Scilab Textbook Companion for Introduction To Chemical Engineering by S. K. Ghoshal, S. K. Sanyal And S. Datta[1]

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Book Description

Title: Introduction To Chemical Engineering

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Introduction

Scilab code Exa 1.1 Air composition

```
clc
clear
printf("example 1.1 page number 19\n\n")
//to find composition of air by weight
y_oxygen = 0.21         //mole fraction of oxygen
y_nitrogen = 0.79       //mole fraction of nitrogen
molar_mass_oxygen = 32
molar_mass_nitrogen = 28

molar_mass_air = y_oxygen*molar_mass_oxygen+y_nitrogen*molar_mass_nitrogen;
mass_fraction_oxygen =y_oxygen*molar_mass_oxygen/molar_mass_air;
mass_fraction_nitrogen = y_nitrogen*molar_mass_nitrogen/molar_mass_air;

printf("mass fraction of oxygen = %f \n\n",mass_fraction_oxygen)
printf("mass fraction of nitrogen = %f \n\n",mass_fraction_nitrogen)

```

```
V1 = 22.4          //in liters
P1 = 760           //in mm Hg
P2= 735.56         //in mm Hg
T1= 273            //in K
T2 = 298       //in K

V2= (P1*T2*V1)/(P2*T1);
density = molar_mass_air/V2;

printf("density = %f gm/l",density)
```

Scilab code Exa 1.2 Volume calculation

```
clc
clear
printf("example 1.2 page number 20\n\n")
//find the volume occupied by propane

mass_propane=14.2     //in kg
molar_mass=44        //in kg
moles=(mass_propane*1000)/molar_mass;
volume=22.4*moles;    //in liters

printf("volume = %d liters\n\n",volume)
```

Scilab code Exa 1.3 Gas Composition

```
clc
clear
printf("example 1.3 page number 20\n\n")
//to find the average weight, weight composition,
   gas volume in absence of SO2
y_CO2 = 0.25;
```

```
y_CO = 0.002;
y_SO2 = 0.012;
y_N2 = 0.680;
y_O2 = 0.056;

Mm = y_CO2*44+y_CO*28+y_SO2*64+y_N2*28+y_O2*32;
printf ("\n molar mass = %d \n",Mm)

printf("\n finding weight composition \n")
w_CO2 = y_CO2*44*100/Mm;
printf ("\n weight_CO2 = %f \n\n",w_CO2)
w_CO = y_CO*28*100/Mm;
printf ("weight_CO = %f \n\n",w_CO)
w_SO2 = y_SO2*64*100/Mm;
printf ("weight_SO2 = %f \n\n", w_SO2)
w_N2 = y_N2*28*100/Mm;
printf ("weight_N2 = %f \n\n", w_N2)
w_O2 = y_O2*32*100/Mm;
printf ("weight_O2 = %f \n\n", w_O2)

printf("if SO2 is removed \n\n")
v_CO2 = 25;
v_CO = 0.2;
v_N2 = 68.0;
v_O2 = 5.6;
v = v_CO2+v_CO+v_N2+v_O2;
v1_CO2 = (v_CO2*100/98.8);

printf ("volume_CO2 = %f \n\n", v1_CO2)
v1_CO = (v_CO*100/98.8);
printf ("volume_CO = %f \n\n",v1_CO)
v1_N2 = (v_N2*100/98.8);
printf ("volume_N2 = %f \n\n",v1_N2)
v1_O2 = (v_O2*100/98.8);
printf ("volume_O2 = %f \n\n",v1_O2 )
```

Scilab code Exa 1.4 Volume calculation

```
clc
clear
printf("example 1.4 page number 24\n\n")
//to find volume of NH3 dissolvable in water

p=1      //atm
H=2.7    //atm
x=p/H;

mole_ratio = (x)/(1-x);
moles_of_water=(100*1000)/18;
moles_of_NH3=mole_ratio*moles_of_water;

printf("moles of NH3 dissolved = %f\n\n",
   moles_of_NH3)

volume_NH3=(moles_of_NH3*22.4*293)/273;
printf("volume of NH3 dissolved = %f liters",
   volume_NH3)
```

Scilab code Exa 1.5 Amount of CO2 released

```
clc
clear

printf("example 1.5 page number 24\n\n")

//to calculate amount of CO2 released by water
p=746     //in mm Hg
H=1.08*10^6    //in mm Hg, Henry's constant
```

```
x= p/H;     //mole fraction of CO2
X=x*(44/18);    //mass ratio of CO2 in water

initial_CO2 = 0.005;      //kg CO2/kg H20
G=1000*(initial_CO2-X);

printf("CO2 given up by 1 cubic meter of water = %f
    kg CO2/cubic meter H20",G)
```

Scilab code Exa 1.6 Vapor pressure

```
clc
clear

printf('example 1.6 page number 27 \n\n')
//to find vapor pressre of ethyl alchohal

pa1 = 23.6;       //VP of ethyl alchohal at 10 degree
     C
pa3=760       //VP of ethyl alchohal at 78.3 degree C
     in mm Hg
pb1 = 9.2       //VP of ethyl water at 10 degree C in
     mm Hg
pb3=332       //VP of ethyl water at 78.3 degree C in
     mm Hg

C=(log10(pa1/pa3)/(log10(pb1/pb3)));

pb2=149       //VP of water at 60 degree C in mm Hg

pas=(pb3/pb2);
pa=C*log10(pas);
pa2=pa3/(10^pa);

```

```
printf("vapor pressure of ethyl alcholoh at 60
   degree C = %f mm Hg",pa2)
```

Scilab code Exa 1.7 Duhring Plot calculations

```
clc
clear

printf('example 1.7 page number 28 \n\n')

//to find vapor pressure using duhring plot

t1 = 41      //in degree C
t2=59         //in degree C
theta_1 =83         //in degree C
theta_2=100         //in degree C

K = (t1-t2)/(theta_1-theta_2);
t=59+(K*(104.2-100));

printf ("boiling point of SCl2 at 880 Torr = %f
   degree celcius",t)
```

Scilab code Exa 1.8 Vapor Pressure of Mixture

```
clc
clear
printf('example 1.8 page number 29\n\n')
//to find the amount of steam released

vp_C6H6 = 520     //in torr
vp_H2O = 225      //in torr
mass_water=18
```

```
mass_benzene=78

amount_of_steam = (vp_H2O/vp_C6H6)/(mass_benzene/
    mass_water);

printf("amount of steam = %f", amount_of_steam)
```

Scilab code Exa 1.9 Vapor pressure

```
clc
clear
printf('example 1.9 page number 30\n\n')

//to find equilibrium vapor liquid composition
p0b = 385      //vapor pressue of benzene at 60
    degree C in torr
p0t=140      //vapor pressue of toluene at 60 degree
    C in torr
xb=0.4;
xt=0.6;

pb=p0b*xb;
pt=p0t*xt;
P=pb+pt;

printf("total pressure = %f torr\n\n",P)

yb=pb/P;
yt=pt/P;
printf("vapor composition of benzene = %f \n vapor
    composition of toluene = %f\n\n",yb,yt)

//for liquid boiling at 90 degree C and 760 torr,
    liquid phase composition
x=(760-408)/(1013-408);
```

```
printf("mole fraction of benzene in liquid mixture = %f \n mole fraction of toluene in liquid mixture = %f",x,1-x)
```

Scilab code Exa 1.10 `Flow relation`

```
clc
clear

printf('example 1.10 page number 33\n')

//to find relation between friction factor and reynold's number

//log f=y, log Re=x, log a=c
sigma_x=23.393;
sigma_y=-12.437;
sigma_x2=91.456
sigma_xy=-48.554;
m=((6*sigma_xy)-(sigma_x*sigma_y))/(6*sigma_x2-(sigma_x)^2);
printf("m = %f \n",m)

c=((sigma_x2*sigma_y)-(sigma_xy*sigma_x))/(6*sigma_x2-(sigma_x)^2);
printf("c = %f \n",c)

printf("f=0.084*Re^-0.256")
```

Scilab code Exa 1.11 `Average Velocity`

```
clc
```

```
clear
printf("example 1.11 page number 35\n\n")

//to find the average velocity

u = [2;1.92;1.68;1.28;0.72;0];
r = [0;1;2;3;4;5];

z = u.*r;
plot(r,z)
title("variation of ur with r")
xlabel("r")
ylabel("ur")

//by graphical integration , we get
u_avg = (2/25)*12.4
printf("average velocity = %f cm/s\n",u_avg)
```

Scilab code Exa 1.12 Velocity determination

```
clc
clear

printf('example 1.12 page number 37\n')

//to find the average velocity
printf('using trapezoid rule\n')

n = 6;
h = (3 - 0)/n;
I = (h/2)*(0+2*0.97+2*1.78+2*2.25+2*2.22+2*1.52+0);
u_avg = (2/3^2)*I;

printf("average velocity = %f cm/s\n",u_avg)

```

```
disp('Simpsons rule')

n = 6;
h = 3/n;
I = (h/3)*(0+4*(0.97+2.25+1.52)+2*(1.78+2.22)+0);
u_avg = (2/3^2)*I;

printf("average velocity = %f cm/s\n",u_avg)
```

Scilab code Exa 1.13 Velocity determination

```
clc
clear

printf('example 1.13 page number 38\n\n')

//to find the settling velocity as a function of
   time
z0 = 30.84;
z1 = 29.89;
z2 = 29.10;
h = 4;

u1_t0 = (-3*z0+4*z1-z2)/(2*h);
u1_t4 = (-z0+z2)/(2*h);
u1_t8 = (z0-4*z1+3*z2)/(2*h);

//considering data set for t = 4,8,12 min
z0 = 29.89;
z1 = 29.10;
z2 = 28.30;
u2_t4 = (-3*z0+4*z1-z2)/(2*h);
u2_t8 = (-z0+z2)/(2*h);
u2_t12 = (z0-4*z1+3*z2)/(2*h);

```

```
//considering data set for t = 8,12,16 min
z0 = 29.10;
z1 = 28.30;
z2 = 27.50;
u3_t8 = (-3*z0+4*z1-z2)/(2*h);
u3_t12 = (-z0+z2)/(2*h);
u3_t16 = (z0-4*z1+3*z2)/(2*h);

//taking average
u_t4 = (u1_t4+u2_t4)/2;
u_t8 = (u1_t8+u2_t8+u3_t8)/3;
u_t12 = (u2_t12+u3_t12)/2;

printf("u_t0 = %f cm/min\n u_t4 = %f cm/min\n u_t8 = %f cm/min \n u_t12 = %f/n cm/min\n u_t16 =%f/n cm/min ",u1_t0,u_t4,u_t8,u_t12,u3_t16)
```

Scilab code Exa 1.14 Dimensional analysis

```
printf('example 1.14 page number 45')
disp ("this is a theoritical question, book shall be referred for solution")
```

Scilab code Exa 1.15 Dimensional analysis

```
printf('example 1.15 page number 46')
disp ("this is a theoritical question, book shall be referred for solution")
```

Scilab code Exa 1.16 Dynamic similarity

```
clc
clear
printf('example 1.16 page number 49\n')

//to find the flow rate and pressure drop
density_water=988     //in kg/m3
viscosity_water=55*10^-5   //in Ns/m2
density_air=1.21      //in kg/m3
viscosity_air=1.83*10^-5   //in Ns/m2
L=1     //length in m

L1=10*L   //length in m
Q=0.0133;

Q1=((Q*density_water*viscosity_air*L)/(L1*
    viscosity_water*density_air))

printf("flow rate = %f cubic meter/s\n",Q1)

//equating euler number

p=9.8067*10^4;     //pressure in pascal
p1=(p*density_water*Q^2*L^4)/(density_air*Q1^2*L1^4)
    ;

printf("pressure drop corresponding to 1kp/square cm
     = %f kP/square cm",p1/p)
```

Scilab code Exa 1.17 Dynamic similarity

```
clc
clear
printf('example 1.17 page number 50\n')

//to find the specific gravity of plasstic
```

```
L=1        //length of prototype in m
L1=10*L    //length of model in m
density_prototype=2.65    //gm/cc
density_water=1        //gm/cc

density_model=(L^3*(density_prototype-density_water)
    )/(L1^3)+1;

printf("specific gravity of plastic = %f",
    density_model)
```

Scilab code Exa 1.18 Nomographic chart

```
clc
clear
printf('example 1.18 page number 53\n\n')

//to find error in actual data and nomographic chat
    value

//for my
ly = 8    //in cm
my = ly/((1/0.25) - (1/0.5));
lz = 10.15    //in cm
mz = lz/((1/2.85) - (1/6.76));
mx = (my*mz)/(my+mz);
printf("mx = %f cm\n",mx)
err = ((1-0.9945)/0.9945)*100;
printf("\nerror = %f \n",err)

x = 2
y = 0.5:0.5:2.5;

plot(x,y)
```

```
title("nomograph")
xlabel("x")
ylabel("y")

x = 3
y = 0.4:0.2:2;
plot(x,y)
```

Scilab code Exa 1.19 Calculation using Nomograph

```
clc
clear
printf('example 1.19 page number 54\n')

//to find the economic pipe diameter from nomograph
//from the nomograph,we get the values of w and
   density

w=450      //in kg/hr
density=1000    //in kg/m3
d=16    //in mm

u=(w/density)/(3.14*d^2/4);
Re=u*density*d/0.001;

if Re>2100 then printf("flow is turbulent and d= %f
   mm",d)
else disp ("flow is laminar and this nomograph is
   not valid")
end
```

Chapter 2

Physico Chemical Calculations

Scilab code Exa 2.1 Ideal gas system

```
clc
clear
printf("example 2.1 page number 71\n\n")

//to find the volume of oxygen that can be obtained

p1=15      //in bar
p2=1.013   //in bar
t1=283     //in K
t2=273     //in K
v1=10      //in l

v2=p1*v1*t2/(t1*p2);

printf("volume of oxygen = %f liters",v2)
```

Scilab code Exa 2.2 Mixture properties

```
clc
clear
printf("example 2.2 page number 71\n\n")

//to find volumetric composition,partial pressue of each gas and total pressure of mixture

nCO2=2/44;      //moles of CO2
nO2=4/32;      //moles of O2
nCH4=1.5/16;    //moles of CH4

total_moles=nCO2+nO2+nCH4;
yCO2=nCO2/total_moles;
yO2=nO2/total_moles;
yCH4=nCH4/total_moles;

printf (" Composition of mixture = \nCH4 = %f \nO2 = %f \n CO2 = %f \n\n",yCH4,yO2,yCO2)

pCO2=nCO2*8.314*273/(6*10^-3);
pO2=nO2*8.314*273/(6*10^-3);
pCH4=nCH4*8.314*273/(6*10^-3);

printf ("pressure of CH4 = %f kPa \npressure of O2 = %f kPa\n pressure of CO2 =%f kPa\n\n",pCH4*10^-3,pO2*10^-3,pCO2*10^-3)

total_pressure=pCO2+pCH4+pO2;
printf ("total pressure =  %f Kpa",total_pressure*10^-3)
```

Scilab code Exa 2.3 Equivalent metal mass

```
clc
clear
```

```
printf("example 2.3 page number 72\n\n")

//to find equivalent mass of metal

P=104.3      //total pressure in KPa
pH2O=2.3     //in KPa
pH2=P-pH2O;  //in KPa

VH2=209*pH2*273/(293*101.3)

printf("volume of hydrogen obtained = %f ml\n\n",VH2)

//calculating amount of metal having 11.2l of hydrogen

m=350/196.08*11.2    //mass of metal in grams
printf("mass of metal equivalent to 11.2 litre/mol of hydrogen = %f gm",m)
```

Scilab code Exa 2.4 Purity of Sodium Hydroxide

```
clc
clear
printf("example 2.4 page number 72\n\n")

//to find NaCl content in NaOH solution

w=2    //in gm
m=0.287   //in gm

//precipitate from 58.5gm of NaCl=143.4gm

mNaCl=58.5/143.4*m;

```

```
printf("mass of NaCl = %f gm\n",mNaCl )

percentage_NaCl=mNaCl/w*100;
printf("amount of NaCl = %f",percentage_NaCl)
```

Scilab code Exa 2.5 Carbon content formulation

```
clc
clear
printf("example 2.5 page number 72\n\n")

//to find the carbon content in sample

w=4.73     //in gm5
VCO2=5.30     //in liters

weight_CO2=44/22.4*VCO2;
carbon_content=12/44*weight_CO2;

percentage_content=(carbon_content/w)*100;

printf("percentage amount of carbon in sample = %f",
   percentage_content)
```

Scilab code Exa 2.6 Combustion of gas

```
clc
clear
printf("example 2.6 page number 73\n\n")
//to find the volume of air

volume_H2=0.5     //in m3
volume_CH4=0.35   //in m3
```

```
volume_CO=0.08    //in m3
volume_C2H4=0.02 //in m3
volume_oxygen=0.21   //in m3 in air

//required oxygen for various gases
H2=0.5*volume_H2;
CH4=2*volume_CH4;
CO=0.5*volume_CO;
C2H4=3*volume_C2H4;

total_O2=H2+CH4+CO+C2H4;
oxygen_required=total_O2/volume_oxygen;

printf("amount of oxygen required = %f cubic meter",
   oxygen_required)
```

Scilab code Exa 2.7 Sulphuric acid preparation

```
clc
clear
printf("example 2.7 page number 73\n\n")

//to find the volume of sulphuric acid and mass of
   water consumed

density_H2SO4 = 1.10    //in g/ml
mass_1 = 100*density_H2SO4;    //mass of 100ml of 15%
    solution
mass_H2SO4 = 0.15*mass_1;
density_std = 1.84    //density of 96% sulphuric acid
mass_std = 0.96*density_std;    //mass of H2SO4 in 1
   ml 96% H2SO4

volume_std = mass_H2SO4/mass_std;     //volume of 96
   %H2SO4
```

```
mass_water = mass_1 - mass_H2SO4;

printf("volume of 0.96 H2SO4 required = %f ml",
   volume_std)
printf("\nmass of water required = %f g",mass_water)
```

Scilab code Exa 2.8 Molarity Molality Normality Calculation

```
clc
clear
printf("example 2.8 page number 73\n\n")

//to find molarity,molality and normality

w_H2SO4=0.15     //in gm/1gm solution
density=1.10    //in gm/ml
m=density*1000;    //mass per liter
weight=m*w_H2SO4;    //H2SO4 per liter solution
molar_mass=98;

Molarity=weight/molar_mass;
printf("Molarity = %f mol/l\n\n",Molarity)

equivalent_mass=49;
normality=weight/equivalent_mass;
printf("Normality = %f N\n\n",normality)

molality=176.5/molar_mass;
printf("Molality = %f",molality)
```

Scilab code Exa 2.9 Normality calculation

```
clc
```

```
clear
printf("example 2.9 page number 74\n\n")

molar_mass_BaCl2=208.3;        //in gm
equivalent_H2SO4=0.144;
normality=equivalent_H2SO4*1000/28.8;

printf("Normality = %f N",normality)
```

Scilab code Exa 2.10 Precipitation of KClO3

```
clc
clear
printf("example 2.10 page number 74\n\n")

//to find amount of KClO3 precipitated

solubility_70=30.2       //in gm/100gm
w_solute=solubility_70*350/130.2;       //in gm

w_water=350-w_solute;
solubility_30=10.1      //in gm/100gm
precipitate=(solubility_70-solubility_30)*w_water
   /100

printf("amount precipitated = %f gm",precipitate)
```

Scilab code Exa 2.11 Solubility of CO2

```
clc
clear
printf("example 2.11 page number 74\n\n")

```

```
//to find the pressure for solubility of CO2

absorbtion_coefficient=1.71     //in liters
molar_mass=44;
solubility=absorbtion_coefficient*molar_mass/22.4;
    //in gm
pressure=8/solubility*101.3;

printf("pressure required = %f kPa",pressure)
```

Scilab code Exa 2.12 Vapor pressure calculation

```
clc
clear
printf("example 2.12 page number 74\n\n")

//to find the vapor pressure of water

w_water=540    //in gm
w_glucose=36   //in gm
m_water=18;       //molar mass of water
m_glucose=180;    //molar mass of glucose

x=(w_water/m_water)/(w_water/m_water+w_glucose/
   m_glucose);
p=8.2*x;
depression=8.2-p;

printf("depression in vapor pressure = %f Pa",
   depression*1000)
```

Scilab code Exa 2.13 Boiling point calculation

```
clc
clear
printf("example 2.13 page number 75\n\n")

//to find the boiling point of solution

w_glucose=9     //in gm
w_water=100     //in gm
E=0.52;
m=90/180;     //moles/1000gm water

delta_t=E*m;
boiling_point=100+delta_t;

printf("boiling_point of water = %f degreeC",
   boiling_point)
```

Scilab code Exa 2.14 Colligative properties

```
clc
clear
printf("example 2.14 page number 75\n\n")

//to find the molar mass and osmotic pressure

K=1.86;
c=15    //concentration of alcohol
delta_t=10.26;

m=delta_t/K;    //molality
M=c/(m*85);     //molar mass
printf("molar mass = %f gm\n\n",M*1000)

density=0.97      //g/ml
cm=c*density/(M*100);
```

```
printf("molar concentration of alcohol = %f moles/l\
   n\n",cm)

p=cm*8.314*293    //osmotic pressure
printf("osmotic pressure = %f Mpa\n\n",p/1000)
```

Scilab code Exa 2.15 Huggins Equation

```
clc
clear
printf("example 2.15 page number 75\n\n")

//to find u_in , M_v, k'

u_in = 0.575    //from the graph
u_s = 0.295    //in mPa-s

M_v = (u_in/(5.80*10^-5))^(1/0.72);
u_red = 0.628;    //in dl/g

c = 0.40    //in g/dl
k = (u_red-u_in)/((u_in^2)*c);

printf("k = %f \nMv = %f\nu_in = %f dl/gm",k,M_v,
   u_in)
```

Scilab code Exa 2.16 Molecular Formula

```
clc
clear
printf("example 2.16 page number 76\n\n")

//to find the molecular formula
```

```
C=54.5      //% of carbon
H2=9.1      //% of hydrogen
O2=36.4     //% of oxygen
x=C/12;     //number of carbon molecules
y=O2/16;    //number of oxygen molecules
z=H2/2     //number of hydrogen molecules
molar_mass=88;
density=44;

ratio=molar_mass/density;
x=ratio*2;
y=ratio*1;
z=ratio*4;

printf("x = %f, y = %f, z = %f",x,y,z)
printf("\n\nformula of butyric acid is = C4H8O2")
```

Scilab code Exa 2.17 Molecular Formula

```
clc
clear
printf("example 2.17 page number 77\n\n")

//to find molecular foemula
C=93.75     //% of carbon
H2=6.25     //% of hydrogen
x=C/12      //number of carbon atoms
y=H2/2      //number of hydrogen atoms
molar_mass=64
density=4.41*29;

ratio=density/molar_mass;

x=ratio*5;
```

```
y=ratio*4;


printf("x = %f, y = %f",x,y)
printf("\n\nformula of butyric acid is = C10H8")
```

Scilab code Exa 2.18 Molecular Formula

```
clc
clear
printf("example 2.18 page number 77\n\n")

//to find molecular formula
C=50.69      //% of carbon
H2=4.23      //% of hydrogen
O2=45.08     //% of oxygen
a=C/12;     //number of carbon molecules
c=O2/16;    //number of oxygen molecules
b=H2/2;     //number of hydrogen molecules
molar_mass=71;

function M=f(m)
    M=(2.09*1000)/(60*m);

endfunction

M=f((1.25/5.1));

printf("actual molecular mass = %f\n\n",M)

ratio=M/molar_mass;
a=ratio*3;
b=ratio*3;
c=ratio*2;

```

```
printf("a = %f, b = %f, c = %f",a,b,c)
printf("\n\nformula of butyric acid is = C6H6O4")
```

Scilab code Exa 2.19 Molecular Formula

```
clc
clear
printf("example 2.19 page number 78\n\n")

//to find the molecular formula
C=64.6      //% of carbon
H2=5.2      //% of hydrogen
O2=12.6     //% of oxygen
N2=8.8      //% of nitrogen
Fe=8.8      //% of iron

a=C/12;     //number of carbon molecules
c=8.8/14;    //number of nitrogen molecules
b=H2/2;     //number of hydrogen molecules
d=O2/16;    //number of oxygen molecules
e=Fe/56     //number of iron atoms

cm=243.4/(8.31*293)      //concentration

 molar_mass=63.3/cm;

 printf("a = %f, b = %f, c = %f, d = %f, e = %f",a
    *6.5,b*6.5,c*6.5,d*6.5,e*6.5)
printf("\n\nformula of butyric acid is =
   C34H33N4O5Fe")
```

Scilab code Exa 2.20 Metal deposition

```
clc
clear
printf("example 2.20 page number 78\n\n")

//to find sequence of deposition
E1=-0.25;
E2=0.80;
E3=0.34;

a=[E1;E2;E3];
b=gsort(a);

printf("sorted potential in volts =")
disp (b)
disp ("E2>E3>E1")
disp ("silver>copper>nickel")
```

Scilab code Exa 2.21 EMF of cell

```
clc
clear
printf("example 2.21 page number 79\n\n")

//to find the emf of cell

E0_Zn=-0.76;
E0_Pb=-0.13;
c_Zn=0.1;
c_Pb=0.02;

E_Zn=E0_Zn+(0.059/2)*log10(c_Zn);
E_Pb=E0_Pb+(0.059/2)*log10(c_Pb);
E=E_Pb-E_Zn;

printf("emf of cell = %f V",E)
```

```
printf("\n\nSince potential of lead is greater than
   that of zinc thus reduction will occur at lead
   electrode and oxidation will occur at zinc
   electrode")
```

Scilab code Exa 2.22 EMF of cell

```
clc
clear
printf("example 2.22 page number 79\n\n")

//to find the emf of cell
E0_Ag=0.80;
E0_AgNO3=0.80;
c_Ag=0.001;
c_AgNO3=0.1;

E_Ag=E0_Ag+(0.059)*log10(c_Ag);
E_AgNO3=E0_AgNO3+(0.059)*log10(c_AgNO3);
E=E_AgNO3-E_Ag;

printf("emf of cell = %f V" ,E)
printf("\n\nsince E is positive, the left hand
   electrode will be anode and the electron will
   travel in the external circuit from the left hand
    to the right hand electrode")
```

Scilab code Exa 2.23 EMF of cell

```
clc
clear
printf("example 2.23 page number 79\n\n")

```

```
//to find emf of cell
pH=12;     //pH of solution
E_H2=0;
E2=-0.059*pH;
E=E_H2-E2;
printf("EMF of cell = %f V",E)
```

Scilab code Exa 2.24 Silver deposition

```
clc
clear
printf("example 2.24 page number 80\n\n")

//to find amount of silver deposited
I=3    //in Ampere
t=900    //in s
m_eq=107.9     //in gm/mol
F=96500;

m=(I*t*m_eq)/F;
printf("mass = %f gm",m)
```

Scilab code Exa 2.25 Electroplating time

```
clc
clear
printf("example 2.25 page number 80\n\n")

//to find the time for electroplating
volume=10*10*0.005;     //in cm3
mass=volume*8.9;
F=96500;
atomic_mass=58.7     //in amu
```

```
current=2.5       //in Ampere

charge=(8.9*F*2)/atomic_mass;
yield=0.95;
actual_charge=charge/(yield*3600);
t=actual_charge/current;

printf("time required = %f hours",t)
```

Scilab code Exa 2.26 Water hardness

```
clc
clear
printf("example 2.26 page number 80\n\n")

//to find hardness of water
m_MgSO4=90    //in ppm
MgSO4_parts=120;
CaCO3_parts=100;

hardness=(CaCO3_parts/MgSO4_parts)*m_MgSO4;

printf("hardness of water = %f mg/l",hardness)
```

Scilab code Exa 2.27 Water hardness

```
clc
clear
printf("example 2.26 page number 80\n\n")

m1 = 162   //mass of calcium bi carbonate in mg
m2 = 73   //mass of magnesium bi carbonate in mg
m3 = 136  // mass of calsium sulfate in mg
```

```
m4 = 95    // mass of magnesium cloride
m5 = 500   //mass of sodium cloride in mg
m6 = 50    // mass of potassium cloride in mg

content_1 = m1*100/m1;     //content of calcium bi carbonate in mg
content_2 = m2*100/(2*m2);    //content of magnesium bi carbonate in mg
content_3 = m3*100/m3;   // content of calsium sufate in mg
content_4 = m4*100/m4;    // content of magnesium cloride

//part_1

temp_hardness = content_1 + content_2;    //depends on bicarbonate only
total_hardness = content_1+content_2+content_3+content_4;
printf("total hardness = %f\n temporary hardness = %f \n",temp_hardness,total_hardness)

//part 2
wt_lime = (74/100)*(content_1+2*content_2+content_4);
actual_lime = wt_lime/0.85;
printf("amount of lime required = %f \n",actual_lime)

soda_required = (106/100)*(content_1+content_4);
actual_soda = soda_required/0.98;
printf("amount of soda required = %f \n",actual_soda)
```

Scilab code Exa 2.28 Water hardness

```
clc
clear
printf("example 2.28 page number 82\n\n")

//to find hardness of water

volume_NaCl=50     //in l
c_NaCl=5000        //in mg/l

m=volume_NaCl*c_NaCl;
equivalent_NaCl=50/58.5;

hardness=equivalent_NaCl*m;

printf("hardness of water = %f mg/l",hardness/1000)
```

Scilab code Exa 2.29 Mixture composition

```
clc
clear
printf("example 2.29 page number 82\n\n")

//to find the total vapor pressure and molar
   compositions

m_benzene = 55   //in kg
m_toluene = 28   //in kg
m_xylene = 17    // in kg

mole_benzene = m_benzene/78;
mole_toluene = m_toluene/92;
mole_xylene = m_xylene/106;

mole_total = mole_benzene+mole_toluene+mole_xylene;
x_benzene = mole_benzene/mole_total;
```

```
x_toluene = mole_toluene/mole_total;
x_xylene = mole_xylene/mole_total;

P = x_benzene*178.6+x_toluene*74.6+x_xylene*28;
printf("total pressure = %f kPa\n",P)

benzene = (x_benzene*178.6*100)/P;
toluene = (x_toluene*74.6*100)/P;
xylene = (x_xylene*28*100)/P;

printf("xylene = %f \n toluene = %f \n benzene = %f"
    ,xylene,toluene,benzene)
```

Scilab code Exa 2.30 Mixture composition

```
clc
clear
printf("example 2.30 page number 83\n\n")

//to find the mixture composition

vapor_pressure=8     //in kPa
pressure=100         //in kPa

//part 1
volume=1      //in m3
volume_ethanol=volume*(vapor_pressure/pressure);
volume_air=1-volume_ethanol;
printf("volumetric composition:- \nair composition =
     %f\n ethanol compostion = %f",volume_air*100,
    volume_ethanol*100)

//part 2
molar_mass_ethanol=46;
molar_mass_air=28.9;
```

```
mass_ethanol=0.08*molar_mass_ethanol;    //in kg
mass_air=0.92*molar_mass_air;     //in kg
fraction_ethanol=(mass_ethanol*100)/(mass_air+mass_ethanol);
fraction_air=(mass_air*100)/(mass_air+mass_ethanol);
printf("\n\ncomposition by weight:-\nAir = %f Ethanol vapor = %f",fraction_air,fraction_ethanol)

//part 3
mixture_volume=22.3*(101.3/100)*(299/273);    //in m3
weight_ethanol=mass_ethanol/mixture_volume;
printf("\n\nweight of ethanol/cubic meter = %f Kg",weight_ethanol)

//part 4
w_ethanol=mass_ethanol/mass_air;
printf("\n\nweight of ethanol/kg vapor free air = %f Kg",w_ethanol)

//part 5
moles_ethanol=0.08/0.92;
printf("\n\nkmol of ethanol per kmol of vapor free air = %f",moles_ethanol)
```

Scilab code Exa 2.31 Mixture properties

```
clc
clear
printf("example 2.31 page number 84\n\n")

//to find relative saturation and dew point

vapor_pressure=8   //in kPa
volume_ethanol=0.05;
```

```

//basis 1kmol of mixture

partial_pressure=volume_ethanol*100;
relative_saturation=partial_pressure/vapor_pressure;
mole_ratio=volume_ethanol/(1-volume_ethanol);
printf("mole ratio = %f \nrelative saturation = %f",
   mole_ratio,relative_saturation*100)

//basis 1kmol saturated gas mixture at 100kPa
volume_vapor=(8/100)*100;
ethanol_vapor=volume_vapor/100;
air_vapor=1-ethanol_vapor;
saturation_ratio=ethanol_vapor/air_vapor;
percentage_saturation=mole_ratio/saturation_ratio;

printf("\n\npercentage saturation = %f",
   percentage_saturation)

//dew point
printf("\n\ncorresponding to partial pressure of 5
   kPa we get a dew point of 17.3 degree celcius")
```

Scilab code Exa 2.32 Humidity

```
clc
clear
printf("example 2.32 page number 84\n\n")

//to find the properties of humid air

p = 4.24   //in kPa
H_rel = 0.8;
p_partial = p*H_rel;
molal_H = p_partial/(100-p_partial);
```

```
printf("initial molal humidity = %f\n\n",molal_H)

//part 2
P = 200   //in kPa
p_partial = 1.70   //in kPa
final_H = p_partial/(P-p_partial);
printf("final molal humidity = %f\n\n",final_H)

//part 3
p_dryair = 100 - 3.39;
v = 100*(p_dryair/101.3)*(273/303);
moles_dryair = v/22.4;
vapor_initial = molal_H*moles_dryair;
vapor_final = final_H*moles_dryair;
water_condensed = (vapor_initial-vapor_final)*18;
printf("amount of water condensed = %f \n\n",
    water_condensed)

//part 4
total_air = moles_dryair+vapor_final;
final_v = 22.4*(101.3/200)*(288/273)*total_air;
printf("final volume of wety air = %f \n\n",final_v)
```

Chapter 3

Material and Energy Balances

Scilab code Exa 3.1 `Coal consumption`

```
clc
clear
printf("example 3.1 page number 90\n\n")

//to find the coal consumption
w_C = 0.6;    //amount of carbon in coal
N2_content = 40    //in m3 per 100m3 air

air_consumed = N2_content/0.79;
weight_air = air_consumed*(28.8/22.4);
O2_content = air_consumed*32*(0.21/22.4);    //in kg

H2_content = 20    //in m3

steam_consumed = H2_content*(18/22.4);

C_consumption1 = (12/18)*steam_consumed;    //in
   reaction 1
C_consumption2 = (24/32)*O2_content;    //in
   reaction 2

```

```
total_consumption = C_consumption1+C_consumption2;
coal_consumption = total_consumption/w_C;

printf("coal consumption = %f kg",coal_consumption)
```

Scilab code Exa 3.2 Nitric acid preparation

```
clc
clear
printf("example 3.2 page number 91\n\n")

//to find amount of ammonia and air consumed

NH3_required = (17/63)*1000;     //NH3 required for 1
    ton of nitric acid
NO_consumption = 0.96;
HNO3_consumption = 0.92;
NH3_consumed = NH3_required/(NO_consumption*
   HNO3_consumption);
volume_NH3 = NH3_consumed*(22.4/17);
printf("volume of ammonia consumed= %f cubic metre/h
   ",volume_NH3)

NH3_content = 11    //% by volume
air_consumption = volume_NH3*((100-11)/11);
printf("\n\nvolume of air consumed = %f cubic metre/
   h",air_consumption)
```

Scilab code Exa 3.3 HCl production

```
clc
clear
printf("example 3.3 page number 91\n\n")
```

```
//to find the consumption of NaCl and H2SO4 in HCl consumption

HCl_production = 500   //required to be produced in kg
NaCl_required = (117/73)*HCl_production;
yield = 0.92;
purity_NaCl= 0.96;

actual_NaCl = NaCl_required/(purity_NaCl*yield);
printf("amount of NaCl required = %f kg",actual_NaCl)

purity_H2SO4 = 0.93;
H2SO4_consumption = (98/73)*(HCl_production/(yield*purity_H2SO4));
printf("\n\namount of H2SO4 consumed = %f kg",H2SO4_consumption)

Na2SO4_produced = (142/73)*HCl_production;
printf("\n\namount of Na2SO4 produced = %f kg",Na2SO4_produced)
```

Scilab code Exa 3.4 Acetylene consumption

```
clc
clear
printf("example 3.4 page number 92\n\n")

//to find the period of service

C2H2_produced = (1/64)*0.86;   //in kmol
volume_C2H2 = C2H2_produced*22.4*1000;    //in l

```

```
//assuming ideal behaviour ,
volume = (100/101.3)*(273/(273+30));
time = (volume_C2H2/volume)*(1/60);
printf("time of service = %f hr",time)
```

Scilab code Exa 3.5 Screen effectiveness

```
clc
clear
printf("example 3.5 page number 92\n\n")

//to find the screen effectiveness

xv = 0.88;
xf = 0.46;
xl = 0.32;
F= 100   //in kg

L = (F*(xf-xv))/(xl-xv);
V = F-L;
printf("L = %f Kg \nV = %f Kg",L,V)
Eo = (V*xv)/(F*xf);

printf(" \n\neffectiveness based on oversized
    partices = %f \n\n",Eo)
Eu = (L*(1-xl))/(F*(1-xf));

printf("effectiveness based on undersized partices =
     %f",Eu)
E=Eu*Eo;

printf("\n\noverall effectiveness = %f",E)
```

Scilab code Exa 3.6 Absorption

```
clc
clear
printf("example 3.6 page number 94\n\n")

//to find the flow rate and concentration

G1 = 3600   //in m3/h
P = 106.6    //in kPa
T = 40   //in degree C
q = G1*(P/101.3)*(273/((273+T)));   //in m3/s
m = q/22.4;   //in kmol/h
y1 = 0.02;
Y1 = y1/(1-y1);

printf("mole ratio of benzene = %f kmol benzene/kmol
    dry gas",Y1)

Gs = m*(1-y1);
printf("\n\nmoles of benzene free gas = %f kmol
   drygas/h",Gs)

//for 95% removal
Y2 = Y1*(1-0.95);
printf("\n\nfinal mole ratio of benzene = %f kmol
   benzene/kmol dry gas",Y2)

x2 = 0.002
X2 = 0.002/(1-0.002);

//at equilibrium y* = 0.2406X
//part 1
//for oil rate to be minimum the wash oil leaving
   the absorber must be in equilibrium with the
   entering gas

y1 = 0.02;
```

```
x1 = y1/(0.2406);
X1 = x1/(1-x1);
min_Ls = Gs*((Y1-Y2)/(X1-X2));
printf("\n\nminimum Ls required = %f kg/h",min_Ls*260)

//for 1.5 times of the minimum
Ls = 1.5*min_Ls;
printf("\n\nflow rate of wash oil = %f kg/h",Ls*260)
X1 = X2 + (Gs*((Y1-Y2)/Ls));
printf("\n\nconcentration of benzene in wash oil = %f kmol benzene/kmol wash oil",X1)
```

Scilab code Exa 3.7 Extraction

```
clc
clear
printf("example 3.7 page number 95\n\n")

//to find the extraction of nicotine
xf = 0.01
Xf = xf/(1-xf);
Feed = 100    //feed in kg
c_nicotine = Feed*Xf;    //nicotine conc in feed
c_water = Feed*(1-Xf)    //water conc in feed

//part 1
function[f] = F1(x)
    funcprot(0)
    f = (x/150)-0.9*((1-x)/99);
endfunction

//initial guess
x = 10;
y = fsolve(x,F1);
```

```
printf("amount of nicotine removed N = %f kg",y)
//part 2
function[f] = F1(x)
    f = (x/50)-0.9*((1-x)/99);
endfunction

//initial guess
x = 10;
N1 = fsolve(x,F1);
printf("\n\namount of nicotine removed in stage 1, N1 = %f kg",N1)
function[f] = F1(x,N1)
    f = (x/50)-0.9*((1-x-N1)/99);
endfunction

//initial guess
x = 10;
N2 = fsolve(x,F1);
printf("\n\namount of nicotine removed in stage 2, N2 = %f kg",N2)
function[f] = F1(x,N1,N2)
    f = (x/50)-0.9*((1-x-N2-N1)/99);
endfunction

//initial guess
x = 10;
N3 = fsolve(x,F1);

printf("\n\namount of nicotine removed in stage 3, N3 = %f kg",N3)
N = N1+N2+N3;
printf("\n\ntotal amount of nicotine removed = %f kg",N)
```

Scilab code Exa 3.8 Distillation

```
clc
clear
printf("example 3.8 page number 96\n\n")

//to find the amount of water in residue

vp_water = 31.06   //in kPa
vp_benzene = 72.92   //in kPa

P = vp_water +vp_benzene;
x_benzene = vp_benzene/P;
x_water = vp_water/P;

initial_water = 50/18;   //in kmol of water
initial_benzene = 50/78   //in kmol of benzene
water_evaporated = initial_benzene*(x_water/
   x_benzene);
water_left = (initial_water - water_evaporated);

printf("amount of water left in residue = %f kg",
   water_left*18)
```

Scilab code Exa 3.9 Distillation

```
clc
clear
printf("example 3.9 page number 97\n\n")

//to find the vapor content of dimethylanaline
po_D = 4.93   //in kPa
po_W = 96.3   //in kPa
n = 0.75   //vaporization efficiency

P = n*po_D+po_W;
printf("P = %f kPa",P)
```

```

x_water = 96.3/100;
x_dimethylanaline = 1-x_water;
wt_dimethylanaline = (x_dimethylanaline*121)/(x_dimethylanaline*121+x_water*18);
printf("\n\nweight of dimethylanaline in water = %f",wt_dimethylanaline*100)

//part 1
n = 0.8;
po_D = 32   //in kPa
actual_vp = n*po_D;
p_water = 100 - actual_vp;
steam_required = (p_water*18)/(actual_vp*121);
printf("\n\namount of steam required = %f kg steam/kg dimethylanaline",steam_required)

//part 2
x_water = p_water/100;
wt_water = x_water*18/(x_water*18+(1-x_water)*121);
printf("\n\nweight of water vapor = %f \nweight of dimethylanaline =%f",wt_water*100,100*(1-wt_water))
```

Scilab code Exa 3.10 Crystallization

```
clc
clear
printf("example 3.10 page number 98\n\n")

//to find the amount of water evaporated
xf = 0.15;
xl = (114.7)/(114.7+1000);
xc = 1;

```

```
K2Cr207_feed = 1000*0.15;     //in kg

n = 0.8;
C = n*K2Cr207_feed;
V = (K2Cr207_feed-120 - 880*0.103)/(-0.103);

printf("amount of water evaporated = %f kg",V)
```

Scilab code Exa 3.11 crystallization

```
clc
clear
printf("example 3.10 page number 98\n\n")

//to find the yield of crystals

xc = 106/286;
xf = 0.25;
xl = 27.5/127.5;

water_present = 100*(1-xf);     //in kg
V = 0.15*75;     //in kg
C = (100*xf - 88.7*xl)/(xc-xl);
Na2CO3_feed = 25/xc;

yield = (C/Na2CO3_feed)*100;

printf("yield = %f ",yield)
```

Scilab code Exa 3.12 Drying

```
clc
clear
```

```
printf("example 3.12 page number 99\n\n")

//to find the fraction of air recirculated

r = 50   //weight of dry air passing through drier
w1 = 1.60   //in kg per kg dry solid
w2 = 0.1    //in kg/kg dry solid
H0 = 0.016  //in kg water vapor/kg dry air
H2 = 0.055  //in kg water vapor/kg dry air

y = 1 - (w1-w2)/(r*(H2-H0));
printf("fraction of air recirculated = %f",y)

H1 = H2 - (w1-w2)/r;
printf("\n\nhumidity of air entering the drier = %f
    kg water vapor/kg kg dry air",H1)

//check
H11 = H2*y+H0*(1-y);
if H1 == H11 then printf("\n\nfraction of air
    recirculated = %f \n verified",y)
end
```

Scilab code Exa 3.13 Conditioning of air

```
clc
clear
printf("example 3.13 page number 100\n\n")

//to find the volumetric flow rate and fraction of
    air passing through the cooler

//basis 60m3/h of conditioned air at 25 degree C and
     60% RH

```

```
Hf = 0.012;
Hi = 0.033;
H1 = 0.0075;

water_vapor = Hf/18;    //in kmol of water vapor
dry_air = 1/28.9;  //in kmol
total_mass = water_vapor+dry_air;

volume = 22.4*(298/273)*total_mass;
weight = 60/volume;
printf("weight of dry air handled per hr = %f kg",
    weight)

//part 1
inlet_watervapor = 0.033/18;     //in kmol of water
    vapor
volume_inlet = 22.4*(308/273)*(inlet_watervapor+
    dry_air);
printf("\n\nvolumetric flow rate of inlet air = %f
    cubic meter",volume_inlet*weight)

//part 2
y = (Hf - Hi)/(H1 - Hi);
printf("\n\nfraction of inlet air passing through
    cooler = %f",y)
```

Scilab code Exa 3.14 Ammonia Synthesis

```
clc
clear
printf("example 3.14 page number 102\n\n")

//to find the fraction of purged recycle and total
    yield

```

```
//x- moles of N2 and H2 recycled; y - moles of N2 H2
    purged

Ar_freshfeed = 0.2;
//argon in fresh feed is equal to argon in purge

y = 0.2/0.0633;    //argon in purge = 0.0633y
x = (0.79*100 - y)/(1-0.79);
printf("y = %f kmol\nx = %f kmol",y,x)

//part 1
fraction = y/x;
printf("\n\nfration of recycle that is purged = %f",
   fraction)

//part 2
yield = 0.105*(100+x);
printf("\n\noverall yield of ammonia = %f kmol",
   yield)
```

Scilab code Exa 3.15 Enthalpy calculation

```
clc
clear
printf("example 3.15 page number 107\n\n")

//to find change in enthalpy
H0_CH4 = -74.9    //in kJ
H0_CO2 = -393.5    //in kJ
H0_H2O = -241.8    //in kJ

delta_H0 = H0_CO2+2*H0_H2O-H0_CH4;
printf("change in enthalpy = %f kJ",delta_H0)
```

Scilab code Exa 3.16 Enthalpy calculation

```
clc
clear
printf("example 3.16 page number 107\n\n")

//to compare the enthalpy change in two reactions

H0_glucose = -1273  //in kJ
H0_ethanol = -277.6  //in kJ
H0_CO2 = -393.5  //in kJ
H0_H2O = -285.8   //in kJ

//for reaction 1
delta_H1 = 2*H0_ethanol+2*H0_CO2-H0_glucose;
printf("enthalpy change in reaction 1 = %f KJ",
   delta_H1)

//for reaction 2
delta_H2 = 6*H0_H2O+6*H0_CO2-H0_glucose;
printf("\n\nenthalpy change in reaction 2 = %f kJ",
   delta_H2)

if delta_H1>delta_H2 then disp ("reaction 2 supplies
    more energy")
     else disp ("reaction 1 supplies more energy")
end
```

Scilab code Exa 3.17 Enthalpy of formation

```
clc
clear
```

```
printf("example 3.17 page number 108\n\n")

//to find enthalpy of formation of CuSO4.5H2O

delta_H2 = 11.7    //in kJ/mol
m_CuSO4 = 16   //in gm
m_H2O = 384    //in gm

delta_H3 = -((m_CuSO4+m_H2O)*4.18*3.95*159.6)
    /(16*10^3)
delta_H1 = delta_H3 - delta_H2;

printf("enthalpy of formation = %f kJ/mol",delta_H1)
```

Scilab code Exa 3.18 Combustion

```
clc
clear
printf("example 3.18 page number 108\n\n")

//to find the temperature of combustion

H_combustion = 1560000     //in kJ/kmol
H0_CO2 = 54.56    //in kJ/kmol
H0_O2 = 35.2    //in kJ/kmol
H0_steam = 43.38    //in kJ/kmol
H0_N2 = 33.32    //in kJ/kmol

t = H_combustion/(2*H0_CO2+3*H0_steam+0.875*H0_O2
    +16.46*H0_N2);

printf("theoritical temperature of combustion = %f
    degree C",t)
```

Scilab code Exa 3.19 Heat of reaction

```
clc
clear
printf("example 3.19 page number 109\n\n")

//to find the heat of reaction and consumption of
   coke

H_NaCl = 410.9   //in MJ/kmol
H_H2SO4 = 811.3   //in MJ/kmol
H_Na2SO4 = 1384   //in MJ/kmol
H_HCl = 92.3   //in MJ/kmol

Q = H_Na2SO4 + 2*H_HCl -2*H_NaCl-H_H2SO4;
printf("heat of reaction = %f MJ\n\n",Q)

heat_required = 64.5*(500/73);
coke_consumption = heat_required/19
printf("amount of coke oven gas consumed = %f cubic
   meter",coke_consumption)
```

Scilab code Exa 3.20 Heat transfer

```
clc
clear
printf("example 3.20 page number 109\n\n")

//to find the rate of heat flow

cp_water = 146.5   //in kj/kg
cp_steam = 3040   //in kJ/kg
```

```
d = 0.102   //in m
u = 1.5   //in m/s
density = 1000    //in kg/m3

m = (3.14/4)*d^2*u*density;
Q = m*(cp_steam-cp_water);

printf("rate of heat flow = %f kW",Q)
```

Scilab code Exa 3.21 Calorific value

```
clc
//EXAMPLE 3.21
//To find the calorific value of coal
disp('this is a theoritical problem.Refer the book
   for solution')
```

Scilab code Exa 3.22 Coal combustion

```
clc
clear
printf("example 3.22 page number 110\n\n")

//to find the amount of air required for combustion
   and composition of flue gas
wt_C = 0.75   //in kg
wt_H2 = 0.05   //in kg
wt_O2 = 0.12   //in kg
wt_N2 = 0.03   //in kg
wt_S = 0.01    //in kg
wt_ash = 0.04  //in kg

O2_C = wt_C*(32/12);  //in kg
```

```
O2_H2 = wt_H2*(16/2);    //in kg
O2_S = wt_S*(32/32);    //in kg
O2_required = O2_C+O2_H2+O2_S;

oxygen_supplied = O2_required - wt_O2;
air_needed = oxygen_supplied/0.23;
printf("amount of air required = %f kg",air_needed)

volume = (22.4/28.8)*air_needed;
printf("\n\nvolume of air needed = %f cubic meter",
   volume)

air_supplied = 1.20*air_needed;
N2_supplied = air_supplied*0.77;
total_N2 = N2_supplied+wt_N2;

O2_fluegas = air_supplied*0.23 - oxygen_supplied;

wt_CO2 = wt_C+O2_C;
wt_SO2 = wt_S+O2_S;

moles_CO2 = wt_CO2/44;
moles_SO2 = wt_SO2/64;
moles_N2 = total_N2/28;
moles_O2 = O2_fluegas/32;
total_moles = moles_CO2+moles_SO2+moles_N2+moles_O2;

x_CO2 = moles_CO2/total_moles;
x_SO2 = moles_SO2/total_moles;
x_N2 = moles_N2/total_moles;
x_O2 = moles_O2/total_moles;

printf("\n\nCO2 = %f",x_CO2*100)
printf("\n\nSO2 = %f",x_SO2*100)
printf("\n\nN2 = %f",x_N2*100)
printf("\n\nO2 = %f",x_O2*100)
```

Scilab code Exa 3.23 Coal combustion

```
clc
clear
printf("example 3.23 page number 110\n\n")

//to find the composition of flue gas

C = 0.8   //in kg
H2 = 0.05   //in kg
S = 0.005   //in kg
ash = 0.145  //in kg

//required oxygen in kg
C_O2 = C*(32/12);
H2_O2 = H2*(16/2);
S_O2 = S*(32/32);
O2_supplied = C_O2+S_O2+H2_O2;
printf("amount of O2 supplied = %f kg\n\n",O2_supplied)

wt_air = O2_supplied*(100/23);
wt_airsupplied = 1.25*wt_air;
printf("amount of air supplied = %f kg\n\n",wt_airsupplied)

//flue gas composition
m_N2 = wt_airsupplied*0.77;   //in kg
mole_N2 = m_N2/28;

m_O2 = (wt_airsupplied-wt_air)*0.23;   //in kg
mole_O2 = m_O2/32;

m_CO2 = C*(44/12);   //in kg
```

```
mole_CO2 = m_CO2/44;

m_H2O = H2*(18/2);    //in kg
mole_H2O = m_H2O/18;

m_SO2 = S*(64/32);    //in kg
mole_SO2 = m_SO2/64;

m = m_N2+m_O2+m_CO2+m_H2O+m_SO2

//percent by weight
w_N2 = m_N2/m;
printf("percentage of N2 by weight = %f\n\n",w_N2
    *100)

w_O2 = m_O2/m;
printf("percentage of O2 by weight = %f\n\n",w_O2
    *100)

w_CO2 = m_CO2/m;
printf("percentage of CO2 by weight = %f\n\n",w_CO2
    *100)

w_H2O = m_H2O/m;
printf("percentage of H2O by weight = %f\n\n",w_H2O
    *100)

w_SO2 = m_SO2/m;
printf("percentage of SO2 by weight = %f\n\n",w_SO2
    *100)

m1 = mole_N2+mole_O2+mole_CO2+mole_H2O+mole_SO2

//percent by mole
x_N2 = mole_N2/m1;
printf("percentage of N2 by mole = %f\n\n",x_N2*100)

x_O2 = mole_O2/m1;
```

```
printf("percentage of O2 by mole = %f\n\n",x_O2*100)

x_CO2 = mole_CO2/m1;
printf("percentage of CO2 by mole = %f\n\n",x_CO2
    *100)

x_H2O = mole_H2O/m1;
printf("percentage of H2O by mole = %f\n\n",x_H2O
    *100)

x_SO2 = mole_SO2/m1;
printf("percentage of SO2 by mole = %f\n\n",x_SO2
    *100)
```

Scilab code Exa 3.24 Petrol combustion

```
clc
clear
printf("example 3.24 page number 112\n\n")

//to find volumetric composition of flue glass

wt_H2 = 0.15;
wt_C = 0.85;
O2_H2 = wt_H2*(16/2);
O2_C = wt_C*(32/12);

total_O2 = O2_H2+O2_C;

wt_air = total_O2/0.23;

air_supplied = 1.15*(wt_air);
N2_supplied = 0.77*air_supplied/28;
O2_supplied = 0.23*(air_supplied-wt_air)/32;
moles_CO2 = 0.85/12;
```

```
printf("moles of CO2 = %f kmol\n\n",moles_CO2)
printf("moles of N2 = %f kmol \n\n",N2_supplied)
printf("moles of O2 = %f kmol\n\n",O2_supplied)

total_moles = N2_supplied+O2_supplied+moles_CO2;

printf("percentage of CO2 = %f\n\n",(moles_CO2/
    total_moles)*100)
printf("percentage of N2 = %f\n\n",(N2_supplied/
    total_moles)*100)
printf("percentage of O2 = %f",(O2_supplied/
    total_moles)*100)
```

Scilab code Exa 3.25 Air supply

```
clc
clear
printf("example 3.25 page number 113\n\n")

//to find the excess air supplied

N2 = 80.5    //in m3
air_supplied = N2/0.79    //in m3
volume_O2 = air_supplied*0.21;   //in m3
O2_fluegas = 6.1    //in m3

O2_used = volume_O2 - O2_fluegas;
excess_air_supplied = (O2_fluegas/O2_used)*100;

printf("percentage of excess air supplied = %f",
    excess_air_supplied)
```

Scilab code Exa 3.26 CO2 cooling

```
clc
clear
printf("example 3.26 page number 114\n\n")

//to find the outlet temperature of water

q_NTP = 10*(200/101.3)*(273/313);
m_CO2 = 44*(q_NTP/22.4);
s_CO2 = 0.85    //in kJ/kg K

Q = m_CO2*s_CO2*(40-20)    //Q = ms*delta_T

d0 = 0.023    //in mm
A0 = (3.14/4)*d0^2;
di = 0.035    //in mm
Ai = (3.14/4)*di^2;

A_annular = Ai-A0;
u = 0.15    //in m/s
m_water = A_annular*(u*3600)*1000    //in kg/hr

s_water = 4.19    //in kJ/kg K
t = 15+(Q/(m_water*s_water));

printf("exit water temperature = %f degree C",t)
```

Scilab code Exa 3.27 Heating area

```
clc
clear
printf("example 3.27 page number 114\n\n")

//to find the area of heating surface
```

```
F = 1000    //in kg
xF = 0.01

solid_feed = F*xF;
water_feed = F - solid_feed;

tF = 40  //in degree C
hF = 167.5    //in kJ/kg
xL = 0.02;

solid_liquor = 10  //in kg
L = solid_liquor/xL;
tL = 100  //in degree C
hL = 418.6    //in kJ/kg

V = F -L;

tv = 100  //in degree C
Hv = 2675    //in kJ/kg
ts = 108.4   //in degree C
Hs = 2690   //in kJ/kg
tc = 108.4   //in degree C
hc = 454    //in kJ/kg

//applying heat balance
S = (F*hF-V*Hv-L*hL)/(hc-Hs);
printf("weight of steam required = %f kg/hr",S)

Q = S*(Hs-hc);
U = 1.4    //in kW/m2K
delta_t = ts-tL;
A = 383.2/(U*delta_t);
printf("\n\narea of heating surface = %f square
    meter",A)
```

Scilab code Exa 3.28 Distillation column

```
clc
clear
printf("example 3.28 page number 115\n\n")

//to find the top and bottom product,condenser duty,
    heat input to rebpoiler
hF = 171  //in kJ/kg
hD = 67   //in kJ/kg
hL = hD;

hW = 200  //in kJ/kg
H = 540  //in kJ/kg

disp('part 1')
F = 1000   //in kg/h
xF = 0.40
xW = 0.02;
xD = 0.97;
D = F*(xF-xW)/(xD-xW);
W = F-D;

printf("bottom product = %f kg/hr",W)
printf("\ntop product = %f kg/hr\n\n",D)

disp('part 2')
L = 3.5*D;
V = L+D;
Qc = V*H-L*hL-D*hD;
printf("condenser duty = %f KJ/hr\n\n",Qc)

disp('part 3')
Qr = Qc - 24200;
printf("rate of heat input to reboiler = %f kJ/hr",
    Qr)
```

Scilab code Exa 3.29 Crystallization

```
clc
clear
printf("example 3.29 page number 117\n\n")

//to find the rate of crystal formation, cooling
    water rate, required area

F = 1000;     //in kg
V = 0.05*F;    //in kg
xF = 0.48;
xL = 75/(100+75);
xC = 1;
C = (F*xF-950*xL)/(1-0.429);
printf ("rate of crystal formation = %f kg",C)

L = F-C-V;

//cooling water
W = (F*2.97*(85-35)+126.9*75.2-V*2414)/(4.19*11);
printf("\n\nrate of cooling water = %f kg",W)

delta_T1 = 56;
delta_T2 = 17;
delta_Tm = (delta_T1-delta_T2)/(log(delta_T1/
    delta_T2))
U = 125;

A=(F*2.97*(85-35)+126.9*75.2-V*2414)/(U*delta_Tm
    *3.6);
printf("\n\narea = %f square meter",A)
```

Scilab code Exa 3.30 Combustion

```
clc
clear
printf("example 3.30 page number 118\n\n")

//to find the heat of combustion

delta_n = 10-12;  //mole per mole napthanlene

//basis 1g
moles_napthalene = (1/128);

disp('part 1')
Qv = 40.28   //in kJ
Qp = Qv-(delta_n*moles_napthalene*8.3144*298/1000);
printf("heat of combustion = %f kJ\n\n",Qp)

disp('part 2')
delta_H = 44.05   //in kJ/gmol
water_formed = 4/128;   //in g mol
Qp1 = Qp - (delta_H*water_formed);
printf("heat of combustion = %f kJ",Qp1)
```

Chapter 4

Flow Of Fluids

Scilab code Exa 4.1 Water compressibility

```
clc
clear
printf("example 4.1 page number 125\n\n")

//to find water compressibility
delta_p=70;    //in bar
Et=20680      //in bar
compressibility = delta_p/Et;
printf("compressibilty of water = %f",
   compressibility)
```

Scilab code Exa 4.2 Isothermal Compressibility

```
clc
clear
printf("example 4.2 page number 125\n\n")

disp("this is a theoritical problem,book shall be
   referred for solution")
```

Scilab code Exa 4.3 Viscosity

```
clc
clear
printf("example 4.3 page number 128\n\n")

//to find the viscosity of oil

F=0.5*9.8;    //in N
A=3.14*0.05*0.15;    //in m2
shear_stress=F/A;    //in Pa
printf("shear_stress = %f Pa",shear_stress)

velocity_distribution =0.1/(0.05*10^-3);
viscosity=shear_stress/velocity_distribution;
printf("\n\nviscosity = %f Pa-s",viscosity)
```

Scilab code Exa 4.4 Streamline flow

```
clc
clear
printf("example 4.4 page number 130\n\n")
printf("this is a theoritical problem,book shall be
    referred for solution")
```

Scilab code Exa 4.5 Frictional losses

```
clc
clear
```

```
printf("example 4.5 page number 133\n\n")

//to find variation of losses with velocity
loss_ratio=3.6;       //delta_P2/delta_P1=3.6
velocity_ratio=2;     //u2/u1=2
n=log2(loss_ratio);   //delta_P2/delta_P1=(u2/u1)^n
printf("power constant = %f flow is turbulent",n)
```

Scilab code Exa 4.6 Velocity profile

```
clc
clear
printf("example 4.6 page number 133\n\n")
printf("this is a theoritical problem,book shall be
   referred for solution")
```

Scilab code Exa 4.7 Velocity profile

```
clc
clear
printf("example 4.7 page number 134")
disp("this is a theoritical problem,book shall be
   referred for solution")
```

Scilab code Exa 4.8 Boundary layer

```
clc
clear
printf("example 4.8 page number 137\n\n")

```

```
//to find the boundary layer properties

disp('part 1')
x=0.05    //in m
density=1000    //in kg/m3
viscosity=1*10^-3     //in Pa-s
u=1    //in m/s
Re=(density*u*x)/viscosity;

printf("Reynolds Number = %f",Re)

thickness=4.65*x*(Re)^-0.5;
printf("\nboundary layer thickness = %f m\n",
   thickness)

disp('part 2')
Re_x=3.2*10^5;
x_cr=(Re_x*viscosity)/(density*u);
printf("transition takes place at x = %f m\n",x_cr)

disp('part 3')
x=0.5    //in m
Re=(density*u*x)/viscosity;
thickness=0.367*x*(Re)^-0.2;
printf("boundary layer thickness= %f m",thickness)

t_sublayer=71.5*x*(Re)^-0.9;
printf("\nsub layer thickness= %f m",t_sublayer)
```

Scilab code Exa 4.9 Pipe flow

```
clc
clear
printf("example 4.9 page number 138\n\n")

```

```
//to find the flow properties
d1=0.05    //in m
A1=(3.14*d1^2)/4;
density_1=2.1    //in kg/m3
u1=15       //in m/s
P1=1.8;     //in bar
P2=1.3;     //in bar

w=density_1*A1*u1;
density_2=density_1*(P2/P1);
printf("density at section 2 = %f kg/cubic meter",
   density_2)

u2=u1*(density_1/density_2)*(0.05/0.075)^2;
printf("\n\nvelocity at section 2 = %f m/s",u2)
```

Scilab code Exa 4.10 Temperature rise

```
clc
clear
printf("example 4.10 page number 139\n\n")

//to find the temperature increase

Q=0.001*10^5    //in J/s
w=0.001*1000    //in kg/s
density=1000    //in kg/m3
cp=4.19*10^3    //in J/kg K

delta_T=Q/(w*cp);
printf("Temperature increase = %f degree celcius",
   delta_T)
```

Scilab code Exa 4.11 Bernoulli equation

```
clc
clear
printf("example 4.11 page number 142\n\n")

//to find the pressure

u1=0;    //in m/s
ws=0;
P1=0.7*10^5      //in Pa
P3=0
density=1000    //in kg/m3

u3=((2*(P1-P3))/density)^0.5;
printf("u3 = %f m/s",u3)

ratio_area=0.5;
u2=u3/ratio_area;
printf("\n\nu2 = %f m/s",u2)

//applying bernoulli's equation
P2=1.7*10^5-((density*u2^2)/2)
printf("\n\nP2 = %f Pa",P2)
printf("\nthis flow is physically unreal")
```

Scilab code Exa 4.12 Power requirements

```
clc
clear
printf("example 4.12 page number 143\n\n")

//to find the power requirements

Q=3800/(24*3600)     //in m3/s
```

```
d=0.202     //in m

u=Q/((3.14/4)*d^2);     //in m/s
delta_P=5.3*10^6     //in Pa
density=897     //in kg/m3
F=delta_P/density;     //in J/kg
ws=9.8*30+F;
mass_flow_rate= Q*density;
power=(ws*mass_flow_rate)/0.6;

printf("power required = %f kW",power/1000)
```

Scilab code Exa 4.13 Hagen Poiseulle equation

```
clc
clear
printf("example 4.13 page number 146\n\n")

//to find the tube length
density=1000     //in kg/m3
viscosity=1*10^-3     //in Pa s
P=100*1000     //in Pa

vdP=P/density;

Q=2.5*10^-3/(24*3600)
A=3.14*(0.0005)^2/4;
u=Q/A;
printf("u = %f m/s",u)

Re=density*u*0.0005/viscosity;
printf("\n\nRe = %f",Re)

//F=18.86*L
L=(-u^2+vdP)/18.86;
```

```
printf("\n\nL = %f m",L)
```

Scilab code Exa 4.14 Pressure Head calculation

```
clc
clear
printf("example 4.14 page number 151\n\n")

//to find the discharge pressure
d=0.025      //in m
u=3          //in m/s
density=894    //in kg/m3
viscosity=6.2*10^4      //in Pa-s

Re=(u*d*density)/viscosity;
f=0.0045;
L=50;

delta_P=2*f*density*u^2*(L/d)
printf("frictional head loss = %f kPa",delta_P/1000)

required_P=25*density*9.8;
total_head=delta_P+required_P;
printf("\n\ntotal pressure head = %f bar",total_head
   /10^5)
```

Scilab code Exa 4.15 Level difference calculation

```
clc
clear
printf("example 4.15 page number 152\n\n")

//to find the level difference
```

```
Q=0.8*10^-3;    //in m3/s
d=0.026     //in m
A=(3.14*(d^2))/4    //in m2

u=Q/A;     //in m/s
density=800     //in kg/m3
viscosity=0.0005    //in Pa-s

Re=(u*density*d)/viscosity;
f=0.079*(Re)^-0.25;
L=60
h_f=2*f*((u^2)/9.8)*(L/d);

printf("level difference = %f m",h_f)
```

Scilab code Exa 4.16 Energy cost calculation

```
clc
clear
printf("example 4.16 page number 153\n\n")

//to find the engery cost
delta_z=50;     //in m
L=290.36     //in m
d=0.18     //in m
Q=0.05     //in m3/s

A=(3.14*d^2)/4;     //in m2
u=Q/A;     //in m/s
density=1180;    //in kg/m3
viscosity=0.0012    //in Pa-s
Re=u*density*d/viscosity;

f=0.004;
```

```
sigma_F=2*f*u^2*L/d;
ws=((9.8*50)+sigma_F)/0.6;
mass_flow_rate=Q*density;      //in Kg/s
power=mass_flow_rate*ws/1000;    //in KW
energy_cost=power*24*0.8;

printf("Energy cost = Rs %f",energy_cost)
```

Scilab code Exa 4.17 Pressure loss

```
clc
clear
printf("example 4.17 page number 154\n\n")

//to find the pressure loss
density=998    //in kg/m3
viscosity=0.0008   //in Pa-s
d=0.03    //in m
u=1.2    //in m/s

Re=density*d*u/viscosity;

f=0.0088;
D=1    //in m
N=10
L=3.14*D*N;
delta_P=(2*f*u^2*L)/d;    //in Pa
delta_P_coil=delta_P*(1+(3.54*(d/D)));

printf("frictional pressure drop = %f kPa",
   delta_P_coil)
```

Scilab code Exa 4.18 Pressure gradient

```
clc
clear
printf("example 4.18 page number 154\n\n")

//to find pressure drop per unit length

b=0.050     //in m
a=0.025     //in m
d_eq=b-a   //in m
density=1000   //in kg/m3
u=3     //in m/s
viscosity = 0.001

Re=d_eq*u*density/viscosity;

e=40*10^6    //in m
f=0.0062;
P_perunit_length=2*f*density*u^2/d_eq;    //in Pa/m

printf("pressure per unit length = %f Pa/m",
   P_perunit_length)
```

Scilab code Exa 4.19 Flow rate

```
clc
clear
printf("example 4.19 page number 155\n\n")

//to find the flow rate
d = 0.3    //in m
u = 17.63    //avg velocity in m/s

q = (3.14/4)*d^2*u;
printf("volumetric flow rate = %f cubic meter per
   second",q)
```

Scilab code Exa 4.20 Pipe dimensions

```
clc
clear
printf("example 4.20 page number 156\n\n")

//to find the size of pipe required
d = 0.15    //in m
u = (0.0191/0.15^2);    //in m/s

q = (3.14/4)*d^2*u;
printf("volumetric flow rate = %f cubic meter/s",q)
```

Scilab code Exa 4.21 Pressure gradient

```
clc
clear
printf("example 4.21 page number 160\n\n")

//to find the pressure gradient

Q=0.0003    //in m3/s
d=0.05    //in m
A=(3.14*d^2)/4;

u=Q/A;

density=1000;    //in kg/m3
viscosity=0.001;   //in Pa-s
e=0.3;
dp=0.00125;    //particle diameter in m
```

```
Re=(dp*u*density)/(viscosity*(1-e));
fm=(150/Re)+1.75;
L=0.5    //in m
delta_Pf=fm*((density*L*u^2)/dp)*((1-e)/e^3);    //in
    Pa

//applying bernoulli's equation, we get
delta_P=delta_Pf-(density*9.8*L);
pressure_gradient=delta_P/(L*1000);    //in kPa/m
printf("required pressure gradient = %f kPa/m of
   packed height",pressure_gradient)
```

Scilab code Exa 4.22 Minimum fluidization velocity

```
clc
clear
printf("example 4.22 page number 163\n\n")

//to find minimum fluidization velocity

d=120*10^-6     //in m
density=2500    //particle density in kg/m3
e_min=0.45;
density_water=1000    //in kg/m3
viscosity=0.9*10^-3;    //in Pa-s
umf=(d^2*(density-density_water)*9.8*e_min^3)/(150*
   viscosity*(1-e_min));
printf("minimum fludization velocity = %f m/s",umf)

Re_mf=(d*umf*density_water)/(viscosity*(1-e_min));


//given that uo/umf=10
function[f] = F(e)
```

```
    f = e^3+1.657*e-1.675;
endfunction

//initial guess
x = 10;
e = fsolve(x,F);

printf("\n\ne = %f",e)
length_ratio=(1-e_min)/(1-e);
printf("\n\nratio of heights = %f",length_ratio)
```

Scilab code Exa 4.23 Pumping of fluids

```
clc
clear
printf("example 4.23 page number 167\n\n")

//to find the power requirements

P=9807    //in Pa
density=1000    //in kg/m3
Q=250/(60*density)
head=25    //in m

w= head*Q*P;      //in kW
power_delivered=w/0.65;
power_taken=power_delivered/0.9;

printf("power_delivered = %f kW",power_delivered
    /1000)
printf("\n\npower taken by motor = %f kW",
    power_taken/1000)
```

Chapter 5

Heat Transfer

Scilab code Exa 5.1 Heat conduction

```
clc
clear
printf("example 5.1 page number 171\n\n")

//to find the rate of heat loss
A=5*4   //in m2
T1=100;    //in K
T2=30;     //in K

delta_T=T1-T2;

x=0.25    //in m
k=0.70     //in W/mK
Q=k*A*(delta_T/x);

printf("rate of heat loss = %f W",Q)
```

Scilab code Exa 5.2 Heat conduction

```
clc
clear
printf("example 5.1 page number 171\n\n")

//to find the heat loss

d1=0.15   //in m
d2=0.16   //in m
l=1   //in m

A1=3.14*d1*l;
A2=3.14*d2*l
Am=(A1-A2)/log (A1/A2);

T1=120;   //in K
T2=119.8;   //in K

delta_T=T1-T2;
x=(d2-d1)/2;
k=50   //in W/mK
Q=k*Am*(delta_T/x);

printf("rate of heat loss per unit length = %f W/m",
   Q)
```

Scilab code Exa 5.3 Heat conduction through sphere

```
clc
clear
printf("example 5.3 page number 172\n\n")

//to find the rate of heat loss

ri=0.5   //in m
ro=0.6;  //in m
```

```
A1=4*3.14*ri^2;
A2=4*3.14*ro^2;

Am=(A1*A2)^0.5;

Ti=140;     //in K
To=50;     //in K
delta_T=Ti-To;
x=0.1    //in m
k=0.12     //in W/mK

Q=k*Am*(delta_T/x);
printf("Heat loss through sphere = %f W",Q)
```

Scilab code Exa 5.4 Composite wall

```
clc
clear
printf("example 5.4 page number 173\n\n")

//to find the heat loss from composite wall
//for the red brick layer

x1=0.250;   //in m
k1=0.7;   //in W/mK
A1=1;    //in m2
R1=x1/(k1*A1);    //in K/W

//for the felt layer
x2=0.020;   //in m
k2=0.046;   //in W/mK
A2=1;    //in m2
R2=x2/(k2*A2);    //in K/W
R=R1+R2;
printf("Total resistance = %f K/W",R)
```

```
T1=110;    //in K
T2=25    //in K
delta_T=T1-T2;
Q=delta_T/R;
printf("\n\nheat loss through wall = %f W/square m",
    Q)
```

Scilab code Exa 5.5 Composite Pipeline

```
clc
clear
printf("example 5.5 page number 173\n\n")

//to find the rate of heat loss through pipeline
//resistance by pipeline

d1=0.15    //in m
d2=0.16    //in m
l=1    //in m
A1=3.14*d1*l;
A2=3.14*d2*l
Am1=(A2-A1)/log (A2/A1);
x1=(d2-d1)/2;
k1=50    //in W/mK
R1=x1/(k1*Am1);

//resistance by insulation
d2=0.16    //in m
d3=0.26    //in m
l=1    //in m
A2=3.14*d2*l;
A3=3.14*d3*l
Am2=(A3-A2)/log (A3/A2);
x2=(d3-d2)/2;
```

```
k2=0.08    //in W/mK
R2=x2/(k2*Am2);
R=R1+R2;

printf("total resistance = %f K/W",R)

T1=120;    //in K
T2=40;    //in K
delta_T=T1-T2;
Q=delta_T/R;

printf("\n\nheat loss = %f W/m",Q)
```

Scilab code Exa 5.6 Parellel Resistance

```
clc
clear
printf("example 5.6 page number 174\n\n")

//to find the increase in heat transfer rate

x1=0.1;    //in m
x2= 0.25;  //in m
k_rb=0.93;    //in W/mK
k_ib=0.116     //in W/mK
k_al=203.6     //in W/mK
A=0.1    //in m2

//to find resistance without rivets
R=(1/A)*((x1/k_rb)+(x2/k_ib));
T1=225    //in K
T2=37     //in K
delta_T=T1-T2;
Q=delta_T/R;
printf("heat transfer rate = %f W",Q)
```

```
//to find resistance with rivet
d=0.03    //in m
rivet_area= (3.14/4)*d^2;
R_r=(x1+x2)/(k_al*rivet_area);
area_norivet=A-rivet_area;
R_cl=(A/area_norivet)*R;
R_eq=1/(1/R_r+1/R_cl);
Q_new=delta_T/R_eq;

printf("\n\nRate of heat transfer with rivet = %f W"
    ,Q_new)
increase=((Q_new-Q)/Q)*100;
printf("\n\npercentage increase in heat transfer
    rate = %f",increase)
```

Scilab code Exa 5.7 Heat transfer coefficient

```
clc
clear
printf("example 5.6 page number 174\n\n")

//to find the increase in heat transfer rate

x1=0.1;    //in m
x2= 0.25;   //in m
k_rb=0.93;    //in W/mK
k_ib=0.116     //in W/mK
k_al=203.6     //in W/mK
A=0.1    //in m2

//to find resistance without rivets
R=(1/A)*((x1/k_rb)+(x2/k_ib));
T1=225    //in K
T2=37     //in K
```

```
delta_T=T1-T2;
Q=delta_T/R;
printf("heat transfer rate = %f W",Q)

//to find resistance with rivet
d=0.03   //in m
rivet_area= (3.14/4)*d^2;
R_r=(x1+x2)/(k_al*rivet_area);
area_norivet=A-rivet_area;
R_cl=(A/area_norivet)*R;
R_eq=1/(1/R_r+1/R_cl);
Q_new=delta_T/R_eq;

printf("\n\nRate of heat transfer with rivet = %f W",Q_new)
increase=((Q_new-Q)/Q)*100;
printf("\n\npercentage increase in heat transfer rate = %f",increase)
```

Scilab code Exa 5.8 Heat transfer coefficient

```
clc
clear
printf("example 5.8 page number 188\n\n")

//to find the heat transfer coefficient
density=984.1      //in kg/cubic meter
v=3   //in m/s
viscosity=485*10^-6;     //in Pa-s
k=0.657    //in W/mK
cp=4178   //in J/kg K
d=0.016    //in m

Re=(density*v*d)/viscosity;
Pr=(cp*viscosity)/k;
```

```
//dittus boelter equation
h=0.023*Re^0.8*Pr^0.3*(k/d);
printf("heat transfer coefficient = %f W/sq meter K"
    ,h)

//Sieder Tate equation
viscosity_w=920*10^-6
h1=0.023*Re^0.8*Pr^(1/3)*(k/d)*(viscosity/
    viscosity_w)^0.14;
printf("\n\nheat transfer coefficient = %f W/sq
    meter K",h1)
```

Scilab code Exa 5.9 Earth Temperature

```
clc
clear
printf("example 5.9 page number 191\n\n")

//to find the surface temperature of earth
T_sun = 5973   //in degree C
d = 1.5*10^13     //in cm
R = 7.1*10^10;   //in cm

T_earth = ((R/(2*d))^0.5)*T_sun;
printf("Temperature of earth = %f C",T_earth-273)
```

Scilab code Exa 5.10 Earth Temperature

```
clc
clear
printf("example 5.10 page number 191\n\n")

```

```
//to find temperature of earth
R=7*10^10;    //in cm
Ts=6000;    //in K
l=1.5*10^13;    //in m
To=((R^2/(4*l^2))^0.25)*Ts;
printf("temperature of earth = %f K",To)
```

Scilab code Exa 5.11 Equilibrium temperature

```
clc
clear
printf("example 5.11 page number 192\n\n")

//to find the equilibrium temperature
R=6.92*10^5     //in km
l=14.97*10^7    //in km
Ts=6200;     //in K
To=(R^2/l^2)^0.25*Ts;
printf("Equilibrium temperature = %f K",To)
```

Scilab code Exa 5.12 Equilibrium temperature

```
clc
clear
printf("example 5.12 page number 192\n\n")

//to find the equilibrium temperature
view_factor=0.5;
R=6.92*10^5     //in km
l=14.97*10^7    //in km
Ts=6200;     //in K
To=(view_factor*(R^2/l^2))^0.25*Ts;
printf("Equilibrium temperature = %f K",To)
```

Scilab code Exa 5.13 Temperature calculation

```
clc
clear
printf("example 5.13 page number 193\n\n")

//to find the surface temperature
view_factor=0.25;
R=7.1*10^10    //in cm
l=1.5*10^13    //in cm
Ts=5973;    //in K
alpha=0.2;
epsilon=0.1;

ratio=alpha/epsilon;
To=(ratio*view_factor*(R^2/l^2))^0.25*Ts;
printf("Equilibrium temperature = %f K",To)
```

Scilab code Exa 5.14 Solar constant

```
clc
clear
printf("example 5.14 page number 193\n\n")

//to find the solar constant
R=7*10^10;    //in cm
l=1.5*10^13;    //in cm
sigma=5.3*10^-5;    //in erd/s(cm2)(K)4
T=6000;    //in K

S=(R/l)^2*(sigma)*(T^4)*60;
printf("solar constant = %f J/sq cm min",S/10^7)
```

Scilab code Exa 5.15 Evaporator

```
clc
clear
printf("example 5.15 page number 207\n\n")

//to find the amount of vapor and liquid and amount
   of heat transfer

F = 5000   //in kg/hr
xF = 0.01
xL = 0.02;

L = F*xF/xL;
V = F-L;
printf("L = %f Kg/hr\n V = %f kg/hr",L,V)

TF= 303  //in K
hF = 125.9   //in KJ/kg
T1 = 373.2   //in K
Hv = 2676.1   //in kJ/kg
hL = 419.04;   //in kJ/kg
Ts = 383.2   //in K
Hs = 2691.5   //in kJ/kg
hs = 461.30   //in kJ/kg

S = (F*hF-L*hL-V*Hv)/(hs-Hs);
printf("\n\namount of steam = %f kg steam/h",S)

q = S*(Hs - hs);
q = q*1000/3600   //conversion to Watt
U = q/(69.9*10);
printf("\n\nheat reansfer coefficient = %f W/sq m K"
   ,U)
```

Scilab code Exa 5.16 Evaporator

```
clc
clear
printf("example 5.16 page number 208\n\n")

//to find the amount of liquid and vapor leaving and
    outlet concentration
//we have two linear equations in L and V so we will
    write them in form of a matrix and then solve
   using principles of linear algebra

b1 = 6000*125.79+3187.56*2691.5-3187.56*461.30;
   //data from previous problem
b2 = 6000;
A = [419.04 2676.1;1 1];

b = [b1;b2];
x = A\b;
L = x(1);
V = x(2);

printf("L = %f kg/hr\nV = %f kg/hr",L,V)

F = 6000   //in kg/hr
xF = 0.01;
xL = F*xF/L;
printf("\n\npercentage increase in outlet
   concentration = %f",xL*100)
```

Scilab code Exa 5.17 Evaporator

```
clc
clear
printf("example 5.17 page number 209\n\n")

//to find the change in heat trnasfer area

Hv=2635.3    //kJ/kg
hL=313.93    //in kJ/kg
S=(2500*313.93+2500*2635.3-5000*125.79)
   /(2691.5-461.30);
printf("steam flow rate = %f kg steam/hr",S)

q = S*(2691.5 - 461.30);
q = q*1000/3600    //in W
U = 2833.13;   //in W/m2 K
delta_T = 383.2-348.2;   //in K
A = q/(U*delta_T);

printf("\n\nArea = %f sq meter",A)
printf("\n\nin this case a condensor and vaccum pump
    should be used")
```

Chapter 6

Mass Transfer

Scilab code Exa 6.1 Diffusivity

```
clc
clear
printf("example 6.1 page number 213\n\n")

printf("This is a theoritical problem and book shall
    be referred for solution")
```

Scilab code Exa 6.2 Absorption

```
clc
clear
printf("example 6.2 page number 214\n\n")

printf("This is a theoritical problem and book shall
    be referred for solution")
```

Scilab code Exa 6.3 Equimolar counter diffusion

```
clc
clear
printf("example 6.3 page number 215\n\n")

//to find the flux and pressure difference

D_AB=6.75*10^-5    //in m2/s
Z=0.03    //in m
R=8314
p_A1=5.5*10^4    //in Pa
p_A2=1.5*10^4    //in Pa
T=298    //in K

N_A=D_AB*(p_A1-p_A2)/(R*T*Z);
printf("flux = %f kmol/sq m s",N_A)

//for partial pressure
Z=0.02;    //in m
p_A2=p_A1-((N_A*R*T*Z)/D_AB);
printf("\n\npressure = %f Pa",p_A2)
```

Scilab code Exa 6.4 Resistane to diffusion

```
clc
clear
printf("example 6.4 page number 216\n\n")

//to find the flux of NH3 and equimolar counter
   diffusion flux

Z=0.15    //in m
P=1.103*10^5     //in Pa
p_A1=1.5*10^4     //in Pa
```

```
p_A2=5*10^3    //in Pa

p_B1=P-p_A1;
p_B2=P-p_A2;

D_AB=2.30*10^-5    //in m2/s
R=8314
T=298    //in K

//for non diffusing N2
p_BM=(p_B2-p_B1)/log (p_B2/p_B1);
N_A=D_AB*(p_A1-p_A2)*P/(R*T*Z*p_BM);
printf("flux = %f kmol/sq m s",N_A)

//for diffusing N2
N_A=D_AB*(p_A1-p_A2)/(R*T*Z);
printf("\n\nflux = %f kmol/sq m s",N_A)
```

Scilab code Exa 6.5 Vapor diffusion

```
clc
clear
printf("example 6.5 page number 216\n\n")
printf("This is a theoritical problem and book shall
    be referred for solution")
```

Scilab code Exa 6.6 Flux of HCl

```
clc
clear
printf("example 6.6 page number 218\n\n")

M_A=36.5    //molar mass of HCl
```

```
M_B=18        //molar masss of water
w_A1=12;      //weight % of HCL
w_A2=4        //weight % of HCL
x_A1=(w_A1/M_A)/((w_A1/M_A)+((100-w_A1)/M_B));
printf('x_A1 =%f',x_A1)

x_B1=1-x_A1;
M1=100/((w_A1/M_A)+((100-w_A1)/M_B));
printf("\n\nmolar mass at point 1 = %f kg/kmol",M1)

//at point 2
x_A2=(w_A2/M_A)/((w_A2/M_A)+((100-w_A2)/M_B));
x_B2=1-x_A2;
M2=100/((w_A2/M_A)+((100-w_A2)/M_B));     //avg molecular weight at point 2
printf("\n\nmolar mass at point 2 = %f Kg/kmol",M2)

density_1=1060.7;     //in kg/m3
density_2=1020.15;    //in kg/m3
C_av=((density_1/M1)+(density_2/M2))/2;
printf("\n\nC_av = %f kmol/cubic m",C_av)

x_BM=(x_B2-x_B1)/(log (x_B2/x_B1));
Z=0.004     //in m
D_AB=2.5*10^-9;
N_A=(D_AB*C_av*(x_A1-x_A2))/(x_BM*Z);
printf("\n\nflux = %f kmol/sq m-s",N_A)
```

Scilab code Exa 6.7 Vaporization

```
clc
clear
printf("example 6.7 page number 220\n\n")

printf("This is a theoritical problem and book shall
```

be referred for solution")

Scilab code Exa 6.8 Gas Absorption

```
clc
clear
printf("example 6.8 page number 229\n\n")

//to find the mean driving force and mass transfer
   area

Gs=700/22.4     //in kmol of dry air/hr
Ls=1500/18      //in kmol of dry air/hr
y1=0.05
Y1=y1/(1-y1);
Y2=0.02*Y1;
X2=0
X1=(Gs/Ls)*(Y1-Y2);
m=Gs*(Y1-Y2);

//driving force
delta_Y1=Y1-1.68*X1;
delta_Y2=Y2-1.68*X2;
delta_Y=(delta_Y1-delta_Y2)/(log (delta_Y1/delta_Y2)
   );
printf("driving force = %f kmol acetone/kmol dry air
   ",delta_Y)

//mass transfer area
K_G=0.4    //in kmol acetone/kmol dry air
A=m/(K_G*delta_Y);
printf("\n\narea = %f sq m",A)
```

Scilab code Exa 6.9 Equilibrium Composition

```
clc
clear
printf("example 6.9 page number 229\n\n")

//to calculate minimum oil circulation rate

G1=(855/22.4)*(106.6/101.3)*(273/299.7);
y1=0.02;
Y1=y1/(1-y1);
Gs=G1*(1-y1);

//for 95% removal
Y2=0.05*Y1;
x2=0.005;
X2=x2/(1-x2);
Y=0.204;
X1=0.176;     //in kmol bgenzene/kmol benzene free oil

Ls_molar=(Gs*(Y1-Y2))/(X1-X2);
Ls=Ls_molar*260;

printf("minimum oil circulation rate = %f kg/hr",Ls)
```

Scilab code Exa 6.10 Equilibrium Composition

```
clc
clear
printf("example 6.10 page number 231\n\n")

// to find the equilibrium composition
P_M = 53.32    //kPa
P_W = 12.33    //in kpA
```

```
P = 40  //IN K pA
x = (P - P_W)/(P_M-P_W);

printf("liquid phase composition = %f",x)

y = P_M*x/P;
printf("\n\nvapor phase composition = %f",y)
```

Scilab code Exa 6.11 `Vapor Liquid Equilibrium`

```
clc
clear
printf("example 6.11 page number 232\n\n")

printf("this is a theoritical question, book shall be referred for solution")
```

Scilab code Exa 6.12 `Distillation Column`

```
clc
clear
printf("example 6.12 page number 231\n\n")

//to find the top and bottom composition
x = [1;0.69;0.40;0.192;0.045;0];
y = [1;0.932;0.78;0.538;0.1775;0];
plot(x,y)
xlabel("x")
ylabel("y")
title("distillation curve")
x = 0:0.1:1;
y = 0:0.1:1;
plot(x,y)
```

```
x = [0.5,0.31];
y = [0.5,0.7];
plot (x,y)
Z=0.5;
y_D=0.69;
x_W=0.31;


printf("composition of top product = %f mole percent
    of hexane",y_D*100)
printf("\n\ncomposition of bottom product = %f mole
   percent of hexane",x_W*100)
```

Scilab code Exa 6.13 Distillation

```
clc
clear
printf("example 6.13 page number 237\n\n")

//to find the composite distillate and residue

F = 100    //moles
xf = 0.4;
D = 60    //moles
W = 40    //moles

x = 0.2:0.05:0.45;
for i =1:((0.45-0.2)/0.05)+1

y(i) = 2.16*x(i)/(1+1.16*x(i));


z(i) = (y(i)-x(i))^-1;

end
```

```
plot (x,z'/10)
title('Batch Distillation Curve')
xlabel('x')
ylabel('y')
xw = 0.22;    //from the graph
yd = (F*xf-W*xw)/D;

printf("composition of distillate = %f",yd)
printf("\n\ncomposition of residue = %f",xw)
```

Scilab code Exa 6.14 Steam Distillation

```
clc
clear
printf("example 6.14 page number 238\n\n")

printf('this is a theoritical question and solution
    can be referred from the book')
```

Scilab code Exa 6.15 Mcabe Thiele Method

```
clc
clear
printf("example 6.15 page number 249\n\n")

//to find the top and bottom product composition

//part 1
x=0.4;
y=0.8;
x_D=y;
x_W=0.135;    //bottom concentration
```

```
D=(100*x-100*x_W)/(y-x_W);     //distillate amount
printf("amount of distillate =%f moles/h",D)

//part 2
alpha=6;    //relative volatility
x_R=y/(y+(alpha*(1-y)));     //liquid leaving partial
    condensor
printf("\n\nliquid leaving partial condenser = %f",
   x_R)

y1=(1/3)*y+(2/3)*x;
x1=y1/(y1+(alpha*(1-y1)));
y_W = (1/3)*x_D+(2/3)*x1;
x_W=y_W/(y_W+(alpha*(1-y_W)));
D=(100*(x-x_W))/(y-x_W);

printf("\n\namount of distillate = %f moles/h",D)
```

Scilab code Exa 6.16 Liquid liquid extraction

```
clc
clear
printf("example 6.16 page number 264\n\n")

//to find the percentage extraction of nicotine
x=0.01;    //% of nicotine
X0 = x/(1-x);
w=150    //weight of nicotine water solution
A0=w*(1-X0);
B0=250;    //kg keroscene
X1 = A0*X0/(A0+B0*0.798);
printf("final concentration of nicotine = %f",X1)

c=A0*(X0-X1);
printf("\n\namount of nicotine removed = %f kg",c)
```

```
percentage = (c*100)/(A0*x);
printf("\n\npercentage recovery = %f percent",
    percentage)
```

Scilab code Exa 6.17 Liquid liquid extraction

```
clc
clear
printf("example 6.17 page number 264\n\n")

//to find the number of stages
x=0.01    //mole fraction of nicotine
yN = 0.0006;    //mole fraction in solvent
xN = 0.001;      //final mole fraction in water

X0=x/(1-x);    //in kg nicotine/kg water
YN =yN/(1-yN);    //in kg nicotine/kg keroscene
XN = xN/(1-xN);
A0=100*(1-X0);     //kgwater/h
B0=150*(1-YN);    //in kg kerosene/h

Y1=((A0*(X0-XN))/B0)+YN;     //in kg nicotine/kg
    kerosene
printf("Y1 = %f kg nicotine/kg kerosene",Y1)

//for graph refer to the book
number_of_stages = 8.4;
printf("\n\nnumnber of stages = %f",number_of_stages
    )
```

Scilab code Exa 6.18 Humidity calculation

```
clc
clear
printf("example 6.18 page number 274\n\n")

//to calculate the humidity
P = 101.3     //in kPa
pA = 3.74     //in kPa
p_AS = 7.415  //in kPa
H = (18.02/28.97)*(pA/(P-pA));
printf("humidity = %f kg H2O/kg air",H)

Hs = (18.02/28.97)*(p_AS/(P-p_AS));
printf("\n\nSaturated humidity = %f kg H2O/kg air",Hs)

%_humidity = 100*(H/Hs);
printf("\n\npercentage humidity = %f percent",%_humidity)

relative_humidity = 100*(pA/p_AS);
printf("\n\npercentage relative humidity = %f percent",relative_humidity)
```

Scilab code Exa 6.19 Drying operation

```
clc
clear
printf("example 6.17 page number 264\n\n")

//to find the air flow rate and outlet humidity
S=425.6    //in kg/h
X1 = 0.035    //in kgwater/kg dry solid
t_s1=25    //in degree C
X2 = 0.017    //in kg H2O/kg dry air
t_s2=60    //in degree C
```

```
H2 = 0.0175     //in kg H2O/kg dry air
t_G2 = 84.2    //in degree C
t_G1= 32.8    //in degree C
C_pS = 1.465    //in kJ/kg dry solid
C_pA = 4.187    //in kg/ kg H2O K

H_G2=(1.005+1.88*H2)*(t_G2-0)+H2*2501;
H_S1 = C_pS*(t_s1-0)+X1*C_pA*(t_s1-0);     //in kJ/kg
H_S2 = C_pS*(t_s2-0)+X2*C_pA*(t_s2-0);    //in kJ/kg
Q=9300;   //in kJ/h

printf("Latent heat of water at 0C, HG2 = %f kJ/kg
    dryair",H_G2)
printf("\n\nEnthalpy of entering solid , HS1 = %f kJ/
    kg dryair",H_S1)
printf("\n\nEnthalpy of exit solid , HS2 = %f kJ/kg
    dryair",H_S2)

//applying GHg2 + SHs1 = GHg1 +SHs2 +Q, we get two
    linear equations
//0.0175G+14.17248 = GH1 and 98.194G-29745.398 =
    2562.664GH1
A = [0.0175 -1;98.194 -2562.664];
b = [-14.17248;29745.398];
x = A\b;
G = x(1);
H1 = x(2)/G;
printf("\n\nAir flow rate , G = %f kg dryair/hr",G)
printf("\n\nHumidity , H1 = %f kg dryair/hr",H1)
```

Scilab code Exa 6.20 Crystallization

```
clc
clear
printf("example 6.20 page number 291\n\n")
```

```

//to find the crystal yield

M_Na2CO3 = 106
M_10H2O = 180.2
M_Na2CO3_10H2O = 286.2;
w_Na2CO3 = 5000   //in kg
%_water = 0.05   //% of water evaporated

W = %_water*w_Na2CO3;
//solving material balance, we have two equations
//equation 1 -> 0.8230L +0.6296C = 3500
//equation 2 -> 0.1769L + 0.3703C = 1250

A=[0.8230 0.6296;0.1769 0.3703]
b = [3500;1250]
x = A\b;
L = x(1);
C = x(2);
printf("L = %f kg solution",L)
printf("\n\nC = %f kg of Na2CO3.10H2O crystals",C)
```

Scilab code Exa 6.21 Crystallization

```
clc
clear
printf("example 6.21 page number 291\n\n")

//to find the crystal yield
//from material balance, we have two linear
    equations
//1400 = 0.7380L+0.5117C and 600 = 0.2619L+0.4882C

A=[0.7380 0.5117;0.2619 0.4882]
b = [1400;600]
```

```
x = A\b;
L = x(1);
C = x(2);
printf("L = %f kg solution",L)
printf("\n\nC = %f kg of MgSO4.7H2O crystals",C)

F = 2000    //in kg/h
cv = 2.93    //in kJ/kg K
H1 = F*cv*(330-293);
printf("\n\nenthalpy of feed = %f kJ",H1)

wt = 246.49    //molar mass MgSO4.7H2O
heat_soln = -13.31*10^3;    //in kJ/kg mol
heat = heat_soln/wt;
heat_crystallization = abs(heat);
H2 = heat_crystallization*C;    //total heat
q = -H1-H2;
printf("\n\nheat absorbed = %f kJ\nthus heat shall
    be removed",q)
```

Chapter 7

Chemical Kinetics

Scilab code Exa 7.1 Constant volume reaction

```
clc
clear
printf("example 7.1 page number 305\n\n")

printf("it is a theoritical problem, book shall be
   referred for solution")
```

Scilab code Exa 7.2 Rate of reaction

```
clc
clear
printf("example 7.2 page number 306\n\n")
printf("it is a theoritical problem, book shall be
   referred for solution")
```

Scilab code Exa 7.3 Rate of reaction

```
clc
clear
printf("example 7.3 page number 305\n\n")

//to find the change on rate of reaction
//part 1
//rate equation r = kC_NO^2*C_O2
//if pressure increases 3 times

r = 3^2*3;    //according to the rate reaction
printf("reaction reate will be increased by with 3
   times increase in pressure = %f times",r)

//part 2
r = 3^2*3;    //according to the rate reaction
printf("\n\nreaction reate will be increased by with
    3 times decrease in volume = %f times",r)

r = 3^2;    //according to the rate reaction
printf("\n\nreaction reate will be increased by with
    3 times increase in conc of NO = %f times",r)
```

Scilab code Exa 7.4 Order of reaction

```
clc
clear
printf("example 7.4 page number 308\n\n")

printf("it is a theoritical problem, book shall be
   referred for solution")
```

Scilab code Exa 7.5 Rate Expression

```
clc
clear
printf("example 7.5 page number 308\n\n")

printf("it is a theoritical problem, book shall be
   referred for solution")
```

Scilab code Exa 7.6 Volume function

```
clc
clear
printf("example 7.6 page number 308\n\n")

printf("it is a theoritical problem, book shall be
   referred for solution")
```

Scilab code Exa 7.7 Pressure time relation

```
clc
clear
printf("example 7.7 page number 309\n\n")

printf("it is a theoritical problem, book shall be
   referred for solution")
```

Scilab code Exa 7.8 Entropy changes

```
clc
clear
printf("example 7.8 page number 312\n\n")
```

```
printf("it is a theoritical problem, book shall be
   referred for solution")
```

Scilab code Exa 7.9 Hydrocarbon cracking

```
clc
clear
printf("example 7.9 page number 312\n\n")

printf("this is a theoretical question, book shall
   be referred for solution")
```

Scilab code Exa 7.10 Equilibrium conversion

```
clc
clear
printf("example 7.10 page number 316\n\n")

//to find the % transformation
moles_A = 3;
moles_B = 5;
K = 1;

function[f] = F(x)
    f = 15-8*x;
endfunction

//initial guess
x = 10;
y = fsolve(x,F);
printf("amount of A transformed = %f percent",y
   *(100/3))
```

Scilab code Exa 7.11 Equilibrium conversion

```
clc
clear
printf("example 7.11 page number 316\n\n")

//to find the product concentration
printf("this is a theoritical question , book shall
   be referred for solution")
```

Scilab code Exa 7.12 Concentration calculation

```
clc
clear
printf("example 7.11 page number 316\n\n")

//to find the initial conc of A and B
Cp = 0.02;
Cq = 0.02;
K = 4*10^-2;
Cb = 0.05;
Cb_i = Cb+Cp;
a = (Cp*Cq)/(K*Cb);
funcprot(0)
function[f] = F(x,a)
    f = x-0.02-a;
endfunction

//initial guess
x = 10;
y = fsolve(x,F);
```

```
printf("conc of A= %f mol/l",y)
printf("\n\nconc of B= %f mol/l",Cb_i)
```

Scilab code Exa 7.13 Equilibrium conversion

```
clc
clear
printf("example 7.11 page number 316\n\n")

//to find the % transformation

moles_A = 0.02;
K = 1;

//part 1
moles_B = 0.02;
function[f] = F(x)
    f = moles_A*moles_B-(moles_A+moles_B)*x;
endfunction

//initial guess
x = 10;
y = fsolve(x,F);
printf("amount of A transformed = %f percent",y
    *(100/0.02))

//part 2
moles_B = 0.1;
y = fsolve(x,F);
printf("\n\namount of A transformed = %f percent",y
    *(100/0.02))

//part 1
moles_B = 0.2;
y = fsolve(x,F);
```

```
printf("\n\namount of A transformed = %f percent',y
    *(100/0.02))
```

Scilab code Exa 7.14 Equilibrium shifts

```
clc
clear
printf("example 7.14 page number 317\n\n")

//to find the initial concentration and shift in
    equilibrium

Ce_N2 = 3;    //equilibrium conc of N2
Ce_H2 = 9;    //equilibrium conc of H2
Ce_NH3 = 4;   //equilibrium conc oh NH3
C_N2 = Ce_N2 + 0.5*Ce_NH3;
C_H2 = Ce_H2 + 1.5*Ce_NH3;

printf("concentration of N2 = %f mol/l\
    nconcentration of H2 = %f mol/l",C_N2,C_H2)
printf("\n\nsecond part is theoritical, book shall
    be referred for solution")

n_H2 = 3;    //stotiometric coefficient
n_N2 = 1;    //stotiometric coefficient
n_NH3= 2;    //stotiometric coefficient
delta_n = n_H2+n_N2-n_NH3;
if delta_n > 0 then printf ("\n\ndelta_n =%f\nsince
    delta_n is greater than 0,equilibrium will shift
    to right with increase in volume",delta_n)
end
```

Scilab code Exa 7.15 Rate equation

```
clc
//example 7.15
//to find the rate equation
t = [0;5;10;15;20;25]
C_A = [25;18.2;13.2;9.6;7;5.1]

//integral method of rate determination
s = 0;
for i = 2:6
    k(i) = (1/t(i))*log(25/C_A(i))
    //disp (k(i),"k values for various conc.")
    s = s+k(i)
end

printf("average value of k = %f",s/5)
disp ("ra =- 0.06367*CA","since its a first order
   reaction,")

subplot(221)
plot(t,C_A)
xlabel("time")
ylabel("concentration")
title("integral method")

//differential method of rate determination
ra = [-1.16;-0.83;-0.60;-0.43];
C_A = [18.2;13.2;9.6;7];

subplot(222)
plot(ra,C_A)
xlabel("Concentration")
ylabel("-ra")
title("differential method")

printf("\n\nrate from differential method = -0.064*
   CA")
```

Scilab code Exa 7.16 `Rate of reaction`

```
clc
clear
//example 7.16
//to find the rate of reaction
E = 75200     //in J/mol
E1 = 50100    //in J/mol
R = 8.314     //in J/mol K
T = 298   //in K
ratio = exp((E1-E)/(R*T));
rate_increase = ratio^-1
disp ("times",rate_increase,"increase in rate of
   reaction =")
```

Chapter 8

Measuring Devices

Scilab code Exa 8.1 Specific gravity

```
clc
clear
printf("example 8.1 page number 334\n\n")

printf("this is a theoritical problem, book shall be
    referred for solution")
```

Scilab code Exa 8.2 Specific gravity

```
clc
clear
printf("example 8.2 page number 335\n\n")

printf("this is a theoritical problem, book shall be
    referred for solution")
```

Scilab code Exa 8.3 Specific gravity

```
clc
clear
printf("example 8.3 page number 335\n\n")

printf("this is a theoritical problem, book shall be
    referred for solution")
```

Scilab code Exa 8.4 Mixture density

```
clc
clear
printf("example 8.4 page number 336\n\n")

//Chapter 8 : Measuring Devices
//Given: Balance Height=4m
//side 1-air, side 2:- N2-H2 mixture

pressure_difference = 3.4           //in mm water
pressure = 1.0133*10^5              //in pa
temperatue = 293        //in K
mass_of_air = 29        //in Kg
density_air = pressure/(temperatue*8314)*mass_of_air
        //in kg/m3
printf("Density of air = %f kg/cu m",density_air)

delta_p = pressure_difference*9.8             //in
   pascal, acceleration due to gravity, g=9.8
Height=4
density_difference = delta_p/(9.8*Height);
printf("\n\nDensity difference = %f kg/cu m",
   density_difference)

density_mixture= density_air-density_difference;
```

```
//in kg/m3
printf("\n\nDensity of mixture = %f kg/cu m",density_mixture)
```

Scilab code Exa 8.5 Viscosity calculation

```
clc
clear
printf("example 8.5 page number 341\n\n")

//to find viscosity of oil
diameter=0.6;      //in m
disk_distance=1.25*10^-3;     //in m
speed=5;       //revolutions/min
torque=11.5;   //in Joules

//we know that torque= pi*omega*viscosity*radius^4/2*disc_distance
viscosity=(2*disk_distance*torque)/(3.14*(10*3.14)*(diameter/2)^4);
printf("viscosity = %f Pa-s",viscosity)
```

Scilab code Exa 8.6 Solution viscosity

```
clc
clear
printf("example 8.6 page number 342\n\n")

//to find the viscosity of solution using given parameters

diameter =10;                  //in mm
density_of_solution = 1750;      //in kg/m3
```

```
density_of_air = 1.2;              //in kg/m3
velocity = 0.9;            //in mm/s
viscosity = (density_of_solution-density_of_air)*9.8*(diameter*10^-3)^2/(18*velocity*10^-3);            //expression for finding viscosity

printf("viscosity of solution = %f Pa-s",viscosity)


//checking stoke's region validity
v=(0.2*viscosity)/(density_of_solution*diameter*10^-3);
if v>0.9 then printf("\n\nsystem follows stokes law")
end
```

Scilab code Exa 8.7 Flow rate calculation

```
clc
clear
printf("example 8.7 page number 367\n\n")

//to find the flow rate in an orifice
density_of_water = 1000;      //in kg/m3
viscosity = 1*10^-3;          //in Pa-s
pipe_diameter = 250;          //in mm
orifice_diameter = 50;        // in mm
density_of_mercury = 13600;   // in mm
manometer_height = 242;       //in mm

//calculation
height_water_equivalent = (density_of_mercury-density_of_water)*(manometer_height*10^-3)/(density_of_water)      //in m

```

```
//assuming Re>30000
Co = 0.61;
velocity = Co*(2*9.8*height_water_equivalent/(1-(orifice_diameter/pipe_diameter)^4))^0.5;      //in m/s

//checking Reynold's number
Re = (orifice_diameter*10^-3*velocity*density_of_water)/viscosity;
printf("reynolds number = %f\nwhich is greater than 30000",Re)

if Re>30000 then printf("\n\nvelocity of water = %f m/s",velocity)

end

rate_of_flow = (3.14*(orifice_diameter*10^-3)^2/4)*velocity*density_of_water;
printf("\n\nrate of flow = %f litre/s",rate_of_flow)
```

Scilab code Exa 8.8 Venturi meter

```
clc
clear
printf("example 8.8 page number 368\n\n")

//to find the coefficient of discharge for converging cone

pipe_diameter=0.15;            //in m
venturi_diameter=0.05;         //in m
pressure_drop=0.12;             //m of water
flow_rate=3;                   //in kg/s
density = 1000;                //in kg/m3
```

```
viscosity = 0.001            //in Pa-s

velocity = ((4/3.14)*flow_rate)/(venturi_diameter^2*
    density);
printf("velociy = %f m/s",velocity)

//calculating coefficient of discharge
Cv=velocity*((1-(venturi_diameter/pipe_diameter)^4)
    /(2*9.8*pressure_drop))^0.5;
printf("\n\ncoefficient of discharge = %f",Cv)

//calculating reynold's number
Re = velocity*(venturi_diameter/pipe_diameter)^2*
    pipe_diameter*density/viscosity;
printf("\n\nreynolds No = %f",Re)
```

Scilab code Exa 8.9 Venturi meter

```
clc
clear
printf("example 8.9 page number 369\n\n")

//to find pA and pB
//part 1

h1=0.66;         //in m
h2=0.203;        //in m
h3=0.305       //in m
density=1000;   //in kg/m3
pB=68900;        //in Pa
s1=0.83;
s2=13.6;
disp("part 1")
pA=pB+(h2*s2-(h1-h3)*s1)*density*9.81;     //in Pa
printf("\npressure at A = %f Pa\n",pA)
```

```
disp("part 2")
pA1=137800        //in Pa
pressure=735    //mm Hg
pB1=pA1-(h2*s2-(h1-h3)*s1)*density*9.81;
pressure_B=(pB1-pressure*133.3)/9810;         //m of
    water
printf("\npressure at B = %f m of water",pressure_B)
```

Scilab code Exa 8.10 Pitot tube

```
clc
clear
printf("example 8.10 page number 370\n\n")

//to find the rate of oil flow in l/s

density_oil=900;         //in kg/m3
viscosity_oil=38.8*10^-3;     //in Pa-s
density_water = 1000;        //in kg/m3
diameter=0.102               //in m
manometer_reading=0.9;        //m of water
delta_H=manometer_reading*(density_water-density_oil
    )/density_oil;
printf("manometer reading as m of oil = %f m",
    delta_H)

maximum_velocity=(2*9.8*delta_H)^0.5;
printf("\n\nmaximum_velocity(Vmax) = %f m/s",
    maximum_velocity)

Re=diameter*maximum_velocity*density_oil/
    viscosity_oil;
printf("\n\nif Re<4000 then v=0.5*Vmax Re = %f",Re)
if Re<4000 then velocity=maximum_velocity*0.5;
```

```
end

printf("\n\nvelocity = %f m/s",velocity)

flow_rate=(3.14/4)*diameter^2*velocity*1000;
printf("\n\nflow rate =%f litre/s",flow_rate)
```

Scilab code Exa 8.11 Rotameter capacity

```
clc
clear
printf("example 8.11 page number 372\n\n")

//to find the maximum capacity of keroscene
flow_rate_steel=1.2;      //l/s
density_steel=7.92;
density_kerosene=0.82;
density_water=1;
flow_rate_kerosene =(((density_steel-density_kerosene)/density_kerosene)/((density_steel-density_water)/density_water))^0.5*flow_rate_steel
printf("maximum_flow rate of kerosene = %f litre/s",flow_rate_kerosene)
```

Scilab code Exa 8.12 Flow rate calculation

```
clc
clear
printf("example 8.12 page number 373\n\n")

//to find the rate of flow of flue gas

```

```
initial_CO2 = 0.02;          //weight fraction
flow_rate_CO2 = 22.5;        //gm/s
final_CO2=0.031;             //weight fraction

//flow rate of flue gas =x
//amount of CO2 entering = 0.02*x
//amount of CO2 leaving = 0.02x+0.0225
//amount of gas leaving = x+0.0225
//amount of CO2 leaving = 0.031*(x+0.0225)

deff('y=f(x)','y=initial_CO2*x+0.0225 - 0.031*(x
   +0.0225)');

flow_rate_flue_gas=fsolve(0,f)

printf("flow rate of flue gas = %f kg/s",
   flow_rate_flue_gas)
```

Chapter 9

Computers and their application

Scilab code Exa 9.1 Coiled tube pressure drop

```
clc
clear
printf("example 9.1 page number 384\n\n")

//to find the pressure drop in the coil

D = 38*10^-3;     //in m
U = 1    //in m/s
density = 998    //in kg/cubic m
viscosity = 8*10^-4    //in Pa-s
DC = 1    //in m
N = 10
e = 4*10^-6;    //in m

Re = (density*U*D)/viscosity;
printf ("Reynolds number = %f",Re)

f = (4*log10((e/D)/3.7+(6.81/Re)^0.9))^-2;
printf("\n\nfriction factor = %f",f);
```

```

L = 3.14*DC*N;

delta_Pstr = (2*f*U*density*L)/D;
printf("\n\npressure drop through straight pipe = %f
    Pa",delta_Pstr)

S = 1+3.54*(D/DC);
printf("\n\ncorrection factor = %f",S)

delta_P = S*delta_Pstr
printf("\n\npressure drop of coil = %f Pa",delta_P)
```

Scilab code Exa 9.2 Heat exchanger pressure drop

```
clc
clear
printf("example 9.2 page number 384\n\n")

//to find the shell side pressure drop in heat
    exchanger

U = 0.5   //in m/s
N = 19;
DT = 0.026   //in m
L = 2.7   //in m
DS = 0.2   //in m
e = 0.0002   //in m
density = 836  //in kg/cu m
viscosity = 0.00032   //in Pa s
Pr = 6.5;
Prw = 7.6;


HYDIA = (DS^2-N*DT^2)/(DS+N*DT);
```

```
Re = HYDIA*U*density/viscosity;
printf ("Reynolds number = %f",Re)

f = (4*log10((e/HYDIA)/3.7+(6.81/Re)^0.9))^-2;
printf("\n\nfriction factor = %f",f);

L = 3.14*DT*N;

delta_Pstr = (2*f*U*density*L)/HYDIA;
printf("\n\npressure drop through straight pipe = %f Pa",delta_Pstr)

S = (Prw/Pr)^0.33;
printf("\n\ncorrection factor = %f",S)

delta_P = S*delta_Pstr
printf("\n\npressure drop of coil = %f Pa",delta_P)
```

Scilab code Exa 9.3 Heat exchanger area

```
clc
clear
printf("example 9.3 page number 385\n\n")

MH = 10   //in kg/s
MC = 12.5  //in kg/s
CPH = 4.2   //in kJ/kg
CPC = 4.2   //in kJ/kg
THI = 353   //in K
THO = 333   //in K
TCI = 300   //in K
U = 1.8    //in kW/sq m K

Q = MH*CPH*(THI-THO);
```

```
printf("heat load = %f J",Q)

TCO = Q/(MC*CPC)+TCI;
printf("\n\ncold fluid outlet temperature = %f K",
   TCO)

//for co current flow

DT1 = THI-TCO;
DT2 = THO-TCO;

LMTD = (DT1-DT2)/log(DT1/DT2);

A = Q/(U*LMTD);
printf("\n\nfor co current flow, area = %f sq m",A);

//for counter current flow

DT1 = THI-TCO;
DT2 = THO-TCI;

LMTD = (DT1-DT2)/log(DT1/DT2);

A = Q/(U*LMTD);
printf("\n\nfor counter current flow, area = %f sq m
   ",A);
```

Scilab code Exa 9.4 Batch distillation

```
clc
clear
printf("example 9.4 page number 387\n\n")

printf("this is a theoretical question, book shall
   be referred for solution")
```

Scilab code Exa 9.5 Gas mixture exit temperature

```
clc
clear
printf("example 9.5 page number 392\n\n")

printf("this is a theoretical question , book shall
   be referred for solution")
```

Scilab code Exa 9.6 Friction factor calculation

```
clc
clear
printf("example 9.6 page number 395\n\n")

printf("this is a theoritical problem , book shall be
    referred for solution")
```