Scilab Textbook Companion for Thermodynamics: An Engineering Approach (SI Units) by Y. A. Cengel, M. A. Boles[1]

Created by
Karan Arora
B-Tech
Civil Engineering
Indian Institute of Technology Roorkee
College Teacher
Not Applicable
Cross-Checked by
TechPassion

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Introduction and Basic Concept

Scilab code Exa 1.1 obtaining formulas for from unit considerations

```
//ques1
//obtaining formulas for from unit considerations
clear
clc
d=850;//density m^3/kg
V=2;//volume m^3
m=d*V;//mass Kg
printf("Mass of the sample m =%.0f Kg",m);
```

Scilab code Exa 1.5 Absolute Pressure of a Vacuum Chamber

```
//ques5
//Absolute Pressure of a Vacuum Chamber
clc
Patm=14.5;//Atmospheric Pressure in psi
Pvac=5.8;//vaccum Pressure in psi
Pabs=Patm-Pvac;//Absolute Pressure in psi
printf("Absolute Pressure=Atmospheric Pressure -
   Vaccum Pressure=%0.1f psi",Pabs);
```

Scilab code Exa 1.6 Measuring Pressure with nanometer

```
//ques6
//Measuring Pressure with nanometer
clc
Patm=96;//Atmospheric Pressure in kPa
d=850;//density in Kg/m^3
g=9.81;//gravitational accelaration
h=0.55;//hieght in metre
P=Patm+d*g*h/1000; //Pressure in kPa
printf("Presure=Patm+ d*g*h=%.1f kPa",P);
```

Scilab code Exa 1.7 Measuring pressure with multifluid manomete

```
//ques7
//Measuring pressure with multifluid manometer
clear
clc
Patm=85.6; //in kPa
dwater=1000;//density of water in Kg/m^3
dmercury=13600;//density of mercury in Kg/m^3
doil=850;//density of oil in Kg/m^3
g=9.81;//acc due to gravity in m/s^2
h1=0.1;//height of water in metre
h2=0.2;//height of oil in metre
h3=0.35;//hieght of mercury in metre
P1=Patm+g*(dmercury*h3-dwater*h1-doil*h2)/1000;
printf("Pressure P1 = %.0f kPa",P1);
```

Scilab code Exa 1.8 Measuring Atmospheric Pressure with barometer

```
//ques8
//Measuring Atmospheric Pressure with barometer
clear
clc
g=9.81;//acc due to gravity in m/s^2
h=0.74;//height in metre
d=13570;//density in Kg/m^3
Patm=d*g*h/1000;//Atmospheric pressure in kPa
printf("Atmospheric pressure from barometer is = %.1
    f kPa",Patm);
```

Scilab code Exa 1.9 Effect of piston weight on Pressure of Cylinder

```
//ques9
//Effect of piston weight on Pressure of Cylinder
clear
clc
Patm=0.97;//Atmospheric pressure in bar
m=60;//mass in kg
g=9.81;//acc due to gravity in m/s^2
A=0.04;//area in m^2
P=Patm+m*g/A/10^5;//net pressure after considering
    the effect in Bar
//divided by 10^5 to convert it into bars
printf("Pressure = %.2f Bar",P);
```

Scilab code Exa 1.10 Hydrostatic Pressure in a Solar Pond with Variable Density

```
//ques10
```

```
//Hydrostatic Pressure in a Solar Pond with Variable
    Density
clear
clc
d=1040;//density of pond in Kg/m^3
g=9.81;//acc due to gravity in m/s^2
h1=0.8;//height of liquid in metre
H=4;//height of liquid of variable density
P1=d*g*h1/1000;//divided by 1000 to convert it into
   kPa
P=P1+integrate('d*g*sqrt(1+tan(%pi/4*z/H)^2)','z'
   ,0,4)/1000;
printf('Pressure at the bottom of the gradient zone
   = %.1f kPa',P);
```

Scilab code Exa 1.12 Analyzing a Multifluid Manometer with EES

```
//ques12
//Analyzing a Multifluid Manometer with EES
clc
g=9.81;//acc due to gravity in m/s^2
Patm=85600;//Atmospheric pressure in Pa
h1=0.1;//height of water in metre
h2=0.2;//height of oil in metre
h3=0.35;//height of mercury in metre
dwater=1000;//density of water in Kg/m^3
doil=850;//density of oil in Kg/m^3
dmercury=13600;//density of mercury in Kg/m^3
P1=Patm-(dwater*g*h1+doil*g*h2-dmercury*g*h3);//in
   Pa
printf('Pressure at point 1 = %.0f Pa',P1);
//Now to find h3 if mercury is replaced by another
   oil
dmercury=1030;//Density of new mercury in Kg/m^3
h3=(P1-Patm+dwater*g*h1+doil*g*h2)/(g*dmercury);//in
```

```
     metre
printf("\n New height h3 = %.2f metres",h3);
```

Chapter 2

Energy Transfer and General Energy Analysis

Scilab code Exa 2.1 General energy analysis

```
// example 1
// general energy analysis
clear
clc
d=0.75 //density of gasoline in kg/l
v=5 //average consumption of gasoline by the car in
    litres/day
h=44000 //heating value of gasoline in kJ/kg
disp('daily consumption of fuel = c = d*v ')
c=d*v //average consumption of gasoline in kg/day
e=c*h //daily energy requirement of car in kJ/day
E=0.1*6.73*10^10 //energy released by complete
    fussion of 0.1 kg of uranium in kJ
x=E/e //no. of days for which E amount of energy can
     meet the energy requirements of car
printf("\n Hence, the car will require refilling
    after = %.0f years. \n",x/365);
```

Scilab code Exa 2.2 Analysis of wind energy

```
//example 2
//analysis of wind energy
clear
clc
v=8.5 //velocity of wind in m/s
e=v^2/2 //wind energy per unit mass of air in j/kg
m=10 //mass of wind to be considered in kg
E=m*e //energy in joules of wind of mass m
mf=1154 //mass flow rate in kg/s
Ef=mf*e //wind energy in W for a mass flow rate of mf
printf("\n Hence,wind energy per unit mass is = %.1f J/kg. \n",e);
printf("\n The wind energy for a mass of 10 kg is = %.0f J. \n",E);
printf("\n The wind energy for flow rate of 1154 kg/s is = %.1f kW. \n",Ef/1000);
```

Scilab code Exa 2.7 Power Transmission by the Shaft of a Car

```
// example 7
// Power Transmission by the Shaft of a Car
clear
clc
t=200 //torque applied in N.m
rpm=4000 //revolutions per minute of shaft
n=rpm/60 //revolutions per second of shaft
w=2*%pi*n*t // shaft power in watts
printf("\n Hence,power transmitted by the shaft of car is = %.1f kW. \n",w/1000);
```

Scilab code Exa 2.8 Power Needs of a Car to Climb a Hill

```
// example 8
// Power Needs of a Car to Climb a Hill
clear
clc
m=1200 //mass of car in kg
v1=90 //velocity of car in km/h
v2=90*5/18 //velocity of car in m/s
x=30 //slope of hill in degrees
g=9.8 //acc. due to gravity in m/s^2
w=m*g*v2*sin(%pi*30/180) //additional power to be
    delivered by engine in watts
printf("\n Hence, additional power to be delivered by
    engine is = %.0f kW. \n",w/1000);
```

Scilab code Exa 2.9 Power needs of a car to accelerate

```
// example 9
// power needs of a car to accelerate
clear
clc
m=900 //mass ofcar in kg
v1=0 //initial velocity of car
v2=80*5/18 //final velocity of car in m/s
t=20 //time in which the car has to reach its
    desired speed in seconds
w=m*(v2^2-v1^2)/2 //work required to accomplish this
    task in joules
p=w/t // power required in watts
printf("\n Hence, power required to accelerate is = %
    .1f kW. \n",p/1000);
```

Scilab code Exa 2.10 Cooling of hot fluid in tank

```
//example 10
// cooling of hot fluid in tank
clear
clc
disp('suppose that there is no change in kinetic and
    potential energy ')
u1=800 //initial internal energy in 800kJ
win=100 //work done by paddle on system in kJ
qout=500 //loss of energy from fluid
disp('applying first law of thermodynamics ')
u2=u1-qout+win //final internal energy in kJ
printf("\n Hence,final internal energy of the fluid
   is = %.1f kJ. \n",u2);
```

Scilab code Exa 2.11 Acceleration of air by fan

```
//example 11
// acceleration of air by fan
clear
clc
v=8 //discharge rate of air in m/s
m=0.25 //mass flow rate in kg/s
p=m*v^2/2 //actual power consumed in W
P=20 //claimed power in W
disp('since,two  powers are not equal,this claim is
   not reasonable ')
```

Scilab code Exa 2.12 Heating effect of a fan

```
//example 12
//heating effect of a fan
clear
clc
t1=25 //initial temperature of room in C
p=200 //power consumption of fan in watts
a=30 //exposed surface area in m^2
u=6 //in w/m^2
t2=p/(u*a)+t1 //final temp. of room in C
printf("\n Hence, the indoor air temperature when
    steady operating conditions are established is =
    %.1f C. \n",t2);
```

Scilab code Exa 2.13 Annual lighting cost of a classroom

```
//example 13
// annual lighting cost of a classroom
clear
clc
p=80 //power consumed by fluoroscent lamp in watt
n=30 //no. of lamps used
P=p*n/1000 //lighting power in kW
t=250*12 //operating hours in a year
E=P*t //lighting energy/year
c=E*0.07 //cost of lighting  a classroom for a year
    in dollars
printf("\n Hence,annual energy cost of lighting for
    the classroom is = %.0f $/year. \n",c);
```

Scilab code Exa 2.15 Cost of cooking with electric and gas charges

```
//example 15
//cost of cooking with electric and gas charges
clear
clc
e1=73 //efficiency of open burner for electric units
e2=38 //efficiency of open burner for gas units
E1=2 //Electrical energy input in 2kW
q1=E1*e1/100 //actually utilised electrical energy
   in kWh
c=0.09/0.73 //cost of utilised energy per kWh
q2=q1/(e2/100) //energy input to a gas burner in kW
c=(0.55/29.3)/(e2/100) //cost of utilised energy of
   gas burner
printf("\n Hence,rate of energy consumption by the
   burner is = %.2f kW. \n",q2);
printf("\n The cost of utilised energy is = $ %.3f /
   kWh. \n",c);
```

Scilab code Exa 2.16 Performance of hydraulic turbine generator

```
// example 16
// performance of hydraulic turbine generator
clear
clc
h=50 //depth of lake in metres
m=5000 // mass flow rate of water in kg/s
g=9.81 //acc. due to gravity in m/s^2
disp('change in mechanical energy= ')
e=g*h/1000 //change in mech. energy in kJ/kg
E1=e*m //Rate at which mechanical energy is supplied
    to the turbine in kW
E2=1862 //electric power generated in kW
n1=E2/E1 //overall efficiency
n2=0.95 //efficiency of generator
n3=n1/n2 //efficiency of turbine
```

```
W=n3*E1 //shaft power output in kW
printf("\n Hence,overall efficiency of turbine generator is = %.2f. \n",n1);
printf("\n The mechanical efficiency of the turbine is = %.2f. \n",n3);
printf("\n The shaft power supplied by the turbine to the generator is =%.0f kW.\n",W)
```

Scilab code Exa 2.17 Cost Savings Associated with High Efficiency motors

```
//example 17
//Cost Savings Associated with High-Efficiency motors
clear
clc
n1=89 //efficiency of first motor
n2=93.2 //efficiency of second motor
c=0.08 //cost of electricity in $/kWh
p=60*0.7457 //rated power in kW
h=3500 //operating hours per year
e=p*h*(1/(n1/100)-1/(n2/100)) //energy savings
s=e*c //cost savings
t=640/s //simple payback period in year
printf("\n Hence,the amount of energy saved is = %.0f kWh/year. \n",e);
printf("\n The money saved is =%.0f $/year. \n",s);
printf("\n The payback period is=%.2f years.\n",t);
```

Scilab code Exa 2.18 Reducing air pollution by geothermal heating

```
//example 18
//reducing air pollution by geothermal heating
```

```
clear
clc
s=18*10^6 //quantity of natural gas that will be
   saved per year in therms
nn=0.0047 //quantity of NOx in kg/therm
nc=6.4 //quantity of CO2 in kg/therm
sn=nn*s //NOx savings per year in kg/year
sc=nc*s //CO2 savings per year in kg/year
printf("\n Hence,geothermal system will save  %.1f
   *10^4 kg NOx/year. \n",sn/10^4);
printf("\n and = %.1f *10^8 kg CO2/year. \n",sc
   /10^8);
```

Scilab code Exa 2.19 Heat transfer from a person

```
// example 19
// heat transfer from a person
clear
clc
T1=20 //room temperature in celsius
T2=29 //body temperature of person in celsius
a=1.6 //exposed surface area in m^2
h=6 //convection heat transfer coefficient in W/m^2*
   C
Qc=h*a*(T2-T1) //heat loss due convection in W
Qr=0.95*5.67*10^-8*a*((T2+273)^4-(T1+273)^4) //heat
   loss due to radiation in W
Q=Qc+Qr //net heat loss from the person in W
printf("\n Hence,the total rate of heat transfer is
   =%.1f W. \n",Q)
```

Chapter 3

Properties of Pure Substances

Scilab code Exa 3.1 Pressure of Saturated Liquid in a Tank

```
//ex1
//Pressure of Saturated Liquid in a Tank
clc
Psat=70.183;//saturated pressure @90C using steam
    table A-4 in kPa
printf('From steam table Psat @ 90 C = %.3f kPa',
    Psat);
vsat=0.001036;//saturated specific volume @90C in m
    ^3/Kg
m=50;//mass in kg
V=m*vsat;//Volume of tank in m^3
printf('\n Total Volume of Tank = %.4f m^3',V);
```

Scilab code Exa 3.2 Temperature of Saturated Vapor in a Cylinder

```
//ques2
//Temperature of Saturated Vapor in a Cylinder
clc
```

```
Tsat=280.99;//Saturated temperature in F @ 50psia from table A-5E
printf("Saturated Temperature = %.2f F \n",Tsat);
v=8.5175;//vg saturated volume of vapor in ft^3/lbm table A-5E
V=2;//Total Volume in ft^3
m=V/v;//mass in lbm
printf('Mass of the sample is = %.3f lbm ',m);
```

Scilab code Exa 3.3 Volume and Energy Change during Evaporation

```
//ques3
//Volume and Energy Change during Evaporation
clc
vg=1.6941; //saturated vapor specific volume from table A-5 @ 100kPa in m^3/Kg
vf=0.001043;//saturated liquid specific volume from table A-5 @ 100kPa in m^3/Kg
vfg=vg-vf;//in m^3/Kg
m=0.2;//in kg
//(a) Volume change
dV=m*vfg;//Volume in m^3
printf('(a) Volume change = %.4f m^3 \n',dV);
//(b) Amount of energy Transfer to water
hfg=2257.5;//change in enthalpy from table A-5 @ 100 kPa in kJ/Kg
E=m*hfg;//In kJ
printf('(b) Energy Transferred = %.1f kJ',E);
```

Scilab code Exa 3.4 Pressure and Volume of a Saturated Mixture

```
//ques4
//Pressure and Volume of a Saturated Mixture
```

```
clc
//(a) Pressure in the tank
P=70.183;//Psat @ 90 C table A-4 in kPa
printf("(a) Pressure in the tank = %.3f kPa ",P);
//(b)volume of tank
disp('(b)V = Vf+Vg = mf*vf+mg*vg');
mf=8;//mass of liquid water in kg
mg=2//mass of vapor water in kg
vf=0.001036;//saturated specific volume of liquid water from table A-4 in m^3/Kg
vg=2.3593;//saturated specific volume of vapor water from Table A-5 in m^3/Kg
V=mf*vf+mg*vg;//Total Volume in m^3
printf('Volume of tank  = %.2f m^3',V);
```

Scilab code Exa 3.5 Properties of Saturated Liquid Vapour Mixture

```
//ques5
//Properties of Saturated Liquid Vapour Mixture
clc
V=0.080;//volume in m^3 given
m=4;//in kg given
v=V/m;//in m^3/kg
vf=0.0007437;//@160kPa from table A-4 in m^3/kg
vg=0.12348;//@160kPa from table A-4 in m^3/kg
//(a)Temperature
Tsat=-15.60;//in C from table A-4
printf('\n(a) Since vf<v<vg so saturated region, so temperature at saturated state = %.2f C \n',Tsat);
//(b)Quality Factor
x=(v-vf)/(vg-vf);
printf('(b) Quality factor =%.3f \n',x);
//(c) Enthalpy of refrigerant
hf=31.21//from table A-12 @ 160kpa in kJ/kg
```

```
hfg=209.90//from table A−12 @ 160kpa in kJ/kg
h=hf+x*hfg;// n kJ/kg
printf('(c) Enthalpy of refrigerant = %.1f kJ/kg \n'
    ,h);
//(d) Volume occupied by phase
mg=x*m//mass of vapour n kg
Vg=mg*vg;//volume of vapour in m^3
printf('(d) Volume of vapour =%.4f m^3 \n',Vg);
```

Scilab code Exa 3.7 Internal Energy of Superheated Vapor using linear interpolation

```
//ex6
//Internal Energy of Superheated Vapor using linear
    interpolation
clc
disp('h1=2855.8 @ T1=200 C and h2=2961.0 @ T2=250 C
    and h=2890 lies in between these two so using
    linear interpolation we can get Temperature ');
h1=2855.8;//Enthalpy at T1 in kJ/Kg
T1=200;//temp in C
h2=2961.0;//Enthalpy at T2 in kJ/Kg
T2=250;//Temp T2 in C
h=2890;//Enthalpy in kJ/kg at which temp is to be
    determined
T=(T2-T1)/(h2-h1)*(h-h1)+T1;//Temp for given value
    of enthalpy in C
printf('Temperature = %.1f C',T);
```

Scilab code Exa 3.8 Approximating Compressed Liquid as Saturated Liquid

```
//ques8
```

```
//Approximating Compressed Liquid as Saturated Liquid
clc
u1=333.82;//(a) internal energy in KJ/Kg @ P=5MPa and T=80 C from table A-7
printf("\n(a) Data as from compress liquid table, u=%.2f kJ/kg\n",u1);
u2=334.97;//(b)internal energy in KJ/Kg @80 C from table A-4
printf("(b) Data as from saturated liquid table, u = %.2f kJ/kg",u2);
er=(u2-u1)/u1*100;//(c) %age error
printf('\n(c)Error involved = %.2f percent',er);
```

Scilab code Exa 3.10 Mass of Air in a Room

```
//ques10
//Mass of Air in a Room
clc
l=4;//length in metres
b=5;//breadth in metres
h=6;//height in metres
V=l*b*h;//volume in m^3
P=100;//Pressure in kPa
R=0.287;//Gas constant for a given gas in kPa.m^3/Kg.k
T=298;//Temp in K
m=P*V/(R*T);//mass in Kg
printf('Mass =P*V/(R*T)= %.1f kg',m);
```

Scilab code Exa 3.11 The Use of Generalized Charts

```
//ques11
```

```
//The Use of Generalized Charts
clear
clc
//(a)specific volume using ideal gas equation of
    state
R=0.0815;//gas constant for given substance in kPa.m
    ^3/Kg.K
Pcr=4.059;//Critical Pressure in MPa
Tcr=374.2;//Critical Temp in K
T=323;//Temp in K
P=1000;//Pressure in kPa
v=R*T/P;//Specific Volume in m^3/Kg
printf('\n(a) Specific Volume = %.6f m^3/kg ',v);
er=(v-0.021796)/0.021796;//error
printf('\n Error = %.3f',er);
//(b) specific volume using chart
Pr=P/Pcr;//reduced pressure
Tr=T/Tcr;//reduced Temperature
Z=0.84;//from compressibility chart
Videal=Z*v;//Ideal Volume in m^3/kg
printf('\n(b) Ideal volume = %.6f m^3/kg ',Videal);
er=(Videal-0.021796)/0.021796;//error
printf('\n Error = %.3f',er);
```

Scilab code Exa 3.12 Using Generalized Charts to Determine Pressure

```
//ques12
//Using Generalized Charts to Determine Pressure
clc
//(a)
R=0.5956;//Gas constant for a given substance in
    psia.ft^3/lbm.R
Pcr=3200;//Critical Pressure in psia
Tcr=1164.8;//Critical Temp in R
v=0.51431;//specific volume in ft^3/lbm
```

```
T=600;//Temperature in F
//so
P=1000;//Pressure in psia from Table A-6E
printf('\n(a) Pressure at a specified state = %.0f
    psia',P);
//(b)
T=1060;//Temperature in F
P=R*T/v;//Pressure in psia
printf('\n(b)Pressure of the steam under specified
    condition = %.0f psia',P);
//(c)using generalised compressibility chart
Vr=v*Pcr/(R*Tcr/Pcr);//reduced volume
Tr=T/Tcr;//reduced temperature
//so
Pr=0.33;//from compressibility chart
P=Pr*Pcr;//final Pressure in psia
printf('\n(c) Pressure(using generalised
    compressibility chart) = %.0f psia ',P);
```

Scilab code Exa 3.13 Different Methods of Evaluating Gas Pressure

```
//ex13
//Different Methods of Evaluating Gas Pressure
clear
clc
T=175//temp in K
v=0.00375//specific volume in m^3/kg
//(a)ideal gas equation of state
// data from table A-1
R=0.2968//gas constant for a given gas in kPa.m^3/kg
    .K
P=R*T/v;//Pressure in kPa
printf('\n(a) Pressure from Ideal gas equation = %.0
    f kPa \n',P);
//(b)van der waals equation
```

```
//a and b are van der waals constant
a=0.175;//m^6.kPa/Kg^2
b=0.00138;//m^3/Kg
P=R*T/(v-b)-a/v^2;//pressure in kPa
printf('(b) Pressure from van der waals equation = %
   .0f kPa \n',P);
//(c)Beattie-Bridgeman equation
A=102.29//constant
B=0.05378//constant
c=4.2*10^4;//constant
Ru=8.314;//universal gas constant value
MM=28.013//molecular Mass of substance
v=0.00375//specific volume in Kg/m^3
V=MM*v//Volume in m^3

P=Ru*T/V^2*(1-c/(V*T^3))*(V+B)-A/V^2;//pressure in
   KPa
printf('(c) Pressure from Beattie-Bridgeman equation
    = %.0f kPa \n',P);
```

Scilab code Exa 3.14 Temperature Drop of a Lake Due to Evaporation

```
//ques14
//Temperature Drop of a Lake Due to Evaporation
clear
clc
Psat=3.17//saturated pressure in kPa @ 25 C
Pv1=0.1*Psat//pressure for 10% humidity in kPa
Pv2=0.8*Psat//pressure for 80% humidity in kPa
Pv3=1*Psat//pressure for 100% humidity in kPa
T1=-8.0;//Temp in K
T2=21.2;//Temp in K
T3=25;//Temp in K
printf( 'Corresponding Temperatures(in C) are(From
   table A-5) \n T1 = %.1f K \n T2 = %.1f K \n T3 =
```

```
%.1f K ',T1,T2,T3);
```

Chapter 4

Energy Analysis of Closed Systems

Scilab code Exa 4.2 Boundary Work for a Constant Pressure Process

```
//ques2
//Boundary Work for a Constant Pressure Process
clear
clc
m=10//mass in lbm
P=60//pressure in psia
//from table A-6 E
v2=8.3548//specific volume at state 1 in Kg/m^3
v1=7.4863//specific volume at state 2 in Kg/m^3
w=integrate('m*P','v',v1,v2)/5.404; //divided by
   5.404 to convert it into Btu
printf('Work done by steam = %.2f Btu',w);
```

Scilab code Exa 4.3 Isothermal Compression of an Ideal Gas

```
//ques3
```

```
//Isothermal Compression of an Ideal Gas
clc
P1=100//Initial Pressure in kPa
V1=0.4;//Initial Volume in m^3
V2=0.1;//final Volume in m^3
w=P1*V1*log(V2/V1);//work done for Isothermal
    process in kJ
printf('Work done = %.1f kJ',w);
```

Scilab code Exa 4.4 Expansion of a Gas against a spring

```
//ques4
//Expansion of a Gas against a spring
clear
clc
V1=0.05//initial volume in m^3
V2=2*V1//final volume in m^3
A=0.25//area of cross section in m^2
k=150//spring constant in kN/m
//(a)
x=(V2-V1)/A//displacement of piston in m
F=k*x//Spring force  in kN
P1=F/A//pressure in kPa due to piston
Po=200//initial pressure in kPa
P=P1+Po;//final pressure in kPa
printf('\n(a) Final pressure = %.0f kPa\n',P);
//(b)
w=(Po+P)/2*(V2-V1);//in kJ
printf('(b) Work done = %.0f kJ\n',w);
//(c)
wspring=(P-Po)/2*V1;
printf('(c) Fraction of work done by spring = %.0f
    kJ\n',wspring);
```

Scilab code Exa 4.5 Electric Heating of a Gas at Constant Pressure

```
//ques5
//Electric Heating of a Gas at Constant Pressure
clear
clc
V=120//voltage in V
I=0.2//current in Ampere
t=300//time in sec
We=V*I*t/1000//work done in kJ
//1-initial condition
P1=400//kPa initial Pressure
V1=0.5//Volume in m^3
R=0.297//gas constant for water
T1=300//Temp in K
m=0.025;//mass in kg
//(a) From Energy equation We-Qout=dH=m(h2-h1)
//     i.e. h2=(We-Qout)/(m)+h1
//(b) Final Temperature
Qout=3.7//heat out in kJ
h1=2724.9//Initial Enthalpy in kJ/kg
h2=(We-Qout)/(m)+h1;//final Enthalpy in kJ/kg
//So from steam table A-6
T2=200;//Temp in C for P2=300kPa and h2
printf('Final Temperature T2 = %.0f C',T2);
```

Scilab code Exa 4.7 Evaluation of the du of an Ideal Gas

```
//ques7
//Evaluation of the du of an Ideal Gas
clear
clc
```

```
//(a) One way of determining the change in internal energy of air is to read the values at T1 and T2 from Table A 17 and take the difference
u1=214.07;//internal energy in kJ @ 300K
u2=434.78;//Internal energy in kJ @ 600K
du=u2-u1;//Change in in internal energy in kJ
printf('(a) Change in Internal Energy(from air data table ) = %.2f kJ \n',du);

//(b) the functional form of the specific heat (Table A 2c)
//constant
a=28.11;
b=0.1967*10^-2;
c=0.4802*10^-5;
d=-1.966*10^-9;
Ru=8.314;//Universal gas constant
//Cp=a+b*T+c*T^2+d*T^3;
//Cv=Cp-Ru
T1=300;//Initial Temp in K
T2=600;//Final  temp in K
U=integrate('a-Ru+b*T+c*T^2+d*T^3','T',T1,T2);
M=28.97;//molicular mass
u=U/M;//specific internal energy in KJ/Kg
printf(' (b) Change in Internal Energy using functional form of the specific heat =  %.2f kJ\n',u);

//(c)the average specific heat value (Table A 2b)
Tavg=(T1+T2)/2;//avg temp in K
Cv=0.733;//heat capacity at constant volume in kJ/K @Tavg from Table-2A
u=Cv*(T2-T1);//average change in internal energy in kJ/kg
printf(' (c) Change in Internal Energy using avg specific heat value = %.2f kJ/kg ',u);
```

Scilab code Exa 4.8 Heating of a Gas in a Tank by Stirring

```
//ques8
//Heating of a Gas in a Tank by Stirring
clear
clc
//(a)Final Temp
w=0.02//power in hp
t=0.5//time in hour
W=w*t*2545//paddle wheel work in  Btu
//As W=m*Cavg*(T2-T1) ie T2=W/(m*Cavg)+T1
m=1.5//mass in lbm
T1=80//temperature in F
Cavg=0.753//average specific heat at constt volume in Btu/F
T2=W/(m*Cavg)+T1;//Temp in F
printf('(a) Temperature = %.1f F\n',T2);

//(b)The final pressure is determined from the ideal-gas relation
//P1V1/T1=P2V2/T2 temperature in rankine or kelvin
T1=T1+460//converted to R
T2=T2+460//converted to R
P1=50//preesure at 1st state in psia
P2=P1*T2/T1;//final Pressure in psia
printf(' (b) Final Pressure = %.1f psia',P2);
```

Scilab code Exa 4.10 Heating of a Gas at Constant Pressure

```
//ques10
//Heating of a Gas at Constant Pressure
clear
```

```
clc
//(a) The final temperature can be determined by using the ideal-gas relation b/w state 1 and 3
P1=150//pressure at state 1 in kPa
P3=350//pressure at state 2 in kPa
T1=300//temperature at state 1 in K
//V3=2*V1
//T3=P3*V3/(P1*V1)*T1;
T3=P3*2/P1*T1;//temperature at state 2 in K
printf('(a) Final Temperature = %.0f K \n',T3);

//(b) The work done is area under the process curve on P-V diagram
V2=0.8//Volume at state 2 in m^3
V1=0.4//volume at state 1 in  m^3
P2=350//pressure at state 2 in kPa
W13=(V2-V1)*P2;//workdone for process 1-3 in kJ
printf(' (b) Work Done = %.0f kJ  \n',W13');

//(c) Mass of the system can be determined by ideal gas equation
R=0.287//gas constant for a given substance water in kJ/mol.K
m=P1*V1/(R*T1)//mass in kg
//from Table A-7
u1=214.07//internal energy at state 1 in kJ/kg @300K
u2=1113.52//internal energy at state 2 in kJ/kg @1400K
//from energy equation
Qout=140//heat output in kJ
Qin=Qout+m*(u2-u1);//heat input in kJ
printf(' (c) Heat input = %.0f kJ',Qin);
```

Scilab code Exa 4.11 Enthalpy of Compressed Liquid

```
//ques11
//Enthalpy of Compressed Liquid
clear
clc
//the water exists as a compressed liquid at the
    specified state
//(a) using compressed liquid table
P=15000;//pressure in kPa
T=100;//temperature in C
h=430.39;//heat of water in kJ/kg from Table A-7
printf('(a) Heat of water using compressed liquid
    table = %.2f kJ/kg \n',h);

//(b) Approximating the compressed liquid as a
    saturated liquid at 100 C
h=419.17;//heat of water at liquid state in kJ/Kg ie
     hf @ 100C
printf(' (b) Heat of Water by approximating
    compressed liquid as saturated = %.2f kJ/kg \n',h
    );

//(c) Using correction method
vf=0.001//specific volume of water in saturated
    liquid state @100C
Psat=101.42//saturated pressure in kPa from Table
h=h+vf*(P-Psat)//corrected value of heat of water at
     given state in kJ/kg
printf(' (c) Heat of water using correction method =
     %.2f kJ/kg ',h);
```

Scilab code Exa 4.12 Cooling of an Iron Block by Water

```
//ques12
//Cooling of an Iron Block by Water
clear
```

```
clc
V=0.5//volume in m^3
v=0.001//specific volume of water in m^3/Kg
m=V/v//mass in kg
//dUiron+dUwater=0 ie change in internal energy of
    system = 0
//mi*Ci*(T2-T1i)+mw*Cw*(T2-T1w)=0
mi=50//mass of ice in Kg
mw=500//mass of water in Kg
Ci=0.45//specific heat of ice in kJ/mol
Cw=4.18//specific heat of water in kJ/mol
T1i=80//initial temperature of ice in C
T1w=25//initial temperature of water in C
T2=(mi*Ci*T1i+mw*Cw*T1w)/(mi*Ci+mw*Cw);//final
    temperature of mixture in C
printf(' Final temperature = %.1f C ',T2);
```

Chapter 5

Mass and Energy Analysis of Control Volumes

Scilab code Exa 5.1 water flow through garden hose nozzle

```
//example 1
// water flow through garden hose nozzle
clear
clc
t=50 //time taken to fill the bucket in seconds
v=10 //volume of bucket in gallon
V=v*3.7854/t //volume flow rate in litres/second
d=1 //density of water in kg/l
M=V*d //mass flow rate in kg/s
A=%pi*(0.4)^2*10^-4 //area of exit in m^2
v1=V/(A*1000) //average velocity of water at exit in
    m/s
printf("\n Hence, the volume flow rate of water
    through the hose is = %.3f L/s. \n",V);
printf("\n The mass flow rate through the hose is =
    %.3f kg/s. \n",M);
printf("\n The average velocity of water at the
    nozzle exit is = %.1f m/s. \n",v1);
```

Scilab code Exa 5.2 Discharge of water from a tank

```
//example 2
//discharge of water from a tank
clear
clc
h0=4 //height of cylindrical water tank in ft
h2=2 //final water level in tank in ft
g=32.2 //acc. due to gravity in ft/s^2
Dt=3*12 //diameter of tank in inches
Djet=0.5 //diameter of water jet in inches
t=(h0^0.5-h2^0.5)*(Dt)^2/((Djet)^2*(g/2)^0.5) //time
     taken for water level to fall to half of its
    initial value in seconds
printf("\n Hence, the time taken for water level to
    fall to half of its initial value is = %.1f min.
    \n",t/60);
```

Scilab code Exa 5.3 Energy transport by mass

```
//example 3
//energy transport by mass
clear
clc
vf=0.001053 //specific volume of saturated liquid
    water  in m3/kg
vg=1.1594  //specific volume of water vapour in m3/
    kg
ug=2519.2  //specific internal energy of water
    vapour kJ/kg
hg=2693.1  //specific enthalpy of water vapour kJ/kg
```

```
disp('Saturation conditions exist in a pressure cooker at all times after the steady operating conditions are established')
disp(' Therefore, the liquid has the properties of saturated liquid and the exiting steam has the properties of saturated vapor at the operating pressure.')
m=0.6/(vf*1000) //reduction in mass of liquid in pressure cooker in kg
M=m/(40*60) //mass flow rate of steam in kg/s
A=8*10^-6 //exit area in m^2
V=M*vg/A //exit velocity in m/s
e=hg-ug //flow energy of steam in kJ/kg
TE=hg //total nergy of steam in kJ/kg
E=M*hg //energy flow rate of steam leaving cooker in kW
printf("\n Hence,The mass flow rate of the steam is = %.6f kg/s. \n",M);
printf("\n The exit velocity is = %.1f m/s. \n",V);
printf("\n The total energy of the steam is = %.1f kJ/kf. \n",TE);
printf("\n The flow energy of the steam is = %.1f kJ/kg. \n",e);
printf("\n The rate at which energy leaves the cooker by steam is = %.3f kW. \n",E);
```

Scilab code Exa 5.4 Deceleration of air in diffuser

```
//example 4
//deceleration of air in diffuser
clear
clc
disp('we assume that Air is an ideal gas since it is at a high temperature and low pressure relative to its critical-point values ')
```

```
T1=283 //Initial temp. of air in kelvins
P1=80 //initial pressure of air in kPa
R=0.287 //gas constant in kPa-m3/kg-K
A1=0.4 //inlet area in m^2
v1=200 //inintial velocity of air in m/s
V1=R*T1/P1 //specific volume of air in m^3/kg
m=v1*A1/V1 //mass flow rate in kg/s
h1=283.14 // specific enthalpy of air in kJ/kg
v2=0 //exit velocity is very small compared to initial velocity
h2=h1-(v2^2-v1^2)/2000 //final specific enthalpy of air in kJ/kg
disp('from steam table , the temperature corresponding to this value of enthalpy is')
T2=303 //Temp. of air leaving the diffuser in K
printf("\n Hence,The mass flow rate of the air is = %.1f kg/s. \n",m);
printf("\n The temp. of air leaving the diffuser is = %.0f K. \n",T2);
```

Scilab code Exa 5.5 Acceleration of steam in nozzle

```
//example 5
//acceleration of steam in nozzle
clear
clc
P1=250 //initial pressure of steam in psia
T1=700 //initial temperature of steam in F
disp('The specific volume and enthalpy of steam at the nozzle inlet are ')
v1=2.6883 //specific volume of steam at the nozzle inlet in ft3/lbm
h1=1371.4 // specific enthalpy of steam at the nozzle inletin Btu/lbm
A1=0.2 //inlet area in ft^2
```

```
M=10 // mass flow rate of steam through nozzle in
    lbm/s
V1=M*v1/A1 // inlet velocity in ft/s
qout=1.2 // heat loss in Btu/lbm
v2=900 //exit velocity in ft/s
h2=h1-qout-(v2^2-v1^2)/(2*25037) // enthalpy after
    exit
disp('from steam table, the temp. corresponding to
    this pressure and specifi enthalpy is ')
T2=662.0 ///in F
printf("\n Hence,the inlet velocity is = %.1f ft/s.
    \n",V1);
printf("\n The exit temp. of the seam is = %.0f F.
    \n",T2);
```

Scilab code Exa 5.6 Compressing air by compressor

```
//example 6
//compressing air by compressor
clear
clc
m=0.02 //mass flow rate of the air in kg/s
qout=16 //heat loss during the process in kJ/kg
h1=280.13 //specific enthalpy of air at 280K in kJ/
    kg
h2=400.98 //specific enthalpy of air at 400K in kJ/
    kg
win=m*qout + m*(h2-h1) //power input to compressor
    in kW
printf("\n Hence,the power input to the compressor
    is = %.2f kW. \n",win);
```

Scilab code Exa 5.7 Power generation by steam turbine

```
//example 7
// power generation by steam turbine
clear
clc
P1= 2 //initial pressure of steam in  MPa
T1= 400 //initial temp. of steam in  C
V1= 50 //initial velocity of steam in m/s
z1= 10 //height of inlet in metres
h1=3248.4 //initial specific enthalpy of air in kJ/
    kg
P2= 15 //final pressure of air in kPa
V2= 180 //final velocity of air in m/s
z2= 6 //exit height in m
x2=0.9 //quality of steam after exit
disp('At turbine exit,we obviously have liquid
    vapour mixture at 15 kPa.')
hf=225.94 //in kJ/kg
hfg=2372.3 //in  kJ/kg
h2=hf+x2*hfg //final specific enthalpy of mixture in
     kJ/kg
dh=h2-h1 // change in enthalpy of steam in kJ/kg
dke=(V2^2-V1^2)/2000 //change in kinetic energy of
    steam in kJ/kg
g=9.8 //acc. due to gravity in m/s^2
dpe=g*(z2-z1)/1000//change in potential energy of
    steam in kJ/kg
wout=-((h2-h1)+(V2^2-V1^2)/2000+g*(z2-z1)/1000) //
    work done per unit mass of the steam flowing
    through the turbine in kJ/kg
m=5000/wout //mass flow rate of steam in kg/s
printf("\n The value of dh is = %.2f kJ/kg. \n",dh);
printf("\n The value of dke is = %.2f kJ/kg. \n",dke
    );
printf("\n The value of dpe is = %.2f kJ/kg. \n",dpe
    );
printf("\n The work done per unit mass of the steam
    flowing through the turbine is = %.2f kJ/kg. \n",
    wout);
```

```
printf("\n The mass flow rate of the steam is = %.2f
    kg/s. \n",m);
```

Scilab code Exa 5.8 Expansion of refrigant 134a in refrigerator

```
//example 8
// expansion of refrigant 134-a in refrigerator
clear
clc
disp('Refrigerant -134a that enters a capillary tube
   as saturated liquid.Therefore,from table of
   refrigerant -134a ')
P1=0.8  // initial pressure in MPa
T1=31.31 //initial temp. in Celsius
h1=95.47 //initial specific enthalpy in kJ/kg
disp('Flow through a capillary tube is a throttling
   process. Thus, the enthalpy of the refrigerant
   remains constant')
h2=h1 //final specific enthalpy
P2=0.12 //final pressure in MPa
T2=-22.32 //final temp. in Celsius
hf=22.49 // in kJ/kg
hg=236.97 // in kJ/kg
hfg=hg-hf //in kJ/kg
disp('Obviously hf<h2<hg  thus, the refrigerant
   exists as a saturated mixture at the exit state')
disp('Thus quality at this state is')
x=(h2-hf)/hfg
dT=T2-T1 //in Celsius
printf("\n The quality of the refrigerant at the
   final state is = %.3f. \n",x);
printf("\n The temp. drop during this process is = %
   .2f C. \n",dT);
```

Scilab code Exa 5.9 Mixing of Hot and Cold Waters in a Shower

```
//example 9
//Mixing of Hot and Cold Waters in a Shower
clear
clc
disp('We take the chamber as system.Then,there are
   two inlets and one exit ')
h3=78.02 //enthalpy at 110 F in Btu/lbm
h2=18.07 //enthalpy at 50 F in Btu/lbm
h1=107.99 //enthalpy at 140F in Btu/lbm
y=(h3-h2)/(h1-h3) //mass ratio of hot to cold water
printf("\n The mass ratio of hot to cold water is =
   %.1f . \n",y);
```

Scilab code Exa 5.10 Cooling of refrigant 134a by water

```
//example 10
//cooling of refrigant 134-a by water
clear
clc
disp('We take the entire heat exchanger as the
   system. This is a control volume since mass
   crosses the system boundary during the process.')
disp('For each fluid stream since there is no mixing
   . Thus, m1=m2=mh and m3=m4=mr')
mr=6 //mass flow rate of R-134a in kg/min
h1=62.982 //specific enthalpy of water in kJ/kg
h2=104.83 //specific enthalpy of water in kJ/kg
P3=1 //pressure of R-134a at inlet in MPa
T3=70 //temperature of R-134a at inlet in Celsius
```

```
h3=303.85 //specific enthalpy corresponding to P3,T3
    in kJ/kg
P4=1 //pressure of R-134a at exit in MPa
T4=35 // temp. of R-134a at exit in Celsius
h4=100.87 // corresponding to P4,T4 in kJ/kg
mw=mr*(h4-h3)/(h1-h2) //mass flow rate of the
   cooling water in kg/min
qin=mw*(h2-h1) //the heat transfer rate from the
   refrigerant to water in kJ/min
printf("\n Hence,mass flow rate of the cooling water
    required is = %.1f kg/min. \n",mw);
printf("\n Heat transfer rate from refrigerant to
   water is = %.0f kJ/min. \n",qin);
```

Scilab code Exa 5.11 Electric heating of air in house

```
//example 11
// electric heating of air in house
clear
clc
T1=290 //Initial temp. of air in K
P1=100 //Initial pressure of air in kPa
R=0.287 //Gas constant in KPa*m^3/kg-K
V1=R*T1/P1 //Initial specific volume of air in m^3/
   kg
v1=150 //volume flow rate in m^3/min
m=v1/(V1*60) //mass flow rate in kg/s
win=15 //Power of Electric heating system in kJ/s
qout=0.2 //heat lost from air to surroundings in kJ/
   s
cp=1.005 //heat capacity in kJ/kg-C
T2=(win-qout)/(m*cp)+(T1-273) //Exit temp. of air in
    C
printf("\n Hence,the exit temp. of air is = %.1f C.
   \n",T2);
```

Scilab code Exa 5.12 Charging of rigid tank by system

```
//example 12
//charging of rigid tank by system
clear
clc
disp('This process can be analyzed as a uniform-flow
     process since the properties of the steam
    entering the control volume remain constant
    during the entire process.')
disp('We take the tank as the system. This is a
    control volume since mass crosses the system
    boundary during the process.We observe that this
    is an unsteady-flow process since changes occur
    within the control volume')
m1=0 //since system is initially evacuated
disp('The properties of the steam at the inlet state
     are')
P1=1 //pressure in MPa
T1=300 //temp. in Celsius
h1=3051.6 //especific enthalpy in kJ/kg
P2=1 // pressure at final state in MPa
u2=h1 //final internal energy of the steam in kJ/kg
disp('From steam table,the temp. corresponding to
    final properties are')
T2=456.1//final temp. in Celsius
printf("\n The final temp. of the steam in the tank
    is = %.1f C. \n",T2);
```

Scilab code Exa 5.13 Cooking with a pressure cooker

```
//example 13
//cooking with a pressure cooker
clear
clc
disp('This process can be analyzed as a uniform-flow process since the properties of the steam leaving the control volume remain constant during the entire cooking process')
disp('We take the pressure cooker as the system. This is a control volume since mass crosses the system boundary during the process.We observe that this is an unsteady-flow process since changes occur within the control volume. Also, there is one exit and no inlets for mass flow.')
Pgage=75 //gage pressure inside cooker in kPa
Patm=100 //atmospheric pressure in kPa
Pabs=Pgage+Patm //absolute pressure inside pressure cooker in kPa
disp('Since saturation conditions exist in the cooker at all times , the cooking temperature must be the saturation temperature corresponding to this pressure.From steam table, it is')
Tsat=116.04 // Saturation Temp. at 175 kPa in Celsius
T=Tsat //Temp. at which cooking takes place
Qin=0.5 //Heat supplied to the pressure cooker in kJ/s
t=30*60 //time for which het is supplied to pressure cooker in seconds
qin=Qin*t //total heat supplied to pressure cooker in kJ
m1=1 //initial mass of water in kg
V=0.006 //volume of pressure cooker in m^3
V1=V/m1 // initial specific volume in kg/m^3
Vf=0.001 //in kg/m^3
Vfg=1.004-0.001 //in kg/m^3
x1=(V1-Vf)/Vfg //quality
uf=486.82 //in kJ/kg
```

```
ufg=2037.7 //in kJ/kg
u1=uf+x1*ufg //specific internal energy in kJ/kg
U1=m1*u1 //total internal energy
disp('V2=Vf+x2*Vfg  and u2=uf+x2*ufg.upon
    substituting various values,we get ')
x2=0.009 //quality of steam in final state
V2=Vf+x2*Vfg //final specific volume in m^3/kg
m2=V/V2 //amount of water left in the pressure
    cooker in kg
printf("\n Hence,the temperature at whih cooking
    takes place is = %.2f C. \n",T);
printf("\n The amount of water left in the pressure
    cooker at the end of the process = %.1f kg. \n",
    m2);
```

Chapter 6

Mass and Energy Analysis of Control Volumes

Scilab code Exa 6.1 Net Power Production of a Heat Engine

```
//ques1
//Net Power Production of a Heat Engine
clear
clc
Qh=80;//heat of source in MW
Ql=50;//heat of sink in MW
W=Qh-Ql;//Output power in MW
printf('The net power output of this heat engine is
   = %.0f MW \n',W);
n=W/Qh;//thermal efficiency =net work/heat of source
printf(' Thermal Efficiency = %.3f \n',n);
```

Scilab code Exa 6.2 Fuel Consumption Rate of a Car

```
//ques2
//Fuel Consumption Rate of a Car
```

```
clear
clc
W=65;//power of car engine in hp
n=0.24;//efficiency of car engine
Qh=W/n*2545;//heat of reservoir in Btu/h
r=19000;//output power required in Btu/lbm
m=Qh/r;//rate of burning of fuel required , in lbm/
    hour
printf('To supply energy at this rate, the engine
    must burn fuel at a rate of = %.1f lbm/h',m);
```

Scilab code Exa 6.3 Heat Rejection by a Refrigerator

```
//ques3
//Heat Rejection by a Refrigerator
clear
clc
//(a)
Ql=6;//heat of sink in kJ/s
W=2;//work done on refrigerator in kW
COPr=Ql/W;//coefficient of performance of
    refrigerator
printf(' (a) The coefficient of performance of the
    refrigerator is = %.0f \n',COPr);

//(b)
Qh=Ql+W;//heat of reservoir in kJ/s
printf('  (b)The rate at which heat is rejected to
    the room that houses the refrigerator = %.0f kJ/s
     \n',Qh);
```

Scilab code Exa 6.4 Heating a House by a Heat Pump

```
//ques4
//Heating a House by a Heat Pump
clear
clc
//(a)
Qh=80000;//heat of reservoir in kJ/h
COPh=2.5;//coefficient of performance of heat engine
W=Qh/COPh;//work done by heat pump in kJ/h
printf(' (a) The power consumed by this heat pump =
   %.0f kJ/h \n',W);
//(b)
Ql=Qh-W;//heat of sink/outdoor in kJ/hour
printf('  (b) The rate of heat transfer from the
    outdoor = %.0f kJ/h \n',Ql);
```

Scilab code Exa 6.5 Analysis of a Carnot Heat Engine

```
//ques5
//Analysis of a Carnot Heat Engine
clear
clc
//(a) The Carnot heat engine is a reversible heat
    engine, and so its efficiency can be determined
    as
Tl=303;//K temp of sink
Th=650+273;//K temp of source
n=1-Tl/Th;//efficiency of heat engine
printf(' (a) Efficiency = %.3f \n',n);

//(b)

Qh=500;//heat of reservoir in kJ
Ql=Tl/Th*Qh;//heat of sink in kJ
printf('  (b) The amount of heat rejected,Ql by this
     reversible heat engine = %.0f kJ \n',Ql);
```

Scilab code Exa 6.6 A Questionable Claim for a Refrigerator

```
//ques6
//A Questionable Claim for a Refrigerator
clear
clc
Th=75+460;//temperature of reservior in R
Tl=35+460;//temperature of sink in R
COPr=1/((Th/Tl-1));//coefficient of performance of
    refrigerator
printf('Coefficient of performance of refrigerator =
    %.1f ',COPr);
```

Scilab code Exa 6.7 Heating a House by a Carnot Heat Pump

```
//ques7
//Heating a House by a Carnot Heat Pump
clear
clc
Tl=-5+273;//temp of sink K
Th=21+273;//temperature of reservior in K
COPh=1/(1-Tl/Th);//coefficient of performance of
    heat engine
Qh=37.5;//heat of reservoir in kW
W=Qh/COPh;//work output of heat engine in kW
printf('The required power input is = %.2f kW',W);
```

Scilab code Exa 6.8 Malfunction of a Refrigerator Light Switch

```
//ques8
//Malfunction of a Refrigerator Light Switch
clear
clc
COPr=1.3;//coefficient of performance of refrigerator
Qref=40;//heat load of refrigerator in W
Wref=Qref/COPr;//power consumed in W
Wlight=Qref;//power consumed by light in W
Wtotal=Wlight+Wref;//total additional power consumed in W
nh=20*30*365/3600;//normal operating hour per yr (h/yr)
//Then the additional hours the light remains on as a result of the malfunction becomes
annualh=8760;// total number of annual hour in a year h/yr
at=annualh-nh;//additional hr in h/yr
aP=Wtotal*at/1000;//additional power consumption in kWh/yr
printf('Additional power consumption = %.0f kWh/yr \n',aP);
uc=0.08;//unit cost 0.08 $/kWh
APC=aP*uc;//additional power cost in $/yr
printf(' Additional power cost = $ %.1f/yr ',APC);
```

Chapter 7

Entropy

Scilab code Exa 7.1 Entropy Change during an Isothermal Process

```
//ques1
//Entropy Change during an Isothermal Process
clear
clc
//The system undergoes an internally reversible,
   isothermal process, and thus its entropy change
   can be determined directly from Eqns
Q=750//heat in kJ
Tsys=300//temperature of system in K
dS=Q/Tsys;//entropy change of process in kJ/K
printf('Change in entropy = %.2f kJ/K',dS);
```

Scilab code Exa 7.2 Entropy Generation during Heat Transfer Processes

```
//ques2
//Entropy Generation during Heat Transfer Processes
clear
clc
```

```
//(a)Sink at 500K
Qsource=-2000//heat of source in kJ
Qsink=2000//heat of sink in kJ
Tsource=800//temperature of source in K
Tsink=500//temperature of sink in K
Ssource=Qsource/Tsource//entropy of source in kJ/K
Ssink=Qsink/Tsink//entropy of surce in kJ/K
Sgen=Ssource+Ssink;//entropy of generation of the
    process in kJ/K
printf(' (a) Enthalpy of generation = %.1f kJ/K \n',
    Sgen);

//(b) for sink of T=750 K
Qsource=-2000//heat of source in kJ
Qsink=2000//heat of sink in kJ
Tsource=800//temperature of source in K
Tsink=750//temperature of sink in K
Ssource=Qsource/Tsource//entropy of source in kJ/K
Ssink=Qsink/Tsink//temperature of sink in kJ/K
Sgen=Ssource+Ssink;//entropy of generation of system
    in kJ/K
printf('  (b) Enthalpy of generation = %.1f kJ/K',
    Sgen);
```

Scilab code Exa 7.3 Entropy Change of a Substance in a Tank

```
//ques3
//Entropy Change of a Substance in a Tank
clear
clc
//specific volume remains constant during this
    process

//state 1
P1=140//initial pressure in kPa
```

```
T1=20 //initial temperature in C
s1=1.0624//entropy in kJ/Kg.K from table
v1=0.16544//specific volume in m^3/Kg

//state 2
P2=100//pressure in kPa
v2=0.16544//specific volume remains same ie v2=v1

//from table
vf=0.0007259//specific volume of saturated water in
    m^3/kg
vg=0.19254//specific volume of saturated vapor in m
    ^3/kg

//Final state-saturated liquid vapor mixture
x2=(v2-vf)/(vg-vf);//x-factor
sf=0.07188//entropy of saturated water in kJ/Kg.K
sfg=0.87995//entropy change in kJ/kg.K
s2=sf+x2*sfg;//entropy at state 2 in kJ/kg.K
m=5//mass in Kg
S=m*(s2-s1);//entropy change in process in kJ
printf('Entropy change = %.3f kJ',S);
```

Scilab code Exa 7.4 Entropy Change during a Constant Pressure Process

```
//ques4
//Entropy Change during a Constant-Pressure Process
clear
clc
//approximating the compressed liquid as a saturated
    liquid

//state 1
P1=20//pressure in psia
T1=70//temperature in F
```

```
s1=0.07459//entropy ie sf @ 70F in Btu/lbm.R
h1=38.08//heat of system in Btu/lbm hf@ 70 F

//state 2
P2=20//pressure in psia
//using Qin=m*(h2-h1)
Qin=3450//input heat in Btu
m=3//mass in lbm
h2=Qin/m+h1//heat of system in Btu/lbm
s2=1.7761//entropy in Btu/lbm/R from table A-6E

S=m*(s2-s1);//change in entropy of system
printf('Entropy change of water during the process =
    %.3f Btu/R',S);
```

Scilab code Exa 7.5 Isentropic Expansion of Steam in a Turbine

```
//ques5
//Isentropic Expansion of Steam in a Turbine
clear
clc
//state 1
P1=5//pressure in MPa
T1=450//temperature in C
h1=3317.2//heat of system in kJ/kg from table
s1=6.8210//entropy of system in kJ/kg.K from table

//state 2
P2=1.4//pressure in MPa
s2=6.8210//entropy of  system remains same ie s2=s1
h2=2967.4//heat of system in kJ/Kg from table

w=h1-h2;//work output of turbine in kJ/kg

printf('The work output of the turbine per unit mass
```

```
is = %.1f kJ/kg',w);
```

Scilab code Exa 7.7 Effect of Density of a Liquid on Entropy

```
//ques7
//Effect of Density of a Liquid on Entropy
clear
clc

//state 1
P1=1//pressure in MPa
T1=110//temperature in K
s1=4.875//entropy in kJ/Kg.K from table
Cp1=3.471//specific heat at constant pressure in kJ/Kg.K from table

//state 2
P2=5//pressure in MPa
T2=120//temperature in K
s2=5.145//entropy in kJ/Kg.K
Cp2=3.486//specific heat at constant pressure in kJ/Kg.K

s=s2-s1;//entropy change in kJ/kg.K
printf('(a) Change in entropy per unit mass = %.3f kJ/kg.K \n',s);

//(b) Approximating liquid methane as an incompressible substance
c=(Cp1+Cp2)/2;//average specific heat
s=c*log(T2/T1);//entropy change in kJ/Kg
printf(' (b) Entropy change per unit mass = %.3f kJ/kg.K',s);
```

Scilab code Exa 7.8 Economics of Replacing a Valve by a Turbine

```
//ques8
//Economics of Replacing a Valve by a Turbine
clear
clc

//state 1
P1=5//pressure in MPa
T1=115//temperature in K
//from table
h1=232.3//heat in kJ/kg
s1=4.9945//entropy in kJ/kg.K
d1=422.15//density

//state 2
P2=1//pressure in MPa
s2=4.9945//entropy s2=s1
h2=222.8//heat in kJ/kg from table
Vs=0.280//volume flow rate in m^3
ms=d1*Vs//mass per second in Kg/sec
// Ein=Eout so Wsout=ms*(h1-h2)
Ws=ms*(h1-h2);//power output of turbine in kJ/sec
printf('The power output of the turbine = %.0f kW \n
    ',Ws);
APP=Ws*8760//kWh/yr annual power production
APS=APP*0.075//$/kWh Annual power savings
printf(' Annual power savings = $ %.0f/yr ',APS);
```

Scilab code Exa 7.9 Entropy Change of an Ideal Gas

```
//ques9
```

```
//Entropy Change of an Ideal Gas
clear
clc
//(a) From table (Table A 17)
s2=1.79783;//entropy of substance a state 2 in kJ/Kg.K
s1=1.66802;//entropy of state 2 in kJ/kg.k
R=0.287;//gas constant for water
P2=600//final pressure in kPa
P1=100//initial pressure in kPa
dS=s2-s1-R*log(P2/P1);//change in entropy in kJ/kg.k
printf('(a) s2-s1 = %.4f kJ/Kg.K \n',dS);

//(b) by using a c value at the average temperature 37 C
Cpavg=1.006//avg specific heat at const pressure in kJ/kg.K
T2=330//final temp in K
T1=290//inial temp in K
dS=Cpavg*log(T2/T1)-R*log(P2/P1);//kJ/kg.k
printf(' (b) Entropy change = %.4f kJ/kg.K',dS);
```

Scilab code Exa 7.10 Isentropic Compression of Air in a Car Engine

```
//ques10
//Isentropic Compression of Air in a Car Engine
clear
clc

//Using equation (T2/T1)=(v1/v2)^(k-1)
T1=295//initial temp in K
t=8//v1/v2 ratio
k=1.391//isentropic ratio
T2=T1*(t)^(k-1);//final temp in K
printf('Final temperature = %.1f K \n',T2);
```

```
printf(' Increase in temperature = %.1f K ',T2-T1);
```

Scilab code Exa 7.11 Isentropic Compression of an Ideal Gas

```
//ques11
//Isentropic Compression of an Ideal Gas
clear
clc
//using the equation P2=P1*(T2/T1)^(k/(k-1))
P1=14;//initial pressure in psia
T2=780;//final temp in R
T1=510;//initial temp in R
k=1.667;//isentropic ratio
P2=P1*(T2/T1)^(k/(k-1));
printf('Final pressure = %.1f psia',P2);
```

Scilab code Exa 7.12 Compressing a Substance in the Liquid versus Gas Phases

```
//ques12
//Compressing a Substance in the Liquid versus Gas
    Phases
clear
clc
// (a)steam as a saturated liquid
v1=0.001043;//=vf(specific volume of fluids) @ 100
    kPa in m^3/kg
P2=1000;//final pressure in kPa
P1=100;//initial pressure in kPa
w=integrate('v1*P^0','P',P1,P2);//work done in kJ/kg
printf('(a) Work done is = %.2f kJ/kg \n',w);

//(b)saturated vapor at the inlet state
```

```
//state 1
P1=100;//pressure at state 1 in kPa
//table A-6
h1=2675.0;//enthalpy of heat in kJ/kg
s1=7.3589;//entropy at in kJ/kg.k
//state 2
P2=1;//pressure in MPa
s2=7.3589;//s2=s1 entropy remains same
h2=3194.5;//table A-6 enthalpy of heat in kJ/kg

w=h2-h1;//work done in kJ/kg
printf(' (b) Work done = %.2f kJ/kg ',w);
```

Scilab code Exa 7.13 Work Input for Various Compression Processes

```
//ques13
//Work Input for Various Compression Processes
clear
clc
//(a) Isentropic compression with k=1.4
k=1.4;//isentropic ratio
R=0.287;//gas constant for water in kJ/K/mol/kg
T1=300;//initial temp in K
P2=900;//final pressure in kPa
P1=100;//initial pressure in kPa
w=k*R*T1/(k-1)*((P2/P1)^((k-1)/k)-1);//work done in
    compression in kJ/kg
printf('(a) Work done in compression = %.1f kJ/kg \n
    ',w);

//(b)Polytropic compression with k=1.3
w=k*R*T1/(k-1)*((P2/P1)^((k-1)/k)-1);
printf(' (b) Work done in compression = %.1f kJ/kg \
    n',w);

```

```
//(c) Isothermal compression
w=R*T1*log(P2/P1);
printf(' (c) Work done = %.1f kJ/kg \n',w);

//(d) Ideal two stage compression with intercooling
    with a polytropic exponent of 1.3
Px=(P1*P2)^(1/2);//pressure in kPa
//the total compressor work is twice the compression
     work for a single stage
w=2*k*R*T1/(k-1)*((Px/P1)^((k-1)/k)-1);
printf(' (d) Work done = %.2f kJ/kg \n',w);
```

Scilab code Exa 7.14 Isentropic Efficiency of a Steam Turbine

```
//ques14
//Isentropic Efficiency of a Steam Turbine
clear
clc
//state 1
P1=3;//pressure in MPa
T1=400;//temperature in C
//from table
h1=3231.7;//enthalpy of heat in kJ/kg
s1=6.9235;//enropy in kJ/kg.k

//state 2a
P2a=50;//pressure in kPa
T2a=100;//temp in C
h2a=2682.4;//enthalpy of heat in kJ/kg

//state 2s
P2s=50;//pressure in kPa
s2s=6.9235;//s2s=s1 entropy remains same
//from table
sf=1.0912;//entropy of fluid state in kJ/kg.k
```

```
sg=7.5931;//entropy of vapor in kJ.kg.k
//at end,steam exists as a saturated mixture since
    sf<s2s<sg
hf=340.54;//enthalpy of heat of fluid state in kJ/kg
hfg=2304.7;//enthalpy difference of vapor and liquid
     state in kJ/kg
x2s=(s2s-sf)/(sg-sf);//x factor
h2s=hf+x2s*(hfg);//enthalpy of heat in kJ/kg
//using the equation 7-61 in book we get
n=(h1-h2a)/(h1-h2s);
printf('(a) Isentropic efficiency = %.1f percent  \n
    ',n*100);

Wout=2000//output power in kJ/s
ms=Wout/(h1-h2a);//mass flow rate in kg/s
printf(' (b) The mass flow rate of steam = %.2f kg/s
     ',ms);//through this turbine from the energy
    balance for steady-flow systems
```

Scilab code Exa 7.15 Effect of Efficiency on Compressor Power Input

```
//ques15
//Effect of Efficiency on Compressor Power Input
clear
clc
T1=285;//initial temperature in K
h1=285.14;//table A-17 initial heat of enthalpy in
    kJ/kg
Pr1=1.1584;//reduced pressure
P2=800;//final pressure in kPa
P1=100;//initial pressure in kPa
Pr2=Pr1*(P2/P1);
//from table corresponding to Pr2
h2s=517.05;//enthalpy of heat in kJ/kg
n=0.80;//efficiency
```

```
//using the formula for efficiency')
h2a=(h2s-h1)/n+h1;//enthalpy of heat in kJ/kg
T2a=569.5; //final temp in K from table
printf('(a) Temperature T2a = %.1f K \n',T2a);
ms=0.2;//mass flow rate in kg/s
w=ms*(h2a-h1);//work done in kJ/kg
printf(' (b) Required power input to compressor as
    determined from the energy balance equation is =
    %.2f kJ/kg \n',w);
```

Scilab code Exa 7.16 Effect of Efficiency on Nozzle Exit Velocity

```
//ques16
//Effect of Efficiency on Nozzle Exit Velocity
clear
clc
//The exit velocity of the air will be a maximum
    when the process in the nozzle involves no
    irreversibilities
T1=950;//initial temp in K
P2s=80;//pressure in kPa
P1=200;//initial pressure in kPa
k=1.354;//isentropic ratio
T2s=T1*(P2s/P1)^(1-1/k);//temp in K
//using Ein = Eout we can get V2s
Cpavg=1.099;//avg specific heat at constant pressure
     in kJ/kg.k
V2s=sqrt(2000*Cpavg*(T1-T2s));//velocity in m/s
printf('(a) The maximum possible exit velocity = %.2
    f m/s \n',V2s);

//(b) The actual exit temperature of the air is
    higher than the isentropic exit temperature
    evaluated above
n=0.92;//efficiency
```

```
T2a=T1-n*(T1-T2s);//temp in K
printf(' (b) The exit temperature = %.0f K \n',T2a);

//(c) The actual exit velocity of air can be determined from the definition of isentropic efficiency of a nozzle
V2a=sqrt(n*V2s^2);//velocity in m/s
printf(' (c) Exit velocity of air = %.0f m/s ',V2a);
```

Scilab code Exa 7.17 Entropy Generation in a Wall

```
//ques17
//Entropy Generation in a Wall
clear
clc
//Entropy change of wall is 0 during process since the state and thus the entropy of the wall do not change anywhere
Qout=1035;//W
Qin=1035;//W
Tout=278;//K
Tin=293;//K
Sgen=Qout/Tout-Qin/Tin;//in W/K
printf('Entropy of generation = %.3f W/K',Sgen);
//To determine rate of total entropy generation, we extend the system to include the regions on both sides of the wall that experience a temperature change. Then one side of the system boundary becomes room temperature while the other side becomes the temperature of the outdoors
Tout=273;//K
Tin=300;//K
Sgen=Qout/Tout-Qin/Tin;//in W/K
printf('\n Entropy of generation = %.3f W/K',Sgen);
```

Scilab code Exa 7.18 Entropy Generation during a Throttling Process

```
//ques18
//Entropy Generation during a Throttling Process
clear
clc
//state 1
P1=7;//MPa
T1=450;//C
//from table
h1=3288.3;//kJ/kg
s1=6.6353;//kJ/kg.K

//state 2
P2=3;//MPa
h2=3288.3;//h2=h1
s2=7.0046;//kJ/kg.K
sgen=(s2-s1);
printf('Entropy of generation per unit mass = %.4f
    kJ/kg.K',sgen);
```

Scilab code Exa 7.19 Entropy Generated when a Hot Block Is Dropped in a Lake

```
//ques19
//Entropy Generated when a Hot Block Is Dropped in a
    Lake
clear
clc
//(a) The entropy change of the iron block
m=50;//mass in kg
Cavg=0.45;//average specific heat in kJ/kg
```

```
T2=285;//final temp in K
T1=500;//initial temp in K
Siron=m*Cavg*log(T2/T1);
printf('(a) Entropy change of iron block = %.2f kJ/K
    \n',Siron);

//(b)
//The temperature of the lake water remains constant
    during this process at 285 K
Qout=m*Cavg*(T1-T2);//heat transfer from iron to
    lake in kJ
S=Qout/T2;//Entropy change of lake in kJ/K
printf(' (b) Entropy change of the lake = %.2f kJ/K
    \n',S);

//(c)
//The entropy generated during this process is
    determined by applying an entropy balance on the
    system
Tb=285;//temp of block in K
Sgen=Qout/Tb+Siron;//Entropy generation in kJ/K
printf(' (c) Entropy generated = %.2f kJ/K \n',Sgen)
    ;
```

Scilab code Exa 7.21 Entropy Generation Associated with Heat Transfer

```
//ques21
//Entropy Generation Associated with Heat Transfer
clear
clc
//(a) Water undergoes an internally reversible
    isothermal process
Q=-600;//kJ
Tsys=100+273;//K
Ssys=Q/Tsys;//kJ/K
```

```
printf('(a) Entropy of system = %.2f kJ/K \n',Ssys);

//(b) The entropy generation is entirely due to
    irreversible heat transfer through a finite
    temperature difference
Qout=600;//heat output in kJ
Tb=25+273//Temperature in K
Sgen=Ssys+Qout/Tb;//Entropy generation in kJ/K
printf(' (b) Entropy of generation = %.2f kJ/K',Sgen
    );
```

Scilab code Exa 7.22 Energy and Cost Savings by Fixing Air Leaks

```
//ques22
//Energy and Cost Savings by Fixing Air Leaks
clear
clc
//The work needed to compress a unit mass of air at
    20 C from the atmospheric pressure of 101 kPa to
    700+101=801 kPa is
R=0.287;//gas constant for water
P2=801;//final pressure in kPa
P1=101;//initial pressure in kPa
n=1.4;
nc=0.8;
T1=293;//initial temperature in K
w=n*R*T1/(nc*(n-1))*((P2/P1)^(1-1/n)-1);//work done
    in kJ/kg
D=3*10^-3;//diameter in metre
A=%pi*D^2/4;//area in m^2
//Line conditions are 297 K and 801 kPa, the mass
    flow rate of the air leaking through the hole is
    determined as
Cdis=0.65;
k=1.4;//k=n
```

```
R=0.287;//gas constant for water
Tline= 297;//temperature of line in K
Pline=801;//pressure of line=P2
ms=Cdis*(2/(k+1))^(1/(k-1))*Pline/(R*Tline)*A*sqrt(1000*k*R*Tline*2/(k+1));//mass flow in kg/s
pw=ms*w//power wasted in kW
Esaving=pw*4200/0.92//in kWh/yr Energy saving=Power saved*operating hr/efficiency of motor
printf('Energy saving = %.0f kWh/yr \n',Esaving);
Csaving=Esaving *0.078;//Cost saving in $/yr = Energy saving * unit cost
printf(' Cost saving = $ %.0f/yr \n',Csaving);
```

Scilab code Exa 7.23 Reducing the Pressure Setting to Reduce Cost

```
//ques23
//Reducing the Pressure Setting to Reduce Cost
clear
clc
Preduced=885.6;//reduced pressure
P1=85.6;//initial pressure in kPa
P2=985.6;//final pressure in kPa
n=1.4;
f=1-((Preduced/P1)^((n-1)/n)-1)/((P2/P1)^(1-1/n)-1);//The fraction of energy saved as a result of reducing the pressure setting
Cc=12000;//current cost in $/yr
Csaving=Cc*f;
printf('Cost saving = $%.0f/yr \n',Csaving);
```

Chapter 8

Exergy A Measure of Work Potential

Scilab code Exa 8.1 Maximum power generation by wind turbine

```
//example 1
//maximum power generation by wind turbine
clear
clc
V=10 //Average velocity of wind in m/s
ke=(V^2/2)/1000 //exegy of the blowing air in kJ/kg
D=12 //diameter of wind turbine in m
d=1.18 //density of air in kg/m^3
M=d*%pi*D^2*V/4 //mass flow rate in kg/s
p=M*ke //maximum power generated by wind turbine in kW
printf("\n Hence, the maximum power generated by wind turbine is = %.1f kW. \n",p);
```

Scilab code Exa 8.2 Exergy transfer from a furnace

```
//example 2
//exergy transfer from a furnace
clear
clc
T0=537 //environmental temperature in R
Th=2000 //furnace temperature in R
nthrev=1-T0/Th //thermal efficiency of reversible
    heat engine
Qin=3000 //heat transfer rate from furnace in Btu/s
Wrev=nthrev*Qin //exergy of the furnace in Btu/s
printf("\n Hence, the rate of exergy flow associated
     with this heat transfer is = %.0f Btu/s. \n",
    Wrev);
```

Scilab code Exa 8.3 The rate of irreversibility of a heat engine

```
//example 3
//the rate of irreversibility of a heat engine
clear
clc
Tsink=300 //Temp. of sink in K
Tsource=1200 //Temp. of source in K
nthrev=1-Tsink/Tsource //efficiency of carnot engine
Qin=500 //rate at which heat is received from the
    source in kW
Wrev=nthrev*Qin //maximum power produced by a heat
    engine in kW
Wout=180 //actual power output in kW
I=Wrev-Wout //irreversibility rate of the process in
     kW
printf("\n Hence, the reversible power for this
    process is = %.0f kW. \n",Wrev);
printf("\n The irreversibility rate is = %.0f kW. \n
    ",I);
```

Scilab code Exa 8.4 Irreversibility during cooling of an iron block

```
//example 4
//irreversibility during cooling of an iron block
clear
clc
m=500 //mass of iron block in kg
cavg=0.45 //kJ/kg-K
T1=473 //Initial Temp. in K
T2=300 //Final Temp. in K
Wrev=m*cavg*((T1-T2)-T2*log(T1/T2)) //reversible
   work in kJ
Wu=0
I=Wrev-Wu //irreversibility of the process in kJ
printf("\n Hence, the reversible owrk for the
   pressure ois = %.0f kJ. \n",Wrev);
printf("\n and irreversibility of the process is = %
   .0f kJ. \n",I);
```

Scilab code Exa 8.5 Heating potential of a hot iron block

```
//example 5
//heating potential of a hot iron block
clear
clc
Tl=278 //Outdoor temp. in K
Th=300 //Room temp. in K
COPhp=1/(1-Tl/Th) //coefficient of performance of
   heat engine if its assumed to be reversible
E=38925-8191+13.6*8191 //potential energy of hot
   iron block in kJ
```

```
printf("\n Hence, the maxuimum amount of heat that can be supplied to the house is = %.0f MJ. \n",E/1000);
```

Scilab code Exa 8.6 Second law efficiency of resistance heaters

```
//example 6
//second law efficiency of resistance heaters
clear
clc
Tl=283 //Outdoor Temp. in K
Th=294 //Indoor Temp. in K
COPhp=1/(1-Tl/Th) //coefficient of performance of reversible heat engine
COP=1 //first law efficiency
n=COP/COPhp //second law efficiency of resistance heater
printf("\n Hence, the second law efficiency of the heater is = %.1f percent. \n",n*100);
```

Scilab code Exa 8.7 Work Potential of compressed air in tank

```
//example 7
//work potential of compressed air in tank
clear
clc
To=300 //in K
T1=To
R=0.287 //kPa-m^3/kg-K
V=200 //in m^3
P1=1000 //kPa
m1=P1*V/(R*T1) //in kg
Po=100 //in kPa
```

```
o1=R*To*(log(P1/Po)+Po/P1-1) //kJ/kg
X1=m1*o1 //exergy content of compressed air in kJ
printf("\n Hence, the exergy content of compressed
    air is = %.0f MJ. \n",X1/1000);
```

Scilab code Exa 8.8 Exergy change during a compression process

```
//example8
//exergy change during a compression process
clear
clc
P1=0.14 //MPa
T1=-10 //in celsius
h1=246.36 //kJ/kg
s1=0.9724 //kJ/kg-K
P2=0.8 //MPa
T2=50 // C
h2=286.69 //kJ/kg
s2=0.9802 //kJ/kg-K
To=293 //in K
dw=h2-h1-To*(s2-s1) //exergy change of the
    refrigerant in kJ/kg
winmin=dw //the minimum work input that needs to be
    supplied to the compressor per unit mass of the
    refrigerant in kJ/kg
printf("\n Hence, the minimum work input that needs
    to be supplied to the compressor per unit mass of
     the refrigerant is = %.1f kJ/kg. \n",winmin);
```

Scilab code Exa 8.10 Exergy destruction during heat conduction

```
//example 10
//exergy destruction during heat conduction
```

```
clear
clc
To=273 //temperature of outdoor in K
Tin=293 //temperature of inner surface of brick wall
    in K
Tout=278 //temperature of outer surface of brick
   wall in K
Q=1035 //rate of heat transfer through wall in W
Xdestroyed=Q*(1-To/Tin)-Q*(1-To/Tout) //exergy
   destruction in wall in W
Th=300 //temperature of house in K
Xdestroyedtotal=Q*(1-To/Th)-Q*(1-To/To) //the rate
   of total exergy destruction during this heat
   transfer process
printf("\n Hence, the rate of exergy destruction in
   the wall is = %.1f W. \n",Xdestroyed);
printf("\n Hence, rate of total exergy destruction
   associated with this heat transfer process is=%.1
   f W. \n",Xdestroyedtotal);
```

Scilab code Exa 8.11 Exergy destruction during expansion of steam

```
//example 11
//exergy destruction during expansion of steam
clear
clc
P1=1 //in MPa
T1=300 //in celsius
u1=2793.7 //kJ/kg
v1=0.25799 //m3/kg
s1=7.1246 //kJ/kg-K
P2=200 //in kPa
T2=150 //in C
u2=2577.1 //in kJ/kg
v2=0.95986 //in m3/kg
```

```
s2=7.2810 //in kJ/kg-K
P0=100 //in kPa
T0=298//in K
u0=104.83 //in kJ/kg
v0=0.00103 //in m3/kg
s0=0.3672 //in kJ/kg-K
m=0.05 //in kg
X1=m*((u1-u0)-T0*(s1-s0)+P0*(v1-v0)) //initial
    exergy of the system in kJ
X2=m*((u2-u0)-T0*(s2-s0)+P0*(v2-v0))//final exergy
    of the system in kJ
dX=X2-X1 //exergy change for the process in kJ
Qout=2 //Heat losses from the system to the
    surroundings in kJ
Wbout=-Qout-m*(u2-u1) //total boundary work done by
    the system,including the work done against the
    atmosphere to push the atmospheric air out of the
     way during the expansion process in kJ
Wu=Wbout-P0*m*(v2-v1) //useful work in kJ
Xdestroyed=X1-X2-Wu //exergy destroyed in kJ
n=Wu/(X1-X2) //second law efficiency for this
    process
printf("\n Hence, the exergy of the steam at the
    initial state is = %.1f kJ. \n",X1);
printf("\n Hence, the exergy of the steam at the
    final state is = %.1f kJ. \n",X2);
printf("\n Hence, the exergy change of the steam is
   = %.1f kJ. \n",dX);
printf("\n Hence, the exergy destroyed is = %.1f kJ.
     \n",Xdestroyed);
printf("\n Hence, the exergy destroyed is = %.1f
    percent. \n",n*100);
```

Scilab code Exa 8.12 exergy destroyed during stirring of gas

```
//example 12
//exergy destroyed during stirring of gas
clear
clc
T0=530 //temperature of surrounding air in R
m=2 //mass of air in insulated rigid tank in lbm
cv=0.172 //in Btu/lbm-R
T2=590 //initial temperature of air in R
T1=530 //final temperature of air in R
Xdestroyed=T0*m*cv*log(T2/T1) //exergy destroyed in
    Btu
Wrevin=m*cv*(T2-T1)-Xdestroyed //minimum work input
    in Btu
printf("\n Hence, the exergy destroyed is = %.1f Btu
    . \n",Xdestroyed);
printf("\n Hence, the reversible work for this
    process  is = %.1f Btu. \n",Wrevin);
```

Scilab code Exa 8.13 Dropping of hot iron block in water

```
//example 13
//dropping of hot iron block in water
clear
clc
miron=5 //mass of iron block in kg
mwater=100 //mass of water in kg
ciron=0.45 //specific heat capacity of iron in kJ/kg
    -C
cwater=4.18 //specific heat capacity of water in kJ/
    kg-C
Tiiron=350 //initial temperature of iron in Celsius
Tiwater=30 //initial temperature of water in Celsius
Tf=(miron*ciron*Tiiron+mwater*cwater*Tiwater)/(miron
    *ciron+mwater*cwater) //final equilbrium
    temperature in Celsius
```

```
T0=293 //temperature of surroundings in K
X1iron=miron*ciron*((Tiiron+273)-T0-T0*log((Tiiron
    +273)/T0)) //initial exergy of iron
X1water=mwater*cwater*((Tiwater+273)-T0-T0*log((
    Tiwater+273)/T0)) //initial exergy of water
X1total=X1iron+X1water //total initial exergy
X2iron=miron*ciron*((Tf+273)-T0-T0*log((Tf+273)/T0))
     //finall exergy of iron
X2water=mwater*cwater*((Tf+273)-T0-T0*log((Tf+273)/
    T0)) //final exergy of water
X2total=X2iron+X2water //total exergy in kJ
Xdestroyed=X1total-X2total //exergy destroyed in kJ
printf("\n Hence, the final equilbrium temperature
    is = %.1f celsius. \n",Tf);
printf("\n The exergy of the combined system at the
    initial state is = %.0f kJ. \n",X1total);
printf("\n The exergy of the combined system at the
    final state is = %.1f kJ. \n",X2total);
printf("\n The wasted work potential during this
    process is = %.1f kJ. \n",Xdestroyed);
```

Scilab code Exa 8.14 Exergy destruction during heat transfer to a gas

```
//example 14
//exergy destruction during heat transfer to a gas
clear
clc
P1=350 //in kPa
V1=0.01 //in m^3
V2=0.02 //in m^3
Wb=P1*V1*log(V2/V1) //quasi equilbrium boundary work
     in kJ
P0=100 //atmospheric pressure in kPa
Wsurr=P0*(V2-V1) //work done against the atmospheric
     pressure in kJ
```

```
Wu=Wb-Wsurr //useful work in kJ
Tsys=400 //temperature of system in K
Tr=1200 //temperature temperature of the boundary in
    K
Q=Wb //heat transfer from furnace to system
Sgen=Q/Tsys-Q/Tr //in kJ/K
T0=300 //temperature of atmospheric air in K
Xdestroyed=T0*Sgen //exergy destroyed in kJ
Wrevout=T0*Q/Tsys-Wsurr+(1-T0/Tr)*Q //reversible
    work in kJ
printf("\n The useful work output is = %.2f kJ. \n",
    Wu);
printf("\n The exergy destroyed is = %.2f kJ/K. \n",
    Xdestroyed);
printf("\n The reversible work for this process is =
    %.2f kJ. \n",Wrevout);
```

Scilab code Exa 8.15 second law analysis of steam turbine

```
//example 15
//second law analysis of steam turbine
clear
clc
P1=3 //in MPa
T1=450 //in C
h1=3344.9 //in kJ/kg
s1=7.0856 //in kJ/kg-K
P2=0.2 //in MPa
T2=150 //in C
h2=2769.1 //in kJ/kg
s2=7.2810 //in kJ/kg-K
P0=100 //in kPa
T0=25//in C
h0=104.83 //in kJ/kg
s0=0.3672 //in kJ/kg-K
```

```
m=8 //mass flow rate of turbine in kg/s
Qout=300 //heat loss to surrounding air in kW
Wout=m*(h1-h2)-Qout //actual power output of turbine
    in kW
Wrevout=m*((h1-h2)-(T0+273)*(s1-s2)) //reversible
   power in kW
n=Wout/Wrevout //second law efficiency
Xdestroyed=Wrevout-Wout //exergy destroyed in kW
w1=h1-h0-(T0+273)*(s1-s0) //maximum work potential
   in kJ/kg
printf("\n Hence,The actual power output is = %.0f
   kW. \n",Wout);
printf("\n The maximum possible power output is = %
   .0f kW. \n",Wrevout);
printf("\n The second law efficiency is = %.1f
   percent. \n",n*100);
printf("\n The exergy destroyed is = %.0f kW. \n",
   Xdestroyed);
printf("\n The exergy of the steam at the inlet
   conditions is =%.0f kJ/kg. \n",w1);
```

Scilab code Exa 8.16 exergy destroyed during mixing of fluid streams

```
//example 16
//exergy destroyed during mixing of fluid streams
clear
clc
m1=300 //in lbm/min
h1=18.07 //in Btu/lbm
T0=530 //temperature of atmospheric air in R
s1=0.03609 //Btu/lbm-R
m2=22.7 //in lbm/min
h2=1162.3 //in Btu/lbm
s2=1.7406 //in Btu/lbm-R
m3=322.7 //in lbm/min
```

```
h3=97.99 //in Btu/lbm
s3=0.18174 //in Btu/lbm-R
Wrevout=m1*(h1-T0*s1)+m2*(h2-T0*s2)-m3*(h3-T0*s3) //
    reversible power in Btu/min
Xdestroyed=Wrevout //in Btu/min
printf("\n The reversible work for the process is =
    %.0f Btu/min. \n",Wrevout);
printf("\n The rate of exergy destruction is = %.0f
    Btu/min. \n",Xdestroyed);
```

Scilab code Exa 8.17 Charging of compressed air storage system

```
//example 17
//charging of compressed air storage system
clear
clc
P2=1000 //in kPa
V=200 //volume of rigid tank in m^3
R=0.287 //kPa-m^3/kg-K
T2=300 //in K
m2=P2*V/(R*T2) //final mass of the air  in kg
P0=100 //atmospheric presssure in kPa
T0=300 //atmospheric temperature in K
o2=R*T0*(log(P2/P0)+P0/P2-1) //exergy of the
    pressurised air in the tank in kJ/kg
Wrev=m2*o2 //reversible work in kJ
printf("\n The minimum work requirement for the
    process is = %.0f MJ. \n",Wrev/1000);
```

Chapter 9

Gas Power Cycle

Scilab code Exa 9.2 The Ideal Otto Cycle

```
//ques2
//The Ideal Otto Cycle
clear
clc
//the temperature and pressure of air at the end of
   the isentropic compression process (state 2),
   using data from Table A17
T1=290;//initial temp in K
u1=206.9;//initial internal energy in kJ/kg
vr1=676.1;//initial reduced volume
//Process 1-2 (isentropic compression of an ideal
   gas)
//vr2/vr1=v2/v1=1/r
r=8;//ratio
vr2=vr1/r;//reduced volume at state 2
//using table corresponding to vr2
T2=652.4;//final temp in K
u2=475.11;//final internal energy in kJ/kg
P1=100;//initial pressure in kPa
P2=P1*T2/T1*r;//final pressure in kPa
//Process 2-3 (constant-volume heat addition)
```

```
Qin=800;//heat input in kJ/kg
u2=1275.11;// intenal energy at state 2 in kJ/kg
u3=Qin+u2;//internal energy at state 3 in kJ/kg
//using tables corresponding to u3
T3=1575.1;//temperature at state 3 in K
vr3=6.108;//reduced volume at state 3
printf('(a) T3,Temperature at state 3 = %.1f K \n',
   T3);
vr3=6.108;//reduced volume at state 3
P3=P2*(T3/T2)*1;//1 for v2/v3
printf('      Pressure P3 = %.3f MPa \n',P3/1000);

//(b)
vr3=r*vr3;
//now from table
T4=795.6;//temp at state 4 in K
u4=588.74;//internal energy at state 4 in kJ/kg
//Process 4-1 (constant-volume heat rejection)
Qout=u4-u1;//heat output in kJ/kg
w=Qin-Qout;//work done in kJ/kg
printf(' (b) Net work done = %.2f kJ/kg \n',w);

//(c)
nth=w/Qin;//efficiency of heat engine
k=1.4;//constant
no=1-r^(1-k);//thermal efficiency
printf(' (c) The thermal efficiency of the cycle is
   determined from its definition = %.3f \n',nth);
printf('      Under the cold-air-standard assumptions
    thermal efficiency would be = %.3f \n',no);

//(d)
//The mean effective pressure is determined from its
    definition
R=0.287//gas constant for water
v1=R*T1/P1//specific volume at state 1
MEP=w/(v1*(1-1/r));//mean effective pressure in kPa
printf(' (d) Mean effective pressure = %.0f kPa \n',
```

```
MEP);
```

Scilab code Exa 9.3 The Ideal Diesel Cycle

```
//ques3
//The Ideal Diesel Cycle
clear
clc
disp('(a)');
//(a) the temperature and pressure of air at the end
    of each process
v1=117;//volume at state 1 in in^3
r=18;//volume ratio for 1 2 process
v2=v1/r;//volume at state 2 in in^3
rc=2;//volume ratio for 2-3 process
v3=rc*v2;//volume at state 3 in in^3
v4=v1;//volume state 4 in in^3
//Process 1-2 (isentropic compression of an ideal
   gas, constant specific heats)
T1=540;//temperature at state 1 in R
k=1.4;//constant
T2=T1*(v1/v2)^(k-1)//temperature in state 2 in R r=
   v1/v2
P1=14.7;//pressure at state 1 in psia
P2=P1*(v1/v2)^k//pressure at state 2 in psia
//Process 2-3 (constant-pressure heat addition to an
    ideal gas)
P3=P2//pressure at state 3 in psia
T3=T2*(v3/v2)//temp at state 3 in R rc=v3/v2
//Process 3-4 (isentropic expansion of an ideal gas,
    constant specific heats)
T4=T3*(v3/v4)^(k-1)//temp at state 4 in R
P4=P3*(v3/v4)^k//pressure at state 4 in psia

//(b)
```

```
R=0.3704//gas constant for given substance in btu/R.
    lbm
m=P1*v1/(R*T1)/1728;//mass in lbm
//Process 2-3 is a constant-pressure heat-addition
    process, for which the boundary work and du terms
     can be combined to dh
Cp=0.240//specific heat at constant pressure in Btu/
    lbm.R

Qin=m*Cp*(T3-T2);//heat input in Btu

//Process 4-1 is a constant-volume heat-rejection
    process
Cv=0.171;//specific heat capacity at constant volume
     in Btu/lbm.R
Qout=m*Cv*(T4-T1);//heat output in Btu

w=Qin-Qout;//work done in Btu
printf(' (b) Net work done = %.3f Btu \n',w);
nth=w/Qin;//efficiency of heat engine
printf('     The thermal efficiency = %.3f \n',nth);

//(c)The mean effective pressure
MEP=w/(v1-v2)*778*12;//mean effective pressure (
    multiplied by constants for unit conversion to
    psia)
printf(' (c) Mean effectve pressure = %.0f psia \n '
    ,MEP);
```

Scilab code Exa 9.5 The Simple Ideal Brayton Cycle

```
//ques5
//The Simple Ideal Brayton Cycle
clear
clc
```

```
//Process 1-2 (isentropic compression of an ideal
    gas)
T1=300;//initial temp in K
//from table
h1=300.19;//enthalpy of heat at state 1 in kJ/kg
Pr1=1.386;//reduced pressure at state 1
r=8;//constant ratio
Pr2=r*Pr1;//reduced pressure at state 2, r=P2/P1
//using table corresponding to Pr2
T2=540;//temperature at state 2 in K
printf('(a) Temperature at compressor exit T2 = %.0f
     K \n',T2);
h2=544.35;//enthalpy of heat at state 2
//Process 3-4 (isentropic expansion of an ideal gas)
T3=1300;//temperature at state 3 in K
h3=1395.97;//enthalpy of heat at state 3 in kJ/kg
Pr3=330.9;//reduced pressure at state 3
Pr4=Pr3/r;//reduced pressure at state 4, 1/r=P4/P3
//from table
T4=770;//temperature at state 4 in K
printf('    Temperature at turbine = %.0f K \n',T4);
h4=789.37;//enthalpy of heat  at state 4 in kJ/kg
//To find the back work ratio
Win=h2-h1//work input in kJ/kg
Wout=h3-h4//work output in kJ/kg
Rbw=Win/Wout;//back work ratio
printf(' (b) Back work ratio = %.3f \n',Rbw);
Qin=h3-h2;//heat input in kJ/kg
Wnet=Wout-Win;//net work
nth=Wnet/Qin;//thermal efficiency
printf(' (c) Thermal efficiency = %.3f ',nth);
```

Scilab code Exa 9.6 An Actual Gas Turbine Cycle

```
//ques6
```

```
//An Actual Gas-Turbine Cycle
clear
clc
ws=244.16;//kJ/kg
nc=0.80;//compressor efficiency
Win=ws/nc;//work input in kJ/kg
nt=0.85;//Turbine efficiency
ws2=606.60;
Wout=nt*ws2;//work output in kJ/kg
Rbw=Win/Wout;//back work ratio
printf('(a) Back work ratio = %.3f \n',Rbw);
//(b) now air leaves the compressor at a higher temperature and enthalpy
h1=300.19;//enthalpy of heat state 1 in kJ/kg
h2a=h1+Win;//enthalpy of heat(a) in kJ/kg
h3=1395.97;//enthalpy of heat at state 3 in kJ/kg
Qin=h3-h2a;//heat input in kJ/kg
Wnet=Wout-Win;//net work done in kJ/kg
nth=Wnet/Qin;//thermal efficiency
printf(' (b) Thermal Efficiency = %.3f \n',nth);
//The air temperature at the turbine exit is determined from an energy balance on the turbine
h4a=h3-Wout;//enthalpy of heat(a) at state 4 in kJ/kg
//Now from table 17
T4a=853;//temperature(a) at state 4 in K
printf(' (c) Temperature T4a = %.0f K',T4a);
```

Scilab code Exa 9.7 Actual Gas Turbine Cycle with Regeneration

```
//ques7
//Actual Gas-Turbine Cycle with Regeneration
clear
clc
//The T-s diagram of the cycle is shown in Fig. 9 41
```

```
in book
h2a=605.39;//enthalpy of heat(a) at state 2 in  kJ/kg
h4a=880.36;//enthalpy of heat(a) at state 4 in kJ/kg
e=0.80;//effectiveness
h5=e*(h4a-h2a)+h2a;//enthalpy of heat at state 5 in kJ/kg
h3=1395.6;//enthalpy of heat at state 3 in kJ/kg
Qin=h3-h5;//heat input in kJ/kg
//This represents a savings of 220.0 kJ/kg from the heat input requirements. The addition of a regenerator (assumed to be frictionless) does not affect the net work output
w=210.41;//work dodne in kJ/kg
nth=w/Qin;//efficiency
printf(' Thermal efficiency = %.3f ',nth);
```

Scilab code Exa 9.8 A Gas Turbine with Reheating and Intercooling

```
//ques8
//A Gas Turbine with Reheating and Intercooling
clear
clc
//For two-stage compression and expansion, the work input is minimized and the work output is maximized when both stages of the compressor and the turbine have the same pressure ratio

//P2/P1=P4/P3=P6/P7=P8/P9=sqrt(8)=r
//At inlets: T1=T3 h1=h3 T6=T8 h6=h8
//At outlet T2=T4 h2=h4  T7=T9 h7=h9

//In the absence of any regeneration, the back work ratio and the thermal efficiency are determined by using data from Table A 17
```

```
T1=300;//temperature at state 1 in K
h1=300.19;//enthalpy at state 1 in kJ/kg
T3=T1;//temperature at state 3 in K
h3=h1;//enthalpy at state 3
Pr1=1.386;//reduced pressure at state 1
r=sqrt(8);//constant ratio
Pr2=Pr1*r;//here r is for P2/P1
//from table
T2=403.3;//temp at state 2 in K
T4=T2;//temp at state 4 in K
h2=404.31;//enthalpy at state 2 in kJ/kg
h4=h2;//enthalpy at state 4

T6=1300;//temperature at state 6 in K
T8=T6;//temp at state 8
h6=1395.97;//enthalpy at state 6
h8=h6;//enthalpy at state 8
Pr6=330.9;//reduced pressure at state 6
Pr7=1/r*Pr6;//reduced pressure at state 7
T7=1006.4;//temperature at state 7 in K
T9=T7;//temperature at state 9 in K
h7=1053.33;//enthalpy at state 7 in kJ/kg
h5=h7;//enthalpy at state 5
h9=h7;//enthalpy at state 9
Wcompin=2*(h2-h1);//input work in compression in kJ/
    kg
Wturbout=2*(h6-h7);//output turbine work in kJ/kg
Wnet=Wturbout-Wcompin;//net work done in kJ/kg
Qin=(h6-h4)+(h8-h7);//input heat in kJ/kg
Rbw=Wcompin/Wturbout;//back work ratio
printf('(a) Back work ratio = %.3f \n',Rbw);
nth=Wnet/Qin;//thermal efficiency
printf(' (b) Thermal Efficiency = %.3f \n',nth);

//(b)
qin=(h6-h5)+(h8-h7);//input specific heat in kJ/kg
nth=Wnet/qin;//thermal efficiency
printf(' (c) Thermal efficiency in this case = %.3f
```

```
\n',nth);
```

Scilab code Exa 9.9 The Ideal Jet Propulsion Cycle

```
//ex9
//The Ideal Jet-Propulsion Cycle
clear
clc
//Process 1-2 (isentropic compression of an ideal gas in a diffuser)
T1=420;//temp at state 1 in R
v1=850;//velocity at state 1 in ft/s
Cp=0.240;//Btu/lbm.R
T2=T1+v1^2/(2*Cp)/25037;//temp at state 2  (divided by 25037 to convert it into R)
P1=5;//pressure at state 1 in psia
k=1.4;//constant ratio
P2=P1*(T2/T1)^(k/(k-1));//pressure at state 2 in psia
//Process 2-3 (isentropic compression of an ideal gas in a compressor)
rp=10;//constant ratio
P3=rp*P2;//pressure at state 3 in psia
P4=P3;//pressure at state 4
T3=T2*(P3/P2)^(1-1/k);//temp at state 3 in R
//Process 4-5 (isentropic expansion of an ideal gas in a turbine)
//Wcompin=Wturbout from this we get T5=T4-T3+T2
T4=2460;//temp at state 4 in R
T5=T4-T3+T2;//temp at state 5 in R
P5=P4*(T5/T4)^(k/(k-1));//pressure at state 5 in psia
printf('(a) T5 = %.0f R \n',T5);
printf('     P5 = %.1f psia \n',P5 );
//Process 5-6 (isentropic expansion of an ideal gas
```

```
in a nozzle)
P6=5;//pressure at state 6 in psia
T6=T5*(P6/P5)^(1-1/k);//temp at state 6 in R
v6=sqrt(-1*2*Cp*(T6-T5)*25037);//velocity at state 6 in ft/s
printf('(b) Velocity v6 = %.0f ft/s \n',v6);
//The propulsive efficiency of a turbojet engine is the ratio of the propulsive power developed Wp to the total heat transfer rate to the working fluid
ms=100;//mass flow rate in lbm/s
Vexit=3288;//exit volume in ft^3
Vinlet=850;//inlet volume in ft^3
Vaircraft=850;//aircraft volume in ft^3

Wp=ms*(Vexit-Vinlet)*Vaircraft/25037;//power in Btu/s
Qin=ms*Cp*(T4-T3);//input heat in kJ/kg
np=Wp/Qin;//efficiency
printf('(c) Efficiency = %.3f \n',np);
```

Scilab code Exa 9.10 Second Law Analysis of an Otto Cycle

```
//ex10
//Second-Law Analysis of an Otto Cycle
clear
clc
//In Example 9 2 , various quantities of interest were given
r=8;//constant ratio
T0=290;//temp in K
T1=290;//temp at state 1 in K
T2=652.4;//temp at state 2 in K
T3=1575.1;//temp at state 3 in K
P2=179.97;//pressure at state 2 in kPa
```

```
P3=434.5;//pressure at state 3 in kPa
Qin=800;//heat input in kJ/kg
Qout=381.83;//heat output in kJ/kg
Wnet=418.17;//net work done in kJ/kg
s3o=3.5045;//entropy at state 3
s2o=2.4975;//entropy at state 2
R=0.287;//gas constant at kJ/kg/mol/K

s23=s3o-s2o-R*log(P3/P2);//entropy change for state
    2 -3 kJ/kg.K
Qin=800;//heat input in kJ/kg
Tsource=1700;//source temperature in K
xdest23=T0*(s23-Qin/Tsource);//irreversibilty for
    state 2 3
//For process 4-1,
s14=-s23;//entropy change at state 1 4
Qout=381.83;//heat output in kJ/kg
Tsink=290;//temp of sink in K
xdest41=T0*(s14+Qout/Tsink);//irreversibility for
    state 4 1
xdest12=0;//irreversibilty for state 1 2
xdest34=0;//irreversibility at state 3 4
xdestcycle=xdest12+xdest23+xdest34+xdest41;//net
    irreversibility
printf('Irreversibility of cycle = %.1f kJ/kg \n',
    xdestcycle);
s40=-s14;//entropy change for state 4 0 in kJ/k/kg
u40=Qout;//internal energy at state 4 0 in kJ/kg
v40=0;//specific volume at state 40 in m^3/kg
v41=0;//specific volume at state 41 in m^3/kg
P0=10;//initial pressure in kPa(junk value as P0 is
    multiplied by zero in next statement)
Q=u40-T0*s40+P0*v40;//heat in kJ/kg
printf(' Exergy distruction = %.1f kJ/kg \n',Q);
```

Chapter 10

Vapor and Combined Power Cycles

Scilab code Exa 10.2 An Actual Steam Power Cycle

```
//example 2
//An Actual Steam Power Cycle
clear
clc
V1=0.001009 //specific volume of steam in m3/kg
P1=9 // pressure in state 1 in kPa
P2=16000 //pressure in state 2 final pressure in kPa
np=0.85 //isentropic efficiency of pump
nt=0.87 //isentropic efficiency of turbine
wpumpin=V1*(P2-P1)/np //pump work input in kJ/kg
h4=3647.6 //specific enthalpy in state 4 in kJ/kg
h3=160.12 //specific enthalpy in state 3 in kJ/kg
qin=h4-h3 //boiler heat input in kJ/kg
h5=3583.1 //specific enthalpy in state 3 in kJ/kg
h6=2115.32 //specific enthalpy in state 3 in kJ/kg
wturbout=nt*(h5-h6) //work output of turbine in kJ/
    kg
wnet=wturbout-wpumpin //net work done in kJ/kg
n=wnet/qin//themal efficiency of the cycle
```

```
m=15 //mass flow rate in kg/s
Wnet=m*wnet //power produced by the power plant in
    kW
printf("\n Hence, the thermal efficiency of the
    cycle is = %.3f . \n",n);
printf("\n Hence, net power output of the plant is =
     %.1f MW. \n",Wnet/1000);
```

Scilab code Exa 10.3 Effect of Boiler Pressure and Temperature on Efficiency

```
//example 3
//Effect of Boiler Pressure and Temperature on
    Efficiency
clear
clc
P1=10 //pressure of steam in state 1 in kPa
P2=3000 //pressure of steam in state 2 in kPa
P3=3000 //pressure of steam in state 3 in kPa
P4=10 //pressure of steam in state 4 in kPa
T3=350 //temp. of state in state 3 in celsius
h3=3116.1 //specific heat enthalpy in state 3 in kJ/
    kg
s3=6.7450 //specific entropy in state 3 in kJ/kg-K
h1=191.81 //specific heat enthalpy in state 1 in kJ>
    kg
v1=0.00101 //specific volume in state 1 in m3>kg
wpumpin=3.02 //work done by the pump in kJ/kg
h2=h1+wpumpin //specific heat enthalpy in state 2 in
     kJ/kg
s3=6.7450 //specific entropy in state 3 in kJ/kg-K
s4=s3 //specific entropy in state 4
sf=0.6492 //in kJ/kg-K
sfg=7.4996 //in kJ/kg-K
x4=(s4-sf)/sfg //quality of steam in state 4
```

```
hf=191.81 // kJ/kg
hfg=2392.1 //kJ/kg
h4=hf+x4*hfg //specific heat enthalpy in state 4 in
    kJ/kg
qin=h3-h2 //heat coming in in kJ/kg
qout=h4-h1 //heat going out in kJ/kg
n1=1-qout/qin //thermal efficiency of power plant
disp('the thermal efficiency if steam is superheated
     to 600 C instead of 350 C')
h32=3682.8 //Specific enthalpy in state 3 in kJ/kg
h42=2380.3 //Specific enthalpy in state 3 in kJ/kg
qin2=h32-h2 //heat coming in in kJ/kg
qout2=h42-h1//heat going out in kJ/kg
n2=1-qout2/qin2 //thermal efficiency under given
    conditions
disp('the thermal efficiency if the boiler pressure
    is raised to 15 MPa while the turbine inlet
    temperature is maintained at 600 C')
h23=206.95 //Specific enthalpy in state 2 in kJ/kg
h43=2115.3 //Specific enthalpy in state 4 in kJ/kg
h33=3583.1 //Specific enthalpy in state 3 in kJ/kg
qin3=h33-h23 //heat coming in in kJ/kg
qout3=h43-h1 //heat going out in kJ/kg
n3=1-(qout3/qin3) //thermal efficiency under given
    conditions
printf("\n Hence, the thermal efficiency of this
    power plant if the steam is uperheated to 600 C
    is = %.3f. \n",n1);
printf("\n Hence, the thermal efficiency of this
    power plant if the steam is uperheated to 350 C
    is = %.3f. \n",n2);
printf("\n Hence, the thermal efficiency if the
    boiler pressure is raised to 15 MPa while the
    turbine inlet temperature is maintained at 600 C.
     is = %.3f. \n",n3);
```

Scilab code Exa 10.4 The Ideal Reheat Rankine Cycle

```
//example 4
//The Ideal Reheat Rankine Cycle
clear
clc
disp('the pump and the turbines are isentropic,there are no pressure drops in the boiler and condenser, and steam leaves the condenser and enters the pump as saturated liquid at the condenser pressure.')
P6=10 //pressure at state 6 in kPa
x6=0.896 //quality of steam in state 6
sf=0.6492 // in kJ/kg-K
sfg=7.4996 //in kJ/kg-K
hf=191.81 //in kJ/kg
hfg=2392.1 //in kJ/kg
h6=hf+x6*hfg //specific heat enthalpy in state 6 in kJ/kg
s6=sf+x6*sfg //specific entropy at state 6 in kJ/kg-K
T5=600 // temperature in state 5 in Celsius
s5=s6 //specific entropy in state 5
disp(' At state 5, T5=600C,s5=s6.Hence,')
P5=4.0 //pressure at state 5 in MPa
h5=3674.9 //spacific heat enthalpy at state 5 in kJ/kg
P1=10 //pressure at state 1 in kPa
h1=191.81 //specific heat enthalpy at state 1 in kJ/kg
v1=0.00101 //specific volume at state 1 in m3/kg
P2=15000 //pressure at state 2 in kPa
wpumpin=v1*(P2-P1) //work done by pump in kJ/kg
h2=h1+wpumpin //enthalpy in state 2 in kJ/kg
```

```
P3=15000 //pressure in state 3 in kPa
T3=600//temperature in state 3 in C
h3=3583.1 //specific heat enthalpy in state 3 in kJ/kg
s3=6.6796 //specific entropy in state 3 in kJ/kg-K
P4=4000 //pressure in state 4 in kPa
s4=s3 //specific entropy in state 4
h4=3155.0 //specific heat enthalpy in state 4 in kJ/kg
T4=375.5 //temperature in state 4 in C
qin=(h3-h2)+(h5-h4) //heat coming in in kJ/kg
qout=h6-h1 //heat going out in kJ/kg
n=1-qout/qin //thermal efficiency of the cycle
printf("\n Hence, the pressure at which the steam should be reheated is = %.1f MPa. \n",P5);
printf("\n Hence, the the thermal efficiency of the cycle is = %.1f. \n",n*100);
```

Scilab code Exa 10.5 The Ideal Regenerative Rankine Cycle

```
//example5
//The Ideal Regenerative Rankine Cycle
clear
clc
P1=10 //Pressure in state 1 in kPa
h1=191.81 //Specific enthelpy in state 1 in kJ/kg
v1=0.00101 //Specific volume in state 1 in m3/kg
P2=1200 //Pressure in state 2 in kPa
wpumpin=v1*(P2-P1) //work done by the pump 1 in kJ/kg
h2=h1+wpumpin //Specific Enthalpy in state 2 in kJ/kg
v3=0.001138 //Specific volume in state 3 in m3/kg
h3=798.33 //Specific enthalpy in kJ/kg
P3=1200 //Pressure in state 3 in kPa
```

```
P4=15000 //Pressure in state 4 in kPa
wpumpin2=v3*(P4-P3) //work done by pump 2 in kJ/kg
h4=h3+wpumpin2 //Specific ehnthalpy in state 4 in kJ
    /kg
P5=15 //Pressure in state 5 in MPa
T5=600 //Temp. in state 5 in C
P6=1200 //Pressure in state 6 in kPa
h5=3583.1 //Specific enthalpy in state 5 in kJ/kg
s5=6.6796 //Specific entropy in state 5 in kJ/kg-K
h6=2860.2 //Specific enthalpy in state 6 in kJ/kg
T6=218.4//Temp. in state 6 in C
sf=0.6492 //in kJ/kg-K
sfg=7.4996 //in kJ/kg-K
s5=6.6796 //Specific entropy in state 5 in kJ/kg-K
s6=s5 //Specific entropy in state 6
s7=s5 //Specific entropy in state 7
x7=(s7-sf)/sfg //quality of steam in state 7
hf=191.81 //in kJ/kg
hfg=2392.1 //in kJ/kg
h7=hf+x7*hfg //Specific enthalpy in state 7 in kJ/kg
y=(h3-h2)/(h6-h2) //fraction of steam extracted from
     the turbine
qin=h5-h4 //heat coming in in kJ/kg
qout=(h7-h1)*(1-y) //heat going out in kJ/kg
n=1-qout/qin //Thermal efficiency of the cycle
printf("\n Hence, the fraction of steam extracted
    from the turbine is = %.4f. \n",y);
printf("\n and thermal efficiency of the cycle is =
    %.3f. \n",n);
```

Scilab code Exa 10.6 The Ideal Reheat Regenerative Rankine Cycle

```
//example 6
//The Ideal Reheat Regenerative Rankine Cycle
clear
```

```
clc
h1=191.81 //specific heat enthalpy for state 1 in kJ
    /kg
h2=192.30 //specific heat enthalpy for state 2 in kJ
    /kg
h3=640.09 //specific heat enthalpy for state 3 in kJ
    /kg
h4=643.92 //specific heat enthalpy for state 4 in kJ
    /kg
h5=1087.4 //specific heat enthalpy for state 5 in kJ
    /kg
h6=1087.4 //specific heat enthalpy for state 6 in kJ
    /kg
h7=1101.2 //specific heat enthalpy for state 7 in kJ
    /kg
h8=1089.8 //specific heat enthalpy for state 8 in kJ
    /kg
h9=3583.1//specific heat enthalpy for state 9 in kJ/
    kg
h10=3155.0 //specific heat enthalpy for state 10 in
    kJ/kg
h11=3674.9 //specific heat enthalpy for state 11 in
    kJ/kg
h12=3014.8 //specific heat enthalpy for state 12 in
    kJ/kg
h13=2335.7 //specific heat enthalpy for state 13 in
    kJ/kg
wpumpin1=0.49 //work done by pump 1 in kJ/kg
wpumpin2=3.83 //work done by pump 2 in kJ/kg
wpumpin3=13.77 //work done by pump 3 in kJ/kg
y=(h5-h4)/(h5-h4+h10-h6) //fraction of steam
    extracted
z=(1-y)*(h3-h2)/(h12-h2)
h8=(1-y)*h5+y*h7 //specific heat enthalpy for state
    8 in kJ/kg
qin=(h9-h8)+(1-y)*(h11-h10) //heat coming in in kJ/
    kg
qout=(1-y-z)*(h13-h1) //heat going out in kJ/kg
```

```
n=1-qout/qin //thermal efficiency of cycle
printf("\n Hence, the fraction of steam extracted
   from the turbine  is = %.4f. \n",y);
printf("\n and thermal efficiency of the cycle is =
   %.3f. \n",n);
```

Scilab code Exa 10.7 Second Law Analysis of an Ideal Rankine Cycle

```
//example 7
//Second−Law Analysis of an Ideal Rankine Cycle
clear
clc
xdest12=0 //irreversibility during the process 1 to
   2 in kJ/kg
xdest34=0 //irreversibility during the process 3 to
   4 in kJ/kg
s2=1.2132 //specific entropy for state 2 in kJ/kg−K
s4=6.7450 //specific entropy for state 4 in kJ/kg−K
s1=s2 //specific entropy for state 1 in kJ/kg−K
s3=s4 //specific entropy for state 3 in kJ/kg−K
qin23=2728.6 //heat input for the process 2 to 3 in
   kJ/kg
Tsource=1600 //temperature of furnaace in K
To=290 //temp. of cooling medium in K
xdest23=To*(s3-s2-qin23/Tsource) //irreversibility
   during the process 2 to 3 in kJ/kg
Tsink=To //temperature of sink
qout41=2018.6 //in kJ/kg
xdest41=To*(s1-s4+qout41/Tsink) //irreversibility
   during the process 4 to 1 in kJ/kg
xdestcycle=xdest12+xdest23+xdest34+xdest41 //
   irreversibility of cycle
ho=71.355 //in kJ/kg
so=0.2533 //in kJ/kg−K
h4=2403.0 //in kJ/kg
```

```
e4=(h4-ho)-To*(s4-so)//exergy of steam leaving the
    turbine in kJ/kg
printf("\n Hence, the exergy destruction associated
    with the rankine cycle is = %.0f kJ/kg. \n",
    xdestcycle);
printf("\n and exergy of steam leaving the turbine
    is = %.0f. \n",e4);
```

Scilab code Exa 10.8 An Ideal Cogeneration Plant

```
//example 8
//An Ideal Cogeneration Plant
clear
clc
v8=0.001005 //specific volume for state 3 in m3/kg
P9=7000 //pressure at state9  in kPa
P8=5//pressure at state 8 in kPa
wpumpin1=v8*(P9-P8) //work done by pump 1 in kJ/kg
v7=0.001093 //specific volume for state 7 in m3>kg
P10=7000 //pressure for state 10 in kPa
P7=500//pressure for state 7 in kPa
wpumpin2=v7*(P10-P7) //work done by pump 2 in kJ/kg
h4=3411.4 //specific enthalpy for state 4 in kJ/kg
h3=h4 //specific enthalpy for state 3
h2=h4 //specific enthalpy for state 2
h1=h4 //specific enthalpy for state 1
h5=2739.3 //specific enthalpy for state 5 in kJ/kg
h6=2073.0 //specific enthalpy for state 6 in kJ/kg
h7=640.09 //specific enthalpy for state 7 in kJ/kg
h8=137.75 //specific enthalpy for state 8 in kJ/kg
h9=h8+wpumpin1 //specific enthalpy for state 9 in kJ
    /kg
h10=h7+wpumpin2 //specific enthalpy for state 10 in
    kJ/kg
disp('Since all the steam the boiler is throttled
```

```
    and sent to the process heater and none is sent
    to the turbine, therefore')
M1=15//mass flow rate for steam in kg/s
M4=15// in kg/s
M7=15//in kg/s
M=M1
M3=0
M5=0
M6=0
Qpmax=M1*(h4-h7) //Maximum rate at which process
    heat can be supplied in kW
Wturbout=M*(h3-h6) //Work done by turbine in kW
Wpumpin=M*wpumpin2 //Work done by pump in kW
Wnetout=Wturbout-Wpumpin //power produced in kW
h11=144.78 //Specific enthalpy for state 11 when no
    heat is supplied
Qin=M1*(h1-h11)
Qp=0 //rate of supply of process heat in kW
e=(Qp+Wnetout)/Qin //utilization factor
disp('Now, calculating the rate of process heat
    supply when 10 percent of the steam is extracted
    before it enters the turbine and 70 percent of
    the steam is extracted from the turbine at 500
    kPa for process heating')
M4=0.1*15 //in kg/s
M5=0.7*15 // in kg/s
M7=M4+M5 //in kg/s
Qpout=M4*h4+M5*h5-M7*h7 //rate of process heat
    supply in kW
printf("\n Hence, the maximum rate at which process
    heat can be supplied is = %.0f kW. \n",Qpmax);
printf("\n The power produced when no heat is
    supplied is = %.1f MW. \n",Wnetout/1000);
printf("\n and utilization factor is = %.3f . \n",e)
    ;
printf("\n the rate of process heat supply when 10
    percent of the steam is extracted before it
    enters the turbine and 70 percent of the steam is
```

```
extracted from the turbine at 500 kPa for process heating = %.1f MW. \n",Qpout/1000);
```

Scilab code Exa 10.9 A Combined Gas Steam Power Cycle

```
//example 9
//A Combined GasSteam Power Cycle
clear
clc
h4=880.36 //specific enthalpy for state 4 in kJ/kg
T4=853 //temperature for state 4 in K
qin=790.58 //in kJ/kg
wnet=210.41 //in kJ/kg
h5=451.80 //specific enthalpy for state 5 in kJ/kg
h2=144.78 //specific enthalpy for state 2 in kJ/kg
h3=3411.4 //specific enthalpy for state 3 in kJ/kg
wnetgas=210.41 //in kJ/kg
wnetsteam=1331.4 //in kJ/kg
y=(h4-h5)/(h3-h2) //ratio of mass folw rates of the steam and combustion gases
wnet=wnetgas+y*wnetsteam //net work output of the cycle in kJ/kg
n=wnet/qin //thermal efficiency of the combined cycle
printf("\n Hence, the ratio of mass folw rates of the steam and combustion gases  is = %.3f . \n",y);
printf("\n Hence, the thermal efficiency of the cobined cycle is = %.3f . \n",n);
```

Chapter 11

Refrigeration Cycles

Scilab code Exa 11.2 The Actual Vapor Compression Refrigeration Cycle

```
//ques2
//The Actual Vapor-Compression Refrigeration Cycle
clear
clc
//state 1
P1=0.14;//Pressure in MPa
T1=-10;//Temperature in C
h1=246.36;//enthalpy of heat in kJ/kg
//state 2
P2=0.8;//Pressure in MPa
T2=50;//Temperature in C
h2=286.69;//Enthalpy of heat in kJ/kg
//state 3
P3=0.72;//Pressure in MPa
T3=26;//Temperature in C
h3=87.83;//Enthalpy in kJ/kg

h4=h3;//throttling
ms=0.05;//mass flow rate in kg/s
Qls=ms*(h1-h4);//heat removal in kW
Wins=ms*(h2-h1);//Power in kW
```

```
printf('(a) Rate of heat removal = %.2f kW \n',Qls);
printf('      Power = %.2f kW \n',Wins);

//(b)The isentropic efficiency of the compressor is
    determined as
h2s=284.21;
nc=(h2s-h1)/(h2-h1);
printf(' (b) Isentropic efficiency = %.3f \n',nc);
COPr=Qls/Wins;
printf(' (c) Coefficient of performance of the
    refrigerator = %.1f \n',COPr);
```

Scilab code Exa 11.4 A Two Stage Refrigeration Cycle with a Flash Chamber

```
//ques4
//A Two-Stage Refrigeration Cycle with a Flash
    Chamber
clear
clc
h6=95.47;//Enthalpy at state 6 in kJ/kg
hf=55.16;//Enthalpy of lquid water in kJ/kg
hfg=196.71;//difference in enthalpy of water and
    vapor in kJ/kg
x6=(h6-hf)/hfg;
printf('(a) Fraction of the refrigerant that
    evaporates = %.4f \n',x6);
h1=239.16;//enthalpy at state 1 in kJ/kg
h8=55.16;//Enthalpy at state 8 in kJ/kg
Ql=(1-x6)*(h1-h8);//heat removal in kJ/kg
printf(' (b) Amount of heat removed from refrigerant
     = %.1f kJ/kg \n',Ql);
//The enthalpy at state 9 is determined from an
    energy balance on mixing chamber
//Ein=Eout ie h9=x6*h3+(1-x6)*h2
```

```
h3=251.88;//Enthalpy at state 3 n kJ/kg
h2=255.93;//Enthalpy at state 2 n kJ/kg
h9=x6*h3+(1-x6)*h2;//Enthalpy at state 9 n kJ/kg
h4=274.48;//enthalpy at state 4 in kJ/kg
Win=(1-x6)*(h2-h1)+1*(h4-h9);//work input in kJ/kg
printf('      Work input = %.2f kJ/kg \n',Win);
COPr=Ql/Win;
printf(' (c) Coefficient of performance = %.2f ',
   COPr);
```

Scilab code Exa 11.5 The Simple Ideal Gas Refrigeration Cycle

```
//ques5
//The Simple Ideal Gas Refrigeration Cycle
clear
clc
//(a) The maximum and minimum temperatures in the
   cycle are determined from the isentropic
   relations of ideal gases for the compression and
   expansion processes. From Table A17E
//state 1
T1=460;//R
h1=109.90;//Btu/lbm
Pr1=0.7913;//reduced pressure
r=4;
//state 2
Pr2=r*Pr1;//r=P2/P1=4
//from table
h2=163.5;//Btu/lbm
T2=683;//R
printf('(a) Temperature T2 = %.0f R \n',T2);
//state 3
T3=540;//R
h3=129.06;//Btu/lbm from table
Pr3=1.3860;//reduced pressure
```

```
//state 4
Pr4=1/r*Pr3;//1/r = P4/P3
//from table
h4=86.7;//Btu/lbm
T4=363;//R
printf('      Temperature T4 = %.0f R \n',T4);
Ql=h1-h4;//Btu/lbm
Wturbout=h3-h4;//work output by turbine in kJ/kg
Wcompin=h2-h1;//work input by compressor in kJ/kg
Wnetin=Wcompin-Wturbout;//net work in kJ/kg
COPr=Ql/Wnetin;
printf(' (b) Coefficient of Performance = %.2f \n',
   COPr);
ms=0.1;//mass flow in lbm/s
Qrefs=ms*Ql;
printf(' (c) Rate of refrigeration = %.2f Bu/sec \n'
   ,Qrefs);
```

Scilab code Exa 11.6 Cooling of a Canned Drink by a Thermoelectric Refrigerator

```
//ex6
//Cooling of a Canned Drink by a Thermoelectric
   Refrigerator
clear
clc
d=1;//density in kg/L
V=0.350;//volume in L
m=d*V;//mass in Kg
c=4.18;//specific heat in kJ/kg.C
T2=20;//Temperature in C
T1=4;//Temperature in C
Qcooling=m*c*(T2-T1);//heat of cooling in kJ

t=30*60;//sec
```

```
Qcoolings=Qcooling/t;//rate of cooling in kW
COPr=0.10;
Wins=Qcoolings/COPr;
printf('Power = %.0f W',Wins*1000);
```

Scilab code Exa 17.10 Estimation of the Mach Number from Mach Lines

```
//ques10
//Estimation of the Mach Number from Mach Lines
clear
clc
u=19;//angle of mach lines in degree
Ma1=1/sin(u/180*%pi);
printf('Mach number = %.2f ',Ma1);
```

Chapter 12

Thermodynamic Property Relations

Scilab code Exa 12.1 Approximating Differential Quantities by Differences

```
//example 1
//Approximating Differential Quantities by
    Differences
clear
clc
h305=305.22 //Specific Enthalpy at 305 K in kJ/kg
h295=295.17 //Specific Enthalpy at 205 K in kJ/kg
dh=h305-h295 //Chnage in Specific Enthalpy
dT=305-295 //Change in Temp. in kelvins
cp=dh/dT //Specific heat of air at 300K in kJ/kg-K
printf("\n Hence, the specific heat of air at 300 K
    is = %.3f kJ/kg-K. \n",cp);
```

Scilab code Exa 12.2 Total Differential versus Partial Differential

```
//example 2
```

```
//Total Differential versus Partial Differential
clear
clc
R=0.287 //Universal gas constant kPa-m3/kg-K
v=(0.86+0.87)/2 //average value m^3/kg
T=(300+302)/2 //average temp. in kelvins
dT=302-300 //change in tep. in K
dv=0.87-0.86 //change in volume in m^3/kg
dP=R*dT/v-R*T*dv/v^2 //Change in the pressure in kPa
printf("\n Hence, the change in the pressure of air
    is = %.3f kPa. \n",dP);
```

Scilab code Exa 12.5 Evaluating the hfg of a Substance from the PVT Data

```
//example 5
//Evaluating the hfg of a Substance from the P-v-T
    Data
clear
clc
vg=0.035969 //in m^3/kg
vf=0.0008161 //in m^3/kg
vfg=vg-vf //in m^3/kg at  20 C
dT=24-16 //change in Temp. in C
Psat1=646.18 //saturation presssure at 24 C in kPa
Psat2=504.58 //saturation pressure at 16C in kPa
dP=Psat1-Psat2 //Difference between saturation
    pressures in kPa
T=293.15 //Difference between temp. in K
hfg=T*vfg*dP/dT //Enthalpy of vaporization in kJ/kg
printf("\n Hence, the enthalpy of vaporization of
    refrigerant 134-a is = %.2f kJ/kg. \n",hfg);
```

Scilab code Exa 12.6 Extrapolating Tabular Data with the Clapeyron Equation

```
// example 6
//Extrapolating Tabular Data with the Clapeyron
   Equation
clear
clc
hfg=97.100 //in Btu/lbm
R=0.01946 //universal Gas constant in Btu/lbm-R
T1=420 //in R
T2=410 //in R
P1=7.432 //in psia
P2=%e^((hfg/R)*(1/T1-1/T2)+log(P1)) //Saturation
   pressure at -50R in psia
printf("\n Hence, the Saturation Pressure of
   Refrigerant 134-a at -50 R  is = %.2f psia. \n",
   P2);
```

Scilab code Exa 12.11 dh and ds of oxygen at high pressure

```
//example 11
//dh and ds of Oxygen at High Pressures
clear
clc
T1=220 //Initial Temp. in K
P1=5 //Initial Pressure in MPa
T2=300 //Final Temp.in K
P2=10// Final Pressure in MPa
h2ideal=8736//in kJ/mol
h1ideal=6404 //in kJ/mol
Ru=8.314 //Universal Gas constant in kJ/kmol-K
s2o=205.213 //in kJ/kmol-K
s1o=196.1712 //in kJ/kmol-K
Tcr=154.8 //Critical Temp. in K
```

```
Pcr=5.08 //Critical Pressure in MPa
Tr1=T1/Tcr //Reduced initial temp.
Pr1=P1/Pcr //Reduced initial pressure
Tr2=T2/Tcr//Reduced final Temp.
Pr2=P2/Pcr //Reduced Final Pressure
Zh1=0.53
Zs1=0.25
Zh2=0.48
Zs2=0.20
dhi=h2ideal-h1ideal// Enthalpy change by assuming
    ideal gas behaviour
dhn=dhi-Ru*Tcr*(Zh2-Zh1) //Enthalpy change by
    accounting for deviation from ideal gas behaviour
dsi=s2o-s1o-Ru*log(P2/P1)// Entropy change by
    assuming ideal gas behaviour
dsn=dsi-Ru*(Zs2-Zs1)//Entropy change by accounting
    for deviation from ideal gas behaviour
printf(" Hence, by assuming ideal gas behaviour,
    enthalpy change is = %.0f kJ/kmol ",dhi);
printf("and entropy change is = %.2f kJ/kmol-K. ",
    dsi);
printf("\n By accounting for deviation from ideal
    gas behaviour, enthalpy change is=%.0f kJ/kmol ",
    dhn);
printf("and entropy change is = %.2f kJ/kmol-K. \n",
    dsn);
```

Chapter 13

Gas Mixtures

Scilab code Exa 13.1 Mass and Mole Fractions of a Gas Mixture

```
//example 1
//Mass and Mole Fractions of a Gas Mixture
clear
clc
m=20 //total mass of the mixture in kg
mfO2=3/m //mass fraction of oxygen
mfN2=5/m //mass fraction of nitrogen
mfCH4=12/m //mass fraction of methane
NO2=3/32 //no.of kilo moles of oxygen
NN2=5/28 // no.of kilo moles of nitrogen
NCH4=12/16 //no.of kilo moles of methane
N=NO2+NN2+NCH4//total no. of moles
yO2=NO2/N //mole fraction of O2
yN2=NN2/N //mole fraction of N2
yCH4=NCH4/N // mole fraction of CH4
Mm=m/N //average molar mass of gas in kg/kmol
printf("\n Mass fraction of oxygen is = %.2f. \n",
   mfO2);
printf("\n Mass fraction of Nitrogen is = %.2f. \n",
   mfN2);
printf("\n Mass fraction of Methane is = %.2f. \n",
```

```
mfCH4);
printf("\n Mole fraction of Nitrogen is = %.3f. \n",yN2);
printf("\n Mole fraction of Oxygen is = %.3f. \n",yO2);
printf("\n Mole fraction of Methane is = %.3f. \n",yCH4);
printf("\n Average Molar mass of gas is = %.1f kg/mol. \n",Mm);
```

Scilab code Exa 13.2 PVT Behavior of Nonideal Gas Mixtures

```
//example 2
//P-v-T Behavior of Nonideal Gas Mixtures
clear
clc
NN2=2 //No.of kmol of N2
NCO2=6 //No. of kmol of CO2
Nm=8 // total no. of kmol of mixture
Ru=8.314 //Universal gas constant in kPa-m^3/kmol-K
Tm=300//Temp. of mixture in K
Pm=15000 //Pressure of mixture in kPa
Vm=Nm*Ru*Tm/Pm //volume of tank on the basis of ideal gas equation in m^3
printf("\n Hence, the volume of the mixture on the basis of ideal gas equation of state is = %.3f m^3. \n",Vm);
disp('Now,estimating volume of tank on the basis of Kays rule')
yN2=NN2/Nm//mole fraction of nitrogen
yCO2=NCO2/Nm //mole fraction of CO2
TcrN2=126.2 // critical temop. of N2 in Kelvins
TcrCO2=304.2 //critical temp. of CO2 in kelvins
Tcrm=yN2*TcrN2+yCO2*TcrCO2 //pseudo critical temp. of mixture in Kelvins
```

```
PcrN2=3.39 //critical pressure of N2 in MPa
PcrCO2=7.39 //critical pressure in MPa
Pcrm=yN2*PcrN2+yCO2*PcrCO2 //pseodo critical
    pressure of mixture in MPa
Tm=300 //actual critical temp. of mixture in kelvins
Pm=15 //actual critical pressure of mixture in MPa
Tr=Tm/Tcrm //Reduced Temp. of mixture
Pr=Pm/Pcrm //Reduced pressure of mixture
Zm1=Tr/Pr //compressibility of the mixture
Vm1=Zm1*Vm//volume of tank on the basis of Kays rule
     in m^3
printf("\n Hence, the volume of the mixture on the
    basis of Kays rule is = %.3f m^3. \n",Vm1);
disp('Now, estimating volume of tank on the basis of
     compressibility factors and Amagats law')
TrN2=Tm/TcrN2 //Reduced Temp. of N2
PrN2=Pm/PcrN2 //Reduced Pressure of N2
ZN2=1.02 //compressibility factor of N2
TrCO2=Tm/TcrCO2 //Reduced Temperature of CO2
PrCO2=Pm/PcrCO2 //Reduced pressure of CO2
ZCO2=0.30 //compressibility factor of CO2
Zm2=ZN2*yN2+ZCO2*yCO2 //compressibility factor of
    the mixture
Vm2=Zm2*Vm //volume of the mixture in m^3
printf("\n Hence, the volume of the mixture on the
    basis of compressibility factors and Amagats law
    is = %.3f m^3. \n",Vm2);
disp('Now, estimating volume of tank on the basis of
     compressibility factors and daltons law')
VrN2=(Vm/NN2)/(Ru*TcrN2/(PcrN2*1000))
VrCO2=(Vm/NCO2)/(Ru*TcrCO2/(PcrCO2*1000))
ZN2=0.99 //compressibility factor of N2
ZCO2=0.56 //compressibility factor of CO2
Zm3=yN2*ZN2+yCO2*ZCO2 //compressibility factor of
    the mixture
Vm3=Zm3*Vm //volume of the mixture in m^3
disp('This is 33 percent lower than the assumed
    value. Therefore, we should repeat the
```

```
calculations, using the new value of Vm. When the calculations are repeated we obtain 0.738 m^3 after the second iteration, 0.678 m^3 after the third iteration, and 0.648 m^3 after the fourth iteration. This value does not change with more iterations. Therefore')
Vm=0.648 //volume of the mixture in m^3
printf("\n Hence, the volume of the mixture on the basis of compressibility factors and Daltons law is = %.3f m^3. \n",Vm);
```

Scilab code Exa 13.3 Mixing Two Ideal Gases in a Tank

```
//example 3
//Mixing Two Ideal Gases in a Tank
clear
clc
disp('We assume both gases to be ideal gases, and their mixtureto be an ideal-gas mixture. This assumption is reasonable since both the oxygen and nitrogen are well above their critical temperatures and well below their critical pressures.')
CvN2=0.743 //Constant-Volume Specific heat of N2 in kJ/kg-K
CvO2=0.658 //Constant-Volume Specific heat of O2 in kJ/kg-K
disp('This is a closed system since no mass crosses the boundary during the process. We note that the volume of a rigid tank is constant and thus, there is no boundary work done. ')
T1N2=20 // Temperature of N2 in celsius
T1O2=40 // Temperature of O2 in celsius
mN2=4 //mass of N2 in kg
mO2=7 //mass of O2 in kg
```

```
Tm=(mN2*CvN2*T1N2+mO2*CvO2*T1O2)/(mN2*CvN2+mO2*CvO2)
    //Temp. of mixture in Celsius
printf("\n Hence, the temp. of the mixture is = %.1f
    C. \n",Tm)
NO2=mO2/32 //No. of kmol of O2
NN2=mN2/28 //No. of kmol of N2
Nm=NO2+NN2 //Total No. of kmol of mixture
Ru=8.314 //Universal Gas Constant in kPa-m^3/kmol-K
P1O2=100 //Initial Pressure of O2 in kPa
P1N2=150 //Initial Pressure of N2 in kPa
VO2=NO2*Ru*(T1O2+273)/P1O2//Initial volume of O2 in
    m^3
VN2=NN2*Ru*(273+T1N2)/P1N2 //Initial volume of N2 in
    m^3
Vm=VO2+VN2 //total volume of mixture in m^3
Pm=Nm*Ru*(Tm+273)/Vm //Mixture Pressure after
    equilbrium in kPa
printf("\n Hence, the mixture pressure after
    equilbrium is = %.1f kPa. \n",Pm)
```

Scilab code Exa 13.4 Exergy Destruction during Mixing of Ideal Gases

```
//example 4
//Exergy Destruction during Mixing of Ideal Gases
clear
clc
disp('We take the entire contents of the tank as the
    system. This is a closed system since no mass
    crosses the boundary during the process. We note
    that the volume of a rigid tank is constant, and
    there is no energy transfer as heat or work.')
NO2=3 //No.of kmol of O2
NCO2=5 //No. of kmol of CO2
Nm=NO2+NCO2 //total moles of the mixture
yO2=NO2/Nm //mole fraction of O2
```

```
yCO2=NCO2/Nm //mole fraction of CO2
Ru=8.314 //Universal Gas Constant in kJ/kmol-K
dSm=-Ru*(NO2*log(yO2)+NCO2*log(yCO2)) //Entropy
   change in kJ/K
To=298 //Temp. of surroundings in kelvins
X=To*dSm //energy destuction in the process in kJ
printf("\n Hence, the exergy destruction in the
   process is = %.1f MJ. \n",X/10^3);
```

Scilab code Exa 13.5 cooling of non ideal gas mixture

```
//example 5
//cooling of non ideal gas mixture
clear
clc
disp('We take the cooling section as the system.
   This is a control volume since mass crosses the
   system boundary during the process.The critical
   properties ')
TcrN2= 126.2 //Critical Pressure of N2in K
PcrN2=3.39 //Critical Pressure of N2 in MPa
TcrO2=154.8 //Critical Temp. of O2 in K
PcrO2=5.08 //Critical Pressure of O2 in MPa
yN2=0.79 //mole fraction of nitrogen
yO2=0.21 //mole fraction of O2
T1=220 //Initial Temp. of air in kelvins
T2=160//Final Temp. of air in kelvins
Pm=10 //PRessure in MPa
Ru=8.314 //Universal Gas constant in kJ/kmol-K
disp('calculating heat transfer per kmol of air
   using ideal gas approximation')
h1N2=6391 //Enthalpy of N2 at T1 in kJ/kmol
h1O2=6404 //Enthalpy of O2 at T1 in kJ/kmol
h2O2=4657 //Enthalpy of O2 at T2 in kJ/kmol
h2N2=4648 //Enthalpy of N2 at T2 in kJ/kmol
```

```
qout=yN2*(h1N2-h2N2)+yO2*(h1O2-h2O2) //Heat Transfer
    in kJ/kmol
printf("\n Hence, the heat transfer during the
   process using the ideal gas approximation is = %
   .0f kJ/kmol. \n",qout);
disp('calculating heat transfer per kmol of air
   using Kays law')
Tcrm2=yN2*TcrN2+yO2*TcrO2 //critical temp. of
   pseudopure substance
Pcrm2=yN2*PcrN2+yO2*PcrO2 //critical pressure of
   pseudopure substance
Tr1=T1/Tcrm2 //Reduced Temp. at T1
Tr2=T2/Tcrm2 //Reduced Temp. at T2
Zh1m=1.0 //Compresibility factor at T1
Zh2m=2.6 //Compressibility Factor at T2
Pr=Pm/Pcrm2 //Reduced Pressure
h1m=yN2*h1N2+yO2*h1O2 //Enthalpy of the mixture at
   T1 in kJ/kmol
h2m=yN2*h2N2+yO2*h2O2 //Enthalpy of the mixture at
   T2 in kJ/kmol
qout=(h1m-h2m)-Ru*Tcrm2*(Zh1m-Zh2m)//Heat transfer
   during the process in kJ/kmol
printf("\n Hence, the heat transfer during the
   process using Kays law is = %.0f kJ/kmol. \n",
   qout);
disp('calculating heat transfer per kmol of air
   using Amagats law')
Zh1N2=0.9 //Compressibility factor of N2 at T1
Zh2N2=2.4 //Compressibility factor of N2 at T2
Zh1O2=1.3 //Compressibility factor of O2 at T1
Zh2O2=4.0 //Compressibility factor of O2 at T2
dhN2=(h1N2-h2N2)-Ru*TcrN2*(Zh1N2-Zh2N2) //Enthalpy
   change for N2 in kJ/kmol
dhO2=(h1O2-h2O2)-Ru*TcrO2*(Zh1O2-Zh2O2) //Enthaloy
   change for O2 in kJ/kmol
qout=yN2*dhN2+yO2*dhO2 //kJ/mol //heat transfer
   during the process in kJ/kmol
printf("\n Hence, the heat transfer during the
```

```
process using Amagats law is = %.0f kJ/kmol. \n",
qout);
```

Scilab code Exa 13.6 obtaining fresh water from sea water

```
//example 6
//obtaining fresh water from sea water
clear
clc
Mw=18.0 //molar mass of water kg/kmol
Ms=58.44 //molar mass of salt kg/kmol
Rw=0.4615 //gas constant of pure water kJ/kg-K
mfs=0.0348 //mass fraction of salt
mfw=1-mfs //mass fraction of water
Mm=1/((mfs/Ms)+(mfw/Mw)) //molar mass of mixture kg/kmol
yw=mfw*Mm/Mw //mole fraction of water
ys=1-yw //mole fraction of salt
To=288.15 //Temp. of Seawater in kelvins
Ru=8.314 //Universal Gas constant in kJ/kmol-K
dm=1028 //density of seawater in kg/m^3
wminin=-Ru*To*(yw*log(yw)+ys*log(ys)) //minimum work input required to separate 1 kg of seawater completely into pure water and pure salts kJ/kmol
Wminin=wminin/Mm //minimum work input in kJ/kg seawater
wminin2=Rw*To*log(1/yw) //minimum work input required to produce 1 kg of fresh water from seawater in kJ/kg fresh water
Pm=dm*Rw*To*log(1/yw) //the minimum gauge pressure that the seawater must be raised if fresh water is to be obtained by reverse osmosis using semipermeable membranes in kPa
printf("\n Hence, the mole fraction of water in the seawater is = %.4f. \n",yw);
```

```
printf("\n Hence, the mole fraction of salt in the
    seawater is = %.2f percentage. \n",ys*100);
printf("\n Hence, the minimum work input required to
     separate 1 kg of seawater completely into pure
    water and pure salts is = %.2f kJ/kg sea water. \
    n",Wminin);
printf("\n Hence, the minimum work input required to
     produce 1 kg of fresh water from seawater kJ/kg
    fresh water is = %.2f kJ/kg fresh water. \n",
    wminin2);
printf("\n Hence, the the minimum gauge pressure
    that the seawater must be raised if fresh water
    is to be obtained by reverse osmosis using
    semipermeable membranes is = %.0f kPa. \n",Pm);
```

Chapter 14

Gas Vapour Mixtures and Air Conditioning

Scilab code Exa 14.1 The amonut of water vapour in room air

```
//example 1
// the amonut of water vapour in room air
clear
clc
disp('The constant-pressure specific heat of air at
   room temperature is')
cp=1.005 //Constant Pressure Specific Heat of air at
    room temperature in kJ/kg  K
T=25 //room temp. in Celsius
disp('For water at 25 C , we have ')
Pg=3.1698 //Saturation pressure in kPa
hg=2546.5 //Specific enthalpy  in kJ/kg
x=0.75 //humidity
Pv=x*Pg //Vapour pressure in kPa
P=100 // Pressure of air in room in kPa
Pa=P-Pv //partial pressure of dry air
w=(0.622*Pv)/(P-Pv) //specific humidity of air
h=cp*T+w*hg //enthalpy of dry air per unit mass
Ra=0.287 //gas constant for dry air in kPa-m^3/kg-K
```

```
Rv=0.4615 //gas constant for water vapour in kPa-m
    ^3/kg-K
V=5*5*3 //volume of room in m^3
ma=(Pa*V)/(Ra*(T+273)) //mass of dry air
mv=(Pv*V)/(Rv*(T+273)) //mass of water vapour
printf("\n Hence, the partial pressure of dry air is
     = %.2f kPa. \n",Pa);
printf("\n The specific humidity is = %.4f . \n",w);
printf("\n The enthalpy per unit mass of dry air is
    = %.1f kJ/kg dry air. \n",h);
printf("\n The mass of dry air is = %.2f kg. \n",ma)
    ;
printf("\n The mass of water vapour is = %.2f kg. \n
    ",mv);
```

Scilab code Exa 14.2 Fogging of the windows in house

```
//example 2
// fogging of the windows in house
clear
clc
x=0.75 //relative humidity
P=2.3392 //saturation pressure of water at 20 C in
    kPa
Pv=x*P //Vapour pressure in kPa
disp('Saturation temp. of water at Pv=15.4 C.
    Therefore, ')
Tdp=15.4 //window temperature in Celsius
printf("\n Hence, window temperature at which
    moisture in the air start condensing on the inner
     surfaces of the windows is = %.1f C. \n",Tdp);
```

Scilab code Exa 14.3 The Specific and Relative Humidity of Air

```
//example 3
// The Specific and Relative Humidity of Air
clear
clc
disp('The saturation pressure of water is 1.7057 kPa
    at 15C, and 3.1698 kPa at 25 C')
T1=25 //dry bulb temperature in Celsius
T2=15 //wet bulb temperature in Celsius
hg1=2546.5 //in kJ/kg
hf2=62.9822 //in kJ/kg
cp=1.005 //Constant pressure specific heatof air at
   room temp. in  kJ/kg-K
hfg2=2465.4 //in kJ/kg
P2=101.325 // Atmospheric pressure in kPa
Pg2=1.7057 //Saturation pressure of water at 15C in
   kPa
w2=0.622*Pg2/(P2-Pg2) //kg water/kg dry air
w1=(cp*(T2-T1)+w2*hfg2)/(hg1-hf2) //specific
   humidity
Pg1=3.1698 //Saturation pressure of water at 25C in
   kPa
o1=w1*P2/((0.622+w1)*Pg1) //relative huumidity
h1=cp*T1+w1*hg1 //enthalpy of air per unit mass of
   dry air
printf("\n Hence, the specific humidity is = %.5f kg
    H2o/kg dry air. \n",w1);
printf("\n The relative humidity = %.3f . \n",o1);
printf("\n The Enthalpy of air per unit mass of dry
   air is = %.1f kJ/kg dry air. \n",h1);
```

Scilab code Exa 14.4 The Use of the Psychrometric Chart

```
//example 4
// The Use of the Psychrometric Chart
clear
```

```
clc
disp('At a given total pressure, the state of
   atmospheric air is completely specifiedby two
   independent properties such as the dry-bulb
   temperature and the relative humidity. Other
   properties are determined by directly reading
   their values at the specified state.')
disp('The specific humidity is determined by drawing
    a horizontal line from the specified state to
   the right until it intersects with the v axis')
v=0.0142 // in kg water/kg dry air
disp('The enthalpy of air per unit mass of dry air
   is determined by drawing a line parallel to the h
   =constant lines from the specific state until it
   intersects the enthalpy scale, giving')
h=71.5 // in kJ/kg dry air
disp('The wet-bulb temperature is determined by
   drawing a line parallel to the Twb=constant lines
    from the specified state until it intersects the
    saturation line, giving')
Twb=24 // in Celsius
disp('The dew-point temperature is determined by
   drawing a horizontal line from the specified
   state to the left until it intersects the
   saturation line, giving')
Tdp=19.4// in Celsius
disp('The specific volume per unit mass of dry air
   is determined by noting the distances between the
    specified state and the v=constant lines on both
    sides of the point. The specific volume is
   determined by visual interpolation to be')
v=0.893 // in m3/kg dry air
```

Scilab code Exa 14.5 Heating and Humidification of Air

```
//example 5
//Heating and Humidification of Air
clear
clc
disp('This is a steady-flow process and thus the mass flow rate of dry air remains constant during the entire process.We take the system to be the heating or the humidifying section,as appropriate.')
o1=0.3 //relative humidity
Psat=1.2281 //Saturation pressure of water in kPa at 10C
P1=100 //Pressure at which entire process takes in kPa
Pv1=0.3682 //Vapour pressure of water in kPa
Ra=0.287 // Gas constant for air in kPa-m3/kg-K
T1=10 // Temp. of outdoor air in K
Pa=P1-Pv1 // Pressure of dry air in kPa
V1=Ra*(T1+273)/Pa // specific volume of dry air in m^3/kg
v1=45 //steady intake of outdoor air in m^3/min
ma=v1/V1 //mass flow rate of dry air in kg/min
w1=0.622*Pv1/(P1-Pv1)//kg water/kg dry air
cp=1.005 //constant pressure specific heat in kJ/kg-C
hg1=2519.2 //in kJ/kg
T2=22 //temp. in celsius (given)
w2=w1
hg2=2541 //specific enthalpy of saturated water vaporin at 22 C in kJ/kg
h1=cp*T1+w1*hg1 //kJ/kg dry air
h2=cp*T2+w2*hg2 //kJ/kg dry air
qin=ma*(h2-h1) //rate of heat transfer to air in the heating section
x3=0.60 //relative humidity
Pg3=3.1698 //saturation pressure of water at 25C in kPa
P3=100 //pressure of entire process in kPa
```

```
w3=0.622*x3*Pg3/(P3-x3*Pg3)//kg water/kg dry air
mw=ma*(w3-w2) //required mass flow rate of the steam
    in the humidifying section in kg/min
printf("\n Hence, the rate of heat supply in the
   heating section is=%.0f kJ/min. \n",qin);
printf("\n The mass flow rate of the steam required
   in the humidifying section is=%.3f kg/min\n",mw);
```

Scilab code Exa 14.6 Cooling and Dehumidification of Air

```
//example 6
//Cooling and Dehumidification of Air
clear
clc
disp('This is a steady-flow process and thus the
   mass flow rate of dry air remains constant during
    the entire process')
h1=85.4 //Specific enthalpy for state 1 in kJ/kg dry
    air
w1=0.0216 //kg water/kg dry air
v1=0.889 //Specific volume for state 1 in m3/kg dry
   air
h2=39.3 // Specific enthalpy for state 2 in kJ/kg
   dry air
w2=0.0100 //kg water/kg dry air
V1=10 //volume flow rate of air in m^3/min
hw=58.8 //enthalpy of saturated liquid water at 14 C
    in kJ/kg
ma=V1/v1 //mass flow rate of dry air in kg/min
mw=ma*(w1-w2) //rate of moisture removal in m^3/min
qout=ma*(h1-h2)-mw*hw //rate of heat removal from
   air in kJ/min
printf("\n Hence, the rate of moisture removal from
   dry air is = %.3f kg/min. \n",mw);
printf("\n and rate of heat removal is = %.0f kJ/min
```

```
. \n",qout);
```

Scilab code Exa 14.8 Mixing of Conditioned Air with Outdoor Air

```
//example 8
//Mixing of Conditioned Air with Outdoor Air
clear
clc
disp('The properties of each inlet stream are
   determined from the psychrometric chart to be')
v2=0.889 //Specific volume of outside air in m3/kg
   dry air
w2=0.0182  //properties of stream 2 in kg water/kg
   dry air
h2=79.0 //Specific enthalpy of outside air in kJ/kg
   dry air
v1=0.826 //Specific volume of saturated air in m3/kg
    dry air
w1=0.010 //in kg water/kg dry air
h1=39.4 //Specific enthalpy for stream 1 in in kJ/kg
    dry air
V1=50 //flow rate of saturated air in m^3/min
V2=20 //flow rate for stream 2 in  m^3/min
ma1=V1/v1 //mass flow rate for stream 1 in kg/min
ma2=V2/v2 //mass flow rate for stream 2 in kg/min
ma3=ma1+ma2 //mass balance of air in kg/min
disp('using the expression ma1/ma2=(w2-w3)/(w3-w1)=(
   h2-h3)/(h3-h1)')
w3=0.0122 //kg water/kg dry air
h3=50.1 //kJ/kg dry air
disp('These two properties fix the state of the
   mixture. Other properties of the mixture are
   determined from the psychrometric chart:')
T3=19.0 //dry bulb temp. in C
x3=0.89//relative humidity of mixture
```

```
v3=0.844 //Specific volume of mixture in m3/kg
V3=ma3*v3 //volume flow rate of the mixture in m^3/min
printf("\n Hence, the specific humidity of the mixture is = %.4f kg H2o/kg dry air. \n",w3);
printf("\n The dry bulb temp.  is = %.1f C. \n",T3);
printf("\n The volume flow rate of the mixture is = %.1f kg H2o/kg dry air. \n",V3);
```

Scilab code Exa 14.9 Cooling of a Power Plant by a Cooling Tower

```
//example 9
//Cooling of a Power Plant by a Cooling Tower
clear
clc
h1=42.2 // Specific enthalpy of dry air in kJ/kg
w1=0.0087 //kg water/kg dry air
v1=0.842 //specific volume of dry air in m3/kg
h2=100.0 //Specific enthalpy of leaving air in kJ/kg
w2=0.0273 //kg water/kg dry air
h3=146.64 //Specific enthalpy of warm water in kJ/kg
h4=92.28 //Specific enthalpy of cool water in kJ/kg
M3=100 //mass flow rate of warm water in kg/s
Ma=M3*(h3-h4)/((h2-h1)-(w2-w1)*h4) //in m^3/s
V1=Ma*v1//volume flow rate of air into the cooling tower in m^3/s
Mmakeup=Ma*(w2-w1) //mass flow rate of required makeup water in kg/s
printf("\n Hence, the mass flow rate of required makeup water= %.2f kg /s. \n",V1);
printf("\n the volume flow rate of air into the cooling tower = %.2f m^3/s. \n",Mmakeup);
```

Chapter 15

Chemical Reactions

Scilab code Exa 15.1 Balancing the Combustion Equation

```
//example 1
//Balancing the Combustion Equation
clear
clc
Mair=28.97 //Molar mass of air in kg/kmol
x=8 //no. of moles of CO2 in products
y=9 //no. of moles of H2O in products
z=7.5 //no. of moles of O2 in products
w=75.2 // no. of moles of N2 in products
NMair=20*4.76*29 //mass of air in kg
NMc=8*12 //mass of carbon in fuel in kg
NMh2=2*9 //mass of hydrogen in fuel in kg
AF=NMair/(NMc+NMh2) //air fuel ratio in kg air/kg
    fuel
printf("\n Hence, the air fuel ratio for this
    combustion process is = %.1f kg air/kg fuel. \n",
    AF);
```

Scilab code Exa 15.2 Dew Point Temperature of Combustion Products

```
//example 2
//Dew-Point Temperature of Combustion Products
clear
clc
mair=4.2*4.76*29 //mass of air in kg
mfuel=2*12+3*2 //mass of fuel in kg
AF=mair/mfuel //air-fuel ratio
Nv=3 //no. of kmol of water vapour
Nprod=21.49 //No. of kmol of products
Pprod=100 //No. of kmol of products in kPa
Pv=Nv*Pprod/Nprod //Partial pressure of water vapour in kPa
disp('therefore,Dew point temp. of products = Saturation temp. at Pv')
Tdp=52.3//Dew point temp. of products in C
printf("\n Hence, the Air fuel ratio is = %.1f kg air/kg fuel. \n",AF);
printf("\n and dew point temp. of products is = %.1f C. \n",Tdp);
```

Scilab code Exa 15.3 Combustion of a Gaseous Fuel with Moist Air

```
//example 3
//Combustion of a Gaseous Fuel with Moist Air
clear
clc
x=0.75 //no. of moles of CO2 in the product
y=1.53 //no. of moles of H2O in the product
z=5.648 //no. of moles of N2 in the product
o=0.8 //relative humidity
Psat=2.3392 //Saturation pressure of water at 20C in kPa
Pvair=o*Psat //partial pressure of moisture in air
Ptotal=101.325 //Total pressure in kPa
Ndryair=6.97 //no.of kmol of dry air
```

```
Nvair=Pvair*Ndryair/(Ptotal*(1-Pvair/Ptotal)) //no.
    of moles of moisture in air
Ntotal=Nvair+Ndryair //total no.of kmol
Pprod=101.325 //Pressure of products in kPa
Nvprod=y+0.131 //no. of kmol of H2O in products
Nprod=x+z+Nvprod //no. of kmol of products
Pvprod=Nvprod*Pprod/Nprod //partial pressure of
    water vapour in the combustion gases
disp('The dew-point temperature of the products is
    equal the saturation temp. of water at P=Pvprod.
    Therefore,')
Tdp=60.9 //in C
printf("\n Hence, the dew point temp. of products is
     = %.1f C. \n",Tdp);
```

Scilab code Exa 15.4 Reverse Combustion Analysis

```
///example 4
//Reverse Combustion Analysis
clear
clc
a=22.20 //No. of kmol of dry air
x=1.36 //No. of kmol of octane
b=12.24 //No. of kmol of H2O
mair=16.32*4.76*29 //mass of air in kg
mfuel=8*12+9*2 //mass of fuel in kg
AF=mair/mfuel //air  fuel ratio kg air/kg fuel
mairact=4.76*16.32 //actual amount of air in kmol
mairth=12.50*4.76 //Theoretical amount of air mol
p=mairact/mairth //percentage of theoretical air
Pv=3.198 //Partial pressure of water vapour in kPa
Pprod=100 //Pressure of products in kPa
Nw=(900-82.53*Pv)/(Pprod-Pv) //no. of kmol of water
    vapour
printf("\n Hence, the Air fuel ratio is = %.2f kg
```

```
    air/kg fuel. \n",AF);
printf("\n The precentage of theoretical air used is
    = %.0f . \n",p*100);
printf("\n The amount of H2O that is condensed as
    products are cooled is=%.2f kmol. \n",Nw);
```

Scilab code Exa 15.5 Evaluation of the Enthalpy of Combustion

```
//example 5
//Evaluation of the Enthalpy of Combustion
clear
clc
hfCO2=-393520 //enthalpy of formation of CO2 in kJ/
    kmol
hfH2O=-285830 //enthalpy of formation of H2O in kJ/
    kmol
hfC8H18=-249950 //enthalpy of formation of octane in
     kJ/kmol
NCO2=8 //No. of kmol of CO2
NH2O=9 //No. of kmol of H2O
NC8H18=1 //No. of kmol of C8H18
hc=NCO2*hfCO2+NH2O*hfH2O-NC8H18*hfC8H18 //Enthalpy
    of combustion of octane in kJ/kmol
hc=hc/114 //enthalpy of combustion in kJ/kg
printf("\n Hence, the enthalpy of combustion of
    liquid octane is = %.0f kg air/kg C8H18. \n",hc);
```

Scilab code Exa 15.6 First Law Analysis of Steady Flow Combustion

```
//example 6
//First-Law Analysis of Steady-Flow Combustion
clear
clc
```

```
mair=7.5*4.76*29 //mass of air in kg
mfuel=3*12+4*2 //mass of fuel in kg
AF=mair/mfuel //air fuel ratio
Mfuel=0.05 //Mass flow rate of fuel in kg/min
Mair=AF*Mfuel //mass flow rate of air in kg/min
qout=1*(-118910)+7.5*(8150-8682)+28.2*(0+8141-8669)
   -2.7*(-393520+71078 -9364)
   -0.3*(-110530+47517-8669)-4*(-241820+57999-9904)
   -2.65*(0+49292-8682)-28.2*(0+47073-8669) //in kJ/
   kmol C3H8
disp('This heat is transferred from the combustion
   chamber for each kmol (44kg) of propane.therefore
    qout = qout/44 kJ/kg')
qout=qout/44 //in kJ/kg propane
M=0.05 //mass flow rate of liquid propane in kg/min
Qout=M*qout //rate of heat transfer in kJ/min
Qout=Qout/60 //rate of heat reansfer in kW
printf("\n Hence, the mass flow rate of air is = %.2
   f kg/min. \n",Mair);
printf("\n and the rate of heat transfer from
   combustion chamber is = %.2f kW. \n",Qout);
```

Scilab code Exa 15.7 First law anlysis of combustion in bomb

```
//example 7
//first law anlysis of combustion in bomb
clear
clc
Preact=1 //initial pressure in atm
Nreact=4 //Mo. of lbmol of reactants
Treact=537 //Temp. of reactants in R
Nprod=4 //No. of lbmol of products
Tprod=1800 //Temp. of products in R
Pprod=Preact*Nprod*Tprod/(Nreact*Treact) //final
   pressure of products in atm
```

```
Qout=1*(-32210-(1.986*537))+3*(0-1.986*537)
   -1*(-169300+18391.5-4027.5-(1.986*1800))
   -2*(-104040+15433.0-4258.0-(1.986*1800))
   -1*(0+13485.8-3725.1-(1.986*1800)) //Heat
   transfer during the process in Btu/lbmol CH4
printf("\n Hence, the final pressure in the tank is
   = %.2f atm. \n",Pprod);
printf("\n The heat transfer during the process is =
    %.0f Btu/lbmol CH4. \n",Qout);
```

Scilab code Exa 15.8 Adiabatic Flame Temperature in Steady Combustion

```
//example 8
//Adiabatic Flame Temperature in Steady Combustion
clear
clc
hfC8H18=-249950 //in kJ/kmol
hfO2=0 //in kJ/kmol
hO2=8682 //in kJ/kmol
hfN2=0 //in kJ/kmol
hN2=8669 //in kJ/kmol
hfH2O=-241820 //in kJ/kmol
hH2O=9904 //in kJ/kmol
hfCO2=-393520 //in kJ/kmol
hCO2=9364 //in kJ/kmol
Hprod=8*hfCO2+9*hfH2O+47*hfN2 //in kJ
Hmol=Hprod/(8+9+47) //enthalpy per mole
disp('This enthalpy value corresponds to about 2650
   K for N2, 2100 K for H2O, and 1800 K for CO2. But
    since, the majority of the moles are N2, we see
   that Tprod should be close to 2650 K, but
   somewhat under it.')
disp('For 2400 K, the value is higher than actual
   Hprod and for 2350 K, it is lower than that value
```

```
    .By interpolation , it comes out to be Tprod=2395
    K')
Tprod=2395 //in K
printf("\n Hence,The adiabatic flame temperature for
    complete combustion with 100 percent theoretical
    air is=%.0f K. \n",Tprod);
disp('Similarily , the adiabatic flame temperature
    for complete combustion with 400 percent
    theoretical air is 962 K and with 90% theoretical
    air is 2236 K.')
```

Scilab code Exa 15.9 Reversible work associated with combustion process

```
//example 9
//reversible work associated with combustion process
clear
clc
NCO2=1 //mass of CO2 in lbmol
gfCO2=-169680 //Enthalpy of formation for CO2 in Btu
    /lbmol
Wrev=-NCO2*gfCO2 //Reversible work for the given
    prcess in Btu
printf("\n Hence, the reversible work for this
    process is = %.0f Btu. \n",Wrev);
```

Scilab code Exa 15.11 Second law analysis of isothermal combustion

```
//example 11
//second law analysis of isothermal combustion
clear
clc
Pv=3.1698 //Partial pressure of water vapour in kPa
Ptotal=101.325 //Total pressure of products in kPa
```

```
x=Pv/Ptotal
Nv=x*13.28/(1-x) //amount of water vapour in kmol
Qout=1*(-74850)-1*(-393520)-0.43*(-241820)-1.57*(-285830) //Heat transfer per kmol of CH4
Sprod=2845.35 //Total entropy of products in kJ/kmol-K
Sreact=3023.69 //Total entropy of reactants in kJ/kmol-K
Tsurr=298 //Temperature of surroundings in K
Sgen=Sprod-Sreact+Qout/Tsurr //Entropy generation during the process in kJ/kmol-K CH4
To=298 //K
Xdestroyed=To*Sgen //exergy destruction in kJ/kmol CH4
Wrev=Xdestroyed //reversible work associated with the process
printf("\n The heat transfer per kmol of CH4 is = %.0f kJ/kmol CH4. \n",Qout);
printf("\n The Entropy generation is = %.0f kJ/kmol-K CH4. \n",Sgen);
printf("\n The Exergy destruction is = %.0f MJ/kmol CH4. \n",Xdestroyed/1000);
printf("\n The reversible work is = %.0f MJ/kmol CH4. \n",Wrev/1000);
```

Chapter 16

Chemical and Phase Equilibrium

Scilab code Exa 16.1 Equilibrium Constant of a Dissociation Process

```
//example 1
//Equilibrium Constant of a Dissociation Process
clear
clc
T=298.15 //Temp. in K
vn=2 //No. of moles of N in products
vn2=1 //No. of moles of N2 in reactants
gN2=0 //Molar gibbs function for N2
gN=455510 //Molar gibbs function for N in kJ/kmol
dG=vn*gN-vn2*gN2 //Change in Gibbs function of the
    mixture
Ru=8.314 //Universal Gas Constant in kJ/kmol-K
Kp=%e^(-dG/Ru*T) //Equilbrium Constant
printf("\n Hence, Equilbrium Constant is = %.0f . \n
    ",Kp);
```

Scilab code Exa 16.2 Dissociation Temperature of Hydrogen

```
//example 2
//Dissociation Temperature of Hydrogen
clear
clc
P=10 //given pressure in atm
Nh=0.2 //No.of kmol of atomic hydrogen produced in the reaction
Nh2=0.9 //No. of kmol of molecular hydrogen left as reactant
Ntotal=Nh+Nh2 //Total no. of kmol of reactant and products
vh=2 //From the stoichometry of the reaction
vh2=1 //From the stoichometry of the reaction
Kp=(Nh^vh/Nh2^vh2)*(P/Ntotal)^(vh-vh2) //Equilbrium constant
T=3535 //Temp. corresponding to evaluated value of Kp
printf("\n Hence,temperature at which 10 percent of diatomic hydrogen (H2) dissociates into monatomic hydrogen (H) is = %.0f K. \n",T);
```

Scilab code Exa 16.6 Enthalpy of Reaction of a Combustion Process

```
//example 6
//Enthalpy of Reaction of a Combustion Process
clear
clc
NH2O=1 //No. of kmol of water
NH2=1 //No. of kmol of Hydrogen
NO2=0.5 //No. of kmol of Oxygen
hfH2O=-241820 //standard heat of formation of liquid water from elemental reactants in kJ/kkmol
hH2O=82593 // in kJ/kmol
```

```
hoH2O=9904 //in kJ/kmol
hfH2=0 //standard heat of formation of H2
hH2=61400 //in kJ/kmol
hoH2=8468 //in kJ/kmol
hfO2=0 //standard heat of formation of O2
hO2=67881 //in kJ/kmol
hoO2=8682//in kJ/kmol
hr1=NH2O*(hfH2O+hH2O-hoH2O)-NH2*(hfH2+hH2-hoH2)-NO2*(hfO2+hO2-hoO2) //Enthalpy of reaction in kJ/kmol using enthalpy data
Ru=8.314 //Universal Gas Constant in kJ/kmol-K
T1=1800 //suitable temp. lower than and closest to 2000K in K
T2=2200 //suitable temp. higher than and closest to 2000K in K
Kp1=18509 //Equilbrium constant at T1
Kp2=869.6 //Equilbrium constant at T2
hr2=Ru*log(Kp2/Kp1)/((1/T1)-(1/T2)) //Enthalpy of reaction in kJ/kmol using Kp data
printf("\n Hence, Equilbrium Constant using Enthalpy data is = %.0f kJ/kmol. \n",hr1);
printf("\n Hence, Equilbrium Constant using Kp data is = %.0f kJ/kmol. \n",hr2);
```

Scilab code Exa 16.7 Phase Equilibrium for a Saturated Mixture

```
//example 7
//Phase Equilibrium for a Saturated Mixture
clear
clc
hf=503.81 // in kJ/kg,
sf=1.5279 // in kJ/kg-K
hg=2706.0 //in kJ/kg
sg=7.1292 //in kJ/kg-K
T=393.15 //Given temp. in K
```

```
gf=hf-T*sf //in kJ/kg
gg=hg-T*sg //in kJ/kg
disp('Since, two results are in close agreement, Therefore mixture of saturated liquid water and saturated water vapor at 120 C satisfies the criterion for phase equilibrium')
```

Scilab code Exa 16.8 Mole Fraction of Water Vapor Just over a Lake

```
//example 8
//Mole Fraction of Water Vapor Just over a Lake
clear
clc
Pv=1.7057 //the partial pressure of water vapor in the air at the lake surface in kPa
P=92 //atmospheric pressure at lake level in kPa
yv=Pv/P //The mole fraction of water vapor in the air at the surface of the lake
printf("\n Hence, The mole fraction of water vapor in the air at the surface of the lake is = %.2f percent. \n",yv*100);
disp('Water contains some dissolved air, but the amount is negligible. Therefore,we can assume the entire lake to be liquid water. So, mole fraction of water in lake is almost 1')
```

Scilab code Exa 16.9 The Amount of Dissolved Air in Water

```
//example 9
//The Amount of Dissolved Air in Water
clear
clc
Pv=1.96 //kPa
```

```
P=92 //atmospheric pressure at lakelevel
Pdryair=(P-Pv)/100 //pressure of dry air in bar
H=62000//Henrys constant for air dissolved in
    waterin bar
ydryair=Pdryair/H //mole fraction of air in the
    water
printf("\n Hence, the mole fraction of air at the
    surface of lake is = %.7f . \n",ydryair);
```

Scilab code Exa 16.10 Diffusion of Hydrogen Gas into a Nickel Plate

```
//example 10
//Diffusion of Hydrogen Gas into a Nickel Plate
clear
clc
s=0.00901 //solubility of hydrogen in nickel in kmol
    /m3-bar
PH2gas=3//Pressure of hydrogen in tank in bar
PH2solid=s*PH2gas //molar density of hydrogen in
    nickel plate in kmol/m^3
MH2=2 //molar mass of hydrogen kg/kmol
dH2solid=PH2solid*MH2 //mass density of hydrogen
printf("\n Hence, the molar density of hydrogen in
    Nickel plate when phase equilbrium is established
     is = %.3f kmol/m^3. \n",PH2solid);
printf("\n and mass density is = %.3f kg/m^3. \n",
    dH2solid);
```

Scilab code Exa 16.11 Composition of Different Phases of a Mixture

```
//example 11
//Composition of Different Phases of a Mixture
clear
```

```
clc
yH2Ol=0.3
yNH3l=0.7
PH2Osat=7.3851 //kPa
PNH3sat=1554.33 //kPa
PH2Og=yH2Ol*PH2Osat //vapour pressure of h2o
PNH3g=yNH3l*PNH3sat // vapour pressure of nh3
Ptotal=PH2Og+PNH3g
yH2Og=PH2Og/Ptotal //mole fraction of h2o in gas
    phase
yNH3=PNH3g/Ptotal //mole fraction of nh3 in gas
    phase
printf("\n The mole fraction of H2O in the mixture
    is = %.4f . \n",yH2Og);
printf("\n The mole fraction of NH3 in the mixture
    is = %.4f . \n",yNH3);
```

Chapter 17

Compressible Flow

Scilab code Exa 17.1 Compression of High Speed Air in an Aircraft

```
//ques1
//Compression of High-Speed Air in an Aircraft
clear
clc
//(a) the stagnation pressure at the compressor inlet (diffuser exit) can be determined from Eq. 17 5 in book
//state 1
T1=255.7;//Temperature in K
V1=250;//velocity in m/s
Cp=1.005;//specifc heat at const pressure in kJ/kg/K
T01=T1+V1^2/(2*Cp)/1000;//divide 1000 to convert it into K
//now from eqn 17-5
P1=54.05;//pressure in kPa

k=1.4;
P01=P1*(T01/T1)^(k/(k-1));
printf('(a) Pressure P01 = %.2f kPa \n',P01);

//(b) To determine the compressor work
```

```
r=8//P02/P01
T02=T01*r^(1-1/k);//Temperature in K
//Disregarding potential energy changes and heat
   transfer, the compressor work per unit mass of
   air is determined from Eq. 17 8
Win=Cp*(T02-T01);//Work input in kJ/kg
printf(' (b) Work input = %.1f kJ/kg \n',Win);
```

Scilab code Exa 17.2 Mach Number of Air Entering a Diffuser

```
//ques2
//Mach Number of Air Entering a Diffuser
clear
clc
//(a) The speed of sound in air at 30 C is
   determined as
k=1.4;
R=0.287;//gas constant
T=303;//air temperature in K
c=sqrt(k*R*T*1000);//speed of light in m/s
printf('(a) speed = %.0f m/s \n',c);
//(b) Mach Mumber
V=200;//speed in m/s
Ma=V/c;
printf(' (b) Mach number = %.3f ',Ma);
```

Scilab code Exa 17.3 Gas Flow through a Converging Diverging Duct

```
//ques3
//Gas Flow through a Converging Diverging Duct
clear
clc
```

```
Cp=0.846;//specific heat at constant pressure in kJ/
    kg/K
R=0.1889;//gas constant for substance
T0=473;//temp at state 0 in K
T1=T0;//temp at state 1 in K
P0=1400;//pressure at state 0 in kPa
P1=P0;//pressure at state 1 in kPa
//from Eqn 17-5
P=1200;//pressure in kPa
k=1.289;
T=T0*(P/P0)^(1-1/k);//Temp in K
//from Eqn 17-4
T=457;//K
V=sqrt(2*Cp*(T0-T)*1000);//velocity in m/s
printf('Velocity = %.1f m/s \n',V);
//From the ideal-gas relation,
d=P/(R*T);
printf(' Density = %.1f kg/m^3 \n',d);
//From the mass flow rate relation,
ms=3;//mass flow in kg/s
A=ms/(d*V);//area in m^2
printf(' Area = %.1f cm^2 \n',A*10000);
//speed
k=1.289;
c=sqrt(k*R*T*1000);//speed in m/s
Ma=V/c;
printf(' Mach number  = %.3f  ',Ma);
```

Scilab code Exa 17.4 Critical Temperature and Pressure in Gas Flow

```
//ques4
//Critical Temperature and Pressure in Gas Flow
clear
clc
k=1.289;
```

```
T0=473;//Temp at in K
Tx=T0*2/(k+1);//Temp in K
P0=1400//pressure in kPa
Px=P0*(2/(k+1))^(k/(k-1));//Pressure in kPa
printf('T* = %.0f K \n',Tx);
printf(' P* = %.0f kPa \n',Px);
```

Scilab code Exa 17.5 Effect of Back Pressure on Mass Flow Rate

```
//ques5
//Effect of Back Pressure on Mass Flow Rate
clear
clc
T=873;//Temperature in K
V=150;//velocity in m/s
Cp=1.005;//specific heat at constant pressure in kJ/
    kg.K
T0=T+V^2/(2*Cp)/1000;//Temperaure in K
P=1;//pressure in MPa
k=1.4;
P0=P*(T0/T)^(k/(k-1));//pressure in MPa
//The critical-pressure ratio is determined from
    Table 17 2 (or Eq. 17 22) to be P*/P=0.5283
Pb=0.7;//back pressure in MPa
Rbw=Pb/P0;//back pressure ratio
//which is greater than the critical-pressure ratio,
    0.5283. Thus the exit plane pressure (or throat
    pressure P) is equal to the back pressure in this
    case
//From Table A 32 Pt/P0=0.670 and Tt/T0=0.892
T0=884;//Temperature in K
Tt=0.892*T0;//Temp in K
Pt=700;//kPa
R=0.287;
dt=Pt/(R*Tt);//density in kg/m^3
```

```
Ma=0.778;//Mach no
k=1.4;
Vt=Ma*sqrt(k*R*Tt*1000);//Velocity in m/s
At=50*10^-4;;//area in m^2
ms=dt*At*Vt;
printf('(a) Mass flow rate = %.2f kg/s \n',ms);
//(b)
Pb=400;//kPa
P0=1045;//kPa
Rbp=Pb/P0;//The back pressure ratio
ms=At*P0*sqrt(k/(R*T0)*1000)*((2/(k+1))^((k+1)/(2*(k
    -1))));//multiply by 1000 to convert it into kg/s
printf(' (b) Mass flow rate = %.2f kg/s \n',ms);
```

Scilab code Exa 17.7 Airflow through a Converging Diverging Nozzle

```
//ques7
//Airflow through a Converging Diverging Nozzle
clc
P0=1000;//pressure in kPa
R=0.287;
T0=800;//Temperature in K
d0=P0/(R*T0);//density in kg/m^3
//(a) At the throat of the nozzle Ma = 1, and from
    Table A 32
//throat conditions
Px=P0*0.5283;//pressure in kPa
Tx=T0*0.8333;//temperature in K
dx=d0*0.6339;//density in kg/m^3
printf('(a) P* = %.4f kPa \n',Px);
printf('     T* = %.1f K \n',Tx);
printf('     d* = %.3f kg/m^3 \n',dx);
k=1.4;
Vx=sqrt(k*R*Tx*1000);
printf('     V* = %.1f m/s \n',Vx);
```

```
//Since the flow is isentropic, the properties at
   the exit plane can also be calculated by using
   data from Table A32. For Ma = 2
Pe=0.1278*P0;//MPa
Te=0.5556*T0;//K
de=0.23*d0;//density in kg/m^3
Ax=20;//cm^2
Ae=1.6875*Ax;//cm^2
Mae=2;
Maex=1.633;
Ve=Maex*Vx;//m/s
printf(' (b) Pe = %.4f kPa \n',Pe);
printf('     Te = %.1f K \n',Te);
printf('     de = %.3f kg/m^3 \n',de);
printf('     Ae = %.2f cm^2 \n',Ae);
printf('     Ve = %.1f m/s \n',Ve);

//(c)
ms=dx*Ax*Vx*10^-4;
printf(' (c) Mass flow rate = %.2f kg/s \n',ms);
```

Scilab code Exa 17.9 Shock Wave in a Converging Diverging Nozzle

```
//ex9
//Shock Wave in a Converging Diverging Nozzle
clear
clc
//fluid property at exi nozzle
P01=1;//pressure in MPa
P1=0.1278;//pressure in MPa
T1=444.5;//temperature in K
d1=1.002;//density in Kg/m^3
//The fluid properties after the shock (denoted by
   subscript 2) are related to those before the
   shock through the functions listed in Table A33
```

```
Ma1=2;
Ma2=0.5774;
P02=0.7209*P01;//stagnation pressure in MPa
P2=4.5*P1;//Static Pressure in MPa
T2=1.6875*T1;//Static Pressure in K
d2=2.6667*d1;//Static Pressure n kg/m^3

printf('(a) Stagnation pressure = %.0f MPa \n',P02);
printf('     Static PRessure = %.4f MPa \n',P2);
printf('     Static Temperature = %.1f K \n',T2);
printf('     static density = %.2f kg/m^3 \n',d2);
//(b)
R=0.287;
Cp=1.005;//specific heat at constant pressure in kJ/
    kg.K
S=Cp*log(T2/T1)-R*log(P2/P1);//entropy change in kJ/
    kg.K
printf(' (b) The entropy change across the shock = %
    .4f kJ/kg.K \n',S);
//(c)
k=1.4;
V2=Ma2*sqrt(k*R*T2*1000);
printf(' (c) Air velocity,V2 = %.0f m/s \n',V2);
ms=2.86;//same as previous example
printf(' (d) Mass Flow rate  = %.2f kg/sec \n',ms);
```

Scilab code Exa 17.16 Steam Flow through a Converging Diverging Nozzle

```
//ques16
//Steam Flow through a Converging Diverging Nozzle
clear
clc
P01=2;//inlet stagnation pressure in MPa
Pt=0.546*P01;//throat pressure in MPa
```

```
//at inlet
P1=2;//inlet pressure in MPa
T1=400;//Inlet Temp in C
T01=T1;//stagnation temp in K
//from tables
h1=3248.4;//enthalpy in kJ/kg
h01=h1;//stagnation enthalpy in kJ/kg
s1=7.1292;//entropy in kJ/kg.K
st=s1;//stagnation in kJ/kg.K
s2s=s1;//entropy at state 2s n kJ/kg.K
//Also, at the throat
Pt=1.09;//pressure in MPa
st=7.1292;//entropy in kJ/kg.K
//from tables
ht=3076.8;//enthalpy in kJ/kg
vt=0.24196;//m^3/kg
//now throat velocity is determined as
Vt=sqrt(2*(h01-ht)*1000);//throat velocity
//The flow area at the throat is determined from the
    mass flow rate relation
ms=2.5;//mass flow rate in kg/s
At=ms*vt/Vt;//area in m^2
printf('(a) Flow area at throat = %.2f cm^2 \n',At
   *10000);
//At state 2s,
P2s=300;//presure in kPa
P2=P2s;//kPa
//from table
h2s=2783.6;//enthalpy at state 2s in kJ/kg
//from the enthalpy of the steam at the actual exit
   state is (see Chap. 7) formulae
n=0.93;
h2=h01-n*(h01-h2s);//enthalpy at state 2 in kJ/kg
//now from table
v2=0.67723;//m^3/kg
s2=7.2019;//entropy in kJ/kg.K
// the exit velocity and the exit area
V2=sqrt(2*(h01-h2)*1000);//Exit velocity in m^2
```

```
A2=(ms*v2)/V2;
printf('      Exit area = %.2f cm^2 \n',A2*10000);
//(b)
//c=(dP/d(1/v))^(1/2)
//The velocity of sound at the throat is determined by evaluating the specific volume at St = 7.1292 kJ/kg  K and at pressures of 1.115 and 1.065 MPa
Pa=1115;//kPa
Pb=1065;//kPa
va=0.23776;//m^3/kg
vb=0.24633;//m^3/kg
c=sqrt((Pa-Pb)/(1/va-1/vb)*1000);//velocity of sound at throat
V=585.8;//velocity in m/s
Ma=V/c;
printf(' (b) Mach number at the throat = %.3f \n',Ma);
//The velocity of sound and the Mach number at the nozzle exit are determined by evaluating the specific volume at St= 7.2019 kJ/kg  K and at pressures of 325 and 275 kPa
Pa=325;//kPa
Pb=275;//kPa
va=0.63596;//m^3/kg
vb=0.72245;//m^3/kg
c=sqrt((Pa-Pb)/(1/va-1/vb)*1000);
V=929.8;//Velocity
Ma=V/c;
printf('      Mach number at nozel exit = %.3f ',Ma);
```