Scilab Textbook Companion for
Energy Management
by W. R. Murphy and G. A. Mckay[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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List of Scilab Codes

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Chapter 1

Energy auditing

Scilab code Exa 1.1 Energy Conversion

```
1
2 clc;
3 // Example 1.1
4 printf('Example 1.1\n\n');
5 printf(' Page No. 08\n\n');
6 // Solution
7
8 // Given
9 m1= 40*10^3;// fuel oil in gallons per year
10 ga= 4.545*10^-3;// m^3
11 m= m1*ga;// fuel oil in m^3 per year
12 Cv1= 175*10^3;// Btu per gallons
13 Bt= .2321*10^6;// J per m^3
14 Cv= Cv1*Bt;// in J per year per m^3
15 q=m*Cv;// in J per year
16 printf(' Heat available is %3.2e J per year\n',q)
```

Scilab code Exa 1.2 Energy conversion

```
1  clear ;
2  clc;
3  // Example 1.2
4  printf('Example 1.2\n\n');
5  printf('Page No. 09\n\n');
6  // Solution
7
8  // Given
9  Eo1= 1.775*10^9;// Annular energy consumption of oil
       in Btu
10 Btu= 1055;// 1 Btu = 1055 Joules
11 Eo= Eo1*Btu;// Annular energy consumption of oil in
       Joules
12 Eg1= 5*10^3;// Annular energy consumption of gas in
       Therms
13 Th= 1055*10^5;//  1 Th = 1055*10^3 Joules
14 Eg= Eg1*Th;// Annular energy consumption of gas in
       Joules
15 Ee1= 995*10^3;// Annular energy consumption of
       electricity in KWh
16 KWh= 3.6*10^6;// 1 KWh = 3.6*10^6 Joules
17 Ee= Ee1*KWh;// Annular energy consumption of
       electricity in Joules
18 Et= ( Eo + Eg + Ee);// Total energy consumption
19 P1= (Eo/Et)*100; // percentage of oil consumption
20 P2= (Eg/Et)*100; // percentage of gas consumption
21 P3= (Ee/Et)*100; // percentage of electricity
       consumption
22 printf('percentage of oil consumption is %3.1f \n',
       P1)
23 printf('percentage of gas consumption is %3.1f \n',
       P2)
24 printf('percentage of electricity consumption is %3
       .1f \n',P3)
```

Scilab code Exa 1.3 Energy Index

```
1  clear ;
2  clc;
3  // Example 1.3
4  printf('Example 1.3\n\n');
5  printf('Page No. 10\n\n');
6  // Solution
7
8  // Given
9  Et = 100*10^3;// total energy production in tonnes
        per annum
10  Eo= 0.520*10^9;// oil consumption in Wh
11  Eg= 0.146*10^9;// gas consumption in Wh
12  Ee= 0.995*10^9;// electricity consumption in Wh
13  Io= Eo/Et;
14  Ig= Eg/Et;
15  Ie= Ee/Et;
16  Et1= Eo + Eg + Ee;// total energy consumption
17  It= Et1/Et;
18  printf('oil energy index is %3.0f Wh per tonne \n',
        Io)
19  printf('gas energy index is %3.0f Wh per tonne \n',
        Ig)
20  printf('electricity energy index is %3.0f Wh per
        tonne \n',Ie)
21  printf('total energy index is %3.0f Wh per tonne ',
        It)
```

Scilab code Exa 1.4 Energy Costs

```
1  clear ;
2  clc;
3  // Example 1.4
4  printf('Example 1.4\n\n');
```

```
5  printf ( 'Page No. 10\n\n');
6  // Solution
7
8  // Given
9  mc= 1.5*10^3;// coke consumption in tonnes
10 mg= 18*10^3;// gas consumption in therms
11 me= 1*10^9;// electricity consumption in Wh
12 Cc1= 72;// cost of coke in Pound per tonne
13 Cg1= 0.20;// cost of gas in Pound per therm
14 Ce1= 2.25*10^-5 ;// cost of electricity in Pound per
       Wh
15 Cc= mc*Cc1;//in Pound
16 Cg= mg*Cg1;//in Pound
17 Ce= me*Ce1;//in Pound
18 Ct= Cc+Cg+Ce;//in Pound
19 printf ( 'cost of coke consumption is %.0f Pound \n',
       Cc)
20 printf ( 'cost of gas consumption is %.0f Pound \n',Cg
       )
21 printf ( 'cost of electricity consumption is %.0f
       Pound \n',Ce)
22 printf ( 'total cost is %3.0f Pound \n',Ct)
```

Scilab code Exa 1.5 `Cost Index`

```
1  clear ;
2  clc;
3  // Example 1.5
4  printf ( 'Example 1.5\n\n');
5  printf ( 'Page No. 11\n\n');
6  // Solution
7
8  // Given
9  Cc= 108.0*10^3;// cost of coke in Pound
10 Cg= 3.6*10^3;// cost of gas in Pound
```

```
11  Ce= 22.5*10^3;// cost of electricity in Pound
12  Ct= Cc+Cg+Ce;// total cost of fuel in Pound
13  E= 15*10^3;// total production in tonnes per year
14  Ic= Cc/E;//Pound per tonne
15  Ig= Cg/E;//Pound per tonne
16  Ie= Ce/E;//Pound per tonne
17  It= Ct/E;//Pound per tonne
18  printf(' coke cost index is %3.2f Pound per tonne \n
       ',Ic)
19  printf(' gas cost index is %3.2f Pound per tonne\n',
       Ig)
20  printf(' electricity cost index is %3.2f Pound per
       tonne\n',Ie)
21  printf(' total cost index is %3.2f Pound per tonne\n
       ',It)
```

Scilab code Exa 1.6 `Pie chart`

```
1  clear ;
2  clc;
3  // Example 1.6
4  printf('Example 1.6\n\n');
5  printf('Page No. 11\n\n');
6  // Solution
7
8  // Given
9  G1= 11.72*10^3;// hourly consumption of gas in
       therms
10  th= 34.13;// in Watts
11  G= G1*th;// hourly consumption of gas in Watts
12  O1= 4.32*10^9;// hourly consumption of oil in Joules
13  J= .278*10^-3;// in Watts
14  O= O1*J;// hourly consumption of oil in Watts
15  E= 500*10^3;// hourly consumption of electricity in
       Watts
```

```
16  // Pie Chart Representation : one input argument  x
       =[G O E]
17  pie([G O E],["gas" "oil" "electricity"]);// Please
        see the graphics window
18  printf('The Pie chart is plotted in the figure');
```

Scilab code Exa 1.7 `Pie chart`

```
1  close
2  clear ;
3  clc;
4  // Example 1.7
5  printf('Example 1.7\n\n');
6  printf('Page No. 12\n\n');
7  // Solution
8
9  // Given
10 O= 150*10^3;// energy consumption in office heating
        in Watts
11 L= 120*10^3;// energy consumption in lighting in
        Watts
12 B= 90*10^3;// energy consumption in boiler house in
        Watts
13 P= 180*10^3;// energy consumption in process in
        Watts
14 // Pie Chart Representation : one input argument  x
       =[O L B P]
15 pie([O L B P],["office heating" "lighting" "boiler
        heating" "process"]);// Please see the graphics
        window
16 printf('The Pie chart is plotted in the figure');
```

Scilab code Exa 1.8 `General auditing`

```
1  clear ;
2  clc;
3  // Example 1.8
4  printf('Example 1.8\n\n');
5  printf('Page No. 16\n\n');
6  // given
7
8  qunty= [40 10000 400 90000]
9  unit_price= [29 0.33 0.18 0.025]
10 cost= (unit_price .* qunty)// in Pound
11 common_basis= [310 492 11.7 90]// in 10^6 Wh
12 per_unit_cost= (unit_price .* qunty) ./ common_basis
       // Pound per 10^6 Wh
13 p= 150;// production in tonnes
14 EI= sum(common_basis)*10^6/150
15 CI= sum(unit_price .* qunty)/150
16 printf('energy index is %3.2f Wh per tonne \n',EI)
17 printf('cost index  is %3.2f Wh per tonne \n',CI)
```

Scilab code Exa 1.9 General Auditing

```
1  clear ;
2  clc;
3  function [coefs]=regress(x,y)
4  coefs=[]
5    if (type(x) <> 1)|(type(y)<>1) then error(msprintf
        (gettext("%s: Wrong type for input arguments:
        Numerical expected.\n"),"regress")), end
6    lx=length(x)
7    if lx<>length(y) then error(msprintf(gettext("%s:
        Wrong size for both input arguments: same size
        expected.\n"),"regress")), end
8    if lx==0 then error(msprintf(gettext("%s: Wrong
        size for input argument #%d: Must be > %d.\n"),
        "regress", 1, 0)), end
```

```
 9    x=matrix(x,lx,1)
10    y=matrix(y,lx,1)
11    xbar=sum(x)/lx
12    ybar=sum(y)/lx
13    coefs(2)=sum((x-xbar).*(y-ybar))/sum((x-xbar).^2)
14    coefs(1)=ybar-coefs(2)*xbar
15 endfunction
16 // Example 1.9
17 printf('Example 1.9\n\n');
18 printf('Page No. 17\n\n');
19 //given
20
21 p= [50, 55, 65, 50, 95, 90, 85, 80, 60, 90, 70, 110,
       60, 105];// weakly production in tonnes
22 s= [0.4, 0.35, 0.45, .31, 0.51,0.55, 0.45, 0.5, 0.4,
       0.51, 0.4, 0.6, 0.45, 0.55];// weakly steam
     consumption in 10^6 kg
23 coefs = regress(p,s);
24 new_p = 0:120
25 new_s = coefs(1) + coefs(2)*new_p;
26 plot(p,s,'r*');
27 mtlb_hold on
28 plot(new_p,new_s);// please see the corresponding
     graph in graphic window
29 xtitle('weakly steam consumption-production','weakly
        output (tonnes)','steam consumption/week (10^6
     kg)')
30 l = legend([_('Given data'); _('Fitting function')
     ],2);
31
32 in= coefs(1)*10^6;// intercept of graph in kg/weak
33 printf('At zero output the steam consumption is %3.0
     f in kg/weak \n',in)
```

Scilab code Exa 1.10 Detailed energy audits

15

```
 1  clear ;
 2  clc;
 3  // Example 1.10
 4  printf('Example 1.10\n\n');
 5  printf('Page No. 19\n\n');
 6  // given
 7
 8  //Monthly Energy Usage
 9  qunty = [15*10^3 4*10^3 90*10^3]
10  cost = [4950 720  2250]// in Pound
11  common_basis1  = [738 117 90]// in 10^6 Wh
12  common_basis= [2655 421 324]// converted into 10^9
        Joules
13  unit_cost = cost ./ common_basis1// in Pound per
        10^6 Wh
14  p= 80;// production in tonnes
15  EI = ((sum(common_basis))/p)*10^9;
16  CI = sum(cost)/80;
17  printf('Monthly energy index is %3.2e J per tonne \n
        ',EI)
18  printf('Monthly cost index is %.0f Pound per tonne \
        n\n',CI)//Deviation in answer is due to
        calculation error for sum of cost in the book
19
20  // Boiler House Energy Audit
21  qunty_b = [15000 10000]
22  Com_basis_b_1 = [2655 36]// in 10^9 J
23  Com_basis_b = [738 10]// in 10^6 Wh
24  Cost_b = [4950 250]// in Pound
25  b_output = 571*10^6;// in Wh
26  EI_b = (b_output/(sum(Com_basis_b)*10^6));
27  CI_b = (sum(Cost_b)/b_output)*10^3;// Pound
        converted into p
28  printf('Energy index  for boiler is %.3f \n',EI_b)
29  printf('Cost index for boiler is %3.2e p per Wh\n \n
        ',CI_b)
30
31  //Power House Energy Audit
```

```
32  P_gen = 200*10^6;// Power generated in Wh
33  Com_basis_p_1 = [14.4 2055 -1000]// in 10^9 J
34  Com_basis_p = [4.0 571 -278]// in 10^6 Wh
35  Cost_p = [100 5196 -2530]// in Pound
36  CI_p = (sum(Cost_p)/P_gen)*10^3;// Pound converted
        into p
37  printf('Cost index for power house is %3.2e p per Wh
        \n\n',CI_p)//Deviation in answer is due to wrong
        calculation in the book
38
39  //Space Heating Energy Audit
40  deg_days = 260;// Number of degree-days
41  Com_basis_s_1 = [36 100 105]// in 10^9 J
42  Com_basis_s = [10.0 27.8 29.2]// in 10^6 Wh
43  Cost_s = [250 253 179]// in Pound
44  EI_s = ((sum(Com_basis_s)*10^6)/deg_days)
45  CI_s = (sum(Cost_s)/deg_days)
46  printf('Energy index  for space heating is %3.2e Wh
        per degree-day\n',EI_s)
47  printf('Cost index for space heating is %3.2f Pound
        per degree-day\n\n',CI_s)
48
49  //Process Energy Audit
50  T_pdt_output = 100;// in tonne
51  Com_basis_pr_1 = [216 720 810 316]// in 10^9 J
52  Com_basis_pr = [60 200 225 88]// in 10^6 Wh
53  Cost_pr = [1500 2766 2047 540]// in Pound
54  EI_pr = ((sum(Com_basis_pr)*10^6)/T_pdt_output);
55  CI_pr = (sum(Cost_pr)/T_pdt_output);
56  printf('Energy index  for Process Energy Audit is %3
        .2e Wh per tonne \n',EI_pr)
57  printf('Cost index for Process Energy Audit is %.2f
        Pound per tonne \n',CI_pr)
```

Chapter 2

Energy Sources

Scilab code Exa 2.1 Energy audit scheme

```
1  clear ;
2  clc ;
3  // Example 2.1
4  printf ( 'Example  2.1\n\n' );
5  printf ( 'Page  No.  44\n\n' );
6
7  // given
8  C= 35000;// cost  of  boiler
9  C_grant =.25;// Capital  grant  available  from
       goverment
10 E= -(C-(C_grant*C));// Net  expenditure
11 Fs= 15250;// Fuel  Saving
12 r_i = 0.15;// interest
13 r_t = 0.55;// tax
14
15 a = [0 E Fs 0 E+Fs r_i*(E+Fs) 0 ]
16 bal_1 = a(5)+a(6)-a(7)// Total  Balance  after  1st
       year
17
18 c_all = 0.55;// capital  allowance  in  2nd  year
19 C_bal= (bal_1+0+Fs+(-(c_all*E)));// Cash  Balance
```

```
       after 2nd year
20 b = [bal_1 0 Fs -(c_all*E) C_bal r_i*C_bal r_t*(Fs+(
      r_i*C_bal))];
21 bal_2 = b(5)+b(6)-b(7)//Total   Balance  after  2nd
      year
22
23 c = [bal_2 0 Fs 0 bal_2+Fs r_i*(bal_2+Fs) r_t*(Fs+(
      r_i*(bal_2+Fs)))]
24 bal_3= c(5)+c(6)-c(7)// Total   Balance  after  3rd
      year
25
26 if(bal_2 >0) then
27     disp('Pay  back  period  is  of  two  year')
28 else
29     disp('Pay  back  period  is  of  three  year')
30 end
31
32 printf('Total  saving  at  the  end  of  second  year  is  %3
      .0f  Pound\n',bal_2);
33 printf('Total  saving  at  the  end  of  third  year  is  %3
      .0f  Pound\n',bal_3);
34 // Deviation  in  answer  due  to  direct  substitution
```

Scilab code Exa 2.2 Energy audit scheme

```
1 clear ;
2 clc ;
3 // Example  2.2
4 printf('Example  2.2\n\n');
5 printf('Page No.  45\n\n');
6
7 // given
8 C= 35000;// cost  of  boiler
9 C_grant =0;// Capital  grant  available  from  goverment
10 E= -(C-(C_grant*C));// Net  expenditure
```

19

```
11  Fs= 15250;// Fuel Saving
12  r_i = 0.15;// interest
13  r_t = 0.55;// tax
14
15  a = [0 E Fs 0 E+Fs r_i*(E+Fs) 0 ]
16  bal_1 = a(5)+a(6)-a(7)// Total  Balance  after  1st
       year
17
18  c_all = 0.55;// capital allowance in 2nd year
19  C_bal= (bal_1+0+Fs+(-(c_all*E)));// Cash Balance
       after 2nd year
20  b = [bal_1 0 Fs -(c_all*E) C_bal r_i*C_bal r_t*(Fs+(
       r_i*C_bal))];
21  bal_2 = b(5)+b(6)-b(7)//Total  Balance  after  2nd
       year
22
23  c = [bal_2 0 Fs 0 bal_2+Fs r_i*(bal_2+Fs) r_t*(Fs+(
       r_i*(bal_2+Fs)))]
24  bal_3= c(5)+c(6)-c(7)// Total  Balance  after  3rd
       year
25
26  if(bal_2>0) then
27      disp('pay back period is of two year')
28  else
29      disp('pay back period is of three year')
30  end
31
32  printf('Total saving at the end of second year is %3
       .2f Pound\n',bal_2);
33  printf('Total saving at the end of third year is %3
       .2f Pound\n',bal_3);
34  // Deviation in answer due to direct substitution
```

Scilab code Exa 2.3 Choice of fuels

```
1  clear ;
2  clc;
3  // Example 2.3
4  printf('Example 2.3\n\n');
5  printf('Page No. 46\n\n');
6
7  // given
8  F= 350*10^3;// fuel oils in gallons
9  Ci= 5000;// cost of insulation of tanks
10
11 As= 7500;//Annual Saving in Pound
12
13 if(As> Ci) then
14 disp("The investment has a pay−back period of less
       than 1 year");
15 else
16 disp("The investment has not a pay−back period of
       less than 1 year");
17 end
18 // Note− Since here pack back period is less than 1
       year and the company is in profit so they can go
       with this fuel oil ,
19 // although it can be noted that there are more
       problems handling heavy fuels oils
20 //and that the pay−back increases considerably the
       smaller the installation .
21 //So the company can changeover from oil to coal as
       a fuel .
```

Scilab code Exa 2.4 Choice of fuels

```
1  clear ;
2  clc;
3  // Example 2.4
4  printf('Example 2.4\n\n');
```

```
5  printf('Page No. 47\n\n');
6
7  // given
8  F1= 500*10^3;// fuel oil in gallons
9  F2= 500*10^3;// coal in gallons in Pound
10 C1= 165*10^3;// cost of oil per year in Pound
11 C2= 92*10^3;// cost of an equivalent of coal in
       Pound
12 Ce= 100*10^3;// capital cost of extra handling
       eqiupment
13
14 Cm= (Ce*0.2);// Maintenance , interest costs per
       year
15 As= C1-C2;// Annual Saving in Pound
16 printf('Annual Saving is %3.0 f Pound\n',As)
17
18 if((2*As)> Ce) then
19 disp("Replacing an obsolete boiler plant is
       considerable");
20 else
21 disp("Replacing an obsolete boiler plant is not
       considerble");
22 end
```

Scilab code Exa 2.5 Economic saving

```
1  clear ;
2  clc;
3  // Example 2.5
4  printf('Example 2.5\n\n');
5  printf('Page No. 49\n\n');
6
7  // given
8  F= 10*10^3;// fuel oils in gallons
9  Cs= 2200;// cost of maintaining tanks per year in
```

```
        Pound
10  Ci= 1850;// cost of insulation of pipe in Pound
11
12  As= (Cs*.85);//company saving is 85 per cent to the
        cost
13  printf('Annual Saving on heating is %3.0f  Pound\n',
      As)
14
15
16  if(As> Ci) then
17  disp("The investment has a pay−back period of less
        than 1 year");
18  else
19  disp("The investment has not a pay−back period of
        less than 1 year");
20  end
```

Scilab code Exa 2.6 `Cycle Efficiency`

```
1  clear ;
2  clc;
3  // Example 2.6
4  printf('Example 2.6\n\n');
5  printf('Page No. 52\n\n');
6
7  // given
8  P1= 50;// Dry saturated steam pressure in bar
9  P2= 0.5;// condenser  pressure in bar
10
11  //By using the steam tables saturation temperature
       is obtained at given pressures
12  T1= 537//The saturation temperatue in K at 50 bar
13  T2= 306//The saturation temperatue in K at 0.5 bar
14
15  // For Carnot Cycle
```

```
16  n=(1-(T2/T1))*100;
17  printf('Efficiency percentage of Carnot Cycle is %3
        .0 f \n',n)
18
19
20  // For Rankine Cycle
21  // By usins steam tables, the total heat and the
        sensibles heat  and other remaining parameter has
         been calculated
22  h1= 2794*10^3;//the total heat in dry steam at 50
        bar in J/kg
23  d= 0.655;// dryness fraction
24  h2= 1725*10^3;// the entropy at state 2 in J/kg
25  h3= 138*10^3;// the sensible heat at 0.5 bar in J/kg
26  Vf= 1.03*10^-3;// volume of fluid im m^3, calculated
        from steam table
27  W= (Vf*(P1-P2))*10^5;// pump work in J/kg
28  E=(((h1-h2)-(W))/((h1-h3)-(W)))*100;
29  printf('Efficiency percentage of Rankine Cycle is %3
        .0 f \n',E)
```

Chapter 3

Economics

Scilab code Exa 3.1 Simple interest

```
1  clear ;
2  clc ;
3  // Example 3.1
4  printf ( 'Example 3.1\n\n');
5  printf ( 'Page No. 58\n\n');
6
7  // given
8  P = 10000;// Principal Amount
9  i = 0.15;// Interest Rate
10 n = 4;//years
11 I = P*i*n;// Simple Interest
12 Ts= P+I;// The total repayment
13 printf ( 'The total repayment is %.0f Euro\n',Ts)
```

Scilab code Exa 3.2 Compound interest

```
1  clear ;
2  clc ;
```

```
3 // Example 3.2
4 printf('Example 3.2\n\n');
5 printf('Page No. 58\n\n');
6
7 // given
8 P = 10000;// Principal Amount in Pound
9 i = 0.15;// Interest Rate
10 n = 4;//years
11 Tc = P*(1+i)^n;
12 printf('The total repayment after adding compond
       interest is %.0f Pound\n',Tc)
```

Scilab code Exa 3.3 `Capital recovery`

```
1 clear ;
2 clc;
3 // Example 3.3
4 printf('Example 3.3\n\n');
5 //Page No. 59
6
7 // given
8 P = 60000;/// Principal Amount in Pound
9 i = 0.18;// Interest Rate
10 n = 10;//years
11 R = P*((i*(1+i)^n)/((1+i)^n -1));//Rate of Capital
       Recovery
12 printf('The annual investment required is %.1f Pound
       \n',R)
```

Scilab code Exa 3.4 `Depreciation`

```
1 clear ;
2 clc;
```

```
3  // Example 3.4
4  printf('Example 3.4\n\n');
5  printf('Page No. 61\n\n');
6
7  // given
8  P = 100000;/// Principal Amount of boiler plant in
       Pound
9  n = 10;// service life in years
10 S = 0;//Zero Salvage value
11 nT = (n*(n+1)/2);//sum of years
12 for i = 0:9
13     d_(i+1) = ((P-S)/nT)*(n-i);
14 end
15 printf('The Annual depreciation for first year is %
       .0f Pound\n',d_(1))
16 printf('The Annual depreciation for second year is %
       .0f Pound\n\n',d_(2))
17 printf('The Annual depreciation for third year is %
       .0f Pound\n',d_(3))
18 printf('The Annual depreciation for ten year is %.0f
        Pound\n',d_(10))
19 // Deviation in answer due to some .approximation of
        values in the book
```

Scilab code Exa 3.5 Depreciation and Asset value

```
1  clear ;
2  clc;
3  // Example 3.5
4  printf('Example 3.5\n\n');
5  printf('Page No. 62\n\n');
6
7  // given
8  P = 40000;/// Principal Amount of boiler plant in
       Pound
```

```scilab
 9  nT = 10;// service life in years
10  S = 4000;// Salvage value
11  n = 6;// years after which Asset value has to be
        calculated
12
13  //(a) Straight line method
14  d = ((P-S)/nT);// Depreciation
15  Aa = (d*(nT-n)) + S;
16  printf('The Asset value at the end of six years
        using Straight line method is %.0f Pound\n',Aa)
17
18  // (b) Declining balance technique
19  f = 1-(S/P)^(1/nT);// Fixed fraction of the residual
         asset
20  Ab = P*(1-f)^n;
21  printf('The Asset value at the end of six years
        using Declining balance technique is %.0f Pound\n
        \n',Ab)
22
23  // (c) Sum of the years digit
24  sum_nT = (nT*(nT+1)/2);//sum of  10 years
25  sum_n = 45;//sum after 6 years
26  dc = ((sum_n/sum_nT)*(P-S));// Depreciation after 6
        years
27  Ac = P-dc;
28  printf('The Asset value at the end of six years
        using Sum of the years digit is %.0f Pound\n',Ac)
        // Deviation in answer due to direct substitution
29
30  //(d) Sinking Fund Method
31  r_i = 0.06;// Rate of interest
32  Ad = P-((P-S)*(((1+r_i)^n-1)/((1+r_i)^nT-1)));
33  printf('The Asset value at the end of six years
        using Sinking Fund Method is %.0f Pound\n',Ad)//
        Deviation in answer due to direct substitution
```

Scilab code Exa 3.6 Rate of Return

```
1  clear ;
2  clc;
3  // Example 3.6
4  printf ('Example 3.6\n\n');
5  printf ('Page No. 67\n\n');
6
7  // given
8  P = 9000;// Capital Cost in Pound
9  n = 5;// Project lifetime
10 Less_dep = 8000;// Less Depreciation
11
12 //For Project A
13 d1 = [4500 3750 3000 1500 750 ]// Saving in every
       year (before depreciation)
14 dT1 = sum (d1)
15 Net_S1 = dT1- Less_dep;// Total Net Saving
16 Avg1 = Net_S1/n;// Average net annual saving
17 R_R1 = (Avg1/P)*100;
18
19 //For Project
20 d2 = [750 2250 4500 4500 1500 ]// Saving in every
       year (before depreciation)
21 dT2 = sum (d2)
22 Net_S2 = dT2- Less_dep;// Total Net Saving
23 Avg2 = Net_S2/n;// Average net annual saving
24 R_R2 = (Avg2/P)*100;
25
26 printf ('The percentage of Rate of Return on original
       investment for Project A is %3.1f \n',R_R1)
27 printf ('The percentage of Rate of Return on original
       investment for Project B is %3.1f \n',R_R2)
```

Scilab code Exa 3.7 Pay back method

```
1  clear ;
2  clc;
3  // Example 3.7
4  printf ('Example 3.7\n\n');
5  printf ('Page No. 68\n\n');
6
7  // given
8  Pc = 10000;// Capital cost for project C in Pound
9  Pd = 10000;// Capital cost for project d in Pound
10 nc = 3;// pay back period for C
11 nd = 3;// pay back period for D
12 Ca = [4500 3500 2000 2000 1000];// Annual Cash flow
        for C in Pound
13 Cc = [4500 8000 10000 12000 13000]// Cumulative Cash
         flow for C in Pound
14 Da = [1500 4000 4500 2200 1800 1000];// Annual Cash
        flow for D in Pound
15 Dc = [1500 5500 10000 12200 14000 15000]//
        Cumulative Cash flow for D in Pound
16 Ac = Cc(5)-Pc;// in Pound
17 Ad = Dc(6)-Pd;// in Pound
18 printf ('Additional amount from C after the pay back
        time is %3.f Pound\n',Ac)
19 printf ('Additional amount from D after the pay back
        time is %3.f Pound\n',Ad)
```

Scilab code Exa 3.8 Discounted cash flow

```
1  clear ;
2  clc;
```

```
3 // Example 3.8
4 printf('Example 3.8\n\n');
5 printf('Page No. 69\n\n');
6
7 //Refer figure 3.6
8 // given
9 n = 5;// years
10 C = 80000;// COst of the project in Pound
11 S = 0;// Zero Salvage Value
12 A_E = [10000 20000 30000 40000 50000]// Annual Net
      cash flow for project E in Pound
13 C_E = [10000 30000 60000 100000 150000]//
      Cummulative Net cash flow for project E in Pound
14 A_F = [50000 40000 30000 20000 10000]// Annual Net
      cash flow for project F in Pound
15 C_F = [50000 90000 120000 140000 150000]//
      Cummulative Net cash flow for project F in Pound
16
17 //From the figure 3.6 (intercept of x-axis)
18 P_F = 1.75;// in years
19 P_E = 3.5;// in years
20 printf('The pay-back time of project F is %.2f \n',
      P_F)
21 printf('The pay-back time of project E is %.1f \n\n'
      ,P_E)
22
23 printf('As the pay-back time is less for project F,\
      nProject F would always be choosen in practice\
      nsince prediction of savings in the early years
      are more reliable than long-term predictions.')
```

Scilab code Exa 3.9 Discounted cash flow

```
1 clear ;
2 clc ;
```

```
3  // Example 3.9
4  printf('Example 3.9\n\n');
5  printf('Page No. 70\n\n');
6
7  // given
8  P = 1;/// Principal Amount in Pound
9
10 r_i = 0.1;// Compound interest rate
11 for i = [1:1:4]
12     c = P*(1+r_i)^i;
13     printf('compound intrest after year %.0f is
           equal to %.2f Pound\n',i,c)
14 end
15
16 new_P = 1000*P;//in Pound
17 new_c = 1000*c;// in Pound
18 printf('The new amount at the compound interest
       after fourth year is %.0f Pound\n\n',new_c)
19
20 // Discount rate
21 r_d = 0.10;// Discount rate
22 for j= 1:1:4
23     d = P*(1/(1+r_d)^j);
24     printf('The amount receivable at discount in
           year %.0f is %.3f Pound\n',j,d)
25 end
26
27 new_P1 = new_c;// in Pound
28 new_d = new_P1*d;// in Pound
29 printf('The  new amount receivable at discount in
       fourth year is %.0f Pound\n',new_d)
```

Scilab code Exa 3.10 Net present value

```
1 clear ;
```

```
2 clc ;
3 // Example 3.10
4 printf ( 'Example 3.10\n\n');
5 printf ( 'Page No. 71\n\n');
6
7 // given
8 C = 2500;// Cost of the project
9 P = 1000;// Cash in flow
10 r_r = 0.12;// Rate of return
11 S = 0;// Zero salvage value
12 n = 4;// years
13
14 for j= 1:1:4 // as for four years
15     d_(j) = P*(1/(1+r_r)^j);
16     end
17
18
19 P_v = d_(1)+d_(2)+d_(3)+d_(4);//Present value of
       cash inflow
20 N = P_v-C;
21 printf ( 'Net present value is %.0f Pound\n',ceil(N))
22
23 if(P_v>C) then
24     disp ('The project may be undertaken')
25 else
26     disp ('The project may not be undertaken')
27     end
```

Scilab code Exa 3.11 Net present value

```
1 clear ;
2 clc ;
3 // Example 3.11
4 printf ( 'Example 3.11\n\n');
5 printf ( 'Page No. 72\n\n');
```

```scilab
 6
 7  // given
 8  Cash_out = 80000;// Present value of cash outflow
        for both projects E and F
 9  r_r = .2;// Rate of return
10  n = 5;// years
11
12  d = [0.833 0.694 0.579 0.482 0.402]// Discount
        Factor for 20% of rate of return for 5 years
13  Ce = [10000 20000 30000 40000 50000]// Cash flow for
         project E in Pound
14  Pe = [8330 13880 17370 19280 20100]// Present value
        for project E in Pound
15
16  Cf = [50000 40000 30000 20000 10000]// Cash flow for
         project F in Pound
17  Pf = [41650 27760 17370 9640 4020]// Present value
        for project F in Pound
18
19  Cash_inE = sum(Pe)//Present value of cash inflow in
        Pound
20  Cash_inF = sum(Pf)//Present value of cash inflow in
        Pound
21
22  Net_E = Cash_inE - Cash_out;// net present value for
         project E in Pound
23  Net_F = Cash_inF - Cash_out;// net present value for
         project F in Pound
24
25  if (Net_E>Net_F) then
26      disp('Project E is selected based on NPV')
27  else
28      disp('Project F is selected based on NPV')
29  end
```

Scilab code Exa 3.12 `Profitability index`

```
1  clear ;
2  clc;
3  // Example 3.12
4  printf('Example 3.12\n\n');
5  printf('Page No. 72\n\n');
6
7  // given
8  Cash_inG = 43000;// Present value of cash inflow for
        project G in Pound
9  Cash_outG = 40000;// Present value of cash outflow
     for   project G in Pound
10 Net_G = Cash_inG - Cash_outG;// Net present value
     for G in Pound
11 PI_G = (Cash_inG/Cash_outG);// Profitability index
     for G
12
13 Cash_inH = 23000;// Present value of cash inflow for
        project H in Pound
14 Cash_outH = 20000;// Present value of cash outflow
     for   project H in Pound
15 Net_H = Cash_inH - Cash_outH;// Net present value
     for H in Pound
16 PI_H = (Cash_inH/Cash_outH);// Profitability index
     for H
17
18 //The higher the profitability index the more
     desirable is the project.
19 if (PI_G>PI_H) then
20     disp('Project G is more attractive than Project
         H')
21 else
22     disp('Project H is more attractive than Project
         G')
23 end
```

Scilab code Exa 3.13 Internal rate of return

```
1  clear ;
2  clc;
3  // Example 3.13
4  printf ( ' Example  3.13\n\n ' ) ;
5  printf ( ' Page  No.  73\n\n ' ) ;
6
7  // given
8  Cash_out = 80000;// Present value of cash outflow
       for project F in Pound
9  n = 5;// years
10 Cash_in= [50000 40000 30000 20000 10000]// Cashn in
       \flow for project F in Pound
11 NPV = 0;//At the end of 5 years
12
13 //Let the unknown rate for project F be rm.
14
15 //The amount standing at the end of 5 years is\n =>
       0 = 80000*(1+rm)^5 - 50000*(1+rm)^4 - 40000*(1+rm
       )^3 - 30000*(1+rm)^2 - 20000*(1+rm)^1 - 10000
16 // By taking (1+rm) = x\n =>8*x^5 - 5*x^4 - 4*x^3 -
       3*x^2 - 2*x - 1 = 0\n\n ' )
17
18 function y=fsol1(x)
19   y= 8*x^5 - 5*x^4 - 4*x^3 - 3*x^2 - 2*x - 1;
20 endfunction
21 [xres]=fsolve(100,fsol1);
22 xres
23 rm = (xres - 1)*100;
24 printf ( ' The value of rm for project F is %3.0f per
       cent\n ' ,ceil(rm))
```

36

Scilab code Exa 3.14 `Discount factor`

```scilab
1  clear ;
2  clc;
3  function [coefs]=regress(x,y)
4  coefs=[]
5    if (type(x) <> 1)|(type(y)<>1) then error(msprintf
       (gettext("%s: Wrong type for input arguments:
       Numerical expected.\n"),"regress")), end
6    lx=length(x)
7    if lx<>length(y) then error(msprintf(gettext("%s:
       Wrong size for both input arguments: same size
       expected.\n"),"regress")), end
8    if lx==0 then error(msprintf(gettext("%s: Wrong
       size for input argument #%d: Must be > %d.\n"),
       "regress", 1, 0)), end
9    x=matrix(x,lx,1)
10   y=matrix(y,lx,1)
11   xbar=sum(x)/lx
12   ybar=sum(y)/lx
13   coefs(2)=sum((x-xbar).*(y-ybar))/sum((x-xbar).^2)
14   coefs(1)=ybar-coefs(2)*xbar
15 endfunction
16 // Example 3.14
17 printf('Example 3.14\n\n');
18 printf('Page No. 74\n\n');
19
20 // given
21 n = 5;//years
22 C = 80000;// Cost of the project in Pound
23 Cash_in = [10000 20000 30000 40000 50000]// Cash
       inflow in Pound
24 r_d1 = 15;// Discount factor of 15%
25 r_d2 = 18 ;// Discount factor of 18%
```

```
26  r_d3 = 20;// Discount  factor  of  20%
27
28  //At  discount  of  15%
29  df_1 = [0.870  0.756  0.658  0.572  0.497]// Discount
        factor  for  every  year
30  PV_1 = [8700  15120  19740  22880  24850]// Present
        value
31  Net_1 = sum (PV_1);// net  present  value
32
33
34  //At  discount  of  18%
35  df_2 = [0.847  0.718  0.609  0.516  0.437]// Discount
        factor  for  every  year
36  PV_2 = [8470  14360  18270  20640  21850]// Present
        value
37  Net_2 = sum (PV_2);// net  present  value
38
39
40  //At  discount  of  20%
41  df_3 = [0.833  0.694  0.579  0.482  0.402]// Discount
        factor  for  every  year
42  PV_3 = [8330  13880  17370  19280  20100]// Present
        value
43  Net_3 = sum (PV_3);// net  present  value
44
45  //  f = N.P.V.  cash  inflow − N.P.V.  cash  outflow
46  //(1) By  Numerical  Method
47  ff = 2*((sum (PV_2) - C)/(sum (PV_2) - sum(PV_3)));
        //  in  percentage
48  f = 18 + ff;
49  printf('the  internal  rate  of  return  in  percentage  is
        %3.2 f \n\n',f)// Deviation  in  answer  due  to
        direct  substitution
50
51  //(2) By  Graphical  Interpolation
52  f_1 = (sum (PV_1) - C)/10^3;//At  discount  factor  of
        15%
53  f_2 = (sum (PV_2) - C)/10^3;//At  discount  factor  of
```

```
       18%
54 f_3 = (sum (PV_3) - C)/10^3;//At discount factor of
       20%
55
56 x = [f_1 f_2 f_3];
57 y = [r_d1 r_d2 r_d3];
58 plot(x,y,'r*');
59
60 plot2d (x,y);// please see the corresponding graph
       in graphic window
61 xtitle('Discount factor against f','f ( *10^3 Pound)
       ','Discount factor(%)')
62 regress(x,y)
63 coefs = regress(x,y);
64 printf('the internal rate of return in percentage is
       %3.1f \n',coefs(1))// Deviation in answer due to
       direct substitution
```

Scilab code Exa 3.15 `Optimisation with one variable`

```
1 clear ;
2 clc;
3 // Example 3.15
4 printf('Example 3.15\n\n');
5 printf('Page No. 77\n\n');
6
7 // given
8 i_t = [20 40 60 80 100];// Insulation thickness in
       mm
9 f_c = [2.2 3.5 4.8 6.1 7.4];// Fixed costs in (10^3
       Pound / year)
10 h_c = [10.2 6.5 5.2 4.6 4.2];// Heat costs in (10^3
       Pound / year)
11 t_c = [12.4 10 10 10.7 11.6];// Total costs in (10^3
       Pound / year)
```

```
12
13 //(a) Graphical solution
14 //Refer figure 3.8
15 C_T = 9750;// Minimum total cost in Pound
16 t = 47;// Corresponding thickness of insulation in
       mm
17 printf('The most economic thickness of insulation is
        %.0f mm \n',t)
18
19 //(b) Numerical solution
20 // The cost due to heat losses ,C1, and the fixed
       costs ,C2, vary according to the equations;-
21 // C1 = (a/x) + b       and     C2 = (c*x) + d
22 // Substituting the values of C1 and C2 together
       with the corresponding insulation thickness
       values , the following equations are obtained :-
23 // C1 = (150*10^3/x) + 2.7*10^3      and     C2 = (65*x
       ) + 0.9*10^3
24 //And to obtain the total costs
25 //CT = C1 + C2 = (150*10^3/x) + (65*x) + 3.6*10^3
26 // Differentiate to optimise , and put dCT/dx equal
       to zero
27 //dCT/dx =-((150*10^3)/x^2) + 65 = 0
28
29 //Let y = dCT/dx
30 function y=fsol1(x)
31    y = -((150*10^3)/x^2) + 65;
32 endfunction
33 [xres]=fsolve(50,fsol1);
34 x = xres;
35 printf('The optimum thickness of insulation is %.0f
       mm \n',x)
```

Scilab code Exa 3.16 Optimum operating time

```
1  clear ;
2  clc;
3  // Example 3.16
4  printf('Example 3.16\n\n');
5  printf('Page No. 79\n\n');
6
7  // given
8  tb = [36*10^3 72*10^3 144*10^3 216*10^3]; //
       operating time in s
9  U = [971 863 727 636];// Mean overall heat transfer
       rate in W/m^2-K
10 A = 50;// area in m^2
11 dT = 25;// temperature difference in degree celcius
12 ts = 54*10^3;// Time in sec (h converted to sec)
13 //As Q = U*A*dT
14 for i = [1:1:4]
15     Q(i) = (U(i)*A*dT)/10^6;
16     Q_a(i) = ((tb(i)*Q(i)*10^6)/(tb(i) + ts))/10^6;
17     printf('the average heat transfer rate is %.3f
           *10^6 W \n',Q_a(i))
18 end
19
20 //Refer figure 3.9
21 printf('\n')
22 Q_max = 0.67*10^6;// Maximum value of Q in W
23 T_opt = 33;// Time in h
24 printf('The maximum value of Q obtained is %3.2e W \
       n',Q_max)
25 printf('The most econnomic opertaing time for the
       heat exchanger to run  is %.0f h ',T_opt)
```

Scilab code Exa 3.17 Optimisation with more than one variable

```
1  clear ;
2  clc;
```

```
3  // Example 3.17
4  printf('Example 3.17\n\n');
5  printf('Page No. 80\n\n');
6
7  // given
8  // C_T = 7*x + (40000/(x*y)) + 6*y + 10
9  //Differentiating C_T with respect to x and y:-
10 //dC_T/dx = 7 - (40000/(x^2*y))
11 //dC_T/dy = - (40000/(x*y^2)) + 6
12
13 //For optimum conditions :- dC_T/dx = dC_T/dy = 0
14 //dC_T/dx = 0    => 7 - (40000/(x^2*y)) = 0
15 //=> y = 40000/(7*x^2).......(1)
16 //dC_T/dy = 0    =>- (40000/(y^2*x)) +6 = 0
17 //=> y = (40000/(6*x))^0.5.......(2)
18
19 //From equation (1) and (2)
20 //=> 40000/(7*x^2) - (40000/(6*x))^0.5 = 0
21
22 function y=fsol1(x)
23   y = 40000/(7*x^2) - (40000/(6*x))^0.5 ;
24 endfunction
25 [xres]=fsolve(20,fsol1);
26 x = xres;
27
28 //from equation (1)
29 y = 40000/(7*x^2);
30
31 //a = d^2C_T/dx^2 = 80000/(x^3*y)
32 //b = d^2C_T/dy^2 = 80000/(x*y^3)
33 a = 80000/(x^3*y);
34 b = 80000/(x*y^3);
35 if a > 0
36     if b > 0
37 //The optimum conditions must occur at a point of
        minimum cost- C_T_m
38 C_T_m = 7*x + (40000/(x*y)) + 6*y + 10;// in Pound
39 printf('The minimum cost is %.1f Pound',C_T_m)
```

```
40        end
41  end
```

Chapter 4

Heat transfer theory

Scilab code Exa 4.1 Conduction

```
1  clear ;
2  clc ;
3  // Example 4.1
4  printf('Example 4.1\n\n');
5  printf('Page No. 88\n\n');
6
7  // given
8  K = 45// Thermal Conductivity in W/m-K
9  L = 5*10^-3;// thickness in metre
10 T1 = 100;// in degree celcius
11 T2 = 99.9;// in degree celcius
12 A = 1;// Area in m^2
13
14 //By Fourier law of conduction
15 Q = ((K*A*(T1-T2))/L);// in Watts
16 printf('The rate of conductive heat transfer is %.0f
       W \n',Q)
```

Scilab code Exa 4.2 Conduction through cylindrical pipe

```
1  clear ;
2  clc;
3  // Example 4.2
4  printf ('Example 4.2\n\n');
5  printf ('Page No. 89\n\n');
6  // given
7  K1 = 45// Thermal Conductivity  of mild steel in W/m
     –K
8  K2 = 0.040// Thermal Conductivity  of insulaton in W
     /m–K
9  L1 = 5*10^-3;// thickness of mild steel in metre
10 L2 = 50*10^-3;// thickness of insulation in metre
11 T1 = 100;// in degree celcius
12 T2 = 25;// in degree celcius
13 A = 1;// Area in m^2
14
15 //By Fourier law of conduction
16 Q = (((T1-T2)/((L1/(K1*A))+(L2/(K2*A)))))// in Watts
17 printf ('The rate of conductive heat transfer is %.0f
      W \n',Q)
```

Scilab code Exa 4.3 `Conduction through pipe with insulation`

```
1  clear ;
2  clc;
3  // Example 4.3
4  printf ('Example 4.3\n\n');
5  printf ('Page No. 90\n\n');
6
7  // given
8  K1 = 26;// Thermal Conductivity  of stainless steel
     in W/m–K
9  K2 = 0.038;// Thermal Conductivity  of insulaton in
     W/m–K
10 L1 = 3*10^-3;// thickness of stainless steel in
```

```
        metre
11 L2 = 40*10^-3;// thickness of insulation in metre
12 T1 = 105;// in degree celcius
13 T2 = 25;// in degree celcius
14 L = 15;// Length of pipe in metre
15 d1 = 50*10^-3;// Internal diameter of pipe in metre
16 d2 = 56*10^-3;// External diameter of pipe in metre
17
18 r1 = d1/2;// in metre
19 r2 = d2/2;// in metre
20
21 rm_p = ((r2-r1)/log(r2/r1));// logarithmic mean
        radius of pipe in m
22 rm_i = (((r2+L2)-r2)/log((r2+L2)/r2));// logarithmic
        mean radius of insulation in m
23
24 //By Fourier law of conduction
25 Q = (((T1-T2)/((L1/(K1*2*%pi*rm_p))+(L2/(K2*2*%pi*
        rm_i)))));// in W/m
26 Q_L = Q*L;
27 printf('The rate of conductive heat transfer per 15
        m length of pie is %3.2f W\n',Q_L)// Deviation in
         answer due to direct substitution
```

Scilab code Exa 4.4 Fouling factors

```
1 clear ;
2 clc;
3 // Example 4.4
4 printf('Example 4.4\n\n');
5 printf('Page No. 93\n\n');
6
7 // given
8 dH = 12*10^-3;// Outer diameter of pipe in m
9 dC = 10*10^-3;// Inner diameter of pipe in m
```

```
10  L = 1*10^-3;// im m
11  h_H = 10*10^3;// Heat Transfer Coefficient  on
       vapour side in W/m^2-K
12  h_C = 4.5*10^3;// Heat Transfer Coefficient  on
       vapour side in W/m^2-K
13  K = 26;// Thermal Conductivity of metal in W/m-K
14  dM = (dH + dC)/2;// mean diameter in m
15  h_Hf = 6*10^3;// Fouling factor for hot side
16  h_Cf = 6*10^3;// Fouling factor for cold side
17
18  U = (1/h_H)+((L*dH)/(K*dM))+(dH/(dC*h_C));
19  Uh = (1/U);// in W/m^2-K
20  printf('The original heat transfer coefficient is %3
       .0 f W/sq.m K \n',Uh )// Deviation in answer due
       to direct substitution
21
22  u = (1/h_H)+(1/h_Hf)+((L*dH)/(K*dM))+(dH/(dC*h_C))+(
       dH/(dC*h_Cf));
23  Uf = (1/u);// in W/m^2-K
24  printf('The final heat transfer coefficient due to
       fouling is %3.0 f W/m^2-K \n',ceil(Uf))
```

Scilab code Exa 4.5 L M T D

```
1  clear ;
2  clc;
3  // Example 4.5
4  printf('Example 4.5\n\n');
5  printf('Page No. 95\n\n');
6
7  // given
8  m_h = 1.05;// Mass flow rate of hot liquid in kg/s
9  Thi = 130;// Inlet Temperature of hot liquid in
       degree celcius
10 Tho = 30;// Outlet Temperature of hot fluid in
```

```
         degree celcius
11  Cph =  2.45*10^3;// Specific heat capacity of hot
        liquid in J/kg−K
12
13  m_c = 4.10;// Mass flow rate of cold liquid in kg/s
14  Tci =  20;// Inlet Temperature of cold liquid in
        degree celcius
15  Cpc =  4.18*10^3;// Specific heat capacity of cold
        liquid in J/kg−K
16
17  A = 6.8;// Area of heat exchanger in m^2
18  Q = m_h*Cph*(Thi-Tho);// in Watts
19
20  //From heat balance
21  // m_c*Cpc*(Tci−Tco)= m_h*Cph*(Thi−Tho)= UAlTm = Q
22  Tco = ((Q/(m_c*Cpc))+Tci);
23  printf(' The Outlet Temperature of cold fluid is %.0
        f degree celcius\n',Tco)
24  // As counter flow  heat exchanger
25  T1 = Thi-Tco;
26  T2 = Tho-Tci;
27  Tm = ((T1-T2)/log(T1/T2));
28
29  U = (Q/(A*Tm));
30  printf('The overall heat transfer coefficient is %.0
        f W/sq.m K \n',U)// Deviation in answer due to
        direct substitution
```

Scilab code Exa 4.6 Forced convection turbulent flow

```
1  clear ;
2  clc;
3  // Example 4.6
4  printf('Example 4.6\n\n');
5  printf('Page No. 98\n\n');
```

```
6
7  // given
8  v = 1.23; // velocity in m/s
9  d = 25*10^-3; // diameter in m
10 p = 980; // density in kg/m^3
11 u = 0.502*10^-3; // viscosity in Ns/m^2
12 Cp = 3.76*10^3; // Specific heat capacity in J/kg-K
13 K = 0.532; // Thermal conductivity in W/m-K
14
15 Re = (d*v*p)/u; // Reynolds Number
16 Pr = (Cp*u)/K; // Prandtl Number
17 Re_d = (Re)^0.8;
18 Pr_d = (Pr)^0.4;
19
20 // By Dittus-Boelter Equation
21 //Nu = 0.0232 * Re^0.8 Pr^0.4 = (hd)/K
22 Nu = 0.0232 * Re_d * Pr_d; // Nusselt Number
23 h = (Nu*K)/d; //W/m^2-K
24 printf('The film heat transfer coefficient is %3.2 f
       W/sq.m K\n',h) // Deviation in answer due to
        direct substitution
```

Scilab code Exa 4.7 Free convection

```
1  clear ;
2  clc;
3  // Example 4.7
4  printf('Example 4.7\n\n');
5  printf('Page No. 99\n\n');
6
7  // (a) without insulation
8  // given
9  d_a = 0.150; // Diameter of pipe in m
10 T1_a = 60; // Surface temperature in degree celcius
11 T2_a = 10; // Ambient temperature in degree celcius
```

```
12
13  //For laminar flow in pipe,h= 1.41*((T1-T2)/d)^0.25
14  h_a = 1.41*((T1_a-T2_a)/d_a)^0.25;//W/m^2-K
15  A_a = %pi * d_a;// Surface Area per unit length in m
      ^2/m
16  Q_a = h_a*A_a*(T1_a - T2_a);// in W/m
17  printf('The heat loss per unit length without
      insulation is %.0f W/m \n',ceil(Q_a))
18
19  // (b) with insulation
20  // given
21  d_b = 0.200;// Diameter of pipe in m
22  T1_b = 20;// Surface temperature in degree celcius
23  T2_b = 10;// Ambient temperature in degree celcius
24
25  //For laminar flow in pipe,h= 1.41*((T1-T2)/d)^0.25
26  h_b = 1.41*((T1_b-T2_b)/d_b)^0.25;//W/m^2-K
27  A_b = %pi * d_b;// Surface Area per unit length in m
      ^2/m
28  Q_b = h_b*A_b*(T1_b - T2_b);// in W/m
29  printf('the heat loss per unit length with
      insulation is %.1f W/m',Q_b)
30  // Deviation in answer due to direct substitution
```

Scilab code Exa 4.8 `Rate oh heat transfer`

```
1  clear ;
2  clc;
3  // Example 4.8
4  printf('Example 4.8\n\n');
5  printf('Page No. 103\n\n');
6
7  // given
8  d = 0.100;// Diameter of pipe in m
9  T1 = 383;// Surface temperature in Kelvin
```

```
10  T2 = 288;// Surrounding air temperature in Kelvin
11  e = 0.9;// Emissivity of pipe
12  A = %pi * d;// Surface Area per unit length in m^2/m
13
14  // By Stefan-Blotzmann law, the radiative heat
       transfer rate is  Q = 5.669*e*A*((T1/100)^4-(T2
       /100)^4)
15  Q = 5.669*e*A*((T1/100)^4-(T2/100)^4);// in W/m
16  printf('The radiative heat loss per unit length is %
       .0f W/sq.m',ceil(Q))
```

Scilab code Exa 4.9 Heat loss from bare surfaces

```
1  clear ;
2  clc;
3  // Example 4.9
4  printf('Example 4.9\n\n');
5  printf('Page No. 103\n\n');
6
7  // given
8  A = 1;// Area in m^2
9  T1 = 423;// Surface temperature in Kelvin
10  T2 = 293;// Surrounding air temperature in Kelvin
11  T1_c = 150;// Surface temperature in degree celcius
12  T2_c = 20;// Ambient temperature in degree celcius
13  e = 0.9;// Emissivity of pipe
14
15  //(a) Horizontal Pipe
16  d = 0.100;// Diameter of pipe in m
17  //For laminar flow in pipe,Q= (1.41*((T1-T2)/d)
       ^0.25)*(T1-T2)
18  Q_Ca = (1.41*((T1_c-T2_c)/d)^0.25)*(T1_c-T2_c);//
       Convective heat transfer rate in W/m^2
19  // By Stefan-Blotzmann law, the radiative heat
       transfer rate is  Q = 5.669*e*((T1/100)^4-(T2
```

```
    /100) ^4)
20  Q_Ra = 5.669*e*((T1/100)^4-(T2/100)^4);// in W/m^2
21  Q_Ta = Q_Ra + Q_Ca;// IN W/m^2
22  printf('The total heat loss from per square meter
        area is %.2f W/sq.m\n',Q_Ta)// Deviation in
        answer due to direct substitution
23
24
25  //(b) Vertical Pipe
26  //For turbulent flow in pipe,Q= (1.24*(T1-T2)^1.33)
27  Q_Cb = (1.24*(T1-T2)^1.33);// Convective heat
        transfer rate in W/m^2
28  // By Stefan-Blotzmann law, the radiative heat
        transfer rate is   Q = 5.669*e*((T1/100)^4-(T2
        /100)^4)
29  Q_Rb = 5.669*e*((T1/100)^4-(T2/100)^4);// in W/m^2
30  Q_Tb = Q_Rb + Q_Cb;// IN W/m^2
31  printf('The total heat loss from per square meter
        area is %.0f W/sq.m\n',floor(Q_Tb))
```

Scilab code Exa 4.10 Heat loss from insulated surfaces

```
1  clear ;
2  clc;
3  // Example 4.10
4  printf('Example 4.10\n\n');
5  printf('Page No. 106\n\n');
6
7  // given
8  T1 = 150;// Surface temperature in degree celcius
9  T2 = 20;// Ambient temperature in degree celcius
10 d = 0.100; //Outside diametr of pipe in m
11 h = 10;// Outside film coefficient in W/m^2-K
12 t = 25*10^-3;// thickness of insulation in m
13 K = 0.040;// Thermal conductivity of insulation in W
```

```
        /m–K
14
15  r2 = d/2; //in m
16  r1 = r2+t; // in m
17  Q = ((T1-T2)/((1/(2*%pi*r1*h))+(log(r1/r2)/(2*%pi*K)
        )));// in W/m
18  printf('The heat loss per unit length is %.0f W/m',Q
        )
```

Chapter 5

Heat transfer media

Scilab code Exa 5.1 Water treatment

```scilab
1  clear ;
2  clc;
3  // Example 5.1
4  printf ( ' Example 5.1\n\n ') ;
5  printf ( ' Page No. 110\n\n ') ;
6
7  // given
8  Q = 0.30*10^6; // Heat transfer rate in W/sq.m
9  T1 = 540; // Mean gas temperature in degree celcius
10 T2 = 207; // Steam temperature in degree celcius
11 K_tube = 40; // Thermal conductivity of tube in W/m-K
12 K_scale = 2.5 ; // Thermal conductivity of scale in W
      /m-K
13 L_tube = 4*10^-3; // Length of tube in m
14
15 // By Fourier equation and neglecting curvature
      effect , Q/A = [(T1- T2)/(( L_tube/K_tube)+(L_scale
      /K_scale))]
16 L_scale = K_scale *(((T1-T2)/Q) -(L_tube/K_tube));
17 printf ( ' The thickness of scale is %.4f m ' ,L_scale)
```

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Scilab code Exa 5.2 Properties of water

```scilab
1  clear ;
2  clc;
3  // Example 5.2
4  printf('Example 5.2\n\n');
5  printf('Page No. 113\n\n');
6
7  // given
8  T1 = 10;// in degree celcius
9  T2 = 70;// in degree celcius
10 d = 25*10^-3;// Inside diameter in m
11 v = 1.5;// veocity in m/s
12
13 Tm = (T1+T2)/2;// Arithmetic Mean temperature in
       degree celcius
14 // At Tm, All physical properties of water is
       calculated by using steam table
15
16 //(a)Heat absorbed by water
17 p = 992;// Density of water in kg/m^3 At Tm
18 A = (%pi*d^2)/4;// Area in m^2
19 m = p*v*A;// Mass flow rate in kg/s
20 h_70 = 293*10^3;// Specific enthalpy of water in J/
       kg at 70 degree celcius(from steam table)
21 h_10 = 42*10^3;// Specific enthalpy of water in J/kg
        at 10 degree celcius(from steam table)
22 Q = m*(h_70 - h_10);// in W
23 printf(' Heat absorbed by water is %.0f W \n',Q)
24
25 //(b) Film heat transfer
26 //At Tm, the following properites of water are found
       by using steam table
27 u = 650*10^-6;// viscosity in Ns/m
```

```
28  Cp = 4180;//Specific heat in J/kg−s
29  K = 0.632;// Thermal conductivity in W/m−s
30
31
32  Re = (d*v*p)/u;//Reynolds Number // answer wrongly
       calculated in the text book
33  Pr = (Cp*u)/K;// Prandtl Number
34  Re_d = (Re)^0.8;
35  Pr_d = (Pr)^0.4;
36
37  // By Dittus−Boelter Equation
38  //Nu = 0.0232 * Re^0.8 Pr^0.4 = (hd)/K
39  Nu = 0.0232 * Re_d * Pr_d;// Nusselt Number
40  h = (Nu*K)/d;//W/m^2−K
41  printf('The film heat transfer coefficient is %.0f W
       /sq.m K\n',h)// Deviation in answer due to direct
        substitution and wrongly calculated in the text
       book
```

Scilab code Exa 5.3 Addition of heat to water

```
1  clear ;
2  clc;
3  // Example 5.3
4  printf('Example 5.3\n\n');
5  printf('Page No. 117\n\n');
6
7  // given
8  T1 = 25;// in degree celcius
9  T2 = 212;// in degree celcius
10  x = 0.96;// dryness fraction
11  m = 1.25;// Mass flow rate in kg/s
12
13  //from steam table
14  hL_212 = 907*10^3;// Specific enthalpy at 212 degree
```

```
                celcius in J/kg
15  hL_25 = 105*10^3;// Specific enthalpy at 25 degree
        celcius in J/kg
16  l_212 = 1890*10^3;// Latent heat of vapourisation at
        212 degree celcius in J/kg
17
18  Q = m*((hL_212+(x*l_212))-hL_25);// in W
19  printf('The required heat is %.0f W',Q)
```

Scilab code Exa 5.4 Thermal efficiency

```
 1  clear ;
 2  clc ;
 3  // Example 5.4
 4  printf('Example 5.4\n\n');
 5  printf('Page No. 117\n\n');
 6
 7  // given
 8  T = 25;// in degree celcius
 9  x = 0.96;// dryness fraction
10  m = 3.15;// Mass flow rate in kg/s
11  CV = 42.6*10^6;// Calorific value in J/kg
12  P = 15;// Pressure in bar
13  n = 0.8;// Efficiency
14
15  //from steam table
16  hL_1 = 843*10^3;// Specific enthalpy in J/kg
17  hL_2 = 293*10^3;// Specific enthalpy  in J/kg
18  l_1 = 1946*10^3;// Latent heat of vapourisation at
        70 degree celcius in J/kg
19
20  Q = m*((hL_1+(x*l_1))-hL_2);// in W
21  Q_Ac = Q/n// Actual heat required in Watts
22  Oil = Q_Ac/CV;
23  printf('The oil required is %.3f kg/s',Oil)
```

Scilab code Exa 5.5 Condensing Steam

```
1  clear ;
2  clc;
3  // Example 5.5
4  printf('Example 5.5\n\n');
5  printf('Page No. 120\n\n');
6
7  // given
8  T1 = 134;// in degree celcius
9  T2 = 100;// in degree celcius
10 x = 0.96;// dryness fraction
11 m = 0.75;// Mass flow rate in kg/s
12
13 //from steam table
14 hL_134 = 563*10^3;// Specific enthalpy at 134 degree
        celcius in J/kg
15 hL_100 = 419*10^3;// Specific enthalpy at 100 degree
        celcius in J/kg
16 l_134 = 2162*10^3;// Latent heat of vapourisation at
        134 degree celcius in J/kg
17
18 Q = m*((hL_134+(x*l_134))-hL_100);// in W
19 printf('The required heat is %.0f W',Q)// Deviation
     in answer due to direct substitution and some
     approximation in answer in book
```

Scilab code Exa 5.6 Direct contact condenser

```
1  clear ;
2  clc;
```

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```
3  // Example 5.6
4  printf('Example 5.6\n\n');
5  printf('Page No. 120\n\n');
6
7  // given
8  x = 0.90;// dryness fraction
9  m = 0.25;// Mass flow rate in kg/s
10 P = 0.7;// pressure in bar
11 T1 = 10;// in degree celcius
12
13 //from steam table
14 h_10= 42*10^3;// Specific enthalpy  of water at 10
       degree celcius in J/kg
15 h_25 = 105*10^3;// Specific enthalpy of water at 25
       degree celcius in J/kg
16 h_30 = 126*10^3;// Specific enthalpy of water at 30
       degree celcius in J/kg
17 h_s = 2432*10^3;// Specific enthalpy of steam in J/
       kg
18
19 //(a)T2 = 25;
20 T2 = 25;// in degree celcius
21 // By heat balance, heat transfered at 10 degree
       celcius = heat gained at 25 degree celcius; "(m*
       h_s)+(h_10*y)= (m*h_25)+(h_25*y)"; where 'y' is
       the quqntity of water to be used at 25 degree
       celcius in kg/s
22 y = (m*(h_s-h_25)/(h_25-h_10));
23 printf('the quantity of water to be used at 25
       degree celcius is %.2f kg/s \n',y)
24
25
26 //(b)T2 = 30;
27 T2 = 30;// in degree celcius
28 // By heat balance, heat transfered at 10 degree
       celcius = heat gained at 30 degree celcius; "(m*
       h_s)+(h_10*y)= (m*h_30)+(h_30*y)"; where 'z' is
       the quqntity of water to be used at 30 degree
```

```
        celcius in kg/s
29  z = (m*(h_s-h_30)/(h_30-h_10));
30  printf('the quantity of water to be used at 30
        degree celcius is %.2f kg/s \n',z)
```

Scilab code Exa 5.7 Diameter of pipe

```
 1  clear ;
 2  clc;
 3  // Example 5.7
 4  printf('Example 5.7\n\n');
 5  printf('Page No. 121\n\n');
 6
 7  // given
 8  x = 0.97;// dryness fraction
 9  m = 4.0;// Mass flow rate in kg/s
10  v = 40;// velocity in m/s
11  P = 10;// pressure in bar
12
13  //from steam table
14  Sp_vol = 0.194;// specific volume at 10 bar dry
        steam in m^3/kg
15
16  Q = Sp_vol*x*m// Volumetric flow rate of steam in m
        ^3/s
17  d = sqrt((Q*m)/(v*%pi));
18  printf('the required diameter of pipe is %.3f m',d)
```

Scilab code Exa 5.8 Superheated steam

```
 1  clear ;
 2  clc;
 3  // Example 5.8
```

```
 4  printf('Example 5.8\n\n');
 5  printf('Page No. 122\n\n');
 6
 7  // given
 8  T1 = 25;// in degree celcius
 9  T2 = 450;// in degree celcius
10  m = 7.5;// Mass flow rate in kg/s
11
12  //from steam table
13  hL_450 = 3303*10^3;// Specific enthalpy at 450
        degree celcius in J/kg
14  hL_25 = 105*10^3;// Specific enthalpy at 25 degree
        celcius in J/kg
15
16  Q = m*(hL_450 - hL_25);// in W
17  printf('The required heat is %.0f W',Q)// Deviation
        in answer due to direct substitution and some
        approximation in answer in book
```

Scilab code Exa 5.9 Wiredrawing

```
 1  clear ;
 2  clc;
 3  // Example 5.9
 4  printf('Example 5.9\n\n');
 5  printf('Page No. 122\n\n');
 6
 7  // given
 8  P1 = 15;// Pressure at state 1 in bar
 9  P2 = 1.5;// Pressure at state 2 in bar
10  T1 = 198;// in degree celcius
11
12  // as the process is adiabatic; => Q = 0; =>
        ehthalpy at state1 = enthalpy at state 2
13  h_1 = 2789*10^3;// specific enthalpy at state 1 in J
```

```
         /kg
14 h_2 = h_1; // specific  enthalpy  at  state  2  in  J/kg
15
16 T3 = 150; // in  degree  celcius
17 T4 = 200; // in  degree  celcius
18 h_3 = 2773*10^3; // specific  enthalpy  at  state  3  in  J
         /kg
19 h_4 = 2873*10^3; // specific  enthalpy  at  state  4  in  J
         /kg
20
21 // Assuming  a  liner  realtionship  between  temperature
         and  enthalpy  for  the  temperature  range  150−200
         degree  celcius
22 h = ((h_4 - h_3)/(T4 - T3)); // specific  enthalpy  per
         degree  celcius  in  J/kg−degC
23 t = ((h_2 - h_3)/h); // in  degree  celcius
24 T2 = T3 + t; // in  degree  celcius
25 printf ('the  temperature  of  the  final  superheated
         steam  at  1.5  bar  is  %.0f  deg  C',T2)
```

Scilab code Exa 5.10 Desuperheating

```
1 clear ;
2 clc;
3 // Example  5.10
4 printf ('Example  5.10\n\n');
5 printf ('Page  No.  123\n\n');
6
7 // given
8 m = 0.45; // Mass  flow  rate  in  kg/s
9 P = 2; // pressure  in  bar
10 T1 = 60; // in  degree  celcius
11 T2 = 250; // in  degree  celcius
12 h_s = 2971*10^3; // Specific  enthalpy  of  superheated
         steam  in  J/kg
```

```
13  h_d = 2706*10^3;// Specific enthalpy of dry
        saturated steam in J/kg
14  h_e = h_s - h_d;// excess Specific enthalpy in J/kg
15  h = 251*10^3;// in J/kg
16  V_s = 0.885;// specific volume of dry saturated
        steam at 2 bar in m^3/kg
17
18  h_r = h_d- h;// heat required to convert water at 60
        deg C into dry saturated steam at 2 bar
19  w = (h_e/h_r);// in kg/kg
20  printf('the quantity of water requried is %.3f kg/kg
        \n\n',w)
21
22  M = m*w;// in kg/s
23  printf('the total mass flow rate of water required
        is %.3f kg/s \n\n',M)
24
25  M_d = M + m;// mass flow rate of desuperheated steam
         in kg/s
26  V = M_d*V_s;// in m^3/s
27  printf('the total mass flow rate of desuperheated
        steam required is %.4f m^3/s \n',V)
28  // Deviation in answer due to some approximation in
        answer in   the book
```

Scilab code Exa 5.11 Synthetic organic chemicals

```
1  clear ;
2  clc;
3  // Example 5.11
4  printf('Example 5.11\n\n');
5  printf('Page No. 130\n\n');
6
7  // given
8  T1 = 180;// in degree celcius
```

```
 9  T2 = 350;// in degree celcius
10  m = 0.5;// Mass flow rate in kg/s
11
12
13  //from steam table
14  hL_180 = 302*10^3;// Specific enthalpy at 180 degree
        celcius in J/kg
15  hL_350 = 690*10^3;// Specific enthalpy at 350 degree
        celcius in J/kg
16
17  Q = m*(hL_350 - hL_180);// in W
18  printf('The required heat is %.0f W',Q)
```

Scilab code Exa 5.12 Synthetic organic chemicals

```
 1  clear ;
 2  clc;
 3  // Example 5.12
 4  printf('Example 5.12\n\n');
 5  printf('Page No. 130\n\n');
 6
 7  // given
 8  T1 = 200;// in degree celcius
 9  T2 = 300;// in degree celcius
10  m_l = 0.55;// Mass flow rate  of liquid in kg/s
11  P = 3; //pressure in bar
12  Cp = 2.34*10^3;// Mean haet capacity in J/kg-K
13  h = 272*10^3;// Latent heat of eutectic mixture at 3
        bar
14
15  Q = m_l*Cp*(T2 -T1);// in Watts
16  m = Q/h;// in kg/s
17  printf('The mass flow rate of dry saturated eutectic
        mixture is %.2f kg/s',m)
```

Scilab code Exa 5.13 `Heat transfer coefficients`

```
1  clear ;
2  clc ;
3  // Example 5.13
4  printf ( 'Example 5.13\n\n' );
5  printf ( 'Page No. 131\n\n' );
6
7  // given
8  T = 300; // in degree celcius
9  v = 2; // velocity in m/s
10 d = 40*10^-3; // diameter in m
11
12 // From the table 5.3 and 5.4 given in the  book
13 K_d = [2.80 2.65 2.55 2.75] // in W/m^2−k
14 Re = [117*10^3 324*10^3 159*10^3 208*10^3] // Reynolds
        number
15 Pr = [12 4.50 10.0 7.3] // Prandtl Number
16
17 // By Dittus−Boelter Equation
18 //Nu = 0.0232 * Re^0.8*Pr^0.3 = (hd)/K
19 //h =  0.0232 * Re^0.8*Pr^0.3 *(K/d)
20
21 h_T = 0.0232 * Re(1)^0.8*Pr(1)^0.3*K_d(1); // //W/m
        ^2−K
22 printf ( 'The film heat transfer coefficient using
        Transcal N is %.0 f W/sq.m K \n',h_T) // Deviation
        in answer due to direct substitution
23
24
25 h_D = 0.0232 * Re(2)^0.8*Pr(2)^0.3*K_d(2); // //W/m
        ^2−K
26 printf ( 'The film heat transfer coefficient using
        Dowtherm A is %.0 f W/sq.m K \n\n',h_D) //
```

```
          Deviation in answer due to direct substitution
27
28
29  h_M = 0.0232 * Re(3)^0.8*Pr(3)^0.3*K_d(3);// //W/m
       ^2-K
30  printf('The film heat transfer coefficient using
       Marlotherm S is %.0f W/sq.m K \n',h_M)//
       Deviation in answer due to direct substitution
31
32
33  h_S = 0.0232 * Re(4)^0.8*Pr(4)^0.3*K_d(4);// //W/m
       ^2-K
34  printf('The film heat transfer coefficient using
       Santotherm 60 is %.0f W/sq.m K \n',h_S)//
       Deviation in answer due to direct substitution
```

Scilab code Exa 5.14 The humidity chart

```
1  clear ;
2  clc;
3  // Example 5.14
4  printf('Example 5.14\n\n');
5  printf('Page No. 137\n\n');
6
7  // given
8  T1 = 25;// Wet-bulb temperature in degree celcius
9  T2 = 40;//Dry-bulb temperature in degree celcius
10
11 //By using the humidity chart and steam tables for
       air-water mixtures at the given temperatures, the
        all following data can be obtained
12
13 //(a) humidity
14 w = 0.014;// in kg/kg
15 printf('the required humidity is %.3f kg/kg \n',w)
```

66

```
16
17
18  //(b) relative humidity
19  R_H = 30;// in percentage
20  printf('the required relative humidity in percentage
        is %.0f\n\n',R_H)
21
22  //(c) the dew point
23  T_w = 20;// in degree celcius
24  printf('the required dew-point temperature is %.0f
      deg C\n',T_w)
25
26  //(d) the humid heat
27  Cpa = 1.006*10^3;// Heat Capacity of bone dry air in
        J/kg-K
28  Cpwv = 1.89*10^3;// Heat Capacity of water vapour in
        J/kg-K
29  S = Cpa + (w*Cpwv);//in J/kg-K
30  printf('the humid heat is %.0f J/kg-K\n\n',S )
31
32  //(e) the humid volume
33  V_G = ((1/29)+(w/18))*22.41*((T2 + 273)/273);//in m
      ^3/kg
34  printf('the humid volume is %.3f m^3/kg \n',V_G)
35
36  //(f) adiabatic process
37  w_A = 0.020;// in kg/kg
38  printf('the humidity of the mixture if saturated
      adiabatically is %.3f kg/kg \n\n',w_A)
39
40  // (h) isothermal process
41  w_i = 0.049;// in kg/kg
42  printf('the humidity of the mixture if saturated
      isothermally is %.3f kg/kg \n',w_i)
```

Scilab code Exa 5.15 The humidity chart and its uses

```
 1  clear ;
 2  clc;
 3  // Example 5.15
 4  printf('Example 5.15\n\n');
 5  printf('Page No. 137\n\n');
 6
 7  // given
 8  T = 25;// Wet-bulb temperature in degree celcius
 9  T1 = 30;//Dry-bulb temperature in degree celcius
10  V = 5;// Volumetric flow rate of initial air-water
        mixture in m^3/s
11  T2 = 70;// Final Dry-bulb temperature in degree
        celcius
12
13  //By using the humidity chart and steam tables for
        air-water mixtures at the given temperatures, the
         all following data can be obtained
14  w = 0.018;// humidity at 25/30 degree celcius in kg/
        kg
15  Cpa_1 = 1.00*10^3;// Heat Capacity of bone dry air
        at 30 degree celcius in J/kg-K
16  Cpwv_1 = 1.88*10^3;// Heat Capacity of water vapour
         at 30 degree celcius in J/kg-K
17  Cpa_2 = 1.008*10^3;// Heat Capacity of bone dry air
        at 70 degree celcius in J/kg-K
18  Cpwv_2 = 1.93*10^3;// Heat Capacity of water vapour
        at 70 degree celcius in J/kg-K
19  lo = 2.50*10^6;//  Specifc Latent heat of
        vapourisation  of water at 0 degree celcius in J/
        kg
20
21  S_1 = Cpa_1 + (w*Cpwv_1);// the humid heat at 30
        degree celcius in J/kg-K
22  S_2 = Cpa_2 + (w*Cpwv_2);//the humid heat at 70
        degree celcius in J/kg-K
23
```

```
24  hG_1 = ((S_1*T1) + (w*lo));//the specific enthalpy
       at 30 degree celcius in J/kg
25  hG_2 = ((S_2*T2) + (w*lo));//the specific enthalpy
       at 70 degree celcius in J/kg
26  VG_1 = ((1/29)+(w/18))*22.41*((T1 + 273)/273);//
       Humid volume at 30 degree celcius in m^3/kg
27  m = V/VG_1;// Mass flow rate in kg/s
28  Q = m*(hG_2 - hG_1);// in Watts
29  printf('The required heat is %3.2f W \n',Q)//
       Deviation in answer is due to some approximation
       in calculation in the book
30
31  w_2 = w;// given in the question
32  VG_2 = ((1/29)+(w_2/18))*22.41*((T2 + 273)/273);//
       Humid volume at 70 degree celcius in m^3/kg
33  V_f = m*VG_2;;// in m^3/s
34  printf( 'The volumetric flow rate of initial air-
       water mixture is %3.2f m^3/s',V_f)
```

Chapter 6

Heat transfer equipment

Scilab code Exa 6.1 Shell and tube heat exchangers

```
1  clear ;
2  clc;
3  // Example 6.1
4  printf('Example  6.1\n\n');
5  printf('Page No.  142\n\n');
6
7  // given
8  L = 2.5; // Length  of  tubes  in  metre
9  Do = 10*10^-3; // Internal  diameter  of  tubes  in  metre
10  m = 3.46; // mass  flow  rate  in  kg/s
11  Th = 120; // Temperature  of  condening  steam  in  degree
         celcius
12  Tl_i = 20; // Inlet  temperature  of  liquid  in  degree
         celcius
13  Tl_o = 80; // Outlet  temperature  of  liquid  in  degree
         celcius
14  Cp = 2.35*10^3; // Specific  heat  capacity  of  liquid
         in  J/kg-K
15  U = 950; // Overall  heat  transfer  coefficent  in  W/m
         ^2-K
16
```

```
17  T1 = Th- Tl_i;// in degree celcius
18  T2 = Th- Tl_o;// in degree celcius
19  Tm = ((T2-T1)/log(T2/T1));// logarithmic mean
       temperature of pipe in  degree celcius
20  a = %pi*Do*L;//Surface area per tube in m^2
21  A = ((m*Cp*(Tl_o - Tl_i))/(U*Tm));// in m^2
22  N = A/a;
23  printf('The number of tubes required is %3.0f',N)
```

Scilab code Exa 6.2 `Number of tube passes`

```
1  clear ;
2  clc;
3  // Example 6.2
4  printf('Example 6.2\n\n');
5  printf('Page No. 142\n\n');
6
7  // given
8  v = 1.50;// velocity in m/s
9  N_t = 100;// Number of tubes
10 Do = 10*10^-3;// Internal diameter of tubes in metre
11 m = 3.46;// mass flow rate in kg/s
12 p = 1180;// density in kg/m^3
13
14 A = (N_t*%pi*Do^2)/4;// otal cross-sectional area in
       m^2
15 V = m/p;//Volumetric flow rate in m^3/s
16 Fv = V/A;// Fluid velocity in m/s
17 N_p = v/Fv;
18 printf('the number of passes is %.0f',N_p)
```

Scilab code Exa 6.3 `L M T D for types of flow`

```scilab
1  clear ;
2  clc;
3  // Example 6.3
4  printf('Example 6.3\n\n');
5  printf('Page No. 144\n\n');
6
7  // given
8  Th_i = 130;//Inlet temperature of hot liquid in
       degree celcius
9  Th_o = 90;// Outlet temperature of hot liquid in
       degree celcius
10 Tc_i = 20;// Inlet temperature of cold liquid in
       degree celcius
11 Tc_o = 50;// Outlet temperature of cold liquid in
       degree celcius
12
13 //For Couter-current flow
14 T1 = Th_i - Tc_o;
15 T2 = Th_o - Tc_i;
16 Tm_1 = ((T2-T1)/log(T2/T1));
17 printf('The logarithmic mean temperature difference
       for counter-current flow is %.0f degree celcius \
       n',Tm_1)
18
19
20 //For Co-current flow
21 T3 = Th_i - Tc_i;
22 T4 = Th_o - Tc_o;
23 Tm_2 = ((T3-T4)/log(T3/T4));
24 printf('The logarithmic mean temperature difference
       for co-current flow is %.0f degree celcius \n',
       Tm_2)
```

Scilab code Exa 6.4 Combustion theory

72

```
 1  clear ;
 2  clc;
 3  // Example 6.4
 4  printf('Example 6.4\n\n');
 5  printf('Page No. 147\n\n');
 6
 7  // given
 8  F = 1;// Fuel feed required in kg
 9  //By ultimate analysis of feed
10  C = 0.86;// Carbon percentage − [%]
11  H2 = 0.05;// Hydrogen percentage − [%]
12  S = 0.001;// Sulphur percentage − [%]
13  O2 = 0.08;// Oxygen percentage − [%]
14
15  w_C = 12;  // mol. weight of C
16  w_H2 = 2;  //mol. weight of H2
17  w_O2 = 32;  // mol. weight of O2
18  w_S = 32;  //mol. weight of S
19  //Basis− Per kg of fuel
20  mol_C = C / w_C;// kmol of C
21  mol_H2 = H2 /w_H2;//kmol of H2
22  mol_O2 = O2 /w_O2;//kmol of O2
23  mol_S = S /w_S;//kmol of S
24  //Calculation of excess air
25  C_req = mol_C*1;//O2 required by entering C given by
        reaction C+O2−>CO2 in kmol
26  H_req = mol_H2*0.5;//O2 required by entering H2
       given by reaction H2+(1/2)O2−>H20 in kmol
27  S_req = mol_S*1;//O2 required by entering S given by
        reaction S+O2−>SO2 in kmol
28  O2_req = (C_req + H_req + S_req) - mol_O2;// in kmol
29  printf('Total number of kmol of O2 required per kg
      of fuel is %3.3f kmol \n',O2_req)
30  m_O2 = O2_req*w_O2;// Mass of O2 required per kg of
       fuel
31  printf('Mass of O2 required per kg of fuel is %3.1f
      kg \n\n',m_O2)
32  //Calculation of air
```

```
33  m_air = m_O2/0.232;// in kg
34  printf('Mass of air required per kg of fuel is %3.1f
         kg \n',m_air')
35  //Considering air as an ideal gas,calculating volume
         of air by ideal gas equation−P∗V = n∗R∗T
36  R = 8310;//Universal gas constant in J/kmol−K
37  T = (273+20);// in K
38  P = 1.013*10^5;// in N/m^2
39  n = 1;// 1 kmol of air
40  V_kmol = (n*R*T)/P;// In m^3/kmol
41  M_air = 29;// Mol. weight of air
42  V_kg = V_kmol/M_air;// in m^3/kg
43  V_air = m_air*V_kg;// in m^3
44  printf('Volume of air required is %3.1f m^3 \n',
         V_air')
45  //Deviation in answer is due to some approximation
         in calculation in the book
```

Scilab code Exa 6.5 Combustion of coal

```
1  clear ;
2  clc;
3  // Example 6.5
4  printf('Example 6.5\n\n');
5  printf('Page No. 148\n\n');
6
7  // given
8  F = 1;// Weight of coal in kg
9  //By analysis of coal in weight basis
10 C = 0.74;// Carbon percentage − [%]
11 H2 = 0.05;// Hydrogen percentage − [%]
12 S = 0.01;// Sulphur percentage − [%]
13 N2 = 0.001;// Nitrogen percentage − [%]
14 O2 = 0.05;// Oxygen percentage − [%]
15 H2O = 0.09;// Moisture percentage − [%]
```

```scilab
16  Ash = 0.05;// Ash percentage - [%]
17
18  w_C = 12;  // mol. weight of C
19  w_H2 = 2; //mol. weight of H2
20  w_O2 = 32;  // mol. weight of O2
21  w_S = 32;  //mol. weight of S
22  //Basis- Per kg of fuel
23  mol_C = C / w_C;// kmol of C
24  mol_H2 = H2 /w_H2;//kmol of H2
25  mol_O2 = O2 /w_O2;//kmol of O2
26  mol_S = S /w_S;//kmol of S
27  //Calculation of excess air
28  C_req = mol_C*1;//O2 required by entering C given by
        reaction C+O2->CO2 in kmol
29  H_req = mol_H2*0.5;//O2 required by entering H2
       given by reaction H2+(1/2)O2->H20 in kmol
30  S_req = mol_S*1;//O2 required by entering S given by
        reaction S+O2->SO2 in kmol
31  O2_req = (C_req + H_req + S_req) - mol_O2;// Total
       number of kmol of O2 required per kg of fuel in
       kmol
32  m_O2 = O2_req*w_O2;// Mass of O2 required per kg of
       fuel
33  printf('Mass of O2 required per kg of fuel is %3.2f
       kg \n',m_O2)
34  //Calculation of air
35  m_air = m_O2/0.232;// in kg
36  printf('Mass of air required per kg of fuel is %3.1f
       kg \n',m_air')
37  //Considering air as an ideal gas,calculating volume
       of air by ideal gas equation-P*V = n*R*T
38  R = 8310;//Universal gas constant in J/kmol-K
39  T = (273+0);// in K
40  P = 1.013*10^5;// in N/m^2
41  n = 1;// 1 kmol of air
42  V_kmol = (n*R*T)/P;// In m^3/kmol
43  M_air = 29;// Mol. weight of air
44  V_kg = V_kmol/M_air;// in m^3/kg
```

```
45 V_air = m_air*V_kg;// in m^3
46 printf('Volume of air required is %3.1f m^3\n',V_air
      ')
```

Scilab code Exa 6.6 Flue gas analysis

```
1 clear ;
2 clc;
3 // Example 6.6
4 printf('Example 6.6\n\n');
5 printf('Page No. 149\n\n');
6
7 // given
8 F = 1;// Fuel feed in kg
9 C = 0.86;// Mass of Carbon in kg
10 H2 = 0.05;// Mass of Hydrogen in kg
11 S = 0.01;// Mass of Sulphur in kg
12 O2 = 0.08;// Mass of Oxygen in kg
13
14 w_C = 12; // mol. weight of C
15 w_H2 = 2; //mol. weight of H2
16 w_O2 = 32; // mol. weight of O2
17 w_S = 32; //mol. weight of S
18 //Basis- Per kg of fuel
19 mol_C = C / w_C;// kmol of C
20 mol_H2 = H2 /w_H2;//kmol of H2
21 mol_O2 = O2 /w_O2;//kmol of O2
22 mol_S = S /w_S;//kmol of S
23 //By kmol of product
24 CO2 = mol_C*1;// CO2 formed by the reaction C + O2
      -> CO2
25 H2O = mol_H2*1;// H2O formed by the reaction H2 +
      (1/2)O2 -> H2O
26 SO2 = mol_S*1;// SO2 formed by the reaction S + O2
      -> SO2
```

```
27 Pdt = CO2 + H2O + SO2;// Total kmol of combustion
      products in kmol
28 //Calculation of excess air
29 C_req = mol_C*1;//O2 required by entering C given by
       reaction C+O2->CO2 in kmol
30 H_req = mol_H2*0.5;//O2 required by entering H2
      given by reaction H2+(1/2)O2->H20 in kmol
31 S_req = mol_S*1;//O2 required by entering S given by
       reaction S+O2->SO2 in kmol
32 O2_req = (C_req + H_req + S_req) - mol_O2//  Total
      number of kmol of O2 required per kg of fuel in
      kmol
33
34 N2 = (O2_req*79)/21;// in kmol (considering air
      consists of 79% N2 and 21% O2 by moles)
35 Wet_pdts = Pdt + N2;// Wet combustion products in
      kmol
36
37 //Considering air as an ideal gas,calculating volume
       of air by ideal gas equation-P*V = n*R*T
38 R = 8310;//Universal gas constant in J/kmol-K
39 T = (273+0);// in K
40 P = 1.013*10^5;// in N/m^2
41 n_wet = Wet_pdts;// in kmol
42 V_wet = (n_wet*R*T)/P;// In m^3
43 n_dry = n_wet - H2O;//in kmol
44 V_dry = (n_dry*R*T)/P;// In m^3
45
46 printf('Volume of wet flue gas is %3.2f m^3 \n',
      V_wet)
47 printf('Volume of dry flue gas is %3.2f m^3',V_dry)
```

Scilab code Exa 6.7 Flue gas analysis with Excess air

```
1 clear ;
```

```scilab
 2  clc;
 3  // Example 6.7
 4  printf('Example 6.7\n\n');
 5  printf('Page No. 150\n\n');
 6
 7  // given
 8  F = 1;// Weight of fuel in kg
 9  e = 0.5;// excess air percentage
10  C = 0.74;// Mass of Carbon in kg
11  H2 = 0.05;// Mass of Hydrogen in kg
12  S = 0.01;// Mass of Sulphur in kg
13  N2 = 0.001;//Mass of Nitrogen in kg
14  O2 = 0.05;// Mass of Oxygen in kg
15  H2O = 0.09;// Mass of Moisture in kg
16  Ash = 0.05;// Mass of Ash in kg
17
18  w_C = 12;  // mol. weight of C
19  w_H2 = 2;  //mol. weight of H2
20  w_O2 = 32;  // mol. weight of O2
21  w_S = 32;  //mol. weight of S
22  w_N2 = 28;// mol. weight of N2
23  w_H2O = 18;// mol. weight of H2O
24  //Basis- Per kg of fuel
25  mol_C = C / w_C;// kmol of C
26  mol_H2 = H2 /w_H2;//kmol of H2
27  mol_O2 = O2 /w_O2;//kmol of O2
28  mol_S = S /w_S;//kmol of S
29  mol_N2 = N2 /w_N2;//kmol of N2
30  mol_H2O = H2O /w_H2O;//kmol of H2O
31
32  //By kmol of product
33  CO2 = mol_C*1;// CO2 formed by the reaction C + O2
         -> CO2
34  H2O_air = mol_H2*1;// H2O formed by the reaction H2
         + (1/2)O2 -> H2O
35  SO2 = mol_S*1;// SO2 formed by the reaction S + O2
         -> SO2
36  Pdt = CO2 + H2O_air + SO2 + mol_N2 + mol_H2O;//
```

```
            Total  kmol  of  combustion  products  in  kmol
37  // Calculation  of  excess  air
38  C_req = mol_C*1; // O2 required by entering C given by
        reaction C+O2->CO2 in kmol
39  H_req = mol_H2*0.5; // O2 required by entering H2
        given by reaction H2+(1/2)O2->H20 in kmol
40  S_req = mol_S*1; // O2 required by entering S given by
        reaction S+O2->SO2 in kmol
41  O2_req = (C_req + H_req + S_req) - mol_O2; // Total
        number of kmol of O2 required per kg of fuel in
        kmol
42
43  Ex_O2 = O2_req*e; //   Amount of excess oxygen in kmol
44
45  N2_air = (O2_req*(1+e)*79)/21; // in kmol (
        considering air consists of 79% N2 and 21% O2 by
        moles )
46  N2_flue = mol_N2 + N2_air; // Total N2 in flue gas in
        kmol
47  H2O_flue =  mol_H2O+ H2O_air; // Total H2O in flue
        gas in kmol
48
49  T_wet = CO2 + H2O_flue + SO2 + Ex_O2 + N2_flue; //
        Total components of flue gas on a wet basis in
        kmol
50  T_dry = CO2 + SO2 + Ex_O2 + N2_flue; // Total
        components of flue gas on a dry basis in kmol
51  H2O_dry = 0;
52  C_wet = ((CO2 / T_wet)*100); // in percentage
53  H_wet = ((H2O_flue/T_wet)*100); // in percentage
54  S_wet = ((SO2/T_wet)*100); // in percentage
55  N_wet = ((N2_flue/T_wet)*100); // in percentage
56  O_wet = ((Ex_O2/T_wet)*100); // in percentage
57
58  C_dry = ((CO2 / T_dry)*100); // in percentage
59  H_dry = ((H2O_dry/T_dry)*100); // in percentage
60  S_dry = ((SO2/T_dry)*100); // in percentage
61  N_dry = ((N2_flue/T_dry)*100); // in percentage
```

```
62  O_dry = ((Ex_O2/T_dry)*100);// in percentage
63  T1 = C_wet + H_wet + S_wet + N_wet + O_wet;// in
        percentage
64  T2 = C_dry + S_dry + N_dry + O_dry;// in percentage
65  printf('\t\t        kmol \t\t    percent composition by
         volume\n Component \t Wet \t        Dry \t\t       Wet
        \t    Dry \n     CO2 \t %.4f      %.4f   \t\t    %.1f \
        t   %.1f \n        H2O \t %.4f      %.0f   \t\t\t    %.1f
        \t\t    %.1f \n     SO2 \t %.4f      %.4f   \t\t    %.1f
         \t\t    %.1f \n      N2 \t\t %.4f      %.4f   \t\t    %
        .1f \t    %.1f \n     O2 \t\t %.4f      %.4f   \t\t    %
        .1f \t\t    %.1f \n     TOTAL \t %.4f      %.4f   \t\t
          %.0f  \t\t   %.0f ',CO2,CO2,C_wet,C_dry,H2O_flue,
        H2O_dry,H_wet,H_dry,SO2,SO2,S_wet,S_dry,N2_flue,
        N2_flue,N_wet,N_dry,Ex_O2,Ex_O2,O_wet,O_dry,T_wet
        ,T_dry,T1,T2)
66  //Deviation in answes is due to some calculation
        approxiamation in the book.
```

Scilab code Exa 6.8 Calorific Values

```
1  clear ;
2  clc;
3  // Example 6.8
4  printf('Example 6.8\n\n');
5  printf('Page No. 156\n\n');
6
7  // given
8  H = 0.05;// Hydrogen percentage - [%]
9  O = 0.08;// Oxygen percentage - [%]
10 C = 0.86;// Carbon percentage - [%]
11 S = 0.001;// Sulphur percentage - [%]
12
13 G_CV = ((33.9*C)+143*(H-(O/8))+(9.1*S))*10^6;
14 printf('The gross calorific value is %3.2e J/kg \n',
```

```
   G_CV)
15
16
17 N_CV = ((33.9*C)+121*(H-(O/8))+(9.1*S))*10^6;
18 printf('The net calorific value is %3.1e J/kg',N_CV)
```

Scilab code Exa 6.9 Boiler efficiency

```
1 clear ;
2 clc;
3 // Example 6.9
4 printf('Example 6.9\n\n');
5 printf('Page No. 157\n\n');
6
7 // given
8 P = 10;// Boiler pressure in bar
9 Ts = 180;// Steam temperature in degree celcius
10 Tf = 80;// Feed water temperature in degree celcius
11 X = 0.95;// Steam dryness fraction
12 m_s = 4100;// steam rate in kg/h
13 m_f = 238;// Gas rate in kg/h
14 G_CV = 53.5*10^6;// In J/kg
15 N_CV = 48*10^6;//in J/kg
16
17 //from steam table ,AT 10 bar and at temperature T =
      Ts
18 h2 = (763+(X*2013))*10^3;//Specific enthalpy of
      steam in J/kg
19 //At temperature T = Tf
20 h1 = 335*10^3;//Specific enthalpy of feed steam in J
      /kg
21
22 E_G = ((m_s*(h2-h1)*100)/(m_f*G_CV));//
23 printf('The gross efficiency percentage is %.0f \n'
      ,E_G)
```

81

```
24
25
26  E_N = ((m_s*(h2-h1)*100)/(m_f*N_CV));//
27  printf('The net efficiency  percentage is %.0f',E_N)
```

Scilab code Exa 6.10 Equivalent evaporation

```
1  clear ;
2  clc;
3  // Example 6.10
4  printf('Example 6.10\n\n');
5  printf('Page No. 158\n\n');
6
7  // given
8  //for Boiler-1
9  P_1 = 15;// Boiler pressure in bar
10 Ts_1 = 300;// Steam temperature in degree celcius
11 Tf_1 = 80;// Feed water temperature in degree
       celcius
12 X_1 = 0;// Steam dryness fraction
13 m_s1 = 9000;// steam rate in kg/h
14 m_f1 = 700;// Gas rate in kg/h
15 G_CV1 = 43.0*10^6;// In J/kg
16 //from steam table,at P = 15 bar and at given
       temperatures
17 h2_1 = 3039*10^3;//Specific enthalpy of steam in J/
       kg
18 h1_1 = 335*10^3;//Specific enthalpy of feed steam in
       J/kg
19
20 E_G1 = ((m_s1*(h2_1-h1_1)*100)/(m_f1*G_CV1));//
21 printf('The gross efficiency  percentage is %.0f \n'
       ,E_G1)
22 Ee_1 = ((m_s1/m_f1)*(h2_1-h1_1))/(2257*10^3);
23 printf('the  equivalent evaporation for boiler-1 is
```

```
        %3.1 f  kg  \n\n ' ,Ee_1)
24
25  //for  Boiler −2
26  P_2 = 10;// Boiler  pressure  in  bar
27  Ts_2 = 180;// Steam  temperature  in  degree  celcius
28  Tf_2 = 60;// Feed  water  temperature  in  degree
        celcius
29  X_2 = 0.96;// Steam  dryness  fraction
30  m_s2 = 7000;// steam  rate  in  kg/h
31  m_f2 = 510;// Gas  rate  in  kg/h
32  G_CV2 = 43.0*10^6;// In  J/kg
33  //from  steam  table ,AT 10  bar  and  at  temperature  T =
        Ts_2
34  h2 = (763+(X_2*2013))*10^3;// Specific  enthalpy  of
        steam  in  J/kg
35  //At  temperature  T = Tf_2
36  h1 = 251*10^3;// Specific  enthalpy  of  feed  steam  in  J
        /kg
37
38  E_G2 = ((m_s2*(h2-h1)*100)/(m_f2*G_CV2));//
39  printf('The  gross  efficiency   percentage  is  %.0f\n',
        E_G2)
40  Ee_2 = ((m_s2/m_f2)*(h2-h1))/(2257*10^3);
41  printf('the   equivalent  evaporation  for  boiler −2 is
        %3.1 f  kg ' ,Ee_2)
```

Scilab code Exa 6.11 Thermal balance sheet

```
1  clear ;
2  clc;
3  // Example  6.11
4  printf('Example  6.11\n\n');
5  printf('Page No.  167\n\n');
6
7  // given
```

```scilab
 8  m = 10*10^3;// Production of boiler in kg/h
 9  X = 0.95;//Dryness fraction
10  P = 10;//Pressure ib bar
11  T_fw = 95;// Feed water temperature in degree
       celcius
12  T_mf = 230;// Mean flue gae temperature in degree
       celcius
13  T_mb = 25;// Mean boiler house temperature in degree
        celcius
14  Coal_c = 900;// Coal consumption in kg/h
15  A = 0.08;// Ash content in coal
16  C_c = 0.15;//carbon content in coal
17  CV_coal = 33.50*10^6;// Calorific value of coal in J
18  M = 28;// Mass of flue gas per kg coal in kg
19  Cp = 1.05*10^3;// Mean Specific heat capacity of the
        flue gas in J/kg-K
20  CV_c = 34*10^6;// Calorific value of carbon in J/kg
21
22  M_s = m/Coal_c;// Mass of steam produced per kg coal
        in kg
23  H_w = (M_s*(763+(X*2013) - 398)*10^3)/10^6;// Heat
       absorbed by water per kg coal in 10^6 J(from
       steam table at given pressure and dryness
       fraction)
24  H_f = (M*Cp*(T_mf - T_mb))/10^6;// Heat in flue gas
        in 10^6 J
25  H_uc = (A*C_c*CV_c)/10^6;//Heat in unburnt carbon in
        10^6 J
26  h_sup = (CV_coal)/10^6;// Heat supplied by coal in
       10^6 J
27  un_acc = (h_sup - (H_w + H_f + H_uc));// unaccounted
        heat losses in 10^6 J
28  a = (h_sup/h_sup)*100;
29  b = (H_w/h_sup)*100;
30  c = (H_f/h_sup)*100;
31  d = (H_uc/h_sup)*100;
32  e = (un_acc/h_sup)*100;
33  T = b + c + d + e;
```

```
34  printf(' THERMAL BALANCE SHEET :\n\t\t\t\t 10^6 J \t
        percentage \n\n Heat supplied by coal \t\t %.2f
       \t\t %.0f\n Heat absorbed by water \t %.1f\t\t  %
       .1f\n Heat in flue gas \t\t  %.2f \t\t  %.0f\n
       Heat in unburnt carbon \t  %.2f \t\t   %.1f \n
       unaccounted heat losses \t  %.2f \t\t   %.1f\n
       TOTAL \t\t\t\t %.2f \t\t %.1f ',h_sup,a,H_w,b,H_f,
       c,H_uc,d,un_acc,e,h_sup,T);
```

Scilab code Exa 6.12 Thermal balance sheet for coal analysis

```
 1  clear ;
 2  clc;
 3  // Example 6.12
 4  printf('Example 6.12\n\n');
 5  printf('Page No. 168\n\n');
 6
 7  // given
 8  C_Rate = 2920;// Coal consumption rate in kg/h
 9  S_Rate = 22.5*10^3;// Steam consumption rate in kg/h
10  Ps = 20;// Steam pressure in bar
11  Ts = 350;// Steam Temperature in degree celcius
12  Tf_in = 70;// Feed water temperature inlet
        economiser in degree celcius
13  Tf_out = 110;// Feed water temperature outlet
        economiser in degree celcius
14  Tm_b = 25;// Mean Boiler house temperature in degree
         celcius
15  Tm_f = 260;// Mean exit flue gas temperature in
        degree celcius
16  CO2_f = 15.8;// CO2 content of dry exit flue gas by
        volume
17  CO_f = 0;// CO content of dry exit flue gas by
        volume
18  C_ash = 0.025;// Carbon in ash in [%]
```

```scilab
19  G = 0.005;// Grit produced in [%]
20  //Analysis of coal(as fired)
21  M = 0.105;// Moisture [%]
22  VM = 0.308;//Volatile matter [%]
23  FC = 0.497;// FIxed carbon [%]
24  Ash =0.09;// ASh [%]
25  C = 0.66;// Carbon percentage − [%]
26  H2 = 0.042;// Hydrogen percentage − [%]
27  S = 0.015;// Sulphur percentage − [%]
28  N2 = 0.012;// Nitrogen percentage − [%]
29  O2 = 0.076;// Oxygen percentage − [%]
30  H20 = 0.105;// Moisture percentage − [%]
31  G_CV = 26.90;// Gross Calorific Value in 10^6 J/kg
32  CV_C = 33.8*10^6;// Calorif Value of carbon in J/kg
33  CV_G = 33.8*10^6;// Calorif Value of Grit in J/kg
34  Ps_l = 20;// Pressure of steam leaving the boiler in
        bar
35
36  //(a) Calculation of excess air usage
37  //(a.1) Theoretical oxygen requirement
38  F = 1;// Fuel feed required in kg
39  w_C = 12;  // mol. weight of C
40  w_H2 = 2;  //mol. weight of H2
41  w_S = 32;  //mol. weight of S
42  w_N2 = 28;  // mol. weight of N2
43  w_O2 = 32;  // mol. weight of O2
44  //Basis− Per kg of fuel
45  mol_C = C / w_C;// kmol of C
46  mol_H2 = H2 /w_H2;//kmol of H2
47  mol_S = S /w_S;//kmol of S
48  mol_N2 = N2 /w_N2;//kmol of N2
49  mol_O2 = O2 /w_O2;//kmol of O2
50  //Calculation of excess air
51  C_req = mol_C*1;//O2 required by entering C given by
        reaction C+O2−>CO2 in kmol
52  H_req = mol_H2*0.5;//O2 required by entering H2
        given by reaction H2+(1/2)O2−>H20 in kmol
53  S_req = mol_S*1;//O2 required by entering S given by
```

```
        reaction S+O2->SO2 in kmol
54 O2_req = (C_req + H_req + S_req) - mol_O2;// in kmol
55 N2_air = (O2_req*76.8)/23.2;// in kmol (considering
       air consists of 76.8% N2 and 23.2% O2 )
56 printf('(a.1) \n')
57 printf('Total number of kmol of O2 required per kg
       of fuel is %3.4f kmol \n',O2_req)
58 printf('N2 associated with O2 is %3.4f kmol \n',
       N2_air)
59
60 //(a.2) Theoretical CO2 content of dry flue gas
61 T = C_req + S_req + mol_N2 + N2_air;// Total flue
       gas in kmol
62 CO2 = (C_req/T)*100;// in [%]
63 printf('(a.2) \n')
64 printf('Theoretical CO2 content of dry flue gas in
       percentage is %3.1f \n',CO2)
65
66 //(a.3)Excess air based on CO2 content
67 Ex_air = ((CO2 - CO2_f)/CO2_f)*100;//  in [%]
68 printf('(a.3) \n')
69 printf('Excess air based on CO2 content in
       percentage is %.0f \n\n',floor(Ex_air))
70
71
72 //(b) Fuel gas components
73 //(b.1) Composition per kg fuel
74 w_CO2 = 44;// mol. weight of CO2
75 w_SO2 = 64;// mol. weight of SO2
76 // FOR DRY GAS
77 CO2_d = C_req * w_CO2;// In kg/kg
78 SO2_d = S_req * w_SO2;// In kg/kg
79 N2_d = mol_N2 * w_N2;//  N2 from fuel In kg/kg
80 N2_air_d = N2_air * w_N2;//  N2 from air In kg/kg
81 T_N2 = N2_d + N2_air_d;// In kg/kg
82 T_dry = CO2_d + SO2_d + T_N2;// In kg/kg
83 printf('(b.1) \n')
84 printf('Composition of dry gas \n')
```

```
85  printf('CO2        %.3f    \n',CO2_d)
86  printf('SO2        %.2f    \n',SO2_d)
87  printf('N2 from fuel       %.2f     \n',N2_d)
88  printf('N2 from air       %.2f    \n',N2_air_d)
89  printf('Total dry air       %.2f kg/kg   \n\n',T_dry)
90
91  //FOR WET GAS
92  w_H2O = 18;// mol. weight of H2O
93  H2O_f = M;//   H2O from fuel
94  H2O_H2 = mol_H2 * w_H2O;// H2O from H2
95  T_H2O = H2O_f + H2O_H2;// in kg/kg
96  printf('Composition of wet gas \n')
97  printf('H2O from fuel       %.3f    \n',H2O_f)
98  printf('H2O from H2       %.3f    \n',H2O_H2)
99  printf('Total H2O in wet gas       %.3f kg/kg   \n\n',
        T_H2O)
100
101 //FOR DRY EXCESS AIR
102 O2_dry_ex = O2_req * w_O2 *0.3;//in kg/kg
103 N2_dry_ex = N2_air * w_N2 *0.3;//in kg/kg
104 T_dry_ex = O2_dry_ex + N2_dry_ex;// in kg/kg
105 printf('Composition of dry excess air \n')
106 printf('O2        %.3f    \n',O2_dry_ex)
107 printf('N2        %.3f    \n',N2_dry_ex)
108 printf('Total dry excess air       %.3f kg/kg   \n\n',
        T_dry_ex)
109
110 //(b.2) Enthalpy
111 // From steam table or from the appendix C.2; at the
        given pressure and temperatures, the following
        specific heat capacity for different gases are
        obtained
112 Cp_CO2_T1 = 1.04*10^3;// Specific heat Capacity of
        CO2 at temperature Tm_f in J/kg–K
113 Cp_CO2_T2 = 0.85*10^3;// Specific heat Capacity of
        CO2 at temperature Tm_b in J/kg–K
114 Cp_SO2_T1 = 0.73*10^3;// Specific heat Capacity of
        SO2 at temperature Tm_f in J/kg–K
```

```
115  Cp_SO2_T2 = 0.62*10^3; // Specific heat Capacity of
         SO2 at temperature Tm_b in J/kg-K
116  Cp_N2_T1 = 1.07*10^3; // Specific heat Capacity of N2
          at temperature Tm_f in J/kg-K
117  Cp_N2_T2 = 1.06*10^3; // Specific heat Capacity of N2
          at temperature Tm_b in J/kg-K
118  Cp_O2_T1 = 0.99*10^3; // Specific heat Capacity of O2
          at temperature Tm_f in J/kg-K
119  Cp_O2_T2 = 0.91*10^3; // Specific heat Capacity of O2
          at temperature Tm_b in J/kg-K
120
121  Cp_dry_T1 = ((CO2_d * Cp_CO2_T1) + (SO2_d *
         Cp_SO2_T1) + (T_N2 * Cp_N2_T1))/T_dry; // in J/kg-
         K
122  Cp_dry_T2 = ((CO2_d * Cp_CO2_T2) + (SO2_d *
         Cp_SO2_T2) + (T_N2 * Cp_N2_T2))/T_dry; // in J/kg-
         K
123  Cp_air_T1 = ((O2_dry_ex * Cp_O2_T1) + (N2_dry_ex *
         Cp_N2_T1))/T_dry_ex; // in J/kg-K
124  Cp_air_T2 = ((O2_dry_ex * Cp_O2_T2) + (N2_dry_ex *
         Cp_N2_T2))/T_dry_ex; // in J/kg-K
125  printf('(b.2) \n')
126  printf('Specific heat Capacity of dry gas at 260 deg
          C is %.0f J/kg-K \n',Cp_dry_T1)
127  printf('Specific heat Capacity of dry gas at 25 deg
         C is %.0f J/kg-K \n',Cp_dry_T2)
128  printf('Specific heat Capacity of dry excess air at
         260 deg C is %.0f J/kg-K \n',Cp_air_T1)
129  printf('Specific heat Capacity of dry excess air at
         25 deg C is %.0f J/kg-K \n\n',Cp_air_T2)
130
131  // From Steam table or Appendix B.3, Enthalpy of
         superheated steam is obtained at 260 deg C and 1
         bar
132  E_s = 2995*10^3; //in J/kg-K
133
134  //(c) Heat transferred to water
135  E_w = S_Rate / C_Rate; // Evaporation of water per kg
```

```
                of fuel in kg
136  E = (E_w*(461 - 293)*10^3)/10^6;// in 10^6 J
137  B = (E_w*(2797 - 461)*10^3)/10^6;// in 10^6 J
138  S = (E_w*(3139 - 2797)*10^3)/10^6;// in 10^6 J
139  printf('(c) \n')
140  printf('Heat to water in Economiser is %.1f *10^6 J
         \n',E)
141  printf('Heat to water in Boiler is %.2f *10^6 J \n',
         B)
142  printf('Heat to water in Superheater is %.2f *10^6 J
         \n\n',S)
143
144  //(d) Heat loss in flue gas
145  hl = 105*10^3;// Enthalpy of steam at 25 deg C (from
          steam table) in J/kg-K
146  loss_dry = T_dry*((Tm_f*Cp_dry_T1) - (Tm_b*Cp_dry_T2
         ))/10^6;// in  10^6 J
147  loss_wet = T_H2O*(E_s - hl)/10^6;// in 10^6 J
148  loss_ex_air = T_dry_ex*((Tm_f*Cp_air_T1) - (Tm_b*
         Cp_air_T2))/10^6;// in 10^6 J
149  printf('(d) \n')
150  printf('Heat loss in dry flue gas is %.2f *10^6 J \n
         ',loss_dry)
151  printf('Heat loss in wet flue gas is %.2f *10^6 J \n
         ',loss_wet)
152  printf('Heat loss in dry excess air is %.2f *10^6 J
         \n\n',loss_ex_air)
153
154  //(e) Heat loss in combustile matter in ash
155  loss_ash = (Ash * C_ash * CV_C)/10^6;// in 10^6 J
156  printf('(e) Heat loss in combustile matter in ash is
          %.2f *10^6 J \n',loss_ash)
157
158  //(f) Heat loss in grit
159  loss_grit = (G * CV_G)/10^6;// in  10^6 J
160  printf('(f) Heat loss in grit is %.2f *10^6 J \n\n',
         loss_grit)
161
```

```
162 //(g) Radiation and unaccounted heat loss
163 h_sup = G_CV;// Heat supplied by the coal in 10^6 J
164 loss_rad = (h_sup - (E + B + S + loss_dry + loss_wet
        + loss_ex_air + loss_ash + loss_grit));//
        Radiation and unaccounted loss in 10^6 J
165 a = (h_sup/h_sup)*100;
166 b = (E/h_sup)*100;
167 c = (B/h_sup)*100;
168 d = (S/h_sup)*100;
169 e = (loss_dry/h_sup)*100;
170 f = (loss_wet/h_sup)*100;
171 g = (loss_ex_air/h_sup)*100;
172 h = (loss_ash/h_sup)*100;
173 i = (loss_grit/h_sup)*100;
174 j = (loss_rad/h_sup)*100;
175 T = b + c + d + e + f + g + h + i + j;
176 printf('(g) THERMAL BALANCE SHEET :\n\t\t\t\t 10^6 J
        \t percentage \n Heat supplied by coal \t\t %.2f
        \t\t %.0f\n Heat to loss in : economiser \t %
        .2f \t\t   %.1f\n \t\t        boiler \t %.2f \t\t
        %.0f\n \t\t  superheater      %.2f \t\t   %.1f\n
        Heat loss in :  dry flue gas     %.2f \t\t   %.1f
        \n \t\t wet flue gas    %.2f \t\t   %.1f\n \t
                dry eecess air     %.2f \t\t   %.1f\n Heat
        loss in ash \t\t  %.2f \t\t   %.1f\n Heat loss in
         grit \t\t  %.2f \t\t   %.1f\n Radiation and
        unaccounted loss   %.1f \t\t   %.1f\n TOTAL \t\t\
        t\t %.2f \t\t %.1f',h_sup,a,E,b,B,c,S,d,loss_dry,
        e,loss_wet,f,loss_ex_air,g,loss_ash,h,loss_grit,i
        ,loss_rad,j,h_sup,T)
```

Scilab code Exa 6.13 Desuperheaters

```
1 clear ;
2 clc;
```

```scilab
3  // Example 6.13
4  printf('Example 6.13\n\n');
5  printf('Page No. 188\n\n');
6
7  // given
8  P = 1.5;// Pressure in bar
9  T = 111;// Temperature in degree celcius
10 m = 2;// mass flow rate of process liquid in kg/s
11 Cp = 4.01*10^3;// Mean Specific heat capacity in J/
      kg_K
12 Tl_i = 20;// Inlet temperature of liquid in degree
      celcius
13 Tl_o = 90;// Outlet temperature of liquid in degree
      celcius
14 Ps = 15;// Pressure of steam in bar
15 X = 0.97;// Dryness fraction of steam
16 Pa = 1.5;//Pressure after adiabatic expansion in bar
17 Ta = 80;// Temperature of injecting condensate in
      degree celcius
18
19 //(a)
20 Q = m*Cp*(Tl_o - Tl_i);// in W
21 L = 2227*10^3;// Latent heat of 1.5 bar steam in J/
      kg
22 m_a = Q/L;
23 printf('(a) Mass flow rate of 1.5 bar steam is %.3f
      kg/s \n',m_a)
24
25 //(b)
26 //from steam table, Specific enthalpy of 0.97 dry 15
       bar absolute steam
27 h = ((843+(X*1946))*10^3);// in J/kg
28 //the balance for the desuperheater,when y is the
      mass flow rate(kg/s) of condensate at 80 deg C is
      ,on the basis of 1kg/s of superheated steam: =>
      (1*2731*10^3)+(335*10^3*y)=(1+y)*2693*10^3
29 y = (((2731-2693)*10^3)/((2693-335)*10^3))// in kg/s
30 m_b = m_a/(1+y);// in kg/s
```

```
31  printf('(b) Mass flow rate of 15 bar steam is %.3f
        kg/s \n',m_b)
32
33  //(c)
34  m_c = y*m_b;//in kg/s
35  printf('(c) Mass flow rate of condensateis %.3f kg/s
        \n',m_c)
36
37  //(d)
38  v = 30;// steam velocity in m/s
39  //from steam table
40  V = 1.16;// Specific volum of 1.5 bar saturated
        steam in m^3/kg
41  V_d = V*m_a;// in m^3/s
42  d = ((V_d*4)/(v*%pi))^0.5;// im m
43  printf('(d) The vapour main diameter is %3.2f m \n',
        d)
44
45  //(e)
46  l = 2.5;// Length of tubes in m
47  d_i = 10*10^-3;// Internal Diameter of tube in m
48  U = 1500;//  Overall heat transfer coefficent in W/m
        ^2-K
49
50  a = %pi*d_i*l;// in m^2
51  T1 = T - Tl_i;// in degree celcius
52  T2 = T - Tl_o;// in degree celcius
53  Tm = ((T2-T1)/log(T2/T1));// logarithmic mean
        temperature of pipe in  degree celcius
54  A = Q/(U*Tm);// in m^2
55  N = A/a;
56  printf('(e) The number of tubes required is %3.0f \n
        ',N)
```

Chapter 7

Energy utilisation and conversion systems

Scilab code Exa 7.1 Combustion process

```
1  clear ;
2  clc;
3  // Example 7.1
4  printf ('Example 7.1\n\n');
5  printf ('Page No. 201\n\n');
6
7  // given
8  C = 220*10^3; // Original annual cost of fuel in Pound
9  O_E = 73; // Original Efficiency
10 Fl_i = 20; // Initial Flue loss
11 Fl_f = 18.7; // Final Flue loss
12 N_E = O_E + (Fl_i - Fl_f); // New Efficiency
13 F_save = C*((N_E-O_E)/N_E);
14 printf ('Fuel saving is %.0f Pound',F_save)
15 // Deviation in answer is due to some wrong
      calculation the book, instead of new efficiency
      in the denominator in line 13, the book has taken
      original efficiency
```

Scilab code Exa 7.2 Financial saving and capital cost

```scilab
1  clear ;
2  clc;
3  // Example 7.2
4  printf('Example 7.2\n\n');
5  printf('Page No. 201\n\n');
6
7  //From Example 2.1
8
9  // given
10 C= 35000;// cost of boiler  in Pound
11 C_grant=.25;// Capital grant available from
       goverment
12 E= -(C-(C_grant*C));// Net expenditure
13 Fs= 15250;// Fuel Saving
14 r_i = 0.15;// interest
15 r_t = 0.55;// tax
16
17 a = [0 E Fs 0 E+Fs r_i*(E+Fs) 0 ]
18 bal_1 = a(5)+a(6)-a(7)// Total Balance after 1st
       year
19
20 c_all = 0.55;// capital allowance in 2nd year
21 C_bal= (bal_1+0+Fs+(-(c_all*E)));// Cash Balance
       after 2nd year
22 b = [bal_1 0 Fs -(c_all*E) C_bal r_i*C_bal r_t*(Fs+(
       r_i*C_bal))];
23 bal_2 = b(5)+b(6)-b(7)//Total  Balance after 2nd
       year
24
25 c = [bal_2 0 Fs 0 bal_2+Fs r_i*(bal_2+Fs) r_t*(Fs+(
       r_i*(bal_2+Fs)))]
26 bal_3= c(5)+c(6)-c(7)// Total  Balance after 3rd
```

```
      year
27
28  if(bal_2 >0) then
29       disp('Pay back period is of two year')
30  else
31       disp('Pay back period is of three year')
32  end
33
34  printf('Total saving at the end of second year is %3
        .0 f Pound\n',bal_2);
35  printf('Total saving at the end of third year is %3
        .0 f Pound\n\n',bal_3);
36  // Deviation in answer due to direct substitution
37
38
39  printf('The data in example 2.1 indicated that:- \n
        Saving could be made by replacing exising oil-
        fired burners by new burners requiring
        considerably less atomising steam.\n The
        financial saving are 15.25*10^3 Pound per year
        for an insulation and capital cost of 35*10^3
        Pound.')
```

Scilab code Exa 7.3 Heat loss in flue gas and ashes

```
1  clear;
2  clc;
3  // Example 7.3
4  printf('Example 7.3\n\n');
5  printf('Page No. 203\n\n');
6
7  // given
8  C = 250*10^3;//Original annual cost of fuel in Pound
9  O_E = 71.5;// Original Efficiency
10 Fl_i = 20;// Initial Flue loss
```

```
11  Fl_f = 17.5;// Final Flue loss
12  N_E = O_E + (Fl_i - Fl_f);// New Efficiency
13  F_save = C*((N_E-O_E)/N_E);// in Pound
14  printf('Fuel saving is %.0f Pound per year',F_save)
15  //Deviation in answer is due to some calculation
        approximation the book
```

Scilab code Exa 7.4 Furnace efficiency

```
1  clear;
2  clc;
3  // Example 7.4
4  printf('Example 7.4\n\n');
5  printf('Page No. 204\n\n');
6
7  // This question doesnot contain any calculation
        part.
8  //Refer figure 7.3, 7.4, 7.5
9  T_max = 200;// Flue gas exit temperature in degree
        celcius
10  printf(' The company investigate four alternative
        methods of heat abstraction using the flue gas.\n
        \n  System-1  The efficiency of the furnace
        without any air preheater is 79.2 per cent.\n
        System-2  The efficiency of the furnace, with
        the air preheater only in the system operating as
         shown in figure 7.3, is increased to 86.6 per
        cent.\n  System-3  By the incorporation of the
        heat exchanger,the furnace efficiency is
        increased to 93.3 per cent using the arrangement
        shown in figure 7.4.\n  System-4  Using no
        preheating,finally achievied an overall thermal
        efficiency of 93.7 per cent.\n  \t     The new
        air preheater scheme is shown in figure 7.5.\n\n
        The pay-back period in all instances is less than
```

Scilab code Exa 7.5 Insulation

```
1 clear ;
2 clc ;
3 // Example 7.5
4 printf ( 'Example 7.5\n\n');
5 printf ( 'Page No. 205\n\n');
6
7 //The temperature difference is not given the
       question.
8 //Refer Table 7.1
9 T1 = 1000; // Furnace operating temperature in degree
        celcius
10 //T2 is  back calculated by the first condition
      given in table 7.1 and applying Fourier,s law of
       condition
11 T2 = 997.9545; // in degree Celcius ()
12 dT = T1 - T2; // in degree celcius
13 t = 120; // Continuous cycle time in h
14 K1 = 44; // Thermal conductivity (W/m–K)
15 K2 = 11; // Thermal conductivity (W/m–K)
16 K3 = 4; // Thermal conductivity (W/m–K)
17 x1 = 250*10^-3; // mm converted into m
18 x2 = 50*10^-3; // mm converted into m
19 dT = T1 - T2; // in K
20
21 //By Fourier ,s law of heat conduction − Q = (dT *K)/x
       in W/sq .m
22
23 //For 250 mm firebrick
24 Q1 = (dT *K1)/x1; // im W/sq .m
25 printf ( 'Energy losses by 250 mm firebrick is %.0 f W/
      sq .m \n ',Q1)
```

```
26
27 //For 250 mm hot−face insulation
28 Q2 = (dT *K2)/x1;// im W/sq.m
29 printf('Energy losses by 250 mm hot−face insulation
       is %.0 f W/sq.m \n',Q2) //Deviation in answer is
       due to assumption of T2 as its not mentioned in
       the question
30
31 //For 250 mm hot−face insulation backed by 50 mm
       insulation
32 //As the resistances are in series − R = (x1/K1)+ (
       x2/K2) and Q = dt/R in W/sq.m
33 R = (x1/K2)+ (x2/K3);// in ohm
34 Q3 = dT/R;// in W/sq.m
35 printf('Energy losses by 250 mm hot−face insulation
       backed by 50 mm insulation is %.0 f W/sq.m \n\n',
       Q3) //Deviation in answer is due to assumption of
        T2 as its not mentioned in the question
```

Scilab code Exa 7.6 Heat recovery

```
1 clear ;
2 clc;
3 // Example 7.6
4 printf('Example 7.6\n\n');
5 printf('Page No. 209\n\n');
6
7 // given
8 P = 150*10^3;// Power of compressor in W
9 F_load = .78;// full load percentage of the time
10 Re = .7;// Heat Recovery
11 T = 2200;//Compressor operating time in h/year
12 C = 20*10^-6;// Energy cost in Pound/Wh
13
14 H_Re = P*F_load*Re;// in W
```

```
15 printf('Heat recovered is %.0f W \n',H_Re)
16 E_save = H_Re*T*C;// in Pound/year
17 printf('Economic Saving is %3.2f Pound per year',
       E_save)
18 //Deviation in answer is due to some calculation
       approximation the book
```

Scilab code Exa 7.7 Steam turbines as alternatives to electric motors

```
1 clear ;
2 clc;
3 // Example 7.7
4 printf('Example 7.7\n\n');
5 printf('Page No. 212\n\n');
6
7 // given
8 C_S = 1/10^3;// Cost of steam production in p/Wh
9 P = 75*10^3;// Power required in W
10 T = 4*10^3;// Production time in h/year
11 C_T = 7*10^3;// Cost of turbine in Pound
12 R_T = 4*10^3;// Annual running cost of turbine in W
13 C_M = 1.5*10^3;// Cost of electric motor in Pound
14 R_M = 14*10^3;// Running cost of electric motor in
       Pound
15 C_M_A = 3.5/10^3;// Auunal running cost of electic
       motor in p/Wh
16 Save_R = R_M - R_T;// in Pound per year
17 printf('The saving in running costs would be %3.1e
       Pound per year',Save_R)
```

Scilab code Exa 7.8 Economics of a CHP system

```
1 clear ;
```

```scilab
2  clc;
3  // Example 7.8
4  printf('Example 7.8\n\n');
5  printf('Page No. 214\n\n');
6
7  // given
8  m_s = 5.3;// Factory requirement of process steam in
        kg/s
9  Pr_s_1 = 2.5;// Pressure of process steam at bar
        absolute
10 E_load_1 = 1.10*10^3;// Electrical load requirement
        in W
11 E_load_2 = 1.5*10^3;// Electrical load requirement
        in W
12 m_e = 6.0;// Mass flow rate of generated electricity
         in kg/s
13 Pr_e = 14;// Pressure of generated electricity at
        bar absolute
14 T_heat = 2.790*10^6;// Total heat content in J/kg
15
16 //The 14 bar absolute steam would undergo an
        adiabatic heat drop and the steam will be
        expanded
17 h_drop = 306*10^3;// Adiabatic heat drop in J/kg
18 Pr_2 = 2.5;// Expanded pressure at bar absolute
19 Ex_stm = 0.11;// Exhaust steam percent
20 Ef_T = 0.65;// Tubine efficiency
21 R_h_drop = h_drop * Ef_T;// Real heat drop in J/kg
22 P_T = m_e * R_h_drop;// Power generated by turbine
        in W
23 Ef_G = 0.94;// Generator efficiency
24 P_G = 1.13*10^6;// Output of generator in W
25
26 //(a) Combined heat and power system
27 Eq_Eva = 8;// Equivalent evaporation of steam per kg
         coal in kg
28 C_req = m_e/Eq_Eva;// in kg/s
29 printf('Coal Required is %.2f kg/s\n',C_req)
```

```scilab
30  printf('If the plant operates on a 140−h week for 50
        weeks per annum the coal consumption is 18.9*0^6
         kg per year.\nAt an average price of, for
        example, 35 Pound per tonne, the aanual cost is
        660*10^3 Pound.\n\n')
31
32  //(b) Coal required for process steam
33  // for low pressure steam
34  Eq_Eva_2 = 8.25;// Equivalent evaporation of steam
        per kg coal in kg
35  Coal_req = m_s/Eq_Eva_2;// in kg/s
36  printf('Coal Required is %.3f kg/s\n\n',Coal_req)
37  printf('Assuming similar operating conditions for
        the plant the total coal consumption is 16.2*10^6
         kg per year,\nand the annual cost is 556*10^6
        Pound.\n')
38
39  //(c)Electrical Power
40  printf('The cost of 1.15*10^6 W of electricity for
        the same period of time is,assuming a cost of 23
        Pound per 10^6 Wh,177*10^3Pound.\nThe coal
        equivalent to generate 1.15*10^6 W of power for
        the grid would be about 5.0*10^6 kg per year.\n\
        nThe C.H.P. unit saves a coal equivalent of
        2.3*10^6kg per year,\nover the system generating
        process steam and utilizing grid electricty.\nThe
         economic savings are 83*1063 Pound per year
        illustrating the benefits of a C.H.P. syatem in
        this case.')
```

Chapter 8

Electrical energy

Scilab code Exa 8.1 `Ohms law`

```
1  clear ;
2  clc ;
3  // Example 8.1
4  printf ( 'Example 8.1\n\n ') ;
5  printf ( 'Page No. 222\n\n ') ;
6
7  // given
8  V = 240; // Voltage in Volts
9  I = 8; // Current in Amps
10 // By ohm's law-> V = I*R
11 R = V/I; // In ohms
12 printf ( 'The resistance of the given circuit is %.0 f
      ohms ',R)
```

Scilab code Exa 8.2 `Kirchhoff law`

```
1  clear ;
2  clc ;
```

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```
3  // Example  8.2
4  printf('Example  8.2\n\n');
5  printf('Page No.  223\n\n');
6
7  // given
8  V1  =  100;// In  Volts
9  V2  =  50;// In  Volts
10 R1  =  8;// Resistance  in  ohm
11 R2  =  5;// Resistance  in  ohm
12 R3  =  10;// Resistance  in  ohm
13 R4  =  50;// Resistance  in  ohm
14 //By  refering  figure  8.3, and  applying  kirchoff's
        current  law  and  kirchoff's  voltage  law  in  the
        given  circuit  diagram,  we  get  following  equations
        :
15 //  I1  =  I2  +  I3
16 //V1  -  R1*I1  -  V2  -  R3*I3  =  0
17 //V2  -  R4*I3  +  R3*I3  -  R2*I2  =  0
18 A  =  [1  -1  -1;8  0  10;0  55  -10];
19 b  =  [0;50;50];
20 x  =  A\b
21 printf('The  currents  in  I1  is  %.1f  A  \n',x(1))
22 printf('The  currents  in  I2  is  %.1f  A  \n',x(2))
23 printf('The  currents  in  I3  is  %.1f  A  \n ',x(3))
```

Scilab code Exa 8.3 Power factor

```
1  clear ;
2  clc;
3  // Example  8.3
4  printf('Example  8.3\n\n');
5  printf('Page No.  226\n\n');
6
7  // given
8  R  =  6;// Resistance  in  ohm
```

```
 9  Xc = 16;// Capacitive resistance in ohm
10  Xl = 24;// Inductive resistance in ohm
11  Z = ((R^2) + (Xc - Xl)^2)^0.5;// Impedance in ohm
12  P_f = R/Z;// Power factor = cos(x) = 0.6
13  x = acos(0.6);
14  y = sqrt(1 - P_f^2);//y = sin (x)
15  V = 200;// in Volts(sin wave voltage = ((200*2^1.5)*
       sinwt)
16  I = V/Z;// Current in Amperes
17  P = I^2 * R;// in W
18  Q = V * I * y;// in VAR
19  S = V * I;// in VA
20  printf('The actual power is %.0f W \n',P)
21  printf('The reactive power is %.0f VAR \n',Q)
22  printf('The apparent power is %.0f VA \n',S)
```

Scilab code Exa 8.4 Cost of electrical energy

```
 1  clear ;
 2  clc;
 3  // Example 8.4
 4  printf('Example 8.4\n\n');
 5  printf('Page No. 232\n\n');
 6
 7  //given
 8  pump_1 = 100*10^3;// Required pump in W
 9  T_1 = 8;// Pump Operating time of each day
10  Inc_op = 0.5;// Increased output per cent
11  pump_ex = 50*10^3;// Extra pump requried in W
12
13  // This question doesnot contain any calculation
       part.
14  printf('there is no computational part in the
       problem')
```

Scilab code Exa 8.5 Annual saving

```
1  clear ;
2  clc;
3  // Example 8.5
4  printf('Example 8.5\n\n');
5  printf('Page No. 232\n\n');
6
7  //given
8  P = 600*10^3; // Power demand of pump in W
9  T = 8; // Operating time in hour per day
10 red = 1.00/10^3; // off-peak reduction in Pound per
      10^3 W month
11 M_save = P*red; // Monthly saving Pound per month
12 A_save = M_save*12; // Annual saving in Pound per
      year
13 printf('Annual saving is %.0f Pound per year', A_save
      )
```

Scilab code Exa 8.6 Illumination

```
1  clear ;
2  clc;
3  // Example 8.6
4  printf('Example 8.6\n\n');
5  printf('Page No. 234\n\n');
6
7  //given
8  T_lamp = 12*10^3; // Output for the tungsten filament
      lamp in lm per 10^3 W
9  F_tube = 63*10^3; // Output for the fluorescent tubes
      in lm per 10^3 W
```

```
10  Save = F_tube - T_lamp;//   in W
11  printf('Energy saving is %.0f lm per 10^3 W \n',Save
       )
12
13  Save_pcent = (Save/F_tube)*100;
14  printf('Energy saving per cent is %.0f ',floor(
       Save_pcent))
```

Scilab code Exa 8.7 Natural lighting

```
1  clear ;
2  clc;
3  // Example 8.7
4  printf('Example 8.7\n\n');
5  printf('Page No. 235\n\n');
6
7  //given
8  N = 40;// Number of lamps
9  T1 = 15;// Operating time in h per day
10 P = 500;// POwer from the lamps in W
11 T2 = 300;// Total operating time in days per year
12 C = 2.5/10^3;// Electricity cost in p per Wh
13
14 An_Cost = N*P*T1*T2*C*10^-2;// In euro
15 printf('The Annual Cost is %.0f Euro \n',An_Cost)
16
17 //Improvement in light by installing glassfibre
       skylights
18 T3 = 5;//    Extra Time for natural lighting in h per
       day
19 New_An_Cost = N*P*(T1-T3)*T2*C*10^-2;// In euro
20 printf('The New Annual Cost is %.0f Euro \n',
       New_An_Cost)
21
22 Save = An_Cost - New_An_Cost;// in euro
```

```
23  printf ('The  annual  saving  for  a  pay−back  period  of
        2.5  years  is  %.0 f  ',Save)
```

Scilab code Exa 8.8 Motive power and power factor improvement

```
1  clear  ;
2  clc ;
3  // Example  8.8
4  printf ('Example  8.8\n\n');
5  printf ('Page  No.  236\n\n');
6
7  //  This  question  doesnot  contain  any  calculation
        part .
8
9  //By  refering  figure  8.7  which  shows  Poer  factor −
        load  curve  for  a  motor  with  a  capacitor  and  one
        without  a  capacitor .
10  printf ('there  is  no  computational  part  in  the
        problem ')
```

Scilab code Exa 8.9 Capacitor rating

```
1  clear  ;
2  clc ;
3  // Example  8.9
4  printf ('Example  8.9\n\n');
5  printf ('Page  No.  238\n\n');
6
7  //  This  question  doesnot  contain  any  calculation
        part .
8  // given
9  l  =  500*10^3; //  Load  in  VA
10  P_F  =  0.6; //  Power  Factor
```

```
11  Req_P_F = 0.9;// Required power factor
12  //Refer to figure 8.8
13  BC = 2.5;// units
14  C_rt = 250*10^3;// in VAR (obtained from figure 8.8)
15  printf('The required condenser rating is %.0f \n',
        C_rt)
```

Scilab code Exa 8.10 Effects of power factor improvement

```
1  clear ;
2  clc;
3  // Example 8.10
4  printf('Example 8.10\n\n');
5  printf('Page No. 240\n\n');
6
7  P = 100;// Power in 10^3 W
8  C = 5;// Charge in Euro per 10^3 per month
9  PF = [1.0 0.9 0.8 0.7 0.6 0.5];// Power factor
10 for i = [1:1:6]
11     VA = (PF(i)\P)*C
12     printf('Charge per month for power factor %.1f
           is %.0f Euro \n', PF(i),VA)
13 end
```

Scilab code Exa 8.11 Effects of power factor improvement

```
1  clear ;
2  clc;
3  // Example 8.11
4  printf('Example 8.11\n\n');
5  printf('Page No. 240\n\n');
6
```

```
7  // This question doesnot contain any calculation
       part.
8  //given
9  P_F_1 = 0.7;// Initial power factor
10 P_F_2 = 0.95;// Final power factor
11 //Refer Figure 8.10
12 red_I = 26;//reduction in current in per cent
13 printf('The reduction in current is %.0f per cent \n
       ',red_I)
14 P_F_3 = 1.0;// Increased power factor
15 // From figure 8.10
16 Save = 4;// per cent
17 printf('Increase in power factor from 0.95-1.0 only
       increases saving further by a %.0f per cent',Save
       )
```

Scilab code Exa 8.12 Effects of power factor improvement

```
1  clear ;
2  clc;
3  // Example 8.12
4  printf('Example 8.12\n\n');
5  printf('Page No. 240\n\n');
6
7  // This question doesnot contain any calculation
       part.
8  //given
9  C = 10000;// Installation cost of capacitors in
       Pound
10 P_F_1 = 0.84;// Initial power factor
11 P_F_2 = 0.97;// Final power factor
12 //Refer Figure 8.10
13 red_dem = 14;//reduction in maximum demand in per
       cent
14 T = 9;// pay-back time in months
```

```
15
16 printf ('The reduction in maximum demand is %.0f per
       cent \n',red_dem)
17 printf ('The pay−back time was %.0f months',T)
18 // This question does not contain any calculation
       part.
```

Scilab code Exa 8.13 Optimum start control

```
1  clear ;
2  clc ;
3  // Example 8.13
4  printf ('Example 8.13\n\n');
5  printf ('Page No. 244\n\n');
6
7  //given
8  T1 = 21;// in degree celcius
9  t1 = 8;// time in h per day
10 c = 3.5;// cost in p per unit
11 C1 = 38;// Total cost in Pound per 10^3 W
12
13 T2 = 16;// in degree celcius
14 t2 = 8;// time in h per day
15 C2 = 27;// Total cost in Pound per 10^3 W
16
17 Save = C1 - C2;// Saving in Pound per 10^3 W
18 Save_deg = Save/(T1 - T2);// Total Saving in Pound
       per 10^3 W for each degree drop
19 Save_per = (Save_deg/C1)*100;// Saving in percent
20 printf ('For each degree drop, an energy saving of %
       .0f per cent is achieved',floor(Save_per))
```

Scilab code Exa 8.14 Induction heating

```
 1  clear ;
 2  clc;
 3  // Example 8.14
 4  printf('Example 8.14\n\n');
 5  printf('Page No. 245\n\n');
 6
 7  // This question doesnot contain any calculation
       part .
 8  //refer Table 8.6
 9  O_1 = 1750;
10  O_2 = 0;
11  O_3 = 2;
12  O_4 = 150;
13  O_5 = 1900;
14  O_6 = 0;
15  I_1 = 580;
16  I_2 = 1658;
17  I_3 = 0.5;
18  I_4 = 40;
19  I_5 = 1698;
20  I_6 = 11;
21  D_1 = 300;
22  D_2 = 869;
23  D_3 = 0.5;
24  D_4 = 40;
25  D_5 = 900;
26  D_6 = 37;
27  printf('\t ENERGY COSTS FOR HEATING STEEL BILLETS\n\
       n Components(10^3 W/tonne) \t (1)Oil fired \t
       (2)Induction \t (3)Direct resistance\n Fuel(
       electricity) \t\t %.0f   \t \t %.0f     \t \t%.0f\
       n Electricity(as prime energy)    %.0f    \t\t \t
       %.0f     \t \t%.0f\n Metal loss(percent)\t\t %.0f
       \t\t \t %.1f    \t \t%.1f\n Metal loss (as energy
       )\t\t %.0f \t\t \t %.0f      \t \t%.0f\n Total
       energy needs\t\t %.0f \t\t \t %.0f     \t \t%.0f\n
        Energy saving to(1)\t\t %.0f \t\t \t %.0f     \t\
       t \t%.0f\n',O_1,I_1,D_1,O_2,I_2,D_2,O_3,I_3,D_3,
```

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```
        O_4 , I_4 , D_4 , O_5 , I_5 , D_5 , O_6 , I_6 , D_6 )
```

Scilab code Exa 8.15 Atmosphere generators

```
1  clear ;
2  clc ;
3  // Example 8.15
4  printf ( 'Example  8.15\n\n ' );
5  printf ( 'Page No.  247\n\n ' );
6
7  // This question doesnot contain any calculation
       part .
8  // refer Table 8.7
9  El = 35; // Percentage of electricity produced from
       primary fuel
10 En_1 = 50; // Endothermic gas (m^3)
11 En_2 = 100; // Endothermic gas (m^3)
12 En_3 = 200; // Endothermic gas (m^3)
13 G_1 = 97; // Gas use (10^3 Wh)
14 G_2 = 194; // Gas use (10^3 Wh)
15 G_3 = 386; // Gas use (10^3 Wh)
16 El_1 = 24; // Electricity use (10^3 Wh)
17 El_2 = 48; // Electricity use (10^3 Wh)
18 El_3 = 95; // Electricity use (10^3 Wh)
19 P_1 = 69; // Primary energy (10^3 Wh)
20 P_2 = 137; // Primary energy (10^3 Wh)
21 P_3 = 271; // Primary energy (10^3 Wh)
22 printf ( '    USE OF ELECTRICITY AND GAS FOR HEATING
       ENDOTHERMIC GAS GENERATORS\n\n  Endothermic gas (
       m^3) \t %.0 f \t %.0 f \t %.0 f \n  Gas use (10^3 Wh
       )       \t %.0 f \t %.0 f \t %.0 f \n  Electricity
       use (10^3 Wh) \t %.0 f \t %.0 f \t %.0 f \n  Primary
        energy (10^3 Wh) \t %.0 f \t %.0 f \t %.0 f \n ',
       En_1 , En_2 , En_3 , G_1 , G_2 , G_3 , El_1 , El_2 , El_3 , P_1 , P_2
       , P_3 )
```

Chapter 9

Building construction

Scilab code Exa 9.1 Fabric loss

```scilab
1  clear ;
2  clc ;
3  // Example 9.1
4  printf ( 'Example  9.1 \ n\n ' ) ;
5  printf ( 'Page  No.  252\n\n ' ) ;
6
7  // given
8  a = 40; //  in  m
9  b = 25; //  in  m
10 c = 20; //  in  m
11 d = 10; //  in  m
12 e = 5; //  in  m
13 f = 2; //  in  m
14 g = 3; //  in  m
15 h = 6; //  in  m
16
17 //(1)  Production  Area
18 T1 = 21; //  Temperature  difference  in  degree  celcius
19 T2 = -3; //  Temperature  difference  in  degree  celcius
20 U1 = 1.2; //  heat  transfer  coefficent  in  W/m–K
21 U2 = 5.6; //  heat  transfer  coefficent  in  W/m–K
```

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```
22  U3 = 2.0;// heat transfer coefficent in W/m–K
23  U4 = 0.7;// heat transfer coefficent in W/m–K
24  U5 = 0.9;// heat transfer coefficent in W/m–K
25  // As Q = U*A*T
26  Q1 = (b*h)*U1*T1;// Heat loss in W. wall in W
27  Q2 = (((a-c)*h) + (d*h) + (d*f))*U1*T1;// Heat loss
        in N. wall in W
28  Q3 = (c*f)*U2*T1;// Heat loss in N. window in W
29  Q4 = (b*g)*U3*T2;// Heat loss in N. wall/internal in
        W
30  Q5 = (b*g)*U1*T1;// Heat loss in E. wall/external in
        W
31  Q6 = (((a-c)*h) + (d*h) + (d*f))*U1*T1;// Heat loss
        in S. wall in W
32  Q7 = (c*f)*U2*T1;// Heat loss in S. window in W
33  Q8 = (b*a)*U4*T1;// Heat loss in roof in W
34  Q9 = (b*a)*U5*T1;// Heat loss in floor in W
35  T_Q_P = Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7 + Q8 + Q9;
        // in W
36
37  //For Office surface
38  T3 = 24;// Temperature difference in degree celcius
39  T4 = 3;// Temperature difference in degree celcius
40  // As Q = U*A*T
41  Q_1 = (b*g)*U3*T4;// Heat loss in W. wall in W
42  Q_2 = (d*g)*U1*T3;// Heat loss in N. wall in W
43  Q_3 = (((b-(2*e))*g) +(e*f))*U1*T3;// Heat loss in E
        . Wall in W
44  Q_4 = (e*f)*U2*T3;// Heat loss in E. window in W
45  Q_5 = (e*f)*U2*T3;// Heat loss in E. window in W
46  Q_6 = (d*g)*U1*T3;// Heat loss in S. wall in W
47  Q_7 = (b*d)*U4*T3;// Heat loss in S. roof in W
48  Q_8 = (b*d)*U5*T3;// Heat loss in floor in W
49  T_Q_O = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 +
        Q_8;  //in W
50
51  T_Q = T_Q_P + T_Q_O;// in W
52  printf('Total building fabric loss is %.0f W',T_Q)
```

Scilab code Exa 9.2 `U value calculation`

```
1  clear ;
2  clc;
3  // Example 9.2
4  printf('Example 9.2\n\n');
5  printf('Page No. 255\n\n');
6
7  //given
8  L_Br = 0.105;// Length of brickwork in m
9  L_Bl = 0.100;// Length of blockwork in m
10 L_C = 0.05;// Length of cavity in m
11 K_Br = 0.84;// Thermal conductivity of brickwork in
      W/m−K
12 K_Bl = 0.22;// Thermal conductivity of blockwork in
      W/m−K
13 K_C_in = 0.033;// Thermal conductivity of insulation
       in cavity in W/m−K
14 R_Ex = 0.055;// Resistance of external surface in W/
      m^2−K
15
16 //As R = L/K
17 R_Br = (L_Br/K_Br);// Resistance of brickwork in W/m
      ^2−K
18 R_Bl = (L_Bl/K_Bl);// Resistance of blockwork in W/m
      ^2−K
19 R_C = 0.18;// Resistance of cavity in W/m^2−K
20
21 //Without insulation of cavity
22 R_T = 0.938;// Total Resistance in W/m^2−K
23 // Thermal transmittance − U = (1/R_T)
24 U = (1/R_T);// in W/m^2−K
25 printf('The U−value of external wall is %.2f W/sq.m
      K \n',U)
```

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```
26
27  //With insulation of cavity
28  //As R = L/K
29  R_C_in = (L_C/K_C_in);// Resistance of insulation in
         cavity in W/m^2-K
30  In = R_C_in - R_C;// Net increase in W/m^2-K
31  R_T_New = R_T + In;// New total resistance in W/m^2-
      K
32  // Thermal transmittance - U = (1/R_T)
33  U_New = (1/R_T_New);// in W/m^2-K
34  printf('The new  U-value is with foamed insulation %
         .3 f W/sq.m K',U_New)
```

Scilab code Exa 9.3 `Ventilation loss`

```
1  clear ;
2  clc;
3  // Example 9.3
4  printf('Example 9.3\n\n');
5  printf('Page No. 256\n\n');
6
7  //given
8  N_1 = 1.5;// Ventilation rate in the production area
         (air changes per hour)
9  N_2 = 1.0;//  Ventilation rate in the office suite (
      air changes per hour)
10
11  //From example 9.1
12  V_P = 6000;// Voulme of production area in m^3
13  V_O = 750;// Voulme of office suite in m^3
14  T1 = 21;// Temperature difference in degree celcius
15  T2 = -3;// Temperature difference in degree celcius
16  T_P = 18;// Temperature difference in degree celcius
17  F_loss = 74.4*10^3;// Total fabric loss in W
18
```

```
19  // As Q_vent = 0.33 * N * V * (T1 - T2)
20  Q_vent_P = 0.33 * N_1 * V_P * (T_P - T2);//
        Ventilation loss in production area in W
21  Q_vent_O = 0.33 * N_2 * V_O * (T1 - T2);//
        Ventilation loss in office suite in W
22  V_loss = Q_vent_P + Q_vent_O;// Total ventilation
        loss in W
23  T_loss = F_loss + V_loss;// Total heat loss in W
24  p = (V_loss/T_loss)*100;
25  printf('percentage of ventilation loss is %.0f
        percent',p)
```

Scilab code Exa 9.4 `Environmental temperature`

```
1  clear ;
2  clc;
3  // Example 9.4
4  printf('Example 9.4\n\n');
5  printf('Page No. 260\n\n');
6
7  //(a) Design loss
8  T1 = 18;// Internal teemperature(specified as an
        Environmental temperature) in degree celcius
9  //From example 9.1
10 A = [150 200 40 75 75 200 40 1000 1000];// in m^2
11 U = [1.2 1.2 5.6 2 1.2 1.2 5.6 0.7 0.9];// in W/m-K
12 Qf = 58.3*10^3;// Fabric loss in production area in
        W
13 T2 = -3;// in degree celcius
14 s1 =0;
15 s2 = 0;
16 for i = [1:1:9]
17     s1 = s1+A(i);
18     s2 = s2+U(i)*A(i);
19 end
```

```
20  A_T = s1;// Total  area  in  m^2
21  UA_T = s2;// sum  of  U*A  in  W/m-K ( answer  wrongly
        calculated  in  the  book )
22
23  //From  example  9.3
24  N_1 = 1.5;// Ventilation  rate  in  the  production  area
        ( air  changes  per  hour )
25  V_P = 6000;// Voulme  of  production  area  in  m^3
26
27  //As  Qvent = C * (T1 − T2) & C = 0.33*N*V*(1 + ((
        UA_T)/(4.8*A_T)))
28  C = 0.33*N_1*V_P*(1 + ((UA_T)/(4.8*A_T)));
29  Q_vent = C * (T1 - T2);// in W
30  T_Q1 = Qf + Q_vent;// in W
31  printf ('The  total  design  loss  is  %.0f W \n',T_Q1) //
        ( deviation  in  answer  is  due  to  error  in
        calculation  in  the  book )
32
33  //(b)  Reduced  heat  loss
34  // The  heat  transfer  coeffieint  in  this  problem  has
        been  changed  as  U1
35  U1 = [0.44  0.44  2.8  2  0.44  0.44  2.8  0.44  0.9];//in W
        /m^2-K
36  T = [21  21  21  -3  21  21  21  21  21];// Temperature
        difference  in  degree  celcius
37  s3 = 0;
38  s4 = 0;
39  for i = [1:1:9]
40      s3 = s3+U1(i)*A(i);
41      s4 = s4+U1(i)*A(i)*T(i);
42  end
43  U1A_T = s3;// in W/m-k ( answer  wrongly  calculated  in
        the  book )
44  Q_loss = s4// in W
45
46
47  //As  Qvent = C * (T1 − T2) & C = 0.33*N*V*(1 + ((
        UA_T)/(4.8*A_T)))
```

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```
48  C = 0.33*N_1*V_P*(1 + ((U1A_T)/(4.8*A_T)))
49  Q_vent = C * (T1 - T2)// in W
50  T_Q2 = Q_loss + Q_vent// in W
51
52  Red = T_Q1 - T_Q2;// In W
53  printf('The reduction in loss is %.0f W',Red) // (
        deviation in answer is due to error in
        calculation in the book)
```

Scilab code Exa 9.5 The degree day method

```
1  clear ;
2  clc;
3  // Example 9.5
4  printf('Example 9.5\n\n');
5  printf('Page No. 265\n\n');
6
7  //given
8  T = 21;// Temperature difference in degree celcius
9  Deg_d = 2186;// Total degree-days base(15.5 deg C)
        September_April
10 T_D = 18;// Design Temperature in degree celcius
11 T_O = 4;// base offset temperature in degree celcius
12 T_b = T_D - T_O;// Base temperature in degree
        celcius
13
14 // From Table 9.11 Correction factor for base
        tempratures other than 15.5 deg C is obtained. So
        for 14 deg c its 0.82
15 C = 0.82;// Correction factor
16 Do = Deg_d * C// Corrected degree-days
17
18 //(a) Original construction
19 //from example 9.4
20 Q_d_1 = 133.7*10^3;// Design heat loss in W
```

```
21
22  H_1 = Q_d_1/T;
23  //As E = 24 * H * Do - E = Energy consumption in (Wh
        )
24  E1 = (24*H_1 *Do)/10^6;// in 10^6 Wh ( from this
        step 'Do' is mistakely taken as 1972 inplace of
        1792 in the solution of the book, so there is
        deviation in answer)
25  E_1 = (E1 * 3600)*10^6;// in J
26  printf('The total energy consumption in original
        construction is %.0e J \n',E_1)// Deviation in
        the answer is due to some calculation error as
        mentioned above
27
28  //(b) Improved insulation
29  //from example 9.4
30  Q_d_2 = 104.4*10^3;// Design heat loss in W
31
32  H_2 = Q_d_2/T;
33  //As E = 24 * H * Do - E = Energy consumption in (Wh
        )
34  E2 = (24*H_2 *Do)/10^6;// in 10^6 Wh ( from this
        step 'Do' is mistakely taken as 2972 inplace of
        2792 in the solution of the book, so there is
        deviation in answer)
35  E_2 = (E2 * 3600)*10^6;// in J
36  printf('The total energy consumption in improved
        insulation is %.4e J \n',E_2)// Deviation in the
        answer is due to some calculation error as
        mentioned above
```

Scilab code Exa 9.6 `Surface condensation`

```
1  clear ;
2  clc;
```

```scilab
3  // Example 9.6
4  printf('Example 9.6\n\n');
5  printf('Page No. 268\n\n');
6
7  //given
8  U1 = 5.6;// Single glazing heat transfer coefficient
       in W/m^2_K
9  U2 = 2.8;// Double glazing heat transfer coefficient
       in W/m^2_K
10 Ti = 21;// Internal Temperature in degree celcius
11 To = -1;// External Temperature in degree celcius
12 R_H = 0.5;// Relative humidity
13 Rs_i = 0.123;// Surface resistance in (W/m^2-K)^-1
14
15 // At 21 Degree celcius and R.H. = 0.5, the dew
      point is 10.5 degree celcius
16 Dew_pt = 10.5;// Dew point in degree celcius
17 //As Ts_i = Ti - (Rs_i * U *(Ti - To))
18
19 //(a) Single Glazing
20 Ts_i_S = Ti - (Rs_i * U1 *(Ti - To));// in degree
      celcius
21 printf('The internal surface temperature for single
      glazing is %.1f deg C \n',Ts_i_S)
22 if (Dew_pt > Ts_i_S) then
23     disp('Surface condensation will occur since it
          is less than 10.5 deg C.')
24 else
25     disp('No surface condensation is expected as it
          is greater than 10.5 deg C.')
26 end
27
28 //(b) Double Glazing
29 Ts_i_D = Ti - (Rs_i * U2 *(Ti - To));// in degree
      celcius
30 printf('The internal surface temperature for single
      glazing is %.1f deg C \n',Ts_i_D)
31 if (Dew_pt > Ts_i_D) then
```

```
32      disp ('Surface condensation will occur since it
          is less than 10.5 deg C. ')
33 else
34      disp ('No surface condensation is expected since
          it is greater than 10.5 deg C. ')
35 end
```

Scilab code Exa 9.7 Interstitial condensataion

```
1  clear ;
2  clc;
3  // Example 9.7
4  printf ('Example 9.7\n\n');
5  printf ('Page No. 269\n\n');
6
7  //given
8  l_1 = 240;// existing length of solid brick in mm
9  l_u = 25;// upgraded internal lining in mm
10 l_e = 9.5;// Expanded polystyrenne in mm
11 T_i = 20;// Internal temperature in degre celcius
12 R_H_i = 50;// Internal Relative humidity in percent
13 T_e = 0;// External temperature in degre celcius
14 R_H_e = 90;// External Relative humidity in percent
15
16 K = [0.123 0.059 0.714 0.286 0.055];// Thermal
       resistance in W/m^2-K
17 V_r = [0.0 0.475 3.57 9.60 0.0];// Vapour Resistance
        in 10^9 N-s/kg
18
19 //Refer Figure 9.3
20 //From Figure 9.3, the tempeature, dew point, vapour
       pressure for different interface are obtained
21 T = [18.01 17.06 5.51 0.89];// Temperature in degree
       celcius
22 V_p = [1170 1148 986 550];//Vapour pressure in N/m^2
```

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```
23  D_P = [9.5 9.2 7.1 -1.5];// Dew point in degree
        celcius
24
25  h = (T_i - T_e)/sum(K);// in W/m^2
26  printf('The heat flow is %.2f W/m^2 \n',h)
27  V_p_i = V_p(1);// Internal vapour pressure in N/m^2
28  V_p_e = V_p(4);// External vapour pressure in N/m^2
29  m = ((V_p_i - V_p_e)/sum(V_r))*10^-9;// in  kg/s
30  printf('The vapour mass flow is %.1e kg/s',m)
```

Scilab code Exa 9.8 Glazing

```
1  clear ;
2  clc;
3  // Example 9.8
4  printf('Example 9.8\n\n');
5  printf('Page No. 275\n\n');
6
7  //given
8  A = 10;// in m^2
9  S = 0.77;
10 Sa = 0.54;
11 //for South
12 printf('\t\t\t SOUTH \n')
13 I1 = [200 185 165 155 165 185 200];// in W-m^2
14 I2 = [500 455 405 385 405 455 500];// in W-m^2
15 for i = [1:1:7]
16 A_G_S (i) = (A*I1(i)*S) + (A*I2(i)*Sa)
17 end
18
19 printf('The monthly peak cooling loads for the month
        March is %.0f W \n',A_G_S(1))
20 printf('The monthly peak cooling loads for the month
        April is %.0f W \n',A_G_S(2))
21 printf('The monthly peak cooling loads for the month
```

```
        May is %.0 f W \n ',A_G_S(3))
22 printf('The monthly peak cooling loads for the month
        June is %.0 f W \n ',A_G_S(4))
23 printf('The monthly peak cooling loads for the month
        July is %.0 f W \n ',A_G_S(5))
24 printf('The monthly peak cooling loads for the month
        Aug. is %.0 f W \n ',A_G_S(6))
25 printf('The monthly peak cooling loads for the month
        Sept. is %.0 f W \n\n ',A_G_S(7))
26
27  //For east
28  printf('\t\t\t EAST \n')
29 I3 = [110 150 180 190 180 150 110];// in W-m^2
30 I4 = [435 510 515 505 515 510 435];// in W-m^2
31 for j = [1:1:7]
32 A_G_E(j) = (A*I3(j)*S) + (A*I4(j)*Sa);
33 end
34 printf('The monthly peak cooling loads for the month
        March is %.0 f W \n ',A_G_E(1))
35 printf('The monthly peak cooling loads for the month
        April is %.0 f W \n ',A_G_E(2))
36 printf('The monthly peak cooling loads for the month
        May is %.0 f W \n ',A_G_E(3))
37 printf('The monthly peak cooling loads for the month
        June is %.0 f W \n ',A_G_E(4))
38 printf('The monthly peak cooling loads for the month
        July is %.0 f W \n ',A_G_E(5))
39 printf('The monthly peak cooling loads for the month
        Aug. is %.0 f W \n ',A_G_E(6))
40 printf('The monthly peak cooling loads for the month
        Sept. is %.0 f W \n\n ',A_G_E(7))
```

Scilab code Exa 9.9 Design data

```
1 clear ;
```

```scilab
2  clc;
3  // Example 9.9
4  printf('Example 9.9\n\n');
5  printf('Page No. 277\n\n');
6
7  //given
8  A = 15;// glazing area in m^2
9  l = 10;// Length of office in m
10 h = 6;// height of office in m
11 w = 3.5;// width of office in m
12 Y_w = 4;// Admittance of wall in W/m^2-K
13 Y_f = 3;// Admittance of floor in W/m^2-K
14 Y_c = 3;// Admittance of ceiling in W/m^2-K
15 N = 1.5;//Ventilation rate (air changes per hour)
16 V = l*h*w;// Volume in m^3
17 U_G = 5.6;// Transmittance in W/m^2-K
18
19 //From table 9.18 and table 9.16
20 To = 16.5;// External temperature of June in degree
       celcius
21 T_O = 7.5;// Swing temperature in degre celcius
22 I = 155;  //Vertical S in W-m^2
23 Is = 385;//Vertical S in W-m^2
24 S = 0.77;// Solar gain factor
25 Sa = 0.54;// Solar gain factor
26
27 //As  For the mean internal temperature -Ti = To +
       ((A*I*S)/((0.33*N*V) + (A*U_G)))
28 Ti = To + ((A*I*S)/((0.33*N*V) + (A*U_G)));// in
       degree celcius
29 printf('the mean internal temperature is %.1f deg C
       \n',Ti)
30
31 A_G = (A*Is*Sa) + ((A*U_G) + (0.33*N*V))*T_O;//
       Swing in gain in W
32 Net_A = 2*((w*h) + (l*w)) - A;// Net wall area in m
       ^2
33 A_f = l*h;// floor area in m^2
```

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```scilab
34  A_c = l*h;//ceiling area in m^2
35  A_Y_w = Net_A * Y_w;// Wall AY in W/K
36  A_Y_f = A_f * Y_f;// Floor AY in W/K
37  A_Y_c = A_c * Y_c;// ceiling AY in W/K
38  A_Y_wi = 84;// Window AY in W/K
39  Net_AY = A_Y_w + A_Y_f + A_Y_c + A_Y_wi// in W/K
40  Ti_s = ((A_G)/((0.33*N*V) + (Net_AY)))// Internal
        Temperature swing in deg C
41  T_p = Ti + Ti_s;// in deg C
42  printf('Peak internal temperature is %.1f deg C',T_p
        ) // Deviation in the answer is due to some
        calculation approximation in the book
```

Chapter 10

Air conditioning

Scilab code Exa 10.1 Sensible heating

```
1  clear ;
2  clc ;
3  // Example 10.1
4  printf ('Example 10.1\n\n');
5  printf ('Page No. 293\n\n');
6
7  // given
8  m = 1;// mass flow rate of initial air mixture in kg
     /s
9  T = 23.5;// Initial temperature in degree celcius
10 m1 = 0.6;// Percentage of fresh air mixture
11 T1 = 5;// Dry Bulb Temperature of fresh air in
     degree celcius
12 w1 = 0.005;// Humidity of fresh air at temperature
     T1 in kg/kg
13 m2 = 0.4;// Percentage of recirculated air mixture
14 T2 = 25;// Dry Bulb Temperature of recirculated air
     in degree celcius
15 w2 = 0.015;// Humidity of recirculated air at
     temperature T2 in kg/kg
16
```

```
17  //In air conditioning => m1*w1 + m2*w2 = m*w
18  w = (m1*w1 + m2*w2)/m;// in kg/kgs
19  printf('The humidity of the air mixture is %.3f kg/
       kg \n',w)
20
21  //The specific enthalpy in J/kg can be calculated by
        the formula => h = (1.005*10^3*T) +(w
       *((2.50*10^6)+(1.86*10^3*T))); where the T is the
        temperature and w is the humidity at temperature
        T
22  h_f = (1.005*10^3*T1) +(w1*((2.50*10^6)+(1.86*10^3*
       T1)));// Specific enthalpy of fresh air in J/kg
23  h_r = (1.005*10^3*T2) +(w2*((2.50*10^6)+(1.86*10^3*
       T2)));// Specific enthalpy of recirculated air
       in J/kg
24  h_m = (1.005*10^3*T) +(w*((2.50*10^6)+(1.86*10^3*T))
       );// Specific enthalpy of final air mixture in J
       /kg
25
26  h_t = (m1*h_f) + (m2*h_r);// Total enthalpy of
       initial air mixturein J/kg
27  Q = m*(h_m - h_t);// in Watts
28  printf('The load on the heater is% .3f W',Q)
29  // Deviation in answer due to direct substitution
       and some approximation in answer in book
```

Scilab code Exa 10.2 Sensible cooling

```
1  clear ;
2  clc;
3  // Example 10.2
4  printf('Example 10.2\n\n');
5  printf('Page No. 298\n\n');
6
7  // given
```

```
 8  m1 = 0.75;// Percentage of fresh air mixture
 9  T1 = 31;// Dry Bulb Temperature of  fresh air in
        degree celcius
10  w1 = 0.0140;// Humidity  of fresh air at temperature
         T1 in kg/kg
11  m2 = 0.75;// Percentage of recirculated air mixture
12  T2 = 22;// Dry Bulb Temperature of recirculated air
        in degree celcius
13  w2 = 0.0080;// Humidity  of recirculated air at
        temperature T2 in kg/kg
14  m = 1.50;// mass flow rate of final air mixture in
        kg/s
15  T = 10;// Dew Point temperature in degree celcius
16
17  //In air conditioning => m1*w1 + m2*w2 = m*w
18  w = (m1*w1 + m2*w2)/m// in kg/kgs
19  printf('The humidity of the air mixture  is %.4f kg/
        kg \n',w)
20
21
22  // from the psychrometric chart, at w = 0.011kg/kg,
        the  dry bulb temperature is = 26.5 degree
        celcius  also the humidity of saturated air at 10
         degree celcius is 0.0075kg/kg
23  T_w = 26.5;// Dry Bulb temerature in degree celcius
24  w_10 = 0.0075;// humidity at temperatue T in kg/kg
25
26  //the specific enthalpy in J/kg can be calculated by
         the formula => h = (1.005*10^3*T) +(w
        *((2.50*10^6)+(1.87*10^3*T))); where the T is the
         temperature and w is the humidity at temperature
         T
27
28  h_a = (1.005*10^3*T_w) +(w*((2.50*10^6)+(1.88*10^3*
        T_w)));// Specific enthalpy of recirculated  air
        in J/kg
29  h_s = (1.005*10^3*T) +(w_10*((2.50*10^6)+(1.87*10^3*
        T)));// Specific enthalpy of saturated air at 10
```

```
       degree  celcius  in  J/kg
30
31  Q = m*(h_a - h_s);// in  Watts
32  printf('The  cooling  load  on  the  washer  is  %.0 f W',Q)
33  // Answer  wrongly  calculated  in  the  book
```

Chapter 11

Heat recovery

Scilab code Exa 11.1 Shell and tube heat exchangers

```
1  clear ;
2  clc;
3  // Example 11.1
4  printf('Example 11.1\n\n');
5  printf('Page No. 308\n\n');
6
7  //given
8  V = 205; // Flow rate in m^3
9  T1 = 74; // in degree celcius
10  T2 = 10; // in degree celcius
11  m = 1000; // Steam in kg
12  p = 950; // Density of steam in kg/m^3
13  C = 85; // Cost in Pound per m^3
14  C_V = 43.3*10^6; // Calorific value in J/kg
15  Cp = 4.18*10^3; // heat capacity of water J/kg-K
16  h = 2.33*10^6; // Heat of the steam in J/kg
17  n = 0.65; // Average bolier efficiency
18
19  S_cost = ((m*h*C)/(C_V*p*n)); // Steam cost in Pound
        per 1000 kg
20  E_save = V*m*(T1 - T2)*Cp; // Energy saving in J per
```

```
        day
21  S_save = E_save/h; // in  kg  per  day
22  printf ( 'the  steam  saving  is  %.0 f  kg  per  day  \n',
        S_save )
23  G_save = (S_cost*S_save)/m; // Pound  per  day
24  printf ( 'The  gross  saving  is  %.0 f  Pound  per  day  per
        year ', G_save )
```

Scilab code Exa 11.2 Multiple effect evaporation

```
1  clear ;
2  clc ;
3  // Example  11.2
4  printf ( 'Example  11.2\n\n');
5  printf ( 'Page  No.  313\n\n');
6
7  // given
8  p1 = 10; // heat−sensitive  liquor  percen
9  p2 = 50; // heat−sensitive  liquor  percent
10  m = 0.28; // mass  rate  in  kg/s
11  t = 150; // time  in  h  per  week
12
13  // This  question  does  not  contain  any  calculation
        part  in  it .
14  I = [8250  1150  14850  16500]; // Installation  cost  in
        Pound
15  A = [69300  36800  23600  24600]; // Annual  steam  cost
        in  Pound
16  A_S = [A(1)-A(1)  A(1)-A(2)  A(1)-A(3)  A(1)-A(4)]; //
        Annual  savings  in  Pound
17
18  printf ( '\t\t  CAPITAL  AND  OPERATING  COSTS  OF
        EVAPORATION  PLANT\n\n\t  \t\tInstallation  \t\t
        Annual  \t\t  Annual  saving\n    Type  \t\t\t   cost  \
        t\t\tsteam  cost  \t\t( to  single  effect )\n  \t  \t\t
```

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```
         ( Pound )  \t \t   ( Pound )  \t \t    ( Pound ) \n \ nSingle
      effect  \t \t   %.0 f  \t \t \t   %.0 f  \t \t \     %.0 f  \
      nDouble  effect  \t \t   %.0 f  \t \t \t   %.0 f  \t \t \
      %.0 f  \ nTriple  effect  +  \n ( vapour  compression )  \t
       %.0 f  \t \t   %.0 f  \t \t \     %.0 f  \ nTriple  effect  \
      t \t   %.0 f  \t \t   %.0 f  \t \t \      %.0 f  \n \n \n ' , I ( 1 ) ,
      A ( 1 ) , A_S ( 1 ) , I ( 2 ) , A ( 2 ) , A_S ( 2 ) , I ( 3 ) , A ( 3 ) , A_S ( 3 ) , I
      ( 4 ) , A ( 4 ) , A_S ( 4 ) )
19
20
21 printf ( ' The  results  enable  the  return  on  investment
       to  be  assessed  by  one  of  the  standard  economic
       procedures  and  the  final  selsction  made . ' )
```

Scilab code Exa 11.3 `Vapour recompression`

```
1 clear ;
2 clc ;
3 // Example 11.3
4 printf ( ' Example  11.3 \n \n ' ) ;
5 printf ( ' Page  No .  314 \n \n ' ) ;
6
7 // given
8 f = 1; // feed  of  sodium  hydroxide  in  kg
9 v = 0.5; // produed  vapour  in  kg
10 A = 30; // in  m^2
11 T1 = 95; // Temperature  of  boiling  solution  in  deg  C
12 U = 3*10^3; // heat  transfer  coefficent  in  W/m^2−K
13 m = 1; // feed  rate  in  kg/s
14 Tf = 70; // Feed  temperature  in  deg  C
15 h_f = 260*10^3; // Enthalpy  of  feed  in  J/kg
16 h_b = 355*10^3; // Enthalpy  of  boiling  solution  in  J/
      kg
17 h_v = 2.67*10^6; // Enthalpy  of  vapour  in  J/kg
18 P1 = 0.6; // Pressure  in  vapour  space  in  bar
```

```
19
20  Q = (v*h_b) + (v*h_v) -(f*h_f);// in W
21  printf('The total energy requirement is %.0f W \n',Q
       )
22
23  // As Q = A*U*dT
24  dT = Q/(U*A);// in degree celcius
25  T2 = dT + T1;// in degree celcius
26  //The temperature of the heating steam T2
       corresponds to a pressure of 1.4 bar. Dry
       saturated steam at 1.4 bar has a total enthalpy
       of 2.69*10^6 J/kg
27  //Assuming an isentropic compression of the vapour
       from 0.6 bar to 1.4 bar, the outlet enthalpy is
       2.84*10^6 J/kg
28
29  // from steam table
30  P2 = 1.4// pressure in bar
31  h_s = 2.69*10^6;// enthalpy of dry saturated steam
       in J/kg
32  h_v2 = 2.84*10^6 ;// the outlet enthalpy of vapour
       in J/kg
33
34  W = v*(h_v2 - h_s);// Work in W
35  T_E = W + 60*10^3;// in W
36  printf('The total energy consumption is %.0f W',T_E)
```

Scilab code Exa 11.4 `Thermal wheel`

```
1  clear ;
2  clc;
3  // Example 11.4
4  printf('Example 11.4\n\n');
5  printf('Page No. 316\n\n');
6
```

```
7  //given
8  Cm_S = 10000;// Company saving in Pound per annum
9  S = Cm_S/12;// Saving in Pound per months
10 Ca_C = 10500;// Capital cost in Pound
11 Ins_C = 7500;// Installation cost in Pound
12 T_C = Ca_C + Ins_C;// Total cost in Pound
13 T = T_C/S;// pay-back time in months
14 printf('The pay-back period was %.0f months\n',T)
```

Scilab code Exa 11.5 Heat pipes

```
1  clear ;
2  clc;
3  // Example 11.5
4  printf('Example 11.5\n\n');
5  printf('Page No. 318\n\n');
6
7  //From the heat balance:-
8  //Heat recovered in the boiler = heat gained by the
      air = heat lost by the flue gases
9  //=> Q = m_a*Cp_a*dT_a = m_f*Cp_f*dT_f
10 // As mass flow rate of air/flue gas is not given in
       the book
11 //Assuming m_a = m_f = 2.273 kg/s & Cp_a = 1*10^3 J/
      kg-K
12
13 m_a = 2.273;// in kg/s
14 m_f = m_a;// in kg/s
15 Cp_a = 1*10^3;// Specific heat capacity of air in J/
      kg-K
16 T1_a = 20;// Entrance temperature of air in degree
      celcius
17 T2_a = 130;// Exit temperature of air in degree
      celcius
18 dT_a = T2_a - T1_a;//in K
```

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```
19  T1_f = 260;// Entrance  temperature  of  flue  gases  in
        degree  celcius
20  T2_f = 155;// Entrance  temperature  of  flue  gases  in
        degree  celcius
21  dT_f = T1_f - T2_f;//in  K
22
23  //From  heat  balance:− Q = m_a∗Cp_a∗dT_a = m_f∗Cp_f∗
        dT_f
24  Cp_f = ((m_a*Cp_a*dT_a)/(m_f*dT_f));//  in  J/kg−K
25  Q = m_f*Cp_f*dT_f;//  in  W
26  printf('The  total  heat  recovered  at  full  load  if  %3
        .2 e  W',Q)
```

Scilab code Exa 11.6 `Heat pumps and COP`

```
1  clear  ;
2  clc;
3  // Example  11.6
4  printf('Example  11.6\n\n');
5  printf('Page  No.  320\n\n');
6
7  C = 10000;// Installation  cost  of  the  pump  in  Pound
8  S = 3500;// Saving  in  Pound  per  annum
9  T = C/S;//  in  year
10 printf('The  pay  back  time  is  %.0 f  year\n\n',T)
11
12 //  This  question  further  does  not  contain  any
        calculation  part  in  it.
13 printf('In  a  heat−pump  system  the  work  input  to
        drive  the  compressor ,W,  produces  a  heat
        absorption  capacity ,Q2,\nand  to  balance  the
        energy  flow ,  a  quantity  of  heat ,  Q1,  must  be
        dissipated.\ nThus  the  energy  equation  is\n −> Q1
        = W + Q2\nand  the  coeffient  of  performance  is  \nC
        .O.P.  = Q1/W = Q1/(Q1 − Q2)\n      Consequently  the
```

C.O.P. is always greater than unity.\nThe maximum theoretical value of the C.O.P. is that predicted by the Carnot in chapter 2,namely :\n
-> (C.O.P.)max = T1/(T1 - T2)')

Scilab code Exa 11.7 Coefficient of performance

```
1  clear ;
2  clc;
3  // Example 11.7
4  printf('Example 11.7\n\n');
5  printf('Page No. 320\n\n');
6
7  //given
8  T1 = 40;// in degree
9  T2 = 0;// in degree celcius
10 //As from carnot cycle, C.O.P = (T1/(T1 - T2)),
      where temperature are in degree celcius
11 C_O_P1 = ((T1+273)/((T1+273) - (T2+273)));
12 printf('C.O.P. is %.1f \n',C_O_P1)
13
14 // A secondary fluid as hot water at 60 deg C is
      used
15 T3 = 60;//  Temperature of hot water in degree
      celcius
16 C_O_P2 = ((T3+273)/((T3+273) - (T2+273)));
17 printf('C.O.P. when secondary fluid is used is %.1f
      \n',C_O_P2)
```

Scilab code Exa 11.8 Incineration plant

```
1  clear ;
2  clc;
```

```
3  // Example 11.8
4  printf ( 'Example 11.8\n\n ');
5  printf ( 'Page No. 323\n\n ');
6
7  // This question does not contain any calculation
       part in it .
8  printf ( 'No calculation is required as not in shown
       in book ')
```

Scilab code Exa 11.9 Regenerators

```
1  clear ;
2  clc ;
3  // Example 11.9
4  printf ( 'Example 11.9\n\n ');
5  printf ( 'Page No. 324\n\n ');
6
7  // given
8  T1 = 273; // Measured temperature In degree celcius
9  P = 1; // Measured pressure in bar
10 T2 = 290; // initial temperature In degree celcius
11 T3 = 1000; // Final temperature In degree celcius
12 T4 = 1150; // Entering tempearture In degree celcius
13 v1 = 7; // in m^3/s
14 v2 = 8; // in m^s
15 M = 22.7; // in kmol/m^3
16 d = 0.1; // Diameter in m
17 A = 0.01; // Surface area per regenerator channel in
       m^2
18 u = 1; // maximum velocity in m/s
19 Cp_1 = 34*10^3; // Heat capacity at T4 temperature in
       J/kmol-K
20 Cp_2 = 32*10^3; // Heat capacity at outlet
       temperature in J/kmol-K
21 Cp_m = 30*10^3; // Heat capacity at mean temperature
```

```
        in  J/kmol–K
22
23  m_c = v1/M; //   Molal  air  flow  rate  in  kmol/s
24  H_c1 = Cp_m*(T3 - T1); // Enthalpy  of  air  at  1000K  in
        J/mol
25  H_c2 = Cp_m*(T2 - T1); // Enthalpy  of  air  at  290  in  J
        /mol
26  Q = (m_c*(H_c1 - H_c2))/10^6; // in  10^6  W
27  printf('The  heat  transfer , Q  is  %.1 f  *10^6  W  \n',Q)
28
29  m_F = v2/M; //   Molal  flow  rate  of  flue  gas  in  kmol/s
30  dH = (Q/m_F)*10^6; // enthaply  chnage  of  the  flue  gas
        in  J/kmol
31  H_F1 = Cp_1*(T4 - T1); // Enthalpy  of  the  flue  gas  at
        1150  K  in  J/kmol
32  H_F2 =H_F1 - dH; // Enthalpy  at  the  exit  temperature
        in  J/kmol
33  T_F2 = (H_F2/Cp_2) + T1; // in  K
34  printf('The  exit  tempearture  of  the  flue  gas  is  %.0 f
        K  \n',T_F2)
35  S_R = v2/u; //cross  sectional  area  of  the  regenerator
        in  m^2
36  N = S_R/A;
37  printf('The  number  of  channels  required  is  %.0 f  \n',
        N)
38  printf('Consequently  for  this  regenerator  a  square
        layout  could  be  achieved  with  40  channels
        arranged  horizontally  and  20  channels  vertically .
        ')
```

Scilab code Exa 11.10 `Waste heat boilers`

```
1  clear ;
2  clc ;
3  // Example  11.10
```

```scilab
 4  printf('Example 11.10\n\n');
 5  printf('Page No. 324\n\n');
 6
 7  //given
 8  Pr = 100;// Production in tonnes per day
 9  p = 10.2;// percentage of sulphur dioxide
10  T1 = 900;//Burner temperature in degree celcius
11  T2 = 425;//Required temperature in degree celcius
12  P = 10;// Dry saturated steam pressure in bar
13  T = 120;// Dry saturated steam temperature in degree
         celcius
14  //At the given Temperature =T and Pressure P, the
        required heat Qr to geberate steam from feed
        water is calculated from the steam table.
15  Qr = 2.27*10^6;// in J/kg
16
17  Sp_1 = 1.14*10^3;// Specific heat of the inlet gas
        in J/kmol–K
18  Sp_2 = 1.03*10^3;// Specific heat of the outlet gas
        in J/kmol–K
19  pr_rate = 1.2;// production rate in kmol/s
20
21  //In the calculation part, the book has taken
        percentage of sulphur dioxide p = 10.6 in the
        place of p = 10.2, so there exists a deviation in
         answer
22  Q_in = ((Pr*pr_rate)/p) * Sp_1 * T1;// Heat content
        of the inlet gas in J/s
23  Q_out = ((Pr*pr_rate)/p) * Sp_2 * T2;// Heat content
         of the outlet gas in J/s
24  Qa = Q_in - Q_out;// Heat available for steam
25  S = Qa/Qr;// in kg/s
26  printf('The steam production is %.3f kg/s',S)//
        Deviation in answer is due to some wrong value
        substition as discussed above
```