // bar
6 p_2=7; // bar
7 p_3=60; // bar
8 T_1=550; // C
9 p_c=730; // mm of Hg
10 p_v=760; // mm of Hg
11 n_t=90/100; // The isentropic efficiency of the
    turbine
12
13 // Calculation
14 p_1=((p_v-p_c)*133.3)/10^5; // bar
15 // From h-s chart:
16 h_1=3420; // kJ/kg
17 h_2a=2860; // kJ/kg

```

```

18 h_2=2900; // kJ/kg
19 h_3=2410; // kJ/kg
20 h_3a=2190; // kJ/kg
21 // From steam tables
22 h_f3=121.5; // kJ/kg(liquid heat at 0.04 bar)
23 h_f2=697; // kJ/kg(liquid heat at 7 bar)
24 function [X]=mass(y)
25     X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f3));
26 endfunction
27 y=[0.1];
28 z=fsolve(y,mass);
29 m=z(1); // kg
30 m_s=(P*10^3)/((h_1-h_2)+((1-m)*(h_2-h_3a))); // kg/
    sec
31 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

```

1 // Example 22_23
2 clc; funcprot(0);
3 // Given data
4 P=120; // MW
5 p_1=86; // bar
6 p_2=7; // bar
7 p_3=0.35; // bar
8 T_1=350; // C
9
10 // Calculation
11 // From h-s chart:
12 h_1=2980; // kJ/kg
13 h_2=2520; // kJ/kg
14 h_3=3170; // kJ/kg

```

```

15 h_4=2550; // kJ/kg
16 // From steam tables
17 h_f1=304.3; // kJ/kg(liquid heat at 0.35 bar)
18 T_s1=72.7; // C
19 h_f2=697; // kJ/kg(liquid heat at 7 bar)
20 T_s2=165; // C
21 h_f4=h_f1; // kJ/kg
22 function [X]=mass(y)
23     X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f4));
24 endfunction
25 y=[0.1];
26 z=fsolve(y,mass);
27 m=z(1); // tons/hr
28 S=(1/m); // The ratio of steam bled to steam
    generated
29 m_s=((P*10^3)/((h_1-h_2)+((1-m)*(h_3-h_4))))
    *(3600/1000); // kg/sec
30 n_th=((((h_1-h_2)+((1-m)*(h_3-h_4)))/((h_1-h_f1)+((1-
    m)*(h_3-h_2)))))*100;
31 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);
32 // The answer vary due to round off error

```

---

**Scilab code Exa 22.24** The Power output capacity of the plant

```

1 // Example 22_24
2 clc; funcprot(0);
3 //Given data
4 T_1=300; // C
5 p_1=30; // bar
6 p_2=10; // bar
7 p_4=5; // bar

```

```

8 T_4=270; // C
9 p_6=0.07; // bar
10 m_s=20; // tons/hr
11 C_pw=4.2; // kJ/kg. C
12 T_9=180; // C
13 T_8=38; // C
14
15 // Calculation
16 // From h-s chart:
17 h_1=3000; // kJ/kg
18 h_2=2780; // kJ/kg
19 h_3=2640; // kJ/kg
20 // From steam tables
21 h_f2=762.5; // kJ/kg
22 function [X]=mass(y)
23     X(1)=(y(1)*(h_2-h_f2))-((1-y(1))*C_pw*(T_9-T_8)
24         );
25 endfunction
26 y=[0.1];
27 z=fsolve(y,mass);
28 m=z(1); // kg
29 // From h-s chart:
30 h_4=3000; // kJ/kg
31 h_5=((1/3)*h_4)+((2/3)-m)*h_3)/(1-m); // kJ/kg
32 // From h-s chart:
33 h_6=2150; // kJ/kg
34 // From steam tables
35 h_f7=h_f2; // kJ/kg
36 W=((2/3)*(h_1-h_2))+((2/3)-m)*(h_2-h_3))+((1-m)*(
37     h_5-h_6)); // kJ/kg
38 n=((2/3)*(h_1-h_2))+((2/3)-m)*(h_2-h_3))+((1-m)*(
39     h_5-h_6))/(((2/3)*h_1)+((1/3)*h_4)-h_f7))*100; //
40     Efficiency of the cycle in %
41 m_s=(m_s*1000)/3600; // Steam generated per second in
42     kg/sec
43 P=m_s*W; // Power generating capacity of the plant in
44     kW
45 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);
40 // The answer provided in the textbook is wrong

```

---

### Scilab code Exa 22.25 Steam supplied by the boiler

```

1 // Example 22_25
2 clc;funcprot(0);
3 //Given data
4 P=30; // MW
5 p_1=60; // bar
6 p_2=3; // bar
7 T_1=500; // C
8 p_v=73; // mm of Hg
9 p_b=76; // mm of Hg
10 n_t=90/100; // The isentropic efficiency of the
    turbine
11
12 //Calculation
13 p_3=((p_b-p_v)/p_b)*1.013; // bar
14 //From h-s chart:
15 h_1=3410; // kJ/kg
16 h_2=2720; // kJ/kg
17 h_3=2220; // kJ/kg
18 // From steam tables
19 h_f2=361.4; // kJ/kg(liquid heat at 0.04 bar)
20 h_f3=121.4; // kJ/kg(liquid heat at 7 bar)
21 function [X]=mass(y)
22     X(1)=(y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f3));
23 endfunction
24 y=[0.1];
25 z=fsolve(y,mass);
26 m=z(1); // kg/kg of steam
27 m_s=(P*10^3)/((h_1-h_2)+((1-m)*(h_2-h_3))); // kg/sec
28 m_s=m_s*(3600/1000); // tons/hr

```

```

29 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

```

1 // Example 22_26
2 clc; funcprot(0);
3 // Given data
4 p_1=80; // bar
5 T_1=470; // C
6 p_2=7; // bar
7 T_1=350; // C
8 p_3=0.35; // bar
9 m_s=50; // kg/sec
10
11 // Calculation
12 // From h-s chart:
13 h_1=3310; // kJ/kg
14 h_2=2780; // kJ/kg
15 h_3=3170; // kJ/kg
16 h_4=2220; // kJ/kg
17 // From steam tables
18 h_f2=697; // kJ/kg
19 h_6=h_f2; // kJ/kg
20 h_5=111.85; // kJ/kg
21 h_f4=h_5; // kJ/kg
22 function [X]=mass(y)
23     X(1)=(y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f4));
24 endfunction
25 y=[0.1];
26 z=fsolve(y,mass);
27 m=z(1); // kg
28 m_b=m*100; // Amount of steam bled off in %
29 m_1=(100-m_b); // Amount of steam supplied to L.P

```

```

    turbine in %
30 Q_b=h_1-h_6; // kJ/kg
31 Q_r=(1-m)*(h_3-h_2); // kJ
32 Q_s=Q_b+Q_r; // Total amount of heat supplied by the
    boiler and reheater in kJ/kg
33 W=(h_1-h_2)+((1-m)*(h_3-h_4)); // kJ/kg
34 n=(W/Q_s)*100;
35 P=(m_s*W)/1000; // Power developed by the steam in MW
36 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);
37 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 22.27 Thermal efficiency

```

1 // Example 22_27
2 clc;funcprot(0);
3 //Given data
4 T_1=600; // C
5 p_1=150; // bar
6 T_3=600; // C
7 p_3=40; // bar
8 p_4=5; // bar
9 p_5=0.1; // bar
10
11 //Calculation
12 //From h-s chart:
13 h_1=3570; // kJ/kg
14 h_2=3280; // kJ/kg
15 h_3=3650; // kJ/kg
16 h_4=2920; // kJ/kg
17 h_5=2280; // kJ/kg

```

```

18 // From steam tables
19 h_f1=1610; // kJ/kg(at 150 bar)
20 h_f2=1087; // kJ/kg(at 40 bar)
21 h_f4=640; // kJ/kg(at 5 bar)
22 h_f5=192; // kJ/kg(at 0.1 bar)
23 function [X]=mass(y)
24     X(1)= (y(1)*(h_2-h_f2))-((1-y(1))*(h_f2-h_f4));
25     X(2)=(y(2)*(h_4-h_f4))-((1-y(1)-y(2))*(h_f4-h_f5
        ));
26 endfunction
27 y=[0.1 0.1];
28 z=fsolve(y,mass);
29 m_1=z(1); // kg/kg of steam supplied by the boiler
30 m_2=z(2); // kg/kg of steam supplied by the boiler
31 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
32 v_w1=1/1000; // m^3/kg
33 v_w2=v_w1; // m^3/kg
34 v_w3=v_w1; // m^3/kg
35 W_p1=(v_w1*(1-m_1-m_2)*(p_4-p_5*10^5))/1000; // kJ/kg
36 W_p2=(v_w2*(1-m_1)*(p_1-p_4)*10^5)/1000; // kJ/kg
37 W_p3=(v_w3*(m_1)*(p_1-p_3)*10^5)/1000; // kJ/kg
38 W_pt=W_p1+W_p2+W_p3; // kJ/kg
39 W_n=W_t-W_pt; // Net work done by the turbine per kg
        of steam supplied by the boiler in kJ
40 Q_f=((1-m_1)*h_f1)+(m_1*h_f1); // Heat of feed water
        entering the boiler in kJ
41 Q_s1=h_1-Q_f; // Heat supplied by the boiler per kg
        of steam in kJ
42 Q_s2=(1-m_1)*(h_3-h_2); // Heat supplied in the
        reheater in kJ/kg
43 Q_st=Q_s1+Q_s2; // Total heat supplied in kJ/kg
44 n=(W_n/Q_st)*100; // Thermal efficiency in %
45 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

```
1 // Example 22_28
2 clc;funcprot(0);
3 //Given data
4 p_1=80;// bar
5 T_1=470;// C
6 p_2=7;// bar
7 T_1=350;// C
8 p_3=0.035;// bar
9 m_s=100;// kg/sec
10
11 //Calculation
12 //From h-s chart:
13 h_1=3350;// kJ/kg
14 h_2=2770;// kJ/kg
15 h_3=3170;// kJ/kg
16 h_4=2220;// kJ/kg
17 // From steam tables
18 h_f5=112;// kJ/kg
19 h_f6=697;// kJ/kg
20 function [X]=mass(y)
21     X(1)= (y(1)*(h_2-h_f6))-((1-y(1))*(h_f6-h_f5));
22 endfunction
23 y=[0.1];
24 z=fsolve(y,mass);
25 m=z(1);// kg
26 m_b=m*100;// The fraction of steam bled for
    reheating in %
27 Q_s=(h_1-h_f6)+((1-m)*(h_3-h_2));// Heat supplied in
    the boiler and reheater in kJ/kg
28 W=(h_1-h_2)+((1-m)*(h_3-h_4));// Power output in kJ/
    kg
29 P=(W*100)/1000;// Capacity of the plant in MW
```

```

30 n=(W/Q_s)*100; // The efficiency of the plant in %
31 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);
32 // The answer vary due to round off error

```

---

**Scilab code Exa 22.29** Over all efficiency of the plant

```

1 // Example 22_29
2 clc; funcprot(0);
3 // Given data
4 p_a=4.5; // bar
5 p_b=0.04; // bar
6 p_1=15; // bar
7 p_2=0.04; // bar
8 m_s=48000; // kg/hr
9 T_a=450; // C
10 T_b=217; // C
11 h_fa=62.9; // kJ/kg
12 h_fb=30.0; // kJ/kg
13 h_ga=356; // kJ/kg
14 h_gb=330; // kJ/kg
15 s_fa=0.135; // kJ/kg-K
16 s_fb=0.081; // kJ/kg-K
17 s_ga=0.539; // kJ/kg-K
18 s_gb=0.693; // kJ/kg-K
19 v_sfa=80*10^-6; // m^3/kg
20 v_sfb=76.5*10^-6; // m^3/kg
21 v_sga=0.068; // m^3/kg
22 v_sgb=5.178; // m^3/kg
23
24 // Calculation

```

```

25 m_h2o=(m_s/3600); // kg/sec
26 // s_a=s_b
27 x_b=(s_ga-s_fb)/(s_gb-s_fb);
28 h_b=h_fb+(x_b*(h_gb-h_fb)); // kJ/kg
29 h_c=30; // kJ/kg
30 h_fc=h_c; // kJ/kg
31 //From h-s chart:
32 h_1=2800; // kJ/kg
33 h_2=1920; // kJ/kg
34 // From steam tables
35 h_f3=121.4; // kJ/kg
36 h_f4=844.6; // kJ/kg
37 m_hg=(m_h2o*(h_1-h_f3))/(h_b-h_fc); // kg/sec
38 m=m_hg/m_h2o;
39 W_Hg=m_hg*(h_ga-h_b); // kW
40 W_H2o=m_h2o*(h_1-h_2); // kW
41 W_t=(W_Hg+W_H2o)/1000; // Total work done per second
    in MW
42 Q_s=m_hg*(h_ga-h_fc); // The total heat supplied in
    kJ/sec
43 n_o=((W_t*1000)/Q_s)*100; // Overall efficiency in %
44 printf('\n\nThe overall efficiency of the cycle=%0.1f
    percentage \n\nThe flow of mercury through mercury
    turbine=%0.1f kg/sec \n\nTotal work done per second
    =%0.1f MW',n_o,m_hg,W_t);
45 // The answer vary due to round off error

```

---

**Scilab code Exa 22.30** The Power generating capacity of the plant

```

1 // Example 22_30
2 clc; funcprot(0);
3 //Given data
4 p_a=10; // bar
5 p_b=0.2; // bar
6 p_1=40; // bar

```

```

7 T_1=400; // C
8 T_2=40; // C
9 m_s=500; // kg/sec
10 T_sa=515.5; // C
11 T_sb=277.3; // C
12 h_fa=72.33 // kJ/kg
13 h_fb=38.35; // kJ/kg
14 h_ga=363.0; // kJ/kg
15 h_gb=336.55; // kJ/kg
16 s_fa=0.1478; // kJ/kg-K
17 s_fb=0.0967; // kJ/kg-K
18 s_ga=0.5167; // kJ/kg-K
19 s_gb=0.6385; // kJ/kg-K
20 v_fa=80.9*10^-6; // m^3/kg
21 v_fb=77.4*10^-6; // m^3/kg
22 v_ga=0.0333; // m^3/kg
23 v_gb=1.163; // m^3/kg
24
25 // Calculation
26 // From h-s chart:
27 h_1=3230; // kJ/kg
28 h_2=2120; // kJ/kg
29 // From steam tables
30 h_3=167.5; // kJ/kg
31 h_4=h_3; // kJ/kg
32 // s_a=s_b
33 x_b=(s_ga-s_fb)/(s_gb-s_fb);
34 h_b=h_fb+(x_b*(h_gb-h_fb)); // kJ/kg
35 h_c=38.35; // kJ/kg
36 h_d=h_c; // kJ/kg
37 //(a)
38 h_a=h_ga; // kJ/kg
39 m_Hg=(h_1-h_4)/(h_b-h_c); // kg/kg of steam
40 n_Hg=((h_a-h_b)/(h_a-h_d))*100; // The efficiency of
    the mercury cycle in %
41 n_H2o=((h_1-h_2)/(h_1-h_3))*100; // The efficiency of
    the steam cycle in %
42 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 %
43 P = ((m_s / 60) * ((m_Hg * (h_a - h_b)) + (1 * (h_1 - h_2)))) / 1000;
    // Total power generated in the system in MW
44 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);
45 // 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

```
1 // Example 24_1
2 clc; funcprot(0);
3 //Given data
4 P_1=1; // bar
5 P_2=5; // bar
6 T_1=27+273 // K
7 T_3=650+273; // K
8 C_p=1; // kJ/kg. C
9 //C_p=C_pg=C_pa;
10 r=1.4; //The specific heat ratio
11 m=5; //kg/s
12 //Air-fuel ratio ,AF_r=m_air/m_fuel
13 AF_r=60/1;
14 n_c=0.80; // Isentropic efficiency of compressor
15 n_t=0.85; // Isentropic efficiency of turbine
16
17 // Calculation
18 //T'2=T_2a;T'4=T_4a;
19 T_2a=T_1*(P_2/P_1)^((r-1)/r); // K
```

```

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

```

---

#### Scilab code Exa 24.2 Air Fuel ratio

```

1 // Example 24_2
2 clc;funcprot(0);
3 //Given data
4 T_1=300; // K
5 P_r=8; // P_r=(p1/p2)
6 p_1=1; // bar
7 T_4=1080; // K
8 m=500; // kg/min
9 n_c=0.8;
10 n_t=n_c; //Isentropic efficiency of the compressor
    and turbine
11 CV=42000; // kJ/kg
12 e=0.6; // The effectiveness of the heat exchanger
13 r=1.4; // Specific heat ratio
14 C_p=1; // kJ/kg. C
15 //C_p=C_pg=C_pa;
16
17 //Calculation

```

```

18 T_2a=T_1*(P_r)^((r-1)/r); // K
19 T_2=((T_2a-T_1)/n_c)+T_1; // Modified equation in K
20 T_5a=T_4*(1/P_r)^((r-1)/r); // K
21 T_5=T_4-(n_t*(T_4-T_5a)); // K
22 T_3=(e*(T_5-T_2))+T_2; // K
23 //m_f=y(1)
24 function [X]=Mass(y);
25     X(1)=(y(1)*CV)-(C_p*(1+y(1))*(T_4-T_3));
26 endfunction
27 y=[0.01]
28 z=fsolve(y,Mass);
29 m_f=z(1); // kJ/kg of air
30 m_a=1; // kg
31 q=m_a*(T_3-T_2); //Heat saved in kJ/kg of air
32 M=(m*60*q)/CV; // Fuel saved per hour in kg/hr
33 W_net=(C_p*(1+m_f)*(T_4-T_5))-(C_p*m_a*(T_2-T_1)); //
    kJ/kg
34 P=(m/60)*W_net; // The capacity of the plant in kW
35 printf('\nFuel saved per hour=%0.2f kg/hr\nThe
    capacity of the plant=%0.1f kW',M,P);
36 // The answer vary due to round off error

```

---

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

```

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

```

```

11 e=0.6; // The effectiveness of the heat exchanger
12 r=1.4; // Specific heat ratio
13 C_p=1; // kJ/kg. C
14 //C_p=C_pg=C_pa
15
16 // Calculation
17 T_2a=T_1*(P_r)^((r-1)/r); // K
18 T_2=((T_2a-T_1)/n_c)+T_1; // K
19 T_4a=T_3/(P_r)^((r-1)/r); // K
20 T_4=T_3-(n_t*(T_3-T_4a)); // K
21 W_c=C_p*(T_2-T_1); // kJ/kg
22 W_t=C_p*(T_3-T_4); // kJ/kg
23 Q_a=C_p*(T_3-T_2); // kJ/kg
24 n_th=((W_t-W_c)/Q_a)*100; // Cycle efficiency
25 W_s=W_t-W_c; // kJ/kg
26 P=((m*1000)/3600)*CV*n_th/100*n_t*n_c; // kW
27 P=P/1000; //MW
28 printf('\n Cycle efficiency=%0.1f percentage \nThe
        specific work output=%0.0f kJ/kg',n_th,W_s);
29 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 24.4** The thermal efficiency of the plant

```

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

```

```

12 // P_r=(P_1/P_2)=(P_3/P_4)
13 P_r=6; // Pressure ratio
14 C_p=1.005; // kJ/kg K
15 r=1.4; // Specific heat ratio
16
17 // Calculation
18 T_2a=T_1*(P_r)^((r-1)/r); // K
19 T_2=((T_2a-T_1)/n_c)+T_1; // K
20 T_4a=T_3/(P_r)^((r-1)/r); // K
21 T_4=T_3-(n_t*(T_3-T_4a)); // K
22 P=m*C_p*((T_3-T_4)-(T_2-T_1)); // kW
23 T_5=(e*(T_4-T_2))+T_2; // K
24 // T_4-T_6=T_5-T_2, neglecting, the weight of the
    fuel
25 T_6=T_4+T_2-T_5; // K
26 n_th1=((T_3-T_4)-(T_2-T_1))/(T_3-T_5)*100; // %
27 n_th2=((T_3-T_4)-(T_2-T_1))/(T_3-T_2)*100; // %
28 printf('\nEfficiency of the plant with regeneration=
    %0.1f percentage \nEfficiency without heat
    exchanger=%0.1f percentage',n_th1,n_th2);
29 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 24.5** The thermal efficiency of the plant

```

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

```

```

11 T_3=980+273; // K
12 C_p=1.006; // kJ/kg.K
13 r=1.4; // Specific heat ratio
14
15 // Calculation
16 T_2a=T_1*(p_2/p_1)^((r-1)/r); // K
17 T_2=((T_2a-T_1)/n_c)+T_1; // K
18 // (1) For the first turbine
19 // Compressor work= Turbine work
20 T_4=T_3-(T_2-T_1); // Turbine exit temperature in K
21 T_4a=T_3-((T_3-T_4)/(n_t)); // K
22 p_3=p_2; // bar
23 p_4a=(p_3)/((T_3/T_4a)^(r/(r-1))); // kN/m^2
24 p_4=p_4a; // kN/m^2
25 // (2) For the power turbine
26 p_5=p_1; // bar
27 T_5a=T_4*(p_5/p_4)^((r-1)/r); // K
28 T_5=T_4-(n_pt*(T_4-T_5a)); // K
29 P=(m*C_p*(T_4-T_5)); // kW
30 n_th=(C_p*(T_4-T_5))/(C_p*(T_3-T_2)); // Thermal
    efficiency
31 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 );
32 // The answer vary due to round off error

```

---

#### Scilab code Exa 24.6 Thermal efficiency of the plant

```

1 // Example 24_6
2 clc; funcprot(0);
3 // Given data
4 T_1=288; // K
5 p_1=1.03; // bar

```

```

6 p_2=6; // bar
7 p_3=p_2-0.1; // bar
8 n_c=80/100; // The isentropic efficiency of
    compressor
9 n_t=n_c; // The isentropic efficiency of turbine
10 n_com=90/100; // Combustion efficiency
11 W=1.1*1000; // kW
12 m=7; // Air flow rate in kg/s
13 T_3=750+273; // K
14 // C_p=C_pa=C_pg
15 C_p=1.0; // kJ/kg.K
16 r=1.4; // Specific heat ratio
17 CV=20000; // kJ/kg
18
19 // Calculation
20 // Applying isentropic law to the process 1-2
21 T_2a=T_1*(p_2/p_1)^((r-1)/r); // K
22 T_2=T_1+((T_2a-T_1)/n_c); // K
23 // m=m_a/m_f
24 m=((CV*n_com)/(T_3-T_2))-1;
25 // Applying isentropic law to the process 3-4'
26 T_4a=T_3/((p_3/p_1)^((r-1)/r)); // K
27 T_4=T_3-(n_t*(T_3-T_4a)); //K
28 m_a=W/(((1+(1/m))*C_p*(T_3-T_4))-(C_p*(T_2-T_1))); //
    kg/sec
29 m_f=m_a/37; // kg/sec
30 m_g=m_a+m_f; // kg/sec
31 W_t=m_g*C_p*(T_3-T_4); // kW
32 W_r=W/W_t; // Work ratio
33 n_th=W/(m_g*C_p*(T_3-T_2)); // Thermal efficiency of
    the plant
34 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);
35 // The answer vary due to round off error

```



**Scilab code Exa 24.7** Thermal efficiency of the plant and Work saved per hour due to intercooling

```

1 // Example 24_7
2 clc;funcprot(0);
3 //Given data
4 p_r=6.5// Pressure ratio
5 T_1=300;// K
6 p_1=1;// bar
7 T_5=850;// K
8 P=10;//The power plant capacity in MW
9 CV=45000;// kJ/kg
10 r=1.4;// Spcific heat ratio for air and gases
11 C_p=1;// kJ/kg-k for air and gases
12 C_pg=C_p;
13
14 //Calculation
15 p_2=p_1*p_r;// bar
16 p_i=sqrt(p_1*p_2);//The required intermediate
    pressure in bar
17 T_2=T_1*(p_i/p_1)^((r-1)/r);// K
18 T_7=T_1*(p_2/p_1)^((r-1)/r);// K
19 T_3=T_1;// K
20 T_4=T_1*(p_2/p_i)^((r-1)/r);// K
21 W_wi=2*C_p*(T_2-T_1);//The workdone per kg of air
    with perfect inter cooling in kJ/kg
22 W_woi=C_p*(T_7-T_1);//The workdone per kg of air
    without inter cooling in kJ/kg
23 W_s=W_woi-W_wi;// Work saved per kg of air
    compressed due to intercooling in kJ/kg
24 // Assume m=m_a/m_f
25 m=(CV/(C_pg*(T_5-T_4)))-1;
26 T_6=T_5*(p_1/p_2)^((r-1)/r);// K
27 W_e=C_pg*(T_5-T_6);// Work done per kg of exhaust

```

```

    gases in turbine in kJ/kg
28 //When 1 kg of fuel used ,m_f=1
29 m_a=m*1; // The mass of air supplied in kg
30 W_net=((1+m_a)*W_e)-(m_a*W_wi); // Net work available
    in kJ/kg of fuel
31 m_f=(P*10^3)/W_net; // kg /sec
32 m_f=m_f*3600; // kg/hr
33 W_si=W_s*m_f*m_a; // kJ/hr
34 W_si=W_si/3600; // kJ/hr
35 P_woi=P-(W_si/1000); // MW
36 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
37 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);
38 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 24_8
2 clc;funcprot(0);
3 //Given data
4 p_1=1; // bar
5 p_2=5; // bar
6 p_i=2.5; // bar
7 T_1=27+273; // K
8 T_3=900; // K
9 T_5=T_3; // K
10 r=1.4; // Specific heat ratio
11 CV=40000; // kJ/kg
12 r=1.4; // Specific heat ratio for air and gases
13 C_p=1; // kJ/kg-k for air and gases
14 m_a=10; // kg/sec
15 C_pg=C_p;

```

```

16 C_pa=C_p
17
18 // Calculation
19 T_2=T_1*(p_2/p_1)^((r-1)/r); // K
20 T_4=T_3*(p_i/p_2)^((r-1)/r); // K
21 T_6=T_5*(p_1/p_i)^((r-1)/r); // K
22 m_f1=1/((CV/(T_3-T_2))-1); // kg/kg of air
23 m_f2=1/((CV/(T_5-T_4))-(1+m_f1)); // kg/kg of air
24 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
25 Q_net=(m_f1+m_f2)*CV; // Net heat supplied per kg of
      air passing through the system in kJ.
26 n_th=(W_net/Q_net)*100; // Thermal efficiency in %
27 P=m_a*W_net; // Capacity of the plant in kW
28 printf('\nThermal efficiency=%0.1f percentage \
      nPlant capacity=%0.1f MW',n_th,P/10^3);
29 // The answer vary due to round off error

```

---

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

```

1 // Example 24_9
2 clc;funcprot(0);
3 //Given data
4 W=2; // Work done in MW
5 p_1=1; // bar
6 p_r=5; // Pressure ratio in bar
7 p_i=2.5; // bar
8 T_1=27+273; // K
9 r=1.4; // Specific heat ratio
10 CV=40000; // kJ/kg
11 n_c=85/100; // The isentropic efficiency of the
      compressor
12 n_t=85/100; // The isentropic efficiency of the

```

```

turbine
13 Q_a=80; // Heat absorbed in kJ/kg of air
14 m_f=0.01; // kg per kg of air
15 m_a=1; // kg
16 r=1.4; // Spcific heat ratio for air and gases
17 C_p=1; // kJ/kg-k for air and gases
18 C_pg=C_p;
19 C_pa=C_p
20
21 // Calculation
22 T_2a=T_1*(p_r)^((r-1)/r); // K
23 T_2=((T_2a-T_1)/n_c)+T_1; // K
24 T_3=T_2+(Q_a/(C_pa*m_a)); // K
25 T_4=((m_f*CV)/((1+m_f)*C_p))+T_3; // K
26 T_5a=T_4*(1/p_r)^((r-1)/r); // K
27 T_5=T_4-(n_t*(T_4-T_5a)); // K
28 n_th=((T_4-T_5)-(T_2-T_1))/(T_4-T_3)*100; //
    Thermal efficiency in %
29 Q=(W*10^3)/(n_th/100); //Heat supplied in kJ/sec
30 F=(Q/CV)*3600; // Fuel required per hour in kg/hr
31 n_cp=(1-(1/(p_r)^((r-1)/r)))*100; //Efficiency of
    normal constant pressure cycle
32 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);
33 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 24_10
2 clc; funcprot(0);
3 //Given data
4 T_1=20+273; // K

```

```

5 p_1=1; // bar
6 T_6=700+273; // K
7 p_r=6; // Pressure ratio
8 e=0.7; // The effectiveness of regenerator
9 m_air=200; // Air flow through the plant in kg/sec
10 n_c=0.82; // Isentropic efficiency of both
    compressors
11 n_t=0.92; // Isentropic efficiency of turbine
12 n_com=0.96; // Combustion efficiency
13 n_m=0.96; // Mechanical efficiency
14 n_g=0.95; // Generation efficiency
15 CV=35000; // kJ/kg
16 C_p=1; // kJ/kg.K
17 r=1.4; // Specific heat ratio
18
19 // Calculation
20 p_2=p_r*p_1; // bar
21 p_i=sqrt(p_1*p_2); // bar
22 T_2a=T_1*(p_i/p_1)^((r-1)/r); // K
23 T_2=((T_2a-T_1)/n_c)+T_1; // K
24 T_3=T_1; // K
25 T_4a=T_3*(p_2/p_i)^((r-1)/r); // K
26 T_4=T_2; // K (as n_c1=n_c2)
27 T_7a=T_6*((p_1/p_2)^((r-1)/r)); // K
28 T_7=T_6-(n_t*(T_6-T_7a)); // K
29 T_5=(e*(T_7-T_4))+T_4; // K
30 function [X]=m_f(y)
31     X(1)=(C_p*(1+y(1))*(T_6-T_5))-(y(1)*CV*n_com);
32 endfunction
33 y=[0.01]
34 z=fsolve(y,m_f);
35 m_fuel=z(1);
36 m_a=1; // kg/kg of air
37 m=(m_a/m_fuel); // Air fuel ratio
38 n_th=((T_6-T_7)-(2*(T_2-T_1)))/(T_6-T_5))*100; //
    Thermal efficiency
39 W=(m_a*(T_6-T_5)*(n_th/100)); // Work done per kg of
    air in kJ

```

```

40 W_s=W*m_air;// Work done per sec in kJ/sec
41 P=W_s/10^3;// Capacity of the plant in MW
42 P_a=W_s*n_m*n_t;// Power available at generation
    terminals in kW
43 F=m_air*3600*m_fuel;// Fuel consumption per hour in
    kg/hr
44 Sfc=F/(P_a);// Specific fuel consumption in kg/kW.hr
45 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);
46 // The answers provided in the textbook is wrong

```

---

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

```

1 // Example 24_11
2 clc;funcprot(0);
3 //Given data
4 P=5;// Power plant capacity in MW
5 T_1=27+273;// K
6 p_1=1;// bar
7 T_4=1000;// K
8 p_r=5;// Pressure ratio
9 n_c=0.85;// Isentropic efficiency of compressor
10 n_t=0.90;// Isentropic efficiency of turbine
11 n_com=0.95;// Combustion efficiency
12 n_m=0.95;// Mechanical efficiency
13 n_g=0.92;// Generation efficiency
14 Tl=10;// Transmission losses
15 CV=40000;// kJ/kg
16 C_pa=1;// kJ/kg.K
17 C_pg=1.1;// kJ/kg.K
18 r=1.4;// Specific heat ratio
19 m=80;// Air fuel ratio
20 Cf_t=5000;// Cost of fuel in Rs./tonne

```

```

21 0c=5000; // All other charges in rupees
22
23 // Calculation
24 n_tt=(1-(T1/100)); // Transmission efficiency
25 p_2=p_1*p_r; // bar
26 T_2a=T_1*(p_r)^((r-1)/r); // K
27 T_2=((T_2a-T_1)/n_c)+T_1; // K
28 T_5a=T_4*(p_1/p_2)^((r-1)/r); // K
29 T_5=T_4-(n_t*(T_4-T_5a)); // K
30 e_g=P*1000; // The energy generated per second in kJ/
    sec
31 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
32 T_3=T_4-((CV*n_com)/(C_pg*(m+1))); // K
33 e=(C_pa*(T_3-T_2))/(C_pg*(1+(1/m))*(T_5-T_2)); //
    Effectiveness of regenerator
34 Fc=(m_a*3600*(1/m)); // The fuel consumption per hour
    in kg/hr
35 Cf=(Fc/1000)*Cf_t; // Cost of fuel per hour in Rs.
36 Tc=Cf+0c; // Total cost to be charged per hour in Rs.
37 E_g=e_g*1; // Energy generated in kW-hr
38 Ce=Tc/E_g; // Charges of energy per kW-hr in Rs./kWh
39 printf('\n\nThe mass of air flow through the
    compressor per second=%0.2f kg/sec \n\nThe
    effectiveness of regenerator=%0.3f \n\nThe charges
    of energy per kW-hr=Rs.%0.2f/kWh',m_a,e,Ce);
40 // The answers provided in the textbook is wrong

```

---

**Scilab code Exa 24.12** The cost of energy generated

```

1 // Example 24_12
2 clc; funcprot(0);
3 // Given data
4 P=10; // Power plant capacity in MW
5 T_1=300; // K

```

```

6 T_4=960; // K
7 e=0.7; // The effectiveness of regenerator
8 n_c=0.8; // Isentropic efficiency of compressor
9 n_t=0.90; // Isentropic efficiency of turbine
10 n_com=0.96; // Combustion efficiency
11 n_m=0.95; // Mechanical efficiency
12 n_g=0.95; // Generation efficiency
13 CV=40000; // kJ/kg
14 C_pa=1; // kJ/kg.K
15 r=1.4; // Specific heat ratio
16 Cf_t=4000; // Cost of fuel in Rs./tonne
17 Oc=3000; // All other charges in rupees
18 Q=90; // Heat developed in combustion chamber in %
19
20 // Calculation
21 p_r=(n_c*n_t*(T_4/T_1))^(r/(2*(r-1))); // Pressure
    ratio
22 T_2a=T_1*(p_r)^((r-1)/r); // K
23 T_2=((T_2a-T_1)/n_c)+T_1; // K
24 T_5a=T_4*(1/p_r)^((r-1)/r); // K
25 T_5=T_4-(n_t*(T_4-T_5a)); // K
26 m_a=(P*1000)/((C_pa*((T_4-T_5)-(T_2-T_1)))*n_com*n_g
    );
27 T_3=T_2+(e*(T_5-T_2)); // K
28 m_f=(m_a*C_pa*(T_4-T_3))/(CV*n_com*(Q/100)); // kg/
    sec
29 Cf=((m_f*3600)/1000)*Cf_t; // Cost of fuel in Rs./hr
30 Tc=Cf+Oc; // Total cost in Rs/hr
31 Ce=Tc/(P*1000); // Cost of energy generated in Rs/kWh
32 m=m_a/m_f; // Air-fuel ratio
33 printf('\nThe cost of energy generated=Rs.%0.2f/kWh'
    ,Ce);
34 // The answer vary due to round off error

```

---

**Scilab code Exa 24.13** The power available at the generator terminals



```

1 // Example 24_13
2 clc; funcprot(0);
3 // Given data
4 T_1=27+273; // K
5 p_1=1; // bar
6 p_2=4; // bar
7 n_c=0.80; // Isentropic efficiency of compressor
8 n_t=0.85; // Isentropic efficiency of turbine
9 e=0.75; // The effectiveness of regenerator
10 p_lr=0.1; // Pressure loss in regenerator along air
    side in bar
11 p_lcc=0.05; // Pressure loss in the combustion
    chamber in bar
12 n_com=0.90; // Combustion efficiency
13 n_m=0.90; // Mechanical efficiency
14 n_g=0.95; // Generation efficiency
15 m_a=25; // kg/sec
16 CV=40000; // kJ/kg
17 C_pa=1; // kJ/kg.K
18 C_pg=1.1; // kJ/kg.K
19 r=1.4; // Specific heat ratio
20 T_4=700+273; // K
21 p_atm=1.03; // bar
22
23 // Calculation
24 p_i=p_2-(p_lr+p_lcc); // Pressure at the inlet of the
    turbine in bar
25 p_e=p_atm+p_lr; // Pressure at the exit of the
    turbine in bar
26 T_2a=T_1*(p_2/p_1)^((r-1)/r); // K
27 T_2=((T_2a-T_1)/n_c)+T_1; // K
28 T_5a=T_4*(p_e/p_i)^((r-1)/r); // K
29 T_5=T_4-(n_t*(T_4-T_5a)); // K
30 // Assume m=(m_a/m_f)
31 // m=y(1), T_3=y(2)
32 function [X]=airfuelratio(y)
33     X(1)=((y(1)+1)*C_pg*(T_4-y(2)))-(CV*n_com);
34     X(2)=((C_pa*(y(2)-T_2))/(e*C_pg*(T_5-T_2)))

```

```

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

```

---

#### Scilab code Exa 24.14 Thermal efficiency of the plant

```

1 // Example 24_14
2 clc; funcprot(0);
3 //Given data
4 P=800; // Plant capacity in kW
5 T_1=15+273; // K
6 p_1=1.01; // bar
7 T_4=700+273; // K
8 p_r=6; // Pressure ratio
9 e=0.75; // The effectiveness of regenerator
10 p_lr=0.15; // Pressure drop in regenerator in bar
11 p_lcc=0.15; // Pressure drop in the combustion

```

```

    chamber in bar
12 n_c=0.80; // Isentropic efficiency of compressor
13 n_t=0.85; // Isentropic efficiency of turbine
14 C_p=1; // kJ/kg.K
15 r=1.4; // Specific heat ratio
16
17 // Calculation
18 p_2=p_r*p_1; // bar
19 p_3=p_2-p_1cc; // Pressure at point 4 in bar
20 T_2a=T_1*(p_r)^((r-1)/r); // K
21 T_2=((T_2a-T_1)/n_c)+T_1; // K
22 p_4=p_1+p_lr; // bar
23 T_5a=T_4/(p_3/p_4)^((r-1)/r); // K
24 T_5=T_4-(n_t*(T_4-T_5a)); // K
25 T_3=T_2+(e*(T_5-T_2)); // K
26 W_c=C_p*(T_2-T_1); // kJ/kg
27 W_t=C_p*(T_4-T_5); // kJ/kg
28 W_n=W_t-W_c; // kJ/kg
29 Q_s=C_p*(T_4-T_3); // kJ/kg
30 n_th=(W_n/Q_s)*100; // Thermal Efficiency in
    percentage
31 printf('\nThe thermal efficiency of the plant=%0.1f
    percentage ',n_th);

```

---

**Scilab code Exa 24.15** The thermal efficiency of the plant

```

1 // Example 24_15
2 clc; funcprot(0);
3 // Given data
4 m_a=10; // kg/sec
5 p_r=6; // Pressure ratio
6 T_1=300; // K
7 p_1=1; // bar
8 T_6=1073; // K
9 e=0.75; // The effectiveness of regenerator

```

```

10 n_c=0.80; // Isentropic efficiency of compressor
11 n_t=0.85; // Isentropic efficiency of turbine
12 C_pa=1; // kJ/kg.K
13 r=1.4; // Specific heat ratio
14 m=1; // kg
15
16 // Calculation
17 p_3=p_1*p_r; // bar
18 p_2=sqrt(p_1*p_3); // bar
19 T_2a=T_1*(p_2/p_1)^((r-1)/r); // K
20 T_2=((T_2a-T_1)/n_c)+T_1; // K
21 //W_c=W_c1+W_c2=2*W_c1 (as intercooling is perfect)
22 W_c=2*m*C_pa*(T_2-T_1); // kJ/kg
23 // As T_3=T_1 and p_r=(p_2/p_1)=(p_3/p_2)
24 T_4=T_2; // K
25 T_7a=T_6/(p_3/p_1)^((r-1)/r); // K
26 T_7=T_6-(n_t*(T_6-T_7a)); // K
27 W_t=C_pa*(T_6-T_7); // kJ/kg
28 T_5=T_4+(e*(T_7-T_4)); // K
29 Q_s=m*C_pa*(T_6-T_5); // kJ/kg
30 W_n=W_t-W_c; // kJ/kg
31 P=m_a*W_n; //Power capacity of the plant in kW
32 n_th=(W_n/Q_s)*100; // Thermal Efficiency in
    percentage
33 printf('\nPower capacity of the plant=%0.0f kW\nThe
    thermal efficiency of the plant=%0.1f percentage'
    ,P,n_th);
34 // The answer vary due to round off error

```

---

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

```

1 // Example 24_16
2 clc;funcprot(0);
3 //Given data

```

```

4 P=5; // Power plant capacity in MW
5 T_1=300; // K
6 p_1=1; // bar
7 T_5=650+273; // K
8 p_r=5; // Pressure ratio
9 e=0.7; // The effectiveness of regenerator
10 n_c=0.8; // Isentropic efficiency of compressor
11 n_t=0.85; // Isentropic efficiency of both turbines
12 n_t1=n_t;
13 n_t2=n_t;
14 n_com=0.97; // Combustion efficiency
15 n_m=0.98; // Mechanical efficiency of both turbines
16 CV=40000; // kJ/kg
17 C_pa=1; // kJ/kg. C
18 C_pg=1.145; // kJ/kg. C
19 r_a=1.4; // Specific heat ratio for air
20 r_g=1.35; // Specific heat ratio for gases
21
22 // Calculation
23 p_2=p_1*p_r; // bar
24 p_i=sqrt(p_1*p_2); // The intermediate pressure
    between two compressors
25 T_2a=T_1*(p_i)^((r_a-1)/r_a); // K
26 T_2=((T_2a-T_1)/n_c)+T_1; // K
27 T_3=T_1; // K
28 T_4=T_2; // K
29 T_7=T_5; // K
30 // Work developed by the compressor turbine = Work
    required to run the compressor
31 T_6=T_5-((2*C_pa*(T_2-T_1))/(C_pg*n_m)); // K
32 T_6a=T_5-((T_5-T_6)/n_t1); // K
33 p_3=p_2/((T_5/T_6a)^(r_g/(r_g-1))); // K
34 T_8a=T_7*(p_1/p_3)^((r_g-1)/r_g); // K
35 T_8=T_7-(n_t2*(T_7-T_8a)); // K
36 T_x=T_4+((e*C_pg*(T_8-T_4))/C_pa); // K
37 W_net=C_pg*(T_7-T_8)*n_m; // Net Work available per kg
    of air in kJ/kg of air
38 Q_s=C_pg*((T_5-T_x)+(T_7-T_6)); // Heat supplied per

```

```

    kg of air kJ/kg of air
39 m_f=Q_s/(CV*n_com); // The total mass of fuel in per
    kg of air flow
40 m=1/m_f; // Air fuel ratio
41 n_o=(W_net/(m_f*CV))*100; // Over all efficiency
42 m_a=(P*1000)/(W_net); // kg/sec
43 M_f=m_a*3600*m_f; // Mass of fuel used per hour in kg
    /hr
44 Sfc=M_f/(P*1000*1); // Specific fuel consumption in
    kg/kW-hr
45 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);
46 // The answer vary due to round off error

```

---

#### Scilab code Exa 24.17 Plant efficiency and Specific fuel consumption

```

1 // Example 24_17
2 clc; funcprot(0);
3 //Given data
4 P=1600; // Power plant capacity in kW
5 T_1=300; // K
6 T_3=1050; // K
7 p_1=1; // bar
8 T_5=1100; // K
9 p_2=5; // bar
10 e=0.7; // The effectiveness of regenerator
11 n_c=0.8; // Isentropic efficiency of compressor
12 n_t1=0.85; // Efficiency of compressor turbine
13 n_t2=0.90; // Efficiency of power turbine
14 n_com=0.95; // Combustion efficiency
15 n_m=0.90; // Mechanical efficiency of both turbines
16 n_g=1; // Generation efficiency
17 CV=40000; // kJ/kg

```

```

18 C_pa=1; // kJ/kg.K
19 C_pg=1.1; // kJ/kg.K
20 r_a=1.4; // Specific heat ratio for air
21 r_g=1.35; // Specific heat ratio for gases
22
23 // Calculation
24 T_2a=T_1*(p_2/p_1)^((r_a-1)/r_a); // K
25 T_2=((T_2a-T_1)/n_c)+T_1; // K
26 T_4a=T_3*(p_1/p_2)^((r_g-1)/r_g); // K
27 T_4=T_3-(n_t1*(T_3-T_4a)); // K
28 T_6a=T_5*(p_1/p_2)^((r_g-1)/r_g); // K
29 T_6=T_5-(n_t2*(T_5-T_6a)); // K
30 m_a2=P/(C_pg*(T_5-T_6)*n_m*n_g); // kg/sec
31 //Power developed by compressor turbine = Power
    absorbed by compressor
32 //m_a1=y(1)
33 function [X]=mass(y);
34     X(1)=((y(1)+m_a2)*C_pa*(T_2-T_1))-(y(1)*C_pg*(
        T_3-T_4)*n_m);
35 endfunction
36 y=[10];
37 z=fsolve(y,mass);
38 m_a1=z(1); // kg/sec
39 T_y=((m_a1/(m_a1+m_a2))*T_4)+((m_a2/(m_a1+m_a2))*T_6
    ); // The temperature after mixing in C
40 T_x=T_2+((e*C_pg*(T_y-T_2))/C_pa); // K
41 m_f=((C_pg*m_a1*(T_3-T_x))+C_pg*m_a2*(T_5-T_x))/(
    CV*n_com); // kg/sec
42 n_th=(P/(m_f*CV))*100; // Plant efficiency in
    percentage
43 Sfc=(m_f*3600)/P; // kg/kWh
44 Afr=(m_a1+m_a2)/m_f; // Air fuel ratio
45 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);
46 // The answer vary due to round off error

```

Scilab code Exa 24.18 Compressor turbine capacity

```
1 // Example 24_18
2 clc;funcprot(0);
3 //Given data
4 P=200;// Power plant capacity in MW
5 T_6=1000;// K
6 T_8=900;// K
7 p_1=1;// bar
8 T_1=27+273;// K
9 p_r=5;// bar
10 e=0.7;// The effectiveness of heat exchanger
11 n_c=1;// Isentropic efficiency of both compressors
12 n_t=0.9;// Efficiency of both turbines
13 n_com=0.95;// Combustion efficiency
14 n_m=0.92;// Mechanical efficiency of compressor and
    generator shafts
15 CV=40000;// kJ/kg
16 C_p=1;// kJ/kg. C
17 r=1.4;// Specific heat ratio for air and gases
18
19 //Calculation
20 p_2=p_1*p_r;// bar
21 p_i=sqrt(p_1*p_2);// bar
22 T_7a=T_6*(p_1/p_2)^((r-1)/r);// K
23 n_t2=n_t;
24 T_7=T_6-(n_t2*(T_6-T_7a));// K
25 W_g=C_p*(T_6-T_7)*n_m;//Work done per kg of air in
    generator-turbine in kJ/kg
26 m_2=CV/W_g;// The mass of exhaust gases in kg/sec
27 T_2=T_1*(p_i)^((r-1)/r);// K
28 W_c=2*C_p*(T_2-T_1);//Work done per kg of air in
    both compressors in kJ/kg
29 T_4=T_2;// K
```



```

30 // Assume m_1=y(1);T_5=y(2)
31 function [X]=massflow(y);
32     X(1)=(m_2*C_p*(y(2)-T_8))-(y(1)*C_p*(T_8-T_4));
33     X(2)=((y(1)*C_p*(T_8-T_4))/(m_2*C_p*(y(2)-T_4)))
        -(e);
34 endfunction
35 y=[100 1000];
36 z=fsolve(y,massflow);
37 T_5=z(2); // K
38 m_1=z(1); // kg/sec
39 T_9a=T_8/(p_i)^((r-1)/r); // K
40 n_t1=n_t;
41 T_9=T_8-(n_t1*(T_8-T_9a)); // K
42 m_c1=(((m_1*(T_8-T_9))/((T_2-T_1)*n_m))-m_1)/2; //
    Air taken from atmosphere in kg/sec
43 m_c2=m_c1+m_1; // kg/sec
44 //Assume m_f=y(1)
45 function [X]=massoffuel(z);
46     X(1)=((m_c2+z(1))*C_p*(T_5-T_4))/(CV*n_com)-z(1)
        ;
47 endfunction
48 z=[10];
49 y=fsolve(z,massoffuel);
50 m_f=y(1); // Mass of fuel used per second
51 n_o=((P*10^3)/(CV*m_f))*100; // Over all efficiency
    of the plant in %
52 Ctc=(m_1*C_p*(T_8-T_9))/1000; // Compressor-turbine
    capacity in MW
53 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=%0.0
    f kW',m_c1,m_f,n_o,Ctc*1000);
54 // The answer vary due to round off error

```

---

Scilab code Exa 24.19 The over all efficiency of the plant

```
1 // Example 24_19
2 clc;funcprot(0);
3 //Given data
4 P=5;// Power plant capacity in MW
5 T_1=30+273;// K
6 p_1=1;// bar
7 T_3=550+273;// K
8 p_r=5;// Pressure ratio
9 p_3=2.24;// bar
10 n_c=0.8;// Isentropic efficiency of compressor
11 n_t=0.85;// Isentropic efficiency of both turbines
12 n_t1=n_t;
13 n_t2=n_t;
14 C_pa=1;// kJ/kg. C
15 C_pg=1.15;// kJ/kg. C
16 r_a=1.4;// Specific heat ratio for air
17 r_g=1.33;// Specific heat ratio for gases
18
19 //Calculation
20 p_2=p_1*p_r;// bar
21 T_5=T_3;// K
22 T_2a=T_1*(p_2/p_1)^((r_a-1)/r_a);// K
23 T_2=((T_2a-T_1)/n_c)+T_1;// K
24 W_c=C_pa*(T_2-T_1);// kJ/kg
25 T_4a=T_3/(p_2/p_3)^((r_g-1)/r_g);// K
26 T_4=T_3-(n_t1*(T_3-T_4a));// K
27 T_6a=T_5/(p_3/p_1)^((r_g-1)/r_g);// K
28 T_6=T_5-(n_t2*(T_5-T_6a));// K
29 W_t=2*C_pg*(T_3-T_4);// kJ/kg
30 W_n=W_t-W_c;// kJ/kg
31 m_a=((P*10^3)/W_n);// kg/sec
32 Q_s=(C_pg*(T_3-T_2))+C_pg*(T_5-T_4);// kJ/kg
33 n_o=(W_n/Q_s)*100;// Over all efficiency in %
34 printf('\nThe over all efficiency=%0.0f percentage \
    nThe mass flow rate=%0.1f kg/sec',n_o,m_a);
35 // The answers provided in the textbook is wrong
```

---

**Scilab code Exa 24.20** Fuel consumption of the plant per hour

```
1 // Example 24_20
2 clc; funcprot(0);
3 //Given data
4 P=5; // Power plant capacity in MW
5 T_1=15+273; // K
6 p_1=1; // bar
7 T_4=750+273; // K
8 p_r=6; // Pressure ratio
9 p_3=2.24; // bar
10 e=0.75; // The effectiveness of heat exchanger
11 n_c=0.8; // Isentropic efficiency of compressor
12 n_t=0.85; // Isentropic efficiency of both turbines
13 n_t1=n_t;
14 n_t2=n_t;
15 C_pa=1; // kJ/kg.K
16 C_pg=1.15; // kJ/kg.K
17 r_a=1.4; // Specific heat ratio for air
18 r_g=1.33; // Specific heat ratio for gases
19 CV=18500; // kJ/kg
20
21 // Calculation
22 p_2=p_1*p_r; // bar
23 p_re=sqrt(p_1*p_2); // Pressure ratio for each turbine
    in bar
24 T_2a=T_1*(p_2/p_1)^((r_a-1)/r_a); // K
25 T_2=((T_2a-T_1)/n_c)+T_1; // K
26 T_6=T_4; // K
27 T_5a=T_4/((p_re)^((r_g-1)/r_g)); // K
28 T_5=T_4-(n_t1*(T_4-T_5a)); // K
29 T_7=T_5; // K
30 T_3=T_2+(e*(T_7-T_2)); // K
31 //(i)
```

```

32 function [X]=massoffuel(y)
33     X(1)=((1+y(1))*C_pg*(T_4-T_3))-(y(1)*CV);
34 endfunction
35 y=[0.01];
36 z=fsolve(y,massoffuel);
37 m_f1=z(1); // kg/kg of air
38 AF=1/m_f1; // Air fuel ratio
39 function [X]=massoffuel1(x)
40     X(1)=(C_pg*((1+m_f1+x(1))*(T_6-T_5)))-(x(1)*CV);
41 endfunction
42 x=[0.001];
43 y=fsolve(x,massoffuel1);
44 m_f2=y(1); // kg/kg of air
45 W_c=C_pg*(T_2-T_1); // kJ/kg of air
46 W_t1=C_pg*(1+(m_f1))*(T_4-T_5); // kJ/kg of air
47 W_t2=C_pg*(1+m_f1+m_f2)*(T_6-T_7); // kJ/kg of air
48 W_t=W_t1+W_t2; // kJ/kg of air
49 W_n=W_t-W_c; // kJ/kg of air
50 //(ii)
51 Q_s=(m_f1+m_f2)*CV; // kJ/kg of air
52 n_th=(W_n/Q_s)*100; // Thermal efficiency of the
    cycle
53 //(iii)
54 m_a=((P*10^3)/W_n); // kg/sec
55 //(iv)
56 F=m_a*(m_f1+m_f2)*3600; // Fuel required per hour in
    kg/hr
57 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);
58 // The answers provided in the textbook is wrong

```

---

Scilab code Exa 24.21 Power developed by the plant

```

1 // Example 24_21
2 clc; funcprot(0);
3 // Given data
4 T_1=25+273; // K
5 p_1=1; // bar
6 T_6=1250+273; // K
7 p_3=9; // bar
8 n_c=0.83; // Isentropic efficiency of both
   compressors
9 n_c1=n_c;
10 n_c2=n_c;
11 n_t=0.83; // Isentropic efficiency of both turbines
12 n_t1=n_t;
13 n_t2=n_t;
14 C_pa=1; // kJ/kg.K
15 r=1.4; // Specific heat ratio
16 m_a=16.5; // kg/sec
17
18 // Calculation
19 p_2=sqrt(p_1*p_3); // bar
20 T_2a=T_1*(p_2/p_1)^((r-1)/r); // K
21 T_2=((T_2a-T_1)/n_c1)+T_1; // K
22 T_8=T_6; // K
23 T_4=T_2; // K
24 T_7a=T_6/(p_3/p_2)^((r-1)/r); // K
25 T_7=T_6-(n_t1*(T_6-T_7a)); // K
26 T_9=T_7; // K
27 W_c=2*C_pa*(T_2-T_1); // kJ/kg
28 W_t=2*C_pa*(T_6-T_7); // kJ/kg
29 W_n=W_t-W_c; // kJ/kg
30 T_5=T_7;
31 //When the ideal regeneration is given, then
32 e=1; // Effectiveness
33 Q_s=2*C_pa*(T_6-T_5); // kJ/kg
34 //(i)
35 n_th=(W_n/Q_s)*100; //The thermal efficiency in %
36 //(ii)
37 P=W_n*m_a; // Power developed by the plant in kW

```

```

38 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);
39 // The answer vary due to round off error

```

---

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

```

1 // Example 24_22
2 clc;funcprot(0);
3 //Given data
4 T_1=290;// K
5 p_1=1.01;// bar
6 T_3=650+273;// K
7 p_r=8;// Pressure ratio
8 n_c=0.8;// Isentropic efficiency of compressor
9 n_t1=0.85;// Isentropic efficiency of H.P turbine
10 n_t2=0.83;// Isentropic efficiency of L.P turbine
11 C_pa=1;// kJ/kg.K
12 C_pg=1.15;// kJ/kg.K
13 r_a=1.4;// Specific heat ratio for air
14 r_g=1.33;// Specific heat ratio for gases
15 m_a=10;// The air flow through the compressor in kg
    /sec
16
17 //Calculation
18 p_2=p_1*p_r;// bar
19 T_2a=T_1*(p_r)^((r_a-1)/r_a);// K
20 T_2=((T_2a-T_1)/n_c)+T_1;// K
21 W_c=1*C_pa*(T_2-T_1);//Work input to the compressor
    in kJ/kg
22 W_t1=W_c;// kJ/kg
23 T_4=T_3-(W_t1/C_pg);// K
24 T_4a=T_3-((T_3-T_4)/n_t1);// K
25 p_3=p_2/((T_3/T_4a)^(r_g/(r_g-1)));// bar
26 p_re=p_3/p_1;// The pressure ratio of expansion in

```

```

    the power turbine
27 T_5a=T_4/(p_3/p_1)^((r_g-1)/r_g); // K
28 dT_45=n_t2*(T_4-T_5a); // (dT_45=T_4-T_5) K
29 W_t2=C_pg*(dT_45); //Work developed by power turbine
    in kJ/kg
30 W_net=W_t2; // The net work done per kg of air in kJ/
    kg
31 W_t=W_t1+W_t2; // Total work done per in kJ/kg
32 W_r=W_t2/W_t; // Work ratio
33 Q_s=C_pa*(T_3-T_2); // kJ/kg
34 n_th=(W_t2/Q_s)*100; // Thermal efficiency in %
35 P=W_t2*m_a; // Power capacity of the plant in kW
36 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);
37 // The answer vary due to round off error

```

---

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

```

1 // Example 24_23
2 clc;funcprot(0);
3 //Given data
4 p_1=1; // bar
5 p_2=5; // bar
6 p_3=2.5; // bar
7 T_1=300; // K
8 T_3=900; // K
9 T_5=T_3; // K
10 m_a=10; // kg/sec
11 CV=33500; // kJ/kg
12 C_p=1; // kJ/kg. C
13 r=1.4; // Specific heat ratio for air and gases
14
15 //Calculation

```

```

16 T_2=T_1*(p_2/p_1)^((r-1)/r); // K
17 T_4=T_3/(p_2/p_3)^((r-1)/r); // K
18 T_6=T_5/(p_2/p_3)^((r-1)/r); // K
19 function[X]=massoffuel(y)
20     X(1)=((1+y(1))*C_p*(T_3-T_2))-(y(1)*CV);
21 endfunction
22 y=[0.01];
23 z=fsolve(y,massoffuel);
24 m_f1=z(1); // kg/kg of air
25 function[X]=massoffuel1(x)
26     X(1)=(C_p*((1+m_f1+x(1))*(T_5-T_4)))-(x(1)*CV);
27 endfunction
28 x=[0.001];
29 y=fsolve(x,massoffuel1);
30 m_f2=y(1); // kg/kg of air
31 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
32 n_g=100; //The generator efficiency is considered 100
    %
33 n_th=(W_n/(m_a*(m_f1+m_f2)*CV))*100; // The
    efficiency of the plant in %
34 printf('\nThe thermal efficiency of the plant=%0.1f
    percentage \nPower generating capacity=%0.0f kW',
    n_th,W_n);
35 // The answers provided in the textbook is wrong

```

---

**Scilab code Exa 24.24** Heat carried away by the exhaust gases

```

1 // Example 24_24
2 clc; funcprot(0);
3 //Given data
4 T_1=300; // K
5 p_1=1; // bar
6 T_4=870+273; // K
7 p_r=6; // Pressure ratio

```



```

8 e=0.65; // The effectiveness of heat exchanger
9 n_c=0.8; // Isentropic efficiency of compressor
10 n_t=0.85; // Isentropic efficiency of turbine
11 n_g=0.95 // Generator efficiency
12 m_a=5; // kg/sec
13 C_p=1; // kJ/kg.K
14 r=1.4; // Specific heat ratio
15
16 // Calculation
17 // (a)
18 T_2a=T_1*(p_r)^((r-1)/r); // K
19 T_2=((T_2a-T_1)/n_c)+T_1; // K
20 T_5a=T_4/(p_r)^((r-1)/r); // K
21 T_5=T_4-(n_t*(T_4-T_5a)); // K
22 W_n=m_a*C_p*((T_4-T_5)-(T_2-T_1))*n_g; // kW
23 // (b)
24 T_3=T_2+(e*(T_5-T_2)); // K
25 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 %
26 T_6=T_5-(T_3-T_2); // K
27 // (c)
28 Q=(m_a*60)*C_p*(T_6-T_1); // KJ/min
29 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);
30 // The answer vary due to round off error

```

---

**Scilab code Exa 24.25** Over all efficiency of the plant

```

1 // Example 24_25
2 clc; funcprot(0);
3 // Given data
4 p_r=4.5; // Pressure ratio
5 m_a=82; // kg/min

```

```

6 m_f=1.4; // kg/min
7 W_o=200; // kW
8 W_c=230 // kW
9 p_1=1; // bar
10 T_1=15+273; // K
11 T_3=765+273; // K
12 r_c=1.4; // The index of compression
13 r_e=1.34; // The index of expansion
14 C_pa=1; // kJ/kg.K
15 C_pg=1.13; // kJ/kg.K
16 n_m=0.98; // Mechanical efficiency of the compressor
17
18 // Calculation
19 W_t=(W_o+W_c)/n_m; // kW
20 m_a=(m_a)/60; // kg/sec
21 m_f=(m_f)/60; // kg/sec
22 AF=m_a/m_f; // Air fuel ratio
23 //(a)
24 T_2a=T_1*(p_r)^((r_c-1)/r_c); // K
25 n_c=(m_a*C_pa*((T_2a-T_1)/W_c))*100; // Isentropic
    efficiency of compressor in %
26 //(b)
27 T_4a=T_3/(p_r)^((r_e-1)/r_e); // K
28 n_t=(W_t/((m_a+m_f)*C_pg*(T_3-T_4a)))*100; //
    Isentropic efficiency of turbine in %
29 //(c)
30 T_2=T_1+((T_2a-T_1)/(n_c/100)); // K
31 n_o=(W_o/((m_a+m_f)*C_pg*(T_3-T_2)))*100; // The over
    all efficiency of the plant in %
32 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);
33 // The answers provided in the textbook is wrong

```

---

**Scilab code Exa 24.26** The power developing capacity of the system

```
1 // Example 24_26
2 clc; funcprot(0);
3 // Given data
4 T_1=303; // K
5 p_1=0.9; // bar
6 p_2=4.5; // bar
7 T_3=1000+273; // K
8 p_3=1.1; // bar
9 e=0.8; // Effectiveness of heat exchanger
10 n_c=0.85; // Isentropic efficiency of compressor
11 n_t=0.80; // Isentropic efficiency of turbine
12 m_a=5; // kg/sec
13 C_p=1.005; // kJ/kg.K
14 r=1.4; // Specific heat ratio
15
16 // Calculation
17 T_2a=T_1*(p_2/p_1)^((r-1)/r); // K
18 T_2=((T_2a-T_1)/n_c)+T_1; // K
19 T_4a=T_3/(p_2/p_3)^((r-1)/r); // K
20 T_4=T_3-(n_t*(T_3-T_4a)); // K
21 T_5=T_2+(e*(T_4-T_2)); // K
22 n_th=((T_3-T_4)-(T_2-T_1))/(T_3-T_5)*100; // The
    thermal efficiency of the system in %
23 P=m_a*C_p*((T_3-T_4)-(T_2-T_1)); // The power
    developed by the system in kW
24 printf('\nThe thermal efficiency of the system=%0.0f
    percentage \n\nThe power developing capacity of
    the system=%0.1f kW', n_th, P);
25 // The answer provided in the textbook is wrong
```

---

Scilab code Exa 24.27 The thermal efficiency of the plant

```

1 // Example 24_27
2 clc;funcprot(0);
3 //Given data
4 T_1=21+273; // K
5 T_4=925+273; // K
6 n_c=0.86; // Isentropic efficiency of compressor
7 n_t1=0.85; // Isentropic efficiency of H.P turbine
8 n_t2=0.87; // Isentropic efficiency of L.P turbine
9 e=0.75; // Effectiveness of heat exchanger
10 n_com=0.98; // Combustion efficiency
11 n_m=0.99; // Mechanical efficiency of compressor and
    H.P turbine assembly
12 P=2040; // kW
13 C_pa=1.005; // kJ/kg.K
14 r=1.4; // Specific heat ratio for air
15 m=1; // kg
16
17 // Calculation
18 // p_r=p_1/p_2;
19 p_r1=7; // Pressure ratio
20 T_2a=T_1*(p_r1)^((r-1)/r); // K
21 T_2=((T_2a-T_1)/n_c)+T_1; // K
22 W_c=1*C_pa*(T_2-T_1); //Work input to the compressor
    in kJ/kg
23 W_t1=W_c/n_m; // kJ/kg
24 T_5=T_4-(W_t1/(m*C_pa)) // K
25 T_5a=T_4-((T_4-T_5)/n_t1); // K
26 p_r2=(T_4/T_5a)^(r/(r-1)); // Pressure ratio(p_2/p_3)
27 p_r3=(1/p_r1)*(p_r2); // Pressure ratio(p_3/p_1)
28 T_6a=T_5*(p_r3)^((r-1)/r); // K
29 T_6=T_5-((T_5-T_6a)*n_t2); // K
30 T_3=T_2+(e*(T_6-T_2)); // K
31 m_a=(P/(C_pa*(T_5-T_6))); // kg/sec
32 n_th=(P)/(m_a*C_pa*(T_4-T_3)*n_com)*100; // The
    thermal efficiency of the plant in %
33 printf('\nThe air flow rate=%0.2f kg/sec \nThe

```

```

    thermal efficiency of the plant=%0.1f percentage',
    ,m_a,n_th);
34 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 24_28
2 clc;funcprot(0);
3 //Given data
4 T_1=15+273;// K
5 p_1=1;// bar
6 T_3=680+273;// K
7 p_2=5;// bar
8 n_c=0.76;// Isentropic efficiency of compressor
9 n_t=0.86;// Isentropic efficiency of both turbines
10 m_a=23;// kg/sec
11 C_pa=1.005;// kJ/kg.K
12 C_pg=1.128;// kJ/kg.K
13 r_a=1.4;// Specific heat ratio for air
14 r_g=1.34;// Specific heat ratio for gases
15 CV=42000;// kJ/kg
16
17 //Calculation
18 //First considering C-TB_1
19 T_2a=T_1*(p_2/p_1)^((r_a-1)/r_a);// K
20 T_2=((T_2a-T_1)/n_c)+T_1;// K
21 // Assume m_r1=m_a1/m_f1
22 m_r1=(CV/(C_pg*(T_3-T_2)))-1;
23 T_4a=T_3/(p_2/p_1)^((r_g-1)/r_g);// K
24 T_4=T_3-((T_3-T_4a)*n_t);// K
25 m_f1=(m_a*C_pa*(T_2-T_1))/((m_r1+1)*C_pg*(T_3-T_4));
    // kg/sec
26 m_a1=m_r1*m_f1;// kg/sec
27 m_a2=m_a-m_a1;// kg/sec

```

```

28 // Now considering G-TB_2
29 //m_f2=y(1)
30 function [X]=massoffuel(y)
31     X(1)=((m_a2+y(1))*C_pg*(T_3-T_2))-(y(1)*CV);
32 endfunction
33 y=[0.01];
34 z=fsolve(y,massoffuel);
35 m_f2=z(1); // kg/kg of air
36 m_r2=m_a2/m_f2;
37 W_2=(m_a2+m_f2)*C_pg*(T_3-T_4); //Work developed by
    TB_2 kW
38 W_1=m_a1*C_pa*(T_2-T_1); // The capacity of TB_1 to
    run the compressor in kW
39 m_f=(m_f1+m_f2)*60; // kg/min
40 n_th=(W_2/((m_f/60)*CV))*100; // The thermal
    efficiency of the plant in %
41 printf('\n\nThe power output of the plant=%0.0f kW \
    nThe thermal efficiency of the plant=%0.1f
    percentage ',W_2,n_th);
42 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 24_29
2 clc; funcprot(0);
3 //Given data
4 T_1=15+273; // K
5 p_1=1; // bar
6 T_5=1000; // K
7 dp_in=0.07; // bar
8 dp_re=0.1; // bar
9 R_c1=2; // Compression ratio
10 n_c=0.80; // Efficiency of compressor
11 n_c1=n_c;

```

```

12 n_c2=n_c;
13 dp_com=0.15; // bar
14 dp_rh=0.1; // bar
15 n_t1=0.87; // Efficiency of turbine 1
16 n_t2=0.7; // Efficiency of turbine 2
17 e=0.75; // Effectiveness of heat exchanger
18 n_com=0.98; // Combustion efficiency
19 n_m=0.99; // Mechanical efficiency of compressor-
    turbine
20 m_a=20; // kg/sec
21 C_pa=1; // kJ/kg.K
22 C_pg=1.1; // kJ/kg.K
23 r_a=1.4; // Specific heat ratio for air
24 r_g=1.33; // Specific heat ratio for gases
25 CV=43.5; // MJ/kg
26
27 // Calculation
28 p_2=p_1*R_c1; // bar
29 p_3=p_2-dp_in; // bar
30 p_4=2*p_3; // bar
31 p_5=p_4-dp_in-dp_re; // bar
32 p_8=1+dp_rh; // bar
33 T_2=T_1+((T_1/n_c1)*(((R_c1)^((r_a-1)/r_a))-1)); // K
34 T_3=T_1; // K
35 T_4=T_3+((T_3/n_c2)*(((R_c1)^((r_a-1)/r_a))-1)); // K
36 // as T_4-T_3=T_2-T_1
37 W_1=2*m_a*C_pa*(T_2-T_1); // Power required to run
    the compressor in kW
38 W_t1=W_1/n_m; // Power developed by compressor
    turbine in kW
39 W_t1=W_t1/m_a; // The work developed by the turbine
    per kg of air in kJ/kg
40 dT_56=W_t1/C_pg; // (dT_56=T_5-T_6) K
41 R_t1=1/(1-((dT_56/(T_5*n_t1))))^(r_a/(r_a-1));
42 p_6=p_5/R_t1; // bar
43 p_7=p_6-dp_rh; // bar
44 R_t2=p_7/p_8; // bar
45 T_7=T_5; // K

```

```

46 dT_78=T_7*n_t2*(1-((1/R_t2)^((r_a-1)/r_a))); // K
47 T_8=T_7-dT_78; // K
48 W=m_a*C_pa*(T_7-T_8); // Net output of the plant in
    kW
49 T_9=T_4+(e*(T_8-T_4)); // K
50 Q_s=C_pa*((T_5-T_9)+(dT_56)); // The total heat
    supplied in the plant per kg of air in kJ/kg
51 m_f=((m_a*Q_s)/(CV*10^3*n_com))*3600; // The mass of
    fuel supplied in kg/hr
52 Sfc=m_f/W; // Specific fuel consumption in kg/kWh
53 n_th=(W/(Q_s*m_a))*100; // Thermal efficiency in %
54 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);
55 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 24.30** The over all efficiency of the plant

```

1 // Example 24_30
2 clc; funcprot(0);
3 //Given data
4 T_1=15+273; // K
5 p_1=1; // bar
6 R_c=5; // Compression ratio
7 T_3=800+273; // K
8 T_9=265+273; // K
9 W=625; // kW
10 e=0.75; // Effectiveness of heat exchanger
11 n_c=0.86; // Isentropic efficiency of compressor
12 n_t=0.86; // Isentropic efficiency of both turbine
13 n_t1=n_t;
14 n_t2=n_t;
15 m_a=5.85; // kg/sec
16 C_p=1; // kJ/kg.K
17 C_pa=C_p;

```



```

18 C_pg=C_p;
19 r=1.4; // Specific heat ratio
20
21 // Calculation
22 R_t1=R_c;
23 R_t2=R_c;
24 dT_21=(T_1/n_c)*(((R_c)^((r-1)/r))-1); // K
25 T_2=T_1+dT_21; // K
26 W_c=m_a*C_pa*(T_2-T_1); // The work done in the
    compressor in kW
27 dT_34=T_3*n_t1*(1-((1/R_t1)^((r-1)/r))); //(T_3-T_4)
    K
28 m_a1=W_c/(dT_34); // kg/sec
29 P_ta=(m_a1/m_a)*100; // Percentage of total air
    supplied to turbine 1 in %
30 m_a2=m_a-m_a1; // kg/sec
31 // Assume T_7=y(1); T_8=y(2);
32 function [X]=Temperature8(y)
33     X(1)=(m_a*C_pg*(y(1)-T_2))-(m_a*C_pg*(y(2)-T_9))
    ;
34     X(2)=((y(1)-T_2)/(y(2)-T_2))-e;
35 endfunction
36 y=[100 100];
37 z=fsolve(y, Temperature8);
38 T_8=z(2); // K
39 T_7=z(1); // K
40 // Assume T_5=x(1); T_6=x(2);
41 function [Y]=Temperature5(x)
42     Y(1)=(x(1)*n_t2*(1-((1/R_t2)^((r-1)/r))))-(x(1)-
    x(2));
43     Y(2)=(m_a2*C_pa*(x(1)-x(2)))-W;
44 endfunction
45 x=[100 100];
46 q=fsolve(x, Temperature5);
47 T_5=q(1); // K
48 T_6=q(2); // K
49 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 %
50 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);
51 // The answer vary due to round off error

```

---

**Scilab code Exa 24.31** The effectiveness of the heat exchanger

```

1 // Example 24_31
2 clc;funcprot(0);
3 //Given data
4 T_1=288;// K
5 p_1=1;// bar
6 R_c=2.5;// Pressure ratio of each compressor stage
7 R_c1=R_c;
8 R_c2=R_c;
9 T_3=300// K
10 T_5=1000;// K
11 W_2=100;// kW/kg of air
12 p_11=0.2;// Pressure loss in air side of H.P and
    main combustion chamber in bar
13 p_12=0.1;// Pressure loss in reheat combustion
    chamber in bar
14 p_13=0.05;// Pressure loss in intercooler in bar
15 n_c=0.85;// Isentropic efficiency of compressor
16 n_c1=n_c;
17 n_c2=n_c;
18 n_t1=0.88;// Isentropic efficiency of turbine 1
19 n_t2=0.85;// Isentropic efficiency of turbine 2
20 m_a=5.85;// kg/sec
21 C_p=1;// kJ/kg.K

```

```

22 n_o=0.30; // The over all efficiency of the plant
23 r=1.4; // Specific heat ratio
24
25 // Calculation
26 T_2=T_1+(T_1/n_c1)*(((R_c1)^((r-1)/r))-1); // K
27 p_2=R_c*p_1; // bar
28 p_3=p_2-p_l3; // bar
29 T_4=T_3+(T_3/n_c2)*(((R_c1)^((r-1)/r))-1); // K
30 p_4=p_3*p_2; // ba
31 T_1=T_3;
32 W_1=C_p*((T_2-T_1)+(T_4-T_3)); //The work required to
    compress one kg of air in kJ/kg
33 n_m=1; // Mechanical efficiency (Assumed)
34 T_6=T_5-(W_1/C_p); // K
35 R_t1=1/(1-(((T_5-T_6)/(T_5*n_t1))))^(r/(r-1)); //
    Pressure ratio in turbine 1
36 p_5=p_4-p_l1; // bar
37 p_6=p_5/R_t1; // bar
38 p_7=p_6-p_l2; // bar
39 T_7=T_5; // K
40 T_8=T_7-(W_2/C_p); // K
41 R_t2=1/(1-(((T_7-T_8)/(T_7*n_t2))))^(r/(r-1)); //
    Pressure ratio in turbine 2
42 p_8=p_7/R_t2; // bar
43 p_m=p_8-p_1; // Maximum pressure loss in H.E towards
    gas side in bar
44 T_9=T_5-(((T_7-T_8)/(n_o))-(T_7-T_6)); // K
45 e=(T_9-T_4)/(T_8-T_4); // The effectiveness of heat
    exchanger
46 printf('\nThe effectiveness of heat exchanger=%0.3f
    \nMaximum pressure loss in H.E towards gas side=
    %0.2f bar',e,p_m);
47 // The answer vary due to round off error

```

---

Scilab code Exa 24.32 The plant efficiency

```

1 // Example 24_32
2 clc; funcprot(0);
3 // Given data
4 T_1=15+273; // K
5 p_1=1; // bar
6 p_r=6; // Pressure ratio
7 T_4=750+273; // K
8 e=0.75; // Effectiveness of heat exchanger
9 n_c=0.80; // Isentropic efficiency of compressor
10 n_t=0.85; // Isentropic efficiency of turbine
11 C_pa=1; // kJ/kg.K
12 C_pg=1; // kJ/kg.K
13 r=1.4; // Specific heat ratio
14
15 // Calculation
16 T_2a=T_1*(p_r)^((r-1)/r); // K
17 T_2=((T_2a-T_1)/n_c)+T_1; // K
18 p_2=p_1*p_r; // bar
19 p_3=sqrt(p_1*p_2); // bar
20 p_r1=p_2/p_3; // Pressure ratio
21 p_r2=p_r1;
22 T_5a=T_4/(p_r1)^((r-1)/r); // K
23 T_5=T_4-(n_t*(T_4-T_5a)); // K
24 T_6=T_4; // K
25 T_7=T_5; // K
26 T_3=T_2+(e*(T_7-T_2)); // K
27 W_c=C_pa*(T_2-T_1); // The work of compression in kJ/
    kg
28 W_t=2*C_pg*(T_4-T_5); // The work developed by both
    turbines in kJ/kg
29 W_n=W_t-W_c; // Net work in kJ/kg
30 Q_1=C_pg*(T_4-T_3); // kJ/kg
31 Q_2=C_pa*(T_6-T_5); // kJ/kg
32 Q_s=Q_1+Q_2; // The total heat supplied in kJ/kg
33 W_r=W_n/W_t; // Work ratio
34 n_p=(W_n/Q_s)*100; // The plant efficiency in %
35 printf('\nEfficiency of the plant=%0.1f percentage \
    \nWork ratio=%0.4f', n_p, W_r);

```

36 // The answer vary due to round off error

---

**Scilab code Exa 24.33** Thermal efficiency and Work ratio

```
1 // Example 24_33
2 clc; funcprot(0);
3 //Given data
4 p_1=1; // bar
5 p_2=9; // bar
6 T_1=25+273; // K
7 T_6=1250+273; // K
8 e=0.83; // The effectiveness of regenerator
9 n_c=0.83; // Isentropic efficiency of both
   compressors
10 n_t=0.83; // Isentropic efficiency of both turbines
11 n_com=0.95; // Combustion efficiency
12 CV=42; // MJ/kg
13 C_p=1; // kJ/kg.K
14 r=1.4; // Specific heat ratio for air and gases
15
16 // Calculation
17 T_8=T_6; // K
18 n_c1=n_c;
19 n_c2=n_c;
20 n_t1=n_t;
21 n_t2=n_t;
22 p_i=sqrt(p_1*p_2); // bar
23 T_2a=T_1*(p_i/p_1)^((r-1)/r); // K
24 T_2=((T_2a-T_1)/n_c)+T_1; // K
25 T_3=T_1; // K
26 T_4=T_2; // K
27 T_7a=T_6/(p_2/p_i)^((r-1)/r); // K
28 T_7=T_6-(n_t1*(T_6-T_7a)); // K
29 T_8=T_6; // K
30 T_9=T_7; // K
```

```

31 T_5=T_2+(e*(T_9-T_4)); // K
32 W_c=2*C_p*(T_2-T_1); // The work developed by both
    compressors in kJ/kg
33 W_t=2*C_p*(T_6-T_7); // The work developed by both
    turbines in kJ/kg
34 W_n=W_t-W_c; // Net work in kJ/kg
35 W_r=W_n/W_t; // Work ratio
36 Q_1=C_p*(T_6-T_5); // kJ/kg
37 Q_2=C_p*(T_8-T_7); // kJ/kg
38 Q_s=Q_1+Q_2; // The total heat supplied in kJ/kg
39 n=(W_n/Q_s)*100; // The plant efficiency in %
40 printf('\nThermal efficiency of the plant=%0.0f
    percentage \nWork ratio=%0.2f',n,W_r);
41 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 24_34
2 clc; funcprot(0);
3 // Given data
4 p_1=1; // bar
5 p_2=8; // bar
6 T_1=300; // K
7 T_3=1000; // K
8 CV=40; // MJ/kg
9 W_2=500; // kW
10 C_pa=1; // kJ/kg. C
11 C_pg=1; // kJ/kg. C
12 r=1.4; // Specific heat ratio for air and gases
13
14 // Calculation
15 p_r=(p_2/p_1); // Pressure ratio
16 T_2=T_1*(p_r)^((r-1)/r); // K
17 T_4=T_3/(p_r)^((r-1)/r); // K

```

```

18 // Assume m_a=y(1); m_f=y(2); // m_g1=y(3); m_g2=y(4)
19 function [X]=mass(y)
20     X(1)=(y(1)+y(2))-(y(3)+y(4));
21     X(2)=(y(4)*C_pg*(T_3-T_4))-(W_2);
22     X(3)=(y(1)*C_pa*(T_2-T_1))-(y(3)*C_pg*(T_3-T_4))
23     ;
24     X(4)=(y(2)*CV*10^3)-((y(1)+y(2))*C_pg*(T_3-T_2))
25     ;
26 endfunction
27 y=[1 0.1 1 1];
28 z=fsolve(y,mass);
29 m_a=z(1)*60; // kg/min
30 m_f=z(2)*3600; // kg/hr
31 m_g1=z(3); // kg/sec
32 m_g2=z(4); // kg/sec
33 Sfc=(m_f/W_2); // kg/kWh
34 AF=(m_a/60)/(m_f/3600); // Air fuel ratio
35 n_th=(W_2/((m_f/3600)*CV*10^3))*100; // Thermal
    efficiency in %
36 printf('\nThe mass of air consumed by the plant=%0.1
    f 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);
37 // The answer vary due to round off error

```

---

#### Scilab code Exa 24.35 Mass of air compressed

```

1 // Example 24.35
2 clc; funcprot(0);
3 // Given data
4 P=2000; // kW
5 p_r=8; // Pressure ratio
6 T_1=300; // K
7 T_3=1000; // K
8 T_3a=900; // K

```

```

9 CV=42*10^3; // kJ/kg
10 n_com=0.95; // Combustion efficiency
11 C_pa=1; // kJ/kg.K
12 C_pg=1; // kJ/kg.K
13 r=1.4; // Specific heat ratio for air and gases
14
15 // Calculation
16 T_2=T_1*(p_r)^((r-1)/r); // K
17 T_4=T_3/(p_r)^((r-1)/r); // K
18 T_4a=T_3a/(p_r)^((r-1)/r); // K
19 // Assume m_a=y(1); m_a1=y(2); m_a2=y(3); m_f1=y(4);
    m_f2=y(5);
20 function [X]=mass(y)
21     X(1)=(y(1)*C_pa*(T_2-T_1))-((y(2)+y(4))*C_pa*(
        T_3-T_4));
22     X(2)=y(1)-(y(2)+y(3));
23     X(3)=P-((y(3)+y(5))*C_pg*(T_3a-T_4a));
24     X(4)=(y(4)*CV*n_com)-((y(2)+y(4))*C_pg*(T_3-T_2)
        );
25     X(5)=(y(5)*CV*n_com)-((y(3)+y(5))*C_pg*(T_3-T_2)
        );
26 endfunction
27 y=[1 1 1 0.01 0.01];
28 z=fsolve(y,mass);
29 m_a=z(1)*60; // kg/min
30 m_a1=z(2)*3600; // kg/hr
31 m_a2=z(3)*3600; // kg/hr
32 m_f1=z(4)*3600; // kg/hr
33 m_f2=z(5)*3600; // kg/hr
34 m_f=m_f1+m_f2; // kg/hr
35 Sfc=m_f/P; // kg/kW-hr
36 n_th=(3600/(Sfc*CV))*100; // Thermal efficiency of
    the plant in %
37 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);

```



38 // The answer provided in the textbook is wrong

---

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

```
1 // Example 24_36
2 clc;funcprot(0);
3 //Given data
4 P=25; // MW
5 p_r=8; // Pressure ratio
6 T_1=300; // K
7 p_1=1; // bar
8 T_8=700; // K
9 AF_1=80; // Air fuel ratio
10 AF_2=70; // Air fuel ratio
11 e=0.7; // Effectiveness of heat exchanger
12 CV=40*10^3; // kJ/kg
13 C_pa=1; // kJ/kg.K
14 C_pg=1; // kJ/kg.K
15 r=1.4; // Specific heat ratio for air and gases
16
17 //Calculation
18 p_2=p_1*p_r; // bar
19 T_2=T_1*(p_r)^((r-1)/r); // K
20 function [Y]=temperature(x)
21     Y(1)=(e*(x(1)-T_2))-(x(1)-T_8);
22 endfunction
23 x=[100];
24 T=fsolve(x,temperature);
25 T_7=T(1); // K
26 T_2a=(T_7-T_8)+T_2; // K
27 //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)
28 function [X]=massoffuel(y)
29     X(1)=(((80*y(1))+y(1))*C_pg*(y(2)-T_2a))-(y(1)*
```

```

CV);
30 X(2)=(((70*y(3))+y(3))*C_pg*(y(4)-T_2a))-(y(3)*
CV);
31 X(3)=(((70*y(3))+y(3))*C_pg*(y(4)-y(5)))-(P
*10^3);
32 X(4)=y(5)-((y(4))/((p_r)^((r-1)/r)));
33 X(5)=(((80*y(1))+y(1))*((y(2))-y(6)))-(((80*y(1)
)+(70*y(3)))*(T_2-T_1));
34 X(6)=y(6)-((y(2))/((p_r)^((r-1)/r)));
35 endfunction
36 y=[0.1 1000 0.1 1000 100 100 ];
37 z=fsolve(y, massoffuel);
38 m_f1=z(1); // kg/sec
39 m_f2=z(3); // kg/sec
40 T_3=z(2); // K
41 T_4=z(6); // K
42 T_5=z(4); // K
43 T_6=z(5); // K
44 m_f=(m_f1+m_f2)*3600; // Total mass of fuel consumed
per hour in kg/hr
45 m_a=((m_f1*AF_1)+(m_f2*AF_2))*60; // Mass of air
compressed per minute in kg/hr
46 Sfc=(m_f)/(P*10^3); // Specific fuel consumption in
kg/kW-hr
47 n_th=((P*10^3)/((m_f1+m_f2)*CV))*100; // Thermal
efficiency in %
48 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);
49 // 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

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

```

18 CV=45*10^3; // kJ/kg
19
20 // Calculation
21 p_2=p_1*p_r; // bar
22 T_2a=T_1*(p_r)^((r_a-1)/r_a); // K
23 T_2=((T_2a-T_1)/n_c)+T_1; // K
24 T_4a=T_3/(p_r)^((r_g-1)/r_g); // K
25 T_4=T_3-((T_3-T_4a)*n_t); // K
26 m_a1=(m_a*1000)/3600; // kg/sec
27 function [X]=mass(y)
28     X(1)=(y(1)*CV)-((m_a1+y(1))*C_pg*(T_3-T_2));
29 endfunction
30 y=[10];
31 z=fsolve(y,mass);
32 m_f1=z(1);
33 AF=(m_a1)/(m_f1);
34 W_g=((m_a1+m_f1)*C_pg*(T_3-T_4))-(m_a1*C_pa*(T_2-
    T_1))/1000;
35 function [Y]=mass2(x)
36     Y(1)=(x(1)*CV)-((m_a1+m_f1+(x(1)))*C_pg*(T_5-
    T_4));
37 endfunction
38 x=[1];
39 m=fsolve(x,mass2);
40 m_f2=m(1); // kg/sec
41 // From h-s chart:
42 h_7=3400; // kJ/kg
43 h_8=2220; // kJ/kg
44 // From steam table
45 h_9=45.5; // kJ/kg
46 m_s=((m_a1+m_f1+m_f2)*C_pg*(T_3-T_6))/(h_7-h_9); //
    kg/sec
47 W_s=(m_s*(h_7-h_8))/1000; // Power developed in steam
    turbine in MW
48 W_t=W_g+W_s; // Total power generated in MW
49 Q_s=(m_f1+m_f2)*CV; // kW
50 n=((W_t*10^3)/Q_s)*100; // Overall efficiency of the
    plant

```

```

51 m_f=((m_f1+m_f2)*3600)/1000; // Mass of fuel supplied
    in tons/hr
52 Sfc=(m_f*10^3)/(W_t*10^3); // Specific fuel
    consumption in kg/kWh
53 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);
54 // The answers provided in the textbook is wrong

```

---

**Scilab code Exa 25.2** Power generating capacity of the plant

```

1 // Example 25_2
2 clc; funcprot(0);
3 // Given data
4 T_1=20+273; // K
5 T_3=1100+273; // K
6 T_5=1000+273; // K
7 T_11=150; // C
8 p_r=8; // Pressure ratio
9 p_7=80; // bar
10 T_6a=300+273; // K
11 T_7=600+273; // K
12 n_c=100/100; // Isentropic efficiency of compressor
13 n_t=100/100; // Isentropic efficiency of both
    turbines
14 p_8=0.05; // bar
15 C_p=1; // kJ/kg
16 C_pa=C_p;
17 C_pg=C_p;
18 r=1.4; // Specific heat ratio
19 CV=61600; // kJ/kg
20 C_pw=4.2; // kJ/kg C
21

```

```

22 // Calculation
23 // The combustion reaction taking place in CC-I is
    given by  $\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O}$ 
24 //  $16 + 64 = 44 + 36$ ;
25 m_o=64/16; // Amount of O2 required in per kg of
    CH4
26 m_a=(100/23)*4; // Amount of air required in kg/kg of
    fuel
27 m_act=m_a*5; // Actual air supplied in kg/kg of fuel
28 m_f1=(1/m_act); // Amount of fuel supplied per kg of
    air flow through CC-I in kg
29 T_2a=T_1*(p_r)^((r-1)/r); // K
30 T_2=((T_2a-T_1)/n_c)+T_1; // K
31 T_4=T_3/(p_r)^((r-1)/r); // K
32 // In CC-II
33 m_a1=1; // kg/sec
34 m_f2=(m_a1*C_pa*(T_5-T_4))/CV; // kg/kg of air flow
35 // From h-s chart:
36 h_7=3510; // kJ/kg
37 h_11=C_pw*T_11; // kJ/kg
38 m_s1=(m_a1*C_pg*(T_5-T_6a))/(h_7-h_11); // kg/kg of
    air
39 AF=(m_a1/m_s1);
40 m_a=1.5; // kg/sec (given)
41 W_g=(m_a*C_pa*((T_3-T_4)-(T_2-T_1)));
42 m_s=m_a*m_s1; // kg/sec
43 // From h-s chart:
44 h_g=2080; // kJ/kg
45 W_s=(m_s*(h_7-h_g)); // kW
46 W_t=W_g+W_s; // Total power generated in MW
47 Q_s=(m_f1+m_f2)*m_a*CV; // kW
48 n=(W_t/Q_s)*100; // Overall efficiency of the plant
49 m_f=((m_f1+m_f2)*m_a*3600); // Mass of fuel supplied
    in kg/hr
50 Sfc=(m_f)/(W_t); // Specific fuel consumption in kg/
    kWh
51 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);
52 // The answer vary due to round off error

```

---

### Scilab code Exa 25.3 Mass of fuel supplied

```

1 // Example 25_3
2 clc;funcprot(0);
3 //Given data
4 T_1=15+273; // K
5 T_3=800+273; // K
6 p_r=8; // Pressure ratio
7 T_6=200+273; // K
8 p_9=0.05; // bar
9 W_t=190; // MW
10 C_pa=1; // kJ/kg.K
11 C_pg=1.1; // kJ/kg.K
12 r=1.33; // Specific heat ratio
13 CV=40*10^3; // kJ/kg
14
15 // Calculation
16 T_2=T_1*(p_r)^((r-1)/r); // K
17 T_4=T_3/(p_r)^((r-1)/r); // K
18 function [X]=mass(y);
19     X(1)=(y(5)+y(6))-(W_t*10^3);
20     X(2)=y(7)-((W_t*10^3)/(y(8)*CV));
21     X(3)=y(5)-(y(1)*C_pa*((T_3-T_4)-(T_2-T_1)));
22     // From Moiller chart:
23     h_7=3370; // kJ/kg
24     h_8=2080; // kJ/kg
25     // From steam tables
26     h_9=32.6; // kJ/kg
27     h_10=h_9; // kJ/kg
28     X(4)=y(6)-(y(4)*(h_7-h_8));

```

```

29     X(5)=(y(1)*C_pa*(T_3-T_2))-(y(2)*CV);
30     T_5=T_3; // K
31     X(6)=(y(1)*C_pa*(T_5-T_6))-(y(4)*(h_7-h_9));
32     X(7)=(y(3)*CV)-((y(1)*C_pa*(T_5-T_4)));
33     X(8)=y(8)-(y(2)+y(3));
34     endfunction
35     y=[100 1 1 10 10 10 .1 1];
36     z=fsolve(y,mass);
37     m_a=z(1); // kg/sec
38     m_f1=z(2); // kg/sec
39     m_f2=z(3); // kg/sec
40     m_s=z(4); // kg/sec
41     W_g=z(5)/1000; // MW
42     W_s=z(6)/1000; // MW
43     n=z(7)*100; // %
44     m_ft=z(8)*(3600/1000); // kg/sec
45     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);
46 // The answers provided in the textbook is wrong

```

---

#### Scilab code Exa 25.4 Quantity of cooling water required

```

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

```



```

10 n_c=0.85; // Isentropic efficiency of compressor
11 n_t=0.90; // Isentropic efficiency of both turbines
12 n_com=0.95; // Combustion efficiency
13 Gc=2500; // Rs./ton
14 T_7=600+273; // K
15 T_6=200+273; // K
16 p_9=0.05; // bar
17 C_pa=1; // kJ/kg.K
18 C_pg=1.1; // kJ/kg.K
19 r_a=1.4; // Specific heat ratio for air
20 r_g=1.33; // Specific heat ratio for gases
21 CV=40*10^3; // kJ/kg
22 dT=10; // C
23 C_pw=4.2; // kJ/kg C
24
25 // Calculation
26 // Considering compressor
27 p_2=p_1*p_r; // bar
28 T_2a=T_1*(p_r)^((r_a-1)/r_a); // K
29 T_2=((T_2a-T_1)/n_c)+T_1; // K
30 // Considering turbine
31 T_4a=T_3/(p_r)^((r_g-1)/r_g); // K
32 T_4=T_3-((T_3-T_4a)*n_t); // K
33 T_5=T_3; // K
34 // Considering heat balance in CC-I
35 function [X]=mass(y);
36     X(1)=(y(1)*CV*n_com)-((y(2)+y(1))*C_pg*(T_3-T_2)
37         );
38     X(2)=(W_g)-(((y(2)+y(1))*C_pg*(T_3-T_4))-(y(2)*
39         C_pa*(T_2-T_1)));
40     X(3)=(y(3)*CV*n_com)-((y(2)+y(1)+y(3))*C_pg*(T_5
41         -T_4));
42 endfunction
43 y=[1 100 1];
44 z=fsolve(y,mass);
45 m_a1=z(2); // kg/sec
46 m_f1=z(1); // kg/sec
47 m_f2=z(3); // kg/sec

```

```

45 AF_1=m_a1/m_f1;
46 m_f=m_f1+m_f2; // kg/sec
47 Q_s=(m_f*CV); // kW
48 n=(W_t/Q_s)*100; // Efficiency of the plant in %
49 // From h-s chart:
50 h_7=3610; // kJ/kg
51 // From steam table
52 h_9=32.6; // kJ/kg
53 m_s=((m_a1+m_f1+m_f2)*C_pg*(T_5-T_6))/(h_7-h_9); //
    kg/sec
54 Afsf=m_a1/m_s; // Air flow to steam flow ratio
55 Cf=((m_f*3600)/1000)*Gc; // Cost of fuel per hour in
    rupees
56 E_g=W_t; // Energy generated per hour kWh
57 Cg=Cf/E_g; // Cost of generation in rupees/kWh
58 // From h-s chart:
59 h_8=2220; // kJ/kg
60 m_w=(m_s*3600*(h_8-h_9))/(C_pw*dT*1000); // Quantity
    of cooling water required in tons/hr
61 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);
62 // The answer provided in the textbook is wrong

```

---

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

```

1 // Example 25_5
2 clc; funcprot(0);
3 // Given data
4 W_t=200*10^3; // kW
5 T_1=300; // K
6 p_1=1; // bar

```

```

7 T_3=800+273; // K
8 T_5=800+273; // K
9 T_6=200; // C
10 p_r=8; // Pressure ratio
11 p_7=50; // bar
12 T_7=600+273; // K
13 n_c=100/100; // Isentropic efficiency of compressor
14 n_t=100/100; // Isentropic efficiency of both
    turbines
15 p_8=0.05; // bar
16 C_p=1; // kJ/kg
17 C_pa=C_p;
18 C_pg=C_p;
19 r=1.4; // Specific heat ratio
20 CV=42*10^3; // kJ/kg
21
22 // Calculation
23 p_2=p_1*p_r; // bar
24 T_2=T_1*(p_r)^((r-1)/r); // K
25 T_4=T_3/(p_r)^((r-1)/r); // K
26 function [X]=mass(y);
27     X(1)=(y(2)*CV)-((y(1)+y(2))*C_pg*(T_3-T_2));
28     X(2)=(y(5))-(((y(1)+y(2))*C_pg*(T_3-T_4))-(y(1)*
        C_pa*(T_2-T_1)));
29     X(3)=(y(3)*CV)-((y(1)+y(2)+y(3))*C_pg*(T_5-T_4))
        ;
30     // From h-s chart:
31     h_7=3620; // kJ/kg
32     h_9=32.6; // kJ/kg
33     h_8=2220; // kJ/kg
34     T_5=800; // C
35     X(4)=(y(4)*(h_7-h_9))-((y(1)+y(2)+y(3))*C_pg*(
        T_5-T_6));
36     X(5)=y(6)-(y(4)*(h_7-h_8));
37     X(6)=(y(5)+y(6))-W_t;
38 endfunction
39 y=[100 1 1 1 100000 10000];
40 z=fsolve(y,mass);

```

```

41 m_a1=z(1); // kg/sec
42 m_f1=z(2); // kg/sec
43 m_f2=z(3); // kg/sec
44 m_s=z(4); // kg/sec
45 W_g=z(5); // kW
46 W_s=z(6); // kW
47 m_f=m_f1+m_f2; // kg/sec
48 R_a=m_a1/m_s; // Ratio of air supplied
49 //(a)
50 n_o=((W_t)/(m_f*CV))*100;
51 //(b)
52 n_g=((W_g)/(m_f1*CV))*100;
53 //(a)
54 n_s=((W_s)/(m_f2*CV))*100;
55 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

```

1 // Example 25_6
2 clc;funcprot(0);
3 //Given data
4 W_t=200; // MW
5 T_a=15+273; // K
6 T_c=750+273; // K
7 p_r=7.5; // Pressure ratio
8 T_e=750+273; // K
9 T_f=100+273; // K
10 C_pg=1.11; // kJ/kg. C
11 C_pa=1.005; // kJ/kg. C
12 r_a=1.4; // Specific heat ratio for air
13 r_g=1.33; // Specific heat ratio for gases

```

```

14 CV=43300; // kJ/kg
15
16 // Calculation
17 T_b=T_a*(p_r)^((r_a-1)/r_a); // K
18 T_d=T_c/(p_r)^((r_g-1)/r_g); // K
19 function [X]=mass(y)
20     X(1)=y(3)-(y(1)*((C_pg*(T_c-T_d))-(C_pa*(T_b-T_a
21         ))));
22     // From Moiller chart:
23     h_1=3670; // kJ/kg
24     h_2=2305; // kJ/kg
25     // From steam tables
26     h_3=192; // kJ/kg
27     h_4=h_3; // kJ/kg
28     X(2)=y(4)-(y(2)*(h_1-h_2));
29     X(3)=(y(3)+y(4))-(W_t*10^3);
30     X(4)=(y(1)*C_pg*(T_e-T_f))-(y(2)*(h_1-h_4));
31 endfunction
32 y=[100 10 10000 10000];
33 z=fsolve(y,mass);
34 m_a=z(1); // kg/sec
35 m_s=z(2); // kg/sec
36 W_g=z(3)/1000; // MW
37 W_s=z(4)/1000; // MW
38 Q_s=m_a*((C_pa*(T_c-T_b))+(C_pg*(T_e-T_d)));
39 n_th=((W_t*10^3)/Q_s)*100; // Thermal efficiency of
40 the cycle
41 AF=CV/((C_pa*(T_c-T_b))+(C_pg*(T_e-T_d)));
42 printf('\n\nThe mass of air supplied per second=%0.1f
43 kg/sec \n\nThe mass of steam supplied per second=%0
44 .1f kg/sec \n\nPower output by gas turbine=%0.1f MW
45 \n\nPower output by steam turbine=%0.1f MW \n\nOver
46 all efficiency of the plant=%0.1f percentage \n\nA:
47 F ratio used in the gas turbine plant=%0.1f',m_a,
48 m_s,W_g,W_s,n_th,AF);
49 // 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

```
1 // Example 32_1
2 clc;funcprot(0);
3 //Given data
4 T_1=[0,5]; // Time in hours
5 T_2=[5,6]; // Time in hours
6 T_3=[6,9]; // Time in hours
7 T_4=[9,18]; // Time in hours
8 T_5=[18,21]; // Time in hours
9 T_6=[21,24]; // Time in hours
10 L=[2,6,20,0,12,8]; // Load in kW
11 L_p=20; // Peak load in kW
12
13 //Calculation
14 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.
15 L_a=E_t/24; // Average load in kW
```

```

16 F_1=L_a/L_p;// Load factor
17 T=[0 5 5 6 6 9 9 18 18 21 21 24 24];//Time in hours
    for load curve
18 L=[2 2 6 6 20 20 0 0 12 12 8 8 22];// Load in kW for
    load curve
19 xlabel('TIME IN HOURS');
20 ylabel('LOAD IN kW');
21 title('Fig.32.1.Load curve');
22 plot(T,L,'b');
23 x=[0 24];// Time in hours
24 y=[L_a L_a];// Load in kW
25 plot(x,y,'r-.');
26 legend('LOAD CURVE','AVERAGE LOAD');
27 printf('\nLoad factor=%0.3f \nTotal energy consumed
    during 24 hours=%0.0f kW-hrs',F_1,E_t);
28 // The answer vary due to round off error

```

---

### Scilab code Exa 32.2 Load Factor of the plant

```

1 // Example 32_2
2 clc;funcprot(0);
3 //Given data
4 T_1=[0,6];// Time in hours
5 T_2=[6,10];// Time in hours
6 T_3=[10,12];// Time in hours
7 T_4=[12,16];// Time in hours
8 T_5=[16,20];// Time in hours
9 T_6=[20,22];// Time in hours
10 T_7=[22,24];// Time in hours
11 L=[20,50,60,40,80,70,40];//load in kW
12
13 //Calculation
14 //(a)
15 L_p=80;// Peak load in kW
16 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
17 L_a=E_g/24; // Average load in kW
18 F_1=L_a/L_p; // Load factor
19 T=[0 0 6 6 10 10 12 12 16 16 20 20 22 22 24 24]; //
    Time in hours for load curve
20 L=[0 20 20 50 50 60 60 40 40 80 80 70 70 40 40 100];
    // Load in kW for load curve
21 xlabel('TIME IN HOURS');
22 ylabel('LOAD IN kW');
23 title('Fig.32.2 Load curve');
24 plot(T,L,'b');
25 printf('\n(a)Load factor=%0.3f',F_1);
26 // (b)
27 L_p=20; // Peak load in kW
28 E_g=(20*4)+(10*2); //MW-hrs
29 T_s=6; //Time during which stand by unit remains in
    operation hours (from the load curve)
30 L_a=E_g/T_s;
31 F_1=L_a/L_p; // Load factor
32 printf('\n(b)Load factor=%0.3f',F_1);
33 x=[16 22]; // Time n hours
34 L=[60 60]; // Load in MW
35 plot(x,L,'r-.');
36 legend('LOAD CURVE');
37 // The answer vary due to round off error

```

---

### Scilab code Exa 32.3 Diversity factor

```

1 // Example 32_3
2 clc; funcprot(0);
3 // Given data
4 L_p=30; // The peak load on a power station in MW
5 L=[25 10 5 7]; // Connected load in MW

```



```

6 F_1=50; // Load factor in %
7
8 // Calculation
9 //(a)
10 L_a=(L_p*(F_1/100)); // Average load in MW
11 //(b)
12 E=L_a*10^3*8760; // Energy supplied per year in kW-
    hrs
13 //(c)
14 L_c=L(1)+L(2)+L(3)+L(4); // MW
15 F_d=L_p/L_c; // Demand factor
16 //(d)
17 F_div=L_c/L_p; // Diversity factor
18 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=%0.2
    f ',L_a,E,F_d,F_div);
19 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 32.4** The capacity of the plant

```

1 // Example 32_4
2 clc; funcprot(0);
3 // Given data
4 L_p=50; // Peak load in MW
5 F_1=60; // Load factor in %
6 Cc=1; // The coal consumption kg per kWh
7 CC=600; // The cost of coal in RS./ton of coal
8 E_s=1; // The energy is sold at Rs./kW-hr
9
10 // Calculation
11 L_a=(L_p*(F_1/100)); // Average load in MW
12 E=L_a*10^3*8760; // Energy generated per year in kW-
    hrs
13 C_py=(E*Cc)/1000; // Coal required per year in tons

```

```

14 CC_py=C_py*CC; // Cost of coal per year in rupees
15 C_e=(E*Cc)/E_s; //Cost of energy sold in rupees
16 R=E-CC_py; // Revenue earned by the power plant per
    year in rupees
17 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

```

1 // Example 32_5
2 clc;funcprot(0);
3 //Given data
4 L_1=60; // Load in MW
5 L_2=60; // Load in MW
6 L_3=30; // Load in MW
7 T_12=8000; // Running time in hours
8 T_3=2000; // Running time in hours
9 E=876*10^6; // kWh per year
10
11 //Calculation
12 P=L_1+L_2+L_3; // Plant capacity in MW
13 L_a=(E/8760)/1000; // MW
14 F_1=(L_a/P)*100; // Load factor in %
15 L=60; // L_1=L_2=L in MW
16 ME=(2*L*T_12)+(1*L_3*T_3); // Maximum possible energy
    which can be produced by the plant in MEWh
17 Puf=(E/(ME*10^3)); // Plant use factor
18 printf('\nLoad factor=%0.0f percentage \nPlant use
    factor=%0.2f ',F_1,Puf);

```

---

**Scilab code Exa 32.6** Annual energy supplied by the power plant

```

1 // Example 32_6
2 clc;funcprot(0);
3 //Given data
4 MD_1=40; // MW
5 MD_2=50; // MW
6 MD_3=30; // MW
7 F_1=60; // Load factor in percentage
8 DF=1.2; // Diversity factor
9
10 // Calculation
11 MD_s=MD_1+MD_2+MD_3; // Sum of individual maximum
    demands in MW
12 SMD=MD_s/DF; // Simultaneous maximum demand in MW
13 P=MD_s; // The capacity of the plant in MW
14 L_a=(F_1/100)*SMD; // Average load in MW
15 E=L_a*10^3*8760; // Energy supplied per year in kWh
16 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 year

```

1 // Example 32_7
2 clc;funcprot(0);
3 //Given data
4 UF=0.5; // Use factor
5 CF=0.4; // Capacity factor
6
7 // Calculation
8 // Use factor=E/(P_c*t);.... (1)
9 // Capacity factor=(average load/P_c)=(E/(P_c*8760))
    ;....(2)
10 // Dividing equations (1) and (2) we get ,

```

```

11 T=(8760*CF)/(UF); // hours
12 printf('\n\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

```

1 // Example 32_8
2 clc;funcprot(0);
3 //Given data
4 L_12=500; // Load in kW
5 L_3=200; // Load in kW
6 CV=40000; // Calorific value in kJ/kg
7 Fc=0.25; // Fuel consumption in kg/kWh
8 CF=4000; // Cost of fuel in rupees
9 Cf=50; // Plant capacity factor in %
10 d=30; // Number of days
11
12 //Calculation
13 P_c=(2*L_12)+L_3; // Plant capacity in kW
14 t=d*24; // Time in hours during the month
15 E=(Cf/100)*P_c*t; // Energy generated during the
    month in kWh/month
16 Fc_p=(Fc*E); //Fuel cost per month in kg
17 Fc_p=(Fc_p)/1000; // tonnes
18 FC=CF*Fc_p; // rupees/month
19 Ce=FC/E; // Cost of energy in Rs./kWhr
20 O=E*3600; // Output
21 I=Fc_p*1000*CV; // Input
22 n_o=(O/I)*100; // Over all efficiency
23 printf('\n\nThe over all efficiency of the plant=%0.0f
    percentage ',n_o);

```

---

**Scilab code Exa 32.9** Capacity factor of the plant

```

1 // Example 32_9
2 clc; funcprot(0);
3 //Given data
4 L_1=45000; // kW
5 L_2=5000; //kW
6 L_34=20000; // Load in kW
7 L_5=10000; // Load in kW
8 L_p=5000;
9
10 // Calculation
11 // The energy generated per year by the plant= Area
    under the load curve
12 E_g=(8760*L_2)+((1/2)*8760*(L_1-L_2)); // kWh/year
13 L_a=(E_g)/8760; // Average load in kW
14 MD=L_1; // Maximum demand in kW
15 F_1=L_a/MD; // Load factor
16 P=(2*L_34)+(1*L_5); // Plant capacity in kW
17 CF=(E_g)/(P*8760);
18 printf('\nLoad factor=%0.2f \nCapacity factor of the
    plant=%0.1f ', F_1, CF);
19 // The answer vary due to round off error

```

---

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

```

1 // Example 32_10
2 clc; funcprot(0);
3 //Given data
4 ML=30; // Maximum load in MW
5 ml=10; // Minimum load in MW
6 L_p=72; // Peak load in MWh/day
7
8 // Calculation
9 // From Fig.Prob.32.10
10 // Area BGFA=(1/2)*xy-72;
11 // FED=(1/2)*(20-x)*(24-y);

```

```

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

```

---

### Scilab code Exa 32.11 Load factor of the system

```

1 // Example 32_11
2 clc; funcprot(0);
3 // Given data
4 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
5 R1=[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
6 S11=[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
7 I1=[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
8 T1=[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
9
10 // Calculation
11 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
12 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
13 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 60 60 60
    60 60 60 60 60 60 60 60 60]; // Street lighting
    load in kW for load curve
14 Il_p=[400 400 400 400 400 400 400 400 400 400 400 300
    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
15 Tl_p=[540 540 540 540 540 540 540 540 540 540 540 460
    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
16 xlabel('TIME IN HOURS');
17 ylabel('LOAD IN kW');
18 title('Fig.Prob.32.11.Load curve');
19 plot(T_p',Rl_p', 'r',T_p',Sll_p', 'b-',T_p',Il_p', 'g',
    T_p',Tl_p');
20 legend(['COMMERCIAL LOAD', 'STREET LIGHTING LOAD', '
    INDUSTRIAL LOAD', 'TOTAL CURVE LOAD']);
21 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
22 L_a1=E_1/24; // Average load of residential consumers
    in kW
23 ML_1=Rl(19); // Maximum load in kW
24 F_11=L_a1/ML_1; // Load factor
25 E_2=(Sll(1)*12); // Total energy consumed by the
    Street lighting load in kW-hrs

```

```

26 ML_2=S11(1); // Maximum load in kW
27 F_12=(E_2/24)*(1/ML_2); //Load factor
28 E_3=(I1(1)*5)+(I1(6)*1)+(I1(7)*2)+(I1(9)*4)+(I1(13)
    *1)+(I1(14)*4)+(I1(18)*1)+(I1(19)*1)+(I1(20)*5);
    // Total energy consumed by the Industrial load
    in kW-hrs
29 ML_3=I1(9); // Maximum load in kW
30 F_13=(E_3/24)*(1/ML_3); //Load factor
31 ML_s=T1(11); // Simultaneous maximum demand in kW
32 ML_si=ML_1+ML_2+ML_3; // Sum of individual maximum
    load in kW
33 F_d=ML_si/ML_s; // Diversity factor
34 F_1=(E_1+E_2+E_3)/(ML_s*24); // Load factor of the
    system
35 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_11,F_12,F_13,F_d,
    F_1);
36 // The answer vary due to round off error

```

---

### Scilab code Exa 32.12 Hours not in service

```

1 // Example 32_12
2 clc; funcprot(0);
3 //Given data
4 F_1=70/100; // Load factor
5 F_c=50/100; // Capacity factor
6 F_u=60/100; // Use factor
7 MD=20; // Maximum demand in MW
8
9 // Calculation
10 //(a)
11 L_a=(MD*F_1)*10^3; // Average load in kW

```



```

12 E=L_a*365*24; // Annual energy produced in kW-hrs
13 //(b)
14 Pc=(L_a/1000)/F_c; // Plant capacity in MW
15 Rc=Pc-MD; // Reserve capacity in MW
16 //(c)
17 t_1=E/(Pc*10^3*F_u); // hours
18 T=8760-t_1; // Hours not in service in hrs in a year
19 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);
20 // The answer provided in the textbook is wrong

```

---

### Scilab code Exa 32.13 Load factor and the monthly bill

```

1 // Example 32_13
2 clc; funcprot(0);
3 // Given data
4 L_i=1500; // Installed load in MW
5 L=[50 0 1200 1000 500]; // kW
6 T=[0 5 8 12 16 24]; // hrs
7 Tp_1=40; // kW
8 Tp_2=1.5; // kWh
9 MD=1200; // Maximum load in kW
10
11 // Calculation
12 L_p=[0 50 50 0 0 1200 1200 1000 1000 500 500 2000];
      // Load in MW
13 T_p=[0 0 5 5 8 8 12 12 16 16 24 24]; // Time in hours
14 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 L_i
      ]; // Installed load in MW for plot
15 plot(T_p',L_p', 'b', T_p',L_I', 'r');
16 a=gca();
17 a.x_ticks.labels=["", "", "5am", "", "8 am", "", "12noon",
      "", "4pm", "", "8 pm", "", "12pm"];

```

```

18 a.x_ticks.locations
    =[0;2;5;6;8;10;12;14;16;18;20;22;24];
19 xlabel('Time in hours');
20 ylabel('Load in kW');
21 xtitle('Fig.Prob.32.13 ');
22 legend('Load curve','Installed load');
23 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)));
24 F_1=(E/(MD*24)); // Load factor
25 Fa=L_i*Tp_1; // Fixed amount in rupees
26 C=(E)*30*Tp_2; // Cost of energy consumed
27 Mb=Fa+C; // Monthly bill in rupees
28 printf('\nLoad factor=%0.3f \nMonthly bill=Rs.%0.0f'
    ,F_1,Mb);
29 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 32.14 Reserve capacity

```

1 // Example 32_14
2 clc;funcprot(0);
3 //Given data
4 F_1=0.6; // Load factor
5 F_c=0.4; // Capacity factor
6 F_u=0.45; // Use factor
7 MD=20; // Maximum demand in MW
8
9 // Calculation
10 //(a)
11 L_a=(MD*F_1)*10^3; // Average load in kW
12 E=L_a*365*24; // Annual energy produced in kWh
13 //(b)
14 Pc=(L_a/1000)/F_c; // Plant capacity in MW
15 Rc=Pc-MD; // Reserve capacity in MW
16 //(c)
17 t=(8760*(F_c/F_u)); // hours

```

```

18 T=8760-t; // Number of hours during which plant
    remains in operation during the year
19 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

```

1 // Example 32_15
2 clc; funcprot(0);
3 // Given data
4 MD_1=15; // Maximum demand in MW
5 MD_2=25; // Maximum demand in MW
6 MD_3=50; // Maximum demand in MW
7 F_di1=1.25; // Diversity factor
8 F_di2=1.20; // Diversity factor
9 F_di3=1.30; // Diversity factor
10 F_d1=0.70; // Demand factor
11 F_d2=0.90; // Demand factor
12 F_d3=0.98; // Demand factor
13 F_dio=1.5; // Diversity factor
14
15 // Calculation
16 //(a)
17 MD_s=MD_1+MD_2+MD_3; // The sum of maximum demands
    from all customers in MW
18 MD=MD_s/F_dio; // Maximum demand of the plant in MW
19 //(b)
20 Md1=MD_1*F_di1; // Maximum domestic load demand in MW
21 Cd1=Md1/F_d1; // Connected domestic load in MW
22 Cc1=(MD_2*F_di2)/F_d2; // Connected commercial load
    in MW
23 Ci1=(MD_3*F_di3)/F_d3; // Connected industrial load

```

```

    in MW
24 Tc1=Cd1+Cc1+Cil;// Total connected load to the plant
    in MW
25 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,Cd1,Cc1,Cil,Tc1);
26 // The answer vary due to round off error

```

---

**Scilab code Exa 32.16** Reserve capacity of the plant

```

1 // Example 32_16
2 clc;funcprot(0);
3 //Given data
4 MD=500;// Maximum demand in MW
5 F_1=0.5;// Load factor
6 F_c=0.4;// Capacity factor
7
8 // Calculation
9 E=MD*F_1*8760;// Energy generated per year in MWh
10 Pc=E/(F_c*8760);// Plant capacity in MW
11 Rc=Pc-MD;// Reserve capacity of the plant in MW
12 printf('\nReserve capacity of the plant=%0.0f MW',Rc
    );

```

---

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

```

1 // Example 32_16A
2 clc;funcprot(0);
3 //Given data
4 P=1000;// Plant capacity in MW
5 P_1=1000;// MW

```

```

6 t_1=2; // hours
7 P_2=500; // MW
8 t_2=6; // hours
9 n=60; // Number of days plant should shut down
  annually
10
11 // Calculation
12 E_d=((P_1*t_1))+((P_2*t_2)); //The amount of energy
  generated per day in Mwh/day
13 N=365-n; // No. of days (the plant is working)
14 E_y=E_d*N; //The amount of energy generated per year
  in Mwh
15 L_f=E_y/(P*(N*24)); // Annual load factor
16 printf('\n Annual load factor=%0.3f',L_f);

```

---

**Scilab code Exa 32.17** The annual load factor of the plant

```

1 // Example 32_17
2 clc; funcprot(0);
3 //Given data
4 P=1000; // Plant capacity in MW
5 P_1=1000; // MW
6 t_1=2; // hours
7 P_2=500; // MW
8 t_2=6; // hours
9 P_3=300; // MW
10 t_3=8; // hours
11 n=50; // Number of days plant should shut down
  completely
12
13 // Calculation
14 E_g=((P_1*t_1))+((P_2*t_2))+((P_3*t_3)); //Eenergy
  generated per working day in Mwh
15 N=365-n; // Working days/year of the plant
16 E_s=E_g*N; // Energy supplied per year in MWh

```

```
17 F_1=E_s/(P*(N*24)); // Annual load factor
18 printf('\n Annual load factor=%0.3f',F_1);
```

---

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

```
1 // Example 32_17A
2 clc;funcprot(0);
3 //Given data
4 L_i=720; // Industrial load in MW
5 L_c=350; // Commercial load in MW
6 L_d=10; // Domestic power in MW
7 L_d1=50; // Domestic load in MW
8 MD=1000; // MW
9 E_g=50*10^5; // Energy generated in MWh/year
10
11 // Calculation
12 //(a)
13 F_d=(L_i+L_c+L_d+L_d1)/MD; // Diversity factor
14 AD=E_g/8760; // Average demand in MW
15 //(b)
16 F_1=AD/MD; // Annual load factor
17 printf('\n Annual load factor=%0.4f',F_1);
```

---

**Scilab code Exa 32.18** Plant capacity factor

```
1 // Example 32_18
2 clc;funcprot(0);
3 //Given data
4 L_max=6000; // MW
5 L_min=2000; // MW
6 P_cap=7000; // MW
7
8 // Calculation
```

```

9 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
10 for(i=1:25)
11     L(i)=(2000+(4000*sin((%pi*t(i))/24)));
12 end
13 t_1=[0 12 24 24]; // Time in hours
14 L_cap=[7000 7000 7000 8000]; // Plant capacity in MW
15 xlabel('t(time in hrs)');
16 ylabel('Load in kW');
17 xtitle('Fig.Prob.32.18 ');
18 plot(t,L,'g', t_1,L_cap,'b-.');
19 a=gca();
20 a.x_ticks.labels=["0", ",", ",", ",", ",", ",", ",", "12", ",", ",", ",", ",",
    ", ", "24"];
21 a.x_ticks.locations
    =[0;2;4;6;8;10;12;14;16;18;20;22;24];
22 legend('Load curve', 'L_cap')
23 t_1=0;
24 t_2=24; // Limits of integration
25 L_av=(1/24)*integrate('(2000+(4000*(sin((%pi*t)/(24)
    )))', 't', t_1, t_2); // Average load on the plant
    in MW
26 PLF=(L_av/L_max); // Plant load factor
27 PCF=(L_av/P_cap); // Plant Capacity factor
28 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

```

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

```

```

6
7 // Calculation
8 //(a)
9 t=[0 12 6]; // Time in hours
10 x=[6 12 6];
11 a=[6 6 6];
12 b=[5 5 5]; // MW
13 for(i=1:3)
14 L=(b(i)/a(i))*sqrt((2*a(i)*x(i))-((x(i))^2));
15 end
16 b=5; // MW
17 L_av=(%pi*b)/4; // Average load in MW
18 // (i)
19 F_l=L_av/L_max; // Load factor
20 E=L_av*12; // Energy used during 12-hrs period MW hr
21 CF=L_av/P; // Capacity factor
22 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);
23 //(b)
24 b=5;
25 a=4;
26 t=[0 8 4]; // Time in hours
27 for(i=1:3)
28     L(i)=2+((b/a)*sqrt((2*a*t(i))-((t(i))^2)));
29 end
30 L_av=(L(1)+L(2)+L(3))/3; // Average load in MW
31 printf('\n(b)The average load of the factory=%0.2f
    MW',L_av);
32 // The answer vary due to round off error

```

---

Scilab code Exa 32.19a Electrical charges to be paid



```

1 // Example 32_19a
2 clc; funcprot(0);
3 //Given data
4 L_min=1; // MW
5 L_max=sqrt(3); // MW
6 P=2; // Plant capacity in MW
7 N=26; // Number of working days per month
8 h=8; // Number of working hours per day
9 c=50; // Charges in Rs./kW
10 c_d=2.5; // Charges in Rs./kW-hr
11
12 // Calculation
13 x_0=4;
14 x_1=12; // Limits of integration
15 L_av=(1/8)*integrate('((1/2)*sqrt(x))','x',x_0,x_1
    )*1000; // Average load on the plant in kW
16 F_1=L_av/(L_max*1000); // Load factor
17 CF=L_max/P; // Capacity factor
18 E=L_av*N*h; // Energy consumption per month in kWhr
19 Ec=(L_max*1000*c)+(E*c_d); // Electrical charges to
    be paid by the factory
20 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_1,CF,E,Ec);
21 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 32.20** The cost of per kWh generated

```

1 // Example 32_20
2 clc; funcprot(0);
3 //Given data
4 P=500; // MW
5 F_c=0.45; // Capacity factor
6 F_1=0.6; // Annual load factor

```

```

7 Cf=1000*10^6; // Cost of fuel used/year in rupees
8 CC=10000*10^6 // Capital cost plant in rupees
9 ID=15/100; // Interest and depreciation
10
11 // Calculation
12 //(a)
13 MD=(F_c/F_1)*P; // Maximum demand in MW
14 Rc=P-MD; // Reserve capacity in MW
15 //(b)
16 E=MD*10^3*F_1*8760; // Number of units generated in
    kW-hrs
17 Afc=CC*ID; // Annual fixed charges in rupees
18 Arc=Cf; // Annual running charges in rupees
19 Tc=Afc+Arc; // Total annual charges in rupees
20 C=Tc/E; // Cost of generation (Rs./kW-hr) in rupees
21 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

```

1 // Example 32_21
2 clc; funcprot(0);
3 // Given data
4 // L=350+10t-t^2;
5
6 // Calculation
7 // Differentiating L with respect to t, we get 10-2t
    =0
8 t=10/2; // hrs
9 L_max=350+(10*t)-t^2; // The maximum load occurs at 5
    th hour during the day in MW
10 t_0=0;
11 t_1=24; // Limits of integration
12 L_av=(1/24)*integrate('(350+(10*t)-t^2)', 't', t_0, t_1

```

```

    );
13 F_1=L_av/L_max;// Load factor
14 printf('\nMaximum load ,L_max=%0.0f MW \nLoad factor
    of the plant=%0.4f',L_max,F_1);
15 // Load duration curve is the representation of load
    with respect to time
16 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
17 for(i=1:25)
18     L(i)=((350+(10*t(i))-t(i)^2));
19 end
20 T=[0 12 24];
21 L_max=[L_max L_max L_max];
22 subplot(2,1,1);
23 plot(t',L,'g',T',L_max','--');
24 xlabel('t');
25 ylabel('L');
26 xtitle('Load curve');
27 // Load duration curve is the representation of load
    with respect to time is decending order.
28 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
29 for(j=1:25)
30     L(j)=((350+(10*T(j))-T(j)^2));
31 end
32 subplot(2,1,2);
33 plot(t',L,'r');
34 xtitle('Load duration curve');
35 xlabel('t');
36 ylabel('L');

```

---

**Scilab code Exa 32.22** Capacity factor of the plant

```

1 // Example 32_22
2 clc;funcprot(0);

```

```

3 //Given data
4 PC_a=32; // Plant capacity in MW
5 PC_b=20; // MW
6 E_a=135*10^6; // The energy output in kWh
7 E_b=9.5*10^6; // kWh
8 MD_b=15; // MW
9 t_b=2900; // Time in hours
10 MD_a=25; // MW
11
12 // Calculation
13 // (a)Base load plant
14 ALF_a=E_a/((MD_a*10^3)*8760); // Annual load factor
15 PUF_a=MD_a/PC_a; // Plant use factor
16 CF_a=E_a/((PC_a*10^3)*8760); // Capacity factor
17 //(b)Peak load plant
18 ALF_b=E_b/((MD_b*10^3)*8760); // Annual load factor
19 PUF_b=MD_b/PC_b; // Plant use factor
20 CF_b=E_b/((PC_b*10^3)*t_b); // Capacity factor
21 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);
22 // The answer vary due to round off error

```

---

### Scilab code Exa 32.23 Total maximum demand

```

1 // Example 32_23
2 clc;funcprot(0);
3 //Given data
4 CL=5; // kW
5 n=1000; // No. of apartments
6 No=[2 2 2 1 4 2 1 2 2 2 2 1];
7 C1=[20 10 60 5 8 10 2 5 120 4 7 5]; // Connected load
    of each in kW

```

```

8 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
9 F_da=40/100; // Demand factor of the apartments
10 F_dir=3.2; // Group diversity factor of the
    residential system
11 F_dirp=1.5; // Peak diversity factor of the
    residential system
12 F_dic=1.6; // Group diversity factor of the
    commercial system
13 F_dicp=1.2; // Peak diversity factor of the
    commercial system
14 E_1=5/100; // Losses of delivered energy
15
16 // Calculation
17 D=n*CL*F_da; // Demand of power from 1000 apartments
    in kW
18 MD_r=D/F_dir; // Maximum demand of 1000 apartments in
    kW
19 D_p1=MD_r/F_dirp; // Demand at the time of system
    peak in kW
20 for (i=1:12)
21     T1(i)=Cl(i)*No(i);
22     MD_c(i)=T1(i)*F_d(i);
23 end
24 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);
25 MD_c=(MD)/F_dic; // Maximum demand of 1000 commercial
    group in kW
26 D_p2=MD_c/F_dicp; // Demand at the time of system
    peak in kW
27 TMD=(D_p1+D_p2)*(1+E_1); // Total maximum demand in
    kW
28 printf('\nThe increase in peak demand=%0.2 f kW',TMD)
    ;
29 // The answer vary due to round off error

```

---

**Scilab code Exa 32.24** The consumption of coal

```
1 // Example 32_24
2 clc;funcprot(0);
3 //Given data
4 P=60; // MW
5 n_o=25/100; // The over all efficiency
6 CV=30000; // The calorific value of value in kJ/kg
7 F_l=30/100; // Load factor
8
9 // Calculation
10 I=(1/n_o)*3600; // Input in kJ
11 Cc=(I/CV); // Consumption of coal per kW-hr in kg
12 E=F_l*P*10^3*24; // kW-hr
13 Cc_d=(E*Cc)/1000; // Consumption of coal per day in
    tons
14 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

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

```

11 T_8=[19,20]; // Time in hours
12 T_9=[20,24]; // Time in hours
13 L_a=[50 150 300 50 50 50 300 200 100]; // Group A(
    Load in kW)
14 L_b=[20 20 100 600 100 600 50 20 20]; // Group B(Load
    in kW)
15 // Load factor=[1-0.8 0.8-0.6 0.6-0.4 0.4-0.2
    below0.2]
16 C=[1 1.6 2.4 5 8]; // Charge in Rs.per kW-hr
17 MD_A=300; // kW
18 MD_B=600; // kW
19
20 // Calculation
21 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
22 F_1A=(E_tA/24)*(1/MD_A); // Load factor of group A
23 R_A=E_tA*C(3); // Revenue earned by from group A
24 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
25 F_1B=(E_tB/24)*(1/MD_B); // Load factor of group A
26 R_B=E_tB*C(4); // Revenue earned by from group A
27 Tr=R_A+R_B; // Total revenue earned per day from both
    groups in Rs./day
28 printf('\nTotal revenue earned per day from both
    groups=Rs. %0.0 f/day ',Tr);
29 // The answer provided in the textbook is wrong

```

---

### Scilab code Exa 32.26 FLUCTUATING LOADS ON POWER PLANTS

```

1 // Example 32_26
2 clc;funcprot(0);
3 //Given data
4 P=25;// The capacity of the plant in MW
5 T_1=[6,8];// Time in hours(A.M)
6 T_2=[8,9];// Time in hours(A.M)
7 T_3=[9,11];// Time in hours(A.M)
8 T_4=[11,2];// Time in hours(A.M,P.M)
9 T_5=[2,5];// Time in hours(P.M)
10 T_6=[5,8];// Time in hours(P.M)
11 T_7=[8,12];// Time in hours(P.M)
12 T_8=[12,5];// Time in hours(A.M)
13 T_9=[5,6];// Time in hours(A.M)
14 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)
15 L_g=[800 600 2000 1200 1400 2000 1000 500 600]/100;
    // Load in MW
16
17 // Calculation
18 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
19 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
20 P_b=15;// Base load plant capacity in MW
21 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
22 subplot(2,1,1);
23 xlabel('TIME');
24 ylabel('LOAD IN MW');
25 xtitle('Fig.32.26(a)');
26 plot(T',L', 'b',T',P_b', 'r-.');
27 legend('LOAD CURVE', 'B');
28 a=gca();

```



```

29 a.x_ticks.labels=["6 A.M","8","10","12 NOON","2","4",
    ,"6","8","10","12 NIGHT","2","4","6 A.M "];
30 a.x_ticks.locations
    =[0;2;4;6;8;10;12;14;16;18;20;22;24];
31 // From the table
32 t=[24 19 18 16 12 9 6 5];
33 for(i=1:8)
34     T_p(i)=(t(i)/24)*100;
35 end
36 l=[0 0 500 500 600 600 800 800 1000 1000 1200 1200
    1400 1400 1600 1600 2000]/100; // Load in MW
37 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
38 subplot(2,1,2);
39 xlabel('PERCENTAGE OF TIME');
40 ylabel('LOAD IN MW');
41 xtitle('Fig.32.26(b)');
42 plot(T_p,'l','b');
43 legend('LOAD DURATION CURVE');
44 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
45 CF=(E_t/(P*24))*100; // Capacity factor in %
46 // The base load plant(15 MW capacity) works for 100
    % of the time
47 // From load curve
48 P_b=15; // MW
49 T=[0 2 5 8 11 14 18 23 24]; // hours
50 L=[800 1500 1200 1400 1500 1000 500 600]/100; // MW
51 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

```

```

52 LF_b=(P_act1/(P_b*24))*100; // Load factor in %
53 CF_b=LF_b; // Capacity factor in %
54 UF_b=LF_b; // Use factor in %
55 // The load above 15 MW capacity is supplied by a 10
    MW capacity peak load plant
56 P_p=10; // Peak load plant capacity in MW
57 L_p=5; // Peak load in MW
58 P_act2=(1*1)+(L_p*5); // (From load curve)The actual
    energy generated by the peak load plant in MW-hrs
59 LF_p=(P_act2/(L_p*24))*100; // Load factor in %
60 CF_p=(P_act2/(P_p*24))*100; // Capacity factor in %
61 UF_p=(P_act2/(P_p*6))*100; // Use factor in %
62 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);
63 // The answer vary due to round off error

```

---

### Scilab code Exa 32.27 Capacity factor and Use factor

```

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

```

```

9 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
10 xlabel('Time (hours)');
11 ylabel('LOAD (kW)');
12 xtitle('Fig.32.27 Load curve');
13 plot(T_p,L_p,'b');
14 a=gca();
15 a.x_ticks.labels=["6 A.M","8","10","12 NOON","2","4",
                   "6","8","10","12 NIGHT","2","4","6 A.M "];
16 a.x_ticks.locations
    =[0;2;4;6;8;10;12;14;16;18;20;22;24];
17 //(a)
18 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
19 L_max=L(3); // Maximum load in kW
20 LF=E_t/(L_max*24); // Load factor
21 //(b)
22 L_1=1200; // kW
23 L_2=800; // kW
24 L_3=2*500; // kW
25 L_4=300; // kW
26 //(c)
27 Rc=1200; // Reserve capacity in MW
28 Ic=L_1+L_2+L_3+L_4+Rc; // Installed capacity in kW
29 CF=(E_t/(Ic*24))*100; // Plant capacity factor
30 //(d)
31 L_1=1200; // kW
32 L_2=800; // kW
33 L_3=500; // kW
34 L_4=300; // kW
35 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;
36 UF=(E_t/E)*100; // Plant use factor

```

```

37 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

```

1 // Example 32_28
2 clc;funcprot(0);
3 //Given data
4 T=[0 6 10 12 16 20 22 24];// Time in hours
5 L=[30 100 110 60 120 100 60];// Load in MW
6
7 // Calculation
8 t=[0 6 6 10 10 12 12 16 16 20 20 22 22 24];// Time
    in hours for load curve
9 l=[30 30 100 100 110 110 60 60 120 120 100 100 60
    60];// Load in MW for load curve
10 subplot(2,1,1);
11 xlabel('Time in hrs');
12 ylabel('Load(MW)');
13 plot(t',l','b');
14 xtitle('(a)Load curve');
15 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; //
    Averde load in MW
16 L_max=L(5);// Maximum load in MW
17 LF=L_a/L_max;// Load factor
18 T_p1=((T(6)-T(5))/24)*100; // % Time
19 T_p2=T_p1+((T(4)-T(3))/24)*100; // % Time

```

```

20 T_p3=T_p2+(((T(3)-T(2))+T(7)-T(6)))/24)*100; // %
    Time
21 T_p4=T_p3+(((T(8)-T(7))+T(5)-T(4)))/24)*100; // %
    Time
22 T_p5=T_p4+((T(2)-T(1))/24)*100; // % Time
23 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
24 L=[0 120 120 110 110 100 100 60 60 30 30]; // Load in
    MW for load duration curve
25 L_avg=[L_a L_a L_a L_a L_a L_a L_a L_a L_a L_a L_a];
    // Averde load in MW for plot
26 subplot(2,1,2);
27 xlabel('% Time');
28 ylabel('Load(MW)');
29 plot(T_p',L', 'b',T_p',L_avg', 'r');
30 xtitle('(b)Load duration curve');
31 legend('Load curve', 'AL');
32 printf('\nAverage load=%0.2f MW \nLoad factor=%0.3f'
    ,L_a,LF);

```

---

### Scilab code Exa 32.29 Diversity factor and the load factor

```

1 // Example 32_29
2 clc;funcprot(0);
3 //Given data
4 L_cap=1200; // MW
5 T=[0 4 8 12 16 20 22]; // hours
6 C_1=[200 600 1000 400 200 100]; // MW
7 C_2=[800 400 200 200 600 400]; // MW
8 T1=[1000 1000 1200 600 800 500]; // MW
9
10 // Calculation
11 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

```

```

12 L_a1=E_1/24; // Average load in MW
13 L_max1=C_1(3); // Maximum load in MW
14 LF_1=L_a1/L_max1; // Load factor of the consumer 1
15 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
16 L_a2=E_2/24; // Average load in MW
17 L_max2=C_2(5); // Maximum load in MW
18 LF_2=L_a2/L_max2; // Load factor of the consumer 1
19 E_t=E_1+E_2; // Total energy consumed by both
      consumers in MW
20 AL_p=E_t/24; // Average load of the plant in MW
21 LF_p=AL_p/L_cap; // Load factor of the plant
22 DF_p=(L_max1+L_max2)/L_cap; // Diversity factor of
      the plant
23 t_p=[0 0 4 4 8 8 12 12 16 16 20 20 22]; // hours
24 C_1p=[0 200 200 600 600 1000 1000 400 400 200 200
      100 100]; // MW
25 C_2p=[0 800 800 400 400 200 200 200 200 600 600 400
      400]; // MW
26 T_p=[0 1000 1000 1000 1000 1200 1200 600 600 800 800
      500 500]; // MW
27 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];
28 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];
29 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];
30 subplot(3,1,1);
31 xlabel('Time in hrs');
32 ylabel('Load (mw)');
33 xtitle('Consumes-I 1200 MW');
34 plot(t_p',C_1p', 'b',t_p',L_avg1', 'r-.');
35 legend('Load curve', 'AL-1');
36 subplot(3,1,2);
37 xlabel('Time in hrs');
38 ylabel('Load (mw)');
39 xtitle('Consumes-II 1200 MW');

```

```

40 plot(t_p',C_2p', 'b',t_p',L_avg2', 'r-.');
41 legend('Load curve', 'AL_2');
42 subplot(3,1,3);
43 xlabel('Time in hrs');
44 ylabel('Load (mw)');
45 plot(t_p',T_p', 'b',t_p',AL_p', 'r-.');
46 legend('Load curve of the generating plant', 'AL_p');
47 //(d)
48 n_g=40/100; // Overall efficiency of generation
49 CV=20000; // kJ/kg
50 E=E_t/n_g; // Thermal energy generated in the plant
    in MWh
51 E=E*10^3*3600; // kJ/hr
52 C_u=(E/(CV*10^3)); // Coal used per hour in tons/hr
53 C=C_u*30; // tons/day
54 C=C_u/L_cap; // tons/MW-hr
55 cc=50/100; // Rs./kg
56 Cc=(C*10^3*cc)/10^3; // Cost of coal per kWh in
    rupees
57 L_am=74.2; // Average load in MW
58 L_max=120; // Maximum demand in MW
59 CF=L_am/L_max; // Capacity factor of the plant
60 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);
61 // The answer provided in the textbook is wrong

```

---

### Scilab code Exa 32.32 Percentage change in profit

```

1 // Example 32_32
2 clc;funcprot(0);
3 //Given data

```

```

4 P=100; // MW
5 T=[0 4 8 12 16 20 24]; // Time in hr
6 L_a=[20 20 80 80 20 20]; // Load A in MW
7 L_b=[30 60 60 60 60 10]; // Load B in MW
8 CV=45000; // kJ/kg
9 C=10; // Cost in Rs./kg
10 Sc=10; // Sale cost in Rs./kWh
11
12 // Calculation
13 t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24]; // Time in
    hrs for load curve
14 L_A=[0 20 20 20 20 80 80 80 80 20 20 20 20 100]; //
    Load A in MW
15 subplot(2,1,1);
16 xlabel('Time(hrs)');
17 ylabel('Load(MW)');
18 xtitle('Consumer-A');
19 plot(t,L_A,'b');
20 L_B=[0 30 30 60 60 60 60 60 60 60 10 10 100];
21 subplot(2,1,2);
22 xlabel('Time(hrs)');
23 ylabel('Load(MW)');
24 xtitle('Consumer-B');
25 plot(t,L_B,'b');
26 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
27 L_max1=80; // MW
28 LF_1=L_a1/L_max1;
29 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
30 L_max2=60; // MW
31 LF_2=L_a2/L_max2;
32 //Consider Consumer-A
33 // Outputs
34 O_a1=(L_a(1)*(T(3)-T(1))); // MWh
35 O_a2=(L_a(3)*(T(5)-T(3))); // MWh
36 O_a3=(L_a(5)*(T(7)-T(5))); // MWh
37 O_a=O_a1+O_a2+O_a3; // Total output of A in MWh

```



```

38 // n=0.4*L;(given)
39 n_a1=0.4*(L_a(1)/100);
40 n_a2=0.4*(L_a(3)/100);
41 n_a3=0.4*(L_a(5)/100);
42 // Inputs
43 I_a1=O_a1/n_a1; // MWh
44 I_a2=O_a2/n_a2; // MWh
45 I_a3=O_a3/n_a3; // MWh
46 I=I_a1+I_a2+I_a3; // Total input in MWh
47 TI=I*10^3*3600; // kJ/day
48 m_fa=(TI)/(CV*1000); // Fuel used in tonnes for
    consumer A in tons/day
49 // Consider Consumer-B
50 // Outputs
51 O_b1=(L_b(1)*(T(2)-T(1))); // MWh
52 O_b2=(L_b(2)*(T(6)-T(2))); // MWh
53 O_b3=(L_b(6)*(T(7)-T(6))); // MWh
54 O_b=O_b1+O_b2+O_b3; // Total output of A in MWh
55 // n=0.4*L;(given)
56 n_b1=0.4*(L_b(1)/100);
57 n_b2=0.4*(L_b(2)/100);
58 n_b3=0.4*(L_b(6)/100);
59 // Inputs
60 I_b1=O_b1/n_b1; // MWh
61 I_b2=O_b2/n_b2; // MWh
62 I_b3=O_b3/n_b3; // MWh
63 I=I_b1+I_b2+I_b3; // Total input in MWh
64 TI=I*10^3*3600; // kJ/day
65 m_fb=(TI)/(CV*1000); // Fuel used in tonnes for
    consumer B in tons/day
66 A_b=m_fb*10^3*C; // The amount spent towards the fuel
    B in rupees
67 C_e=O_b*10^3*Sc; // The charges of energy received
    from B in rupees
68 N_p=C_e-A_b; // Net profit in Rs./day
69 pc=((C_e-A_b)/A_b)*100; // Percentage change in
    revenue in %
70 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);
71 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 32.33** Over all efficiency of the plant

```

1 // Example 32_33
2 clc;funcprot(0);
3 //Given data
4 L_cap=100; // MW
5 // n=0.4*L;(given)
6 L=[20 80 30]; // MW
7 T=[0 8 16 24]; // Time in hours
8 CV=35; // MJ/kg
9 C=2; // Coal cost in Rs./kg
10 Sc=2.5; // Rs./kWh
11 n_com=95/100; // Combustion efficiency
12
13 // Calculation
14 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
15 L_a=E/24; // Average load of the plant in MW
16 L_max=80; // MW
17 LF=L_a/L_max;
18 CF=L_a/L_cap;
19 // Outputs
20 O_1=(L(1)*(T(2)-T(1))); // MWh
21 n_1=0.4*(L(1)/100);
22 I_1=O_1/n_1; // MWh
23 O_2=(L(2)*(T(3)-T(2))); // MWh
24 n_2=0.4*(L(2)/100);
25 I_2=O_2/n_2; // MWh

```

```

26 O_3=(L(3)*(T(4)-T(3))); // MWh
27 n_3=0.4*(L(3)/100);
28 I_3=O_3/n_3; // MWh
29 I=(I_1+I_2+I_3)*10^3; // Total input in MWh
30 m_f=(I*3600)/(CV*10^3*n_com*24); // kg/hr
31 m_f=(m_f*24)/10^3; // tons/day
32 Cf=m_f*10^3*C; // The cost of fuel in Rs./day
33 Mg=E*10^3*Sc; // The money gained by selling the
    energy generated in rupees
34 Pr=(Mg-Cf); // Profit gained during the day in rupees
    /day
35 n_o=(E/(I/10^3))*100; // The overall efficiency of
    the plant in %
36 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);
37 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 32.34** The cost of saling the energy

```

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

```

```

13 pr=15/100; // The profit required
14 oc=30/100; // The other costs
15 n_com=92/100; // Combustion efficiency
16
17 // Calculation
18 t=[0 4 4 8 8 12 12 16 16 20 20 24 24]; // Time in hrs
    for load curve
19 L_A=[200 200 600 600 1000 1000 400 400 200 200 100
    100 1500]; // Load A in kW for load curve
20 subplot(3,1,1);
21 xlabel('Time in hours');
22 ylabel('Load in kW');
23 xtitle('Load of consumer-A');
24 plot(t,L_A,'b');
25 legend('Load curve for (A)');
26 t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24]; // Time in
    hrs for load curve
27 L_B=[0 800 800 400 400 200 200 200 200 600 600 400
    400 1500]; // Load B in kW for load curve
28 subplot(3,1,2);
29 xlabel('Time in hours');
30 ylabel('Load in kW');
31 xtitle('Load of consumer-B');
32 plot(t,L_B,'b');
33 legend('Load curve for (B)');
34 t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24]; // Time in
    hrs for load curve
35 L_AB=[0 1000 1000 1000 1000 1200 1200 600 600 800
    800 500 500 1500]; // Load A+B in kW for load
    curve
36 subplot(3,1,3);
37 xlabel('Time in hours');
38 ylabel('Load in kW');
39 xtitle('Load of on plant for consumerA and B');
40 plot(t,L_AB,'b');
41 legend('Load curve for (A+B)');
42 //(i)
43 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
44 L_a1=E/24; // kW
45 L_max1=1000; // kW
46 LF_A=L_a1/L_max1;
47 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
48 L_b1=E/24; // kW
49 L_max2=800; // kW
50 LF_B=L_b1/L_max2;
51 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
52 L_ab=E/24; // kW
53 L_max=1200;
54 LF_AB=L_ab/L_max;
55 PL=((LF_AB-LF_A)/LF_A)*100; // Maximum percentage
        increase in load factor
56 DF=(L_max1+L_max2)/L_max; // Diversity factor
57 O_1=(L_t(1)*(T(3)-T(1))); // kWh
58 n_1=0.43*(L_t(1)/L_cap)^0.48;
59 I_1=O_1/n_1; // kWh
60 O_2=(L_t(3)*(T(4)-T(3))); // kWh
61 n_2=0.43*(L_t(3)/L_cap)^0.48;
62 I_2=O_2/n_2; // kWh
63 O_3=(L_t(4)*(T(5)-T(4))); // kWh
64 n_3=0.43*(L_t(4)/L_cap)^0.48;
65 I_3=O_3/n_3; // kWh
66 O_4=(L_t(5)*(T(6)-T(5))); // kWh
67 n_4=0.43*(L_t(5)/L_cap)^0.48;
68 I_4=O_4/n_4; // kWh
69 O_5=(L_t(6)*(T(7)-T(6))); // kWh
70 n_5=0.43*(L_t(6)/L_cap)^0.48;
71 I_5=O_5/n_5; // kWh

```

```

72 I_t=(I_1+I_2+I_3+I_4+I_5)*3600; // Total input in kJ
73 m_f=I_t/(CV*n_com*24); // kg/hr
74 V_f=m_f/0.85; // liters/hr
75 V_f=V_f*24; // liters
76 C_f=V_f*Dc; // Cost of fuel in Rs./day
77 Oc=C_f*oc; // The other cost running the plants in Rs
./day
78 Tc=C_f+Oc; // The total cost running the plants in Rs
./day
79 Pr=Tc*pr; // The profit required in Rs./day
80 Tcs=Tc+Pr; // Total cost of saling the energy
generated/day in rupees
81 O_t=O_1+O_2+O_3+O_4+O_5; // Total energy generated in
kWh
82 Cs=Tcs/O_t; // The cost of sailing the energy in Rs./
kWh
83 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);
84 // The answer vary due to round off error

```

---

**Scilab code Exa 32.35** Capacity factor of the plant

```

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

```

```

10
11 // Calculation
12 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
13 L_a1=E/24; // MW
14 L_max1=1000; // MW
15 LF_1=L_p/L_max1; // Load factor
16 t=[0 4 4 8 8 12 12 16 16 20 20 24 24]; // Time in hrs
    for load curve
17 c_1=[200 200 600 600 1000 1000 400 400 200 200 100
    100 1600]; // Load C_1 in MW for load curve
18 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
19 subplot(3,1,1);
20 xlabel('hrs');
21 ylabel('MW');
22 xtitle('Load curve for C_1');
23 plot(t',c_1','b',t',L_a1','r');
24 legend('Load curve','Average');
25 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
26 L_a2=E/24; // MW
27 L_max2=800; // MW
28 LF_2=L_a2/L_max2;
29 t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24]; // Time in
    hrs for load curve
30 c_2=[0 800 800 400 400 200 200 200 200 600 600 400
    400 1600]; // Load C_2 in MW for load curve
31 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
32 subplot(3,1,3);
33 subplot(3,1,2);

```

```

34 xlabel('hrs');
35 ylabel('MW');
36 xtitle('Load curve for C_2');
37 plot(t',c_2','b',t',L_a2','r');
38 legend('Load curve','Average');
39 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
40 L_p=E/24; // MW
41 L_max=1200; // Maximum load in MW
42 LF_p=L_p/L_max; // Load factor of the plant
43 t=[0 0 4 4 8 8 12 12 16 16 20 20 24 24]; // Time in
      hrs for load curve
44 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
45 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 L_p]; // Average load of the plant in MW
      for plot
46 subplot(3,1,3);
47 xlabel('hrs');
48 ylabel('MW');
49 xtitle('Load curve of the plant');
50 plot(t',c_t','b',t',L_a_p','r');
51 legend('Load curve','Average');
52 DF=(L_max1+L_max2)/L_max; // Diversity factor
53 L_min=C_t(6); // MW
54 n_min=(0.43*(L_min/L_cap)^0.95)*100; // Minimum
      thermal efficiency
55 L_max=C_t(3); // MW
56 n_max=(0.43*(L_max/L_cap)^0.95)*100; // Maximum
      thermal efficiency
57 CF=L_p/L_cap; // Capacity factor of the plant
58 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

```

1 // Example 32_36
2 clc;funcprot(0);
3 //Given data
4 L_cap=150; // MW
5 // n=0.435*(L)^0.925;(given)
6 T_1=[0 8 18 24]; // Time in hours
7 T_2=[0 6 20 24]; // Time in hours
8 L_a=[20 80 40]; // Load in MW
9 L_b=[30 70 20]; // Load in MW
10 SG=0.88; // Specific gravity
11 CV=40.5; // MJ/kg
12
13 // Calculation
14 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
15 L_avga=E_a/24; // MW
16 L_max1=L_a(2); // MW
17 LF_a=(L_avga/L_max1); // Load factor
18 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
19 L_avgb=E_b/24; // MW
20 L_max2=L_b(2); // MW
21 LF_b=(L_avgb/L_max2); // Load factor
22 E_t=E_a+E_b; // The total energy supplied by the
    plant in MWh
23 L_p=E_t/24; // The average load on the plant in MW
24 L_max=L_max1+L_max2; // MW
25 LF_p=L_p/L_max; // Load factor of the plant
26 E_1=(L_a(1)+L_b(1)); // MW

```

```

27 E_2=(L_a(1)+L_b(2)); // MW
28 E_3=(L_a(2)+L_b(2)); // MW
29 E_4=(L_a(3)+L_b(2)); // MW
30 E_5=(L_a(3)+L_b(3)); // MW
31 E_t=[0 E_1 E_1 E_2 E_2 E_3 E_3 E_4 E_4 E_5 E_5]; //
    MW
32 T=[0 0 6 6 8 8 18 18 20 20 24]; // Time in hrs
33 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
34 plot(T',E_t','b',T',L_avgp','r-');
35 xlabel('Time in hrs');
36 ylabel('Load in MW');
37 legend('Load curve','Average load');
38 n_com=1; // Combustion efficiency
39 O_1=E_1*6; // Output in MWh
40 n_1=0.435*(E_1/L_cap)^0.925; // Efficiency
41 I_1=O_1/n_1; // Input in MWh
42 m_f1=(I_1*10^3*3600)/(CV*10^3); // The mass of fuel
    supplied in kg
43 O_2=E_2*2; // Output in MWh
44 n_2=0.435*(E_2/L_cap)^0.925; // Efficiency
45 I_2=O_2/n_2; // Input in MWh
46 m_f2=(I_2*10^3*3600)/(CV*10^3); // The mass of fuel
    supplied in kg
47 O_3=E_3*10; // Output in MWh
48 n_3=0.435*(E_3/L_cap)^0.925; // Efficiency
49 I_3=O_3/n_3; // Input in MWh
50 m_f3=(I_3*10^3*3600)/(CV*10^3); // The mass of fuel
    supplied in kg
51 O_4=E_4*2; // Output in MWh
52 n_4=0.435*(E_4/L_cap)^0.925; // Efficiency
53 I_4=O_4/n_4; // Input in MWh
54 m_f4=(I_4*10^3*3600)/(CV*10^3); // The mass of fuel
    supplied in kg
55 O_5=E_5*4; // Output in MWh
56 n_5=0.435*(E_5/L_cap)^0.925; // Efficiency
57 I_5=O_5/n_5; // Input in MWh
58 m_f5=(I_5*10^3*3600)/(CV*10^3); // The mass of fuel

```

```

    supplied in kg
59 m_fta=m_f1+m_f2+m_f3+m_f4+m_f5; // The total fuel
    consumed during 24 hrs in kg per day
60 T_fa=m_fta; // Total fuel required for 10 days in kg
61 V_fa=T_fa/SG; // Volume of the fuel in litres/day
62 V=(V_fa*10)/1000; // The capacity of the tank
    required for 10 days in m^3
63 //(b)
64 n=0.435*(L_p/L_cap)^0.925; // Efficiency
65 E_t=E_a+E_b; // MWh
66 I_t=E_t/n; // MWh
67 m_ftb=(I_t*10^3*3600)/(CV*10^3); // Mass of fuel
    required per day
68 T_f=m_ftb*10; // kg
69 V_fb=(T_f/SG)/1000; // Volume of fuel in m^3
70 m_f=m_ftb/24; // kg/hr
71 bsfc=m_f/(L_p*10^3); // kg/kWh
72 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);
73 // The answer is varied due to round off error

```

---

**Scilab code Exa 32.37** Over all efficiency of the plant

```

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

```

```

11 // Calculation
12 //(i)
13 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
14 L_a=E_a/24; // Average load on the plant in MW
15 L_max=L_1(1); // Maximum load in MW
16 LF=(L_a/L_max); // Load factor of the plant
17 CF=(L_a/L_cap); // Capacity factor of the plant
18 //(ii)
19 O_1=L_1(1)*(T_1(2)-T_1(1)); // Output in MWh
20 n_1=0.91*(L_1(1)/L_cap)^0.49; // Efficiency
21 I_1=O_1/n_1; // Input in MW
22 O_2=L_1(2)*(T_1(3)-T_1(2)); // Output in MWh
23 n_2=0.91*(L_1(2)/L_cap)^0.49; // Efficiency
24 I_2=O_2/n_2; // Input in MW
25 O_3=L_1(3)*(T_1(4)-T_1(3)); // Output in MWh
26 n_3=0.91*(L_1(3)/L_cap)^0.49; // Efficiency
27 I_3=O_3/n_3; // Input in MW
28 // 1MWh=3.6*10^6 kJ
29 E_1=I_1*3.6*10^6; // kJ
30 E_2=I_2*3.6*10^6; // kJ
31 E_3=I_3*3.6*10^6; // kJ
32 m_w1=(E_1*1000)/(9.81*H*(T_1(2)-T_1(1))*3600); //
      Water flow in kg/sec
33 M_w1=(m_w1*(T_1(3)-T_1(2))*3600)/1000; // m^3
34 m_w2=(E_2*1000)/(9.81*H*(T_1(3)-T_1(2))*3600); //
      Water flow in kg/sec
35 M_w2=(m_w2*(T_1(3)-T_1(2))*3600)/1000; // m^3
36 m_w3=(E_3*1000)/(9.81*H*(T_1(4)-T_1(3))*3600); //
      Water flow in kg/sec
37 M_w3=(m_w3*(T_1(4)-T_1(3))*3600)/1000; // m^3
38 V=M_w1+M_w2+M_w3; // The water supplied during the
      day in m^3/day
39 n_o=(E_a/(I_1+I_2+I_3))*100; // Over all efficiency
      of the plant
40 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);  
41 // The answer provided in the textbook is wrong
```

---

**Scilab code Exa 32.38** The total quantity of water required

```
1 // Example 32_38  
2 clc;funcprot(0);  
3 //Given data  
4 L_cap=100; // MW  
5 H=50; // m  
6 //  $n=0.91*(L)^{0.49}$ ; (given)  
7 L_a1=60; // Load in MW  
8 L_a2=30; // Load in MW  
9 T_a1=16; // Time in hours  
10 T_a2=8; // Time in hours  
11 L_b1=100; // Load in MW  
12 L_b2=33.33; // Load in MW  
13 T_b1=6; // Time in hours  
14 T_b2=18; // Time in hours  
15 g=9.81; // m/s2  
16  
17 // Calculation  
18 // Consider the Consumer A  
19 t_a1=T_a1*3600; // sec  
20 P_a1=L_a1*106; // Watts  
21 n_a1=0.91*(L_a1/L_cap)0.49; // Efficiency  
22 m_wa1=(P_a1/(n_a1*g*H)); // Mass of water in liters/  
    sec  
23 V_wa1=(m_wa1/1000)*t_a1; // Volume of water supplied  
    in m3  
24 t_a2=T_a2*3600; // sec  
25 P_a2=L_a2*106; // Watts  
26 n_a2=0.91*(L_a2/L_cap)0.49; // Efficiency  
27 m_wa2=(P_a2/(n_a2*g*H)); // Mass of water in liters/  
    sec
```

```

28 V_wa2=(m_wa2/1000)*t_a2; // Volume of water supplied
    in m^3
29 V_wta=V_wa1+V_wa2; // Total water supplied to the
    power plant in m^3/day
30 // Consider the Consumer B
31 t_b1=T_b1*3600; // sec
32 P_b1=L_b1*10^6; // Watts
33 n_b1=0.91*(L_b1/L_cap)^0.49; // Efficiency
34 m_wb1=(P_b1/(n_b1*g*H)); // Mass of water in liters/
    sec
35 V_wb1=(m_wb1/1000)*t_b1; // Volume of water supplied
    in m^3
36 t_b2=T_b2*3600; // sec
37 P_b2=L_b2*10^6; // Watts
38 n_b2=0.91*(L_b2/L_cap)^0.49; // Efficiency
39 m_wb2=(P_b2/(n_b2*g*H)); // Mass of water in liters/
    sec
40 V_wb2=(m_wb2/1000)*t_b2; // Volume of water supplied
    in m^3
41 V_wtb=V_wb1+V_wb2; // Total volume of water supplied
    in m^3
42 E_tA=(L_a1*T_a1)+(L_a2*T_a2); // Total energy
    generated in MWh
43 Uw1=V_wta/24; // m^3/hr
44 W_a=Uw1/E_tA; // m^3/MW
45 E_tB=(L_b1*T_b1)+(L_b2*T_b2); // Total energy
    generated in MWh
46 Uw2=V_wtb/24; // m^3/hr
47 W_b=Uw2/E_tB; // m^3/MW
48 printf('\nWater used by A=%0.0f m^3/MW \nWater used
    by B=%0.1f m^3/MW',W_a,W_b)
49 // The answer provided in the textbook is wrong

```

---

Scilab code Exa 32.40 The power supplied by the plant

```

1 // Example 32_40
2 clc;funcprot(0);
3 //Given data
4 L_cap=150; // MW
5 L=[20 60 30]; // Load in MW
6 T=[0 8 16 24]; // Time in hours
7 n_1=0.9;
8 n_2=2.7;
9
10 // Calculation
11 // Considering the Consumer C_1
12 E_1=(L(1)*(T(2)-T(1)))+(L(2)*(T(3)-T(2)))+(L(3)*(T
    (4)-T(3))); // MWh
13 L_a1=E_1/24; // Average load in MW
14 L_max1=L(2); // Maximum load in MW
15 LF_1=L_a1/L_max1; // Load factor
16 // Considering the Consumer C_1
17 T=[0 4 12 20 24]; // Time in hours
18 L_4=30; // Load in MW
19 t_4=4; // Time in hours
20 L_12=80; // Load in MW
21 t_12=12; // Time in hours
22 L_20=20; // Load in MW
23 t_20=20; // Time in hours
24 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)));
25 L_a2=E_1/24; // Average load in MW
26 L_max2=L_12; // Maximum load in MW
27 LF_2=L_a2/L_max2; // Load factor
28 E_t=E_1+E_2; // Total energy supplied in MW
29 L_ap=E_t/24; // Average load on the plant in MW
30 L_pmax=L_max1+L_max2; // Maximum load in MW
31 LF_p=L_ap/L_pmax; // Load factor
32 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
33 L_5=(L_4*(t(5)/t(4))^n_1); // MW
34 L_6=(L_5*(t(6)/t(5))^n_1); // MW

```

```

35 L_7=(L_6*(t(7)/t(6))^n_1); // MW
36 L_8=(L_7*(t(8)/t(7))^n_1); // MW
37 L_9=(L_8*(t(9)/t(8))^n_1); // MW
38 L_10=(L_9*(t(10)/t(9))^n_1); // MW
39 L_11=(L_10*(t(11)/t(10))^n_1); // MW
40 L_12=(L_11*(t(12)/t(11))^n_1); // MW
41 L_12=80; // MW
42 L_13=(L_12*((t(12)/t(13))^n_2)); // MW
43 L_14=(L_13*(t(13)/t(14))^n_2); // MW
44 L_15=(L_14*(t(14)/t(15))^n_2); // MW
45 L_16=(L_15*(t(15)/t(16))^n_2); // MW
46 L_17=(L_16*(t(16)/t(17))^n_2); // MW
47 L_18=(L_17*(t(17)/t(18))^n_2); // MW
48 L_19=(L_18*(t(18)/t(19))^n_2); // MW
49 L_20=(L_19*(t(19)/t(20))^n_2); // MW
50 P_8=L(1)+L_8; // MW
51 P_6=L(2)+L_16; // MW
52 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

```
1 // Example 34_1
2 clc; funcprot(0);
3 //Given data
4 P=120000; // The cost of the water softner plant in
   rupees
5 S=(8/100)*P; // The salvage value of the plant in
   rupees
6 r=8/100; //Interest on sinking fund
7 n=12; //The life of the plant in years
8 RMLc=8000; //Repair, maintainence and labour costs
9 Cc=5000; // Chemical cost
10
11 //Calculation
12 A=(P-S)*(r/(((1+r)^n)-1)); // Annual sinking fund
   payment for the plant in rupees
13 Ac=A+RMLc+Cc; // Annual cost of the plant in rupees
14 printf('\nAnnual cost of the plant=Rs.%0.0f',Ac);
```

15 // The answer vary due to round off error

---

**Scilab code Exa 34.2** The salvage value of the preheater

```
1 // Example 34_2
2 clc;funcprot(0);
3 //Given data
4 P=12000;//The cost of a small preheater in rupees
5 r=5/100;// Interest
6 n=16;// Expected life in years
7 A=425;//The cost of the equipment in rupees
8
9 //Calculation
10 S=round(P-((A)/(r/(((1+r)^n)-1))));// The salvage
    value of the preheater in rupees
11 printf('\n\nThe salvage value of the preheater after
    16 years of service ,S=Rs.%0.0f',S);
12 // The answer provided in the textbook is wrong
```

---

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

```
1 // Example 34_3
2 clc;funcprot(0);
3 //Given data
4 C=40000;//Capital cost in Rupees
5 V_1=4000;// Salvage value in Rupees
6 n=20;// Useful life in years
7 r=6/100;//Interest rate
8
9 //Calculation
10 //(a)
11 TD=C-V_1;//Total depreciation in rupees
12 D=TD/2;//Depreciation in 10 years in rupees
```

```

13 V_2a=C-D; //Plant value at the end of 10 years in
    rupees
14 //(b)
15 // Assume p_d=(1-p)
16 p_d=(V_1/C)^(1/n);
17 n=10; // Plant life in years
18 V_2b=C*(p_d)^(n); // Plant value at the end of 10
    years in rupees
19 //(c)
20 n=20; // Plant life in years
21 Q=C-V_1; // Replacement cost in rupees
22 q=(Q*r)/(((1+r)^n)-1); //The amonut set aside per
    year
23 n=10; // Plant life in years
24 Q=(q*(((1+r)^n)-1))/(r); // The amount deposited in
    sinking fund in rupees
25 V_2c=C-Q; // Plant value at the end of 10 years in
    rupees
26 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)
27 // The answer vary due to round off error

```

---

#### Scilab code Exa 34.4 The cost of coal

```

1 // Example 34_4
2 clc; funcprot(0);
3 //Given data
4 PC=30; // Plant capacity in MW
5 F_1=0.4; // Load factor
6 Cc=650; // Caoal costs in Rupees
7 t=24; // hours
8 n_o=25; // Over all efficiency in %
9 CV=25000; // kJ/kg

```

```

10
11 // Calculation
12 E_g=PC*F_1*24; // Energy generated in the form of
    electricity per day in kWh
13 E_i=E_g/(n_o/100); // Input energy per day in kWh
14 E_i=E_i*10^3*3600; // kJ
15 m_f=E_i/CV; // Mass of fuel consumed per day in kg/
    day
16 m_f=m_f/1000; // tonnes/day
17 Cc_d=Cc*m_f; // Cost of coal/day in rupees
18 printf('\nCost of coal/day=Rs.%0.0f',Cc_d);
19 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 34.5 Unit energy charge

```

1 // Example 34_5
2 clc;funcprot(0);
3 //Given data
4 //Demand rates
5 DR_1=200; //0–5kW:Rs./kW
6 DR_2=150; // 6–10kW:Rs./kW
7 DR_3=120; //11–15kW:Rs./kW
8 //Energy rates
9 Er_1=2; //First –100 kW–hr:Rs. kW–hr
10 Er_2=1.5; //Next –500 kW–hr:Rs. kW–hr
11 Er_3=1; //Next –2000 kW–hr:Rs. kW–hr
12 Er_4=0.8; ///Excess over –2000 kW–hr:Rs./kW–hr
13 Ecpm=2300; // Energy consumption per month in kW–hr
14
15 // Calculation
16 //(a)
17 DC=(5*DR_1)+(5*DR_2)+(2*DR_3); // Demand charges per
    month in rupees
18 EC=(100*Er_1)+(500*Er_2)+(1700*Er_3); // Energy
    charge in rupees

```

```

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

```

---

**Scilab code Exa 34.6** The average rate of heat supplied

```

1 // Example 34_6
2 clc;funcprot(0);
3 //Given data
4 t_25=10; // Operating time at 25 MW load in hours
5 t_z=14; //Remaining period at zero load in hours
6 //  $I=5*10^6*(7+0.2L+0.1L^3)$  where I is in kJ/hr and
    L is in MW
7
8 //Calculation
9 //(a)
10 L_0=0; // Zero load
11 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
12 L_1=25; // Load in MW
13 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
14 T_e=(L_1*t_25)+(L_0*t_z); // Total energy generated

```

```

    with in 24 hours in MW-hrs.
15 T_p=(I_1*t_25)+(I_0*t_z); // Total energy input to the
    plant within 24 hours
16 H_i1=T_p/T_e; // Average rate of heat input in kJ/MW-
    hr.
17
18 //(b)
19 A_1=T_e/24; // The average load on the plant MW
20 L=A_1; // Load in MW
21 I=5*10^6*(7+0.2*L+0.1*L^2); // The input per hour at
    L=10.41 MW in kJ/hr
22 H_i2=I/L; // The heat rate in kJ/MW-hr
23 H_rs=H_i1-H_i2; // Saving in heat rate in kJ/MW-hr
24 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);
25 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 34.7 Total increase in input

```

1 // Example 34_7
2 clc; funcprot(0);
3 // Given data
4 L_p=10; // MW
5 // I=5*10^6(18+12L+0.5L^2)
6 L_1=5; // MW
7 L_2=7; // MW
8
9 // Calculation
10 //(a)
11 // n=(L/I)=(1/(5*10^6((18/L)+12+0.5L)));
12 // The efficiency will be maximum when ((18/L)
    +12+0.5L), differentiating we get
13 L_m=sqrt((-18)/(-0.5)); // MW
14 L=L_m*10^3*3600; // kJ/hr

```

```

15 I_6=5*10^6*(18+(12*L_m)+(0.5*L_m^2)); // kJ/hr
16 n_max=(L/I_6)*100; // Maximum efficiency in %
17 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);
18 //(b)
19 I_5=5*10^6*(18+(12*L_1)+(0.5*L_1^2)); // kJ/hr
20 I_7=5*10^6*(18+(12*L_2)+(0.5*L_2^2)); // kJ/hr
21 dI=I_7-I_5; // Increase in output to the plant per
    hour in kJ/hr
22 L=(L_1+L_2)/2; // MW
23 IR=5*10^6*(12+L); // kJ/hr
24 Ti=IR*(L_2-L_1); // Total increase in input in kJ/hr
25 printf('\n(b)Total increase in input=%0.2e kJ/hr',Ti
    );

```

---

**Scilab code Exa 34.8** Which plant should be preferable

```

1 // Example 34_8
2 clc;funcprot(0);
3 //Given data
4 a=[5 4 2 1 0.5]; // Load in kW
5 b=[200 4000 2000 1000 1560]; // No of hours at load
6 CV_c=28000; // kJ/kg
7 Cc=350; // Cost of coal in Rs./ton
8 CV_d=36000; // kJ/kg
9 Cd=1200; // Cost of diesel oil in Rs./ton
10 Ci_s=18500; // Capital investment for steam plant in
    Rs/kW
11 Ci_d=17000; // Capital investment for diesel plant in
    Rs/kW
12 Es=320000; // Extra annual salary for steam plant in
    rupees
13
14 // Calculation

```

```

15 Cce=(10^6*Cc)/(CV_c*1000); // The cost of coal energy
    per 10^6 kJ
16 Cde=(10^6*Cd)/(CV_d*1000); // The cost of diesel oil
    energy per 10^6 kJ
17 for (i=1:5)
18     c(i)=a(i)*b(i); // MW-hrs
19     d(i)=5*10^6*(1.5+(2*a(i))+(0.025*(a(i))^3)); //
    Input rate in kJ per hour for steam plant
20     e(i)=b(i)*d(i); // Total input in kJ
21     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
22     g(i)=b(i)*f(i); // Total input in kJ
23 end
24 N=b(1)+b(2)+b(3)+b(4)+b(5); // Total no. of hours at
    load
25 MW_hrs=c(1)+c(2)+c(3)+c(4)+c(5); // Total MW-hrs
26 T_s=e(1)+e(2)+e(3)+e(4)+e(5); // Total input in kJ
    for steam plant
27 T_d=g(1)+g(2)+g(3)+g(4)+g(5); // Total input in kJ
    for diesel plant
28 Ahr_s=(T_s)/(MW_hrs*1000); // Average heat rate in kJ
    per kW hour (for steam plant)
29 Ahr_d=(T_d)/(MW_hrs*1000); // Average heat rate in kJ
    per kW hour (for diesel plant)
30 // Steam plant
31 Fc_s=a(1)*10^3*Ci_s*(12/100); // Fixed cost in Rs./
    year
32 Oc_s=((T_s/10^6)*Cce)+(Es); // Operating cost in Rs./
    year
33 Tc_s=Fc_s+Oc_s; // Total cost in rupees
34 // Diesel plant
35 Fc_d=a(1)*10^3*Ci_d*(12/100); // Fixed cost in Rs./
    year
36 Oc_d=((T_d/10^6)*Cde); // Operating cost in Rs./year
37 Tc_d=Fc_d+Oc_d; // Total cost in rupees
38 printf('\nTotal cost of steam plant=Rs.%0.4e \nTotal
    cost of diesel plant=Rs.%0.4e',Tc_s,Tc_d)

```



```

39 if(Tc_s<Tc_d)
40     printf('\nThe steam plant would be the choice
           under the given circumstances despite the
           higher investment and the greater relative
           labour cost.');
```

```

41 else
42     printf('\nThe diesel plant would be the choice
           under the given circumstances.');
```

```

43 end
44 // The answer provided in the textbook is wrong
```

---

**Scilab code Exa 34.9** Saving per kWh energy produced

```

1 // Example 34_9
2 clc;funcprot(0);
3 //Given data
4 L=60;// MW
5 L_0=0;// Zero load in MW
6 //  $I=5*10^6*(8+8*L+0.4L^2)$ 
7 T_f=20;// Time in hours
8 T_0=4;// Time in hours
9
10 // Calculation
11 E_g=(T_f*L)+(T_0*0);// Total energy generated by the
           power plant during 24 hoursbin MWh
12 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
13 I_0=5*10^6*(8+(8*L_0)+(0.4*L_0^2))*20;// Input at no
           load in kJ
14 Ti=I_60+I_0;// Total input to the plant during 24
           hours in kJ/day
15 Q=Ti/(E_g*10^3);// Average heat supplied per kWh
           generated in kJ/kWh
16 L_a=E_g/24;// Average load in MW
```

```

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

```

---

**Scilab code Exa 34.10** The loss in fuel cost per hour

```

1 // Example 34_10
2 clc; funcprot(0);
3 // Given data
4 // dF_a/dP_a=0.065*P_a+25;
5 // dF_b/dP_b=0.08*P_b+20;
6 L=160; // Total load in MW
7
8 // Calculation
9 //(a)
10 function [X]=power(y)
11     X(1)=(y(1)+y(2))-L;
12     X(2)=((0.065*y(1))+25)-((0.08*y(2))+20);
13 endfunction
14 y=[10 100];
15 z=fsolve(y, power);
16 P_a=z(1); // MW
17 P_b=z(2); // MW
18 //(b)
19 L=160/2; // If the load is equally shared by both the
    units
20 p_a1=P_a;
21 p_a2=L; // Limits of integration
22 Ic_A=integrate('((0.065*p_a)+25)', 'p_a', p_a1, p_a2);
    // Increase in cost for unit A in Rs/hr.

```

```

23 p_b1=P_b;
24 p_b2=L; // Limits of integration
25 Ic_B=integrate('((0.08*p_b)+20)', 'p_b', p_b1, p_b2); //
    Increase in cost for unit B in Rs/hr.
26 dC=Ic_A+Ic_B;
27 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);
28 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 34.11 The most economical loading

```

1 // Example 34_11
2 clc; funcprot(0);
3 // Given data
4 L=30; // Total load in MW
5 L_12=20; // Capacity of two steam turbines in MW
6 // S_1=2000+10*L_1-0.0001*L_1^2
7 // S_2=1000+7*L_1-0.00005*L_2^2
8
9 // Calculation
10 // L_1+L_2=L*10^3;
11 // For the most loading, the required condition is (
    dS_1/dL_1=dS_2/dL_2)
12 function [X]=Load(y)
13     X(1)=(y(1)+y(2))-(L*10^3);
14     X(2)=(10-(0.0002*y(1)))-(7-(0.0001*y(2)));
15 endfunction
16 y=[10 10];
17 z=fsolve(y, Load);
18 L_1=z(1)/1000; // MW
19 L_2=z(2)/1000; // MW
20 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

```
1 // Example 34_12
2 clc;funcprot(0);
3 //Given data
4 C_1=5000; //Cost of first unit in Rupees
5 MD_1=100; // Maximum demand in kW
6 C_2=14000; //Cost of second unit in Rupees
7 MD_2=60; // Maximum demand in kW
8 n=40000; // Useful life in hours
9 C_e=80; //Energy charge per kW in Rupees/year
10 C_kwh=5/100; //Energy charge per kW-hr in Rupees
11
12 //Calculation
13 //(a)First unit
14 Cc=C_1/n; // Capital cost of unit per hour in Rupees
15 C_MD=((MD_1*C_e)/8760); // Charge for maximum demand
    per hour in Rupees
16 C_eh=MD_1*1*C_kwh; // Energy charge per hour in
    Rupees
17 TC_1=Cc+C_MD+C_eh; // Total charges per hour for the
    operation of first unit in Rupees
18 //(b)Second unit
19 Cc=C_2/n; // Capital cost of unit per hour in Rupees
20 C_MD=((MD_2*C_e)/8760); // Charge for maximum demand
    per hour in Rupees
21 C_eh=MD_2*1*C_kwh; // Energy charge per hour in Rupee
22 TC_2=Cc+C_MD+C_eh; // Total charges per hour for the
    operation of second unit in Rupees
23 printf('\n(a)Total charges per hour for the
    operation of first unit=Rs.%.3f\n(b)Total
    charges per hour for the operation of second unit
    =Rs.%.3f',TC_1,TC_2);
24 if(TC_1>TC_2)
```

```

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

```

---

**Scilab code Exa 34.13** Which supply will be more economical

```

1 // Example 34_13
2 clc; funcprot(0);
3 //Given data
4 C_kw=500; // Charges in Rs./kW
5 MD=800; // Maximum demand in kW
6 Cc_1=8*10^5; // Capital cost of Public supply in
   Rupees
7 F_1=30/100; // Load factor
8 ID_1=10; // Interest and depreciation charges on
   capital of public supply in %
9 Cc_2=3*10^6; // Capital cost of private supply in
   Rupees
10 ID_2=12; // Interest and depreciation charges on
   capital of private supply in %
11 Fc=0.35; // Fuel consumption in kg/kW-hr
12 Cf=80; // Percentage per kg
13 C_e=40; // Percentage per kW-hr
14 C_m1=10; //The maintainence and labour charges in
   percentage per kW-hr
15
16 //Calculation
17 L_a=MD*F_1; // Average load in kW
18 ERPY=240*8760; // Energy required per year in kW-hrs
19
20 //(a) Public supply
21 C_MD=C_kw*MD; //Charge for maximum demand per year in

```

```

    Rupees
22 ID=(ID_1/100)*Cc_1; // Interest and depreciation in
    Rupees
23 C_ey=(C_e/100)*ERP; // Energy cost per year in
    Rupees
24 TC=C_MD+ID+C_ey; // Total cost in Rupees
25 AEC_1=TC/ERP; // Average energy cost in Rs./kWh
26
27 //(b) Private supply
28 Fc_y=(Fc*ERP)/1000; // Fuel consumption per year in
    tons
29 C_f=Fc_y*1000*(Cf/100); // Cost of fuel in Rupees
30 MLC=(C_ml/100)*ERP; // The maintenance and labour
    charges per year
31 ID=(ID_2/100)*Cc_2; // Interest and depreciation in
    Rupees
32 TC=C_f+MLC+ID; // Total cost in Rupees
33 AEC_2=TC/ERP; // Average energy cost in Rs./kWh
34 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);
35 if(AEC_1>AEC_2)
36     printf('\n As the average energy cost for oil
    engine is less than the public supply, the oil
    engine generation is more preferable. ');
37 else(AEC_1<AEC_2)
38     printf('\n Public supply is preferable ');
39 end

```

---

**Scilab code Exa 34.14** The cost of energy per unit

```

1 // Example 34_14
2 clc; funcprot(0);
3 // Given data
4 MD=80; // MW

```

```

5 F_1=40/100; // Load factor
6 E=120*10^6; // kW-hr
7 MO=30; // Maximum output in MW
8 CC_ss=18000; // Capital cost of steam station in Rs./
  kW of installed capacity
9 CC_psp=12000; // Capital cost of pump storage plant
  in Rs./kW of installed capacity
10 Oc_s=0.80; // Operating cost of steam plant in Rs./kW
  -hr
11 Oc_psp=0.05; // Operating cost of pump storage plant
  in Rs./kW-hr
12 ID_s=12/100; // Interest and depreciation
13
14 // Calculation
15 //(a)
16 CC_s=MD*1000*CC_ss; // Capital cost of steam station
  in rupees
17 ID=ID_s*CC_s; // Interest and depreciation in rupees
18 L_a=MD*1000*F_1; // Average load in kW
19 E_s=L_a*8760; // Energy supplied per year in kW-hrs
20 IDc=(ID/E_s)*100; // Interest and depreciation
  charges per unit of energy in paise/kWh
21 Tc_a=(Oc_s*100)+IDc; // Total cost per unit in paise/
  unit
22 Tc_a=Tc_a/100; // Rs./kWh
23 //(b)
24 L=MD-MO; // The load supplied by the steam plant in
  MW
25 CC_s=L*1000*CC_ss; // Capital cost of steam plant in
  rupees
26 CC_psp=CC_psp*MO*1000; // Capital cost of pump
  storage plant in rupees
27 Tc_cs=CC_s+CC_psp; // Total capital cost of combined
  station in rupees
28 IDc=ID_s*Tc_cs; // Interest and depreciation charges
  on capital investment in rupees
29 Oc_psp=(Oc_psp*E); // Operating cost of pump storage
  plant in rupees

```

```

30 e_s=E_s-E; // The energy units supplied by steam
    station in kW-hr
31 Oc_s=Oc_s*e_s; // Operating cost of steam station in
    rupees
32 Tcpy=IDc+Oc_psp+Oc_s; // Total cost per year in
    rupees
33 Tc_b=Tcpy/E_s; // The cost per unit in Rs./kWh
34 printf('\n(a) Total cost per unit=Rs.%.3f/kWh \n(b)
    Total cost per unit=Rs.%.2f/kWh',Tc_a,Tc_b);

```

---

**Scilab code Exa 34.15** The cost of generation per kW hr

```

1 // Example 34_15
2 clc;funcprot(0);
3 //Given data
4 CP=120*1000; // Capacity of the plant in kW
5 Cc=12000; //Capital cost in per kW installed in
    rupees
6 Swrm=600000; // Salaries ,wages ,repairs and
    maintainence per year in rupees
7 MD=80; // MW
8 F_l=40/100; // Load factor
9 Fc=400; // Fuel cost per tonne in rupees
10 F_c=1.2; // kg/kW-hr
11
12 //Calculation
13 Ci=CP*Cc; // Capital investment in rupees
14 ID=(10/100)*Ci; // Interest and Depreciation in
    rupees
15 L_a=MD*10^6*F_l; //Average Load in MW
16 L_a=L_a/1000; // kW
17 E_t=L_a*8760; // kW-hr
18 F_c=F_c*E_t; // Fuel consumption in kg
19 Fc=(Fc/1000)*F_c; // Fuel cost in rupees
20 TAC=ID+Fc+Swrm;

```



```

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

```

---

**Scilab code Exa 34.16** The cost of generation

```

1 // Example 34_16
2 clc;funcprot(0);
3 //Given data
4 CC_kw=15000;// Capital cost/kW installed
5 TP=2200;// Total power of the diesel power plant in
    kW
6 AOC=600000;// Annual operating costs in rupees
7 FC=100000;// Fixed cost in rupees
8 VC=200000;// Variable cost in rupees
9 AMC=FC+VC;// Annual maintainence costs in rupees
10 Cf=0.8;// Cost of fuel per kg in rupees
11 Clo=40;// Cost of lubricating oil per kg in rupees
12 CV=40000;// kJ/kg
13 cf=0.5;// Consumption of fuel in kg/kWh
14 clo=1/400;// Consumption of lubricant oil in kg/kWh
15 MD=1600;// Maximum demand in kW
16 F_l=45/100;//Load factor
17
18 //Calculation
19 CC=ceil (TP*CC_kw);// Capital costof the plant in
    rupees/ year;
20 I=ceil(CC*(15/100));// Interest on capital
21 AE=ceil(MD*F_l*8760);// Annual energy generated in
    kWh/year
22 F_c=ceil(cf*AE);// kg/year
23 Fc=ceil(F_c*Cf);// Cost of fuel in rupees per year
24 Lc=ceil(clo*AE);// Lubrication consumption in kg /
    year
25 CLO=ceil(Clo*Lc);//Cost of lubricant oil Rs/year

```

```

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

```

---

Scilab code Exa 34.17 Over all cost of generation

```

1 // Example 34_17
2 clc; funcprot(0);
3 // Given data
4 L=120; // Steam power station capacity in MW
5 Ac=1000; // Annual cost towards the interest and
    depreciation in Rs./kW
6 MD=100; // Peak demand in MW
7 OC=1200*10^4; // Operating costs in Rs./ year
8 Mc_f=200*10^4; // Maintenance costs (fixed) in Rs./
    year
9 Mc_v=400*10^4; /// Maintenance costs (variable) in Rs
    ./ year
10 Mic=100*10^4; // Miscellaneous costs in Rs./ year
11 C_c=320; // Cost of coal used in Rs./ton
12 CV=25000; // Calorific value in kJ/kg
13 n_o=20; // Over all efficiency of the plant in %
14 F_l=80/100; // Load factor
15
16
17 // Calculation
18 E_g=MD*10^3*F_l*8760; // Energy generated in kWh/year
19 SC=(0.8+3.5*F_l); // Steam consumption per kW load in
    kg
20 // 1 kW load generates 0.8 kWh energy as load factor

```

```

    is 0.8.
21 SC_kW=SC/F_1; // Steam consumption per kWh in kg
22 // If W_c is the weight of the coal in tons used per
    year ,
23 W_c=(E_g*3600)/(10^3*CV*(n_o/100)); // tons/year
24 CC=W_c*C_c; // Cost of coal in Rs./year
25 Tfc=(Ac*L*10^3)+Mc_f; //Total fixed costs in Rs./
    year
26 Tvc=OC+Mc_v+Mic+CC; //Total variable costs in Rupees
27 Tac=Tfc+Tvc; // Total annual cost in Rupees
28 Gc=Tac/E_g; //Generation cost in Rs./kWh
29 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

```

1 // Example 34_18
2 clc; funcprot(0);
3 //Given data
4 MD=80; // Maximum demand in MW
5 F_1=35/100; // Load factor
6 E_s=120*10^6; // Energy supplied by steam plant in
    kWh/year
7 MD_s=50; // Maximum load in MW
8 CC_s=18000; // Capital cost of steam plant in Rs./ kW
    installed
9 CC_h=30000; // Capital cost of hydro plant in Rs./ kW
    installed
10 CC_n=25000; // Capital cost of nuclear plant in Rs./
    kW installed
11 OC_s=0.5; // Operating cost of steam plant in Rs./
    kWh
12 OC_h=0.1; // Operating cost in hydro plant Rs./ kWh
13 T_h=0.05; // Transmission cost of hydro plant in Rs./
    kWh

```

```

14 ID_s=(12/100)*CC_s;// Interest and depreciation for
    steam plant
15 ID_h=(10/100)*CC_h;// Interest and depreciation for
    hydro plant
16 Rc_n=0.25;// Running cost of nuclear plant in Rs./
    kWh
17 ID_n=10;// Interest and depreciation for nuclear
    plant in % per annum
18
19 //Calculation
20 E=MD*10^3*F_1*8760;// Energy required per year in
    kWh
21 //(a)Steam plant
22 ID_1=ID_s*MD*10^3;// Interest and depreciation(
    fixed plant)in Rs./year
23 OC_1=OC_s*E;// Operating cost Rs./year
24 Tc_1=ID_1+OC_1;// Total cost in Rs./year
25 Oc_kWh1=Tc_1/E;// Over all cost per kWh in Rs./kWh
26
27 //(b(i))Hydel Plant
28 ID_2=ID_h*(MD-MD_s)*10^3;// Interest and
    depreciation(fixed cost)in Rs./year
29 E_h=(E-E_s);// Energy supplied by the hydro plant in
    kWh/year
30 OC_2=(E_h*OC_h)+T_h;// Operating or running cost
    including transmission in Rs./year
31 //(b(ii)) Steam station
32 L_t=E_s/8760;// Load taken in kW
33 MD_m=L_t/F_1;// Maximum load (Minimum plant capacity
    ) in kW
34 ID_3=ID_s*MD_m;//Interest and depreciation in Rs./
    year
35 OC_3=E_s*OC_s;// Operating cost Rs./year
36 Tc_2=ID_2+OC_2+ID_3+OC_3;// Total cost of both the
    plants in Rs./year
37 Oc_kWh2=Tc_2/E;// Over all cost per kWh in Rs./kWh
38
39 //(c)Nuclear plant

```

```

40 ID_4=MD*10^3*CC_n*(ID_n/100); // Interest and
    depreciation in Rs./year
41 Rc=E*Rc_n; // Running cost in Rs./year
42 Tc_3=(ID_4+Rc); // Total cost in Rs./year
43 Oc_kWh3=Tc_3/E; // Over all cost per kWh in Rs./kWh
44 printf('\n(a)The annual cost=Rs.%.2e /year \n    The
    over all cost=Rs.%.2f/kWh \n(b)The annual cost=
    Rs.%.2e /year \n    The over all cost=Rs.%.3f/
    kWh \n(c)The annual cost=Rs.%.2e /year \n    The
    over all cost=Rs.%.2f/kWh',Tc_1,Oc_kWh1,Tc_2,
    Oc_kWh2,Tc_3,Oc_kWh3);
45 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 34.19 Energy cost

```

1 // Example 34_19
2 clc;funcprot(0);
3 //Given data
4 //(i)A private diesel generating plant
5 MD=900; // kW
6 F_1=30; // Load factor in %
7 Cc=90*10^5; // Capital cost in rupees
8 Cf=800; // Fuel cost in Rs./ton
9 Fc=0.3; //Fuel consumption in kg/kWh-generated
10 Mc=2.5; // Cost of maintainence in paise/kWh-
    generated
11 Oc=0.3; // Cost of lubricating oil ,water ,store ,etc in
    paise/kWh-generated
12 W=180000; // Wages in Rs./year
13 ID_1=10; //Interest and deprecation in % per year
14 //(ii)Public supply
15 MD_pub=1500; // Maximum demand per year in Rs./kW
16 Mc_pub=80; // paise/kWh
17
18 //Calculation

```

```

19 //(i)Private plant
20 ID=ID_1*Cc;//Interest and depreciation in rupees
21 Nu=MD*(F_1/100)*8760;//Number of units required per
    year in kWh/year
22 Fr=(F_1/100)*(Nu);// Fuel required in kg/year
23 CF=Fr*(Mc_pub/100);// Fuel cost in Rs./year
24 Cmo=((0.3+2.5)/100)*Nu;//Cost of maintainence ,oil
    and water in Rs./year
25 Tc=ID+CF+Cmo+W;// Total cost of running the plant
    per year in rupees
26 Ec_1=(Tc/Nu);//The energy cost in Rs./kWh
27 //(ii)Public supply
28 Tc=(MD_pub*MD)+((Mc_pub/100)*Nu);// Total cost in Rs
    ./year
29 Ec_2=Tc/Nu;// Energy cost in Rs./kWh
30 if(Ec_1>Ec_2)
31     printf('\nThe public supply set is preferable as
        its cost is less than diesel set.');
```

```

32 else
33     printf('\nThe private supply set is preferable
        as its cost is less than diesel set.');
```

```

34 end
35 // The answer provided in the textbook is wrong
```

---

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

```

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

```

9
10 // Calculation
11 MD=(P*F_ac)/F_al; // Maximum demand in MW
12 Rc=P-MD; // Reserve capacity in MW
13 L_a=F_al*MD; // Average load in MW
14 E_py=L_a*10^3*8760; // Energy produced/year in kWh
15 E_a=E_py*0.95; // kWh
16 TCC=CC*P*10^3; // Total capital cost of the plant in
    rupees
17 ID=.10*TCC; // Interest and depreciation in rupees
18 p=.10*TCC; // Profit to be gained in rupees
19 TC=ID+p+Arc; // Total charges to be recovered in
    rupees
20 C_eg=(TC/E_a); // Cost of energy generated in Rs./kWh
21 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

```

1 // Example 34_21
2 clc; funcprot(0);
3 // Given data
4 P=142.5; // Plant capacity in MW
5 CC=130*10^7; // The Capital cost in rupees
6 Ac_o=18.8*10^7; // Annual cost of coal, oil, tax and
    salaries in rupees
7 R_i=5; // Rate of interest in % of capital
8 R_d=5; // Rate of depreciation in % of capital
9 U_e=6; // Unit of energy used in % of the total units
    supplied
10 F_l=0.6; // The annual load factor
11 F_c=0.5; // Annual capacity factor
12
13 // Calculation
14 MD=(P*F_c)/F_l; // Maximum demand in MW

```

```

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

```

---

#### Scilab code Exa 34.22 Three charge rate

```

1 // Example 34_22
2 clc;funcprot(0);
3 //Given data
4 N=50000; // Number of domestic customers
5 Fc=2.5*10^7; // Fixed charges in rupees
6 Ec=2*10^7; // Energy charges in rupees
7 Cc=0.5*10^7; // Customer charges in rupees
8 p=20*10^5; // Profit in rupees
9 MD=5000; // kW
10 F_d=4; // Diversity factor
11 F_l=0.3; // Load factor
12
13 // Calculation
14 FC=Fc+((25/100)*p); // Fixed cost in rupees
15 EC=Ec+((50/100)*p); // Energy cost in rupees
16 CC=Cc+((25/100)*p); // Customer charges in rupees
17 MD_i=MD*F_d; // kW
18 E=MD*F_l*8760; // kW-hrs
19 Fc_kW=FC/(MD_i); // Fixed cost per kW per year in Rs
    ./kW

```



```

20 C=CC/N; // Changes per customer per year in rupees
21 Er=EC/E; // Energy rate in Rs./kWh
22 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);
23 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 34.23** The generation charge in two part tariff

```

1 // Example 34_23
2 clc; funcprot(0);
3 //Given data
4 P=100; // MW
5 CC=10000; // Rs./kW
6 R=2; // Royalty in Rs./kW
7 C_e=0.3; //Rs./kWh
8 MD=70; // MW
9 F_1=0.6; // Annual load factor
10 S_a=10^7; // Salaries and maintainence in rupees
11
12 //Calculation
13 E=(MD*10^3)*F_1*8760; // kWh
14 CC=P*10^3*CC; // Capital cost of the plant in rupees
15
16 // Annual fixed charges
17 D=(15/100)*CC; // Depreciation in rupees
18 S=(20/100)*S_a; // Salaries and maintainence in
    rupees
19 Tfc=D+S; // Total fixed charges in rupees
20 C_kw=(Tfc/(MD*10^3)); // Cost per kW
21
22 // Annual fixed charges
23 S=(80/100)*S_a; // Salaries and maintainence in
    rupees
24 Tc=(S/E)+C_e; // Total cost in rupees

```

```

25 Tc=(Tc*100); // paise/kWh
26 printf('\nTwo part tariff=Rs.%.0f/kW+%.3f/kWh',
        C_kw, Tc/100);

```

---

**Scilab code Exa 34.24** The average cost kW hr

```

1 // Example 34_24
2 clc; funcprot(0);
3 // Given data
4 P=25; // MW
5 CC=12000; // Rs/kW
6 CC_ps=15*10^6; // Capital cost of primary and
    secondary distribution in rupees
7 Mc=80*10^4; // Plant maintainence cost in Rs./year
8 Mc_ps=2*10^6; // Maintanence cost of primary and
    secondary equipments in Rs./year
9 Sw=6*10^6; // Salaries and wages in Rs./year
10 Cc=80*10^3; // Consumption of coal in tonnes/year
11 cc=800; // Cost of coal Rs./tonne
12 Di=12*10^6; // Rs./year
13 E_l=10/100; // Energy loss in transmission
14 F_d=1.5; // Diversity factor
15 F_l=80/100; // Load factor
16 MD=14; // MW
17
18 // Calculation
19 L_a=MD*10^3*F_l; // kW
20 E_g=L_a*8760; // kW-hr
21 CC=P*10^3*CC; // Rs.
22 IiD=(10/100)*CC; // Interest, insurance, depreciation
    charges of plant in rupees
23 IiD_ps=(80/100)*CC; // Interest, insurance,
    depreciation charges of primary and secondary
    equipments in rupees
24 Tfc=IiD+IiD_ps+Di; // Total fixed cost in rupees

```

```

25 MD_i=MD*10^3*F_d;
26 FC=Tfc/MD_i;// Fixed cost per kW in rupees
27 Fc=Cc*cc;// Rs./year
28 Tvc=Mc+Mc_ps+Sw+Fc;// Total variable charges in
    rupees
29 E_t=E_g*(1-E_l);// Energy generated in kW-hr
30 Cec=Tvc/E_t;// Charges for energy consumption in Rs
    ./kW-hr
31 Tc=Tfc+Tvc;// Total charges in rupees
32 Ac=Tc/E_t;// Average cost of supply in Rs./kWh
33 printf('\nAverage cost of supply=Rs.%0.2f/kWh',Ac);
34 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 34.25** Over all cost of generation

```

1 // Example 34_25
2 clc;funcprot(0);
3 //Given data
4 P=12;// MW
5 MD=10;// MW
6 F_l=0.7;// load factor
7 CC=17000;// Rs./kW
8 C_td=3*10^6;// Cost of transmission and distribution
    system in rupees
9 ID=5;// Interest ,depriciation on distribution system
    in %
10 Oc=3*10^6;// Operating cost in rupees
11 Cc=800;// Cost of coal in Rs./ton
12 Mc_f=0.3*10^6;// Plant maintainence costs in Rs./
    year (fixed)
13 Mc_r=350000;//Plant maintainence costs in Rs./year (
    running)
14 c=30*10^3;// Coal used in tons/year
15
16

```

```

17 // Calculation
18 ID_f=(10/100)*CC*P*10^3; // Interest , depreciation
    etc. of the plant in Rs./year
19 ID_ftd=(5/100)*C_td; // Interest , depreciation etc. of
    the transmission and distribution in Rs./year
20 Ac_r=c*Cc; // Annual cost of coal in Rs./year
21 FC=ID_f+ID_ftd+Mc_f; // Fixed cost in Rs./year
22 RC=Ac_r+0c+Mc_r; // Running cost in Rs./year
23 Gtc=FC+RC; // Grand total cost in Rs./year
24 E_g=MD*10^3*F_l*8760; // Energy generated per year in
    kWh
25 Tpt_1=(FC/(MD*10^3)); // Rs./kW
26 Tpt_2=(RC/(E_g)); // Rs./kWh
27 Oac=(FC+RC)/(E_g); // Over all cost/kWh
28 printf('\nTwo part tariff=Rs.%0.0f/kW+Rs.%0.3f/kWh \
    \nOver all cost/kWh=Rs.%0.2f',Tpt_1,Tpt_2,Oac);
29 // The answer provided in the textbook is wrong

```

---

#### Scilab code Exa 34.26 Over all cost per unit

```

1 // Example 34_26
2 clc; funcprot(0);
3 // Given data
4 P=5000; // kW
5 MD_d=3000; // kW
6 F_ld=20/100; // Load factor
7 MD_s=1800; // kW
8 F_ls=50/100; // Load factor
9 MD_st=200; // kW
10 F_lst=30/100; // Load factor
11 CC=18000; // Rs./kW
12 Trc=6.2*10^6; // Total running cost in Rs./year
13 ID=10/100; // Annual rate of depreciation and
    interest in capital
14

```

```

15 //Calculation
16 E_s=((MD_d*F_ld)+(MD_s*F_ls)+(MD_st*F_1st))*8760; //
    The energy supplied per year to all three
    consumers in kW-hrs
17 Oc=Trc/E_s; // Operating charges per kW-hr in rupees
18 CC=P*CC; // Capital cost of the plant in rupees
19 Fcpy=CC*ID; // Fixed cost per year in rupees
20 Fc=Fcpy/P; // Fixed cost per kW in rupees
21 //(a)
22 Tc_d=(MD_d*Fc)+((MD_d*F_ld)*8760*Oc); // The total
    charges in rupees
23 Oac_d=Tc_d/((MD_d*F_ld)*8760); // Over all cost per
    unit in rupees
24 //(b)
25 Tc_s=(MD_s*Fc)+((MD_s*F_ls)*8760*Oc); // The total
    charges in rupees
26 Oac_s=Tc_s/((MD_s*F_ls)*8760); // Over all cost per
    unit in rupees
27 //(c)
28 Tc_st=(MD_st*Fc)+((MD_st*F_1st)*8760*Oc); // The
    total charges in rupees
29 Oac_st=((Tc_st)/((MD_st*F_1st)*8760)); // Over all
    cost per unit in rupees
30 printf('\n(a)Over all cost per unit=Rs.%.2 f/kW-hr \
    n(b)Over all cost per unit=Rs.%.3 f/kW-hr \n(c)
    Over all cost per unit=Rs.%.2 f/kW-hr ',Oac_d,
    Oac_s,Oac_st);
31 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 34.27** Load factor and the generation cost

```

1 // Example 34_27
2 clc; funcprot(0);
3 //Given data
4 // Annual fixed and running charges

```

```

5 // Diesel Rs.(300/kW + 0.5/kWh)
6 // Steam Rs.(1200/kW + 0.125/kWh)
7 E=500*10^6; //kWh
8 // Calculation
9 //(a)
10 // P=Maximum load in kW
11 // K=Load factor
12 // C_1=(300*P + (0.5*P*K*8760))
13 // C_2=(1200*P + (0.125*P*K*8760))
14 // Unit energy cost by Diesel=Unit energy cost by
    steam
15 function [X]=loadfactor(y)
16     X(1)=((300)+(0.5*y(1)*8760))-((1200)+(0.125*y(1)
        *8760))
17 endfunction
18 y=[0.1];
19 z=fsolve(y,loadfactor)
20 K=z(1);
21
22 //(b)
23 P=(E/(8760*K)); // kW
24 C_1=((300*P)+(0.5*P*K*8760)); // Rupees
25 GC=C_1/E; // Generation cost in Rs./kWh
26 printf('\nLoad factor=%0.1f percentage \nThe
    generation cost=Rs.%0.3f/kWh',K*100,GC);
27 // The answer vary due to round off error

```

---

**Scilab code Exa 34.28** Which motor will be economical

```

1 // Example 34_28
2 clc; funcprot(0);
3 //Given data
4 P=30; // kW
5 C_a=60000; // Cost of motor A in rupees
6 C_b=40000; // Cost of motor B in rupees

```

```

7 n_a=90; // Efficiency of motor A at full load
8 n_b=85; // Efficiency of motor B at full load
9 n_50a=86; // Efficiency of motor A at 50% load
10 n_50b=82; // Efficiency of motor B at 50% load
11 N=20; // Life of each motor
12 I=5/100; // Interest
13 T=25; // Time in %
14 Mc_a=4200; // The annual maintainence cost of motor A
    in rupees
15 Mc_b=2400; // The annual maintainence cost of motor B
    in rupees
16 Er=1; // Energy rate in Re./kWh
17
18 // Calculation
19 //(a)
20 SV=(10/100)*C_a; // Salary value in rupees
21 D=(C_a-SV)/N; // Depreciation in Rs./year
22 I=(5/100)*C_a; // Interest in Rs./year
23 E=((P/1)*(8760*(T/100)*(1/(n_a/100))))+((P/2)
    *(8760*((100-T)/100)*(1/(n_50a/100)))); // Energy
    cost in rupees
24 Tc_a=D+I+Mc_a+E; // Total cost of motor A
25 //(b)
26 SV=(10/100)*C_b; // Salary value in rupees
27 D=(C_b-SV)/N; // Depreciation in Rs./year
28 I=(5/100)*C_b; // Interest in Rs./year
29 E=((P/1)*(8760*(T/100)*(1/(n_b/100))))+((P/2)
    *(8760*((100-T)/100)*(1/(n_50b/100)))); // Energy
    cost in rupees
30 Tc_b=D+I+Mc_b+E; // Total cost of motor B
31 printf('\nTotal cost of motor A=Rs.%0.0f/year \
    nTotal cost of motor B=Rs.%0.0f/year ',Tc_a,Tc_b);
32 if(Tc_a<Tc_b)
33     printf('\nMotor A is recommended as its annual
    cost is less than motor B. ');
34 else(Tc_b<Tc_a)
35     printf('\nMotor B is recommended as its annual
    cost is less than motor A. ');

```

```

36 end
37 // The answer vary due to round off error

```

---

**Scilab code Exa 34.29** The price of coal

```

1 // Example 34_29
2 clc;funcprot(0);
3 //Given data
4 P=50; // MW
5 F_1=40/100; // Load factor
6 CC_s=15000; // Initial cost of steam plant in Rs./kW
7 Mc_s=20; // Maintenance cost in paise/kWh
8 n_os=25/100; // The over all efficiency of the steam
   plant
9 CV=25000; // kJ/kg
10 CC_h=30000; // Capital cost of hydel plant in Rs./kW
11 Rc=5; // Running cost in paise/kWh
12 ID_s=12/100; // Interest and depreciation for steam
   plant
13 ID_h=9/100; // Interest and depreciation for hydel
   plant
14
15 // Calculation
16 E=P*10^3*F_1*8760; // Energy required per year in kWh
   /year
17 //(a) Steam plant
18 ID_s=P*10^3*CC_s*ID_s; //Interest and depreciation in
   Rs./year
19 Mc_s=(Mc_s/100)*E; //Maintainence cost in Rs./year
20 m_c=E/(10^3*CV*n_os)*3600; // The mass of coal in
   tons/year
21 //(b)Hydel plant
22 ID_h=P*10^3*CC_h*ID_h; //Interest and depreciation in
   Rs./year
23 Rc_h=(Rc/100)*E; // Running cost in Rs./year

```



```

24 Tc_h=ID_h+Rc_h; // Total cost of hydel plant in
    rupees
25 // Tc_s=ID_s+Mc_s+(m_c*C); where C is the cost of
    coal
26 function [X]=costofcoal(y)
27     X(1)=(ID_s+Mc_s+(m_c*y(1)))-Tc_h;
28 endfunction
29 y=[0.1];
30 z=fsolve(y,costofcoal);
31 C=z(1); // Rs./ton
32 printf('\nThe cost of coal=Rs.%0.0f/ton',C);

```

---

**Scilab code Exa 34.30** The number of working hours per week

```

1 // Example 34_30
2 clc; funcprot(0);
3 // Given data
4 // High voltage—Rs.450/kW per year + paise 35/kWh
5 // Low voltage—Rs.470/kW per year + paise 40/kWh
6 CC=1000; // Rs./kW
7 T_1=3/100; // Losses in the transformer
8 N=50; // Working weeks per year
9 P=1; // MW
10
11 // Calculation
12 Cl=1000; // Consumer load in kW
13 Rr=Cl/(1-T_1); // Required rating of transformer in
    kW
14 Ct=Cl*Rr; // Cost of transformer to the consumer in
    rupees
15 ID=(Ct/P)*(10/100); // Annual Interest and
    depreciation in rupees
16 // P=50*h; Power used during the year in hours
17 // N_1=Cl*P; Number of units consumed from low
    voltage side in kWh/year

```

```

18 // N_h=Rr*P; Number of units consumed from high
    voltage side in hours
19 function [X]=hours(y)
20     X(1)=((C1*470)+(((C1*50*y(1))/P)*(40/100)))-((Rr
        *450)+(((Rr*50*y(1))/P)*(35/100))+ID);
21 endfunction
22 y=[10];
23 z=fsolve(y, hours);
24 h=z(1); // The number of working hours per week (hrs/
    week)
25 printf('\nThe number of working hours per week=%0.2f
    hrs/week', h);
26 // The answer vary due to round off error

```

---

#### Scilab code Exa 34.31 The cost of generation

```

1 // Example 34_31
2 clc; funcprot(0);
3 // Given data
4 P=2500; // kW
5 MD=1600; // Maximum load in kW
6 F_l=0.48; // Load factor
7 CC_s=15000; // Initial cost of
8 Ic=18000; // Installation cost in Rs./kW
9 I=15/100; // Interest on capital
10 Mc=200000; // Maintenance cost in Rs./year
11 Tlo=850000; // Total labour and other consumables in
    Rs./year
12 Fc=7; // Fuel cost in Rs./kg
13 Lc=30; // Lubricating oil cost in Rs./kg
14 F=0.25; // Fuel consumed in kg/kWh
15 O=0.025; // Oil consumed in kg/kWh
16
17 // Calculation
18 CC=P*Ic; // Capital cost of the plant in rupees

```

```

19 I=CC*I; // Interest on capital in rupees
20 E_g=MD*F_1*8760; // Energy generated per year in kWh
21 Cf=F*E_g*Fc; // Cost of fuel in Rs./year
22 Cl=O*E_g*Lc; // Cost of Lubricating oil in rupees
23 Tfc=I+Mc; // Total fixed cost in rupees
24 Trc=Cf+Cl+Tlo; // Total running cost in rupees
25 Tc=Tfc+Trc; // Total cost in rupees
26 Gc=Tc/E_g; // Generation cost in Rs./kWh
27 printf('\nThe cost of generation=Rs.%.2f/kWh',Gc);
28 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 34.32** The generating cost per kWh

```

1 // Example 34_32
2 clc; funcprot(0);
3 // Given data
4 P=200; // MW
5 Fc=24*10^6; // Fixed cost Rs./year
6 Cf=1800; // Cost of fuel in Rs./ton
7 CV=20000; // Calorific value in kJ/kg
8 Oe=280; // Other expanses in Rs./kW
9 Q_1=18000; // Plant heat rate at 100% capacity factor
   in kJ/kWh
10 F_c1=100/100; // Capacity factor
11 Q_2=10500; // Plant heat rate at 50% capacity factor
   in kJ/kWh
12 F_c2=50/100; // Capacity factor
13
14 // Calculation
15 Fc=Oe+(Fc/(P*10^3)); // Fixed cost per kW capacity
   per year in Rs./kW
16
17 // (a) At 100% C.F
18 AD=P*10^3*F_c1; // The average demand in kW
19 E_g=AD*8760; // Energy generated per year in kWh

```

```

20 Fc_1=((Fc*AD)/(E_g))*100; // Fixed cost per kWh in
    paise
21 C=Q_1/CV; // Coal burned per kWh in kg
22 Cc=(C*Cf)/1000; // Cost of coal per kWh energy
    generated in rupees
23 Tc_1=(Fc_1/100)+Cc; // Total cost of generation per
    kWh in rupees
24
25 //(b)At 50% C.F
26 AD=P*10^3*F_c2; // The average demand in kW
27 E_g=AD*8760; // Energy generated per year in kWh
28 Fc_2=((Fc*AD)/(E_g))*100; // Fixed cost per kWh in
    paise
29 C=Q_2/CV; // Coal burned per kWh in kg
30 Cc=(C*Cf)/1000; // Cost of coal per kWh energy
    generated in rupees
31 Tc_2=(Fc_2/100)+Cc; // Total cost of generation per
    kWh in rupees
32 printf('\n(a)Total cost of generation per kWh=Rs.%0
    .3f \n(b)Total cost of generation per kWh=Rs.%0.3
    f ',Tc_1,Tc_2);
33 // The answer provided in the textbook is wrong

```

---

**Scilab code Exa 34.33** The generating cost

```

1 // Example 34_33
2 clc;funcprot(0);
3 //Given data
4 P=210*10^3; // kW
5 CC=10000; // Rs./kW
6
7 //Calculation
8 CC=CC*P; // Capital cost of the plant in rupees
9 //(a)When the plant is operating at full load
10 F_1=1; // Load factor

```

```

11 Fc=CC*(13/100); // Fixed cost in rupees
12 Vc=Fc*1.3; // Variable cost in rupees
13 Tc=Fc+Vc; // Total cost in rupees
14 E_t=(P*F_1*8760); // Total units generated per year in
    kWh
15 Gc_1=(Tc/E_t)*100; // Generating cost in paise/kWh
16
17 // (b) When the plant is running at 50% load
18 F_1=50/100;
19 E_t=E_t*F_1; // Total units generated per year in kWh
20 Vc=Vc/2; // Variable cost in rupees
21 Tc=Fc+Vc; // Total operating cost in rupees
22 Gc_2=(Tc/E_t)*100; // Generating cost in paise/kWh
23 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);
24 // The answer vary due to round off error

```

---

**Scilab code Exa 34.34** Over all efficiency of the plant

```

1 // Example 34_34
2 clc; funcprot(0);
3 // Given data
4 P=[600 600 600 400]; // Capacity of 4-generating sets
    in kW
5 MD=1600; // kW
6 F_1=0.45; // Load factor
7 CC=10000; // Capital cost in Rs./kW
8 Mc=60000; // Annual maintainence cost in rupees
9 Oc=100000; // Operation cost in rupees
10 Fc=7; // Fuel cost in Rs./kg
11 Lc=40; // Lubricating oil cost in Rs./kg
12 F=0.5; // Fuel consumed in kg/kWh
13 O=0.0025; // Lubricating oil consumed in kg/kWh

```

```

14 CV=42000; // kJ/kg
15 n_g=0.92; // Generator efficiency
16
17 // Calculation
18 //(a)
19 R_f3=P(1)/n_g; // Rating of first 3 sets in kW
20 R_4=P(4)/n_g; // Rating of last set in kW
21 //(b)
22 AD=MD*F_1; // Average demand in kW
23 E_g=AD*8760; // Energy generated/year in kWh
24 //(c)(i) Fixed costs per year
25 CC=((3*P(1))+(1*P(4)))*CC;
26 Afc=.15*CC; // Annual fixed cost in rupees
27 Tfc=Afc+Mc; // Total fixed cost in rupees
28 //(i) Variable costs per year
29 Fc=(E_g*F)*Fc; // Fuel cost in rupees
30 Lc=(E_g*O)*Lc; // Lubricating oil cost in rupees
31 Tvc=Fc+Lc+Oc; // Total variable cost in rupees
32 Tc=Tfc+Tvc; // Total cost in rupees
33 C=Tc/E_g; // Cost per kWh generated
34 //(d)
35 n_o=((E_g*3600)/(E_g*F*CV))*100; // Over all
    efficiency of the plant in %
36 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);
37 // The answer vary due to round off error

```

---

**Scilab code Exa 34.35** The cost of energy generated

```

1 // Example 34_35
2 clc; funcprot(0);
3 // Given data

```

```

4 P=30; // MW
5 Pc=10*10^7; // Plant cost in rupees
6 Ii=13/100; // Interest and insurance
7 D=5/100; // Depreciation
8 Mc=50*10^5; // Plant maintenance cost in rupees
9 Fc=700*10^5; // Fuel cost in rupees
10 Lc=25*10^5; // Lubricating cost in rupees
11 LC=75*10^5; // Labour cost in rupees
12 MD=25; // MW
13 F_1=0.75; // Load factor
14 p=5; // Profit expected in paise/kWh
15
16 // Calculation
17 L_a=(MD*F_1); // Average load in MW
18 E_g=L_a*10^3*24*365; // Energy generated/year in kWh
19 Iic=Ii*Pc; // Interest and insurance cost in rupees
20 D=D*Pc; // Depreciation in rupees
21 Pr=(p/100)*E_g; // Profit required in rupees
22 Tc=Iic+D+Mc+Fc+Lc+LC+Pr; // Total cost in rupees
23 Ce=(Tc*100)/(E_g); // Cost of energy generated in
    paise/kWh
24 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

```
1 // Example 35_1
2 clc; funcprot(0);
3 // Given data
4 MD=100; // Maximum demand in MW
5 md=20; // Minimum demand in MW
6 A_1=200; // Rs./kW-year
7 A_2=50; // Rs./kW-year
8 B_1=0.05; // Rs./kWh
9 B_2=0.1; // Rs./kWh
10
11 // Calculation
12 L=(A_1-A_2)/(B_2-B_1); // Time in hours
13 P_b=MD-((L/8760)*(MD-md)); // MW
14 P_p=100-P_b; // MW
15 // (b)
16 Area_STbcS=(1/2)*(1000+8760)*(P_p-md);
17 Area_bb1c1cb=(8760*md);
```



```

18 LF_b=((Area_STbcS+Area_bb1c1cb)/(P_p*8760))*100; //
    Load factor
19 A_aTSa=(1/2)*(3000*P_b);
20 LF_p=(A_aTSa/(P_p*8760))*100; // Load factor
21 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);
22 // The answer provided in the textbook is wrong

```

---

### Scilab code Exa 35.2 Average cost

```

1 // Example 35_2
2 clc;funcprot(0);
3 //Given data
4 // C_1=2500 kW+0.550 kWh
5 // C_2=2400 kW+0.6 kWh
6 A_1=2500;
7 A_2=2400;
8 B_1=0.55;
9 B_2=0.6;
10 MD=100; // Maximum demand in MW
11 md=10; // Minimum demand in MW
12 t=8760; // hours
13
14 // Calculation
15 L=(A_1-A_2)/(B_2-B_1); // Time in hours
16 P_b=MD-((L/t)*(MD-md)); // MW
17 P_p=100-P_b; // MW
18 // (a)
19 I_c_b=P_b; // MW
20 I_c_p=P_p*1.2; // MW
21 // (b)
22 // For base load plant
23 E_g1=((1/2)*(L+t)*(P_b-md))+(md*t); // MW-hrs

```

```

24 LF_b=(E_g1/(P_b*t))*100; // Load factor
25 CF_b=LF_b; // Capacity factor
26 UF_b=CF_b/LF_b; // Use factor
27 // For peak load plant
28 E_g2=((1/2)*(L)*(MD-P_b)); // MW-hrs
29 LF_p=(E_g2/(P_p*t))*100; // Load factor
30 CF_p=(E_g2/(24*t))*100; // Capacity factor
31 UF_p=(CF_p/LF_p)*100; // Use factor
32 // (c) For I-plant (base)
33 E_g1=((1/2)*(L+t)*(P_b-md))+(md*t)*1000; // kW-hrs
34 C_1=(P_b*10^3*A_1)+(E_g1*B_1); // rupees
35 // (c) For I-plant (peak)
36 E_g2=((1/2)*(L)*(P_b-md))*1000; // kWh
37 C_2=(P_p*10^3*A_2)+(E_g2*B_2); // rupees
38 E_t=E_g1+E_g2; // kWh
39 C=C_1+C_2; // Total generating cost in rupees
40 C_a=C/E_t; // Average cost in Rs./kWh
41 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);
42 // The answer vary due to round off error

```

---

### Scilab code Exa 35.3 The minimum cost of generation

```

1 // Example 35_3
2 clc; funcprot(0);
3 // Given data
4 // C_1=840000+840 kW+0.116 kWh
5 // C_2=500000+440 kW+0.2985 kWh
6 A_1=840;
7 A_2=440;
8 B_1=0.116;
9 B_2=0.2985;
10 MD=64000; // kW

```

```

11 t=8760; // hours
12
13 // Calculation
14 L=(A_1-A_2)/(B_2-B_1); // Time in hours
15 P_p=(MD/t)*L; // kW
16 P_b=MD-P_p; // kW
17 E_b=((1/2)*(L+t)*(P_b)); // The kWh generated by base
    load plant
18 E_p=((1/2)*L*P_p); // The kWh generated by peak load
    plant
19 E_t=E_b+E_p; // // Total energy generated in kWh
20 C_1=840000+(A_1*P_b)+(B_1*E_b); // rupees
21 C_2=500000+(A_2*P_p)+(B_2*E_p); // rupees
22 C=C_1+C_2; // Total cost in rupees
23 Gc=C/E_t; // Generating cost in rupees
24 printf('\nGenerating cost=Rs.%.2f/kWh',Gc);
25 // The answer vary due to round off error

```

---

#### Scilab code Exa 35.4 Over all cost of generation

```

1 // Example 35_4
2 clc; funcprot(0);
3 //Given data
4 // C_1=100*10^4+ 600 kW+0.1 kWh
5 // C_2=60*10^4+ 350 kW+0.2 kWh
6 A_1=600;
7 A_2=350;
8 B_1=0.1;
9 B_2=0.2;
10 t=8760; // hours
11
12 // Calculation
13 // C=[100*10^4+600x+0.1S_a]+[60*10^4+350*(P-x)+0.2*(
    S_t-S_a)];
14 // The required condition is dC/dx=0;

```

```

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

```

---

### Scilab code Exa 35.5 Load factor Capacity factor and Use factor

```

1 // Example 35_5
2 clc;funcprot(0);
3 //Given data
4 T=[0 10 20 30 40 50 60 70 80 90 100];// Percentage
    time of a year
5 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
6 // C_1=48 kW+0.03 kWh
7 // C_2=36 kW+0.035 kWh
8 L_b=32;// MW

```

```

 9 L_p=7; // MW
10 A_1=48;
11 A_2=36;
12 B_1=0.030;
13 B_2=0.035;
14 t=8760; // hours
15 MD=L(1); // MW
16
17 // Calculation
18 xlabel('TIME IN PERCENT OF YEAR');
19 ylabel('LOAD IN MW');
20 xtitle('Fig.Prob.35.5');
21 plot(T,L,'r');
22 legend('Load duration curve');
23 L=(A_1-A_2)/(B_2-B_1); // Time in hours
24 T=(L/t)*100; // % of a year
25 // From Fig.Prob.35.5,
26 P_b=30; // MW
27 P_p=MD-P_b; // MW
28 A_b=12.38; // cm^2
29 A_p=0.38; // cm^2
30 x=20; // Percentage of time
31 y=10*10^3; // kW
32 // For base load plant
33 Q_b=A_b*((x/100)*t)*y; // kWh
34 LF_b=(Q_b/(P_b*10^3*t))*100; // Load factor
35 CF_b=(Q_b/(L_b*10^3*t))*100; // Capacity factor
36 UF_b=(CF_b/LF_b)*100; // Use factor
37 // For peak load plant
38 Q_p=A_p*((x/100)*t)*y; // kWh
39 LF_p=(Q_p/(P_p*10^3*t))*100; // Load factor
40 CF_p=(Q_p/(L_p*10^3*t))*100; // Capacity factor
41 UF_p=(CF_p/LF_p)*100; // Use factor
42 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=%0.3 f
percentage \n                                Use factor=%0.2 f
percentage',LF_b,CF_b,UF_b,LF_p,CF_p,UF_p);
43 // The answer vary due to round off error

```

---

**Scilab code Exa 35.6** Capacity of hydel plant and steam plant

```

1 // Example 35_6
2 clc; funcprot(0);
3 // Given data
4 MD=50; // MW
5 md=10; // MW
6 n_o=60/100; // Over all efficiency of the plant
7 L_h=60; // MWh
8
9 // Calculation
10 // From Fig.Prob.35.6
11 // Area DEGHD=0.6*Area EFBE;
12 //  $xy - 120 \times 10^3 = (24 - x) \times (40 \times 10^3 - y) \times 0.6$ ; ..... (a)
13 //  $y/40000 = x/24$ ; ..... (b)
14 // Solving (a) and (b), we get
15 //  $x^2 + 72x - 1044 = 0$ 
16 coeff=[1,72,-1044];
17 y=roots(coeff);
18 x=y(2); // hours
19 y=(40000/24)*x*(1/1000); // Total capacity of hydel
    plant in MW
20 L_s=MD-y; // Capacity of steam plant in MW
21 printf(' \nTotal capacity of hydel plant=%0.3 f MW \
    nCapacity of steam plant=%0.3 f MW',y,L_s);
22 // The answer vary due to round off error

```

---