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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Author: B. Claus And R. E. Sonntag

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 2

Control Volumes and Units

Scilab code Exa 2.1 Weight of a person

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

Scilab code Exa 2.2 Average Volume and Density

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

```
7  Vstone=0.12 //volume of stone in m^3
8  Vsand=0.15 //volume of sand in m^3
9  Vair=0.53 //vo;ume of air in m^3
10 mliq=Vliq*dliq //mass of liquid in kg
11 dstone=2750 //density of stone in kg/m^3
12 dsand=1500 //density of sand in kg/m^3
13 mstone=Vstone*dstone //volume of stone in m^3
14 msand=Vsand*dsand //volume of sand in m^3
15 Vtot=1 //total volume in m^3
16 dair=1.1 //density of air in kg/m^3
17 mair=Vair*dair //mass of air
18 mtot=mair+msand+mliq+mstone //total mass in kg
19 v=Vtot/mtot //specific volume in  m^3/kg
20 d=1/v //overall density in kg/m^3
21 printf("\n hence,average specific volume is v=%.6f
      m^3/kg. \n",v )
22 printf("\n and overall density is d=%.0f kg/m^3. \n"
      ,d)
```

Scilab code Exa 2.3 Calculating the required force

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

```
13  F=Pcyl*Acyl-Po*(Acyl-Arod)-mp*g //the force that rod
         can push within the upward direction in N
14  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

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

Scilab code Exa 2.5 Pressure inside vessel

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

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

Scilab code Exa 2.6 Calculating Pressure

```
1 //example 6
2 //calculating pressure
3 clear
4 clc
5 dg=750 //density of gaasoline in kg/m^3
6 dR=1206 //density of R-134a in kg/m^3
7 H=7.5 //height of storage tank in metres
8 g=9.807 //acc. due to gravity in m/s^2
9 dP1=dg*g*H/1000 //in kPa
10 Ptop1=101 //atmospheric pressure in kPa
11 P1=dP1+Ptop1
12 disp('hence,pressure at the bottom of storage tank
       if fluid is gasoline is 156.2 kPa')
13 dP2=dR*g*H/1000 //in kPa
14 Ptop2=1000 //top surface pressure in kPa
15 P2=dP2+Ptop2
16 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

```
1 //example 6
2 //calculating balancing force
```

```
3  clear
4  clc
5  Po=100 //Outside atmospheric pressure in kPa
6  F1=25 //net force on the smallest piston in kN
7  A1=0.01 //cross sectional area of lower piston in m
       ^2
8  P1=Po+F1/A1 //fluid pressure in kPa
9  d=900 //density of fluid in kg/m^3
10 g=9.81 //acc. due to gravity in m/s^2
11 H=6 //height of second piston in comparison to first
       one in m
12 P2=P1-d*g*H/1000 //pressure at higher elevation on
       piston 2 in kPa
13 A2=0.05 // cross sectional area of higher piston in
       m^3
14 F2=(P2-Po)*A2 //balancing force on second piston in
       kN
15 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

```
1  //example 1
2  //determinig the phase of water
3  clear
4  clc
5  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.')
6  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

```
1  //example 2
2  //determinig the phase
3  clear
4  clc
```

14

```
5  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.')
6  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

```
1  //example 3
2  //determining the quality and specific volume
3  clear
4  clc
5  v1=0.5 //given specific volume in m^3/kg
6  vf=0.001073 //specific volume when only liquid phase
       is present in m^3/kg
7  vfg=0.60475 //in m^3/kg
8  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 ')
9  x=(v1-vf)/vfg //quality
10 v2=1 //given specific volume in m^3/kg
11 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.')
12 T=((400-300)*(1.0-0.8753))/(1.0315-0.8753)+300 //
       temperature of the water
```

Scilab code Exa 3.4 Percentage of vapor

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

Scilab code Exa 3.5 Calculating pressure after heat addition

```
1   //example 5
2   //calculating pressure after heat addition
3   clear
4   clc
5   v1=0.14922 //specific volume of sautrated ammonia in
        m^3/kg
6   disp('Since the volume does not change during the
        process,the specific volume remains constant.
        therefore, ')
7   v2=v1 //in m^3/kg
8   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
        ')
9   P2=945 //final pressure in kPa
10  disp('hence,the final pressure is 945 kPa')
```

Scilab code Exa 3.6 Determinig the missing property

```
 1 //example 6
 2 //Determinig the missing property
 3 clear
 4 clc
 5 T1=273-53.2 //given temperature in K
 6 P1=600 //given pressure in kPa
 7 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')
 8 T2=100 //given temp. in K
 9 v2=0.008 //given specific volume in m^3/kg
10 vf=0.001452 //in m^3/kg
11 vg=0.0312 //in m^3/kg
12 Psat=779.2 //saturation pressure in kPa
13 vfg=vg-vf //in m^3/kg
14 x=(v2-vf)/vfg //quality
15 printf("\n hence, the pressure is Psat = %.1f kPa. \
      n",Psat)
16 printf("\n and quality is x = %.4f . \n",x)
```

Scilab code Exa 3.7 Determining the pressure of water

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

17

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

Scilab code Exa 3.8 Calculating mass of air

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

Scilab code Exa 3.9 Calculating pressure inside tank

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

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

Scilab code Exa 3.10 Mass flow rate

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

Scilab code Exa 3.11 Predicting the nature of given state

```
1  //example  11
2  //predicting  the  nature  of  given  state
3  clear
4  clc
```

19

```
5  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.')
6  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.')
7  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

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

```
          generalized chart
15  Pr=3/4.06 //reduced pressure using generalized chart
16  Z=0.67 //compressibility factor
17  v3=Z*v2 // specific volume using generalized chart
          in m^3/kg
18  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

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

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Chapter 4

Energy Transfers

Scilab code Exa 4.1 Work done during different processes

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

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

Scilab code Exa 4.3 work produced

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

Scilab code Exa 4.4 Calculating work done

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

23

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

Scilab code Exa 4.7 Heat transfer

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

Chapter 5

Energy Equation for a Control Mass

Scilab code Exa 5.1 Calculating height

```
1  //example 1
2  //calculating height
3  clear
4  clc
5  m=1100 //mass of car in kg
6  ke=400 //kinetic energy of car in kJ
7  V=(2*ke*1000/m)^0.5 //velocity of car in m/s
8  g=9.807 //acc. due to gravity in m/s^2
9  H=ke*1000/(m*g) //height to which the car  should be
        lifted so that its potential energy equals its
       kinetic energy
10  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

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

Scilab code Exa 5.3 Analysis of energy transfer

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

```
17  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)
18  printf("\n and dU = %.3f J. \n",dU2)
19  dKE3=0 //change in kinetic energy when stone enters
        state 4
20  dPE=0 //change in potential energy when stone enters
        state 4 in J
21  W3=0 //no work done when stone enters state 4 in J
22  dU3=-1 //change in internal energy when stone enters
        state 4 in J
23  Q3=dU3 //heat transfer when stone enters state 4 in
        J
24  printf("\n hence ,when stone has entered state 4, dPE
        =0, W3=0,dKE=0, dU= %.3f J. \n",dU3)
25  printf("\n and Q3= %.3f J. \n",Q3)
```

Scilab code Exa 5.4 Determinig the missing properties

```
1  //example 4
2  //Determinig the missing properties
3  clear
4  clc
5  T1=300 //given temp. in Celsius
6  u1=2780 //given specific internal enrgy in kJ/kg
7  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')
8  P2=2000 //hiven pressure in kPa
9  u2=2000 //given specific intrernal energy in kJ/kg
10 disp('at P=2000 kPa,')
11 uf=906.4 //in kJ/kg
12 ug=2600.3 //in kJ/kg
13 x2=(u2-906.4)/(ug-uf)
```

27

```
14  disp('Also, under the given conditions')
15  vf=0.001177  //in m^3/kg
16  vg=0.099627  //in m^3/kg
17  v2=vf+x2*(vg-vf)//Specific volume for water in m^3/
       kg
18  printf("\n hence,specific volume for water is v2 = %
       .5f m^3/kg. \n",v2)
19  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

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

```
19  U2=m*u2  //internal energy at final state in kJ
20  Q=U2-U1  //heat transfer for the process in kJ
21  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

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

Scilab code Exa 5.8 Calculating change in enthalpy

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

```
 3  clear
 4  clc
 5  h1=273.2 //specific heat enthalpy for oxygen at 300
        K
 6  h2=1540.2 //specific heat enthalpy for oxygen at
        1500 K
 7  T1=300 //initial temperature in K
 8  T2=1500 //final temparature in K
 9  x=poly([0],'x');
10  Cp=0.88-0.00001*x+0.54*x^2-0.33*x^3 //expression for
         constant pressure specific heat enthalpy for
        oxygen
11  dh1=h2-h1 //this change in specific heat enthalpy is
         calculated using ideal gas tables
12  dh2=1000*integrate('0.88-0.00001*x+0.54*x^2-0.33*x^3
        ','x',T1/1000,T2/1000) //using empirical equation
13  dh3=0.922*(T2-T1) //it is claculated if we assume
        specific heat enthalpy to be constant and uses
        its value at 300K
14  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
15  printf("\n Hence,change in specific heat enthalpy if
         ideal gas tables are used is dh1=%.1f kJ/kg. \n"
        , dh1)
16  printf("\n if empirical equations are used, dh2=%.1f
        kJ/kg. \n", dh2)
17  printf("\n if specific heat is assumed to be
        constant and using its value at T1, dh3=%.1f kJ/
        kg. \n", dh3)
18  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

```
1  //example 9
2  //determining amount of heat transfer
3  clear
4  clc
5  P=150 //pressure of nitrogen in cylinder in kPa
6  V=0.1 //initial volume of cylinder in m^3
7  T1=25 //initial temperature of nitrogen in celsius
8  T2=150 //final tempareture of nitrogen in celsius
9  R=0.2968 //in kJ/kg-K
10 m=P*V/(R*(T1+273)) //mass of nitrogen in kg
11 Cv=0.745 //constant volume specific heat for
       nitrogen in kJ/kg-K
12 W=-20 //work done on nitrogen gas in kJ
13 Q=m*Cv*(T2-T1)+W //heat transfer during the process
       in kJ
14 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

```
1  //example 10
2  //calculating rate of increase of internal energy
3  clear
4  clc
5  W=-12.8*20 //power consumed in  J/s
6  Q=-10 //heat transfer rate from battery in J/s
7  r=Q-W //rate of increase of internal energy
8  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

```scilab
1  //example 11
2  //rate of change of temperature
3  clear
4  clc
5  Q=1500 //power produced by burning wood in J/s
6  mair=1 //mass of air in kg
7  mwood=5 //mass of soft pine wood in kg
8  miron=25 //mass of cast iron in kg
9  Cvair=0.717 //constant volume specific heat for air
       in kJ/kg
10 Cwood=1.38 //constant volume specific heat for wood
       in kJ/kg
11 Ciron=0.42 //constant volume specific heat for iron
       in kJ/kg
12 dT=75-20 //increase in temperature in Celsius
13 T=(Q/1000)/(mair*Cvair+mwood*Cwood+miron*Ciron) //
       rate of change of temperature in K/s
14 dt=(dT/T)/60 //in minutes
15 printf(" hence ,the rate of change of temperature is
        dt=%.4f K/s.\n", T)
16 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

```
1  //example 1
2  //calculating mass flow rate in kg/s
3  clear
4  clc
5  R=0.287 //in kJ/kg-K
6  T=25 //temperature in celsius
7  P=150 //pressure in kPa
8  v=R*(T+273.2)/P //specific volume in m^3/kg
9  D=0.2 //diameter of pipe in metre
10 A=%pi*D^2/4 //cross sectional area in m^2
11 V=0.1 //velocity of air in m/s
12 m=V*A/v //mass flow rate in kg/s
13 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

```
1  //example 2
2  //work done for adding the fluid
3  clear
4  clc
5  P=600 //pressure in kPa
6  m=1 //in kg
7  v=0.001 //specific volume in m^3/kg
8  W=P*m*v //necessary work in kJ for adding the fluid
9  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

```
1  //example 3
2  //rate of flow of water
3  clear
4  clc
5  hir=441.89 //in kJ/kg for refrigerant using steam
       table
6  her=249.10 //in kJ/kg for refrigerant using steam
       table
7  hiw=42 //in kJ/kg for water using steam table
8  hew=83.95 //in kJ/kg for water using steam table
9  mr=0.2 //the rate at which refrigerant enters the
       condenser in kg/s
10 mw=mr*(hir-her)/(hew-hiw) //rate of flow of water in
       kg/s
11 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

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

Scilab code Exa 6.5 Quality of ammonia leaving expansion valve

```
1  //example 5
2  //quality of ammonia leaving expansion valve
3  clear
4  clc
5  hi=346.8 //specific heat enthalpy for ammonia at
       initial state in kJ/kg
6  he=hi //specific heat enthalpy for ammonia at final
       state will be equal that at initial state because
        it is a throttling process
7  hf=134.4 //at final state in kJ/kg
8  hfg=1296.4//at final state in kJ/kg
9  xe=(he-hf)/hfg //quality at final state
10 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

```scilab
1  //example 6
2  //power output of turbine in kW
3  clear
4  clc
5  hi=3137 //initial specific heat of enthalpy in kJ/kg
6  he=2675.5 //final specific heat of enthalpy in kJ/kg
7  Vi=50 //initial velocity of steam in m/s
8  Ve=100 //final velocity of steam in m/s
9  Zi=6 //height of inlet conditions in metres
10 Ze=3 //height of exit conditions in metres
11 m=1.5 //mass flow rate of steam in kg/s
12 g=9.8066 //acc. due to gravity in m/s^2
13 Qcv=-8.5 //heat transfer rate from turbine in kW
14 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
15 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

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

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

Scilab code Exa 6.8 Required Pump work

```
1  //example 8
2  //Required pump work
3  clear
4  clc
5  m=1.5 //mass flow rate of water in kg/s
6  g=9.807 //acceleration due to gravity in m/s^2
7  Zin=-15 //depth of water pump in well in metres
8  Zex=0 //in metres
9  v=0.001001 //specific volume in m^3/kg
10  Pex=400+101.3 //exit pressure in kPa
11  Pin=90 //in kPa
12  W=m*(g*(Zin-Zex)*0.001-(Pex-Pin)*v) //power input in
        kW
13  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

```
1  //example 9
2  //heat tranfer in simple steam power plant
3  clear
4  clc
```

```
5  h1=3023.5 //specific heat of enthalpy of steam
       leaving boiler in kJ/kg
6  h2=3002.5 //specific heat of enthalpy of steam
       entering turbine in kJ/kg
7  x=0.9 //quality of steam entering condenser
8  hf=226 //in kJ/kg
9  hfg=2373.1 //in kJ/kg
10 h3=hf+x*hfg //specific heat of enthalpy of steam
       entering condenser in kJ/kg
11 h4=188.5 //specific heat of enthalpy of steam
       entering pump in kJ/kg
12 q12=h2-h1 //heat transfer in line between boiler and
        turbine in kJ/kg
13 w23=h2-h3 //turbine work in kJ/kg
14 q34=h4-h3 //heat transfer in condenser
15 w45=-4 //pump work in kJ/kg
16 h5=h4-w45 //in kJ/kg
17 q51=h1-h5 //heat transfer in boiler in kJ/kg
18 printf("\n hence, heat transfer in line between
       boiler and turbine is q12=%.1f kJ/kg. \n",q12')
19 printf("\n hence, turbine work is w23=%.1f kJ/kg. \n
       ",w23')
20 printf("\n hence, heat transfer in condenser is q34=
       %.1f kJ/kg. \n",q34')
21 printf("\n hence, heat transfer in boiler is q51=%.0
       f kJ/kg. \n",q51')
```

Scilab code Exa 6.10 Analysis of refrigerator

```
1  //example 10
2  //analysis of refrigerator
3  clear
4  clc
5  hf4=167.4 //in kJ/kg
6  hfg4=215.6 //in kJ/kg
```

```
7  h3=241.8 //specific heat of enthalpy of R−134a
      entering expansion valve
8  h4=h3 //specific heat of enthalpy of R−134a leaving
      expansion valve
9  h1=387.2 //in kJ/kg
10 h2=435.1 //in kJ/kg
11 x4=(h3-hf4)/hfg4 //quality of R−134a at evaporator
      inlet
12 m=0.1 //mass flow rate in kg/s
13 Qevap=m*(h1-h4) //rate of heat transfer to the
      evaporator
14 Wcomp=-5 //power input to compressor in kW
15 Qcomp=m*(h2-h1)+Wcomp //rate of heat transfer from
      compressor
16 printf("\n hence, the quality at the evaporator
      inlet is x4=%.3f. \n",x4')
17 printf("\n hence, the rate of heat transfer to the
      evaporator is Qevap=%.2f kW. \n",Qevap')
18 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

```
1  //example 11
2  //Determining the final temperature of steam
3  clear
4  clc
5  u2=3040.4 //final internal energy in kJ/kg
6  hi=u2 //in kJ/kg
7  P2=1.4 //final Pressure in MPa
8  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  ')
9  T2=452  // final  temperature  in  Celsius
```

Scilab code Exa 6.12 Calculating mass flow of steam in tank

```
1  // example  12
2  // Calculating  mass  flow  of  steam  in  tank
3  clear
4  clc
5  V1=0.4  // initial  volume  fo  tank  in  m^3
6  v1=0.5243  // initial  specific  volume  in  m^3/kg
7  h1=3040.4  // initial  specific  enthalpy  in  kJ/kg
8  u1=2548.9  // initial  specific  internal  energy  in  kJ/
       kg
9  m1=V1/v1  // initial  mass  of  steam  in  tank  in  kg
10  V2=0.4  // final  volume  in  m^3
11  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 ,')
12  T2=342  // final  temperature  in  Celsius
13  v2=0.1974  // final  specific  volume  in  m^3/kg
14  m2=V2/v2  // final  mass  of  the  steam  in  the  tank  in  kg
15  m=m2-m1  // mass  of  steam  that  flowsinto  the  tank
16  printf("  \n  Hence , mass  of  the  steam  that  flows  into
       the  tank  is  m=%.3 f  kg.  \n",m)
```

Scilab code Exa 6.13 Calculating mass flow of steam in tank

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

```scilab
 3  clear
 4  clc
 5  vf1=0.001725 //in m^3/kg
 6  vf2=0.0016 //in m^3/kg
 7  uf1=368.7 //in kJ/kg
 8  uf2=226 //in kJ/kg
 9  vg1=0.08313 //in m^3/kg
10  vfg2=0.20381
11  ug1=1341 //in kJ/kg
12  ufg2=1099.7 //in kJ/kg
13  Vf=1 //initial volume of liquid in m^3
14  Vg=1 //initial volume of vapor in m^3
15  mf1=Vf/vf1 //initial mass of liquid in kg
16  mg1=Vg/vg1 //initial mass of vapor in kg
17  m1=mf1+mg1 //initial mass of liquid in kg
18  he=1461.1 //in kJ/kg
19  V=2 //volume of tank in m^3
20  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.')
21  disp('Also,m2*(he-u2)=m1*he-m1u1.From this equation,
       we will get an equation for x2.')
22  x2=((2*1461.1)-(2*226)-(0.00160*634706))
       /((634706*0.20381)+(2*1099.7)) //quality of
       ammonia
23  v2=0.00160+(0.20381*x2) //final specific volume in m
       ^3/kg
24  m2=V/v2 //final mass of ammonia in kg
25  m=m1-m2 //mass of ammonia withdrawn
26  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

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

Scilab code Exa 7.2 Coefficient of performance of refrigerator

```
1  //example 2
2  //coefficient of performance of refrigerator
3  clear
4  clc
5  Qh=400 //heat rejected to kitchen air in W
6  W=150 //electrical input power in W
7  Ql=Qh-W //rate of energy taken out to cold space in
       W
8  B=Ql/W //coefficicent of performnace of refrigerator
9  printf("\n hence,rate of energy taken out of the
       cold space is Ql=%.3f W.\n",Ql)
10 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

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

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

Scilab code Exa 7.5 Calculating required work

```
1 //example 5
2 //calculating required work
3 clear
4 clc
5 Tl=24+273 //room temperature in Kelvins
6 Th=35+273 //atmospheric temperature in Kelvins
7 Ql=4 //rate of heat rejection from room
8 B=Tl/(Th-Tl) //coefficient of performance of air
      conditioner
9 W=Ql/B //required work in kW
10 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

```
1  //example 1
2  //coefficient of performance of refrigerator
3  clear
4  clc
5  Th=60 //temperature at which heat is rejected from R
       -134a
6  Tl=0 //temperature at which heat is absorbed into
       the R-134a
7  s1=1.7262 //specific entropy at 0 Celsius
8  s2=s1 //process of state change from 1-2 is
       isentropic
9  s3=1.2857 //specific entropy at 60 celsius
10 s4=s3 //process of state change from 3-4 is
       isentropic
11 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
       ')
12 P2=1400+(1600-1400)*(1.7262-1.736)/(1.7135-1.736) //
       pressure after compression in kPa
13 B=(Th+273)/(Th-Tl) //coefficient of performance of
       refrigerator
```

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

Scilab code Exa 8.2 Heat transfer in a given process

```
1 //example 2
2 //heat transfer in a given process
3 clear
4 clc
5 u1=87.94 //specific internal energy of R−12 at state
        1 in kJ/kg
6 u2=276.44 //specific internal energy of R−12 at
        state 2 in kJ/kg
7 s1=0.3357 //specific entropy at state 1 in kJ/kg−K
8 s2=1.2108 //specific entropy at state 2 in kJ/kg−K
9 V=0.001 //volume of saturated liquid in mˆ3
10 v1=0.000923 //specific volume in mˆ3/kg
11 m=V/v1 //mass of saturated liquid in kg
12 T=20 //temperature of liquid in celsius
13 Q12=m*(T+273.15)*(s2-s1) //heat transfer in kJ to
        accomplish the process
14 W12=m*(u1-u2)+Q12 //work required to accomplish the
        process
15 printf(" \n hence , work required to accomplish the
        process is W12=%.1f kJ.\n",W12)
16 printf(" \n and heat transfer is Q12=%.1f kJ.\n",Q12
        )
```

Scilab code Exa 8.3 Entropy change

```
1 //example 3
```

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

Scilab code Exa 8.4 Entropy change with different assumptions

```
1 //example 4
2 //entropy change with different assumptions
3 clear
4 clc
5 T1=300 //initial temperature in kelvins
6 T2=1500 //final temperature in kelvins
7 P1=200 //initial pressure in kPa
8 P2=150 //final pressure in kPa
9 R=0.2598 // in kJ/kg–K
10 Cp=0.922 //specific heat in kJ/kg–K at constant
      pressure
11 dsT2=8.0649 //in kJ/kg–K
12 dsT1=6.4168 //in kJ/kg–K
13 dS1=dsT2-dsT1-R*log(P2/P1) //entropy change
      calculated using ideal gas tables
14 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
15 dS3=Cp*log(T2/T1)-R*log(P2/P1) //entropy change
```

```
        assuming  constant  specific  heat  in  kJ/kg-K
16  dS4=1.0767*log(T2/T1)+0.0747 //entropy change
        assuming  specific  heat  is  constant  at  its  value
        at  990K
17  printf("\n hence,change in entropy using ideal gas
        tables  is  dS1=%.4f  kJ/kg-K.\n",dS1)
18  printf("\n hence,change in entropy using empirical
        equation  is  dS2=%.4f  kJ/kg-K.\n",dS2)
19  printf("\n hence,change in entropy using the value
        of  specific  heat  at  300K  is  dS3=%.4f  kJ/kg-K.\n",
        dS3)
20  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

```
1  //example 5
2  //entropy  change
3  clear
4  clc
5  Cp=1.004 //specific  heat  at  constant  pressure  in  kJ/
        kg-K
6  R=0.287 //gas  constant  in  kJ/kg-K
7  P1=400 //initial  pressure  in  kPa
8  P2=300 //final  pressure  in  kPa
9  T1=300 //initial  temperature  in  K
10  T2=600 //final  temperature  in  K
11  dS1=Cp*log(T2/T1)-R*log(P2/P1) //entropy  change
        assuming  constant  specific  heat
12  s1=6.8693 //specific  entropy  at  T1
13  s2=7.5764 //specific  entropy  at  T2
14  dS2=s2-s1-R*log(P2/P1) //entropy  change  assuming
        variable  specific  heat
15  printf("\n hence,entropy change assuming constant
```

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

Scilab code Exa 8.6 Work done by air

```
1  //example 6
2  //work done by air
3  clear
4  clc
5  T1=600 //initial temperature of air in K
6  P1=400 //intial pressure of air in kPa
7  P2=150 //final pressure in kPa
8  u1=435.10 //specific internal energy at temperature
        T1 in kJ/kg
9  sT1=7.5764 //specific entropy at temperature T1 in
        kJ/kg-K
10 R=0.287 //gas constant in kJ/kg-K
11 ds=0
12 sT2=ds+sT1+R*log(P2/P1) //specific entropy at
        temperature T2 in kJ/kg-K
13 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')
14 T2=457 //final temperature in K
15 u2=328.14 //specific internal energy at temperature
        T2 in kJ/kg
16 w=u1-u2 //work done by air in kJ/kg
17 printf("\n hence,work done by air is w=%.2f kJ/kg.\n
        ",w)
```

Scilab code Exa 8.7 Work and heat transfer

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

Scilab code Exa 8.8 Calculating increase in entropy

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

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

Scilab code Exa 8.9 Entropy generation

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

Scilab code Exa 8.10 Determiining the entropy generated

```
1  //example 10
2  //Determiining the entropy generated
3  clear
4  clc
5  B=4 //COP of air conditioner
6  W=10 //power input of air conditioner in kW
7  Qh=B*W //in kW
8  Ql=Qh-W //in kW
9  Thigh=323 //in Kelvin
10 Tlow=263 //in Kelvin
11 SgenHP=(Qh*1000/Thigh)-(Ql*1000/Tlow) //in W/K
12 Tl=281 // in K
```

```
13  Th=294  //in K
14  SgenCV1=Ql*1000/Tlow-Ql*1000/Tl  //in W/K
15  SgenCV2=Qh*1000/Th-Qh*1000/Thigh  //in W/K
16  SgenTOT=SgenCV1+SgenCV2+SgenHP  //in W/K
17  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

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

```
16  he=hf+xe*hfg //final specific heat of enthalpy of
        steam in kJ/kg
17  w=hi+vi^2/(2*1000)-he-ve^2/(2*1000) //work of steam
        for isentropic process in kJ/kg
18  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

```
1  //example 2
2  //exit velocity of steam from nozzle
3  clear
4  clc
5  hi=3051.2 //initial specific heat of enthalpy in kJ/
        kg
6  si=7.1228 //initial specific entropy in kJ/kg−K
7  se=si //final specific entropy
8  Pe=0.3 //final pressure in MPa
9  disp('from steam table, various properties at final
        state are ')
10 he=2780.2 //final specific heat of enthalpy in kJ/kg
        −K
11 Te=159.1 //final temperature in celsius
12 vi=30 //velocity with which steam enters the nozzle
        in m/s
13 ve=((2*(hi-he)+(vi^2/1000))*1000)^0.5 //final
        velocity of steam with which it exits in m/s
14 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

```
1  //example 3
```

```
2  // violation  of  second  law
3  clear
4  clc
5  disp ( ' from  R−134a  tables ')
6  se =1.7148  // specific  entropy  in  final  state  in  kJ/kg
       −K
7  si =1.7395  // initial  specific  entropy  in  kJ/kg−K
8  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

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

Scilab code Exa 9.5 Entropy generation

```
1  // example  5
```

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```
2  //entropy generation
3  clear
4  clc
5  h1=2865.54 //specific heat of enthalpy at state 1 in
       kJ/kg
6  h2=83.94 //specific heat of enthalpy  at state 2 in
      kJ/kg
7  h3=2725.3 //specific heat of enthalpy at state 3 in
      kJ?kg
8  s1=7.3115 //specific entropy at state 1 in kJ/kg−K
9  s2=0.2966 //specific entropy at state 2 in kJ/kg−K
10 s3=6.9918 //specific entropy at state 3in kJ/kg−K
11 m1=2 //mass flow rate at state 1 in kg/s
12 m2=m1*(h1-h3)/(h3-h2) //mass flow rate at state 2 in
       kg/s
13 m3=m1+m2 //mass flow rate at state 3 in kg/s
14 Sgen=m3*s3-m1*s1-m2*s2 //entropy generation in the
      process
15 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

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

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

Scilab code Exa 9.7 Work required to pump water isentropically

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

Scilab code Exa 9.8 Velocity in exit flow

```
1  // example  8
2  // Velocity  in  exit  flow
3  clear
```

```
 4 clc
 5 disp('From Steam Tables, for liquid water at 20 C')
 6 vf=0.001002 //in m^3/kg
 7 v=vf
 8 Pi=300 //Line pressure in kPa
 9 Po=100 //in kPa
10 Ve=(2*v*(Pi-Po)*1000)^0.5 //velocity in the exit
       flow
11 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

```
 1 //example 9
 2 //Rate of Entropy Generation
 3 clear
 4 clc
 5 disp('From R-410a tables ,we get')
 6 hi=280.6 //in kJ/kg
 7 he=307.8 //in kJ/kg
 8 si=1.0272 //in kJ/kg
 9 se=1.0140 //in kJ/kg
10 m=0.08 //flow rate of refrigerant in kg/s
11 P=3 //electrical power input in kW
12 Qcv=m*(he-hi)-P //in kW
13 To=30 //in Celsius
14 Sgen=m*(se-si)-Qcv/(To+273.2) //rate of entropy
       generation
15 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

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

Scilab code Exa 9.11 Turbine inlet pressure

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

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

Scilab code Exa 9.12 Required work input

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

Chapter 10

Availibility

Scilab code Exa 10.1 Calculating reversible work

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

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

Scilab code Exa 10.2 Calculating reversible work

```
1  //example 2
2  //Calculating reversible work
3  clear
4  clc
5  //Form the Steam Tables, the inlet and the exit state
          properties are
6  hi=298.6 //initial specific heat of enthalpy in kJ/
       kg
7  si=6.8631 //initial specific entropy in kJ/kg-K
8  se=7.4664 //final specific entropy in kJ/kg-K
9  he=544.7 //final specific heat of enthalpy in kJ/kg-
       K
10 q=-50 //heat lost to surroundings in kJ/kg
11 w=hi-he+q //work in kJ/kg
12 To=25+273.2 //Temp. of the surroundings in K
13 P1=100 //Pressure of ambient air in kPa
14 P2=1000 //Final pressure of air after compression in
        kPa
15 R=0.287 //Universal gas constant in kJ/kg-K
16 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
17 i=wrev-w //irreversibility in kJ/kg
18 printf(" \n Hence, the irreversibility is i=%.1f kJ/
       kg. \n",i)
```

Scilab code Exa 10.3 Calculating reversible work and irreversibility

```scilab
1  //example 3
2  //Calculating reversible work and irreversibility
3  clear
4  clc
5  //Form the Steam Tables at state 1
6  u1=1243.5 //initial specific internal energy in kJ/
       kg
7  s1=4.4819 //initial specific entropy in kJ/kg-K
8  v1=28.895 //initial specific volume in m^3/kg
9  v2=2*v1 //final specific volume in kg/m^3
10 u2=u1 //initial specific internal energy in kJ/kg
11 //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
12 T2=9.1+273.2 //final temp. in K
13 x2=0.513 //quality in final state
14 s2=4.644 //final specific entropy in kJ/kg
15 V1=1 //volume of part of A in m^3
16 m=V1/v1  //mass flow rate in kg/s
17 To=20+273.2 //Room temperature in K
18 Wrev=To*m*(s2-s1) //reversible work in kJ
19 I=Wrev //irreversibility of the process
20 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

```
1  //Ques 1
2  //To determine the efficiency of Rankine cycle
3  clc
4  clear
5  //1-Inlet state of pump
6  //2-Exit state of pump
7  P2=2000;//Exit pressure in kPa
8  P1=10;//Inlet pressure in kPa
9  v=0.00101;//specific weight of water in m^3/kg
10 wp=v*(P2-P1);//work done in pipe in kJ/kg
11 h1=191.8;//Enthalpy in kJ/kg from table
12 h2=h1+wp;//enthalpy in kJ/kg
13 //2-Inlet state for boiler
14 //3-Exit state for boiler
15 h3=2799.5;//Enthalpy in kJ/kg
16 //3-Inlet state for turbine
17 //4-Exit state for turbine
18 //s3=s4(Entropy remain same)
19 s4=6.3409;//kJ/kg
```

```
20 sf =0.6493;//Entropy at liquid state in kJ/kg
21 sfg=7.5009;//Entropy difference for vapor and liquid
      state in kJ/kg
22 x4=(s4-sf)/sfg;//x-factor
23 hfg=2392.8;//Enthalpy difference in kJ/kg for
     turbine
24 h4=h1+x4*hfg;//Enthalpy in kJ/kg
25
26 nth=((h3-h2)-(h4-h1))/(h3-h2);
27 printf('Percentage efficiency = %.1f ',nth*100);
```

Scilab code Exa 11.2 To determine the efficiency of Rankine cycle

```
1 //Ques 2
2 //To determine the efficiency of Rankine cycle
3 clc
4 clear
5 //1-Inlet state of pump
6 //2-Exit state of pump
7 P2=4000;//Exit pressure in kPa
8 P1=10;//Inlet pressure in kPa
9 v=0.00101;//specific weight of water in m^3/kg
10 wp=v*(P2-P1);//work done in pipe in kJ/kg
11 h1=191.8;//Enthalpy in kJ/kg from table
12 h2=h1+wp;//enthalpy in kJ/kg
13 //2-Inlet state for boiler
14 //3-Exit state for boiler
15 h3=3213.6;//Enthalpy in kJ/kg from table
16 //3-Inlet state for turbine
17 //4-Exit state for turbine
18 //s3=s4(Entropy remain same)
19 s4=6.7690;//Entropy in kJ/kg from table
20 sf=0.6493;//Entropy at liquid state in kJ/kg from
      table
21 sfg=7.5009;//Entropy difference for vapor and liquid
```

```
         state  in  kJ/kg  from  table
22  x4=(s4-sf)/sfg;//x-factor
23  hfg=2392.8;//Enthalpy  difference  in  kJ/kg  for
        turbine
24  h4=h1+x4*hfg;//Enthalpy  in  kJ/kg
25
26  nth=((h3-h2)-(h4-h1))/(h3-h2);
27  printf('Percentage  efficiency  =  %.1f  ',nth*100);
```

Scilab code Exa 11.3 To determine the efficiency of a cycle

```
1  //Ques  3
2  //To  determine  the  efficiency  of  a  cycle
3  clc
4  clear
5  //1-Inlet  state  of  pump
6  //2-Exit  state  of  pump
7  P2=4000;//Exit  pressure  in  kPa
8  P1=10;//Inlet  pressure  in  kPa
9  v=0.00101;//specific  weight  of  water  in  m^3/kg
10  wp=v*(P2-P1);//work  done  in  pipe  in  kJ/kg
11  h1=191.8;//Enthalpy  in  kJ/kg  from  table
12  h2=h1+wp;//enthalpy  in  kJ/kg
13  //2-Inlet  state  for  boiler
14  //3-Exit  state  for  Boiler
15  h3=3213.6;//Enthalpy  in  kJ/kg  from  table
16  //3-Inlet  state  for  high  pressure  turbine
17  //4-Exit  state  for  high  pressure  turbine
18  //s3=s4(Entropy  remain  same)
19  s4=6.7690;//Entropy  in  kJ/kg  from  table
20  sf=1.7766;//Entropy  at  liquid  state  in  kJ/kg  from
        table
21  sfg=5.1193;//Entropy  difference  for  vapor  and  liquid
         state  in  kJ/kg  from  table
22  x4=(s4-sf)/sfg;//x-factor
```

```
23  hf =604.7// Enthalpy of liquid state in kJ/kg
24  hfg =2133.8;// Enthalpy difference in kJ/kg for
        turbine
25  h4=hf+x4*hfg ;// Enthalpy in kJ/kg
26  //5−Inlet state for low pressure turbine
27  //6−Exit pressure for low pressure turbine
28  sf =0.6493;// Entropy in liquid state in kJ/kg for
        turbine
29  h5 =3273.4;// enthalpy in kJ/kg
30  s5 =7.8985;// Entropy in kJ/kg
31  sfg =7.5009;// entropy diff in kJ/kg
32  x6 =(s5-sf)/sfg ;//x−factor
33  hfg =2392.8;// enthalpy difference for low pressure
        turbine in kj/kg
34  h6=h1+x6*hfg ;// entropy in kg/kg
35  wt =(h3-h4)+(h5-h6);// work output in kJ/kg
36  qh =(h3-h2)+(h5-h4);
37
38  nth =(wt-wp)/qh;
39  printf('Percentage efficiency = %.1f ',nth*100);
```

Scilab code Exa 11.4 Efficiency of Refrigeration cycle

```
1  // ques4
2  // Efficiency of Refrigeration cycle
3  clc
4  clear
5  //from previous examples
6  h1 =191.8;//kJ/kg
7  h5 =3213.6;//kg/kg
8  h6 =2685.7;//kJ/kg
9  h7 =2144.1;//kJ/kg
10  h3 =604.7;//kJ/kg
11  //1−Inlet state of pump
12  //2−Exit state of pump
```

```
13  P2 =400;// Exit  pressure  in  kPa
14  P1 =10;    // Inlet  pressure  in  kPa
15  v =0.00101;// specific  weight  of  water  in  m^3/kg
16  wp1 = v *( P2 - P1 ) ;// work  done  for  low  pressure  pump  in
         kJ / kg
17  h1 =191.8;// Enthalpy  in  kJ/kg  from  table
18  h2 = h1 + wp1 ;// enthalpy  in  kJ/kg
19  //5− Inlet  state  for  turbine
20  //6,7− Exit  state  for  turbine
21  y =( h3 - h2 ) /( h6 - h2 ) ;// extraction  fraction
22  wt =( h5 - h6 ) +(1 - y ) *( h6 - h7 ) ;// turbine  work  in  kJ/kg
23  //3− Inlet  for  high  pressure  pump
24  //4− Exit  for  high  pressure  pump
25  P3 =400;// kPa
26  P4 =4000;// kPa
27  v =0.001084;// specific  heat  for  3−4  process  in  m^3/kg
28  wp2 = v *( P4 - P3 ) ;// work  done  for  high  pressure  pump
29  h4 = h3 + wp2 ;// Enthalpy  in  kJ/kg
30  wnet = wt -(1 - y ) * wp1 - wp2 ;
31  qh = h5 - h4 ;// Heat  output  in  kJ/kg
32  nth = wnet / qh ;
33  printf ( ' Refrigerator  Efficiency  = %.1 f  ',nth *100);
```

Scilab code Exa 11.5 To determine thermal efficiency of cycle

```
1  // ques5
2  // To  determine  thermal  efficiency  of  cycle
3  clear
4  clc
5  //5− Inlet  state  for  turbine
6  //6− Exit  state  for  turbine
7  //h− Enthalpy  at  a  state
8  //s− Entropy  at  a  state
9  // from  steam  table
10 h5 =3169.1;// kJ/kg
```

```
11  s5=6.7235; //kJ/kg
12  s6s=s5;
13  sf=0.6493; //Entropy for liquid state in kJ/kg
14  sfg=7.5009; //Entropy difference in kJ/kg
15  hf=191.8; //kJ/kg
16  hfg=2392.8; //Enthalpy difference in kJ/kg
17  x6s=(s6s-sf)/sfg; //x-factor
18  h6s=hf+x6s*hfg; //kJ/Kg at state 6s
19  nt=0.86; //turbine efficiency given
20  wt=nt*(h5-h6s);
21  //1-Inlet state for pump
22  //2-Exit state for pump
23  np=0.80; //pump efficiency given
24  v=0.001009; //specific heat in m^3/kg
25  P2=5000; //kPa
26  P1=10; //kPa
27  wp=v*(P2-P1)/np; //Work done in pump in kJ/kg
28  wnet=wt-wp; //net work in kJ/kg
29  //3-Inlet state for boiler
30  //4-Exit state for boiler
31  h3=171.8; //in kJ/kg from table
32  h4=3213.6; //kJ/kg from table
33  qh=h4-h3;
34  nth=wnet/qh;
35  printf('Cycle Efficiency = %.1f ',nth*100);
```

Chapter 12

Power and Refrigeration Systems gaseous working fluids

Scilab code Exa 12.1 Standard brayton cycle

```
1  //ques1
2  //Standard brayton cycle
3  clc
4  clear
5  //1-Inlet for compressor
6  //2-Exit for compressor
7  //T-Temperature at a state
8  //P-Pressure at a state
9  T1=288.2;//K
10 P2=1000;//kPa
11 P1=100;//kPa
12 k=1.4;
13 T2=T1*(P2/P1)^(1-1/k);//K
14 Cp=1.004;//Specific heat at constant pressure in kJ/
      kg
15 wc=Cp*(T2-T1);//compressor work in kJ/kg;
16 printf('Temperature T2 = %.1f K\n',T2);
17 printf(' Compressor work = %.1f kJ/kg \n',wc);
18 //3-Turbine Inlet
```

```
19  //4−Turbine  Exit
20  P4=P1;
21  P3=P2;
22  T3=1373.2;//K
23  T4=T3*(P4/P3)^(1-1/k);//K
24  wt=Cp*(T3-T4);
25  wnet=wt-wc;
26  printf('  Temperature  T3  =  %.1f  K\n',T3);
27  printf('  Temperature  T4  =  %.1f  K\n',T4);
28  printf('  Turbine  work  =  %.1f  kJ/kg\n',wt);
29  printf('  Net  work  =  %.1f  kJ/kg\n',wt-wc);
30  //2−Also  high  temperature  heat  exchanger  Inlet
31  //3−(−do−)  Exit
32  qh=Cp*(T3-T2);//Heat  of  source  in  kJ/kg
33  //4−high  temp  heat  exchanger  inlet
34  //1−(−do−)  Exit
35  ql=Cp*(T4-T1);//Heat  of  sink  in  kJ/kg
36  nth=wnet/qh;
37  printf('  Thermal  Efficiency  of  cycle  =  %.1f  percent'
        ,nth*100);
```

Scilab code Exa 12.2 Standard brayton cycle

```
 1  //Calculation  mistake  in  book
 2  //ques2
 3  //Standard  brayton  cycle
 4  clc
 5  clear
 6  //Calculation  mistake  in  book
 7  //1−Inlet  for  compressor
 8  //2−Exit  for  compressor
 9  //T−Temperature  at  a  state
10  //P−Pressure  at  a  state
11  T1=288.2;//K
12  P2=1000;//kPa
```

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```scilab
13  P1=100;//kPa
14  k=1.4;
15  T2s=T1*(P2/P1)^(1-1/k);//K
16  nc=.80;//Compressor Efficiency
17  T2=T1+(T2s-T1)/0.80;
18  Cp=1.004;//Specific heat at constant pressure in kJ/
        kg
19  wc=Cp*(T2-T1);//compressor work in kJ/kg;
20  printf('Temperature T2 = %.1f K\n',T2);
21  printf(' Compressor work = %.1f kJ/kg \n',wc);
22  //3-Turbine Inlet
23  //4-Turbine Exit
24  P4=P1;
25  P3=P2;
26  T3=1373.2;//K
27  T4s=T3*(P4/P3)^(1-1/k);//K
28  nt=0.85;//turbine Efficiency
29  T4=T3-(T3-T4s)*0.85;
30  wt=Cp*(T3-T4);
31  wnet=wt-wc;
32  printf(' Temperature T3 = %.1f K\n',T3);
33  printf(' Temperature T4 = %.1f K\n',T4);
34  printf(' Turbine work = %.1f kJ/kg\n',wt);
35  printf(' Net work = %.1f kJ/kg\n',wt-wc);
36  //2-Also high temperature heat exchanger Inlet
37  //3-(-do-) Exit
38  qh=Cp*(T3-T2);//Heat of source in kJ/kg
39  //4-high temp heat exchanger inlet
40  //1-(-do-) Exit
41  ql=Cp*(T4-T1);//Heat of sink in kJ/kg
42  nth=wnet/qh;
43  printf(' Thermal Efficiency of cycle = %.1f percent '
        ,nth*100);
```

Scilab code Exa 12.3 efficiency of the cycle

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

Scilab code Exa 12.4 Calculation of work in the given cycle

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

Scilab code Exa 12.5 air standard cycle for jet repulsion

```
1  //ques5
2  //air standard cycle for jet repulsion
3  clear
4  clc
5  //1−compressor inlet
6  //2−Compressor exit
7  //P−Pressure at given point
8  //T−Temperature at given point
9  P1=100;//kPa
10 P2=1000;//kPa
11 T1=288.2;//K
12 T2=556.8;//K
13 wc=269.5;//from ex 12.1 work done in compressor in
     kJ/kg
14 //2−Burner inlet
15 //3−Burner exit
16 P3=1000;//kPa
17 T3=1373.2;//K
18 //wc=wt
19 Cp=1.004;//specific enthalpy of heat at constant
     pressure in kJ/kg
20 k=1.4;
21 T4=T3-wc/Cp;
22 P4=P3*(T4/T3)^(1-1/k);
23 //from s4=s5 and h4=h5+v2/2 we get
24 T5=710.8//K, from second law
25 v=sqrt(2*Cp*1000*(T4-T5));//m/s
26 printf('Velocity of air leaving the nozel = %.0f m/s
     ',v);
```

Scilab code Exa 12.6 air standard refrigeration cycle

```
1  //ques6
2  //air standard refrigeration cycle
3  clear
```

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```
4  clc
5  //1−compressor inlet
6  //2−compressor exit
7  P1=100;//kPa
8  P2=500;//kPa
9  k=1.4;
10 rp=P2/P1;
11 cop=(rp^(1-1/k)-1)^-1;
12 printf('Coefficient of performance = %.3f \n',cop);
13 //3−Expander inlet
14 //4−Expander exit
15 P3=P2;
16 P4=P1;
17 T3=288.23;//K, given and fixed
18 T4=T3/(P3/P4)^(1-1/k);
19 T1=253.2;//K, given
20 Cp=1.004;//Specific heat at cons pressure in kJ/kg
21 ql=Cp*(T1-T4);//heat released in kJ/kg
22 P=1//power required in kW
23 ms=P/ql;//kg/s
24 printf(' Rate at which the air enter the compressor
       = %.3f kg/s ',ms);
```

Scilab code Exa 12.7 the otto cycle

```
1  //ques7
2  //the otto cycle
3  clear
4  clc
5  //1−compressor inlet
6  //2−compressor exit
7  P1=100;//kPa
8  T1=288.2;//K
9  R=0.287;//gas constant
10 v1=R*T1/P1;//specific volume at inlet in m^3/kg
```

```scilab
11  rv=10;//compression ratio given
12  k=1.4;//constant
13  T2=T1*rv^(k-1);//K
14  printf('Temperature at compressor exit, T2 = %.1f K
        \n',T2);
15  P2=P1*rv^k;//kPa
16  printf(' Pressure at compressor exit, P2 = %.3f MPa
        \n ',P2/1000);
17  v2=v1/rv;//specific heat at exit in m^3/kg
18  //23-heat addition process
19  //q23=Cv*(T3-T2)=1800 kJ/kg given
20  q23=1800;//kJ/kg heat addition, given
21  Cv=0.717;//specific heat at constant volume in kJ/kg
22  T3=T2+q23/Cv;//K
23  printf('\n Initial Temperature during heat additon
        process, T3 = %.0f K \n',T3);
24  P3=P2*(T3/T2);//kPa
25  printf( ' Initial pressure during heat addition
        process, P3 = %.3f MPa \n',P3/1000);
26  r=10;//k=V4/V3=P3/P4
27  T4=T3*(1/r)^(k-1);
28  printf(' \n Final temperature during heat addition
        process, T4 = %.1f K \n',T4);
29  P4=P3/r^k;//kPa
30  printf(' Final pressure during heat addition process
        , P4 = %.4f MPa \n',P4/1000);
31  nth=1-1/r^k;//thermal efficiency
32  printf('\n Thermal efficiency = %.1f percent \n',nth
        *100);
33  q41=Cv*(T1-T4);///heat for process 4-1 in kJ/kg
34  wnet=q23+q41;
35  mep=wnet/(v1-v2);//effective mean pressure n kPa
36  printf('\n Mean effective pressure = %.0f kPa \n',
        mep);
```

Scilab code Exa 12.8 the diesel cycle

```scilab
1  //ques7
2  //the diesel cycle
3  clear
4  clc
5  //1-compressor inlet
6  //2-compressor exit
7  P1=100;//kPa
8  T1=288.2;//K
9  R=0.287;//gas constant
10 v1=R*T1/P1;//specific volume at inlet in m^3/kg
11 rv=20;//compression ratio given
12 k=1.4;//constant
13 T2=T1*rv^(k-1);//K
14 printf('Temperature at compressor exit, T2 = %.1f K
       \n',T2);
15 P2=P1*rv^k;//kPa
16 printf(' Pressure at compressor exit, P2 = %.3f MPa
       \n ',P2/1000);
17 v2=v1/rv;//specific heat at exit in m^3/kg
18 //23-heat addition process
19 //q23=Cv*(T3-T2)=1800 kJ/kg given
20 q23=1800;//kJ/kg heat addition, given
21 Cv=.717;
22 Cp=1.004;//specific heat at constant pressure in kJ/
       kg
23 T3=T2+q23/Cp;//K
24 printf('\n Initial Temperature during heat addition
        process, T3 = %.0f K \n',T3);
25 r=T3/T2;//T3/T2=V3/V2=r
26 v3=r*v2;
27 T4=T3/(v1/v3)^(k-1);
28 printf(' Final temperature during heat addition
        process, T4 = %.0f K \n',T4);
29 q41=Cv*(T1-T4);///heat for process 4-1 in kJ/kg
30 wnet=q23+q41;
31 mep=wnet/(v1-v2);//effective mean pressure in kPa
```

```
32  qh=1800;//heat transfer in kJ/kg
33  nth=wnet/qh;//thermal efficiency
34
35  printf('\n Thermal efficiency = %.1f percent \n',nth
        *100);
36  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 vapor

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

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

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

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

```
1  //ques5
2  //calculating heat transfer per kilogram of dry air
3  clear
4  clc
5  //1-inlet state
6  //2-Exit state
7  r1=0.80;//realtive humidity at state 1
8  Pg1=4.246;//saturation pressure of vapour in kPa
9  P1=105;//net pressure at state 1 in kPa
10 P2=100;//net pressure at state 2 in kPa
11 Pv1=r1*Pg1;//partial pressure of vapour in kPa
12 w1=0.622*Pv1/(P1-Pv1);//humidity ratio at state 1
13 r2=0.95;//relative humidity at state 2
```

```
14  Pg2=1.7051; // saturation pressure of vapour in kPa
15  Pv2=r2*Pg2; // partial pressure of vapour in kPa
16  w2=0.622*Pv2/(P2-Pv2); // humidity ratio at state 2
17  T1=30; //C
18  T2=15; //C
19  Cp=1.004; // specific heat of water vapour in kJ/kg
20  hv2=2528.9; // enthalpy of vapourisation of vapour in
        kJ/kg
21  hv1=2556.3; // enthalpy of vapourisation of vapour in
        kJ/kg
22  hl2=62.99; // enthalpy of
23  q=Cp*(T2-T1)+w2*hv2-w1*hv1+hl2*(w1-w2); //kJ/kg
24  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

```
1  //ques6
2  //calculating heat transferred in gas vapour mixture
3  clear
4  clc
5  //n-Nitrogen
6  //v-water vapour
7  Pn2=1995; // Pressure of nitrogen in kPa
8  V=0.5; // Volume in m^3
9  Rn2=0.2968; // Gas constant for nitrogen in kJ/kg.K
10 Rv=0.4615; // gas constant for vapour
11 T1=323.2; // Temperature in K
12 T2=283.2; // Temperature in K
13 Pv1=5; // Pressure of water vapour in kPa at state 1
14 Pv2=1.2276; // Pressure of water vapour in kPa at
        state 2
15 mn2=Pn2*V/(Rn2*T1); // mass of nitrogen
16 mv1=Pv1*V/(Rv*T1); // mass of vapour in kg
17 mv2=Pv2*V/(Rv*T2); // mass of vapour in kg
```

```
18  ml2=mv1-mv2;//mass of liquid condensed n kg
19  uv1=2443.1;//specific internal energy of vapour in
        kJ/kg at state 1
20  uv2=2389.2;//specific internal energy of vapour in
        kJ/kg at state 2
21  ul2=42.0;//specific internal energy of liquid water
        in kJ/kg
22  Cv=0.745;//specific heat at constant volume in kJ/kg
        .K
23  Q=mn2*Cv*(T2-T1)+mv2*uv2+ml2*ul2-mv1*uv1;
24  printf('Heat transferred = %.1f kJ ',Q);
```

Scilab code Exa 13.7 calculating humidity ratio and relative humidity

```
1  //ques7
2  //calculating humidity ratio and relative humidity
3  clear
4  clc
5  //1-Inlet state
6  //2-Exit state
7  P=100;//net pressure n kPa
8  //it is steady state adiabatic process
9  //water vapour leaving is saturated so Pv2=Pg2
10  Pg2=2.339;//saturation pressure of vapour in kPa
11  Pv2=Pg2;//partial pressure of vapour
12  w2=0.622*Pv2/(P-Pg2);
13  Cpa=1.004;//specific heat n kJ/kg/K
14  T2=20;// final temp in C
15  T1=30;// initial temp in C
16  Hfg2=2454.1;//specific heat difference at state 2 in
        kJ/kg
17  hv1=2556.3;//enthalpy of water vapour at state 1 in
        kJ/kg
18  hl2=83.96;//enthalpy of liquid water in kJ/kg
19  w1=(Cpa*(T2-T1)+w2*Hfg2)/(hv1-hl2);
```

```scilab
20  printf('Relative humidity = %.4f \n',w1);
21  //also w1=0.622*Pv1/(100-Pv2)
22  Pv1=100*w1/(0.622+w1);
23  Pg1=4.246;//saturation pressure at state 1 in kPa
24  r=Pv1/Pg1;//humidity ratio
25  printf(' Humidity ratio = %.3f ',r);
```

Chapter 14

Thermodynamics Property Relations

Scilab code Exa 14.1 to determine the sublimation pressure of water

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

Scilab code Exa 14.4 Volume expansivity Isothermal and Adiabatic compressibility

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

Scilab code Exa 14.5 adiabatic steady state processes

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

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

Scilab code Exa 14.6 isothermal steady state processes

```
1  // ques6
2  // isothermal steady state processes
3  clear
4  clc
5  // from table A.2
6  P1=8;// pressure at state 1 in MPa
7  P2=0.5;// pressure at state 2 in MPa
8  T1=150;// Temperature at state 1 in K
9  Pr1=P1/3.39;// Reduced pressure at state 1
10 Pr2=P2/3.39;// Reduced pressure at state 2
11 Tr1=T1/126.2;// Reduced temperature
12 T2=125;// temperature at state 2
13 // from compressibility chart h1∗−h1=2.1∗R∗Tc
14 // from zero pressure specific heat data h1∗−h2∗=Cp∗(
      T1a−T2a)
15 // h2∗−h2=0.5∗R∗Tc
16 // this gives dh=h1−h2=−2.1∗R∗Tc+Cp∗(T1a−T2a)+0.15∗R∗
      Tc
17 R=0.2968;// gas constant for given substance
18 Tc=126.2;//K, Constant temperature
```

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

Scilab code Exa 14.7 percent deviation using specific volume calculated by kays rule and vander waals rule

```
1 //ques7
2 //percent deviation using specific volume calculated
      by kays rule and vander waals rule
3 clear
4 clc
5 //a-denotes C02
6 //b-denotes CH4
7 T=310.94;//Temperature of mixture K
8 P=86.19;//Pressure of mixture in MPa
9 //Tc- critical Temperature
10 //Pc-critical pressure
11 Tca=304.1;//K
12 Tcb=190.4;//K
13 Pca=7.38;//MPa
14 Pcb=4.60;//MPa
15 Ra=0.1889;//gas constant for a in kJ/kg.K
16 Rb=0.5183;//gas constant for b in kJ/kg.K
17 xa=0.8;//fraction of CO2
18 xb=0.2;//fraction of CH4
```

```scilab
19  Rm=xa*Ra+xb*Rb;//mean gas constant in kJ/kg.K
20  Ma=44.01;//molecular mass of a
21  Mb=16.043;//molecular mass of b
22  //1.Kay's rule
23  ya=xa/Ma/(xa/Ma+xb/Mb);//mole fraction of a
24  yb=xb/Mb/(xa/Ma+xb/Mb);//mole fraction of b
25  Tcm=ya*Tca+yb*Tcb;//mean critical temp in K
26  Pcm=ya*Pca+yb*Tcb;//mean critical pressure n MPa
27  //therefore pseudo reduced property of mixture
28  Trm=T/Tcm;
29  Prm=P/Pcm;
30  Zm=0.7;//Compressiblity from generalised
        compressibility chart
31  vc=Zm*Rm*T/P/1000;//specific volume calculated in m
        ^3/kg
32  ve=0.0006757;//experimental specific volume in m^3/
        kg
33  pd1=(ve-vc)/ve*100;//percent deviation
34  printf('Percentage deviation in specific volume
        using Kays rule = %.1f percent \n',pd1);
35
36  //2. using vander waals equation
37  //values of vander waals constant
38  Aa=27*Ra^2*Tca^2/(64*Pca*1000);
39  Ba=Ra*Tca/(8*Pca*1000);
40  Ab=27*Rb^2*Tcb^2/(64*Pcb*1000);
41  Bb=Rb*Tcb/(8*Pcb*1000);
42  //mean vander waals constant
43  Am=(xa*sqrt(Aa)+xb*sqrt(Ab))^2;
44  Bm=(xa*Ba+xb*Bb);
45  //using vander waals equation we get cubic equation
46  //solving we get
47  vc=0.0006326;//calculated specific volume in m^3/kg
48  pd2=(ve-vc)/ve*100;
49  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

```
1 // ques1
2 // theoratical air−fuel ratio for combustion of
       octane
3 clear
4 clc
5 rm=(12.5+47.0)/1;// air fuel ratio on mole basis
6 rma=rm*28.97/114.2;// air fuel ratio on mass basis;
7 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 combustion chamber

```
1 // ques6
2 // determining heat transfer per kilomole of fuel
       entering combustion chamber
3 clear
4 clc
```

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```
5  //1−CH4
6  //2−CO2
7  //3−H2O
8  //hf−standard  enthalpy  of  given  substance
9  hf1=-74.873;//kJ
10 hf2=-393.522;//kJ
11 hf3=-285.830;//kJ
12 Qcv=hf2+2*hf3-hf1;//kJ
13 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 temperature

```
1  //ques7
2  //calculating  enthalpy  of  water  at  given  pressure
       and  temperature
3  clear
4  clc
5  //1.Assuming  steam  to  be  an  ideal  gas  with  value  of
       Cp
6  T1=298.15;//Initial  temperature  in  K
7  T2=573.15;//final  temperature  in  K
8  T=(T1+T2)/2;//average  temperature  in  K
9  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
10 M=18.015;//mass  in  kg
11 dh=M*Cp*(T2-T1);//enthalpy  change  in  kJ/kmol
12 ho=-241.826;//enthalpy  at  standard  temperature  and
       pressure  in  kJ/mol
13 htp1=ho+dh/1000;//enthalpy  at  given  temp  and
       pressure  in  kJ/kmol
14 printf('1.  Enthalpy  of  water  at  given  pressure  and
       temperature  using  value  of  Cp = %.3f  kJ/kmol  \n',
```

```
     htp1 ) ;
15
16  // 2 . . Assuming  steam  to  be  an  i d e a l  gas  with  value
         for  dh
17  dh =9359; // enthalpy  change  from  table  A . 9  in  kJ / mol
18  htp2=ho+dh /1000; // enthalpy  at  given  temp  and
         pressure  in  kJ / kmol
19  printf ( ' 2 . Enthalpy  of  water  at  given  pressure  and
         temperature  assuming  value  od  dh = %.3 f  kJ / kmol  \
         n ' , htp2 ) ;
20
21  // 3 .  Using  steam  table
22  dh=M ∗ (2977.5 -2547.2) ; // enthalpy  change  for  gases  in
         kJ / mol
23  htp3g=dh /1000+ho ;
24  dh=M ∗ (2977.5 -104.9) ; // enthalpy  change  for  liquid  in
         kJ / mol
25  hl = -285.830; // standard  enthalpy  for  liquid  in  kJ /
         kmol
26  htp3l=hl+dh /1000; // enthalpy  at  given  temp  and
         pressure  in  kJ / kmol
27  printf ( ' 3 . ( i )  enthalpy  at  given  temp  and  pressure
         in  kJ / kmol  in  terms  of  liquid = %.3 f  kJ / kmol  \ n ' ,
         htp3l ) ;
28  printf ( ' 3 . ( ii )  enthalpy  at  given  temp  and  pressure
         in  kJ / kmol  in  terms  of  liquid = %.3 f  kJ / kmol  \ n ' ,
         htp3g ) ;
29  // 4 . using  generalised  charts
30  // htp=ho −(h2∗−h2 )+(h2∗−h1∗)+(h1∗−h1 ) ;
31  // h2∗−h2=Z∗R∗Tc ,
32  // h2∗−h1∗=9539  kJ / mol ,  from  part  2
33  // h1∗−h1=0  , as  i d e a l  gas
34  Z=0.21; // from  chart
35  R=8.3145; // gas  constant  in  SI  units
36  Tc=647.3; // c r i t i c a l  temperature  in  K
37  htp4=ho+9539/1000 -Z ∗R∗Tc /1000; // enthalpy  at  given
         temp  and  pressure  in  kJ / kmol
38  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

```
1  //ques15
2  //calculatng reversible elecromotive force
3  clear
4  clc
5  //1-H2O
6  //2-H2
7  //3-O2
8  //hf-standard enthalpy
9  //sf-standard entropy
10 hf1=-285.830;//kJ
11 hf2=0;//kJ
12 hf3=0;//kJ
13 sf1=69.950;//kJ/K
14 sf2=130.678;//kJ/K
15 sf3=205.148;//kJ/K
16 dH=2*hf1-2*hf2-hf3;//change in enthalpy in kJ
17 dS=2*sf1-2*sf2-sf3;//change in entropy in kJ/K
18 T=298.15;//temperature in K
19 dG=dH-T*dS/1000;//change in gibbs free energy in kJ
20 E=-dG*1000/(96485*4);//emf in V
21 printf('Reversible electromotive Force = %.3f V',E);
```

Scilab code Exa 15.17 efficiency of generator and plant

```
1  //ques17
2  //efficiency of generator and plant
3  clear
4  clc
```

```
5  q=325000*(3398.3-856.0);//heat transferred to H2O/kg
       fuel in kJ/kg
6  qv=26700*33250;//higher heating value in kJ/kg
7  nst=q/qv*100;//efficiency of steam generator
8  w=81000*3600;//net work done in kJ/kg
9  nth=w/qv*100;//thermal efficiency
10 printf('Efficiency of generator = %.1f percent\n',
       nst);
11 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

```scilab
1  //ques2
2  //to determine change in gibbs free energy
3  clear
4  clc
5  //1-H2
6  //2-O2
7  //3-H2O
8
9  //at T=298 K
10 T1=298;//K
11 Hf1=0;//Enthalpy of formation of H2 at 298 K
12 Hf2=0;//Enthalpy of formation of O2 at 298 K
13 Hf3=-241.826;//enthalpy of formation of H2O at 298 K
        in kJ
14 dH=2*Hf1+Hf2-2*Hf3;//Change in enthalpy in kJ
15 Sf1=130.678;//Entropy of H2 at 298 K n J/K
16 Sf2=205.148;//Entropy of O2 at 298 K in J/K
17 Sf3=188.834;//entropy of H2O at 298 K in J/K
18 dS=2*Sf1+Sf2-2*Sf3;//Change in entropy in J/K
```

```
19  dG1=dH-T1*dS/1000;//change n gibbs free energy in kJ
20  printf(' Change in gibbs free energy at %.0f K = %.3
        f kJ \n' ,T1,dG1);
21
22  //at T=2000 K
23  T2=2000;//K
24  Hf1=52.942-0;//Enthalpy of formation of H2 at 2000 K
25  Hf2=59.176-0;//Enthalpy of formation of O2 at 2000 K
26  Hf3=-241.826+72.788;//enthalpy of formation of H2O
        at 2000 K in kJ
27  dH=2*Hf1+Hf2-2*Hf3;//Change in enthalpy in kJ
28  Sf1=188.419;//Entropy of H2 at 2000 K n J/K
29  Sf2=268.748;//Entropy of O2 at 2000 K in J/K
30  Sf3=264.769;//entropy of H2O at 2000 K in J/K
31  dS=2*Sf1+Sf2-2*Sf3;//Change in entropy in J/K
32  dG2=dH-T2*dS/1000;//change n gibbs free energy in kJ
33  printf('  Change in gibbs free energy at %.0f K = %
        .3f kJ ' ,T2,dG2);
```

Scilab code Exa 16.3 calculating equilibrium constant

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

```
      ,K1);
13 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

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

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

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

Scilab code Exa 17.5 determining velocity of sound in air

```scilab
1  //ques5
2  //determining velocity of sound in air
3  clear
4  clc
5  k=1.4;//constant
6  R=0.287;//gas constant
7  //at 300K
8  T1=300;//K
9  c1=sqrt(k*R*T1*1000);
10 printf('Speed of sound at %.0f K = %.1f m/s \n',T1,
      c1);
11 T2=1000;//K
```

```
12  c2=sqrt(k*R*T2*1000);
13  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

```
 1  //ques6
 2  //determining mass flow rate through control volume
 3  clear
 4  clc
 5  k=1.4;//constant
 6  R=0.287;//gas constant
 7  To=360;//stagnation Temperature in K
 8  T=To*0.8333;//Temperature of air in K, 0.8333
        stagnation ratio from table
 9  v=sqrt(k*R*T*1000);//velocity in m/s
10  P=528;//stagnation pressure in kPa
11  d=P/(R*T);//stagnation density in kg/m^3
12  A=500*10^-6;//area in m^2
13  ms=d*A*v;//mass flow rate in kg/s
14  printf('Mass flow rate at the throat section = %.4f
        kg/s \n',ms);
15  //e-exit state
16  Te=To*0.9381;//exit temperature in K, ratio from
        table
17  ce=sqrt(k*R*Te*1000);//exit velocity of sound in m/s
18  Me=0.573;//Mach number
19  ve=Me*ce;
20  Pe=800;//exit pressure in kPa
21  de=Pe/R/Te;
22  mse=de*A*ve;
23  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

```
1  //ques7
2  //determining exit properties in a control volume
3  clear
4  clc
5  Po=1000;//stagnation pressure in kPa
6  To=360;//stagnation temperature in K
7
8  //when diverging section acting as nozzle
9  Pe1=0.0939*Po;//exit pressure of air in kPa
10 Te1=0.5089*To;//exit temperature in K
11 k=1.4;//constant
12 R=0.287;//gas constant for air
13 ce=sqrt(k*R*Te1*1000);//velocity of sound in exit
        section in m/s
14 Me=2.197;//mach number from table
15 ve1=Me*ce;//velocity of air at exit section in m/s
16 disp(" When diverging section act as a nozzle :-");
17 printf('Exit pressure  = %.1f kPa \n',Pe1);
18 printf('Exit Temperature = %.1f K \n',Te1);
19 printf('Exit velocity = %.1f m/s \n',ve1);
20
21 //when diverging section act as diffuser
22 Me=0.308;
23 Pe2=0.0936*Po;//exit pressure of air in kPa
24 Te2=0.9812*To;//exit temperature in K
25 ce=sqrt(k*R*Te2*1000);//velocity of sound in exit
        section in m/s
26 ve2=Me*ce;
27 disp(" When diverging section act as a diffuser :-")
        ;
28 printf('Exit pressure  = %.1f kPa \n',Pe2);
29 printf('Exit Temperature = %.1f K \n',Te2);
```

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

Scilab code Exa 17.9 determining exit plane properties in control volume

```
1  //ques9
2  //determining exit plane properties in control
       volume
3  clear
4  clc
5  //x-inlet
6  //y-exit
7  Mx=1.5;//mach number for inlet
8  My=0.7011;//mach number for exit
9  Px=272.4;//inlet pressure in kPa
10 Tx=248.3;//inlet temperature in K
11 Pox=1000;//stagnation pressure for inlet
12 Py=2.4583*Px;//Exit Pressure in kPa
13 Ty=1.320*Tx;//Exit temperature in K
14 Poy=0.9298*Pox;//Exit pressure in kPa
15
16 printf('Exit pressure = %.1f kPa \n',Py);
17 printf(' Exit temperature = %.1f K \n',Ty);
18 printf(' Exit stagnation pressure = %.1f kPa \n',Poy
       );
```