Scilab Textbook Companion for Fundamentals Of Thermodynamics by B. Claus And R. E. Sonntag[1]

Created by
Kush Garg
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 2

Control Volumes and Units

Scilab code Exa 2.1 Weight of a person

```
//example 1
//weight of a person
clear
clc
m=1 //kg
g=9.75 //acc.due to gravity in m/s^2
F=m*g //weight of 1 kg mass in N
printf("\n hence,weight of person is F = %.3f N. \n"
    ,F)
```

Scilab code Exa 2.2 Average Volume and Density

```
//example 2
//average volume and density
clear
clc
Vliq=0.2 //volume of liquid in m^3
dliq=997 //density of liquid in kg/m^3
```

```
Vstone=0.12 //volume of stone in m^3
Vsand=0.15 //volume of sand in m^3
Vair=0.53 //vo;ume of air in m^3
mliq=Vliq*dliq //mass of liquid in kg
dstone=2750 //density of stone in kg/m^3
dsand=1500 //density of sand in kg/m^3
mstone=Vstone*dstone //volume of stone in m^3
msand=Vsand*dsand //volume of sand in m^3
Vtot=1 //total volume in m^3
dair=1.1 //density of air in kg/m^3
mair=Vair*dair //mass of air
mtot=mair+msand+mliq+mstone //total mass in kg
v=Vtot/mtot //specific volume in  m^3/kg
d=1/v //overall density in kg/m^3
printf("\n hence,average specific volume is v=%.6f
  m^3/kg. \n",v )
printf("\n and overall density is d=%.0f kg/m^3. \n"
  ,d)
```

Scilab code Exa 2.3 Calculating the required force

```
//example 3
//calculating the required force
clear
clc
Dcyl=0.1 //cylinder diameter in m
Drod=0.01 //rod diameter in m
Acyl=%pi*Dcyl^2/4 //cross sectional area of cylinder
   in m^2
Arod=%pi*Drod^2/4 //cross sectional area of rod in m
  ^2
Pcyl=250000 //inside hydaulic pressure in Pa
Po=101000 //outside atmospheric pressure in kPa
g=9.81 //acc. due to gravity in m/s^2
mp=25 //mass of (rod+piston) in kg
```

```
F=Pcyl*Acyl-Po*(Acyl-Arod)-mp*g //the force that rod
    can push within the upward direction in N
printf("\n hence,the force that rod can push within
    the upward direction is F = %.3f N. \n",F)
```

Scilab code Exa 2.4 Calculating atmospheric pressure

```
//example 4
//Calculating atmospheric pressure
clear
clc
dm=13534 //density of mercury in kg/m^3
H=0.750 //height difference between two columns in
    metres
g=9.80665 //acc. due to gravity  in m/s^2
Patm=dm*H*g/1000 //atmospheric pressure in kPa
printf("\n hence, atmospheric pressure is Patm = %.2
    f kPa. \n",Patm)
```

Scilab code Exa 2.5 Pressure inside vessel

```
//example 5
//pressure inside vessel
clear
clc
dm=13590 //density of mercury in kg/m^3
H=0.24 //height difference between two columns in
    metres
g=9.80665 //acc. due to gravity  in m/s^2
dP=dm*H*g //pressure difference in Pa
Patm=13590*0.750*9.80665 //Atmospheric Pressure in
    Pa
```

```
Pvessel=dP+Patm //Absolute Pressure inside vessel in
    Pa
Pvessel=Pvessel/101325//Absolute Pressure inside
   vessel in atm
printf("\n hence, the absolute pressure inside
   vessel is Pvessel = %.3f atm. \n",Pvessel)
```

Scilab code Exa 2.6 Calculating Pressure

```
//example 6
//calculating pressure
clear
clc
dg=750 //density of gaasoline in kg/m^3
dR=1206 //density of R-134a in kg/m^3
H=7.5 //height of storage tank in metres
g=9.807 //acc. due to gravity in m/s^2
dP1=dg*g*H/1000 //in kPa
Ptop1=101 //atmospheric pressure in kPa
P1=dP1+Ptop1
disp('hence,pressure at the bottom of storage tank
   if fluid is gasoline is 156.2 kPa')
dP2=dR*g*H/1000 //in kPa
Ptop2=1000 //top surface pressure in kPa
P2=dP2+Ptop2
printf("\n hence, pressure at the bottom of storage
   tank if liquid is R-134a is P2 = %.0f kPa. \n",P2
   )
```

Scilab code Exa 2.7 Calculating Balancing Force

```
//example 6
//calculating balancing force
```

```
clear
clc
Po=100//Outside atmospheric pressure in kPa
F1=25 //net force on the smallest piston in kN
A1=0.01 //cross sectional area of lower piston in m^2
P1=Po+F1/A1 //fluid pressure in kPa
d=900 //density of fluid in kg/m^3
g=9.81 //acc. due to gravity in m/s^2
H=6 //height of second piston in comparison to first one in m
P2=P1-d*g*H/1000 //pressure at higher elevation on piston 2 in kPa
A2=0.05 // cross sectional area of higher piston in m^3
F2=(P2-Po)*A2 //balancing force on second piston in kN
printf("\n hence, balancing force on second larger piston is F2 = %.1f N. \n",F2)
```

Chapter 3

Pure Substance Behaviour

Scilab code Exa 3.1 `Determining the phase of water`

```
//example 1
//determinig the phase of water
clear
clc
disp('from the table,we find that at 120C,saturation
    pressure of water is 198.5 kPa.But here we have
   pressure of 500 kPa.hence,water exists as a
   compressed liquid here.')
disp('also at 120C,vf=0.00106 kg/m^3 and vg=0.89186
   kg/m^3.given v=0.5 m^3/kg i.e. vf<v<vg,so we have
    two phase mixture of liquid and vapor.')
```

Scilab code Exa 3.2 `Determining the phase of Ammonia`

```
//example 2
//determinig the phase
clear
clc
```

```
disp('from the table,we find that at 30C,saturation
   pressure of ammonia is 1167 kPa.But here we have
   pressure of 1000 kPa.hence,ammonia exists in
   superheated vapor state.')
disp('for R-22 at 200 kPa,vg=0.1119 kg/m^3.given v
   =0.15 m^3/kg i.e. v>vg,so the state is
   superheated vapor')
```

Scilab code Exa 3.3 Determining the quality and specific volume

```
//example 3
//determining the quality and specific volume
clear
clc
v1=0.5 //given specific volume in m^3/kg
vf=0.001073 //specific volume when only liquid phase
    is present in m^3/kg
vfg=0.60475 //in m^3/kg
disp('For water at a pressure of 300 kPa,the state
   at which v1 is 0.5 m^3/kg is seen to be in the
   liquid-vapor two-phase region,at which T=133.6 C
   and the quality x is ')
x=(v1-vf)/vfg //quality
v2=1 //given specific volume in m^3/kg
disp('By comparing with the values given in the
   table,this state is seen to be in the superheated
    vapor region.temperature will be calculated
   using the method of interplotation.')
T=((400-300)*(1.0-0.8753))/(1.0315-0.8753)+300 //
   temperature of the water
```

Scilab code Exa 3.4 Percentage of vapor

```
 //example 4
//percentage of vapor
clear
clc
vliq=0.1 //volume of saturated liquid in m^3
vf=0.000843 //in m^3/kg
vvap=0.9 //volume of saturated vapor R-134a in
   equilbrium
vg=0.02671 //in m^3/kg
mliq=vliq/vf //mass of liquid in kg
mvap=vvap/vg //mass of vapor in kg
m=mliq+mvap //total mass in kg
x=mvap/m //percentage of vapor on mass basis
disp('hence,% vapor on mass basis is 22.1')
```

Scilab code Exa 3.5 `Calculating pressure after heat addition`

```
//example 5
//calculating pressure after heat addition
clear
clc
v1=0.14922 //specific volume of sautrated ammonia in
    m^3/kg
disp('Since the volume does not change during the
   process,the specific volume remains constant.
   therefore, ')
v2=v1 //in m^3/kg
disp('Since vg at 40C is less than v2,it is evident
   that in the final state the Ammonia is
   superheated vapor.By interplotation,we find that
   ')
P2=945 //final pressure in kPa
disp('hence,the final pressure is 945 kPa')
```

Scilab code Exa 3.6 Determinig the missing property

```
//example 6
//Determinig the missing property
clear
clc
T1=273-53.2 //given temperature in K
P1=600 //given pressure in kPa
disp('This temperature is higher than the critical
   temperature (critical temp. at P=600 kPa) is
   96.37 K.Hence,v=0.10788 m^3/kg')
T2=100 //given temp. in K
v2=0.008 //given specific volume in m^3/kg
vf=0.001452 //in m^3/kg
vg=0.0312 //in m^3/kg
Psat=779.2 //saturation pressure in kPa
vfg=vg-vf //in m^3/kg
x=(v2-vf)/vfg //quality
printf("\n hence, the pressure is Psat = %.1f kPa. \
   n",Psat)
printf("\n and quality is x = %.4f . \n",x)
```

Scilab code Exa 3.7 Determining the pressure of water

```
//example 7
//determining the pressure of water
clear
clc
vg=0.12736 //specific volume in m^3/kg for water at
   200C
v=0.4 //specific volume in m^3/kg
P1=500 //in kPa
```

```
v1=0.42492 //specific volume at P1 in m^3/kg
P2=600 //in kPa
v2=0.35202 //specific volume at P2 in m^3/kg
P=P1+(P2-P1)*(v-v1)/(v2-v1) //calculating pressure
   by interplotation
disp('hence,the pressure of water is 534.2 kPa')
```

Scilab code Exa 3.8 Calculating mass of air

```
//example 8
//calculating mass of air
clear
clc
P=100 //pressure in kPa
V=6*10*4 //volume of room in m^3
R=0.287 //in kN-m/kg-K
T=25 //temperature in Celsius
m=P*V/(R*(T+273.2)) //mass of air contained in room
printf("\n hence, mass of air contained in room is m
    = %.3f kg. \n",m)
```

Scilab code Exa 3.9 Calculating pressure inside tank

```
//example 9
//calculating pressure inside tank
clear
clc
V=0.5 //volumr of tank in m^3
m=10 //mass of ideal gas in kg
T=25 //temperature of tank in Celsius
M=24 //molecular mass of gas in kg/kmol
Ru=8.3145 //universal gas constant in kN-m/kmol-K
```

```
R=Ru/M //gas constant for given ideal gas in kN-m/kg
   -K
P=m*R*(T+273.2)/V //pressure inside tank
printf("\n hence,pressure inside tank is P = %.0f
   kPa. \n",P)
```

Scilab code Exa 3.10 Mass flow rate

```
//example 10
//mass  flow rate
clear
clc
dt=185 //time period in seconds over which there is
   incrrease in volume
dV=0.75 //increase in volume in 0.75 in m^3
V=dV/dt //volume flow rate in m^3/s
P=105 //pressure inside gas bell kPa
T=21 //temperature in celsius
R=0.1889 //ideal gas constant in kJ/kg-K
m=P*V/(R*(T+273.15)) //mass flow rate of the flow in
    kg/s
printf("\n hence,mass flow rate is m = %.3f kg/s. \n
   ",m)
printf("\n and volume flow rate is V = %.3f m^3/s. \
   n",V)
```

Scilab code Exa 3.11 Predicting the nature of given state

```
//example 11
//predicting the nature of given state
clear
clc
```

```
disp('For Nitrogn, the critical properties are 126.2 K, 3.39 MPa. Given T=20+273.2 K, P=1.0 MPa. Since, given temperature is more than twice Tc and the reduced pressure is less than 0.3, ideal gas behaviour is a very good assumption.')
disp('For Carbon Dioxide, the critical properties are 304.1 K,7.38 MPa.Given T=20+273.2 K, P=1.0 MPa Therefore, reduced properties are 0.96(T/Tc) and 0.136 (P/Pc). CO2 is a gas with a Z of about 0.95, os the ideal gas is accurate to within about 5% in this case.')
disp('Given P=1.0MPa, T=20+273.2 K. For Ammonia, at T=293.2 K, Pg=858 kPa. Since, P>Pg, this state is compressible liquid and not a gas.')
```

Scilab code Exa 3.12 Determining specific using diffenet laws

```
//example 12
//determining specific using diffenet laws
clear
clc
T=100 //given temp.in 100 celsius
P=3 //given pressure in MPa
v1=0.0065 //specific volume in m^3/kg using table
printf("\n hence,the specific volume for R-134a using R-134a tables is v1 = %.3f m^3/kg. \n",v1)
M=102.3 //molecular mass in kg
R=8.3145 //in kJ/K
Ru=R/M //in kJ/K-kg
v2=Ru*(T+273)/(P*1000) //specific volume assuming R-134a to be ideal gas in m^3/kg
printf("\n hence,the specific volume for R-134a using R-134a the ideal gas laws is v2 = %.3f m^3/kg. \n",v2)
Tr=373.2/374.2 //reduced temperature using
```

```
generalized chart
Pr=3/4.06 //reduced pressure using generalized chart
Z=0.67 //compressibility factor
v3=Z*v2 // specific volume using generalized chart
    in m^3/kg
printf("\n hence,the specific volume for R-134a
    using the generalized chart is v3 = %.3f m^3/kg.
    \n",v3)
```

Scilab code Exa 3.13 Calculating mass of gas

```
//example 13
//calculating mass of gas
clear
clc
Pc=4250 //critical pressure of propane in kPa
Tc=369.8 //critical temperature in K
T=15 //temperature of propane in celsius
Tr=T/Tc //reduced temperature
Prsat=0.2 // reduced pressure
P=Prsat*Pc //pressure in kPa
x=0.1 //given quality
Zf=0.035 //from graph
Zg=0.83 //from graph
Z=(1-x)*Zf+x*Zg //overall compressibility factor
V=0.1 //volume of steel bottle in m^3
R=0.1887 //in kPa-m^3/kg-K
m=P*V/(Z*R*(T+273)) //total propane mass in kg
printf("\n hence,the total propane mass is m = %.3f
    kg. \n",m)
printf("\n and pressure is P = %.3f kPa. \n",P)
```

Chapter 4

Energy Transfers

Scilab code Exa 4.1 Work done during different processes

```
//example 1
//work done during different processes
clear
clc
P1=200 //initial pressure inside cylinder in kPa
V2=0.1 //in m^3
V1=0.04 //initial volume of gas in m^3
W1=P1*(V2-V1) //work done in isobaric process in kJ
printf("\n hence,the work done during the isobaric
    process is W1 = %.3f kJ. \n",W1)
W2=P1*V1*log(V2/V1) //work done in isothermal
    process in kJ
printf("\n hence,the work done in isothermal process
     is W2 = %.3f kJ. \n",W2)
P2=P1*(V1/V2)^(1.3) //final pressure according to
    the given process
W3=(P2*V2-P1*V1)/(1-1.3)
printf("\n hence,the work done during the described
    process is W3 = %.3f kJ. \n",W3)
W4=0 //work done in isovolumic process
printf("\n hence,the work done in the isovolumic
```

```
    process is W4 = %.3f kJ. \n",W4)
```

Scilab code Exa 4.3 work produced

```
//example 3
//work produced
clear
clc
Psat=190.2 //in kPa
P1=Psat //saturation pressure in state 1
vf=0.001504 //in m^3/kg
vfg=0.62184 //in m^3/kg
x1=0.25 //quality
v1=vf+x1*vfg //specific volume at state 1 in m^3/kg
v2=1.41*v1 //specific volume at state 2 in m^3/kg
P2=600 //pressure in state 2 in kPa
m=0.5 //mass of ammonia in kg
W=m*(P1+P2)*(v2-v1)/2 //woork produced by ammonia in
    kJ
disp('hence,work produced by ammonia is 12.71 kJ')
```

Scilab code Exa 4.4 Calculating work done

```
//example 4
//calculating work done
clear
clc
v1=0.35411 //specific volume at state 1 in m^3/kg
v2=v1/2
m=0.1 //mass of water in kg
P1=1000 //pressure inside cylinder in kPa
W=m*P1*(v2-v1) //in kJ
```

```
disp('hence,the work in the overall process is -17.7 kJ')
```

Scilab code Exa 4.7 Heat transfer

```
//example 7
//heat transfer
clear
clc
k=1.4 //conductivity of glass pane in W/m-K
A=0.5 //total surface area of glass pane
dx=0.005 //thickness of glasspane in m
dT1=20-12.1 //temperature difference between room air and outer glass surface temperature in celsius
Q=-k*A*dT1/dx //conduction through glass slab in W
h=100 //convective heat transfer coefficient in W/m^2-K
dT=12.1-(-10)  //temperature difference between warm room and colder ambient in celsius
Q2=h*A*dT //heat transfer in convective layer in W
printf("\n hence,the rate of heat transfer in the glass and convective layer is Q2 = %.0f kW. \n",Q2)
```

Chapter 5

Energy Equation for a Control Mass

Scilab code Exa 5.1 Calculating height

```
//example 1
//calculating height
clear
clc
m=1100 //mass of car in kg
ke=400 //kinetic energy of car in kJ
V=(2*ke*1000/m)^0.5 //velocity of car in m/s
g=9.807 //acc. due to gravity in m/s^2
H=ke*1000/(m*g) //height to which the car  should be
     lifted so that its potential energy equals its
    kinetic energy
disp('hence,the car should be raised to a height of
    37.1 m to make its potential energy equal to
    kinetic energy')
```

Scilab code Exa 5.2 Change in internal energy

```
//example 2
//change in internal energy
clear
clc
W=-5090 //work input to paddle wheel in kJ
Q=-1500 //heat transfer from tank in kJ
dU=Q-W //change in internal energy in kJ
disp('hence,change in internal energy is 3590 kJ')
```

Scilab code Exa 5.3 `Analysis of energy transfer`

```
//example 3
//analysis of energy transfer
clear
clc
g=9.806 //acceleration due to gravity in m/s^2
m=10 //mass of stone in kg
H1=10.2 //initial height of stone above water in metres
H2=0 //final height in metres
dKE1=-m*g*(H2-H1) //change in kinetic energy when stone enters state 2 in J
dPE1=-1 //change in potential energy when stone enters state 2 in J
printf("\n hence,when stone is about to enter state 2, dKE = %.3f J. \n",dKE1)
printf("\n and dPE = %.3f J. \n",dPE1)
dPE2=0 //change in potential energy when stone enters state 3 in JQ2=0 //no heat transfer when stone enters state 3 in J
W2=0 //no work done when stone enters state 3 in J
dKE2=-1 //change in kinetic energy when stone enters state 3
dU2=-dKE2 //change in internal energy when stone enters state 3 in J
```

```
printf("\n hence,when stone has just come to rest in
    the bucket i.e. state 3, W=0, dPE=0, dKE1 = %.3f
    J. \n",dKE2)
printf("\n and dU = %.3f J. \n",dU2)
dKE3=0 //change in kinetic energy when stone enters
   state 4
dPE=0 //change in potential energy when stone enters
    state 4 in J
W3=0 //no work done when stone enters state 4 in J
dU3=-1 //change in internal energy when stone enters
    state 4 in J
Q3=dU3 //heat transfer when stone enters state 4 in
   J
printf("\n hence,when stone has entered state 4, dPE
   =0, W3=0,dKE=0, dU= %.3f J. \n",dU3)
printf("\n and Q3= %.3f J. \n",Q3)
```

Scilab code Exa 5.4 Determinig the missing properties

```
//example 4
//Determinig the missing properties
clear
clc
T1=300 //given temp. in Celsius
u1=2780 //given specific internal enrgy in kJ/kg
disp('From steam table, at T=300 C,ug=2563.0 kJ/kg.
   So,u1>ug ,it means the state is in the
   superheated vapor region.So, by interplotation,we
    find P=1648 kPa and v=0.1542 m^3/kg')
P2=2000 //hiven pressure in kPa
u2=2000 //given specific intrernal energy in kJ/kg
disp('at P=2000 kPa,')
uf=906.4 //in kJ/kg
ug=2600.3 //in kJ/kg
x2=(u2-906.4)/(ug-uf)
```

```
disp('Also, under the given conditions')
vf=0.001177 //in m^3/kg
vg=0.099627 //in m^3/kg
v2=vf+x2*(vg-vf)//Specific volume for water in m^3/
    kg
printf("\n hence,specific volume for water is v2 = %
    .5f m^3/kg. \n",v2)
printf("\n Therefore ,this state is in the two phase
     region with quality x2=%.4f . \n",x2)
```

Scilab code Exa 5.5 Calculating heat transfer for the given process

```
//example 5
//calculating heat transfer for the given process
clear
clc
Vliq=0.05 //volume of saturated liquid in m^3
vf=0.001043 //in m^3/kg
Vvap=4.95 //volume of saturated water vapour in m^3
vg=1.6940 //in m^3/kg
m1liq=Vliq/vf //mass of liquid in kg
m1vap=Vvap/vg //mass of vapors in kg
u1liq=417.36 //specific internal energy of liquid in
     kJ/kg
u1vap=2506.1 //specific internal energy of vapors in
     kJ/kg
U1=m1liq*u1liq+m1vap*u1vap //total internal energy
    in kJ
m=m1liq+m1vap //total mass in kg
V=5 //total volume in m^3
v2=V/m //final specific volume in m^3/kg
disp('by interplotation we find that for steam, if
    vg=0.09831 m^3/kg then pressure is 2.03 MPa')
u2=2600.5 //specific internal energy at final state
    in kJ/kg
```

```
U2=m*u2 //internal energy at final state in kJ
Q=U2-U1 //heat transfer for the process in kJ
printf("\n hence,heat transfer for the process is Q
    = %.0f kJ. \n",Q)
```

Scilab code Exa 5.6 Calculating work and heat transfer for the process

```
//example 6
//calculating work and heat transfer for the process
clear
clc
V1=0.1 //volume of cylinder in m^3
m=0.5 //mass of steam in kg
v1=V1/m //specific volume of steam in m^3/kg
vf=0.001084 //m^3/kg
vfg=0.4614 //m^3/kg
x1=(v1-vf)/vfg //quality
hf=604.74 //kJ/kg
hfg=2133.8//kJ/kg
h2=3066.8 //final specific heat enthalpy in kJ/kg
h1=hf+x1*hfg //initial specific enthalpy in kJ/kg
Q=m*(h2-h1) //heat transfer for this process in kJ
P=400 //pressure inside cylinder in kPa
v2=0.6548 //specific enthalpy in m^3/kg
W=m*P*(v2-v1) //work done for the process in kJ
printf("\n hence, work done for the process, W = %.3
    f kJ. \n",W)
printf("\n and heat transfer, Q=%.3f kJ.\n",Q)
```

Scilab code Exa 5.8 Calculating change in enthalpy

```
//example 8
//calculating change in enthalpy
```

```
clear
clc
h1=273.2 //specific heat enthalpy for oxygen at 300
   K
h2=1540.2 //specific heat enthalpy for oxygen at
   1500 K
T1=300 //initial temperature in K
T2=1500 //final temparature in K
x=poly([0],'x');
Cp=0.88-0.00001*x+0.54*x^2-0.33*x^3 //expression for
    constant pressure specific heat enthalpy for
   oxygen
dh1=h2-h1 //this change in specific heat enthalpy is
    calculated using ideal gas tables
dh2=1000*integrate('0.88-0.00001*x+0.54*x^2-0.33*x^3
   ','x',T1/1000,T2/1000) //using empirical equation
dh3=0.922*(T2-T1) //it is claculated if we assume
   specific heat enthalpy to be constant and uses
   its value at 300K
dh4=1.0767*(T2-T1) //it is claculated if we assume
   specific heat enthalpy to be constant and uses
   its value at 900K i.e mean of initial and final
   temperature
printf("\n Hence,change in specific heat enthalpy if
    ideal gas tables are used is dh1=%.1f kJ/kg. \n"
   , dh1)
printf("\n if empirical equations are used, dh2=%.1f
    kJ/kg. \n", dh2)
printf("\n if specific heat is assumed to be
   constant and using its value at T1, dh3=%.1f kJ/
   kg. \n", dh3)
printf("\n if specific heat is assumed to be
   constant at its value at (T1+T2)/2, dh4=%.1f kJ/
   kg. \n", dh4)
```

Scilab code Exa 5.9 Determining amount of heat transfer

```
//example 9
//determining amount of heat transfer
clear
clc
P=150 //pressure of nitrogen in cylinder in kPa
V=0.1 //initial volume of cylinder in m^3
T1=25 //initial temperature of nitrogen in celsius
T2=150 //final tempareture of nitrogen in celsius
R=0.2968 //in kJ/kg-K
m=P*V/(R*(T1+273)) //mass of nitrogen in kg
Cv=0.745 //constant volume specific heat for
    nitrogen in kJ/kg-K
W=-20 //work done on nitrogen gas in kJ
Q=m*Cv*(T2-T1)+W //heat transfer during the process
    in kJ
printf("\n hence,the heat transfer for the above
    process is Q=%.1f kJ. \n", Q)
```

Scilab code Exa 5.10 Calculating rate of increase of internal energy

```
//example 10
//calculating rate of increase of internal energy
clear
clc
W=-12.8*20 //power consumed in  J/s
Q=-10 //heat transfer rate from battery in J/s
r=Q-W //rate of increase of internal energy
printf("\n hence,the rate of increase of internal
    energy is r=%.0f J/s. \n", r)
```

Scilab code Exa 5.11 Rate of change of temperature

```
//example 11
//rate of change of temperature
clear
clc
Q=1500 //power produced by burning wood in J/s
mair=1 //mass of air in kg
mwood=5 //mass of soft pine wood in kg
miron=25 //mass of cast iron in kg
Cvair=0.717 //constant volume specific heat for air
    in kJ/kg
Cwood=1.38 //constant volume specific heat for wood
    in kJ/kg
Ciron=0.42 //constant volume specific heat for iron
    in kJ/kg
dT=75-20 //increase in temperature in Celsius
T=(Q/1000)/(mair*Cvair+mwood*Cwood+miron*Ciron) //
    rate of change of temperature in K/s
dt=(dT/T)/60 //in minutes
printf(" hence,the rate of change of temperature is
    dt=%.4f K/s.\n", T)
printf(" and time taken to reach a temperature of T=
    %.0f min.\n", dt)
```

Chapter 6

Energy Equation for a Control Volume

Scilab code Exa 6.1 Calculating mass flow rate

```
//example 1
//calculating mass flow rate in kg/s
clear
clc
R=0.287 //in kJ/kg-K
T=25 //temperature in celsius
P=150 //pressure in kPa
v=R*(T+273.2)/P //specific volume in m^3/kg
D=0.2 //diameter of pipe in metre
A=%pi*D^2/4 //cross sectional area in m^2
V=0.1 //velocity of air in m/s
m=V*A/v //mass flow rate in kg/s
printf("\n hence,the mass flow rate is m=%.4f kg/s.\
   n",m)
```

Scilab code Exa 6.2 Work done for adding the fluid

```
//example 2
//work done for adding the fluid
clear
clc
P=600 //pressure in kPa
m=1 //in kg
v=0.001 //specific volume in m^3/kg
W=P*m*v //necessary work in kJ for adding the fluid
printf(" \n hence,the work involved in this process
   is W=%.3f kJ. \n",W)
```

Scilab code Exa 6.3 Rate of flow of water

```
//example 3
//rate of flow of water
clear
clc
hir=441.89 //in kJ/kg for refrigerant using steam
   table
her=249.10 //in kJ/kg for refrigerant using steam
   table
hiw=42 //in kJ/kg for water using steam table
hew=83.95 //in kJ/kg for water using steam table
mr=0.2 //the rate at which refrigerant enters the
   condenser in kg/s
mw=mr*(hir-her)/(hew-hiw) //rate of flow of water in
    kg/s
printf("\n hence,the rate at which cooling water
   flows thorugh the condenser is mw=%.3f kg/s. \n",
    mw)
```

Scilab code Exa 6.4 Determining quality of steam

```
//example 4
//determining quality of steam
clear
clc
hi=2850.1 //initial specific heat enthalpy for steam in kJ/kg
Vi=50 //initial velocity of steam in m/s
Ve=600 //final velocity of steam in m/s
he=hi+Vi^2/(2*1000)-Ve^2/(2*1000) //final specific heat enthalpy for steam in kJ/kg
hf=467.1 //at final state in kJ/kg
hfg=2226.5 //at final state in kJ/kg
xe=(he-hf)/hfg //quality of steam in final state
printf(" \n hence, the quality is xe=%.3f. \n",xe)
```

Scilab code Exa 6.5 `Quality of ammonia leaving expansion valve`

```
//example 5
//quality of ammonia leaving expansion valve
clear
clc
hi=346.8 //specific heat enthalpy for ammonia at initial state in kJ/kg
he=hi //specific heat enthalpy for ammonia at final state will be equal that at initial state because it is a throttling process
hf=134.4 //at final state in kJ/kg
hfg=1296.4//at final state in kJ/kg
xe=(he-hf)/hfg //quality at final state
printf("\n hence,quality of the ammonia leaving the expansion valve is xe=%.4f. \n",xe')
```

Scilab code Exa 6.6 `Power output of turbine in kW`

```
//example 6
//power output of turbine in kW
clear
clc
hi=3137 //initial specific heat of enthalpy in kJ/kg
he=2675.5 //final specific heat of enthalpy in kJ/kg
Vi=50 //initial velocity of steam in m/s
Ve=100 //final velocity of steam in m/s
Zi=6 //height of inlet conditions in metres
Ze=3 //height of exit conditions in metres
m=1.5 //mass flow rate of steam in kg/s
g=9.8066 //acc. due to gravity in m/s^2
Qcv=-8.5 //heat transfer rate from turbine in kW
Wcv=Qcv+m*(hi+Vi^2/(2*1000)+g*Zi/1000)-m*(he+Ve
    ^2/(2*1000)+g*Ze/1000) //power output of turbine
    in kW
printf("\n hence,the power output of the turbine is
    Wcv=%.3f kW. \n",Wcv)
```

Scilab code Exa 6.7 `Heat transfer rate in aftercooler`

```
//example 7
//heat transfer rate in aftercooler
clear
clc
V1=0 //we assume initial velocity to be zero because
     its given that it enters with a low velocity
V2=25 //final velocity with which carbon dioxide
    exits in m/s
h2=401.52 //final specific enthalpy of heat when
    carbon dioxide exits in kJ/kg
h1=198 //initial specific enthalpy of heat in kJ/kg
w=h1-h2-V2^2/(2*1000) //in kJ/kg
Wc=-50 //power input to the compressor in kW
m=Wc/w //mass flow rate of carbon dioxide in kg/s
```

```
h3=257.9 //final specific enthalpy of heat when
    carbon dioxide flows into a constant pressure
    aftercooler
Qcool=-m*(h3-h2) //heat transfer rate in the
    aftercooler in kW
printf(" \n hence,heat transfer rate in the
    aftercooler is Qcool=%.3f kW. \n",Qcool)
```

Scilab code Exa 6.8 Required Pump work

```
//example 8
//Required pump work
clear
clc
m=1.5 //mass flow rate of water in kg/s
g=9.807 //acceleration due to gravity in m/s^2
Zin=-15 //depth of water pump in well in metres
Zex=0 //in metres
v=0.001001 //specific volume in m^3/kg
Pex=400+101.3 //exit pressure in kPa
Pin=90 //in kPa
W=m*(g*(Zin-Zex)*0.001-(Pex-Pin)*v) //power input in
    kW
printf(" \n Hence, the pump requires power input of
    W=%.0f W. \n",W*1000)
```

Scilab code Exa 6.9 Heat tranfer in simple steam power plant

```
//example 9
//heat tranfer in simple steam power plant
clear
clc
```

```
h1=3023.5 //specific heat of enthalpy of steam
    leaving boiler in kJ/kg
h2=3002.5 //specific heat of enthalpy of steam
    entering turbine in kJ/kg
x=0.9 //quality of steam entering condenser
hf=226 //in kJ/kg
hfg=2373.1 //in kJ/kg
h3=hf+x*hfg //specific heat of enthalpy of steam
    entering condenser in kJ/kg
h4=188.5 //specific heat of enthalpy of steam
    entering pump in kJ/kg
q12=h2-h1 //heat transfer in line between boiler and
     turbine in kJ/kg
w23=h2-h3 //turbine work in kJ/kg
q34=h4-h3 //heat transfer in condenser
w45=-4 //pump work in kJ/kg
h5=h4-w45 //in kJ/kg
q51=h1-h5 //heat transfer in boiler in kJ/kg
printf("\n hence, heat transfer in line between
    boiler and turbine is q12=%.1f kJ/kg. \n",q12')
printf("\n hence, turbine work is w23=%.1f kJ/kg. \n
    ",w23')
printf("\n hence, heat transfer in condenser is q34=
    %.1f kJ/kg. \n",q34')
printf("\n hence, heat transfer in boiler is q51=%.0
    f kJ/kg. \n",q51')
```

Scilab code Exa 6.10 `Analysis of refrigerator`

```
//example 10
//analysis of refrigerator
clear
clc
hf4=167.4 //in kJ/kg
hfg4=215.6 //in kJ/kg
```

```
h3=241.8 //specific heat of enthalpy of R-134a
   entering expansion valve
h4=h3 //specific heat of enthalpy of R-134a leaving
   expansion valve
h1=387.2 //in kJ/kg
h2=435.1 //in kJ/kg
x4=(h3-hf4)/hfg4 //quality of R-134a at evaporator
   inlet
m=0.1 //mass flow rate in kg/s
Qevap=m*(h1-h4) //rate of heat transfer to the
   evaporator
Wcomp=-5 //power input to compressor in kW
Qcomp=m*(h2-h1)+Wcomp //rate of heat transfer from
   compressor
printf("\n hence, the quality at the evaporator
   inlet is x4=%.3f. \n",x4')
printf("\n hence, the rate of heat transfer to the
   evaporator is Qevap=%.2f kW. \n",Qevap')
printf("\n hence, rate of heat transfer from the
   compressor is Qcomp=%.2f kW. \n",Qcomp')
```

Scilab code Exa 6.11 Determining the final temperature of steam

```
//example 11
//Determining the final temperature of steam
clear
clc
u2=3040.4 //final internal energy in kJ/kg
hi=u2 //in kJ/kg
P2=1.4 //final Pressure in MPa
disp('Since, the final pressure is given as 1.4 MPa,
   we know two properties at the final state and
   hence,final state can be determined.The
   temperature corresponding to a pressure of 1.4
   MPa and an internal energy of 3040.4 kJ/kg is
```

```
    found to be ')
T2=452 //final temperature in Celsius
```

Scilab code Exa 6.12 `Calculating mass flow of steam in tank`

```
//example 12
//Calculating mass flow of steam in tank
clear
clc
V1=0.4 //initial volume fo tank in m^3
v1=0.5243 //initial specific volume in m^3/kg
h1=3040.4 //initial specific enthalpy in kJ/kg
u1=2548.9 //initial specific internal energy in kJ/
    kg
m1=V1/v1 //initial mass of steam in tank in kg
V2=0.4 //final volume in m^3
disp('let x=V*(h1-u2)/v2-m1*(h1-u1).If we assume T2
    =300C, then v2=0.1823m^3/kg ,u2=2785.2kJ/kg and x
    =+ve.If we assume T2=350C,then v2=0.2003 m^3/kg,
    u2=2869.1kJ/kg and x=-ve.Hence,actualt T2 must be
     between these two assumed values in order that x
    =0.By interplotation ,')
T2=342 //final temperature in Celsius
v2=0.1974 //final specific volume in m^3/kg
m2=V2/v2 //final mass of the steam in the tank in kg
m=m2-m1 //mass of steam that flowsinto the tank
printf(" \n Hence,mass of the steam that flows into
    the tank is m=%.3f kg. \n",m)
```

Scilab code Exa 6.13 `Calculating mass flow of steam in tank`

```
//example 13
//Calculating mass flow of steam in tank
```

```
clear
clc
vf1=0.001725 //in m^3/kg
vf2=0.0016 //in m^3/kg
uf1=368.7 //in kJ/kg
uf2=226 //in kJ/kg
vg1=0.08313 //in m^3/kg
vfg2=0.20381
ug1=1341 //in kJ/kg
ufg2=1099.7 //in kJ/kg
Vf=1 //initial volume of liquid in m^3
Vg=1 //initial volume of vapor in m^3
mf1=Vf/vf1 //initial mass of liquid in kg
mg1=Vg/vg1 //initial mass of vapor in kg
m1=mf1+mg1 //initial mass of liquid in kg
he=1461.1 //in kJ/kg
V=2 //volume of tank in m^3
disp('m1u1=mf1*uf1+mg1*ug1.If x2 is the quality,then
    m2=V/v2=2/(0.00160+0.20381*x2) and u2=uf2+x2*
    ufg2=226.0+1099.7*x2.')
disp('Also,m2*(he-u2)=m1*he-m1u1.From this equation,
    we will get an equation for x2.')
x2=((2*1461.1)-(2*226)-(0.00160*634706))
    /((634706*0.20381)+(2*1099.7)) //quality of
    ammonia
v2=0.00160+(0.20381*x2) //final specific volume in m
    ^3/kg
m2=V/v2 //final mass of ammonia in kg
m=m1-m2 //mass of ammonia withdrawn
printf("\n Hence,mass of ammonia withdrawn is m=%.1
    f kg. \n",m)
```

Chapter 7

The Classical Second Law of Thermodynamics

Scilab code Exa 7.1 Rate of fuel consumption

```
//example 1
//rate of fuel consumption
clear
clc
W=136*0.7355 //output of automobile engine in kW
neng=0.3 //thermal efficiency of automobile engine
Qh=W/neng //energy output of fuel in kW
Ql=Qh-W //total rate of energy rejected to the
    ambient
qh=35000 //energy output of fuel in kJ/kg
m=Qh/qh //rate of fuel consumption in kg/s
printf("\n hence,total rate of energy rejected is Ql
    =%.0f kW.\n",Ql)
printf("\n and rate of fuel consumption is m=%.4f kg
    /s.\n",m)
```

Scilab code Exa 7.2 Coefficient of performance of refrigerator

```
//example 2
//coefficient of performance of refrigerator
clear
clc
Qh=400 //heat rejected to kitchen air in W
W=150 //electrical input power in W
Ql=Qh-W //rate of energy taken out to cold space in
   W
B=Ql/W //coefficicent of performnace of refrigerator
printf("\n hence,rate of energy taken out of the
   cold space is Ql=%.3f W.\n",Ql)
printf("\n and coefficient of performance of the
   refrigerator is B=%.3f .\n",B)
```

Scilab code Exa 7.4 Comparison of ideal carnot heat engine with actual heat engine

```
//example 4
//comparison of ideal carnot heat engine with actual
    heat engine
clear
clc
Qh=1000 //rate of heat transfer to heat engine in kW
W=450 //rate of production of work in kW
Ql=Qh-W //rate of heat rejected by heat engine in kW
nthermal=W/Qh //efficiency from the definition of
   efficiency
Tl=300 //temperature of surroundings in K
Th=550 //temperature of heat source in Celsius
ncarnot=1-Tl/(Th+273) //efficiency if heat engine is
    considered to be ideal carnot heat engine
W2=ncarnot*Qh //rate of work production if heat
   engine is assumed to be ideal carnot heat engine
   in kW
```

```
Ql2=Qh-W2 //rate of heat rejected by heat engine in
   kW if heat engine is assumed to be ideal carnot
   heat engine
printf("\n hence,energy discarded to the ambient
   surroundings is Ql2=%.0fkW.\n",Ql2)
printf("\n and the engine efficiency is ncarnot=%.3f
   .\n",ncarnot)
```

Scilab code Exa 7.5 Calculating required work

```
//example 5
//calculating required work
clear
clc
Tl=24+273 //room temperature in Kelvins
Th=35+273 //atmospheric temperature in Kelvins
Ql=4 //rate of heat rejection from room
B=Tl/(Th-Tl) //coefficient of performance of air
   conditioner
W=Ql/B //required work in kW
printf("\n hence,the magnitude of reqiured work is W
   =%.2f kW.\n",W)
```

Chapter 8

Entropy for a Control Mass

Scilab code Exa 8.1 Coefficient of performance of refrigerator

```
//example 1
//coefficient of performance of refrigerator
clear
clc
Th=60 //temperature at which heat is rejected from R
    -134a
Tl=0 //temperature at which heat is absorbed into
    the R-134a
s1=1.7262 //specific entropy at 0 Celsius
s2=s1 //process of state change from 1-2 is
    isentropic
s3=1.2857 //specific entropy at 60 celsius
s4=s3 //process of state change from 3-4 is
    isentropic
disp('if Pressure is 1400 kPa,then s=1.7360 kJ/kg-K
    and if P=1600 kPa,then s=1.7135 kJ/kg-K.Therefore
    ')
P2=1400+(1600-1400)*(1.7262-1.736)/(1.7135-1.736) //
    pressure after compression in kPa
B=(Th+273)/(Th-Tl) //coefficient of performance of
    refrigerator
```

```
printf(" \n hence,pressure after compression is P2=%.3f kPa.\n",P2)
printf("\n and coefficient of performance of refrigerator is B=%.3f .\n",B)
```

Scilab code Exa 8.2 Heat transfer in a given process

```
//example 2
//heat transfer in a given process
clear
clc
u1=87.94 //specific internal energy of R-12 at state 1 in kJ/kg
u2=276.44 //specific internal energy of R-12 at state 2 in kJ/kg
s1=0.3357 //specific entropy at state 1 in kJ/kg-K
s2=1.2108 //specific entropy at state 2 in kJ/kg-K
V=0.001 //volume of saturated liquid in m^3
v1=0.000923 //specific volume in m^3/kg
m=V/v1 //mass of saturated liquid in kg
T=20 //temperature of liquid in celsius
Q12=m*(T+273.15)*(s2-s1) //heat transfer in kJ to accomplish the process
W12=m*(u1-u2)+Q12 //work required to accomplish the process
printf(" \n hence,work required to accomplish the process is W12=%.1f kJ.\n",W12)
printf(" \n and heat transfer is Q12=%.1f kJ.\n",Q12)
```

Scilab code Exa 8.3 Entropy change

```
//example 3
```

```
//entropy change
clear
clc
C=4.184 // specific heat of water in kJ/kg-K
T1=20 //initial temperature of water in celsius
T2=90 //final temperature of water in celsius
dS1=C*log((T2+273.2)/(T1+273.2)) //change in entropy
    in kJ/kg-K
dS2=1.1925-0.2966 //in kJ/kg-K using steam tables
printf("\n hence,change in entropy assuming constant
    specific heat is dS1=%.4f kJ/kg-K.\n",dS1)
printf("\n using steam table is dS2=%.4f kJ/kg-K.\n"
   ,dS2)
```

Scilab code Exa 8.4 Entropy change with different assumptions

```
//example 4
//entropy change with different assumptions
clear
clc
T1=300 //initial temperature in kelvins
T2=1500 //final temperature in kelvins
P1=200 //initial pressure in kPa
P2=150 //final pressure in kPa
R=0.2598 // in kJ/kg-K
Cp=0.922 //specific heat in kJ/kg-K at constant
   pressure
dsT2=8.0649 //in kJ/kg-K
dsT1=6.4168 //in kJ/kg-K
dS1=dsT2-dsT1-R*log(P2/P1) //entropy change
   calculated using ideal gas tables
dS2=integrate('0.88/x-0.0001+0.54*x-0.33*x^2','x'
   ,0.3,1.5)-R*log(P2/P1) //entropy change
   calculated using empirical equation
dS3=Cp*log(T2/T1)-R*log(P2/P1) //entropy change
```

```
    assuming constant specific heat in kJ/kg-K
dS4=1.0767*log(T2/T1)+0.0747 //entropy change
    assuming specific heat is constant at its value
    at 990K
printf("\n hence,change in entropy using ideal gas
    tables is dS1=%.4f kJ/kg-K.\n",dS1)
printf("\n hence,change in entropy using empirical
    equation is dS2=%.4f kJ/kg-K.\n",dS2)
printf("\n hence,change in entropy using the value
    of specific heat at 300K is dS3=%.4f kJ/kg-K.\n",
    dS3)
printf("\n hence,change in entropy assuming specific
     heat is constant at its value at 900K is dS4=%.4
    f kJ/kg-K.\n",dS4)
```

Scilab code Exa 8.5 Entropy change

```
//example 5
//entropy change
clear
clc
Cp=1.004 //specific heat at constant pressure in kJ/
    kg-K
R=0.287 //gas constant in kJ/kg-K
P1=400 //initial pressure in kPa
P2=300 //final pressure in kPa
T1=300 //initial temperature in K
T2=600 //final temperature in K
dS1=Cp*log(T2/T1)-R*log(P2/P1) //entropy change
    assuming constant specific heat
s1=6.8693 //specific entropy at T1
s2=7.5764 //specific entropy at T2
dS2=s2-s1-R*log(P2/P1) //entropy change assuming
    variable specific heat
printf("\n hence,entropy change assuming constant
```

```
specific heat is dS1=%.4f kJ/kg-K.\n",dS1)
printf("\n and assuming variable specific heat is dS2=%.4f kJ/kg-K.\n",dS2)
```

Scilab code Exa 8.6 `Work done by air`

```
//example 6
//work done by air
clear
clc
T1=600 //initial temperature of air in K
P1=400 //intial pressure of air in kPa
P2=150 //final pressure in kPa
u1=435.10 //specific internal energy at temperature T1 in kJ/kg
sT1=7.5764 //specific entropy at temperature T1 in kJ/kg-K
R=0.287 //gas constant in kJ/kg-K
ds=0
sT2=ds+sT1+R*log(P2/P1) //specific entropy at temperature T2 in kJ/kg-K
disp('we know the values of s and P for state 2.So, in order to fully determine the state,we will use steam table')
T2=457 //final temperature in K
u2=328.14 //specific internal energy at temperature T2 in kJ/kg
w=u1-u2 //work done by air in kJ/kg
printf("\n hence,work done by air is w=%.2f kJ/kg.\n",w)
```

Scilab code Exa 8.7 `Work and heat transfer`

```
//example 7
//work and heat transfer
clear
clc
P2=500  //final pressure in cylinder in kPa
P1=100 //initial pressure in cylinder in kPa
T1=20+273.2 //initial temperature inside cylinder in
    Kelvins
n=1.3
T2=(T1)*(P2/P1)^((n-1)/n) //final temperature inside
    cylinder in K
R=0.2968 //gas constant in kJ/kg-K
w12=R*(T2-T1)/(1-n) //work in kJ/kg
Cvo=0.745 //specific heat at constant volume in kJ/
   kg-K
q12=Cvo*(T2-T1)+w12 //heat transfer in kJ/kg
printf(" \n hence,work done is w12=%.1f kJ/kg.\n",
   w12)
printf("\n and heat transfer are q12=%.1f kJ/kg.\n",
   q12)
```

Scilab code Exa 8.8 Calculating increase in entropy

```
//example 3
//calculating increase in entropy
clear
clc
m=1 //mass of saturated water vapour
sfg=6.0480 //in kJ/K
T=25 //temperature of surrounding air in celsius
dScm=-m*sfg //change in entropy of control mass in
   kJ/K
hfg=2257.0 //in kJ/kg
Qtosurroundings=m*hfg //heat transferred to
   surroundings in kJ
```

```
dSsurroundings=Qtosurroundings/(T+273.15) //in kJ/K
dSnet=dScm+dSsurroundings //net increase in entropy
    in kJ/K
printf(" hence,net increase in entropy of water plus
     surroundings is dSnet=%.4f kJ/K.\n",dSnet)
```

Scilab code Exa 8.9 Entropy generation

```
//example 9
//entropy generation
clear
clc
Qout=1 //value of heat flux generated by 1kW of
    electric power
T=600 //temperature of hot wire surface in K
Sgen=Qout/T //entropy generation in kW/K
printf(" \n hence,entropy generation is Sgen=%.5f kW
    /K.\n",Sgen)
```

Scilab code Exa 8.10 Determiining the entropy generated

```
//example 10
//Determiining the entropy generated
clear
clc
B=4 //COP of air conditioner
W=10 //power input of air conditioner in kW
Qh=B*W //in kW
Ql=Qh-W //in kW
Thigh=323 //in Kelvin
Tlow=263 //in Kelvin
SgenHP=(Qh*1000/Thigh)-(Ql*1000/Tlow) //in W/K
Tl=281 // in K
```

```
Th=294 //in K
SgenCV1=Ql*1000/Tlow-Ql*1000/Tl //in W/K
SgenCV2=Qh*1000/Th-Qh*1000/Thigh //in W/K
SgenTOT=SgenCV1+SgenCV2+SgenHP //in W/K
printf(" \n Hence,Total entropy generated is SgenTOT
   =%.1f W/K. \n",SgenTOT)
```

Chapter 9

Entropy Equation for a Control Volume

Scilab code Exa 9.1 Entropy generation

```
//example 1
//work done by steam
clear
clc
hi=3051.2 //initial specific heat of enthalpy of
   steam in kJ/kg
si=7.1228 //initial specific entropy of steam in kJ/
   kg-K
Pe=0.15 //final pressure in MPa
se=si //specific entropy in final state in kJ/kg-K
sf=1.4335 //in kJ/kg-K
sfg=5.7897 //in kJ/kg-K
vi=50 //velocity with which steam enters turbine in
   m/s
ve=200 //velocity with which steam leaves the
   turbine in m/s
xe=(se-sf)/sfg //quality of steam in final state
hf=467.1 //in kJ/kg
hfg=2226.5 //in kJ/kg
```

```
he=hf+xe*hfg //final specific heat of enthalpy of
    steam in kJ/kg
w=hi+vi^2/(2*1000)-he-ve^2/(2*1000) //work of steam
    for isentropic process in kJ/kg
printf("\n hence, work per kilogram of steam for
    this isentropic process is w=%.1f kJ/kg-K.\n",w)
```

Scilab code Exa 9.2 Exit velocity of steam from nozzle

```
//example 2
//exit velocity of steam from nozzle
clear
clc
hi=3051.2 //initial specific heat of enthalpy in kJ/
    kg
si=7.1228 //initial specific entropy in kJ/kg-K
se=si //final specific entropy
Pe=0.3 //final pressure in MPa
disp('from steam table,various properties at final
    state are ')
he=2780.2 //final specific heat of enthalpy in kJ/kg
    -K
Te=159.1 //final temperature in celsius
vi=30 //velocity with which steam enters the nozzle
    in m/s
ve=((2*(hi-he)+(vi^2/1000))*1000)^0.5 //final
    velocity of steam with which it exits in m/s
printf("\n hence,exit velocity of the steam from the
     nozzle is ve=%.0f m/s.\n",ve)
```

Scilab code Exa 9.3 Violation of second law

```
//example 3
```

```
//violation of second law
clear
clc
disp('from R-134a tables')
se=1.7148 //specific entropy in final state in kJ/kg
   -K
si=1.7395 //initial specific entropy in kJ/kg-K
disp('therefore,se<si,whereas for this process the
   second law requires that se>=si.The process
   described involves a violation of the second law
   and thus would be impossible.')
```

Scilab code Exa 9.4 Calculating required specific work

```
//example 4
//calculating required specific work
clear
clc
Cp=1.004 //specific heat of air at constant pressure
    in kJ/kg-K
Ti=290 //initial temperature in kelvins
Pi=100 //initial pressure in kPa
Pe=1000 //final pressure in kPa
k=1.4
Te=Ti*(Pe/Pi)^((k-1)/k) //final temperature in
   kelvins
we=Cp*(Ti-Te) //required specific work in kJ/kg
printf("\n hence,specific work required is we=%.3f
   kJ/kg.\n",we)
```

Scilab code Exa 9.5 Entropy generation

```
//example 5
```

```
//entropy generation
clear
clc
h1=2865.54 //specific heat of enthalpy at state 1 in kJ/kg
h2=83.94 //specific heat of enthalpy  at state 2 in kJ/kg
h3=2725.3 //specific heat of enthalpy at state 3 in kJ?kg
s1=7.3115 //specific entropy at state 1 in kJ/kg-K
s2=0.2966 //specific entropy at state 2 in kJ/kg-K
s3=6.9918 //specific entropy at state 3in kJ/kg-K
m1=2 //mass flow rate at state 1 in kg/s
m2=m1*(h1-h3)/(h3-h2) //mass flow rate at state 2 in kg/s
m3=m1+m2 //mass flow rate at state 3 in kg/s
Sgen=m3*s3-m1*s1-m2*s2 //entropy generation in the process
printf("\n hence,entropy generated in this process is Sgen=%.3f kW/K.\n",Sgen)
```

Scilab code Exa 9.6 `Work required to fill the tank`

```
//example 6
//work required to fill the tank
clear
clc
T1=17+273 //initial temperature of tank in Kelvins
sT1=6.83521 //specific entropy in kJ/kg-K
R=0.287 //gas constant in kJ/kg-K
P1=100 //initial pressure in kPa
P2=1000 //final pressure in kPa
sT2=sT1+R*log(P2/P1) //specific entropy at temperature T2 in kJ/kg-K
T2=555.7 //from interplotation
```

```
V1=0.04 //volume of tank in m^3
V2=V1 //final volume is equal to initial volume
m1=P1*V1/(R*T1) //initial mass of air in tank in kg
m2=P2*V2/(R*T2) //final mass of air in tank in kg
Min=m2-m1 //in kg
u1=207.19 //initial specific heat of enthalpy in kJ/
    kg
u2=401.49 //final specific heat of enthalpy in kJ/kg
hin=290.43 //in kJ/kg
W12=Min*hin+m1*u1-m2*u2 //work required to fill the
    tank in kJ
printf("\n hence,the total amount of work required
    to fill the tank is W12=%.1f m/s.\n",W12)
```

Scilab code Exa 9.7 Work required to pump water isentropically

```
//example 7
//work required to pump water isentropically
clear
clc
P1=100 //initial pressure in kPa
P2=5000 //final pressure in kPa
v=0.001004 //specific volume in m^3/kg
w=v*(P2-P1) //work required to pump water
    isentropically
printf("\n hence,work required to pump water
    isentropically  is w=%.2f kJ/kg.\n",w)
```

Scilab code Exa 9.8 Velocity in exit flow

```
//example 8
//Velocity in exit flow
clear
```

```
clc
disp('From Steam Tables, for liquid water at 20 C')
vf=0.001002 //in m^3/kg
v=vf
Pi=300 //Line pressure in kPa
Po=100 //in kPa
Ve=(2*v*(Pi-Po)*1000)^0.5 //velocity in the exit
    flow
printf(" \n Hence, an ideal nozzle can generate upto
     Ve=%.0f m/s in the exit flow. \n",Ve)
```

Scilab code Exa 9.9 Rate of Entropy Generation

```
//example 9
//Rate of Entropy Generation
clear
clc
disp('From R-410a tables,we get')
hi=280.6 //in kJ/kg
he=307.8 //in kJ/kg
si=1.0272 //in kJ/kg
se=1.0140 //in kJ/kg
m=0.08 //flow rate of refrigerant in kg/s
P=3 //electrical power input in kW
Qcv=m*(he-hi)-P //in kW
To=30 //in Celsius
Sgen=m*(se-si)-Qcv/(To+273.2) //rate of entropy
    generation
printf("\n Hence,the rate of entropy generation for
    this process is Sgen=%.5f kW/K. \n",Sgen)
```

Scilab code Exa 9.10 Turbine efficiency

```
//example 10
//turbine efficiency
clear
clc
hi=3051.2 //initial specific heat of enthalpy in kJ/
   kg
si=7.1228 //initial specific entropy in kJ/kg-K
sf=0.7548 //in kJ/kg-K
sfg=7.2536 //in kJ/kg-K
ses=si //final specific entropy is same as the
   initial
xes=(si-sf)/sfg //quality of steam when it leaves
   the turbine
hf=225.9 //in kJ/kg
hfg=2373.1 //in kJ/kg
hes=hf+xes*hfg //final specific heat of enthalpy in
   kJ/kg
ws=hi-hes //work output of turbine calculated
   ideally in kJ/kg
wa=600 //actual work output of turbine in kJ/kg
nturbine=wa/ws //efiiciency of turbine
printf("\n hence, efficiency of the turbine is
   nturbine=%.1f.\n",nturbine*100)
```

Scilab code Exa 9.11 Turbine inlet pressure

```
//example 11
//turbine inlet pressure
clear
clc
hi=1757.3 //initial specific heat of enthalpy of air
    in kJ/kg
si=8.6905 //initial specifc entropy of airin kJ/kg-K
he=855.3 //final specific heat of enthalpy of air in
    kJ/kg
```

```
w=hi-he //actual work done by turbine in kJ/kg
n=0.85 //efficiency of turbine
ws=w/n //ideal work done by turbine in kJ/kg
hes=hi-ws //from first law of isentropic process
Tes=683.7 //final temperature in kelvins from air
    tables
ses=7.7148 //in kJ/kg-K
R=0.287 //gas constant in kJ/kg-K
Pi=100/%e^((si-ses)/-R) //turbine inlet pressure in
    kPa
printf("\n hence, turbine inlet pressure is Pi=%.0f
    kPa.\n",Pi)
```

Scilab code Exa 9.12 Required work input

```
//example 12
//required work input
clear
clc
Pe=150 //final pressure of air in kPa
Pi=100 //initial presure of air in kPa
k=1.4
Ti=300 //initial temperature of air in kelvis
Tes=Ti*(Pe/Pi)^((k-1)/k) //from second law
ws=1.004*(Ti-Tes) //from first law of isentropic
    process
n=0.7 //efficiency of automotive supercharger
w=ws/n //real work input in kJ/kg
Te=Ti-w/1.004 //temperature at supercharger exit in
    K
printf("\n hence, required work input is w=%.1f kJ/kg
    .\n",w)
printf("\n and exit temperature is Te=%.1f K.\n",Te)
```

Chapter 10

Availibility

Scilab code Exa 10.1 Calculating reversible work

```
//example 1
//Calculating reversible work
clear
clc
//Form the Steam Tables,the inlet and the exit state
    properties are
hi=171.95 //initial specific heat of enthalpy in kJ/
    kg
si=0.5705 //initial specific entropy in kJ/kg-K
se=2.1341 //final specific entropy in kJ/kg-K
he=765.34 //final specific heat of enthalpy in kJ/kg
    -K
m=5 //mass flow rate of feedwater in kg/s
q1=900/m //heat added by one of the sources in kJ/kg
q2=he-hi-q1 //second heat transfer in kJ/kg
To=25+273.3 //Temp. of the surroundings in K
T1=100+273.2 //temp. of reservoir of one of the
    source in K
T2=200+273.2 //temp. of reservoir of second source
    in K
wrev=To*(se-si)-(he-hi)+q1*(1-To/T1)+q2*(1-To/T2) //
```

```
reversible work in kJ/kg
printf("\n Hence, the irreversibility is i=%.1f kJ/kg.\n",wrev)
```

Scilab code Exa 10.2 Calculating reversible work

```
//example 2
//Calculating reversible work
clear
clc
//Form the Steam Tables,the inlet and the exit state properties are
hi=298.6 //initial specific heat of enthalpy in kJ/kg
si=6.8631 //initial specific entropy in kJ/kg-K
se=7.4664 //final specific entropy in kJ/kg-K
he=544.7 //final specific heat of enthalpy in kJ/kg-K
q=-50 //heat lost to surroundings in kJ/kg
w=hi-he+q //work in kJ/kg
To=25+273.2 //Temp. of the surroundings in K
P1=100 //Pressure of ambient air in kPa
P2=1000 //Final pressure of air after compression in kPa
R=0.287 //Universal gas constant in kJ/kg-K
wrev=To*(se-si-R*log(P2/P1))-(he-hi)+q*(1-To/To)//reversible work for the given change of state in kJ/kg
i=wrev-w //irreversibility in kJ/kg
printf("\n Hence, the irreversibility is i=%.1f kJ/kg.\n",i)
```

Scilab code Exa 10.3 Calculating reversible work and irreversibility

```
//example 3
//Calculating reversible work and irreversibility
clear
clc
//Form the Steam Tables at state 1
u1=1243.5 //initial specific internal energy in kJ/kg
s1=4.4819 //initial specific entropy in kJ/kg-K
v1=28.895 //initial specific volume in m^3/kg
v2=2*v1 //final specific volume in kg/m^3
u2=u1 //initial specific internal energy in kJ/kg
//These two independent properties , v2 and u2 , fix state 2.The final temp. is calculated by interplotation using the data for T2=5C and v2,x=0/3928 and u=948.5 kJ/kg. For T2=10C and v2, x=0.5433 and u=1317 kJ/kg
T2=9.1+273.2 //final temp. in K
x2=0.513 //quality in final state
s2=4.644 //final specific entropy in kJ/kg
V1=1 //volume of part of A in m^3
m=V1/v1 //mass flow rate in kg/s
To=20+273.2 //Room temperature in K
Wrev=To*m*(s2-s1) //reversible work in kJ
I=Wrev //irreversibility of the process
printf("\n The irreversibility is I=%.3f kJ/kg.\n",I)
```

Chapter 11

Power and Refrigeration Systems with phase change

Scilab code Exa 11.1 To determine the efficiency of Rankine cycle

```
//Ques 1
//To determine the efficiency of Rankine cycle
clc
clear
//1-Inlet state of pump
//2-Exit state of pump
P2=2000;//Exit pressure in kPa
P1=10;//Inlet pressure in kPa
v=0.00101;//specific weight of water in m^3/kg
wp=v*(P2-P1);//work done in pipe in kJ/kg
h1=191.8;//Enthalpy in kJ/kg from table
h2=h1+wp;//enthalpy in kJ/kg
//2-Inlet state for boiler
//3-Exit state for boiler
h3=2799.5;//Enthalpy in kJ/kg
//3-Inlet state for turbine
//4-Exit state for turbine
//s3=s4(Entropy remain same)
s4=6.3409;//kJ/kg
```

```
sf=0.6493;//Entropy at liquid state in kJ/kg
sfg=7.5009;//Entropy difference for vapor and liquid
    state in kJ/kg
x4=(s4-sf)/sfg;//x-factor
hfg=2392.8;//Enthalpy difference in kJ/kg for
   turbine
h4=h1+x4*hfg;//Enthalpy in kJ/kg

nth=((h3-h2)-(h4-h1))/(h3-h2);
printf('Percentage efficiency = %.1f ',nth*100);
```

Scilab code Exa 11.2 To determine the efficiency of Rankine cycle

```
//Ques 2
//To determine the efficiency of Rankine cycle
clc
clear
//1-Inlet state of pump
//2-Exit state of pump
P2=4000;//Exit pressure in kPa
P1=10;//Inlet pressure in kPa
v=0.00101;//specific weight of water in m^3/kg
wp=v*(P2-P1);//work done in pipe in kJ/kg
h1=191.8;//Enthalpy in kJ/kg from table
h2=h1+wp;//enthalpy in kJ/kg
//2-Inlet state for boiler
//3-Exit state for boiler
h3=3213.6;//Enthalpy in kJ/kg from table
//3-Inlet state for turbine
//4-Exit state for turbine
//s3=s4(Entropy remain same)
s4=6.7690;//Entropy in kJ/kg from table
sf=0.6493;//Entropy at liquid state in kJ/kg from
   table
sfg=7.5009;//Entropy difference for vapor and liquid
```

```
    state in kJ/kg from table
x4=(s4-sf)/sfg;//x-factor
hfg=2392.8;//Enthalpy difference in kJ/kg for
   turbine
h4=h1+x4*hfg;//Enthalpy in kJ/kg

nth=((h3-h2)-(h4-h1))/(h3-h2);
printf('Percentage efficiency = %.1f ',nth*100);
```

Scilab code Exa 11.3 To determine the efficiency of a cycle

```
//Ques 3
//To determine the efficiency of a cycle
clc
clear
//1-Inlet state of pump
//2-Exit state of pump
P2=4000;//Exit pressure in kPa
P1=10;//Inlet pressure in kPa
v=0.00101;//specific weight of water in m^3/kg
wp=v*(P2-P1);//work done in pipe in kJ/kg
h1=191.8;//Enthalpy in kJ/kg from table
h2=h1+wp;//enthalpy in kJ/kg
//2-Inlet state for boiler
//3-Exit state for Boiler
h3=3213.6;//Enthalpy in kJ/kg from table
//3-Inlet state for high pressure turbine
//4-Exit state for high pressure turbine
//s3=s4(Entropy remain same)
s4=6.7690;//Entropy in kJ/kg from table
sf=1.7766;//Entropy at liquid state in kJ/kg from
   table
sfg=5.1193;//Entropy difference for vapor and liquid
    state in kJ/kg from table
x4=(s4-sf)/sfg;//x-factor
```

```
hf=604.7//Enthalpy of liquid state in kJ/kg
hfg=2133.8;//Enthalpy difference in kJ/kg for
    turbine
h4=hf+x4*hfg;//Enthalpy in kJ/kg
//5-Inlet state for low pressure turbine
//6-Exit pressure for low pressure turbine
sf=0.6493;//Entropy in liquid state in kJ/kg for
    turbine
h5=3273.4;//enthalpy in kJ/kg
s5=7.8985;//Entropy in kJ/kg
sfg=7.5009;//entropy diff in kJ/kg
x6=(s5-sf)/sfg;//x-factor
hfg=2392.8;//enthalpy difference for low pressure
    turbine in kj/kg
h6=h1+x6*hfg;//entropy in kg/kg
wt=(h3-h4)+(h5-h6);//work output in kJ/kg
qh=(h3-h2)+(h5-h4);

nth=(wt-wp)/qh;
printf('Percentage efficiency = %.1f ',nth*100);
```

Scilab code Exa 11.4 `Efficiency of Refrigeration cycle`

```
//ques4
//Efficiency of Refrigeration cycle
clc
clear
//from previous examples
h1=191.8;//kJ/kg
h5=3213.6;//kg/kg
h6=2685.7;//kJ/kg
h7=2144.1;//kJ/kg
h3=604.7;//kJ/kg
//1-Inlet state of pump
//2-Exit state of pump
```

```
P2=400;//Exit pressure in kPa
P1=10;  //Inlet pressure in kPa
v=0.00101;//specific weight of water in m^3/kg
wp1=v*(P2-P1);//work done for low pressure pump in
    kJ/kg
h1=191.8;//Enthalpy in kJ/kg from table
h2=h1+wp1;//enthalpy in kJ/kg
//5-Inlet state for turbine
//6,7-Exit state for turbine
y=(h3-h2)/(h6-h2);//extraction fraction
wt=(h5-h6)+(1-y)*(h6-h7);//turbine work in kJ/kg
//3-Inlet for high pressure pump
//4-Exit for high pressure pump
P3=400;//kPa
P4=4000;//kPa
v=0.001084;//specific heat for 3-4 process in m^3/kg
wp2=v*(P4-P3);//work done for high pressure pump
h4=h3+wp2;//Enthalpy in kJ/kg
wnet=wt-(1-y)*wp1-wp2;
qh=h5-h4;//Heat output in kJ/kg
nth=wnet/qh;
printf('Refrigerator Efficiency = %.1f ',nth*100);
```

Scilab code Exa 11.5 To determine thermal efficiency of cycle

```
//ques5
//To determine thermal efficiency of cycle
clear
clc
//5-Inlet state for turbine
//6-Exit state for turbine
//h-Enthalpy at a state
//s-Entropy at a state
//from steam table
h5=3169.1;//kJ/kg
```

```
s5=6.7235;//kJ/kg
s6s=s5;
sf=0.6493;//Entropy for liquid state in kJ/kg
sfg=7.5009;//Entropy difference in kJ/kg
hf=191.8;//kJ/kg
hfg=2392.8;//Enthalpy difference in kJ/kg
x6s=(s6s-sf)/sfg;//x-factor
h6s=hf+x6s*hfg;//kJ/Kg at state 6s
nt=0.86;//turbine efficiency given
wt=nt*(h5-h6s);
//1-Inlet state for pump
//2-Exit state for pump
np=0.80;//pump efficiency given
v=0.001009;//specific heat in m^3/kg
P2=5000;//kPa
P1=10;//kPa
wp=v*(P2-P1)/np;//Work done in pump in kJ/kg
wnet=wt-wp;//net work in kJ/kg
//3-Inlet state for boiler
//4-Exit state for boiler
h3=171.8;//in kJ/kg from table
h4=3213.6;//kJ/kg from table
qh=h4-h3;
nth=wnet/qh;
printf('Cycle Efficiency = %.1f ',nth*100);
```

Chapter 12

Power and Refrigeration Systems gaseous working fluids

Scilab code Exa 12.1 Standard brayton cycle

```
//ques1
//Standard brayton cycle
clc
clear
//1-Inlet for compressor
//2-Exit for compressor
//T-Temperature at a state
//P-Pressure at a state
T1=288.2;//K
P2=1000;//kPa
P1=100;//kPa
k=1.4;
T2=T1*(P2/P1)^(1-1/k);//K
Cp=1.004;//Specific heat at constant pressure in kJ/kg
wc=Cp*(T2-T1);//compressor work in kJ/kg;
printf('Temperature T2 = %.1f K\n',T2);
printf(' Compressor work = %.1f kJ/kg \n',wc);
//3-Turbine Inlet
```

```
//4-Turbine Exit
P4=P1;
P3=P2;
T3=1373.2;//K
T4=T3*(P4/P3)^(1-1/k);//K
wt=Cp*(T3-T4);
wnet=wt-wc;
printf('Temperature T3 = %.1f K\n',T3);
printf('Temperature T4 = %.1f K\n',T4);
printf('Turbine work = %.1f kJ/kg\n',wt);
printf('Net work = %.1f kJ/kg\n',wt-wc);
//2-Also high temperature heat exchanger Inlet
//3-(-do-) Exit
qh=Cp*(T3-T2);//Heat of source in kJ/kg
//4-high temp heat exchanger inlet
//1-(-do-) Exit
ql=Cp*(T4-T1);//Heat of sink in kJ/kg
nth=wnet/qh;
printf('Thermal Efficiency of cycle = %.1f percent'
    ,nth*100);
```

Scilab code Exa 12.2 Standard brayton cycle

```
//Calculation mistake in book
//ques2
//Standard brayton cycle
clc
clear
//Calculation mistake in book
//1-Inlet for compressor
//2-Exit for compressor
//T-Temperature at a state
//P-Pressure at a state
T1=288.2;//K
P2=1000;//kPa
```

```
P1=100;//kPa
k=1.4;
T2s=T1*(P2/P1)^(1-1/k);//K
nc=.80;//Compressor Efficiency
T2=T1+(T2s-T1)/0.80;
Cp=1.004;//Specific heat at constant pressure in kJ/
    kg
wc=Cp*(T2-T1);//compressor work in kJ/kg;
printf('Temperature T2 = %.1f K\n',T2);
printf(' Compressor work = %.1f kJ/kg \n',wc);
//3-Turbine Inlet
//4-Turbine Exit
P4=P1;
P3=P2;
T3=1373.2;//K
T4s=T3*(P4/P3)^(1-1/k);//K
nt=0.85;//turbine Efficiency
T4=T3-(T3-T4s)*0.85;
wt=Cp*(T3-T4);
wnet=wt-wc;
printf(' Temperature T3 = %.1f K\n',T3);
printf(' Temperature T4 = %.1f K\n',T4);
printf(' Turbine work = %.1f kJ/kg\n',wt);
printf(' Net work = %.1f kJ/kg\n',wt-wc);
//2-Also high temperature heat exchanger Inlet
//3-(-do-) Exit
qh=Cp*(T3-T2);//Heat of source in kJ/kg
//4-high temp heat exchanger inlet
//1-(-do-) Exit
ql=Cp*(T4-T1);//Heat of sink in kJ/kg
nth=wnet/qh;
printf(' Thermal Efficiency of cycle = %.1f percent'
    ,nth*100);
```

Scilab code Exa 12.3 efficiency of the cycle

```
//ques3
//efficiency of the cycle
clc
clear
wnet=395.2;//kJ/kg from example no 1
//Tx=T4
Tx=710.8;//K from example no 1
T3=1373.2;//K from example no 1
Cp=1.004;//specific heat in kJ/kg
qh=Cp*(T3-Tx);
nth=wnet/qh;
printf('Thermal efficiency = %.1f percent',nth*100);
```

Scilab code Exa 12.4 Calculation of work in the given cycle

```
//ques4
//Calculation of work in the given cycle
clear
clc
R=0.287;//gas constant
T1=288.2;//compressor temperature K
T2=1373.2;//K turbine temperature K
//Pe/Pi=c=10, Pi/Pe=1/c from example 12.1
c=10;
wc=-R*T1*log(c);
printf('Isothermal work in compressor = %.1f kJ/kg \
   n',wc);
wt=-R*T2*log(1/c);
printf(' Isothermal work in turbine = %.1f kJ/kg\n',
   wt);
```

Scilab code Exa 12.5 air standard cycle for jet repulsion

```
//ques5
//air standard cycle for jet repulsion
clear
clc
//1-compressor inlet
//2-Compressor exit
//P-Pressure at given point
//T-Temperature at given point
P1=100;//kPa
P2=1000;//kPa
T1=288.2;//K
T2=556.8;//K
wc=269.5;//from ex 12.1 work done in compressor in
   kJ/kg
//2-Burner inlet
//3-Burner exit
P3=1000;//kPa
T3=1373.2;//K
//wc=wt
Cp=1.004;//specific enthalpy of heat at constant
   pressure in kJ/kg
k=1.4;
T4=T3-wc/Cp;
P4=P3*(T4/T3)^(1-1/k);
//from s4=s5 and h4=h5+v2/2 we get
T5=710.8//K, from second law
v=sqrt(2*Cp*1000*(T4-T5));//m/s
printf('Velocity of air leaving the nozel = %.0f m/s
   ',v);
```

Scilab code Exa 12.6 air standard refrigeration cycle

```
//ques6
//air standard refrigeration cycle
clear
```

```
clc
//1-compressor inlet
//2-compressor exit
P1=100;//kPa
P2=500;//kPa
k=1.4;
rp=P2/P1;
cop=(rp^(1-1/k)-1)^-1;
printf('Coefficient of performance = %.3f \n',cop);
//3-Expander inlet
//4-Expander exit
P3=P2;
P4=P1;
T3=288.23;//K, given and fixed
T4=T3/(P3/P4)^(1-1/k);
T1=253.2;//K, given
Cp=1.004;//Specific heat at cons pressure in kJ/kg
ql=Cp*(T1-T4);//heat released in kJ/kg
P=1//power required in kW
ms=P/ql;//kg/s
printf(' Rate at which the air enter the compressor
    = %.3f kg/s ',ms);
```

Scilab code Exa 12.7 the otto cycle

```
//ques7
//the otto cycle
clear
clc
//1-compressor inlet
//2-compressor exit
P1=100;//kPa
T1=288.2;//K
R=0.287;//gas constant
v1=R*T1/P1;//specific volume at inlet in m^3/kg
```

```
rv=10;//compression ratio given
k=1.4;//constant
T2=T1*rv^(k-1);//K
printf('Temperature at compressor exit, T2 = %.1f K \n',T2);
P2=P1*rv^k;//kPa
printf(' Pressure at compressor exit, P2 = %.3f MPa \n ',P2/1000);
v2=v1/rv;//specific heat at exit in m^3/kg
//23-heat addition process
//q23=Cv*(T3-T2)=1800 kJ/kg given
q23=1800;//kJ/kg heat addition, given
Cv=0.717;//specific heat at constant volume in kJ/kg
T3=T2+q23/Cv;//K
printf('\n Initial Temperature during heat additon process, T3 = %.0f K \n',T3);
P3=P2*(T3/T2);//kPa
printf( ' Initial pressure during heat addition process, P3 = %.3f MPa \n',P3/1000);
r=10;//k=V4/V3=P3/P4
T4=T3*(1/r)^(k-1);
printf(' \n Final temperature during heat addition process, T4 = %.1f K \n',T4);
P4=P3/r^k;//kPa
printf(' Final pressure during heat addition process, P4 = %.4f MPa \n',P4/1000);
nth=1-1/r^k;//thermal efficiency
printf('\n Thermal efficiency = %.1f percent \n',nth*100);
q41=Cv*(T1-T4);///heat for process 4-1 in kJ/kg
wnet=q23+q41;
mep=wnet/(v1-v2);//effective mean pressure n kPa
printf('\n Mean effective pressure = %.0f kPa \n',mep);
```

Scilab code Exa 12.8 the diesel cycle

```
//ques7
//the diesel cycle
clear
clc
//1-compressor inlet
//2-compressor exit
P1=100;//kPa
T1=288.2;//K
R=0.287;//gas constant
v1=R*T1/P1;//specific volume at inlet in m^3/kg
rv=20;//compression ratio given
k=1.4;//constant
T2=T1*rv^(k-1);//K
printf('Temperature at compressor exit, T2 = %.1f K
    \n',T2);
P2=P1*rv^k;//kPa
printf(' Pressure at compressor exit, P2 = %.3f MPa
    \n ',P2/1000);
v2=v1/rv;//specific heat at exit in m^3/kg
//23-heat addition process
//q23=Cv*(T3-T2)=1800 kJ/kg given
q23=1800;//kJ/kg heat addition, given
Cv=.717;
Cp=1.004;//specific heat at constant pressure in kJ/
    kg
T3=T2+q23/Cp;//K
printf('\n Initial Temperature during heat addition
    process, T3 = %.0f K \n',T3);
r=T3/T2;//T3/T2=V3/V2=r
v3=r*v2;
T4=T3/(v1/v3)^(k-1);
printf(' Final temperature during heat addition
    process, T4 = %.0f K \n',T4);
q41=Cv*(T1-T4);///heat for process 4-1 in kJ/kg
wnet=q23+q41;
mep=wnet/(v1-v2);//effective mean pressure in kPa
```

```
qh=1800;//heat transfer in kJ/kg
nth=wnet/qh;//thermal efficiency

printf('\n Thermal efficiency = %.1f percent \n',nth
   *100);
printf('\n Mean effective pressure = %.0f kPa \n',
   mep);
```

Chapter 13

Ideal Gas Mixtures

Scilab code Exa 13.3 calculating humidity ratio dew point mass of air mass of vapo

```
//ques3
//calculating humidity ratio , dew point ,mass of air ,
    mass of vapor
clear
clc
r=0.70;//relative humidity
Pg=5.628;//saturation pressure in kPa
Pv=r*Pg;//vapour pressure in kPa
P=100;//net pressure kPa
Pa=P-Pv;//Partial pressure of air
w=0.622*Pv/Pa;//humidity ratio formula
V=100;//volume in m^3
Ra=0.287;//gas constant for water vapour
T=308.2;//Temperature in K
ma=Pa*V/(Ra*T);//mass in kg
mv=w*ma;//mass of vapour
printf('Mass of vapour = %.2f Kg ', mv);
```

Scilab code Exa 13.4 calculating amount of water vapour condensed on cooling

```
//ques4
//calculating amount of water vapour condensed on
   cooling
clear
clc
//from example 3
w1=0.0255;//w1=w, humidity ratio at initial
   temperature
ma=108.6;//mass of air in kg
P=100;//kPa net pressure
//at 5 C mixture is saturated so Pv2=Pg2
Pg2=0.8721;
Pv2=Pg2;
w2=0.622*Pv2/(P-Pg2);
mc=ma*(w1-w2);
printf('Mass of vapour condense = %.3f kg \n',mc);
```

Scilab code Exa 13.5 calculating heat transfer per kilogram of dry air

```
//ques5
//calculating heat transfer per kilogram of dry air
clear
clc
//1-inlet state
//2-Exit state
r1=0.80;//realtive humidity at state 1
Pg1=4.246;//saturation pressure of vapour in kPa
P1=105;//net pressure at state 1 in kPa
P2=100;//net pressure at state 2 in kPa
Pv1=r1*Pg1;//partial pressure of vapour in kPa
w1=0.622*Pv1/(P1-Pv1);//humidity ratio at state 1
r2=0.95;//relative humidity at state 2
Pg2=1.7051;//saturation pressure of vapour in kPa
Pv2=r2*Pg2;//partial pressure of vapour in kPa
w2=0.622*Pv2/(P2-Pv2);//humidity ratio at state 2
```

```
T1=30;//C
T2=15;//C
Cp=1.004;//specific heat of water vapour in kJ/kg
hv2=2528.9;//enthalpy of vapourisation of vapour in
    kJ/kg
hv1=2556.3;//enthalpy of vapourisation of vapour in
    kJ/kg
hl2=62.99;//enthalpy of
q=Cp*(T2-T1)+w2*hv2-w1*hv1+hl2*(w1-w2);//kJ/kg
printf('Heat transferred per unit mass = %.2f kJ/kg
    of dry air',q);
```

Scilab code Exa 13.6 calculating heat transferred in gas vapour mixture

```
//ques6
//calculating heat transferred in gas vapour mixture
clear
clc
//n-Nitrogen
//v-water vapour
Pn2=1995;//Pressure of nitrogen in kPa
V=0.5;//Volume in m^3
Rn2=0.2968;//Gas constant for nitrogen in kJ/kg.K
Rv=0.4615;//gas constant for vapour
T1=323.2;//Temperature in K
T2=283.2;//Temperature in K
Pv1=5;//Pressure of water vapour in kPa at state 1
Pv2=1.2276;//Pressure of water vapour in kPa at
    state 2
mn2=Pn2*V/(Rn2*T1);//mass of nitrogen
mv1=Pv1*V/(Rv*T1);//mass of vapour in kg
mv2=Pv2*V/(Rv*T2);//mass of vapour in kg
ml2=mv1-mv2;//mass of liquid condensed n kg
uv1=2443.1;//specific internal energy of vapour in
    kJ/kg at state 1
```

```
uv2=2389.2;//specific internal energy of vapour in
    kJ/kg at state 2
ul2=42.0;//specific internal energy of liquid water
    in kJ/kg
Cv=0.745;//specific heat at constant volume in kJ/kg
    .K
Q=mn2*Cv*(T2-T1)+mv2*uv2+ml2*ul2-mv1*uv1;
printf('Heat transferred = %.1f kJ ',Q);
```

Scilab code Exa 13.7 calculating humidity ratio and relative humidity

```
//ques7
//calculating humidity ratio and relative humidity
clear
clc
//1-Inlet state
//2-Exit state
P=100;//net pressure n kPa
//it is steady state adiabatic process
//water vapour leaving is saturated so Pv2=Pg2
Pg2=2.339;//saturation pressure of vapour in kPa
Pv2=Pg2;//partial pressure of vapour
w2=0.622*Pv2/(P-Pg2);
Cpa=1.004;//specific heat n kJ/kg/K
T2=20;// final temp in C
T1=30;// initial temp in C
Hfg2=2454.1;//specific heat difference at state 2 in
    kJ/kg
hv1=2556.3;//enthalpy of water vapour at state 1 in
    kJ/kg
hl2=83.96;//enthalpy of liquid water in kJ/kg
w1=(Cpa*(T2-T1)+w2*Hfg2)/(hv1-hl2);
printf('Relative humidity = %.4f \n',w1);
//also w1=0.622*Pv1/(100-Pv2)
Pv1=100*w1/(0.622+w1);
```

```
Pg1=4.246;//saturation pressure at state 1 in kPa
r=Pv1/Pg1;//humidity ratio
printf(' Humidity ratio = %.3f ',r);
```

Chapter 14

Thermodynamics Property Relations

Scilab code Exa 14.1 to determine the sublimation pressure of water

```
//ques1
//to determine the sublimation pressure of water
clear
clc
//from table in appendix B.1.5
T1=213.2;//K, Temperature at state 1
P2=0.0129;//kPa, pressure at state 2
T2=233.2;//K, Temperature at state 2
hig=2838.9;//kJ/kg, enthalpy of sublimation
R=.46152;//Gas constant
//using relation log(P2/P1)=(hig/R)*(1/T1-1/T2)
P1=P2*exp(-hig/R*(1/T1-1/T2));
printf('Sublimation Pressure = %.5f kPa \n',P1);
```

Scilab code Exa 14.4 Volume expansivity Isothermal and Adiabatic compressibility

```
//ques4
//Volume expansivity , Isothermal and Adiabatic
   compressibility
clear
clc
//known data
ap=5*10^-5;//K^-1 Volume expansivity
bt=8.6*10^-12;//m^2/N, Isothermal compressibility
v=0.000114;//m^3/kg, specific volume
P2=100*10^6;//pressure at state 2 in kPa
P1=100;//pressure at state 1 in kPa
w=-v*bt*(P2^2-P1^2)/2;//work done in J/kg
//q=T*ds and ds=-v*ap*(P2-P1)
//so q=-T*v*ap*(P2-P1)
T=288.2;//Temperature in K
q=-T*v*ap*(P2-P1);//heat in J/kg
du=q-w;//change in internal energy in J/kg
printf('Change in internal energy = %.1f J/kg ',du);
```

Scilab code Exa 14.5 adiabatic steady state processes

```
//ques5
//adiabatic steady state processes
clear
clc
//from table A.2
P1=20;//pressure at state 1 in MPa
P2=2;//pressure at state 2 in MPa
T1=203.2;//Temperature at state 1 in K
Pr1=P1/3.39;//Reduced pressure at state 1
Pr2=P2/3.39;//Reduced pressure at state 2
Tr1=T1/126.2;//Reduced temperature
//from compressibility chart h1*-h1=2.1*R*Tc
//from zero pressure specific heat data h1*-h2*=Cp*(
   T1a-T2a)
```

```
//h2*-h2=0.5*R*Tc
//this gives dh=h1-h2=-2.1*R*Tc+Cp*(T1a-T2a)+0.5*R*
    Tc
R=0.2968;//gas constant for given substance
Tc=126.2;//K, Constant temperature
Cp=1.0416;//heat enthalpy at constant pressure in kJ
    /kg
T2=146;//temperature at state 2
dh=-1.6*R*Tc+Cp*(T1-T2);//
printf('Enthalpy change = %.0f kJ/kg \n',dh);
printf(' Since Enthalpy change is %.0f kJ/kg so
    Temperature = %.1f K',dh,T2);
```

Scilab code Exa 14.6 isothermal steady state processes

```
//ques6
//isothermal steady state processes
clear
clc
//from table A.2
P1=8;//pressure at state 1 in MPa
P2=0.5;//pressure at state 2 in MPa
T1=150;//Temperature at state 1 in K
Pr1=P1/3.39;//Reduced pressure at state 1
Pr2=P2/3.39;//Reduced pressure at state 2
Tr1=T1/126.2;//Reduced temperature
T2=125;//temperature at state 2
//from compressibility chart h1*-h1=2.1*R*Tc
//from zero pressure specific heat data h1*-h2*=Cp*(
    T1a-T2a)
//h2*-h2=0.5*R*Tc
//this gives dh=h1-h2=-2.1*R*Tc+Cp*(T1a-T2a)+0.15*R*
    Tc
R=0.2968;//gas constant for given substance
Tc=126.2;//K, Constant temperature
```

```
Cp=1.0416;//heat enthalpy at constant pressure in kJ
   /kg
dh=(2.35)*R*Tc+Cp*(T2-T1);//
printf('Enthalpy change = %.2f kJ/kg \n',dh);
//change in entropy
//ds= -(s2*-s2)+(s2*-s1*)+(s1*-s1)
//s1*-s1=1.6*R
//s2*-s2=0.1*R
//s2*-s1*=Cp*log(T2/T1)-R*log(P2/P1)
//so
ds=1.6*R-0.1*R+Cp*log(T2/T1)-R*log(P2/P1);
printf(' Entropy Change = %.4f kJ/kg.K ',ds);
```

Scilab code Exa 14.7 percent deviation using specific volume calculated by kays ru

```
//ques7
//percent deviation using specific volume calculated
    by kays rule and vander waals rule
clear
clc
//a-denotes C02
//b-denotes CH4
T=310.94;//Temperature of mixture K
P=86.19;//Pressure of mixture in MPa
//Tc- critical Temperature
//Pc-critical pressure
Tca=304.1;//K
Tcb=190.4;//K
Pca=7.38;//MPa
Pcb=4.60;//MPa
Ra=0.1889;//gas constant for a in kJ/kg.K
Rb=0.5183;//gas constant for b in kJ/kg.K
xa=0.8;//fraction of CO2
xb=0.2;//fraction of CH4
Rm=xa*Ra+xb*Rb;//mean gas constant in kJ/kg.K
```

```
Ma=44.01;//molecular mass of a
Mb=16.043;//molecular mass of b
//1.Kay's rule
ya=xa/Ma/(xa/Ma+xb/Mb);//mole fraction of a
yb=xb/Mb/(xa/Ma+xb/Mb);//mole fraction of b
Tcm=ya*Tca+yb*Tcb;//mean critical temp in K
Pcm=ya*Pca+yb*Tcb;//mean critical pressure n MPa
//therefore pseudo reduced property of mixture
Trm=T/Tcm;
Prm=P/Pcm;
Zm=0.7;//Compressiblity from generalised compressibility chart
vc=Zm*Rm*T/P/1000;//specific volume calculated in m^3/kg
ve=0.0006757;//experimental specific volume in m^3/kg
pd1=(ve-vc)/ve*100;//percent deviation
printf('Percentage deviation in specific volume using Kays rule = %.1f percent \n',pd1);

//2. using vander waals equation
//values of vander waals constant
Aa=27*Ra^2*Tca^2/(64*Pca*1000);
Ba=Ra*Tca/(8*Pca*1000);
Ab=27*Rb^2*Tcb^2/(64*Pcb*1000);
Bb=Rb*Tcb/(8*Pcb*1000);
//mean vander waals constant
Am=(xa*sqrt(Aa)+xb*sqrt(Ab))^2;
Bm=(xa*Ba+xb*Bb);
//using vander waals equation we get cubic equation
//solving we get
vc=0.0006326;//calculated specific volume in m^3/kg
pd2=(ve-vc)/ve*100;
printf(' Percentage deviation in specific volume using vander waals eqn = %.1f percent \n',pd2);
```

Chapter 15

Comustion

Scilab code Exa 15.1 theoratical air fuel ratio for combustion of octane

```
//ques1
//theoratical air-fuel ratio for combustion of
   octane
clear
clc
rm=(12.5+47.0)/1;//air fuel ratio on mole basis
rma=rm*28.97/114.2;//air fuel ratio on mass basis;
printf('Theoratical air fuel ratio on mass basis = %
   .1f kg air/kg fuel \n',rma);
```

Scilab code Exa 15.6 determining heat transfer per kilomole of fuel entering combu

```
//ques6
//determining heat transfer per kilomole of fuel
   entering combustion chamber
clear
clc
//1-CH4
```

```
//2-CO2
//3-H2O
//hf-standard enthalpy of given substance
hf1=-74.873;//kJ
hf2=-393.522;//kJ
hf3=-285.830;//kJ
Qcv=hf2+2*hf3-hf1;//kJ
printf('Heat transfer per kilomole of fuel entering
    combustion chamber = %.3f kJ ',Qcv);
```

Scilab code Exa 15.7 calculating enthalpy of water at given pressure and temperatu

```
//ques7
//calculating enthalpy of water at given pressure
    and temperature
clear
clc
//1.Assuming steam to be an ideal gas with value of
    Cp
T1=298.15;//Initial temperature in K
T2=573.15;//final temperature in K
T=(T1+T2)/2;//average temperature in K
Cp=1.79+0.107*T/1000+0.586*(T/1000)^2-.20*(T/1000)
    ^3;//specific heat at constant pressure in kj/kg.
    K
M=18.015;//mass in kg
dh=M*Cp*(T2-T1);//enthalpy change in kJ/kmol
ho=-241.826;//enthalpy at standard temperature and
    pressure in kJ/mol
htp1=ho+dh/1000;//enthalpy at given temp and
    pressure in kJ/kmol
printf('1. Enthalpy of water at given pressure and
    temperature using value of Cp = %.3f kJ/kmol \n',
    htp1);

```

```
//2..Assuming steam to be an ideal gas with value for dh
dh=9359;//enthalpy change from table A.9 in kJ/mol
htp2=ho+dh/1000;//enthalpy at given temp and pressure in kJ/kmol
printf(' 2. Enthalpy of water at given pressure and temperature assuming value od dh = %.3f kJ/kmol \n',htp2);

//3. Using steam table
dh=M*(2977.5-2547.2);//enthalpy change for gases in kJ/mol
htp3g=dh/1000+ho;
dh=M*(2977.5-104.9);//enthalpy change for liquid in kJ/mol
hl=-285.830;//standard enthalpy for liquid in kJ/kmol
htp3l=hl+dh/1000;//enthalpy at given temp and pressure in kJ/kmol
printf(' 3.(i) enthalpy at given temp and pressure in kJ/kmol in terms of liquid = %.3f kJ/kmol \n',htp3l);
printf(' 3.(ii) enthalpy at given temp and pressure in kJ/kmol in terms of liquid = %.3f kJ/kmol \n',htp3g);
//4.using generalised charts
//htp=ho-(h2*-h2)+(h2*-h1*)+(h1*-h1);
//h2*-h2=Z*R*Tc,
//h2*-h1*=9539 kJ/mol, from part 2
//h1*-h1=0 ,as ideal gas
Z=0.21;//from chart
R=8.3145;//gas constant in SI units
Tc=647.3;//critical temperature in K
htp4=ho+9539/1000-Z*R*Tc/1000;//enthalpy at given temp and pressure in kJ/kmol
printf(' 4. enthalpy at given temp and pressure in kJ/kmol using compressibility chart = %.3f kJ/kmol \n',htp4);
```

Scilab code Exa 15.15 calculatng reversible elecromotive force

```
//ques15
//calculatng reversible elecromotive force
clear
clc
//1-H2O
//2-H2
//3-O2
//hf-standard enthalpy
//sf-standard entropy
hf1=-285.830;//kJ
hf2=0;//kJ
hf3=0;//kJ
sf1=69.950;//kJ/K
sf2=130.678;//kJ/K
sf3=205.148;//kJ/K
dH=2*hf1-2*hf2-hf3;//change in enthalpy in kJ
dS=2*sf1-2*sf2-sf3;//change in entropy in kJ/K
T=298.15;//temperature in K
dG=dH-T*dS/1000;//change in gibbs free energy in kJ
E=-dG*1000/(96485*4);//emf in V
printf('Reversible electromotive Force = %.3f V',E);
```

Scilab code Exa 15.17 efficiency of generator and plant

```
//ques17
//efficiency of generator and plant
clear
clc
q=325000*(3398.3-856.0);//heat transferred to H2O/kg
    fuel in kJ/kg
```

```
qv=26700*33250;//higher heating value in kJ/kg
nst=q/qv*100;//efficiency of steam generator
w=81000*3600;//net work done in kJ/kg
nth=w/qv*100;//thermal efficiency
printf('Efficiency of generator = %.1f percent\n',
   nst);
printf(' Thermal Efficiency = %.1f percent\n',nth);
```

Chapter 16

Phase and Chemical Equilbrium

Scilab code Exa 16.2 to determine change in gibbs free energy

```
//ques2
//to determine change in gibbs free energy
clear
clc
//1-H2
//2-O2
//3-H2O

//at T=298 K
T1=298;//K
Hf1=0;//Enthalpy of formation of H2 at 298 K
Hf2=0;//Enthalpy of formation of O2 at 298 K
Hf3=-241.826;//enthalpy of formation of H2O at 298 K
    in kJ
dH=2*Hf1+Hf2-2*Hf3;//Change in enthalpy in kJ
Sf1=130.678;//Entropy of H2 at 298 K n J/K
Sf2=205.148;//Entropy of O2 at 298 K in J/K
Sf3=188.834;//entropy of H2O at 298 K in J/K
dS=2*Sf1+Sf2-2*Sf3;//Change in entropy in J/K
```

```
dG1=dH-T1*dS/1000;//change n gibbs free energy in kJ
printf(' Change in gibbs free energy at %.0f K = %.3
    f kJ \n' ,T1,dG1);

//at T=2000 K
T2=2000;//K
Hf1=52.942-0;//Enthalpy of formation of H2 at 2000 K
Hf2=59.176-0;//Enthalpy of formation of O2 at 2000 K
Hf3=-241.826+72.788;//enthalpy of formation of H2O
    at 2000 K in kJ
dH=2*Hf1+Hf2-2*Hf3;//Change in enthalpy in kJ
Sf1=188.419;//Entropy of H2 at 2000 K n J/K
Sf2=268.748;//Entropy of O2 at 2000 K in J/K
Sf3=264.769;//entropy of H2O at 2000 K in J/K
dS=2*Sf1+Sf2-2*Sf3;//Change in entropy in J/K
dG2=dH-T2*dS/1000;//change n gibbs free energy in kJ
printf('  Change in gibbs free energy at %.0f K = %
    .3f kJ ' ,T2,dG2);
```

Scilab code Exa 16.3 calculating equilibrium constant

```
//ques3
//calculating equilibrium constant
clear
clc
dG1=-457.166;//change in gibbs free energy at temp
    298 K from example2 in kJ
dG2=-271.040;;//change in gibbs free energy at temp
    2000 K from example2 n kJ
T1=298;//K
T2=2000;//K
R=8.3145;//gas constant
K1=dG1*1000/(R*T1);
K2=dG2*1000/(R*T2);
printf('Equilibrium constant at %.0f K = %.3f \n',T1
```

```
    ,K1);
printf(' Equilibrium constant at %.0f K = %.3f \n',
    T2,K2);
```

Chapter 17

Compressible Flow

Scilab code Exa 17.1 to determine isentropic stagnation pressure and temperature

```
//ques1
//to determine isentropic stagnation pressure and
   temperature
clear
clc
T=300;//Temperature of air in K
P=150;//Pressure of air in kPa
v=200;//velocity of air flow n m/s
Cp=1.004;//specific heat at constant pressure in kJ/
   kg
To=v^2/(2000*Cp)+T;//stagnation temperature in K
k=1.4;//constant
Po=P*(To/T)^(k/(k-1));//stagnation pressure in kPa
printf('Stagnation Temperature = %.1f K \n',To);
printf(' Stagnation Pressure = %.1f kPa \n',Po);
```

Scilab code Exa 17.3 determining the thrust acting on a control surface

```
//ques3
//determining the thrust acting on a control surface
clear
clc
//i-inlet
//e-exit
//using momentum equation on control surface in x
    direction
me=20.4;//mass exiting in kg
mi=20;//mass entering in kg
ve=450;//exit velocity in m/s
vi=100;//exit velocity in m/s
Pi=95;//Pressure at inlet in kPa
Pe=125;//Pressure at exit in kPa
Po=100;//surrounding pressure in kPa
Ai=0.2;//inlet area in m^2
Ae=0.1;//exit area in m^2
Rx=(me*ve-mi*vi)/1000-(Pi-Po)*Ai+(Pe-Po)*Ae;//thrust
     in x direction in kN
printf('Thrust acting in x direction = %.2f kN',Rx);
```

Scilab code Exa 17.5 determining velocity of sound in air

```
//ques5
//determining velocity of sound in air
clear
clc
k=1.4;//constant
R=0.287;//gas constant
//at 300K
T1=300;//K
c1=sqrt(k*R*T1*1000);
printf('Speed of sound at %.0f K = %.1f m/s \n',T1,
    c1);
T2=1000;//K
```

```
c2=sqrt(k*R*T2*1000);
printf(' Speed of sound at %.0f K = %.1f m/s \n',T2,
    c2);
```

Scilab code Exa 17.6 determining mass flow rate through control volume

```
//ques6
//determining mass flow rate through control volume
clear
clc
k=1.4;//constant
R=0.287;//gas constant
To=360;//stagnation Temperature in K
T=To*0.8333;//Temperature of air in K, 0.8333
    stagnation ratio from table
v=sqrt(k*R*T*1000);//velocity in m/s
P=528;//stagnation pressure in kPa
d=P/(R*T);//stagnation density in kg/m^3
A=500*10^-6;//area in m^2
ms=d*A*v;//mass flow rate in kg/s
printf('Mass flow rate at the throat section = %.4f
    kg/s \n',ms);
//e-exit state
Te=To*0.9381;//exit temperature in K, ratio from
    table
ce=sqrt(k*R*Te*1000);//exit velocity of sound in m/s
Me=0.573;//Mach number
ve=Me*ce;
Pe=800;//exit pressure in kPa
de=Pe/R/Te;
mse=de*A*ve;
printf(' Mass flow rate at the exit section = %.4f
    kg/s \n',mse);
```

Scilab code Exa 17.7 determining exit properties in a control volume

```
//ques7
//determining exit properties in a control volume
clear
clc
Po=1000;//stagnation pressure in kPa
To=360;//stagnation temperature in K

//when diverging section acting as nozzle
Pe1=0.0939*Po;//exit pressure of air in kPa
Te1=0.5089*To;//exit temperature in K
k=1.4;//constant
R=0.287;//gas constant for air
ce=sqrt(k*R*Te1*1000);//velocity of sound in exit section in m/s
Me=2.197;//mach number from table
ve1=Me*ce;//velocity of air at exit section in m/s
disp(" When diverging section act as a nozzle :-");
printf('Exit pressure  = %.1f kPa \n',Pe1);
printf('Exit Temperature = %.1f K \n',Te1);
printf('Exit velocity = %.1f m/s \n',ve1);

//when diverging section act as diffuser
Me=0.308;
Pe2=0.0936*Po;//exit pressure of air in kPa
Te2=0.9812*To;//exit temperature in K
ce=sqrt(k*R*Te2*1000);//velocity of sound in exit section in m/s
ve2=Me*ce;
disp(" When diverging section act as a diffuser :-");
printf('Exit pressure  = %.1f kPa \n',Pe2);
printf('Exit Temperature = %.1f K \n',Te2);
```

```
printf('Exit velocity = %.1f m/s \n',ve2);
```

Scilab code Exa 17.9 determining exit plane properties in control volume

```
//ques9
//determining exit plane properties in control
   volume
clear
clc
//x-inlet
//y-exit
Mx=1.5;//mach number for inlet
My=0.7011;//mach number for exit
Px=272.4;//inlet pressure in kPa
Tx=248.3;//inlet temperature in K
Pox=1000;//stagnation pressure for inlet
Py=2.4583*Px;//Exit Pressure in kPa
Ty=1.320*Tx;//Exit temperature in K
Poy=0.9298*Pox;//Exit pressure in kPa

printf('Exit pressure = %.1f kPa \n',Py);
printf(' Exit temperature = %.1f K \n',Ty);
printf(' Exit stagnation pressure = %.1f kPa \n',Poy
   );
```