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

Created by
Richa Bharti
B.Tech
Chemical Engineering
IIT Guwahati
College Teacher
NA
Cross-Checked by
Chaya Ravindra

June 2, 2016

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

Book Description

Title: Energy Management

Author: W. R. Murphy and G. A. Mckay

Publisher: Butterworth, Gurgaon Haryana

Edition: 2

Year: 2009

ISBN: 978-81-312-0738-3

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Energy auditing

Scilab code Exa 1.1 Energy Conversion

```
clc;
// Example 1.1
printf('Example 1.1\n\n');
printf(' Page No. 08\n\n');
// Solution

// Given
m1= 40*10^3;// fuel oil in gallons per year
ga= 4.545*10^-3;// m^3
m= m1*ga;// fuel oil in m^3 per year
Cv1= 175*10^3;// Btu per gallons
Bt= .2321*10^6;// J per m^3
Cv= Cv1*Bt;// in J per year per m^3
q=m*Cv;// in J per year
printf(' Heat available is %3.2e J per year\n',q)
```

Scilab code Exa 1.2 Energy conversion

```
clear ;
clc;
// Example 1.2
printf('Example 1.2\n\n');
printf('Page No. 09\n\n');
// Solution

// Given
Eo1= 1.775*10^9;// Annular energy consumption of oil in Btu
Btu= 1055;// 1 Btu = 1055 Joules
Eo= Eo1*Btu;// Annular energy consumption of oil in Joules
Eg1= 5*10^3;// Annular energy consumption of gas in Therms
Th= 1055*10^5;//  1 Th = 1055*10^3 Joules
Eg= Eg1*Th;// Annular energy consumption of gas in Joules
Ee1= 995*10^3;// Annular energy consumption of electricity in KWh
KWh= 3.6*10^6;// 1 KWh = 3.6*10^6 Joules
Ee= Ee1*KWh;// Annular energy consumption of electricity in Joules
Et= ( Eo + Eg + Ee);// Total energy consumption
P1= (Eo/Et)*100; // percentage of oil consumption
P2= (Eg/Et)*100; // percentage of gas consumption
P3= (Ee/Et)*100; // percentage of electricity consumption
printf('percentage of oil consumption is %3.1f \n',P1)
printf('percentage of gas consumption is %3.1f \n',P2)
printf('percentage of electricity consumption is %3.1f \n',P3)
```

Scilab code Exa 1.3 Energy Index

```
clear ;
clc;
// Example 1.3
printf('Example 1.3\n\n');
printf('Page No. 10\n\n');
// Solution

// Given
Et = 100*10^3;// total energy production in tonnes per annum
Eo= 0.520*10^9;// oil consumption in Wh
Eg= 0.146*10^9;// gas consumption in Wh
Ee= 0.995*10^9;// electricity consumption in Wh
Io= Eo/Et;
Ig= Eg/Et;
Ie= Ee/Et;
Et1= Eo + Eg + Ee;// total energy consumption
It= Et1/Et;
printf('oil energy index is %3.0f Wh per tonne \n',Io)
printf('gas energy index is %3.0f Wh per tonne \n',Ig)
printf('electricity energy index is %3.0f Wh per tonne \n',Ie)
printf('total energy index is %3.0f Wh per tonne ',It)
```

Scilab code Exa 1.4 Energy Costs

```
clear ;
clc;
// Example 1.4
printf('Example 1.4\n\n');
```

```
printf('Page No. 10\n\n');
// Solution

// Given
mc= 1.5*10^3;// coke consumption in tonnes
mg= 18*10^3;// gas consumption in therms
me= 1*10^9;// electricity consumption in Wh
Cc1= 72;// cost of coke in Pound per tonne
Cg1= 0.20;// cost of gas in Pound per therm
Ce1= 2.25*10^-5 ;// cost of electricity in Pound per Wh
Cc= mc*Cc1;//in Pound
Cg= mg*Cg1;//in Pound
Ce= me*Ce1;//in Pound
Ct= Cc+Cg+Ce;//in Pound
printf('cost of coke consumption is %.0f Pound \n',Cc)
printf('cost of gas consumption is %.0f Pound \n',Cg)
printf('cost of electricity consumption is %.0f Pound \n',Ce)
printf('total cost is %3.0f Pound \n',Ct)
```

Scilab code Exa 1.5 Cost Index

```
clear ;
clc;
// Example 1.5
printf('Example 1.5\n\n');
printf('Page No. 11\n\n');
// Solution

// Given
Cc= 108.0*10^3;// cost of coke in Pound
Cg= 3.6*10^3;// cost of gas in Pound
```

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

Scilab code Exa 1.6 Pie chart

```
clear ;
clc;
// Example 1.6
printf('Example 1.6\n\n');
printf('Page No. 11\n\n');
// Solution

// Given
G1= 11.72*10^3;// hourly consumption of gas in
   therms
th= 34.13;// in Watts
G= G1*th;// hourly consumption of gas in Watts
O1= 4.32*10^9;// hourly consumption of oil in Joules
J= .278*10^-3;// in Watts
O= O1*J;// hourly consumption of oil in Watts
E= 500*10^3;// hourly consumption of electricity in
   Watts
```

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

Scilab code Exa 1.7 Pie chart

```
close
clear ;
clc;
// Example 1.7
printf('Example 1.7\n\n');
printf('Page No. 12\n\n');
// Solution

// Given
O= 150*10^3;// energy consumption in office heating
    in Watts
L= 120*10^3;// energy consumption in lighting in
    Watts
B= 90*10^3;// energy consumption in boiler house in
    Watts
P= 180*10^3;// energy consumption in process in
    Watts
// Pie Chart Representation : one input argument x
    =[O L B P]
pie([O L B P],["office heating" "lighting" "boiler
    heating" "process"]);// Please see the graphics
    window
printf('The Pie chart is plotted in the figure');
```

Scilab code Exa 1.8 General auditing

```
clear ;
clc;
// Example 1.8
printf('Example 1.8\n\n');
printf('Page No. 16\n\n');
// given

qunty= [40 10000 400 90000]
unit_price= [29 0.33 0.18 0.025]
cost= (unit_price .* qunty)// in Pound
common_basis= [310 492 11.7 90]// in 10^6 Wh
per_unit_cost= (unit_price .* qunty) ./ common_basis // Pound per 10^6 Wh
p= 150;// production in tonnes
EI= sum(common_basis)*10^6/150
CI= sum(unit_price .* qunty)/150
printf('energy index is %3.2f Wh per tonne \n',EI)
printf('cost index  is %3.2f Wh per tonne \n',CI)
```

Scilab code Exa 1.9 General Auditing

```
clear ;
clc;
// Example 1.9
printf('Example 1.9\n\n');
printf('Page No. 17\n\n');
//given

p= [50, 55, 65, 50, 95, 90, 85, 80, 60, 90, 70, 110, 60, 105];// weakly production in tonnes
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
coefs = regress(p,s);
new_p = 0:120
```

```
new_s = coefs(1) + coefs(2)*new_p;
plot(p,s,'r*');
set(gca(),"auto_clear","off")

plot(new_p,new_s);// please see the corresponding graph in graphic window
xtitle('weakly steam consumption-production','weakly output (tonnes)','steam consumption/week (10^6 kg)')
l = legend([_('Given data'); _('Fitting function')],2);

in= coefs(1)*10^6;// intercept of graph in kg/weak
printf('At zero output the steam consumption is %3.0f in kg/weak \n',in)
```

Scilab code Exa 1.10 Detailed energy audits

```
clear ;
clc;
// Example 1.10
printf('Example 1.10\n\n');
printf('Page No. 19\n\n');
// given

//Monthly Energy Usage
qunty = [15*10^3 4*10^3 90*10^3]
cost = [4950 720  2250]// in Pound
common_basis1  = [738 117 90]// in 10^6 Wh
common_basis= [2655 421 324]// converted into 10^9 Joules
unit_cost = cost ./ common_basis1// in Pound per 10^6 Wh
p= 80;// production in tonnes
EI = ((sum(common_basis))/p)*10^9;
```

```
CI = sum(cost)/80;
printf('Monthly energy index is %3.2e J per tonne \n
    ',EI)
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

// Boiler House Energy Audit
qunty_b = [15000 10000]
Com_basis_b_1 = [2655 36]// in 10^9 J
Com_basis_b = [738 10]// in 10^6 Wh
Cost_b = [4950 250]// in Pound
b_output = 571*10^6;// in Wh
EI_b = (b_output/(sum(Com_basis_b)*10^6));
CI_b = (sum(Cost_b)/b_output)*10^3;// Pound
    converted into p
printf('Energy index  for boiler is %.3f \n',EI_b)
printf('Cost index for boiler is %3.2e p per Wh\n \n
    ',CI_b)

//Power House Energy Audit
P_gen = 200*10^6;// Power generated in Wh
Com_basis_p_1 = [14.4 2055 -1000]// in 10^9 J
Com_basis_p = [4.0 571 -278]// in 10^6 Wh
Cost_p = [100 5196 -2530]// in Pound
CI_p = (sum(Cost_p)/P_gen)*10^3;// Pound converted
    into p
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

//Space Heating Energy Audit
deg_days = 260;// Number of degree-days
Com_basis_s_1 = [36 100 105]// in 10^9 J
Com_basis_s = [10.0 27.8 29.2]// in 10^6 Wh
Cost_s = [250 253 179]// in Pound
EI_s = ((sum(Com_basis_s)*10^6)/deg_days)
CI_s = (sum(Cost_s)/deg_days)
```

```
printf('Energy index  for space heating is %3.2e Wh per degree-day\n',EI_s)
printf('Cost index for space heating is %3.2f Pound per degree-day\n\n',CI_s)

//Process Energy Audit
T_pdt_output = 100;// in tonne
Com_basis_pr_1 = [216 720 810 316]// in 10^9 J
Com_basis_pr = [60 200 225 88]// in 10^6 Wh
Cost_pr = [1500 2766 2047 540]// in Pound
EI_pr = ((sum(Com_basis_pr)*10^6)/T_pdt_output);
CI_pr = (sum(Cost_pr)/T_pdt_output);
printf('Energy index  for Process Energy Audit is %3.2e Wh per tonne \n',EI_pr)
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

```
clear ;
clc;
// Example 2.1
printf('Example 2.1\n\n');
printf('Page No. 44\n\n');

// given
C= 35000;// cost of boiler
C_grant=.25;// Capital grant available from
    goverment
E= -(C-(C_grant*C));// Net expenditure
Fs= 15250;// Fuel Saving
r_i = 0.15;// interest
r_t = 0.55;// tax

a = [0 E Fs 0 E+Fs r_i*(E+Fs) 0 ]
bal_1 = a(5)+a(6)-a(7)// Total Balance after 1st
    year

c_all = 0.55;// capital allowance in 2nd year
C_bal= (bal_1+0+Fs+(-(c_all*E)));// Cash Balance
```

```
after 2nd year
b = [bal_1 0 Fs -(c_all*E) C_bal r_i*C_bal r_t*(Fs+(
    r_i*C_bal))];
bal_2 = b(5)+b(6)-b(7)//Total  Balance after 2nd
    year

c = [bal_2 0 Fs 0 bal_2+Fs r_i*(bal_2+Fs) r_t*(Fs+(
    r_i*(bal_2+Fs)))]
bal_3= c(5)+c(6)-c(7)// Total  Balance after 3rd
    year

if(bal_2>0) then
    disp('Pay back period is of two year')
else
    disp('Pay back period is of three year')
end

printf('Total saving at the end of second year is %3
    .0f Pound\n',bal_2);
printf('Total saving at the end of third year is %3
    .0f Pound\n',bal_3);
// Deviation in answer due to direct substitution
```

Scilab code Exa 2.2 Energy audit scheme

```
clear ;
clc;
// Example 2.2
printf('Example 2.2\n\n');
printf('Page No. 45\n\n');

// given
C= 35000;// cost of boiler
C_grant=0;// Capital grant available from goverment
E= -(C-(C_grant*C));// Net expenditure
```

```
Fs= 15250;// Fuel Saving
r_i = 0.15;// interest
r_t = 0.55;// tax

a = [0 E Fs 0 E+Fs r_i*(E+Fs) 0 ]
bal_1 = a(5)+a(6)-a(7)// Total  Balance after 1st year

c_all = 0.55;// capital allowance in 2nd year
C_bal= (bal_1+0+Fs+(-(c_all*E)));// Cash Balance after 2nd year
b = [bal_1 0 Fs -(c_all*E) C_bal r_i*C_bal r_t*(Fs+(r_i*C_bal))];
bal_2 = b(5)+b(6)-b(7)//Total  Balance after 2nd year

c = [bal_2 0 Fs 0 bal_2+Fs r_i*(bal_2+Fs) r_t*(Fs+(r_i*(bal_2+Fs)))]
bal_3= c(5)+c(6)-c(7)// Total  Balance after 3rd year

if(bal_2>0) then
    disp('pay back period is of two year')
else
    disp('pay back period is of three year')
end

printf('Total saving at the end of second year is %3.2f Pound\n',bal_2);
printf('Total saving at the end of third year is %3.2f Pound\n',bal_3);
// Deviation in answer due to direct substitution
```

Scilab code Exa 2.3 Choice of fuels

```
clear ;
clc;
// Example 2.3
printf('Example 2.3\n\n');
printf('Page No. 46\n\n');

// given
F= 350*10^3;// fuel oils in gallons
Ci= 5000;// cost of insulation of tanks

As= 7500;//Annual Saving in Pound

if(As> Ci) then
disp("The investment has a pay-back period of less than 1 year");
else
disp("The investment has not a pay-back period of less than 1 year");
end
// 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 ,
// although it can be noted that there are more problems handling heavy fuels oils
//and that the pay-back increases considerably the smaller the installation.
//So the company can changeover from oil to coal as a fuel.
```

Scilab code Exa 2.4 Choice of fuels

```
clear ;
clc;
// Example 2.4
printf('Example 2.4\n\n');
```

```
printf('Page No. 47\n\n');

// given
F1= 500*10^3;// fuel oil in gallons
F2= 500*10^3;// coal in gallons in Pound
C1= 165*10^3;// cost of oil per year in Pound
C2= 92*10^3;// cost of an equivalent of coal in
    Pound
Ce= 100*10^3;// capital cost of extra handling
    eqiupment

Cm= (Ce*0.2);// Maintenance , interest costs per
    year
As= C1-C2;// Annual Saving in Pound
printf('Annual Saving is %3.0f Pound\n',As)

if((2*As)> Ce) then
disp("Replacing an obsolete boiler plant is
    considerable");
else
disp("Replacing an obsolete boiler plant is not
    considerble");
end
```

Scilab code Exa 2.5 Economic saving

```
clear ;
clc;
// Example 2.5
printf('Example 2.5\n\n');
printf('Page No. 49\n\n');

// given
F= 10*10^3;// fuel oils in gallons
Cs= 2200;// cost of maintaining tanks per year in
```

```
Pound
Ci= 1850;// cost of insulation of pipe in Pound

As= (Cs*.85);//company saving is 85 per cent to the cost
printf('Annual Saving on heating is %3.0f  Pound\n',As)


if(As> Ci) then
disp("The investment has a pay-back period of less than 1 year");
else
disp("The investment has not a pay-back period of less than 1 year");
end
```

Scilab code Exa 2.6 Cycle Efficiency

```
clear ;
clc;
// Example 2.6
printf('Example 2.6\n\n');
printf('Page No. 52\n\n');

// given
P1= 50;// Dry saturated steam pressure in bar
P2= 0.5;// condenser  pressure in bar

//By using the steam tables saturation temperature is obtained at given pressures
T1= 537//The saturation temperatue in K at 50 bar
T2= 306//The saturation temperatue in K at 0.5 bar

// For Carnot Cycle
```

```
n=(1-(T2/T1))*100;
printf('Efficiency percentage of Carnot Cycle is %3
    .0f \n',n)


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

Chapter 3

Economics

Scilab code Exa 3.1 Simple interest

```
clear ;
clc;
// Example 3.1
printf('Example 3.1\n\n');
printf('Page No. 58\n\n');

// given
P = 10000;// Principal Amount
i = 0.15;// Interest Rate
n = 4;//years
I = P*i*n;// Simple Interest
Ts= P+I;// The total repayment
printf('The total repayment is %.0f Euro\n',Ts)
```

Scilab code Exa 3.2 Compound interest

```
clear ;
clc;
```

```
// Example 3.2
printf('Example 3.2\n\n');
printf('Page No. 58\n\n');

// given
P = 10000;// Principal Amount in Pound
i = 0.15;// Interest Rate
n = 4;//years
Tc = P*(1+i)^n;
printf('The total repayment after adding compond
    interest is %.0f Pound\n',Tc)
```

Scilab code Exa 3.3 Capital recovery

```
clear ;
clc;
// Example 3.3
printf('Example 3.3\n\n');
//Page No. 59

// given
P = 60000;/// Principal Amount in Pound
i = 0.18;// Interest Rate
n = 10;//years
R = P*((i*(1+i)^n)/((1+i)^n -1));//Rate of Capital
    Recovery
printf('The annual investment required is %.1f Pound
    \n',R)
```

Scilab code Exa 3.4 Depreciation

```
clear ;
clc;
```

```
// Example 3.4
printf('Example 3.4\n\n');
printf('Page No. 61\n\n');

// given
P = 100000;/// Principal Amount of boiler plant in
    Pound
n = 10;// service life in years
S = 0;//Zero Salvage value
nT = (n*(n+1)/2);//sum of years
for i = 0:9
    d_(i+1) = ((P-S)/nT)*(n-i);
end
printf('The Annual depreciation for first year is %
    .0f Pound\n',d_(1))
printf('The Annual depreciation for second year is %
    .0f Pound\n\n',d_(2))
printf('The Annual depreciation for third year is %
    .0f Pound\n',d_(3))
printf('The Annual depreciation for ten year is %.0f
    Pound\n',d_(10))
// Deviation in answer due to some .approximation of
    values in the book
```

Scilab code Exa 3.5 Depreciation and Asset value

```
clear ;
clc;
// Example 3.5
printf('Example 3.5\n\n');
printf('Page No. 62\n\n');

// given
P = 40000;/// Principal Amount of boiler plant in
    Pound
```

```
nT = 10;// service life in years
S = 4000;// Salvage value
n = 6;// years after which Asset value has to be
    calculated

//(a) Straight line method
d = ((P-S)/nT);// Depreciation
Aa = (d*(nT-n)) + S;
printf('The Asset value at the end of six years
    using Straight line method is %.0f Pound\n',Aa)

// (b) Declining balance technique
f = 1-(S/P)^(1/nT);// Fixed fraction of the residual
    asset
Ab = P*(1-f)^n;
printf('The Asset value at the end of six years
    using Declining balance technique is %.0f Pound\n
    \n',Ab)

// (c) Sum of the years digit
sum_nT = (nT*(nT+1)/2);//sum of  10 years
sum_n = 45;//sum after 6 years
dc = ((sum_n/sum_nT)*(P-S));// Depreciation after 6
    years
Ac = P-dc;
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

//(d) Sinking Fund Method
r_i = 0.06;// Rate of interest
Ad = P-((P-S)*(((1+r_i)^n-1)/((1+r_i)^nT-1)));
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

```
clear ;
clc;
// Example 3.6
printf('Example 3.6\n\n');
printf('Page No. 67\n\n');

// given
P = 9000;// Capital Cost in Pound
n = 5;// Project lifetime
Less_dep = 8000;// Less Depreciation

//For Project A
d1 = [4500 3750 3000 1500 750 ]// Saving in every
    year (before depreciation)
dT1 = sum (d1)
Net_S1 = dT1- Less_dep;// Total Net Saving
Avg1 = Net_S1/n;// Average net annual saving
R_R1 = (Avg1/P)*100;

//For Project
d2 = [750 2250 4500 4500 1500 ]// Saving in every
    year (before depreciation)
dT2 = sum (d2)
Net_S2 = dT2- Less_dep;// Total Net Saving
Avg2 = Net_S2/n;// Average net annual saving
R_R2 = (Avg2/P)*100;

printf('The percentage of Rate of Return on original
     investment for Project A is %3.1f \n',R_R1)
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

```
clear ;
clc;
// Example 3.7
printf('Example 3.7\n\n');
printf('Page No. 68\n\n');

// given
Pc = 10000;// Capital cost for project C in Pound
Pd = 10000;// Capital cost for project d in Pound
nc = 3;// pay back period for C
nd = 3;// pay back period for D
Ca = [4500 3500 2000 2000 1000];// Annual Cash flow for C in Pound
Cc = [4500 8000 10000 12000 13000]// Cumulative Cash flow for C in Pound
Da = [1500 4000 4500 2200 1800 1000];// Annual Cash flow for D in Pound
Dc = [1500 5500 10000 12200 14000 15000]// Cumulative Cash flow for D in Pound
Ac = Cc(5)-Pc;// in Pound
Ad = Dc(6)-Pd;// in Pound
printf('Additional amount from C after the pay back time is %3.f Pound\n',Ac)
printf('Additional amount from D after the pay back time is %3.f Pound\n',Ad)
```

Scilab code Exa 3.8 Discounted cash flow

```
clear ;
clc;
```

```
// Example 3.8
printf('Example 3.8\n\n');
printf('Page No. 69\n\n');

//Refer figure 3.6
// given
n = 5;//years
C = 80000;// COst of the project in Pound
S = 0;// Zero Salvage Value
A_E = [10000 20000 30000 40000 50000]// Annual Net cash flow for project E in Pound
C_E = [10000 30000 60000 100000 150000]// Cummulative Net cash flow for project E in Pound
A_F = [50000 40000 30000 20000 10000]// Annual Net cash flow for project F in Pound
C_F = [50000 90000 120000 140000 150000]// Cummulative Net cash flow for project F in Pound

//From the figure 3.6 (intercept of x-axis)
P_F = 1.75;// in years
P_E = 3.5;// in years
printf('The pay-back time of project F is %.2f \n',P_F)
printf('The pay-back time of project E is %.1f \n\n',P_E)

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

```
clear ;
clc;
```

```
// Example 3.9
printf('Example 3.9\n\n');
printf('Page No. 70\n\n');

// given
P = 1;/// Principal Amount in Pound

r_i = 0.1;// Compound interest rate
for i = [1:1:4]
    c = P*(1+r_i)^i;
    printf('compound intrest after year %.0f is equal to %.2f Pound\n',i,c)
end

new_P = 1000*P;//in Pound
new_c = 1000*c;// in Pound
printf('The new amount at the compound interest after fourth year is %.0f Pound\n\n',new_c)

// Discount rate
r_d = 0.10;// Discount rate
for j= 1:1:4
    d = P*(1/(1+r_d)^j);
    printf('The amount receivable at discount in year %.0f is %.3f Pound\n',j,d)
end

new_P1 = new_c;// in Pound
new_d = new_P1*d;// in Pound
printf('The  new amount receivable at discount in fourth year is %.0f Pound\n',new_d)
```

Scilab code Exa 3.10 Net present value

```
clear ;
```

```
clc;
// Example 3.10
printf('Example 3.10\n\n');
printf('Page No. 71\n\n');

// given
C = 2500;// Cost of the project
P = 1000;// Cash in flow
r_r = 0.12;// Rate of return
S = 0;// Zero salvage value
n = 4;//years

for j= 1:1:4 // as for four years
    d_(j) = P*(1/(1+r_r)^j);
    end


P_v = d_(1)+d_(2)+d_(3)+d_(4);//Present value of
    cash inflow
N = P_v-C;
printf('Net present value is %.0f Pound\n',ceil(N))

if(P_v>C) then
    disp('The project may be undertaken')
else
    disp('The project may not be undertaken')
    end
```

Scilab code Exa 3.11 Net present value

```
clear ;
clc;
// Example 3.11
printf('Example 3.11\n\n');
printf('Page No. 72\n\n');
```

```
// given
Cash_out = 80000;// Present value of cash outflow
    for both projects E and F
r_r = .2;// Rate of return
n = 5;// years

d = [0.833 0.694 0.579 0.482 0.402]// Discount
    Factor for 20% of rate of return for 5 years
Ce = [10000 20000 30000 40000 50000]// Cash flow for
     project E in Pound
Pe = [8330 13880 17370 19280 20100]// Present value
    for project E in Pound

Cf = [50000 40000 30000 20000 10000]// Cash flow for
     project F in Pound
Pf = [41650 27760 17370 9640 4020]// Present value
    for project F in Pound

Cash_inE = sum(Pe)//Present value of cash inflow in
    Pound
Cash_inF = sum(Pf)//Present value of cash inflow in
    Pound

Net_E = Cash_inE - Cash_out;// net present value for
     project E in Pound
Net_F = Cash_inF - Cash_out;// net present value for
     project F in Pound

if (Net_E>Net_F) then
    disp('Project E is selected based on NPV')
else
    disp('Project F is selected based on NPV')
end
```

Scilab code Exa 3.12 Profitability index

```
clear ;
clc;
// Example 3.12
printf('Example 3.12\n\n');
printf('Page No. 72\n\n');

// given
Cash_inG = 43000;// Present value of cash inflow for
    project G in Pound
Cash_outG = 40000;// Present value of cash outflow
   for  project G in Pound
Net_G = Cash_inG - Cash_outG;// Net present value
   for G in Pound
PI_G = (Cash_inG/Cash_outG);// Profitability index
   for G

Cash_inH = 23000;// Present value of cash inflow for
    project H in Pound
Cash_outH = 20000;// Present value of cash outflow
   for  project H in Pound
Net_H = Cash_inH - Cash_outH;// Net present value
   for H in Pound
PI_H = (Cash_inH/Cash_outH);// Profitability index
   for H

//The higher the profitability index the more
   desirable is the project.
if (PI_G>PI_H) then
    disp('Project G is more attractive than Project
       H')
else
    disp('Project H is more attractive than Project
       G')
end
```

Scilab code Exa 3.13 Internal rate of return

```
clear ;
clc;
// Example 3.13
printf('Example 3.13\n\n');
printf('Page No. 73\n\n');

// given
Cash_out = 80000;// Present value of cash outflow
    for project F in Pound
n = 5;// years
Cash_in= [50000 40000 30000 20000 10000]// Cashn in
    \flow for project F in Pound
NPV = 0;//At the end of 5 years

//Let the unknown rate for project F be rm.

//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
// By taking (1+rm) = x\n =>8*x^5 - 5*x^4 - 4*x^3 -
    3*x^2 - 2*x - 1 = 0\n\n')

function y=fsol1(x)
  y= 8*x^5 - 5*x^4 - 4*x^3 - 3*x^2 - 2*x - 1;
endfunction
[xres]=fsolve(100,fsol1);
xres
rm = (xres - 1)*100;
printf('The value of rm for project F is %3.0f per
    cent\n',ceil(rm))
```

Scilab code Exa 3.14 Discount factor

```
clear ;
clc;
// Example 3.14
printf('Example 3.14\n\n');
printf('Page No. 74\n\n');

// given
n = 5;//years
C = 80000;// Cost of the project in Pound
Cash_in = [10000 20000 30000 40000 50000]// Cash
    inflow in Pound
r_d1 = 15;// Discount factor of 15%
r_d2 = 18 ;// Discount factor of 18%
r_d3 = 20;// Discount factor of 20%

//At discount of 15%
df_1 = [0.870 0.756 0.658 0.572 0.497]// Discount
    factor for every year
PV_1 = [8700 15120 19740 22880 24850]// Present
    value
Net_1 = sum (PV_1);// net present value


//At discount of 18%
df_2 = [0.847 0.718 0.609 0.516 0.437]// Discount
    factor for every year
PV_2 = [8470 14360 18270 20640 21850]// Present
    value
Net_2 = sum (PV_2);// net present value


//At discount of 20%
```

```
df_3 = [0.833 0.694 0.579 0.482 0.402]// Discount
    factor for every year
PV_3 = [8330 13880 17370 19280 20100]// Present
    value
Net_3 = sum (PV_3);// net present value

// f = N.P.V. cash inflow - N.P.V. cash outflow
//(1) By Numerical Method
ff = 2*((sum (PV_2) - C)/(sum (PV_2) - sum(PV_3)));
    // in percentage
f = 18 + ff;
printf('the internal rate of return in percentage is
    %3.2f \n\n',f)// Deviation in answer due to
    direct substitution

//(2) By Graphical Interpolation
f_1 = (sum (PV_1) - C)/10^3;//At discount factor of
    15%
f_2 = (sum (PV_2) - C)/10^3;//At discount factor of
    18%
f_3 = (sum (PV_3) - C)/10^3;//At discount factor of
    20%

x = [f_1 f_2 f_3];
y = [r_d1 r_d2 r_d3];
plot(x,y,'r*');

plot2d (x,y);// please see the corresponding graph
    in graphic window
xtitle('Discount factor against f','f ( *10^3 Pound)
    ','Discount factor(%)')
regress(x,y)
coefs = regress(x,y);
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

```
clear ;
clc;
// Example 3.15
printf('Example 3.15\n\n');
printf('Page No. 77\n\n');

// given
i_t = [20 40 60 80 100];// Insulation thickness in mm
f_c = [2.2 3.5 4.8 6.1 7.4];// Fixed costs in (10^3 Pound / year)
h_c = [10.2 6.5 5.2 4.6 4.2];// Heat costs in (10^3 Pound / year)
t_c = [12.4 10 10 10.7 11.6];// Total costs in (10^3 Pound / year)

//(a) Graphical solution
//Refer figure 3.8
C_T = 9750;// Minimum total cost in Pound
t = 47;// Corresponding thickness of insulation in mm
printf('The most economic thickness of insulation is %.0f mm \n',t)

//(b) Numerical solution
// The cost due to heat losses ,C1, and the fixed costs ,C2, vary according to the equations;-
// C1 = (a/x) + b      and     C2 = (c*x) + d
// Substituting the values of C1 and C2 together with the corresponding insulation thickness values , the following equations are obtained :-
// C1 = (150*10^3/x) + 2.7*10^3     and     C2 = (65*x
```

```
    ) + 0.9*10^3
//And to obtain the total costs
//CT = C1 + C2 = (150*10^3/x) + (65*x) + 3.6*10^3
// Differentiate to optimise , and put dCT/dx equal
    to zero
//dCT/dx =-((150*10^3)/x^2) + 65 = 0

//Let y = dCT/dx
function y=fsol1(x)
  y = -((150*10^3)/x^2) + 65;
endfunction
[xres]=fsolve(50,fsol1);
x = xres;
printf('The optimum thickness of insulation is %.0f
   mm \n',x)
```

Scilab code Exa 3.16 Optimum operating time

```
clear ;
clc;
// Example 3.16
printf('Example 3.16\n\n');
printf('Page No. 79\n\n');

// given
tb = [36*10^3 72*10^3 144*10^3 216*10^3]; //
    operating time in s
U = [971 863 727 636];// Mean overall heat transfer
    rate in W/m^2-K
A = 50;// area in m^2
dT = 25;// temperature difference in degree celcius
ts = 54*10^3;// Time in sec (h converted to sec)
//As Q = U*A*dT
for i = [1:1:4]
    Q(i) = (U(i)*A*dT)/10^6;
```

```
    Q_a(i) = ((tb(i)*Q(i)*10^6)/(tb(i) + ts))/10^6;
    printf('the average heat transfer rate is %.3f
       *10^6 W \n',Q_a(i))
end

//Refer figure 3.9
printf('\n')
Q_max = 0.67*10^6;// Maximum value of Q in W
T_opt = 33;// Time in h
printf('The maximum value of Q obtained is %3.2e W \
   n',Q_max)
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

```
clear ;
clc;
// Example 3.17
printf('Example 3.17\n\n');
printf('Page No. 80\n\n');

// given
// C_T = 7*x + (40000/(x*y)) + 6*y + 10
//Differentiating C_T with respect to x and y:-
//dC_T/dx = 7 - (40000/(x^2*y))
//dC_T/dy = - (40000/(x*y^2)) + 6

//For optimum conditions :- dC_T/dx = dC_T/dy = 0
//dC_T/dx = 0   => 7 - (40000/(x^2*y)) = 0
//=> y = 40000/(7*x^2).......(1)
//dC_T/dy = 0    =>- (40000/(y^2*x)) +6 = 0
//=> y = (40000/(6*x))^0.5.......(2)

//From equation (1) and (2)
```

```
//=> 40000/(7*x^2) - (40000/(6*x))^0.5 = 0

function y=fsol1(x)
  y = 40000/(7*x^2) - (40000/(6*x))^0.5 ;
endfunction
[xres]=fsolve(20,fsol1);
x = xres;

//from equation (1)
y = 40000/(7*x^2);

//a = d^2C_T/dx^2 = 80000/(x^3*y)
//b = d^2C_T/dy^2 = 80000/(x*y^3)
a = 80000/(x^3*y);
b = 80000/(x*y^3);
if a > 0
    if b > 0
//The optimum conditions must occur at a point of
   minimum cost- C_T_m
C_T_m = 7*x + (40000/(x*y)) + 6*y + 10;// in Pound
printf('The minimum cost is %.1f Pound',C_T_m)
    end
end
```

Chapter 4

Heat transfer theory

Scilab code Exa 4.1 Conduction

```
clear ;
clc;
// Example 4.1
printf('Example 4.1\n\n');
printf('Page No. 88\n\n');

// given
K = 45// Thermal Conductivity in W/m-K
L = 5*10^-3;// thickness in metre
T1 = 100;// in degree celcius
T2 = 99.9;// in degree celcius
A = 1;// Area in m^2

//By Fourier law of conduction
Q = ((K*A*(T1-T2))/L);// in Watts
printf('The rate of conductive heat transfer is %.0f
    W \n',Q)
```

Scilab code Exa 4.2 Conduction through cylindrical pipe

```
clear ;
clc;
// Example 4.2
printf('Example 4.2\n\n');
printf('Page No. 89\n\n');
// given
K1 = 45// Thermal Conductivity  of mild steel in W/m-K
K2 = 0.040// Thermal Conductivity  of insulaton in W/m-K
L1 = 5*10^-3;// thickness of mild steel in metre
L2 = 50*10^-3;// thickness of insulation in metre
T1 = 100;// in degree celcius
T2 = 25;// in degree celcius
A = 1;// Area in m^2

//By Fourier law of conduction
Q = (((T1-T2)/((L1/(K1*A))+(L2/(K2*A)))))// in Watts
printf('The rate of conductive heat transfer is %.0f W \n',Q)
```

Scilab code Exa 4.3 Conduction through pipe with insulation

```
clear ;
clc;
// Example 4.3
printf('Example 4.3\n\n');
printf('Page No. 90\n\n');

// given
K1 = 26;// Thermal Conductivity  of stainless steel in W/m-K
K2 = 0.038;// Thermal Conductivity  of insulaton in W/m-K
L1 = 3*10^-3;// thickness of stainless steel in
```

```
metre
L2 = 40*10^-3;// thickness of insulation in metre
T1 = 105;// in degree celcius
T2 = 25;// in degree celcius
L = 15;// Length of pipe in metre
d1 = 50*10^-3;// Internal diameter of pipe in metre
d2 = 56*10^-3;// External diameter of pipe in metre

r1 = d1/2;// in metre
r2 = d2/2;// in metre

rm_p = ((r2-r1)/log(r2/r1));// logarithmic mean radius of pipe in m
rm_i = (((r2+L2)-r2)/log((r2+L2)/r2));// logarithmic mean radius of insulation in m

//By Fourier law of conduction
Q = (((T1-T2)/((L1/(K1*2*%pi*rm_p))+(L2/(K2*2*%pi*rm_i)))));// in W/m
Q_L = Q*L;
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

```
clear ;
clc;
// Example 4.4
printf('Example 4.4\n\n');
printf('Page No. 93\n\n');

// given
dH = 12*10^-3;// Outer diameter of pipe in m
dC = 10*10^-3;// Inner diameter of pipe in m
```

```
L = 1*10^-3;// im m
h_H = 10*10^3;// Heat Transfer Coefficient  on
    vapour side in W/m^2-K
h_C = 4.5*10^3;// Heat Transfer Coefficient  on
    vapour side in W/m^2-K
K = 26;// Thermal Conductivity of metal in W/m-K
dM = (dH + dC)/2;// mean diameter in m
h_Hf = 6*10^3;// Fouling factor for hot side
h_Cf = 6*10^3;// Fouling factor for cold side

U = (1/h_H)+((L*dH)/(K*dM))+(dH/(dC*h_C));
Uh = (1/U);// in W/m^2-K
printf('The original heat transfer coefficient is %3
    .0f W/sq.m K \n',Uh )// Deviation in answer due
    to direct substitution

u = (1/h_H)+(1/h_Hf)+((L*dH)/(K*dM))+(dH/(dC*h_C))+(
    dH/(dC*h_Cf));
Uf = (1/u);// in W/m^2-K
printf('The final heat transfer coefficient due to
    fouling is %3.0f W/m^2-K \n',ceil(Uf))
```

Scilab code Exa 4.5 L M T D

```
clear ;
clc;
// Example 4.5
printf('Example 4.5\n\n');
printf('Page No. 95\n\n');

// given
m_h = 1.05;// Mass flow rate of hot liquid in kg/s
Thi = 130;// Inlet Temperature of hot liquid in
    degree celcius
Tho = 30;// Outlet Temperature of hot fluid in
```

```
degree celcius
Cph =  2.45*10^3;// Specific heat capacity of hot liquid in J/kg-K

m_c = 4.10;// Mass flow rate of cold liquid in kg/s
Tci =  20;// Inlet Temperature of cold liquid in degree celcius
Cpc =  4.18*10^3;// Specific heat capacity of cold liquid in J/kg-K

A = 6.8;// Area of heat exchanger in m^2
Q = m_h*Cph*(Thi-Tho);// in Watts

//From heat balance
// m_c*Cpc*(Tci-Tco)= m_h*Cph*(Thi-Tho)= UAlTm = Q
Tco = ((Q/(m_c*Cpc))+Tci);
printf(' The Outlet Temperature of cold fluid is %.0f degree celcius\n',Tco)
// As counter flow  heat exchanger
T1 = Thi-Tco;
T2 = Tho-Tci;
Tm = ((T1-T2)/log(T1/T2));

U = (Q/(A*Tm));
printf('The overall heat transfer coefficient is %.0f W/sq.m K \n',U)// Deviation in answer due to direct substitution
```

Scilab code Exa 4.6 Forced convection turbulent flow

```
clear ;
clc;
// Example 4.6
printf('Example 4.6\n\n');
printf('Page No. 98\n\n');
```

```

// given
v = 1.23;// velocity in m/s
d = 25*10^-3;// diameter in m
p = 980;// density in kg/m^3
u = 0.502*10^-3;// viscosity in Ns/m^2
Cp = 3.76*10^3;// Specific heat capacity in J/kg-K
K = 0.532;// Thermal conductivity in W/m-K

Re = (d*v*p)/u;//Reynolds Number
Pr = (Cp*u)/K;// Prandtl Number
Re_d = (Re)^0.8;
Pr_d = (Pr)^0.4;

// By Dittus-Boelter Equation
//Nu = 0.0232 * Re^0.8 Pr^0.4 = (hd)/K
Nu = 0.0232 * Re_d * Pr_d;// Nusselt Number
h = (Nu*K)/d;//W/m^2-K
printf('The film heat transfer coefficient is %3.2f
   W/sq.m K\n',h)// Deviation in answer due to
    direct substitution
```

Scilab code Exa 4.7 Free convection

```
clear ;
clc;
// Example 4.7
printf('Example 4.7\n\n');
printf('Page No. 99\n\n');

// (a) without insulation
// given
d_a = 0.150;// Diameter of pipe in m
T1_a = 60;// Surface temperature in degree celcius
T2_a = 10;// Ambient temperature in degree celcius
```

```
//For laminar flow in pipe,h= 1.41*((T1-T2)/d)^0.25
h_a = 1.41*((T1_a-T2_a)/d_a)^0.25;//W/m^2-K
A_a = %pi * d_a;// Surface Area per unit length in m
    ^2/m
Q_a = h_a*A_a*(T1_a - T2_a);// in W/m
printf('The heat loss per unit length without
    insulation is %.0f W/m \n',ceil(Q_a))

// (b) with insulation
// given
d_b = 0.200;// Diameter of pipe in m
T1_b = 20;// Surface temperature in degree celcius
T2_b = 10;// Ambient temperature in degree celcius

//For laminar flow in pipe,h= 1.41*((T1-T2)/d)^0.25
h_b = 1.41*((T1_b-T2_b)/d_b)^0.25;//W/m^2-K
A_b = %pi * d_b;// Surface Area per unit length in m
    ^2/m
Q_b = h_b*A_b*(T1_b - T2_b);// in W/m
printf('the heat loss per unit length with
    insulation is %.1f W/m',Q_b)
// Deviation in answer due to direct substitution
```

Scilab code Exa 4.8 Rate oh heat transfer

```
clear ;
clc;
// Example 4.8
printf('Example 4.8\n\n');
printf('Page No. 103\n\n');

// given
d = 0.100;// Diameter of pipe in m
T1 = 383;// Surface temperature in Kelvin
```

```
T2 = 288;// Surrounding air temperature in Kelvin
e = 0.9;// Emissivity of pipe
A = %pi * d;// Surface Area per unit length in m^2/m

// By Stefan-Blotzmann law, the radiative heat transfer rate is   Q = 5.669*e*A*((T1/100)^4-(T2/100)^4)
Q = 5.669*e*A*((T1/100)^4-(T2/100)^4);// in W/m
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

```
clear ;
clc;
// Example 4.9
printf('Example 4.9\n\n');
printf('Page No. 103\n\n');

// given
A = 1;// Area in m^2
T1 = 423;// Surface temperature in Kelvin
T2 = 293;// Surrounding air temperature in Kelvin
T1_c = 150;// Surface temperature in degree celcius
T2_c = 20;// Ambient temperature in degree celcius
e = 0.9;// Emissivity of pipe

//(a) Horizontal Pipe
d = 0.100;// Diameter of pipe in m
//For laminar flow in pipe,Q= (1.41*((T1-T2)/d)^0.25)*(T1-T2)
Q_Ca = (1.41*((T1_c-T2_c)/d)^0.25)*(T1_c-T2_c);// Convective heat transfer rate in W/m^2
// By Stefan-Blotzmann law, the radiative heat transfer rate is   Q = 5.669*e*((T1/100)^4-(T2
```

```
/100)^4)
Q_Ra = 5.669*e*((T1/100)^4-(T2/100)^4);// in W/m^2
Q_Ta = Q_Ra + Q_Ca;// IN W/m^2
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


//(b) Vertical Pipe
//For turbulent flow in pipe,Q= (1.24*(T1-T2)^1.33)
Q_Cb = (1.24*(T1-T2)^1.33);// Convective heat transfer rate in W/m^2
// By Stefan-Blotzmann law, the radiative heat transfer rate is  Q = 5.669*e*((T1/100)^4-(T2/100)^4)
Q_Rb = 5.669*e*((T1/100)^4-(T2/100)^4);// in W/m^2
Q_Tb = Q_Rb + Q_Cb;// IN W/m^2
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

```
clear ;
clc;
// Example 4.10
printf('Example 4.10\n\n');
printf('Page No. 106\n\n');

// given
T1 = 150;// Surface temperature in degree celcius
T2 = 20;// Ambient temperature in degree celcius
d = 0.100; //Outside diametr of pipe in m
h = 10;// Outside film coefficient in W/m^2-K
t = 25*10^-3;// thickness of insulation in m
K = 0.040;// Thermal conductivity of insulation in W
```

```
/m-K

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

Chapter 5

Heat transfer media

Scilab code Exa 5.1 Water treatment

```
clear ;
clc;
// Example 5.1
printf('Example 5.1\n\n');
printf('Page No. 110\n\n');

// given
Q = 0.30*10^6;// Heat transfer rate in W/sq.m
T1 = 540;// Mean gas temperature in degree celcius
T2 = 207;// Steam temperature in degree celcius
K_tube = 40;// Thermal conductivity of tube in W/m-K
K_scale = 2.5 ;// Thermal conductivity of scale in W
    /m-K
L_tube = 4*10^-3;// Length of tube in m

// By Fourier equation and neglecting curvature
    effect , Q/A = [(T1- T2)/((L_tube/K_tube)+(L_scale
    /K_scale))]
L_scale = K_scale*(((T1-T2)/Q)-(L_tube/K_tube));
printf('The thickness of scale is %.4f m',L_scale)
```

Scilab code Exa 5.2 Properties of water

```
clear ;
clc;
// Example 5.2
printf('Example 5.2\n\n');
printf('Page No. 113\n\n');

// given
T1 = 10;// in degree celcius
T2 = 70;// in degree celcius
d = 25*10^-3;// Inside diameter in m
v = 1.5;// veocity in m/s

Tm = (T1+T2)/2;// Arithmetic Mean  temperature in degree celcius
// At Tm, All physical properties of water is calculated by using steam table

//(a)Heat absorbed by water
p = 992;// Density of water in kg/m^3 At Tm
A = (%pi*d^2)/4;// Area in m^2
m = p*v*A;// Mass flow rate in kg/s
h_70 = 293*10^3;// Specific enthalpy of water in J/kg  at 70 degree celcius(from  steam table)
h_10 = 42*10^3;// Specific enthalpy of water in J/kg at 10 degree celcius(from  steam table)
Q = m*(h_70 - h_10);// in W
printf(' Heat absorbed by water is %.0f W \n',Q)

//(b) Film heat transfer
//At Tm, the following properites of water are found by using steam table
u = 650*10^-6;// viscosity in Ns/m
```

```
Cp = 4180;//Specific heat in J/kg-s
K = 0.632;// Thermal conductivity in W/m-s


Re = (d*v*p)/u;//Reynolds Number // answer wrongly
    calculated in the text book
Pr = (Cp*u)/K;// Prandtl Number
Re_d = (Re)^0.8;
Pr_d = (Pr)^0.4;

// By Dittus-Boelter Equation
//Nu = 0.0232 * Re^0.8 Pr^0.4 = (hd)/K
Nu = 0.0232 * Re_d * Pr_d;// Nusselt Number
h = (Nu*K)/d;//W/m^2-K
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

```
clear ;
clc;
// Example 5.3
printf('Example 5.3\n\n');
printf('Page No. 117\n\n');

// given
T1 = 25;// in degree celcius
T2 = 212;// in degree celcius
x = 0.96;// dryness fraction
m = 1.25;// Mass flow rate in kg/s

//from steam table
hL_212 = 907*10^3;// Specific enthalpy at 212 degree
```

```
celcius in J/kg
hL_25 = 105*10^3;// Specific enthalpy at 25 degree celcius in J/kg
l_212 = 1890*10^3;// Latent heat of vapourisation at 212 degree celcius in J/kg

Q = m*((hL_212+(x*l_212))-hL_25);// in W
printf('The required heat is %.0f W',Q)
```

Scilab code Exa 5.4 Thermal efficiency

```
clear ;
clc;
// Example 5.4
printf('Example 5.4\n\n');
printf('Page No. 117\n\n');

// given
T = 25;// in degree celcius
x = 0.96;// dryness fraction
m = 3.15;// Mass flow rate in kg/s
CV = 42.6*10^6;// Calorific value in J/kg
P = 15;// Pressure in bar
n = 0.8;// Efficiency

//from steam table
hL_1 = 843*10^3;// Specific enthalpy in J/kg
hL_2 = 293*10^3;// Specific enthalpy  in J/kg
l_1 = 1946*10^3;// Latent heat of vapourisation at 70 degree celcius in J/kg

Q = m*((hL_1+(x*l_1))-hL_2);// in W
Q_Ac = Q/n// Actual heat required in Watts
Oil = Q_Ac/CV;
printf('The oil required is %.3f kg/s',Oil)
```

Scilab code Exa 5.5 Condensing Steam

```
clear ;
clc;
// Example 5.5
printf('Example 5.5\n\n');
printf('Page No. 120\n\n');

// given
T1 = 134;// in degree celcius
T2 = 100;// in degree celcius
x = 0.96;// dryness fraction
m = 0.75;// Mass flow rate in kg/s

//from steam table
hL_134 = 563*10^3;// Specific enthalpy at 134 degree
    celcius in J/kg
hL_100 = 419*10^3;// Specific enthalpy at 100 degree
    celcius in J/kg
l_134 = 2162*10^3;// Latent heat of vapourisation at
    134 degree celcius in J/kg

Q = m*((hL_134+(x*l_134))-hL_100);// in W
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

```
clear ;
clc;
```

```
// Example 5.6
printf('Example 5.6\n\n');
printf('Page No. 120\n\n');

// given
x = 0.90;// dryness fraction
m = 0.25;// Mass flow rate in kg/s
P = 0.7;// pressure in bar
T1 = 10;// in degree celcius

//from steam table
h_10= 42*10^3;// Specific enthalpy  of water at 10
    degree celcius in J/kg
h_25 = 105*10^3;// Specific enthalpy of water at 25
    degree celcius in J/kg
h_30 = 126*10^3;// Specific enthalpy of water at 30
    degree celcius in J/kg
h_s = 2432*10^3;// Specific enthalpy of steam in J/
    kg

//(a)T2 = 25;
T2 = 25;// in degree celcius
// 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
y = (m*(h_s-h_25)/(h_25-h_10));
printf('the quantity of water to be used at 25
    degree celcius is %.2f kg/s \n',y)


//(b)T2 = 30;
T2 = 30;// in degree celcius
// 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
z = (m*(h_s-h_30)/(h_30-h_10));
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

```
clear ;
clc;
// Example 5.7
printf('Example 5.7\n\n');
printf('Page No. 121\n\n');

// given
x = 0.97;// dryness fraction
m = 4.0;// Mass flow rate in kg/s
v = 40;// velocity in m/s
P = 10;// pressure in bar

//from steam table
Sp_vol = 0.194;// specific volume at 10 bar dry
   steam in m^3/kg

Q = Sp_vol*x*m// Volumetric flow rate of steam in m
   ^3/s
d = sqrt((Q*m)/(v*%pi));
printf('the required diameter of pipe is %.3f m',d)
```

Scilab code Exa 5.8 Superheated steam

```
clear ;
clc;
// Example 5.8
```

```
printf('Example 5.8\n\n');
printf('Page No. 122\n\n');

// given
T1 = 25;// in degree celcius
T2 = 450;// in degree celcius
m = 7.5;// Mass flow rate in kg/s

//from steam table
hL_450 = 3303*10^3;// Specific enthalpy at 450 degree celcius in J/kg
hL_25 = 105*10^3;// Specific enthalpy at 25 degree celcius in J/kg

Q = m*(hL_450 - hL_25);// in W
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

```
clear ;
clc;
// Example 5.9
printf('Example 5.9\n\n');
printf('Page No. 122\n\n');

// given
P1 = 15;// Pressure at state 1 in bar
P2 = 1.5;// Pressure at state 2 in bar
T1 = 198;// in degree celcius

// as the process is adiabatic; => Q = 0; => ehthalpy at state1 = enthalpy at state 2
h_1 = 2789*10^3;// specific enthalpy at state 1 in J
```

```
/kg
h_2 = h_1;//specific enthalpy at state 2 in J/kg

T3 = 150;// in degree celcius
T4 = 200;// in degree celcius
h_3 = 2773*10^3;// specific enthalpy at state 3 in J/kg
h_4 = 2873*10^3;// specific enthalpy at state 4 in J/kg

// Assuming a liner realtionship between temperature and enthalpy for the temperature range 150-200 degree celcius
h = ((h_4 - h_3)/(T4 - T3));// specific enthalpy per degree celcius in J/kg-degC
t = ((h_2 - h_3)/h);// in degree celcius
T2 = T3 + t;// in degree celcius
printf('the temperature of the final superheated steam at 1.5 bar is %.0f deg C',T2)
```

Scilab code Exa 5.10 Desuperheating

```
clear ;
clc;
// Example 5.10
printf('Example 5.10\n\n');
printf('Page No. 123\n\n');

// given
m = 0.45;// Mass flow rate in kg/s
P = 2;// pressure in bar
T1 = 60;// in degree celcius
T2 = 250;// in degree celcius
h_s = 2971*10^3;// Specific enthalpy of superheated steam in J/kg
```

```
h_d = 2706*10^3;// Specific enthalpy of dry saturated steam in J/kg
h_e = h_s - h_d;//excess Specific enthalpy in J/kg
h = 251*10^3;// in J/kg
V_s = 0.885;// specific volume of dry saturated steam at 2bar in m^3/kg

h_r = h_d- h;// heat required to convert water at 60 deg C into dry saturated steam at 2 bar
w = (h_e/h_r);// in kg/kg
printf('the quantity of water requried is %.3f kg/kg \n\n',w)

M = m*w;// in kg/s
printf('the total mass flow rate of water required is %.3f kg/s \n\n',M)

M_d = M + m;// mass flow rate of desuperheated steam in kg/s
V = M_d*V_s;// in m^3/s
printf('the total mass flow rate of desuperheated steam required is %.4f m^3/s \n',V)
// Deviation in answer due to some approximation in answer in  the book
```

Scilab code Exa 5.11 Synthetic organic chemicals

```
clear ;
clc;
// Example 5.11
printf('Example 5.11\n\n');
printf('Page No. 130\n\n');

// given
T1 = 180;// in degree celcius
```

```
T2 = 350;// in degree celcius
m = 0.5;// Mass flow rate in kg/s


//from steam table
hL_180 = 302*10^3;// Specific enthalpy at 180 degree
    celcius in J/kg
hL_350 = 690*10^3;// Specific enthalpy at 350 degree
    celcius in J/kg

Q = m*(hL_350 - hL_180);// in W
printf('The required heat is %.0f W',Q)
```

Scilab code Exa 5.12 Synthetic organic chemicals

```
clear ;
clc;
// Example 5.12
printf('Example 5.12\n\n');
printf('Page No. 130\n\n');

// given
T1 = 200;// in degree celcius
T2 = 300;// in degree celcius
m_l = 0.55;// Mass flow rate  of liquid in kg/s
P = 3; //pressure in bar
Cp = 2.34*10^3;// Mean haet capacity in J/kg-K
h = 272*10^3;// Latent heat of eutectic mixture at 3
    bar

Q = m_l*Cp*(T2 -T1);// in Watts
m = Q/h;// in kg/s
printf('The mass flow rate of dry saturated eutectic
    mixture is %.2f kg/s',m)
```

Scilab code Exa 5.13 Heat transfer coefficients

```
clear ;
clc;
// Example 5.13
printf('Example 5.13\n\n');
printf('Page No. 131\n\n');

// given
T = 300;// in degree celcius
v = 2;// velocity in m/s
d = 40*10^-3;// diameter in m

// From the table 5.3 and 5.4 given in the  book
K_d = [2.80 2.65 2.55 2.75]// in W/m^2-k
Re = [117*10^3 324*10^3 159*10^3 208*10^3]//Reynolds
    number
Pr = [12 4.50 10.0 7.3]//Prandtl Number

// By Dittus-Boelter Equation
//Nu = 0.0232 * Re^0.8*Pr^0.3 = (hd)/K
//h =  0.0232 * Re^0.8*Pr^0.3 *(K/d)

h_T = 0.0232 * Re(1)^0.8*Pr(1)^0.3*K_d(1);// //W/m
   ^2-K
printf('The film heat transfer coefficient using
   Transcal N is %.0f W/sq.m K \n',h_T)// Deviation
   in answer due to direct substitution


h_D = 0.0232 * Re(2)^0.8*Pr(2)^0.3*K_d(2);// //W/m
   ^2-K
printf('The film heat transfer coefficient using
   Dowtherm A is %.0f W/sq.m K \n\n',h_D)//
```

```
Deviation in answer due to direct substitution


h_M = 0.0232 * Re(3)^0.8*Pr(3)^0.3*K_d(3);// //W/m^2-K
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


h_S = 0.0232 * Re(4)^0.8*Pr(4)^0.3*K_d(4);// //W/m^2-K
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

```
clear ;
clc;
// Example 5.14
printf('Example 5.14\n\n');
printf('Page No. 137\n\n');

// given
T1 = 25;// Wet-bulb temperature in degree celcius
T2 = 40;//Dry-bulb temperature in degree celcius

//By using the humidity chart and steam tables for air-water mixtures at the given temperatures, the all following data can be obtained

//(a) humidity
w = 0.014;// in kg/kg
printf('the required humidity is %.3f kg/kg \n',w)
```

```
//(b) relative humidity
R_H = 30;// in percentage
printf('the required relative humidity in percentage
    is %.0f\n\n',R_H)

//(c) the dew point
T_w = 20;// in degree celcius
printf('the required dew-point temperature is %.0f
   deg C\n',T_w)

//(d) the humid heat
Cpa = 1.006*10^3;// Heat Capacity of bone dry air in
    J/kg-K
Cpwv = 1.89*10^3;// Heat Capacity of water vapour in
    J/kg-K
S = Cpa + (w*Cpwv);//in J/kg-K
printf('the humid heat is %.0f J/kg-K\n\n',S )

//(e) the humid volume
V_G = ((1/29)+(w/18))*22.41*((T2 + 273)/273);//in m
   ^3/kg
printf('the humid volume is %.3f m^3/kg \n',V_G)

//(f) adiabatic process
w_A = 0.020;// in kg/kg
printf('the humidity of the mixture if saturated
   adiabatically is %.3f kg/kg \n\n',w_A)

// (h) isothermal process
w_i = 0.049;// in kg/kg
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

```
clear ;
clc;
// Example 5.15
printf('Example 5.15\n\n');
printf('Page No. 137\n\n');

// given
T = 25;// Wet-bulb temperature in degree celcius
T1 = 30;//Dry-bulb temperature in degree celcius
V = 5;// Volumetric flow rate of initial air-water
    mixture in m^3/s
T2 = 70;// Final Dry-bulb temperature in degree
    celcius

//By using the humidity chart and steam tables for
    air-water mixtures at the given temperatures, the
     all following data can be obtained
w = 0.018;// humidity at 25/30 degree celcius in kg/
    kg
Cpa_1 = 1.00*10^3;// Heat Capacity of bone dry air
    at 30 degree celcius in J/kg-K
Cpwv_1 = 1.88*10^3;// Heat Capacity of water vapour
     at 30 degree celcius in J/kg-K
Cpa_2 = 1.008*10^3;// Heat Capacity of bone dry air
    at 70 degree celcius in J/kg-K
Cpwv_2 = 1.93*10^3;// Heat Capacity of water vapour
    at 70 degree celcius in J/kg-K
lo = 2.50*10^6;//  Specifc Latent heat of
    vapourisation  of water at 0 degree celcius in J/
    kg

S_1 = Cpa_1 + (w*Cpwv_1);// the humid heat at 30
    degree celcius in J/kg-K
S_2 = Cpa_2 + (w*Cpwv_2);//the humid heat at 70
    degree celcius in J/kg-K

```

```
hG_1 = ((S_1*T1) + (w*lo));//the specific enthalpy at 30 degree celcius in J/kg
hG_2 = ((S_2*T2) + (w*lo));//the specific enthalpy at 70 degree celcius in J/kg
VG_1 = ((1/29)+(w/18))*22.41*((T1 + 273)/273);// Humid volume at 30 degree celcius in m^3/kg
m = V/VG_1;// Mass flow rate in kg/s
Q = m*(hG_2 - hG_1);// in Watts
printf('The required heat is %3.2f W \n',Q)// Deviation in answer is due to some approximation in calculation in the book

w_2 = w;// given in the question
VG_2 = ((1/29)+(w_2/18))*22.41*((T2 + 273)/273);// Humid volume at 70 degree celcius in m^3/kg
V_f = m*VG_2;;// in m^3/s
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

```
clear ;
clc;
// Example 6.1
printf('Example 6.1\n\n');
printf('Page No. 142\n\n');

// given
L = 2.5;// Length of tubes in metre
Do = 10*10^-3;// Internal diameter of tubes in metre
m = 3.46;// mass flow rate in kg/s
Th = 120;// Temperature of condening steam in degree celcius
Tl_i = 20;// Inlet temperature of liquid in degree celcius
Tl_o = 80;// Outlet temperature of liquid in degree celcius
Cp = 2.35*10^3;// Specific heat capacity of liquid in J/kg-K
U = 950;// Overall heat transfer coefficent in W/m^2-K

```

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

Scilab code Exa 6.2 Number of tube passes

```
clear ;
clc;
// Example 6.2
printf('Example 6.2\n\n');
printf('Page No. 142\n\n');

// given
v = 1.50;// velocity in m/s
N_t = 100;// Number of tubes
Do = 10*10^-3;// Internal diameter of tubes in metre
m = 3.46;// mass flow rate in kg/s
p = 1180;// density in kg/m^3

A = (N_t*%pi*Do^2)/4;// otal cross-sectional area in
     m^2
V = m/p;//Volumetric flow rate in m^3/s
Fv = V/A;// Fluid velocity in m/s
N_p = v/Fv;
printf('the number of passes is %.0f',N_p)
```

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

```
clear ;
clc;
// Example 6.3
printf('Example 6.3\n\n');
printf('Page No. 144\n\n');

// given
Th_i = 130;//Inlet temperature of hot liquid in degree celcius
Th_o = 90;// Outlet temperature of hot liquid in degree celcius
Tc_i = 20;// Inlet temperature of cold liquid in degree celcius
Tc_o = 50;// Outlet temperature of cold liquid in degree celcius

//For Couter-current flow
T1 = Th_i - Tc_o;
T2 = Th_o - Tc_i;
Tm_1 = ((T2-T1)/log(T2/T1));
printf('The logarithmic mean temperature difference for counter-current flow is %.0f degree celcius \n',Tm_1)


//For Co-current flow
T3 = Th_i - Tc_i;
T4 = Th_o - Tc_o;
Tm_2 = ((T3-T4)/log(T3/T4));
printf('The logarithmic mean temperature difference for co-current flow is %.0f degree celcius \n',Tm_2)
```

Scilab code Exa 6.4 Combustion theory

```
clear ;
clc;
// Example 6.4
printf('Example 6.4\n\n');
printf('Page No. 147\n\n');

// given
F = 1;// Fuel feed required in kg
//By ultimate analysis of feed
C = 0.86;// Carbon percentage - [%]
H2 = 0.05;// Hydrogen percentage - [%]
S = 0.001;// Sulphur percentage - [%]
O2 = 0.08;// Oxygen percentage - [%]

w_C = 12; // mol. weight of C
w_H2 = 2; //mol. weight of H2
w_O2 = 32; // mol. weight of O2
w_S = 32; //mol. weight of S
//Basis- Per kg of fuel
mol_C = C / w_C;// kmol of C
mol_H2 = H2 /w_H2;//kmol of H2
mol_O2 = O2 /w_O2;//kmol of O2
mol_S = S /w_S;//kmol of S
//Calculation of excess air
C_req = mol_C*1;//O2 required by entering C given by reaction C+O2->CO2 in kmol
H_req = mol_H2*0.5;//O2 required by entering H2 given by reaction H2+(1/2)O2->H20 in kmol
S_req = mol_S*1;//O2 required by entering S given by reaction S+O2->SO2 in kmol
O2_req = (C_req + H_req + S_req) - mol_O2;// in kmol
printf('Total number of kmol of O2 required per kg of fuel is %3.3f kmol \n',O2_req)
m_O2 = O2_req*w_O2;// Mass of O2 required per kg of fuel
printf('Mass of O2 required per kg of fuel is %3.1f kg \n\n',m_O2)
//Calculation of air
```

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

Scilab code Exa 6.5 Combustion of coal

```
clear ;
clc;
// Example 6.5
printf('Example 6.5\n\n');
printf('Page No. 148\n\n');

// given
F = 1;// Weight of coal in kg
//By analysis of coal in weight basis
C = 0.74;// Carbon percentage - [%]
H2 = 0.05;// Hydrogen percentage - [%]
S = 0.01;// Sulphur percentage - [%]
N2 = 0.001;// Nitrogen percentage - [%]
O2 = 0.05;// Oxygen percentage - [%]
H2O = 0.09;// Moisture percentage - [%]
```

```
Ash = 0.05;// Ash percentage - [%]

w_C = 12; // mol. weight of C
w_H2 = 2; //mol. weight of H2
w_O2 = 32; // mol. weight of O2
w_S = 32; //mol. weight of S
//Basis- Per kg of fuel
mol_C = C / w_C;// kmol of C
mol_H2 = H2 /w_H2;//kmol of H2
mol_O2 = O2 /w_O2;//kmol of O2
mol_S = S /w_S;//kmol of S
//Calculation of excess air
C_req = mol_C*1;//O2 required by entering C given by reaction C+O2->CO2 in kmol
H_req = mol_H2*0.5;//O2 required by entering H2 given by reaction H2+(1/2)O2->H20 in kmol
S_req = mol_S*1;//O2 required by entering S given by reaction S+O2->SO2 in kmol
O2_req = (C_req + H_req + S_req) - mol_O2;// Total number of kmol of O2 required per kg of fuel in kmol
m_O2 = O2_req*w_O2;// Mass of O2 required per kg of fuel
printf('Mass of O2 required per kg of fuel is %3.2f kg \n',m_O2)
//Calculation of air
m_air = m_O2/0.232;// in kg
printf('Mass of air required per kg of fuel is %3.1f kg \n',m_air')
//Considering air as an ideal gas,calculating volume of air by ideal gas equation-P*V = n*R*T
R = 8310;//Universal gas constant in J/kmol-K
T = (273+0);// in K
P = 1.013*10^5;// in N/m^2
n = 1;// 1 kmol of air
V_kmol = (n*R*T)/P;// In m^3/kmol
M_air = 29;// Mol. weight of air
V_kg = V_kmol/M_air;// in m^3/kg
```

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

Scilab code Exa 6.6 Flue gas analysis

```
clear ;
clc;
// Example 6.6
printf('Example 6.6\n\n');
printf('Page No. 149\n\n');

// given
F = 1;// Fuel feed in kg
C = 0.86;// Mass of Carbon in kg
H2 = 0.05;// Mass of Hydrogen in kg
S = 0.01;// Mass of Sulphur in kg
O2 = 0.08;// Mass of Oxygen in kg

w_C = 12; // mol. weight of C
w_H2 = 2; //mol. weight of H2
w_O2 = 32; // mol. weight of O2
w_S = 32; //mol. weight of S
//Basis- Per kg of fuel
mol_C = C / w_C;// kmol of C
mol_H2 = H2 /w_H2;//kmol of H2
mol_O2 = O2 /w_O2;//kmol of O2
mol_S = S /w_S;//kmol of S
//By kmol of product
CO2 = mol_C*1;// CO2 formed by the reaction C + O2
   -> CO2
H2O = mol_H2*1;// H2O formed by the reaction H2 +
   (1/2)O2 -> H2O
SO2 = mol_S*1;// SO2 formed by the reaction S + O2
   -> SO2
```

```
Pdt = CO2 + H2O + SO2;// Total kmol of combustion products in kmol
//Calculation of excess air
C_req = mol_C*1;//O2 required by entering C given by reaction C+O2->CO2 in kmol
H_req = mol_H2*0.5;//O2 required by entering H2 given by reaction H2+(1/2)O2->H20 in kmol
S_req = mol_S*1;//O2 required by entering S given by reaction S+O2->SO2 in kmol
O2_req = (C_req + H_req + S_req) - mol_O2//  Total number of kmol of O2 required per kg of fuel in kmol

N2 = (O2_req*79)/21;// in kmol (considering air consists of 79% N2 and 21% O2 by moles)
Wet_pdts = Pdt + N2;// Wet combustion products in kmol

//Considering air as an ideal gas,calculating volume of air by ideal gas equation-P*V = n*R*T
R = 8310;//Universal gas constant in J/kmol-K
T = (273+0);// in K
P = 1.013*10^5;// in N/m^2
n_wet = Wet_pdts;// in kmol
V_wet = (n_wet*R*T)/P;// In m^3
n_dry = n_wet - H2O;//in kmol
V_dry = (n_dry*R*T)/P;// In m^3

printf('Volume of wet flue gas is %3.2f m^3 \n',V_wet)
printf('Volume of dry flue gas is %3.2f m^3',V_dry)
```

Scilab code Exa 6.7 Flue gas analysis with Excess air

```
clear ;
```

```
clc;
// Example 6.7
printf('Example 6.7\n\n');
printf('Page No. 150\n\n');

// given
F = 1;// Weight of fuel in kg
e = 0.5;// excess air percentage
C = 0.74;// Mass of Carbon in kg
H2 = 0.05;// Mass of Hydrogen in kg
S = 0.01;// Mass of Sulphur in kg
N2 = 0.001;//Mass of Nitrogen in kg
O2 = 0.05;// Mass of Oxygen in kg
H2O = 0.09;// Mass of Moisture in kg
Ash = 0.05;// Mass of Ash in kg

w_C = 12; // mol. weight of C
w_H2 = 2; //mol. weight of H2
w_O2 = 32; // mol. weight of O2
w_S = 32; //mol. weight of S
w_N2 = 28;// mol. weight of N2
w_H2O = 18;// mol. weight of H2O
//Basis- Per kg of fuel
mol_C = C / w_C;// kmol of C
mol_H2 = H2 /w_H2;//kmol of H2
mol_O2 = O2 /w_O2;//kmol of O2
mol_S = S /w_S;//kmol of S
mol_N2 = N2 /w_N2;//kmol of N2
mol_H2O = H2O /w_H2O;//kmol of H2O

//By kmol of product
CO2 = mol_C*1;// CO2 formed by the reaction C + O2 -> CO2
H2O_air = mol_H2*1;// H2O formed by the reaction H2 + (1/2)O2 -> H2O
SO2 = mol_S*1;// SO2 formed by the reaction S + O2 -> SO2
Pdt = CO2 + H2O_air + SO2 + mol_N2 + mol_H2O;//
```

```
Total kmol of combustion products in kmol
//Calculation of excess air
C_req = mol_C*1;//O2 required by entering C given by reaction C+O2->CO2 in kmol
H_req = mol_H2*0.5;//O2 required by entering H2 given by reaction H2+(1/2)O2->H20 in kmol
S_req = mol_S*1;//O2 required by entering S given by reaction S+O2->SO2 in kmol
O2_req = (C_req + H_req + S_req) - mol_O2;// Total number of kmol of O2 required per kg of fuel in kmol

Ex_O2 = O2_req*e;//  Amount of excess oxygen in kmol

N2_air = (O2_req*(1+e)*79)/21;// in kmol (considering air consists of 79% N2 and 21% O2 by moles)
N2_flue = mol_N2 + N2_air;// Total N2 in flue gas in kmol
H2O_flue =  mol_H2O+ H2O_air;// Total H2O in flue gas in kmol

T_wet = CO2 + H2O_flue + SO2 + Ex_O2 + N2_flue;// Total components of flue gas on a wet basis in kmol
T_dry = CO2 + SO2 + Ex_O2 + N2_flue;//Total components of flue gas on a dry basis in kmol
H2O_dry = 0;
C_wet = ((CO2 / T_wet)*100);// in percentage
H_wet = ((H2O_flue/T_wet)*100);// in percentage
S_wet = ((SO2/T_wet)*100);// in percentage
N_wet = ((N2_flue/T_wet)*100);// in percentage
O_wet = ((Ex_O2/T_wet)*100);// in percentage

C_dry = ((CO2 / T_dry)*100);// in percentage
H_dry = ((H2O_dry/T_dry)*100);// in percentage
S_dry = ((SO2/T_dry)*100);// in percentage
N_dry = ((N2_flue/T_dry)*100);// in percentage
```

```
O_dry = ((Ex_O2/T_dry)*100);// in percentage
T1 = C_wet + H_wet + S_wet + N_wet + O_wet;// in percentage
T2 = C_dry + S_dry + N_dry + O_dry;// in percentage
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)
//Deviation in answes is due to some calculation approxiamation in the book.
```

Scilab code Exa 6.8 Calorific Values

```
clear ;
clc;
// Example 6.8
printf('Example 6.8\n\n');
printf('Page No. 156\n\n');

// given
H = 0.05;// Hydrogen percentage - [%]
O = 0.08;// Oxygen percentage - [%]
C = 0.86;// Carbon percentage - [%]
S = 0.001;// Sulphur percentage - [%]

G_CV = ((33.9*C)+143*(H-(O/8))+(9.1*S))*10^6;
printf('The gross calorific value is %3.2e J/kg \n',
```

```
G_CV)


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

Scilab code Exa 6.9 Boiler efficiency

```
clear ;
clc;
// Example 6.9
printf('Example 6.9\n\n');
printf('Page No. 157\n\n');

// given
P = 10;// Boiler pressure in bar
Ts = 180;// Steam temperature in degree celcius
Tf = 80;// Feed water temperature in degree celcius
X = 0.95;// Steam dryness fraction
m_s = 4100;// steam rate in kg/h
m_f = 238;// Gas rate in kg/h
G_CV = 53.5*10^6;// In J/kg
N_CV = 48*10^6;//in J/kg

//from steam table ,AT 10 bar and at temperature T = Ts
h2 = (763+(X*2013))*10^3;//Specific enthalpy of steam in J/kg
//At temperature T = Tf
h1 = 335*10^3;//Specific enthalpy of feed steam in J/kg

E_G = ((m_s*(h2-h1)*100)/(m_f*G_CV));//
printf('The gross efficiency  percentage is %.0f \n',E_G)
```

```


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

Scilab code Exa 6.10 Equivalent evaporation

```
clear ;
clc;
// Example 6.10
printf('Example 6.10\n\n');
printf('Page No. 158\n\n');

// given
//for Boiler-1
P_1 = 15;// Boiler pressure in bar
Ts_1 = 300;// Steam temperature in degree celcius
Tf_1 = 80;// Feed water temperature in degree
    celcius
X_1 = 0;// Steam dryness fraction
m_s1 = 9000;// steam rate in kg/h
m_f1 = 700;// Gas rate in kg/h
G_CV1 = 43.0*10^6;// In J/kg
//from steam table,at P = 15 bar and at given
    temperatures
h2_1 = 3039*10^3;//Specific enthalpy of steam in J/
    kg
h1_1 = 335*10^3;//Specific enthalpy of feed steam in
     J/kg

E_G1 = ((m_s1*(h2_1-h1_1)*100)/(m_f1*G_CV1));//
printf('The gross efficiency  percentage is %.0f \n'
    ,E_G1)
Ee_1 = ((m_s1/m_f1)*(h2_1-h1_1))/(2257*10^3);
printf('the  equivalent evaporation for boiler-1 is
```

```
%3.1f kg \n\n',Ee_1)

//for Boiler-2
P_2 = 10;// Boiler pressure in bar
Ts_2 = 180;// Steam temperature in degree celcius
Tf_2 = 60;// Feed water temperature in degree
    celcius
X_2 = 0.96;// Steam dryness fraction
m_s2 = 7000;// steam rate in kg/h
m_f2 = 510;// Gas rate in kg/h
G_CV2 = 43.0*10^6;// In J/kg
//from steam table,AT 10 bar and at temperature T =
    Ts_2
h2 = (763+(X_2*2013))*10^3;//Specific enthalpy of
    steam in J/kg
//At temperature T = Tf_2
h1 = 251*10^3;//Specific enthalpy of feed steam in J
    /kg

E_G2 = ((m_s2*(h2-h1)*100)/(m_f2*G_CV2));//
printf('The gross efficiency  percentage is %.0f\n',
    E_G2)
Ee_2 = ((m_s2/m_f2)*(h2-h1))/(2257*10^3);
printf('the  equivalent evaporation for boiler-2 is
    %3.1f kg',Ee_2)
```

Scilab code Exa 6.11 Thermal balance sheet

```
clear ;
clc;
// Example 6.11
printf('Example 6.11\n\n');
printf('Page No. 167\n\n');

// given
```

```
m = 10*10^3;// Production of boiler in kg/h
X = 0.95;//Dryness fraction
P = 10;//Pressure ib bar
T_fw = 95;// Feed water temperature in degree celcius
T_mf = 230;// Mean flue gae temperature in degree celcius
T_mb = 25;// Mean boiler house temperature in degree celcius
Coal_c = 900;// Coal consumption in kg/h
A = 0.08;// Ash content in coal
C_c = 0.15;//carbon content in coal
CV_coal = 33.50*10^6;// Calorific value of coal in J
M = 28;// Mass of flue gas per kg coal in kg
Cp = 1.05*10^3;// Mean Specific heat capacity of the flue gas in J/kg-K
CV_c = 34*10^6;// Calorific value of carbon in J/kg

M_s = m/Coal_c;// Mass of steam produced per kg coal in kg
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)
H_f = (M*Cp*(T_mf - T_mb))/10^6;// Heat in flue gas in 10^6 J
H_uc = (A*C_c*CV_c)/10^6;//Heat in unburnt carbon in 10^6 J
h_sup = (CV_coal)/10^6;// Heat supplied by coal in 10^6 J
un_acc = (h_sup - (H_w + H_f + H_uc));// unaccounted heat losses in 10^6 J
a = (h_sup/h_sup)*100;
b = (H_w/h_sup)*100;
c = (H_f/h_sup)*100;
d = (H_uc/h_sup)*100;
e = (un_acc/h_sup)*100;
T = b + c + d + e;
```

```
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

```
clear ;
clc;
// Example 6.12
printf('Example 6.12\n\n');
printf('Page No. 168\n\n');

// given
C_Rate = 2920;// Coal consumption rate in kg/h
S_Rate = 22.5*10^3;// Steam consumption rate in kg/h
Ps = 20;// Steam pressure in bar
Ts = 350;// Steam Temperature in degree celcius
Tf_in = 70;// Feed water temperature inlet economiser in degree celcius
Tf_out = 110;// Feed water temperature outlet economiser in degree celcius
Tm_b = 25;// Mean Boiler house temperature in degree celcius
Tm_f = 260;// Mean exit flue gas temperature in degree celcius
CO2_f = 15.8;// CO2 content of dry exit flue gas by volume
CO_f = 0;// CO content of dry exit flue gas by volume
C_ash = 0.025;// Carbon in ash in [%]
```

```
G = 0.005;// Grit produced in [%]
//Analysis of coal(as fired)
M = 0.105;// Moisture [%]
VM = 0.308;//Volatile matter [%]
FC = 0.497;// FIxed carbon [%]
Ash =0.09;// ASh [%]
C = 0.66;// Carbon percentage - [%]
H2 = 0.042;// Hydrogen percentage - [%]
S = 0.015;// Sulphur percentage - [%]
N2 = 0.012;// Nitrogen percentage - [%]
O2 = 0.076;// Oxygen percentage - [%]
H20 = 0.105;// Moisture percentage - [%]
G_CV = 26.90;// Gross Calorific Value in 10^6 J/kg
CV_C = 33.8*10^6;// Calorif Value of carbon in J/kg
CV_G = 33.8*10^6;// Calorif Value of Grit in J/kg
Ps_l = 20;// Pressure of steam leaving the boiler in
    bar

//(a) Calculation of excess air usage
//(a.1) Theoretical oxygen requirement
F = 1;// Fuel feed required in kg
w_C = 12; // mol. weight of C
w_H2 = 2; //mol. weight of H2
w_S = 32; //mol. weight of S
w_N2 = 28; // mol. weight of N2
w_O2 = 32; // mol. weight of O2
//Basis- Per kg of fuel
mol_C = C / w_C;// kmol of C
mol_H2 = H2 /w_H2;//kmol of H2
mol_S = S /w_S;//kmol of S
mol_N2 = N2 /w_N2;//kmol of N2
mol_O2 = O2 /w_O2;//kmol of O2
//Calculation of excess air
C_req = mol_C*1;//O2 required by entering C given by
    reaction C+O2->CO2 in kmol
H_req = mol_H2*0.5;//O2 required by entering H2
   given by reaction H2+(1/2)O2->H20 in kmol
S_req = mol_S*1;//O2 required by entering S given by
```

```
reaction S+O2->SO2 in kmol
O2_req = (C_req + H_req + S_req) - mol_O2;// in kmol
N2_air = (O2_req*76.8)/23.2;// in kmol (considering air consists of 76.8% N2 and 23.2% O2 )
printf('(a.1) \n')
printf('Total number of kmol of O2 required per kg of fuel is %3.4f kmol \n',O2_req)
printf('N2 associated with O2 is %3.4f kmol \n',N2_air)

//(a.2) Theoretical CO2 content of dry flue gas
T = C_req + S_req + mol_N2 + N2_air;// Total flue gas in kmol
CO2 = (C_req/T)*100;// in [%]
printf('(a.2) \n')
printf('Theoretical CO2 content of dry flue gas in percentage is %3.1f \n',CO2)

//(a.3)Excess air based on CO2 content
Ex_air = ((CO2 - CO2_f)/CO2_f)*100;//  in [%]
printf('(a.3) \n')
printf('Excess air based on CO2 content in percentage is %.0f \n\n',floor(Ex_air))


//(b) Fuel gas components
//(b.1) Composition per kg fuel
w_CO2 = 44;// mol. weight of CO2
w_SO2 = 64;// mol. weight of SO2
// FOR DRY GAS
CO2_d = C_req * w_CO2;// In kg/kg
SO2_d = S_req * w_SO2;// In kg/kg
N2_d = mol_N2 * w_N2;//  N2 from fuel In kg/kg
N2_air_d = N2_air * w_N2;//  N2 from air In kg/kg
T_N2 = N2_d + N2_air_d;// In kg/kg
T_dry = CO2_d + SO2_d + T_N2;// In kg/kg
printf('(b.1) \n')
printf('Composition of dry gas \n')
```

```
printf('CO2       %.3f    \n',CO2_d)
printf('SO2       %.2f    \n',SO2_d)
printf('N2 from fuel       %.2f    \n',N2_d)
printf('N2 from air       %.2f    \n',N2_air_d)
printf('Total dry air       %.2f kg/kg   \n\n',T_dry)

//FOR WET GAS
w_H2O = 18;// mol. weight of H2O
H2O_f = M;//  H2O from fuel
H2O_H2 = mol_H2 * w_H2O;// H2O from H2
T_H2O = H2O_f + H2O_H2;// in kg/kg
printf('Composition of wet gas \n')
printf('H2O from fuel       %.3f    \n',H2O_f)
printf('H2O from H2       %.3f    \n',H2O_H2)
printf('Total H2O in wet gas       %.3f kg/kg   \n\n',
   T_H2O)

//FOR DRY EXCESS AIR
O2_dry_ex = O2_req * w_O2 *0.3;//in kg/kg
N2_dry_ex = N2_air * w_N2 *0.3;//in kg/kg
T_dry_ex = O2_dry_ex + N2_dry_ex;// in kg/kg
printf('Composition of dry excess air \n')
printf('O2       %.3f    \n',O2_dry_ex)
printf('N2       %.3f    \n',N2_dry_ex)
printf('Total dry excess air       %.3f kg/kg   \n\n',
   T_dry_ex)

//(b.2) Enthalpy
// 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
Cp_CO2_T1 = 1.04*10^3;// Specific heat Capacity of
   CO2 at temperature Tm_f in J/kg-K
Cp_CO2_T2 = 0.85*10^3;// Specific heat Capacity of
   CO2 at temperature Tm_b in J/kg-K
Cp_SO2_T1 = 0.73*10^3;// Specific heat Capacity of
   SO2 at temperature Tm_f in J/kg-K
```

```
Cp_SO2_T2 = 0.62*10^3;// Specific heat Capacity of SO2 at temperature Tm_b in J/kg-K
Cp_N2_T1 = 1.07*10^3;// Specific heat Capacity of N2 at temperature Tm_f in J/kg-K
Cp_N2_T2 = 1.06*10^3;// Specific heat Capacity of N2 at temperature Tm_b in J/kg-K
Cp_O2_T1 = 0.99*10^3;// Specific heat Capacity of O2 at temperature Tm_f in J/kg-K
Cp_O2_T2 = 0.91*10^3;// Specific heat Capacity of O2 at temperature Tm_b in J/kg-K

Cp_dry_T1 = ((CO2_d * Cp_CO2_T1) + (SO2_d * Cp_SO2_T1) + (T_N2 * Cp_N2_T1))/T_dry;// in J/kg-K
Cp_dry_T2 = ((CO2_d * Cp_CO2_T2) + (SO2_d * Cp_SO2_T2) + (T_N2 * Cp_N2_T2))/T_dry;// in J/kg-K
Cp_air_T1 = ((O2_dry_ex * Cp_O2_T1) + (N2_dry_ex * Cp_N2_T1))/T_dry_ex;// in J/kg-K
Cp_air_T2 = ((O2_dry_ex * Cp_O2_T2) + (N2_dry_ex * Cp_N2_T2))/T_dry_ex;// in J/kg-K
printf('(b.2) \n')
printf('Specific heat Capacity of dry gas at 260 deg C is %.0f J/kg-K \n',Cp_dry_T1)
printf('Specific heat Capacity of dry gas at 25 deg C is %.0f J/kg-K \n',Cp_dry_T2)
printf('Specific heat Capacity of dry excess air at 260 deg C is %.0f J/kg-K \n',Cp_air_T1)
printf('Specific heat Capacity of dry excess air at 25 deg C is %.0f J/kg-K \n\n',Cp_air_T2)

// From Steam table or Appendix B.3, Enthalpy of superheated steam is obtained at 260 deg C and 1 bar
E_s = 2995*10^3;//in J/kg-K

//(c) Heat transferred to water
E_w = S_Rate / C_Rate;// Evaporation of water per kg
```

```
    of fuel in kg
E = (E_w*(461 - 293)*10^3)/10^6;// in 10^6 J
B = (E_w*(2797 - 461)*10^3)/10^6;// in 10^6 J
S = (E_w*(3139 - 2797)*10^3)/10^6;// in 10^6 J
printf('(c) \n')
printf('Heat to water in Economiser is %.1f *10^6 J \n',E)
printf('Heat to water in Boiler is %.2f *10^6 J \n',B)
printf('Heat to water in Superheater is %.2f *10^6 J \n\n',S)

//(d) Heat loss in flue gas
hl = 105*10^3;// Enthalpy of steam at 25 deg C (from steam table) in J/kg-K
loss_dry = T_dry*((Tm_f*Cp_dry_T1) - (Tm_b*Cp_dry_T2))/10^6;// in  10^6 J
loss_wet = T_H2O*(E_s - hl)/10^6;// in 10^6 J
loss_ex_air = T_dry_ex*((Tm_f*Cp_air_T1) - (Tm_b*Cp_air_T2))/10^6;// in 10^6 J
printf('(d) \n')
printf('Heat loss in dry flue gas is %.2f *10^6 J \n',loss_dry)
printf('Heat loss in wet flue gas is %.2f *10^6 J \n',loss_wet)
printf('Heat loss in dry excess air is %.2f *10^6 J \n\n',loss_ex_air)

//(e) Heat loss in combustile matter in ash
loss_ash = (Ash * C_ash * CV_C)/10^6;// in 10^6 J
printf('(e) Heat loss in combustile matter in ash is %.2f *10^6 J \n',loss_ash)

//(f) Heat loss in grit
loss_grit = (G * CV_G)/10^6;// in  10^6 J
printf('(f) Heat loss in grit is %.2f *10^6 J \n\n',loss_grit)

```

```
//(g) Radiation and unaccounted heat loss
h_sup = G_CV;// Heat supplied by the coal in 10^6 J
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
a = (h_sup/h_sup)*100;
b = (E/h_sup)*100;
c = (B/h_sup)*100;
d = (S/h_sup)*100;
e = (loss_dry/h_sup)*100;
f = (loss_wet/h_sup)*100;
g = (loss_ex_air/h_sup)*100;
h = (loss_ash/h_sup)*100;
i = (loss_grit/h_sup)*100;
j = (loss_rad/h_sup)*100;
T = b + c + d + e + f + g + h + i + j;
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

```
clear ;
clc;
```

```
// Example 6.13
printf('Example 6.13\n\n');
printf('Page No. 188\n\n');

// given
P = 1.5;// Pressure in bar
T = 111;// Temperature in degree celcius
m = 2;// mass flow rate of process liquid in kg/s
Cp = 4.01*10^3;// Mean Specific heat capacity in J/kg_K
Tl_i = 20;// Inlet temperature of liquid in degree celcius
Tl_o = 90;// Outlet temperature of liquid in degree celcius
Ps = 15;// Pressure of steam in bar
X = 0.97;// Dryness fraction of steam
Pa = 1.5;//Pressure after adiabatic expansion in bar
Ta = 80;// Temperature of injecting condensate in degree celcius

//(a)
Q = m*Cp*(Tl_o - Tl_i);// in W
L = 2227*10^3;// Latent heat of 1.5 bar steam in J/kg
m_a = Q/L;
printf('(a) Mass flow rate of 1.5 bar steam is %.3f kg/s \n',m_a)

//(b)
//from steam table, Specific enthalpy of 0.97 dry 15 bar absolute steam
h = ((843+(X*1946))*10^3);// in J/kg
//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
y = (((2731-2693)*10^3)/((2693-335)*10^3))// in kg/s
m_b = m_a/(1+y);// in kg/s
```

```
printf('(b) Mass flow rate of 15 bar steam is %.3f kg/s \n',m_b)

//(c)
m_c = y*m_b;//in kg/s
printf('(c) Mass flow rate of condensateis %.3f kg/s \n',m_c)

//(d)
v = 30;// steam velocity in m/s
//from steam table
V = 1.16;// Specific volum of 1.5 bar saturated steam in m^3/kg
V_d = V*m_a;// in m^3/s
d = ((V_d*4)/(v*%pi))^0.5;// im m
printf('(d) The vapour main diameter is %3.2f m \n', d)

//(e)
l = 2.5;// Length of tubes in m
d_i = 10*10^-3;// Internal Diameter of tube in m
U = 1500;//  Overall heat transfer coefficent in W/m^2-K

a = %pi*d_i*l;// in m^2
T1 = T - Tl_i;// in degree celcius
T2 = T - Tl_o;// in degree celcius
Tm = ((T2-T1)/log(T2/T1));// logarithmic mean temperature of pipe in  degree celcius
A = Q/(U*Tm);// in m^2
N = A/a;
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

```
clear ;
clc;
// Example 7.2
printf('Example 7.2\n\n');
printf('Page No. 201\n\n');

//From Example 2.1

// given
C= 35000;// cost of boiler  in Pound
C_grant=.25;// Capital grant available from
    goverment
E= -(C-(C_grant*C));// Net expenditure
Fs= 15250;// Fuel Saving
r_i = 0.15;// interest
r_t = 0.55;// tax

a = [0 E Fs 0 E+Fs r_i*(E+Fs) 0 ]
bal_1 = a(5)+a(6)-a(7)// Total Balance after 1st
    year

c_all = 0.55;// capital allowance in 2nd year
C_bal= (bal_1+0+Fs+(-(c_all*E)));// Cash Balance
    after 2nd year
b = [bal_1 0 Fs -(c_all*E) C_bal r_i*C_bal r_t*(Fs+(
    r_i*C_bal))];
bal_2 = b(5)+b(6)-b(7)//Total  Balance after 2nd
    year

c = [bal_2 0 Fs 0 bal_2+Fs r_i*(bal_2+Fs) r_t*(Fs+(
    r_i*(bal_2+Fs)))]
bal_3= c(5)+c(6)-c(7)// Total  Balance after 3rd
```

```
year

if(bal_2>0) then
    disp('Pay back period is of two year')
else
    disp('Pay back period is of three year')
end

printf('Total saving at the end of second year is %3.0f Pound\n',bal_2);
printf('Total saving at the end of third year is %3.0f Pound\n\n',bal_3);
// Deviation in answer due to direct substitution


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

```
clear;
clc;
// Example 7.3
printf('Example 7.3\n\n');
printf('Page No. 203\n\n');

// given
C = 250*10^3;//Original annual cost of fuel in Pound
O_E = 71.5;// Original Efficiency
Fl_i = 20;// Initial Flue loss
```

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

Scilab code Exa 7.4 Furnace efficiency

```
clear;
clc;
// Example 7.4
printf('Example 7.4\n\n');
printf('Page No. 204\n\n');

// This question doesnot contain any calculation
    part.
//Refer figure 7.3, 7.4, 7.5
T_max = 200;// Flue gas exit temperature in degree
    celcius
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
```

```
3.5 years.')
```

Scilab code Exa 7.5 Insulation

```
clear ;
clc;
// Example 7.5
printf('Example 7.5\n\n');
printf('Page No. 205\n\n');

//The temperature difference is not given the
    question.
//Refer Table 7.1
T1 = 1000;// Furnace operating temperature in degree
     celcius
//T2 is  back calculated by the first condition
    given in table 7.1 and applying Fourier,s law of
    condition
T2 = 997.9545;// in degree Celcius()
dT = T1 - T2;// in degree celcius
t = 120;// Continuous cycle time in h
K1 = 44;// Thermal conductivity (W/m-K)
K2 = 11;// Thermal conductivity (W/m-K)
K3 = 4;// Thermal conductivity (W/m-K)
x1 = 250*10^-3;// mm converted into m
x2 = 50*10^-3;// mm converted into m
dT = T1 - T2;// in K

//By Fourier,s law of heat conduction- Q = (dT *K)/x
     in W/sq.m

//For 250 mm firebrick
Q1 = (dT *K1)/x1;// im W/sq.m
printf('Energy losses by 250 mm firebrick is %.0f W/
    sq.m \n',Q1)
```

```

//For 250 mm hot-face insulation
Q2 = (dT *K2)/x1;// im W/sq.m
printf('Energy losses by 250 mm hot-face insulation is %.0f W/sq.m \n',Q2) //Deviation in answer is due to assumption of T2 as its not mentioned in the question

//For 250 mm hot-face insulation backed by 50 mm insulation
//As the resistances are in series - R = (x1/K1)+ (x2/K2) and Q = dt/R in W/sq.m
R = (x1/K2)+ (x2/K3);// in ohm
Q3 = dT/R;// in W/sq.m
printf('Energy losses by 250 mm hot-face insulation backed by 50 mm insulation is %.0f 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

```
clear ;
clc;
// Example 7.6
printf('Example 7.6\n\n');
printf('Page No. 209\n\n');

// given
P = 150*10^3;// Power of compressor in W
F_load = .78;// full load percentage of the time
Re = .7;//  Heat Recovery
T = 2200;//Compressor operating time in h/year
C = 20*10^-6;// Energy cost in Pound/Wh

H_Re = P*F_load*Re;// in W
```

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

Scilab code Exa 7.7 Steam turbines as alternatives to electric motors

```
clear ;
clc;
// Example 7.7
printf('Example 7.7\n\n');
printf('Page No. 212\n\n');

// given
C_S = 1/10^3;// Cost of steam production in p/Wh
P = 75*10^3;// Power required in W
T = 4*10^3;// Production time in h/year
C_T = 7*10^3;// Cost of turbine in Pound
R_T = 4*10^3;// Annual running cost of turbine in W
C_M = 1.5*10^3;// Cost of electric motor in Pound
R_M = 14*10^3;// Running cost of electric motor in
    Pound
C_M_A = 3.5/10^3;// Auunal running cost of electic
    motor in p/Wh
Save_R = R_M - R_T;// in Pound per year
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

```
clear ;
```

```
clc;
// Example 7.8
printf('Example 7.8\n\n');
printf('Page No. 214\n\n');

// given
m_s = 5.3;// Factory requirement of process steam in
    kg/s
Pr_s_1 = 2.5;// Pressure of process steam at bar
    absolute
E_load_1 = 1.10*10^3;// Electrical load requirement
    in W
E_load_2 = 1.5*10^3;// Electrical load requirement
    in W
m_e = 6.0;// Mass flow rate of generated electricity
    in kg/s
Pr_e = 14;// Pressure of generated electricity at
    bar absolute
T_heat = 2.790*10^6;// Total heat content in J/kg

//The 14 bar absolute steam would undergo an
    adiabatic heat drop and the steam will be
    expanded
h_drop = 306*10^3;// Adiabatic heat drop in J/kg
Pr_2 = 2.5;// Expanded pressure at bar absolute
Ex_stm = 0.11;// Exhaust steam percent
Ef_T = 0.65;// Tubine efficiency
R_h_drop = h_drop * Ef_T;// Real heat drop in J/kg
P_T = m_e * R_h_drop;// Power generated by turbine
    in W
Ef_G = 0.94;// Generator efficiency
P_G = 1.13*10^6;// Output of generator in W

//(a) Combined heat and power system
Eq_Eva = 8;// Equivalent evaporation of steam per kg
    coal in kg
C_req = m_e/Eq_Eva;// in kg/s
printf('Coal Required is %.2f kg/s\n',C_req)
```

```
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')

//(b) Coal required for process steam
// for low pressure steam
Eq_Eva_2 = 8.25;// Equivalent evaporation of steam
    per kg coal in kg
Coal_req = m_s/Eq_Eva_2;// in kg/s
printf('Coal Required is %.3f kg/s\n\n',Coal_req)
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')

//(c)Electrical Power
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

```
clear ;
clc;
// Example 8.1
printf('Example 8.1\n\n');
printf('Page No. 222\n\n');

// given
V = 240;// Voltage in Volts
I = 8;// Current in Amps
//By ohm's law-> V = I*R
R = V/I;// In ohms
printf('The resistance of the given circuit is %.0f
    ohms',R)
```

Scilab code Exa 8.2 Kirchhoff law

```
clear ;
clc;
```

```
// Example 8.2
printf('Example 8.2\n\n');
printf('Page No. 223\n\n');

// given
V1 = 100;// In Volts
V2 = 50;// In Volts
R1 = 8;// Resistance in ohm
R2 = 5;// Resistance in ohm
R3 = 10;// Resistance in ohm
R4 = 50;// Resistance in ohm
//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 :
// I1 = I2 + I3
//V1 - R1*I1 - V2 - R3*I3 = 0
//V2 - R4*I3 + R3*I3 - R2*I2 = 0
A = [1 -1 -1;8 0 10;0 55 -10];
b = [0;50;50];
x = A\b
printf('The currents in I1 is %.1f A \n',x(1))
printf('The currents in I2 is %.1f A \n',x(2))
printf('The currents in I3 is %.1f A \n ',x(3))
```

Scilab code Exa 8.3 Power factor

```
clear ;
clc;
// Example 8.3
printf('Example 8.3\n\n');
printf('Page No. 226\n\n');

// given
R = 6;// Resistance in ohm
```

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

Scilab code Exa 8.4 Cost of electrical energy

```
clear ;
clc;
// Example 8.4
printf('Example 8.4\n\n');
printf('Page No. 232\n\n');

//given
pump_1 = 100*10^3;// Required pump in W
T_1 = 8;// Pump Operating time of each day
Inc_op = 0.5;// Increased output per cent
pump_ex = 50*10^3;// Extra pump requried in W

// This question doesnot contain any calculation part.
printf('there is no computational part in the problem')
```

Scilab code Exa 8.5 Annual saving

```
clear ;
clc;
// Example 8.5
printf('Example 8.5\n\n');
printf('Page No. 232\n\n');

//given
P = 600*10^3;// Power demand of pump in W
T = 8;// Operating time in hour per day
red = 1.00/10^3;// off-peak reduction in Pound per 10^3 W month
M_save = P*red;//  Monthly saving Pound per month
A_save = M_save*12;// Annual saving in Pound per year
printf('Annual saving is %.0f Pound per year',A_save)
```

Scilab code Exa 8.6 Illumination

```
clear ;
clc;
// Example 8.6
printf('Example 8.6\n\n');
printf('Page No. 234\n\n');

//given
T_lamp = 12*10^3;// Output for the tungsten filament lamp in lm per 10^3 W
F_tube = 63*10^3;// Output for the fluorescent tubes in lm per 10^3 W
```

```
Save = F_tube - T_lamp;//  in W
printf('Energy saving is %.0f lm per 10^3 W \n',Save
   )

Save_pcent = (Save/F_tube)*100;
printf('Energy saving per cent is %.0f ',floor(
   Save_pcent))
```

Scilab code Exa 8.7 Natural lighting

```
clear ;
clc;
// Example 8.7
printf('Example 8.7\n\n');
printf('Page No. 235\n\n');

//given
N = 40;// Number of lamps
T1 = 15;// Operating time in h per day
P = 500;// POwer from the lamps in W
T2 = 300;// Total operating time in days per year
C = 2.5/10^3;// Electricity cost in p per Wh

An_Cost = N*P*T1*T2*C*10^-2;// In euro
printf('The Annual Cost is %.0f Euro \n',An_Cost)

//Improvement in light by installing glassfibre
   skylights
T3 = 5;//   Extra Time for natural lighting in h per
    day
New_An_Cost = N*P*(T1-T3)*T2*C*10^-2;// In euro
printf('The New Annual Cost is %.0f Euro \n',
   New_An_Cost)

Save = An_Cost - New_An_Cost;// in euro
```

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

Scilab code Exa 8.8 Motive power and power factor improvement

```
clear ;
clc;
// Example 8.8
printf('Example 8.8\n\n');
printf('Page No. 236\n\n');

// This question doesnot contain any calculation
    part.

//By refering figure 8.7 which shows Poer factor-
    load curve for a motor with a capacitor and one
    without a capacitor.
printf('there is no computational part in the
    problem')
```

Scilab code Exa 8.9 Capacitor rating

```
clear ;
clc;
// Example 8.9
printf('Example 8.9\n\n');
printf('Page No. 238\n\n');

// This question doesnot contain any calculation
    part.
//given
l = 500*10^3;// Load in VA
P_F = 0.6;// Power Factor
```

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

Scilab code Exa 8.10 Effects of power factor improvement

```
clear ;
clc;
// Example 8.10
printf('Example 8.10\n\n');
printf('Page No. 240\n\n');

P = 100;// Power in 10^3 W
C = 5;// Charge in Euro per 10^3 per month
PF = [1.0 0.9 0.8 0.7 0.6 0.5];// Power factor
for i = [1:1:6]
    VA = (PF(i)\P)*C
    printf('Charge per month for power factor %.1f
        is %.0f Euro \n', PF(i),VA)
end
```

Scilab code Exa 8.11 Effects of power factor improvement

```
clear ;
clc;
// Example 8.11
printf('Example 8.11\n\n');
printf('Page No. 240\n\n');

```

```
// This question doesnot contain any calculation
   part.
//given
P_F_1 = 0.7;// Initial power factor
P_F_2 = 0.95;// Final power factor
//Refer Figure 8.10
red_I = 26;//reduction in current in per cent
printf('The reduction in current is %.0f per cent \n
   ',red_I)
P_F_3 = 1.0;// Increased power factor
// From figure 8.10
Save = 4;// per cent
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

```
clear ;
clc;
// Example 8.12
printf('Example 8.12\n\n');
printf('Page No. 240\n\n');

// This question doesnot contain any calculation
   part.
//given
C = 10000;// Installation cost of capacitors in
   Pound
P_F_1 = 0.84;// Initial power factor
P_F_2 = 0.97;// Final power factor
//Refer Figure 8.10
red_dem = 14;//reduction in maximum demand in per
   cent
T = 9;// pay-back time in months
```

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

Scilab code Exa 8.13 Optimum start control

```
clear ;
clc;
// Example 8.13
printf('Example 8.13\n\n');
printf('Page No. 244\n\n');

//given
T1 = 21;// in degree celcius
t1 = 8;// time in h per day
c = 3.5;// cost in p per unit
C1 = 38;// Total cost in Pound per 10^3 W

T2 = 16;// in degree celcius
t2 = 8;// time in h per day
C2 = 27;// Total cost in Pound per 10^3 W

Save = C1 - C2;// Saving in Pound per 10^3 W
Save_deg = Save/(T1 - T2);// Total Saving in Pound
    per 10^3 W for each degree drop
Save_per = (Save_deg/C1)*100;// Saving in percent
printf('For each degree drop, an energy saving of %
    .0f per cent is achieved',floor(Save_per))
```

Scilab code Exa 8.14 Induction heating

```
clear ;
clc;
// Example 8.14
printf('Example 8.14\n\n');
printf('Page No. 245\n\n');

// This question doesnot contain any calculation
   part.
//refer Table 8.6
O_1 = 1750;
O_2 = 0;
O_3 = 2;
O_4 = 150;
O_5 = 1900;
O_6 = 0;
I_1 = 580;
I_2 = 1658;
I_3 = 0.5;
I_4 = 40;
I_5 = 1698;
I_6 = 11;
D_1 = 300;
D_2 = 869;
D_3 = 0.5;
D_4 = 40;
D_5 = 900;
D_6 = 37;
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,
```

```
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

```
clear ;
clc;
// Example 8.15
printf('Example 8.15\n\n');
printf('Page No. 247\n\n');

// This question doesnot contain any calculation
   part.
//refer Table 8.7
El = 35;// Percentage of electricity produced from
   primary fuel
En_1 = 50;// Endothermic gas (m^3)
En_2 = 100;// Endothermic gas (m^3)
En_3 = 200;// Endothermic gas (m^3)
G_1 = 97;// Gas use (10^3 Wh)
G_2 = 194;// Gas use (10^3 Wh)
G_3 = 386;// Gas use (10^3 Wh)
El_1 = 24;// Electricity use (10^3 Wh)
El_2 = 48;// Electricity use (10^3 Wh)
El_3 = 95;// Electricity use (10^3 Wh)
P_1 = 69;// Primary energy (10^3 Wh)
P_2 = 137;// Primary energy (10^3 Wh)
P_3 = 271;// Primary energy (10^3 Wh)
printf('    USE OF ELECTRICITY AND GAS FOR HEATING
   ENDOTHERMIC GAS GENERATORS\n\n  Endothermic gas (
   m^3) \t %.0f \t %.0f \t %.0f \n  Gas use (10^3 Wh
   )        \t %.0f \t %.0f \t %.0f \n  Electricity
   use (10^3 Wh) \t %.0f \t %.0f \t %.0f \n  Primary
    energy (10^3 Wh) \t %.0f \t %.0f \t %.0f \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

```
clear;
clc;
// Example 9.1
printf('Example 9.1\n\n');
printf('Page No. 252\n\n');

//given
a = 40;// in m
b = 25;// in m
c = 20;// in m
d = 10;// in m
e = 5;// in m
f = 2;// in m
g = 3;// in m
h = 6;// in m

//(1) Production Area
T1 = 21;// Temperature difference in degree celcius
T2 = -3;// Temperature difference in degree celcius
U1 = 1.2;// heat transfer coefficent in W/m-K
U2 = 5.6;// heat transfer coefficent in W/m-K
```

```
U3 = 2.0;// heat transfer coefficent in W/m-K
U4 = 0.7;// heat transfer coefficent in W/m-K
U5 = 0.9;// heat transfer coefficent in W/m-K
// As Q = U*A*T
Q1 = (b*h)*U1*T1;// Heat loss in W. wall in W
Q2 = (((a-c)*h) + (d*h) + (d*f))*U1*T1;// Heat loss in N. wall in W
Q3 = (c*f)*U2*T1;// Heat loss in N. window in W
Q4 = (b*g)*U3*T2;// Heat loss in N. wall/internal in W
Q5 = (b*g)*U1*T1;// Heat loss in E. wall/external in W
Q6 = (((a-c)*h) + (d*h) + (d*f))*U1*T1;// Heat loss in S. wall in W
Q7 = (c*f)*U2*T1;// Heat loss in S. window in W
Q8 = (b*a)*U4*T1;// Heat loss in roof in W
Q9 = (b*a)*U5*T1;// Heat loss in floor in W
T_Q_P = Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7 + Q8 + Q9; // in W

//For Office surface
T3 = 24;// Temperature difference in degree celcius
T4 = 3;// Temperature difference in degree celcius
// As Q = U*A*T
Q_1 = (b*g)*U3*T4;// Heat loss in W. wall in W
Q_2 = (d*g)*U1*T3;// Heat loss in N. wall in W
Q_3 = (((b-(2*e))*g) +(e*f))*U1*T3;// Heat loss in E. Wall in W
Q_4 = (e*f)*U2*T3;// Heat loss in E. window in W
Q_5 = (e*f)*U2*T3;// Heat loss in E. window in W
Q_6 = (d*g)*U1*T3;// Heat loss in S. wall in W
Q_7 = (b*d)*U4*T3;// Heat loss in S. roof in W
Q_8 = (b*d)*U5*T3;// Heat loss in floor in W
T_Q_O = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8; //in W

T_Q = T_Q_P + T_Q_O;// in W
printf('Total building fabric loss is %.0f W',T_Q)
```

Scilab code Exa 9.2 U value calculation

```
clear ;
clc;
// Example 9.2
printf('Example 9.2\n\n');
printf('Page No. 255\n\n');

//given
L_Br = 0.105;// Length of brickwork in m
L_Bl = 0.100;// Length of blockwork in m
L_C = 0.05;// Length of cavity in m
K_Br = 0.84;// Thermal conductivity of brickwork in W/m-K
K_Bl = 0.22;// Thermal conductivity of blockwork in W/m-K
K_C_in = 0.033;// Thermal conductivity of insulation in cavity in W/m-K
R_Ex = 0.055;// Resistance of external surface in W/m^2-K

//As R = L/K
R_Br = (L_Br/K_Br);// Resistance of brickwork in W/m^2-K
R_Bl = (L_Bl/K_Bl);// Resistance of blockwork in W/m^2-K
R_C = 0.18;// Resistance of cavity in W/m^2-K

//Without insulation of cavity
R_T = 0.938;// Total Resistance in W/m^2-K
// Thermal transmittance - U = (1/R_T)
U = (1/R_T);// in W/m^2-K
printf('The U-value of external wall is %.2f W/sq.m K \n',U)
```

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

Scilab code Exa 9.3 Ventilation loss

```
clear ;
clc;
// Example 9.3
printf('Example 9.3\n\n');
printf('Page No. 256\n\n');

//given
N_1 = 1.5;// Ventilation rate in the production area (air changes per hour)
N_2 = 1.0;//  Ventilation rate in the office suite (air changes per hour)

//From example 9.1
V_P = 6000;// Voulme of production area in m^3
V_O = 750;// Voulme of office suite in m^3
T1 = 21;// Temperature difference in degree celcius
T2 = -3;// Temperature difference in degree celcius
T_P = 18;// Temperature difference in degree celcius
F_loss = 74.4*10^3;// Total fabric loss in W

```

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

Scilab code Exa 9.4 Environmental temperature

```
clear ;
clc;
// Example 9.4
printf('Example 9.4\n\n');
printf('Page No. 260\n\n');

//(a) Design loss
T1 = 18;// Internal teemperature(specified as an Environmental temperature) in degree celcius
//From example 9.1
A = [150 200 40 75 75 200 40 1000 1000];// in m^2
U = [1.2 1.2 5.6 2 1.2 1.2 5.6 0.7 0.9];// in W/m-K
Qf = 58.3*10^3;// Fabric loss in production area in W
T2 = -3;// in degree celcius
s1 =0;
s2 = 0;
for i = [1:1:9]
    s1 = s1+A(i);
    s2 = s2+U(i)*A(i);
end
```

```
A_T = s1;// Total area in m^2
UA_T = s2;// sum of U*A in W/m-K (answer wrongly
    calculated in the book)

//From example 9.3
N_1 = 1.5;// Ventilation rate in the production area
     (air changes per hour)
V_P = 6000;// Voulme of production area in m^3

//As Qvent = C * (T1 - T2) & C = 0.33*N*V*(1 + ((
    UA_T)/(4.8*A_T)))
C = 0.33*N_1*V_P*(1 + ((UA_T)/(4.8*A_T)));
Q_vent = C * (T1 - T2);// in W
T_Q1 = Qf + Q_vent;// in W
printf('The total design loss is %.0f W \n',T_Q1) //
     (deviation in answer is due to error in
    calculation in the book)

//(b) Reduced heat loss
// The heat transfer coeffieint in this problem has
    been changed as U1
U1 = [0.44 0.44 2.8 2 0.44 0.44 2.8 0.44 0.9];//in W
    /m^2-K
T = [21 21 21 -3 21 21 21 21 21];// Temperature
    difference in degree celcius
s3 = 0;
s4 = 0;
for i = [1:1:9]
    s3 = s3+U1(i)*A(i);
    s4 = s4+U1(i)*A(i)*T(i);
end
U1A_T = s3;// in W/m-k (answer wrongly calculated in
     the book)
Q_loss = s4// in W


//As Qvent = C * (T1 - T2) & C = 0.33*N*V*(1 + ((
    UA_T)/(4.8*A_T)))
```

```
C = 0.33*N_1*V_P*(1 + ((U1A_T)/(4.8*A_T)))
Q_vent = C * (T1 - T2)// in W
T_Q2 = Q_loss + Q_vent// in W

Red = T_Q1 - T_Q2;// In W
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

```
clear ;
clc;
// Example 9.5
printf('Example 9.5\n\n');
printf('Page No. 265\n\n');

//given
T = 21;// Temperature difference in degree celcius
Deg_d = 2186;// Total degree-days base(15.5 deg C) September_April
T_D = 18;// Design Temperature in degree celcius
T_O = 4;// base offset temperature in degree celcius
T_b = T_D - T_O;// Base temperature in degree celcius

// 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
C = 0.82;// Correction factor
Do = Deg_d * C// Corrected degree-days

//(a) Original construction
//from example 9.4
Q_d_1 = 133.7*10^3;// Design heat loss in W
```

```

H_1 = Q_d_1/T;
//As E = 24 * H * Do - E = Energy consumption in (Wh)
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)
E_1 = (E1 * 3600)*10^6;// in J
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

//(b) Improved insulation
//from example 9.4
Q_d_2 = 104.4*10^3;// Design heat loss in W

H_2 = Q_d_2/T;
//As E = 24 * H * Do - E = Energy consumption in (Wh)
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)
E_2 = (E2 * 3600)*10^6;// in J
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

```
clear ;
clc;
```

```
// Example 9.6
printf('Example 9.6\n\n');
printf('Page No. 268\n\n');

//given
U1 = 5.6;// Single glazing heat transfer coefficient
    in W/m^2_K
U2 = 2.8;// Double glazing heat transfer coefficient
    in W/m^2_K
Ti = 21;// Internal Temperature in degree celcius
To = -1;// External Temperature in degree celcius
R_H = 0.5;// Relative humidity
Rs_i = 0.123;// Surface resistance in (W/m^2-K)^-1

// At 21 Degree celcius and R.H. = 0.5, the dew
   point is 10.5 degree celcius
Dew_pt = 10.5;// Dew point in degree celcius
//As Ts_i = Ti - (Rs_i * U *(Ti - To))

//(a) Single Glazing
Ts_i_S = Ti - (Rs_i * U1 *(Ti - To));// in degree
   celcius
printf('The internal surface temperature for single
   glazing is %.1f deg C \n',Ts_i_S)
if (Dew_pt > Ts_i_S) then
    disp('Surface condensation will occur since it
       is less than 10.5 deg C.')
else
    disp('No surface condensation is expected as it
       is greater than 10.5 deg C.')
end

//(b) Double Glazing
Ts_i_D = Ti - (Rs_i * U2 *(Ti - To));// in degree
   celcius
printf('The internal surface temperature for single
   glazing is %.1f deg C \n',Ts_i_D)
if (Dew_pt > Ts_i_D) then
```

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

Scilab code Exa 9.7 Interstitial condensataion

```
clear ;
clc;
// Example 9.7
printf('Example 9.7\n\n');
printf('Page No. 269\n\n');

//given
l_1 = 240;// existing length of solid brick in mm
l_u = 25;// upgraded internal lining in mm
l_e = 9.5;// Expanded polystyrenne in mm
T_i = 20;// Internal temperature in degre celcius
R_H_i = 50;// Internal Relative humidity in percent
T_e = 0;// External temperature in degre celcius
R_H_e = 90;// External Relative humidity in percent

K = [0.123 0.059 0.714 0.286 0.055];// Thermal resistance in W/m^2-K
V_r = [0.0 0.475 3.57 9.60 0.0];// Vapour Resistance in 10^9 N-s/kg

//Refer Figure 9.3
//From Figure 9.3, the tempeature, dew point, vapour pressure for different interface are obtained
T = [18.01 17.06 5.51 0.89];// Temperature in degree celcius
V_p = [1170 1148 986 550];//Vapour pressure in N/m^2
```

```
D_P = [9.5 9.2 7.1 -1.5];// Dew point in degree
    celcius

h = (T_i - T_e)/sum(K);// in W/m^2
printf('The heat flow is %.2f W/m^2 \n',h)
V_p_i = V_p(1);// Internal vapour pressure in N/m^2
V_p_e = V_p(4);// External vapour pressure in N/m^2
m = ((V_p_i - V_p_e)/sum(V_r))*10^-9;// in  kg/s
printf('The vapour mass flow is %.1e kg/s',m)
```

Scilab code Exa 9.8 Glazing

```
clear ;
clc;
// Example 9.8
printf('Example 9.8\n\n');
printf('Page No. 275\n\n');

//given
A = 10;// in m^2
S = 0.77;
Sa = 0.54;
//for South
printf('\t\t\t SOUTH \n')
I1 = [200 185 165 155 165 185 200];// in W-m^2
I2 = [500 455 405 385 405 455 500];// in W-m^2
for i = [1:1:7]
A_G_S (i) = (A*I1(i)*S) + (A*I2(i)*Sa)
end

printf('The monthly peak cooling loads for the month
     March is %.0f W \n',A_G_S(1))
printf('The monthly peak cooling loads for the month
     April is %.0f W \n',A_G_S(2))
printf('The monthly peak cooling loads for the month
```

```
    May is %.0f W \n',A_G_S(3))
printf('The monthly peak cooling loads for the month
    June is %.0f W \n',A_G_S(4))
printf('The monthly peak cooling loads for the month
    July is %.0f W \n',A_G_S(5))
printf('The monthly peak cooling loads for the month
    Aug. is %.0f W \n',A_G_S(6))
printf('The monthly peak cooling loads for the month
    Sept. is %.0f W \n\n',A_G_S(7))

 //For east
 printf('\t\t\t EAST \n')
I3 = [110 150 180 190 180 150 110];// in W/m^2
I4 = [435 510 515 505 515 510 435];// in W/m^2
for j = [1:1:7]
A_G_E(j) = (A*I3(j)*S) + (A*I4(j)*Sa);
end
printf('The monthly peak cooling loads for the month
    March is %.0f W \n',A_G_E(1))
printf('The monthly peak cooling loads for the month
    April is %.0f W \n',A_G_E(2))
printf('The monthly peak cooling loads for the month
    May is %.0f W \n',A_G_E(3))
printf('The monthly peak cooling loads for the month
    June is %.0f W \n',A_G_E(4))
printf('The monthly peak cooling loads for the month
    July is %.0f W \n',A_G_E(5))
printf('The monthly peak cooling loads for the month
    Aug. is %.0f W \n',A_G_E(6))
printf('The monthly peak cooling loads for the month
    Sept. is %.0f W \n\n',A_G_E(7))
```

Scilab code Exa 9.9 Design data

```
clear ;
```

```
clc;
// Example 9.9
printf('Example 9.9\n\n');
printf('Page No. 277\n\n');

//given
A = 15;// glazing area in m^2
l = 10;// Length of office in m
h = 6;// height of office in m
w = 3.5;// width of office in m
Y_w = 4;// Admittance of wall in W/m^2-K
Y_f = 3;// Admittance of floor in W/m^2-K
Y_c = 3;// Admittance of ceiling in W/m^2-K
N = 1.5;//Ventilation rate (air changes per hour)
V = l*h*w;// Volume in m^3
U_G = 5.6;// Transmittance in W/m^2-K

//From table 9.18 and table 9.16
To = 16.5;// External temperature of June in degree
    celcius
T_O = 7.5;// Swing temperature in degre celcius
I = 155; //Vertical S in W-m^2
Is = 385;//Vertical S in W-m^2
S = 0.77;// Solar gain factor
Sa = 0.54;// Solar gain factor

//As  For the mean internal temperature -Ti = To +
    ((A*I*S)/((0.33*N*V) + (A*U_G)))
Ti = To + ((A*I*S)/((0.33*N*V) + (A*U_G)));// in
    degree celcius
printf('the mean internal temperature is %.1f deg C
    \n',Ti)

A_G = (A*Is*Sa) + ((A*U_G) + (0.33*N*V))*T_O;//
    Swing in gain in W
Net_A = 2*((w*h) + (l*w)) - A;// Net wall area in m
    ^2
A_f = l*h;// floor area in m^2
```

```
A_c = l*h;//ceiling area in m^2
A_Y_w = Net_A * Y_w;// Wall AY in W/K
A_Y_f = A_f * Y_f;// Floor AY in W/K
A_Y_c = A_c * Y_c;// ceiling AY in W/K
A_Y_wi = 84;// Window AY in W/K
Net_AY = A_Y_w + A_Y_f + A_Y_c + A_Y_wi// in W/K
Ti_s = ((A_G)/((0.33*N*V) + (Net_AY)))// Internal Temperature swing in deg C
T_p = Ti + Ti_s;// in deg C
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

```
clear ;
clc;
// Example 10.1
printf('Example 10.1\n\n');
printf('Page No. 293\n\n');

// given
m = 1;// mass flow rate of initial air mixture in kg
    /s
T = 23.5;// Initial temperature in degree celcius
m1 = 0.6;// Percentage of fresh air mixture
T1 = 5;// Dry Bulb Temperature of  fresh air in
    degree celcius
w1 = 0.005;// Humidity  of fresh air at temperature
    T1 in kg/kg
m2 = 0.4;// Percentage of recirculated air mixture
T2 = 25;// Dry Bulb Temperature of recirculated air
    in degree celcius
w2 = 0.015;// Humidity  of recirculated air at
    temperature T2 in kg/kg

```

```
//In air conditioning => m1*w1 + m2*w2 = m*w
w = (m1*w1 + m2*w2)/m;// in kg/kgs
printf('The humidity of the air mixture  is %.3f kg/kg \n',w)

//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
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
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
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

h_t = (m1*h_f) + (m2*h_r);// Total enthalpy of initial air mixturein J/kg
Q = m*(h_m - h_t);// in Watts
printf('The load on the heater is% .3f W',Q)
// Deviation in answer due to direct substitution and some approximation in answer in book
```

Scilab code Exa 10.2 Sensible cooling

```
clear ;
clc;
// Example 10.2
printf('Example 10.2\n\n');
printf('Page No. 298\n\n');

// given
```

```
m1 = 0.75;// Percentage of fresh air mixture
T1 = 31;// Dry Bulb Temperature of  fresh air in degree celcius
w1 = 0.0140;// Humidity  of fresh air at temperature T1 in kg/kg
m2 = 0.75;// Percentage of recirculated air mixture
T2 = 22;// Dry Bulb Temperature of recirculated air in degree celcius
w2 = 0.0080;// Humidity  of recirculated air at temperature T2 in kg/kg
m = 1.50;// mass flow rate of final air mixture in kg/s
T = 10;// Dew Point temperature in degree celcius

//In air conditioning => m1*w1 + m2*w2 = m*w
w = (m1*w1 + m2*w2)/m// in kg/kgs
printf('The humidity of the air mixture  is %.4f kg/kg \n',w)


// 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
T_w = 26.5;// Dry Bulb temerature in degree celcius
w_10 = 0.0075;// humidity at temperatue T in kg/kg

//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

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
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

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

Chapter 11

Heat recovery

Scilab code Exa 11.1 Shell and tube heat exchangers

```
clear ;
clc;
// Example 11.1
printf('Example 11.1\n\n');
printf('Page No. 308\n\n');

//given
V = 205;// Flow rate in m^3
T1 = 74;// in degree celcius
T2 = 10;// in degree celcius
m = 1000;// Steam in kg
p = 950;// Density of steam in kg/m^3
C = 85;// Cost in Pound per m^3
C_V = 43.3*10^6;// Calorific value in J/kg
Cp = 4.18*10^3;// heat capacity of water J/kg-K
h = 2.33*10^6;// Heat of the steam in J/kg
n = 0.65;// Average bolier efficiency

S_cost = ((m*h*C)/(C_V*p*n));// Steam cost in Pound
    per  1000 kg
E_save = V*m*(T1 - T2)*Cp;// Energy saving in J per
```

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

Scilab code Exa 11.2 Multiple effect evaporation

```
clear ;
clc;
// Example 11.2
printf('Example 11.2\n\n');
printf('Page No. 313\n\n');

//given
p1 = 10;//heat-sensitive liquor percen
p2 = 50;//heat-sensitive liquor percent
m = 0.28;// mass rate in kg/s
t = 150;// time in h per week

// This question does not contain any calculation part in it.
I = [8250 1150 14850 16500];//Installation cost in Pound
A = [69300 36800 23600 24600];// Annual steam cost in Pound
A_S = [A(1)-A(1) A(1)-A(2) A(1)-A(3) A(1)-A(4)];// Annual savings in Pound

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
```

```
(Pound) \t\t (Pound) \t\t (Pound)\n\nSingle effect \t\t %.0f \t\t\t %.0f \t\t\ %.0f \nDouble effect \t\t %.0f \t\t\t %.0f \t\t\ %.0f \nTriple effect + \n(vapour compression) \t %.0f \t\t %.0f \t\t\ %.0f \nTriple effect \t\t %.0f \t\t %.0f \t\t\ %.0f \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))


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

```
clear ;
clc;
// Example 11.3
printf('Example 11.3\n\n');
printf('Page No. 314\n\n');

//given
f = 1;// feed of sodium hydroxide in kg
v = 0.5;// produed vapour in kg
A = 30;// in m^2
T1 = 95;// Temperature of boiling solution in deg C
U = 3*10^3;// heat transfer coefficent in W/m^2-K
m = 1;// feed rate in kg/s
Tf = 70;// Feed temperature in deg C
h_f = 260*10^3;// Enthalpy of feed in J/kg
h_b = 355*10^3;// Enthalpy of boiling solution in J/kg
h_v = 2.67*10^6;// Enthalpy of vapour in J/kg
P1 = 0.6;// Pressure in vapour space in bar
```

```
Q = (v*h_b) + (v*h_v) -(f*h_f);// in W
printf('The total energy requirement is %.0f W \n',Q)

// As Q = A*U*dT
dT = Q/(U*A);// in degree celcius
T2 = dT + T1;// in degree celcius
//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
//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

// from steam table
P2 = 1.4// pressure in bar
h_s = 2.69*10^6;// enthalpy of dry saturated steam in J/kg
h_v2 = 2.84*10^6 ;// the outlet enthalpy of vapour in J/kg

W = v*(h_v2 - h_s);// Work in W
T_E = W + 60*10^3;// in W
printf('The total energy consumption is %.0f W',T_E)
```

Scilab code Exa 11.4 Thermal wheel

```
clear ;
clc;
// Example 11.4
printf('Example 11.4\n\n');
printf('Page No. 316\n\n');

```

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

Scilab code Exa 11.5 Heat pipes

```
clear ;
clc;
// Example 11.5
printf('Example 11.5\n\n');
printf('Page No. 318\n\n');

//From the heat balance:-
//Heat recovered in the boiler = heat gained by the
    air = heat lost by the flue gases
//=> Q = m_a*Cp_a*dT_a = m_f*Cp_f*dT_f
// As mass flow rate of air/flue gas is not given in
    the book
//Assuming m_a = m_f = 2.273 kg/s & Cp_a = 1*10^3 J/
    kg-K

m_a = 2.273;// in kg/s
m_f = m_a;// in kg/s
Cp_a = 1*10^3;// Specific heat capacity of air in J/
    kg-K
T1_a = 20;// Entrance temperature of air in degree
    celcius
T2_a = 130;// Exit temperature of air in degree
    celcius
dT_a = T2_a - T1_a;//in K
```

```
T1_f = 260;// Entrance temperature of flue gases in
    degree celcius
T2_f = 155;// Entrance temperature of flue gases in
    degree celcius
dT_f = T1_f - T2_f;//in K

//From heat balance:- Q = m_a*Cp_a*dT_a = m_f*Cp_f*
    dT_f
Cp_f = ((m_a*Cp_a*dT_a)/(m_f*dT_f));// in J/kg-K
Q = m_f*Cp_f*dT_f;// in W
printf('The total heat recovered at full load if %3
    .2e W',Q)
```

Scilab code Exa 11.6 Heat pumps and COP

```
clear ;
clc;
// Example 11.6
printf('Example 11.6\n\n');
printf('Page No. 320\n\n');

C = 10000;// Installation cost of the pump in Pound
S = 3500;// Saving in Pound per annum
T = C/S;// in year
printf('The pay back time is %.0f year\n\n',T)

// This question further does not contain any
    calculation part in it.
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

```
clear ;
clc;
// Example 11.7
printf('Example 11.7\n\n');
printf('Page No. 320\n\n');

//given
T1 = 40;// in degree
T2 = 0;// in degree celcius
//As from carnot cycle , C.O.P = (T1/(T1 - T2)),
   where temperature are in degree celcius
C_O_P1 = ((T1+273)/((T1+273) - (T2+273)));
printf('C.O.P. is %.1f \n',C_O_P1)

// A secondary fluid as hot water at 60 deg C is
   used
T3 = 60;//  Temperature of hot water in degree
   celcius
C_O_P2 = ((T3+273)/((T3+273) - (T2+273)));
printf('C.O.P. when secondary fluid is used is %.1f
   \n',C_O_P2)
```

Scilab code Exa 11.8 Incineration plant

```
clear ;
clc;
```

```
// Example 11.8
printf('Example 11.8\n\n');
printf('Page No. 323\n\n');

// This question does not contain any calculation
   part in it.
printf('No calculation is required as not in shown
   in book')
```

Scilab code Exa 11.9 Regenerators

```
clear ;
clc;
// Example 11.9
printf('Example 11.9\n\n');
printf('Page No. 324\n\n');

//given
T1 = 273;// Measured temperature In degree celcius
P = 1;// Measured pressure in bar
T2 = 290;// initial temperature In degree celcius
T3 = 1000;// Final temperature In degree celcius
T4 = 1150;// Entering tempearture In degree celcius
v1 = 7;// in m^3/s
v2 = 8;// in m^s
M = 22.7;// in kmol/m^3
d = 0.1;// Diameter in m
A = 0.01;// Surface area per regenerator channel in
   m^2
u = 1;// maximum velocity in m/s
Cp_1 = 34*10^3;// Heat capacity at T4 temperature in
    J/kmol-K
Cp_2 = 32*10^3;// Heat capacity at outlet
   temperature in J/kmol-K
Cp_m = 30*10^3;// Heat capacity at mean temperature
```

```
    in J/kmol-K

m_c = v1/M;//  Molal air flow rate in kmol/s
H_c1 = Cp_m*(T3 - T1);// Enthalpy of air at 1000K in
     J/mol
H_c2 = Cp_m*(T2 - T1);// Enthalpy of air at 290 in J
    /mol
Q = (m_c*(H_c1 - H_c2))/10^6;// in 10^6 W
printf('The heat transfer , Q is %.1f *10^6 W \n',Q)

m_F = v2/M;//  Molal flow rate of flue gas in kmol/s
dH = (Q/m_F)*10^6;// enthaply chnage of the flue gas
     in J/kmol
H_F1 = Cp_1*(T4 - T1);// Enthalpy of the flue gas at
     1150 K in J/kmol
H_F2 =H_F1 - dH;// Enthalpy at the exit temperature
    in J/kmol
T_F2 = (H_F2/Cp_2) + T1;// in K
printf('The exit tempearture of the flue gas is %.0f
     K \n',T_F2)
S_R = v2/u;//cross sectional area of the regenerator
     in m^2
N = S_R/A;
printf('The number of channels required is %.0f \n',
    N)
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

```
clear ;
clc;
// Example 11.10
```

```
printf('Example 11.10\n\n');
printf('Page No. 324\n\n');

//given
Pr = 100;// Production in tonnes per day
p = 10.2;// percentage of sulphur dioxide
T1 = 900;//Burner temperature in degree celcius
T2 = 425;//Required temperature in degree celcius
P = 10;// Dry saturated steam pressure in bar
T = 120;// Dry saturated steam temperature in degree
    celcius
//At the given Temperature =T and Pressure P, the
   required heat Qr to geberate steam from feed
   water is calculated from the steam table.
Qr = 2.27*10^6;// in J/kg

Sp_1 = 1.14*10^3;// Specific heat of the inlet gas
   in J/kmol-K
Sp_2 = 1.03*10^3;// Specific heat of the outlet gas
   in J/kmol-K
pr_rate = 1.2;// production rate in kmol/s

//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
Q_in = ((Pr*pr_rate)/p) * Sp_1 * T1;// Heat content
   of the inlet gas in J/s
Q_out = ((Pr*pr_rate)/p) * Sp_2 * T2;// Heat content
    of the outlet gas in J/s
Qa = Q_in - Q_out;// Heat available for steam
S = Qa/Qr;// in kg/s
printf('The steam production is %.3f kg/s',S)//
   Deviation in answer is due to some wrong value
   substition as discussed above
```