

Scilab Textbook Companion for
Thermodynamics
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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

THERMODYNAMIC CONCEPTS AND THE ZEROTH LAW

Scilab code Exa 2.1 MASS OF PISTON

```
1 clc;  
2 patm = 14.5 ; // atmospheric pressure in psia  
3 pgauge = 2.5; // gauge pressure in psia  
4 A = 10; // Area of the piston in in^2  
5 g=9.80665; // Acceleration due to gravity in m/s^2  
6 p = patm + pgauge; //total pressure of gas  
7 m=(p-patm)*A ; //mass of the piston  
8 disp("lbm",m,"Mass of the piston =", "In English  
    units");  
9 p=(p*0.454*g)/(0.0254^2); // conversion of English  
    unit to SI units  
10 patm=(patm*0.454*g)/(0.0254^2); // conversion of  
    English unit to SI units  
11 m = ((p-patm)*(A*2.54^2*10^-4))/g; // Mass of the  
    piston  
12 disp("kg",m,"Mass of the piston =", "In SI units");
```

Scilab code Exa 2.2 INCLINED MANOMETER

```
1 clc;
2 d_r = 13600; // Density of manometric fluid (mercury
   ) in kg/m^3
3 g = 8.92; // Gravitational acceleration in m/s^2
4 z1=0.589*sind(60); // vertical height of fluid at
   section 1
5 z2=2*sind(30); // vertical height of fluid at
   section 2
6 z=z2-z1; // Difference in vertical heights of fluid
7 patm = 14.7; // Atmospheric pressure in lbf/in^2
8 patm=(patm*4.44822*144/0.3048^2); // conversion of
   lbf/in^2 unit to N/m^2 unit
9 p=patm + (d_r*g*(z2-z1)); // Balance of force at A
10 disp ("m",z,"Difference in vertical heights of fluid
   ");
11 disp ("kPa",p/1000,"The pressure of fluid in the
   vessel");
```

Chapter 3

PROPERTIES OF A PURE SUBSTANCE

Scilab code Exa 3.1 MASS OF WATER AND VAPOUR

```
1  clc;
2  V=0.01; // Volume of water in a rigid vessel in m^3
3  m=4.5; // Mass of water+ steam in a rigid vessel in
      kg
4  T=35; // Temperature of water in a rigid vessel in
      degree celcius
5  // (a)
6  v=V/m; // specific volume of water
7  // From steam table
8  vf=0.001006; vg=25.22; // specific volume in m^3/kg
9  x=(v-vf)/(vg-vf); // Quality of steam
10 x1=1-x; // Quality of water
11 mg=x*m; // Mass of steam
12 mf=x1*m; // Mass of water
13 disp ("kg",mf,"Mass of water in a rigid vessel = ","
      kg",mg,"Mass of steam in a rigid vessel = ",x1,"
      Quality of water in a rigid vessel = ",x,"Quality
      of steam in a rigid vessel = "," (a) ");
14 // (b)
```

```

15 vc=0.003155; // Critical volume for water in m^3/
    kg
16 disp ("The level of liquid water will rise in the
    vessel. Since v < vc and refer figure 3.21", " (b
    ) ");
17 // (c)
18 disp ("The final temperature after heating is 370.04
    oC. Because it is constant volume process and
    refer figure 3.21", " (c) ");
19 // (d)
20 m1=0.45; // Mass of water in kg
21 v1=V/m; // specific volume of water
22 disp ("Level of liquid drops to bottom (v1 > vc).
    Temperature on reaching saturation state is 298.5
    oC and refer figure 3.21", " (d) ");

```

Scilab code Exa 3.2 THE QUALITY OF VAPOUR

```

1 clc;
2 // (a) Ammonia 26 oC and 0.074 m^3/kg
3 // From saturation table of ammonia at 26 oC
4 v=0.074; // specific volume of ammonia in m^3/kg
5 vf=0.001663; vg=0.1245; // specific volume of
    ammonia in m^3/kg
6 x=(v-vf)/(vg-vf); // Quality of vapour since v<vg
7 disp (x,"The Quality of ammonia = ", "(a) Ammonia 26
    oC and 0.074 m^3/kg");
8 // (b).Ammonia 550kPa and 0.31m^3/kg
9 // From saturation table of ammonia at 550 kPa
10 v=0.31; // specific volume of ammonia in m^3/kg
11 vg=0.23; // specific volume of ammonia in m^3/kg
12 // v > vg . Since from superheated table by
    interpolation for 550kPa and v
13 T=82.1; // Temperature of ammonia in degree celcius
14 disp ("oC",T,"Temperature of ammonia = ", "(b)");

```

```

    Ammonia 550kPa and 0.31m3/kg");
15 // (c).Freon 12, 0.35MPa and 0.036 m3/kg
16 // From saturation table of Freon 12 at 0.35MPa
17 v=0.036; // specific volume of Freon 12 in m3/kg
18 vf=0.000722; vg=0.049329; // specific volume of
    Freon 12 in m3/kg
19 x=(v-vf)/(vg-vf); // Quality of vapour since v<vg
20 disp (x,"The Quality of Freon 12 = ", "(c).Freon 12,
    0.35MPa and 0.036 m3/kg");
21 // (d).Methane 0.5MPa and 1.0 m3/kmol
22 v=1; // specific volume of Methane in m3/kmol
23 // From table at 0.5 MPa molar values are
24 vf=0.04153; vg=2.007; // specific volume of Methane
    in m3/kmol
25 x=(v-vf)/(vg-vf); // Quality of vapour since v<vg
26 disp (x,"The Quality of Methane = ", "(d).Methane
    0.5MPa and 1.0 m3/kmol");

```

Scilab code Exa 3.3 MASS OF AIR

```

1 clc;
2 V=300; // Volume of air in the room in m3
3 p=1; // Atmospheric pressure in bar
4 T=25; // Temperature of air in Degree Celcius
5 R=287; // Characteristic constant of Air in J/kg k
6 m=(p*105*V)/(R*(T+273)); // Ideal gas equation
7 disp ("kg",m,"Mass of air in room");

```

Scilab code Exa 3.4 MOLECULAR WEIGHT OF THE GAS

```

1 clc;
2 D=20; // Diameter of the sphere in cm
3 m=2.54; // Mass of gas filled in sphere in gram

```



```

4 p=10; // Pressure of gas in bar
5 T=25; // Temperature of gas in Degree Celcius
6 R=8.3144*10^3; // Universal gas constant in J/kmol K
7 V=(3.14*(D*10^-2)^3)/16; // Volume of das in sphere
   in m^3
8 M=(m*10^-3*R*(T+273))/(p*10^5*V); // Molecular
   weight of the gas
9 disp (M,"Molecular weight of the gas");
10 disp ("Therefore gas in sphere is Helium (unless
   mixture of two or more gases)");

```

Scilab code Exa 3.5 PRESSURE AND TEMPERATURE OF AIR

```

1 clc;
2 p2=2.5; // Pressure of air in the cylinder in bar
3 T1=430; // Temperature of air in cylinder in Degree
   Celcius
4 V1=1.2; // Volume of cylinder in m^3
5 V2=0.6; // Volume of cylinder upto end stops in m^3
6 // (a) Temperature of air when the piston reaches
   the stops
7 T2=(T1+273)*(V2/V1); // constant pressure process
8 disp ("K",T2,"Temperature of air when the piston
   reaches the stops");
9 // (b) The pressure of air when its temperature
   equals to 25 oC
10 T3=25; //Room temperature in Degree Celcius
11 p3=p2*((T3+273)/T2); // constant volume process
12 disp ("bar",p3,"The pressure of air when its
   temperature equals to 25 oC");

```

Scilab code Exa 3.7 DETERMINATION OF SPECIFIC VOLUME

```

1  clc;
2  p=6000; // Pressure of nitrogen gas in kPa
3  T=150; // Temperature of nitrogen gas in kelvin
4  V=250; // Volume of tank in litres
5  R_1=8.3143; // Universal gas constant in kJ/kmol K
6  M=28.1013; // Molecular mass
7  // (a).Beattie – Bridgeman equation of state
8  // Constants for nitrogen gas
9  c=4.2*10^4; Ao=136.2315; a=0.02617; Bo=0.05046; b
    =-0.00691;
10 // By substituting these values in the following
    equation
11 //  $p=(R_1*T/v^2)*(1-(c/(vT^3)))*(v+Bo*(1-(b/v)))-(Ao/v^2*(1-(a/v)))$ 
12 // By trial and error we get
13 v=0.1222; // specific volume in m3/kmol
14 m=(M*V/1000)/v; // Mass of nitrogen gas
15 disp ("m3/kmol",v,"specific volume of nitrogen gas
    = ", "kg",m,"Mass of nitrogen gas = ", "(a).Beattie
    – Bridgeman equation of state");
16 // (b).Nitrogen tables
17 // From property table of nitrogen gas
18 v=0.004413; // specific volume in m3/kg
19 m=(V/1000)/v; // Mass of nitrogen gas
20 disp ("m3/kg",v,"specific volume of nitrogen gas =
    ", "kg",m,"Mass of nitrogen gas = ", "(b).Nitrogen
    tables");
21 // (c).Ideal gas equation of state
22 m=(p*V/1000)/(R_1*T/M); //Mass of nitrogen gas
23 disp ("kg",m,"Mass of nitrogen gas = ", "(c).Ideal
    gas equation of state");
24 // (d).Generalized compressibility chart
25 // The critical properties for nitrogen gas
26 Tc=126.2; // Temperature in kelvin
27 Pc=3.349; // Pressure in MPa
28 // Reduced properties are
29 Pr=p/Pc; Tr=T/Tc;
30 z=0.6; // From chart

```

```

31 m=(p*V/1000)/(z*R_1*T/M); //Mass of nitrogen gas
32 disp ("kg",m,"Mass of nitrogen gas = ",(d).
    Generalized compressibility chart");
33 disp ("Ideal gas equation of state", "Generalized
    compressibility chart", "Beattie – Bridgeman
    equation of state", "Nitrogen tables", (e).
    Arrangement the methods in order of percentage
    error : ");

```

Scilab code Exa 3.8 CALCULATION OF SPECIFIC VOLUME USING REDLICH KWONG EQUATION

```

1  clc;
2  T=-58.7; //Normal boling point of CF3Br in Degree
    Celcius
3  Tc=340.9; // Crittical temperature of CF3Br in K
4  pc=4.05; // Crittical pressure of CF3Br in MPa
5  M=148.9; // Moleclar mass of CF3Br
6  p=1.01325*10^5; // Atmospheric pressure in N/m^2
7  R1=8314.4; // Universal gas constant in J/kmol K
8  R=R1/M; // Gas constant of CF3Br
9  a=(0.42748*R^2*Tc^2.5)/(pc*10^6); // Constant of
    Redlich–Kwong equation of state
10 b=(0.08664*R*Tc)/(pc*10^6); // Constant of Redlich–
    Kwong equation of state
11 vi=(R*(T+273))/p; // Ideal gas volume for assigning
    initial value
12 // By substituting these values in the Redlich–Kwong
    equation of state
13 // vi_1=(R*(T+273)/p)+b-((a/(p*(273+T)^0.5*vi)))
    and and solving it by trial and error method we
    get
14 vi_1=0.11443; // in m^3/kg
15 disp ("m^3/kg",vi_1,"Saturated vapour volume");

```

Chapter 4

WORK AND HEAT

Scilab code Exa 4.1 CALCULATION OF WORKDONE DURING POLYTROPIC PROCESS

```
1  clc ;
2  p1=5; // Pressure of Helium gas at initial state in
      bar
3  T1=222; // Temperature of Helium gas at initial
      state in K
4  V1=0.055; // Volume of Helium gas at initial state
      in m^3
5  n=1.5; // Index of expansion process
6  R=2.078; // Characteristic gas constant of Helium gas
      in kJ/kg K
7  p2=2; // Pressure of Helium gas at final state (
      after expansion) in bar
8  disp ("Method I");
9  V2=V1*(p1/p2)^(1/n); // From Polytropic process
      relation for final volume
10 W=((p2*10^2*V2)-(p1*10^2*V1))/(n-1); // Work done
      from Polytropic process relation
11 disp ("kJ",W,"Work done =");
12 disp ("Method II");
13 m=(p1*10^2*V1)/(R*T1); // ideal gas equation
14 T2=T1*(p2/p1)^((n-1)/n); // From Polytropic process
```

```

relation of final temperature
15 W=(m*R*(T1-T2))/(1-n); // Work done from Polytropic
process relation
16 disp ("kJ",W,"Work done =");

```

Scilab code Exa 4.3 CALCULATION OF WORKDONE

```

1 clc;
2 p1=1.3; // Initial pressure of gas in bar
3 V1=0.03; // Initial volume of gas in m^3
4 V2=0.1; // Final volume of gas in m^3
5 disp ("(a). Constant pressure process");
6 W=p1*10^2*(V2-V1); // work done by gas
7 disp("kJ",W,"work done by gas =");
8 disp ("(b). Constant Temperature process");
9 W=p1*10^2*V1*log(V2/V1); // Work done by gas
10 disp("kJ",W,"work done by gas =");
11 disp ("(c). polytropic process of index 1.3");
12 n=1.3; //index of polytropic process
13 p2=p1*(V1/V2)^n; // From Polytropic process relation
for final pressure
14 W=((p2*10^2*V2)-(p1*10^2*V1))/(1-n); // Work done by
gas
15 disp("kJ",W,"work done by gas =");

```

Scilab code Exa 4.4 FREE EXPANSION OF FREON 12

```

1 clc;
2 patm=1; // Atmospheric pressure in bar
3 V1=0.0135; // Volume of Freon 12 at initial state in
m^3
4 D=9; // Diameter of the cylinder in cm
5 m=90; // Mass of the piston in kg

```

```

6 g=9.80665; // acceleration due to gravity in m/s^2
7 // (a). Determination of the final pressure and
  volume of the system
8 A=%pi/4 * (D*10^-2)^2; // Area of the cylinder
9 p1=0.7449; // Initial pressure of saturated vapour
  at 30 degree celcius in MPa
10 v1=0.023508; // Initial specific volume of saturated
  vapour at 30 degree celcius in m^3/kg
11 p2=(patm*10^5)+(m*g)/A; // Final pressure of Freon
  12
12 v2=0.084022; // Final specific volume from
  superheated table at p2 and 30 degree celcius in
  m^3/kg
13 mf=V1/v1; // Mass of Freon 12
14 V2=mf*v2; // Final volume of Freon 12
15 disp ("Pa",p2,"Final pressure = ","(a)");
16 disp ("m^3 (round off error)",V2,"Final volume = "
  );
17 // (b). Calculation of workdone by Freon 12 during
  this process
18 Wirrev=p2*(V2-V1); // P dv Work done
19 disp ("kJ (round off error)",Wirrev/1000,"Work
  done = ","(b)");
20 // (c). Calculation of workdone by Freon 12 during
  reversible process
21 Wrev=p1*10^6*V1*log (V2/V1); //From reversible
  process relation for work done
22 disp ("kJ (round off error)",Wrev/1000,"Work done
  in reveersible process = ","(c)");

```

Scilab code Exa 4.5 CALCULATION OF POWER AND CLEARANCE VOLUMETRIC EFFICIENCY

```

1 clc;
2 p1=0.1; // Initial pressure (before compression) of
  air in MPa

```

```

3 T1=30; // Initial temperature (before compression)
   of air in degree celcius
4 p2=0.9; // Final pressure (after compression) of air
   in MPa
5 R=0.287; // Characteristic constant of air in kJ/kg
   k
6 // (i) Actual work in the flow process
7 // (a).Isothermal Process
8 w=-R*(T1+273)*log (p2/p1); // work done for
   isothermal process
9 disp ("kJ/kg",w,"work done = ", "(a).Isothermal
   Process", "(i) Actual work in the flow process");
10 // (b).Polytropic process
11 n=1.4; // Index of polytropic process
12 T2=(T1+273)*(p2/p1)^((n-1)/n); // From Polytropic
   process relation for final temperature
13 w=(n/(1-n))*R*(T2-(T1+273)); // work done for
   polytropic process
14 disp ("kJ/kg",w,"compression work = ", "(b).
   Polytropic process");
15 // (ii).Nonflow work
16 // (a).Isothermal Process
17 w=-R*(T1+273)*log (p2/p1); // work done for
   isothermal process
18 disp ("kJ/kg",w,"work done = ", "(a).Isothermal
   Process", "(ii).Nonflow work");
19 // (b).Polytropic process
20 w=(1/(1-n))*R*(T2-(T1+273)); // work done for
   polytropic process
21 disp ("kJ/kg",w,"compression work = ", "(b).
   Polytropic process");

```

Scilab code Exa 4.6 WORK OF COMPRESSION

```
1 clc;
```

```

2 p1=1; // Initial pressure (before compression) of
   air in bar
3 p2=8; // Final pressure (after compression) of air
   in bar
4 Vp=15; // Displacement volume of reciprocating air
   compressor in litres
5 Vc=0.05*Vp; // Clearance volume of reciprocating air
   compressor in litres
6 N=600; // Speed of compressor in rpm
7 V1=Vc+Vp; // Total volume of reciprocating air
   compressor in litres
8 p3=p2; // constant pressure process
9 p4=p1; // constant pressure process
10 V3=Vc; // Clearance volume of reciprocating air
   compressor in litres
11 n=1.3; // Index of reversible adiabatic compression
   process
12 m=1.4; // Index of reversible adiabatic expansion
   process
13 V4=V3*(p3/p4)^(1/m);
14 // (a).Work per machine cycle
15 Wcycle = ((n/(n-1))*p1*10^2*V1*10^-3*(1-(p2/p1)^((n
   -1)/n)))-((m/(m-1))*p4*10^2*V4*10^-3*(1-(p3/p4)
   ^((m-1)/m))); // Work per machine cycle
16 disp ("kJ",Wcycle,"Work per machine cycle (Error in
   textbook)", "(a)");
17 Wpower=abs (Wcycle)*(N/60); // Power consumption of
   the compressor
18 disp ("kW",Wpower,"Power consumption of the
   compressor");
19 // (b).Work of the cycle if m=n
20 m=n;
21 W_cycle=(n/(n-1))*p1*10^2*(V1-V4)*10^-3*(1-(p2/p1)
   ^((n-1)/n)); // Work per machine cycle
22 disp ("kJ",W_cycle,"Work per machine cycle", "(b)");
23 er=((W_cycle-Wcycle)/Wcycle) * 100 // Error involved
   in calculating work if m=n
24 disp ("%",er,"Error (Error in textbook)= ");

```



```

25 // (c). Clearance volumetric efficiency
26 C=Vc/Vp;
27 eff = 1+C+-C*(p2/p1)^(1/n); // Clearance volumetric
    efficiency
28 disp ("% ",eff*100," Clearance volumetric efficiency =
    ", "(c). Clearance volumetric efficiency");

```

Scilab code Exa 4.7 WORK OF STEAM ENGINE

```

1  clc;
2  D=150; // Cylinder Diameter in mm
3  L=200; // Piston stroke in mm
4  C=0.05; // Clearance factor
5  p1=15; // Steam inlet conditions (saturated) in bar
6  p4=1; // Exhaust or back pressure in bar
7  p2=p1; // Constant pressure process
8  p5=p4; // Constant pressure process
9  Vp=(%pi*(D*10^-3)^2*L*10^-3)/4; // Swept volme of
    cylinder
10 Vc=C*Vp; // Clearance volume of cylinder
11 V3=Vc+Vp; // Total volume of cylinder
12 V1=Vc; // Clearance volume
13 V6=V1; // constant volume process
14 V4=V3; // constant volume process
15 V5=Vc+0.3*Vp; // Compression begins at 30% of stroke
16 V2=Vc+0.4*Vp; // Cut-off occurs at 40% of stroke
17 p6=p5*(V5/V6); // Pressure after compression
18 Wcycle=(p1*10^2*(V2-V1))+(p2*10^2*V2*log (V3/V2))-(
    p4*10^2*(V4-V5))-(p5*10^2*V5* log (V5/V6)); //
    Work per Cycle
19 disp ("kJ",Wcycle," Work per cycle =");

```

Scilab code Exa 4.8 INDICATOR WORK

```

1  clc;
2  D=10; //Bore in cm
3  L=12.5; //Stroke length in cm
4  a=9.68; // Area of indicator card in cm^2
5  l=5.33; // Card length in cm
6  Ks=21.7; // Indicator spring constant per meter of
      card length
7  A=(%pi*(D*10^-2)^2)/4; // Area of piston
8  Pm=(a/l)*10^-2*Ks*10^6; // Mean effective pressure
9  W=Pm*A*L*10^-2; // Work done by cycle
10 disp("kJ",W,"Work done by cycle = ");

```

Scilab code Exa 4.9 DOUBLE ACTING STEAM ENGINE

```

1  clc;
2  D=152; // Bore of steam engine in mm
3  l=89; // Stroke length of steam engine in mm
4  a1=8;a2=10; // area of indicator diagram on two
      sides
5  Ks=50; // Indicator spring constant in lbf/in^2/in
6  N=310; // Engine speed in rpm
7  d=0.664; // Diameter of flywheel in m
8  // (a)
9  a=(a1+a2)/2; // Average area of indicator diagram
10 Ks=50*4.44822/(0.0254)^3; // Unit conversion from
      lbf/in^2/in to N/m^2
11 pm=(a/(l/10))*10^-2*Ks; // Mean effective pressure
12 A=(%pi*(D*10^-3)^2)/4; // Area of the piston
13 IP=2*pm*l*10^-3*A*N/60; // Indicated power
14 disp ("kW",IP/1000,"Indicated power of Engine =", "(a
      )");
15 // (b)
16 F=12-1.5; // Tangential force on the brake drum in
      kgf
17 BP=F*9.81*d/2*2*%pi*N/60; // Brake power of Engine

```

```

18 eff=BP/IP *100 ; // Mechanical efficiency
19 disp ("kW",BP/1000," Brake power of Engine = ", "(b)")
    ;
20 disp ("%",eff," Mechanical efficiency of Engine =");

```

Scilab code Exa 4.10 ECONOMISER SURFACE AREA

```

1  clc;
2  Tc1=10; // Feed water inlet temperature in degree
    celcius
3  Tc2=77; // Feed water outlet temperature in degree
    celcius
4  th1=166; // Initial temperature of flue gas in
    degree celcius
5  r=4; // Ratio of mass flow rates of flue gases and
    water
6  Ch=1.05; // The specific heat of flue gas in kJ/kg K
7  Cc=4.187; // The specific heat of feed water in kJ/
    kg K
8  U=114; // Overall heat transfer coefficient in W/m^2
9  mc=1; // massflowrate of feed water in kg/s
10 th2=th1-((Cc*(Tc2-Tc1))/(r*Ch)); // Outlet
    temperature of flue gas in degree celcius
11 Q=mc/3600*Cc*(Tc2-Tc1); // Heat transfer rate per kg
    /h of water flow
12 // Parallel flow
13 del_Tm=((th1-Tc1)-(th2-Tc2))/log ((th1-Tc1)/(th2-Tc2
    )); // Logarithmic Mean Temperature Difference in
    degree celcius
14 A=Q*10^3/(U*del_Tm); // Economiser surface area
15 disp ("degree celcius",del_Tm," Logarithmic Mean
    Temperature Difference=", "(a) Parallel flow");
16 disp ("m^2",A," Economiser surface area =");
17 // Counter flow
18 del_Tm=((th1-Tc2)-(th2-Tc1))/log ((th1-Tc2)/(th2-Tc1

```

```
    )); // Logarithmic Mean Temperature Difference in
        degree celcius
19 A=Q*10^3/(U*del_Tm); // Economiser surface area
20 disp ("degree celcius",del_Tm,"Logarithmic Mean
        Temperature Difference=", "(b) Counter flow");
21 disp ("m^2",A,"Economiser surface area =");
```

Chapter 5

FIRST LAW OF THERMODYNAMICS AND INTERNAL ENERGY AND ENTHALPY

Scilab code Exa 5.1 CHARGING AND DISCHARGING OF BATTERY

```
1 clc ;
2 Q12=-250; // Heat transfer during Discharging of
   battery in kcal
3 W21=-0.53; // Consumption of electricity dring
   Charging process in kWh
4 Q21=(W21*3600)-(Q12*4.1868); // First law of
   thermodynamics
5 disp ("kJ",Q21,"Heat loss from battery during
   charging process");
```

Scilab code Exa 5.2 BOMB CALORIMETER

```

1  clc;
2  m=5; // Mass of water in a tank in kg
3  T1=30; // Temperature of water at initial state (1)
      in degree celcius
4  T2=95; // Temperature of water at final state (2) in
      degree celcius
5  Qout=70; // Heat transfer from the water tank to the
      surrounding air in kJ
6  W=75; // Electric energy input to a stirrer inside
      water in kJ
7  mf=32.3; // Mass of fel in bomb in grams
8  u1=125.78; // Internal energy of water from steam
      table (uf at T1) in kJ/kg
9  u2=397.88; // Internal energy of water from steam
      table (uf at T2) in kJ/kg
10 Qf=m*(u2-u1)-W+Qout; // From First law of
      thermodynamics
11 qf=Qf/(mf*10^-3); // Heat consumption per unit mass
      of fuel
12 disp ("kJ/kg",qf,"Heat consumption per unit mass of
      fuel =");

```

Scilab code Exa 5.3 CALCULATION OF HEAT TRANSFER

```

1  clc;
2  V=50; // Volume of water in a tank in litres
3  T1=120; // Temperature of water at initial state (1)
      in degree celcius
4  x1=0.6; // Dryness fraction at initial state (1)
5  T2=-10; // Temperature of water at final state (2)
      in degree celcius
6  vf1=0.00106; // specific volume of water from steam
      tables at T1 in m^3/kg
7  vg1=0.8919; // specific volume of water from steam
      tables at T1 in m^3/kg

```

```

8 v1=(1-x1)*vf1+x1*vg1; // Specific volume of mixture
  of liquid and water at state (1)
9 m=(V*10^-3)/v1; // Mass of water in the tank
10 vs2=0.0010891; // Specific volume of saturated ice
  at T2 in m^3/kg
11 vg2=466.7; // Specific volume of water vapour at T2
  in m^3/kg
12 v2=v1; // constant specific volume during cooling
  process
13 x2=(v2-vs2)/(vg2-vs2); // Dryness fraction at state
  (2)
14 uf1=503.5; // Specific internal energy at state (1)
  in kJ/kg
15 ug1=2529.3; // Specific internal energy at state (1)
  in kJ/kg
16 us2=-354.09; // Specific internal energy at state
  (2) in kJ/kg
17 ug2=2361.4; // Specific internal energy at state (2)
  in kJ/kg
18 u1=(1-x1)*uf1+x1*ug1; // Total Specific internal
  energy at state (1) in kJ/kg
19 u2=(1-x2)*us2+x2*ug2; // Total Specific internal
  energy at state (2) in kJ/kg
20 Q12=m*(u2-u1); // Heat transfer during cooling
  process
21 disp ("kJ",Q12,"Heat transfer during cooling process
  = ");

```

Scilab code Exa 5.4 CALCULATION OF OVERALL HEAT TRANSFER AND WORKDONE

```

1 clc;
2 V1=0.3; // Initial volume of water upto stop 1 in m
  ^3
3 p1=1; // Initial pressure of water in bar
4 x1=0.2; // Dryness fraction at initial state (1)

```

```

5 p2=3; // Pressur required to lift the piston in bar
6 V4=0.45; // Volume of water upto stop 2 in m^3
7 vf1=0.001043; // Specific volume at state (1) from
  steam table in m^3/kg
8 vg1=1.694; // Specific volume at state (1) from
  steam table in m^3/kg
9 v1=vf1+x1*(vg1-vf1); // Total Specific volume at
  state (1) from steam table in m^3/kg
10 m=V1/v1; // Mass of water
11 v3=V4/m; // Specific volume at stop 2
12 v2=v1; p3=p2; v4=v3; V3=V4; V2=V1; // From process
  diagram
13 // (a)
14 p4=0.361; // Final Pressure at v4 from steam table
  in Mpa
15 disp ("MPa",p4,"Fianl pressure = ", "(a)");
16 // (b)
17 W14=p2*10^2*(V3-V2); // Work done in process
18 uf1=417.36; // Specific internal energ at initial
  state in kJ/kg
19 ufg1=2088.7; // Specific internal energ at initial
  state in kJ/kg
20 u1=uf1+x1*ufg1; // Total Specific internal energ
  at initial state in kJ.kg
21 u4=2550.2; // Specific internal energ at final state
  in kJ/kg
22 Q14=m*(u4-u1)+W14; // From first law of
  thermodynamics
23 disp ("kJ",W14,"Work done during the process = ", "(b
  )");
24 disp ("kJ",Q14,"Heat transfer during the process = "
  );

```

Scilab code Exa 5.5 WORKDONE IN A POLYTROPIC COMPRESSION PROCESS


```

1  clc;
2  V1=0.01; // Initial Volume of Freon 12 vapour in
           cylinder in m^3
3  T1=15; // Initial Temperature of Freon 12 vapour in
           degree celcius
4  p1=4.914; // Initial pressure (Psat at T1) in bar
5  p2=9; // Final pressure of Freon 12 vapour after
           compression in bar
6  T2=65; // Final temperature of Freon 12 vapour after
           compression in degree celcius
7  Q=-0.5; // Heat lost to surroundings during
           compresson process in kJ
8  v1=0.035413; // Initial specific volume of Freon 12
           vapour from table in m^3/kg
9  m=V1/v1; // Mass of vapour
10 hg1=193.644; // specific enthalpy of Freon 12 vopour
           at state 1 in kJ/kg
11 u1=hg1-(p1*10^2*v1); // Total Specific internal
           energy at state 1
12 h2=222.9; // specific enthalpy of Freon 12 vapour at
           state 2 in kJ/kg
13 v2=0.022537; // specific volume of Freon 12 vapour
           at state 2 in m^3/kg
14 u2=h2-(p2*10^2*v2); // Total Specific internal
           energy at state 2
15 W=-m*(u2-u1)+Q; // From first law of thermodynamics
16 disp ("kJ",W,"Work of compression = ");

```

Scilab code Exa 5.6 COOLING OF ICE

```

1  clc;
2  tS=-10; // initial temperature of ice in degree
           celcius
3  ts=0; // Melting temperature of ice in degree
           celcius

```

```

4 Cs=1.94; // Specific heat of ice in kJ/kg k
5 m=1000; // Mass of ice in kg
6 tF=10; // Temperature of water after 24 hours in
    degree celcius
7 tf=0; // Freezing temperature of water in degree
    celcius
8 Cf=4.1868; // Specific heat of water in kJ/kg K
9 hsg=335; // Latent heat of fusion of ice in kJ/kg
10 Q=m*(Cs*(ts-tS)+hsg+Cf*(tF-tf)); // Heat gain of
    water
11 Q_dot=Q/(24*3600); // Rate of cooling
12 disp ("kW",Q_dot,"Rate of cooling = ");

```

Scilab code Exa 5.7 CHANGE IN ENTHALPY OF AIR

```

1 clc;
2 T1=300; // Temperature of air at state 1 in Kelvin
3 T2=500; // Temperature of air at state 2 in Kelvin
4 m_=28.966; // Molecular weight oh air in kg
5 Cpoav=1.017; // Average value of specific heat of
    air in kJ/kg K
6 // (a). change in enthalpy
7 h_ =27.43*(T2-T1)+3.09*10^-3*(T2^2-T1^2)
    -0.2296*10^-6*(T2^3-T1^3); //change in enthalpy
    during process in kJ/kmol
8 h=h_/m_; // change in enthalpy during process in kJ/
    kg
9 disp ("kJ/kg",h,"(a).change in enthalpy during
    process = ");
10 // (b).change in enthalpy
11 h=Cpoav*(T2-T1); // change in enthalpy in kJ/kg
12 disp ("kJ/kg",h,"(b).change in enthalpy during
    process with average specfic heat = ");

```

Scilab code Exa 5.8 DIRECTION AND MAGNITUDE OF WORKDONE

```
1  clc;
2  m=0.1; // mass of nitrogen gas in kg
3  V1=0.1; // Initial volme of nitrogen gas in m^3
4  p1=1.2; // Initial pressure of nitrogen gas in bar
5  V2=0.075; // Final volume of nitrogen gas in m^3
6  Cpo=1.041; // Specific heat at constant pressure of
   nitrogen in kJ/kg K
7  R=0.2969393; // Characteristic gas constant of
   nitrogen in Kj/kg K
8  T1=(p1*10^2*V1)/(m*R); // Initial temperature of
   nitrogen gas
9  T2=T1*(V2/V1); // Final temperature of nitrogen gas
   (constant pressure process)
10 Q=m*Cpo*(T2-T1); // Heat transfer to surroundings
11 W=p1*10^2*(V2-V1); // Work done
12 disp ("K",T2,"Final Temperature of nitrogen gas = ")
   ;
13 disp ("kJ",Q,"Heat transfer to surroundings = ");
14 disp ("The Work is done on the gas","kJ",W,"Work
   done = ");
```

Scilab code Exa 5.9 QUASI EQUILIBRIUM PROCESS

```
1  clc;
2  p=1; // pressure inside piston cylinder arrangement
   in MPa
3  // stae 1 = saturated liquid
4  // state 2 = saturated vapour
5  // state 3 = superheated vapour
6  v1=0.001127; // specific volume at state 1 in m^3/kg
```

```

7 v2=0.19444; // specific volume at state 2 in m^3/kg
8 v3=0.4011; // specific volume at state 3 in m^3/kg
9 u1=761.68; // specific internal energy at state 1 in
    kK/kg
10 u2=2583.6; // specific internal energy at state 2 in
    kK/kg
11 u3=3296.8; // specific internal energy at state 3 in
    kK/kg
12 h1=762.81; // specific enthalpy at state 1 in kJ/kg
13 h2=2778.1; // specific enthalpy at state 2 in kJ/kg
14 h3=3697.9; // specific enthalpy at state 3 in kJ/kg
15 w12=p*10^3*(v2-v1); // Work done during process 1-2
16 w23=p*10^3*(v3-v2); // Work done during process 2-3
17 wtotal=w12+w23; // Total work done
18 disp ("kJ/kg",wtotal,"Work done = ");
19 // Calculation of heat transfer
20 // Method I
21 q12=(u2-u1)+w12; // Heat transfer during process 1-2
22 q23=(u3-u2)+w23; // Heat transfer during process 2-3
23 qtotal=q12+q23; // Total Heat transfer
24 disp ("kJ/kg",qtotal,"Heat Transfer = ","Method I","
    Calculation of Heat Transfer");
25 // Method II
26 q12=h2-h1; // Heat transfer during process 1-2
27 q23=h3-h2; // Heat transfer during process 2-3
28 qtotal=q12+q23; // Total Heat transfer
29 disp ("kJ/kg",qtotal,"Heat Transfer = ","Method II")
    ;

```

Scilab code Exa 5.10 CALCULATION OF WORKDONE AND HEAT TRANSFER

```

1 clc;
2 p1=1; // initial pressure of air in piston cylinder
    arrangement in bar
3 T=300; // Temperature of air in piston cylinder

```

```

    arrangement in kelvin
4  p2=10; // Final pressure of air in piston cylinder
    arrangement in bar
5  R=0.287; // Characteristic gas constant of air in kJ
    /kg K
6  disp("The change in internal energy during the
    isothermal process is zero");
7  w=R*T*log (p1/p2); // Work done
8  disp ("kJ/kg",w,"Work done = ");
9  q=w; // From first law of thermodynamics
10 disp ("kJ/kg",q,"Heat transfer = ");

```

Scilab code Exa 5.12 EXPANSION OF AIR

```

1  clc;
2  p1=65; // (Error in textbook) // Pressure of air at
    state 1 in bar
3  v1=0.0135; // Volume of air at state 1 in m^3
4  v2=0.1; // Volume of air at state 2 in m^3
5  R=0.287; // Characteristic gas constant of air in kJ
    /kg K
6  Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
7  // (a).Adiabatic process
8  k=1.4; // Index of adiabatic process
9  p2=p1*(v1/v2)^k; // Pressure of air at state 2
10 T1=p1*10^2*v1/R; // Tempewrature of air at state 1
11 T2=p2*10^2*v2/R; // Tempewrature of air at state 2
12 w=R*(T2-T1)/(1-k); // work done
13 q=0; // Adiabatic expansion process
14 delta_u=Cvo*(T2-T1); // Change in internal energy of
    air
15 disp ("kJ",q,"Heat Ineraction = ", "kJ",delta_u,"
    Change in internal energy of air = ", "kJ",w,"Work
    done = ", "K",T2," Final Temperature = ", "(a).

```

```

        Adiabatic Process");
16 // (b).Polytropic process
17 n=1.3; // Index of adiabatic process
18 p2=p1*(v1/v2)^n; // Pressure of air at state 2
19 T1=p1*10^2*v1/R; // Tempewrature of air at state 1
20 T2=p2*10^2*v2/R; // Tempewrature of air at state 2
21 w=R*(T2-T1)/(1-n); // work done
22 delta_u=Cvo*(T2-T1); // Change in internal energy of
    air
23 q=delta_u+w; // Adiabatic expansion process
24 disp ("kJ",q,"Heat Ineraction = ","kJ",delta_u,"
    Change in internal energy of air = ","kJ",w,"Work
    done = ","K",T2,"Final Temperature = ","(b).
    Polytropic Process");
25 // (c).Isothermal process
26 T1=p1*10^2*v1/R; // Tempewrature of air at state 1
27 T2=T1; // Tempewrature of air at state 2
28 p2=p1*(v1/v2); // Pressure of air at state 2
29 w=R*T1*log (v2/v1); // work done
30 delta_u=Cvo*(T2-T1); // Change in internal energy of
    air
31 q=delta_u+w; // Adiabatic expansion process
32 disp ("kJ",q,"Heat Ineraction = ","kJ",delta_u,"
    Change in internal energy of air = ","kJ",w,"Work
    done = ","K",T2,"Final Temperature = ","(c).
    Isothermal Process");

```

Scilab code Exa 5.13 ANALYSIS OF CONTROL VOLUME

```

1 clc;
2 m=10; // mass flow rate of chilled water in kg/s
3 V1=50; //velocity of chilled water at section 1 in m
    /s
4 z1=30; // Elevation of section 1 in m
5 V2=10; //velocity of chilled water at section 2 in m

```

```

        /s
6  z2=60; // Elevation of section 2 in m
7  h1=21; // Enthalpy of chilled water at section 1 in
        kJ/kg
8  h2=43; // Enthalpy of chilled water at section 2 in
        kJ/kg
9  W=35; // Rate of work done by pump in kW
10 g=9.80665; // Acceleration due to gravity in m/s^2
11 Q=m*(h2-h1)+(m*(V2^2-V1^2)/2000)+(m*g*(z2-z1)/1000)-
        W; // Steady flow energy equation
12 disp ("kW",Q,"The rate of Heat Transfer From
        Building (Error in textbook)= ");

```

Scilab code Exa 5.14 A RECIPROCATING COMPRESSOR

```

1  clc;
2  p1=1; // Suction pressure of air in bar
3  p2=5; // Delivery pressure of air in bar
4  T1=310; // Suction Temperature of air in kelvin
5  Cpo=1.0035; // Specific heat at constant pressure in
        kJ/kg K
6  // (a) Polytropic compression
7  T2=475; // Delivery Temperature of air in kelvin
8  Q=-0.15; // Heat loss to the cooling water in kW
9  Wpoly=-5.3; // Power consumption of compressor in kW
10 m=(-Wpoly+Q)/(Cpo*(T2-T1)); // mass flow rate of air
        from SSSF energy equation
11 n=1/((1-((log (T2/T1))/(log (p2/p1))))); // Index of
        polytropic process
12 disp (n,"Index of polytropic process = ", "kg/s",m,"
        mass flow rate of air = ", "(a). Polytropic
        compression");
13 // (b) Adiabatic compression
14 k=1.4; // Index of adiabatic process
15 Wad=-m*Cpo*T1*((p2/p1)^((k-1)/k)-1); // power

```

```

        consumption of compressor
16 disp ("kW",Wad,"Power consumption of compressor = ",
        "(b).Adiabatic compression");
17 // (c).Difference between specific work
18 wdifff=(abs(Wad)-abs(Wpoly))/m; // Difference between
        specific work
19 disp ("kJ/kg",wdiff,"Difference between specific
        work = ", "(c).Difference between specific work");

```

Scilab code Exa 5.15 APPLICATION OF SSSF ENERGY EQUATION TO A STEAM TURBINE

```

1  clc;
2  W=500; // Power output from steam turbine in MW
3  Q=10; // Heat loss to surroundings in MW
4  p1=12.5; // Pressure of steam at steam turbine inlet
        in MPa
5  p2=10; // Pressure of steam at steam turbine outlet
        in kPa
6  V1=50; // Velocity of steam at steam turbine inlet
        in m/s
7  V2=100; // Velocity of steam at steam turbine outlet
        in m/s
8  x2=0.85; // Quality of steam at steam turbine outlet
9  h1=3341.8; // Specific enthalpy of steam at inlet
        from steam table in kJ/kg
10 hf2=191.83; hg2=2584.7; // Specific enthalpies of
        fluid and steam at outlet from steam table in kJ/
        kg
11 h2=(1-x2)*hf2+x2*hg2; // Specific enthalpy of steam
        at outlet in kJ/kg
12 m=(W-Q)*10^3/((h1-h2)+(V1^2-V2^2)/2000); // Mass
        flow rate of steam
13 disp ("kg/s",m,"Mass flow rate of steam = ");

```

Scilab code Exa 5.16 COMBINATION OF COMBUSTION CHAMBER AIR TURBINE AND NOZZLE

```

1  clc;
2  p1=3; // Pressre of air at state 1 in bar
3  p2=p1; // constant pressure process
4  T1=450; // Temperature of air at state 1 in kelvin
5  T2=1250; // Temperature of air at state 2 in kelvin
6  T3=1000; // Temperature of air at state 3 in kelvin
7  V3=50; // Velocity of air at state 3 in m/s
8  T4=800; // Temperature of air at state 4 in kelvin
9  Cpo=1.0035; // Specific heat at constant pressure in
      kJ/kg K
10 // (a).Combustion chamber
11 q=Cpo*(T2-T1); // Heat added to air
12 disp ("kJ/kg (round off error)",q,"Heat added to
      air = ", "(a).Combustion chamber");
13 // (b).Turbine
14 k=1.4; // Index of adiabatic process
15 w=Cpo*(T2-T3)-V3^2/2000; // Work done
16 disp ("kJ/kg (round off error)",w,"Work done = ",(
      "(b).Turbine)"));
17 // (c).Nozzle
18 V4=sqrt (2*Cpo*10^3*(T3-T4)+V3^2); // Velocity of
      air leaving the nozzle
19 disp ("m/s (round off error)",V4,"Velocity of air
      leaving the nozzle = ", "(c).Nozzle");
20 // (d).Pressure drop
21 p3=p2*(T3/T2)^(k/(k-1)); // Pressure of air leaving
      turbine
22 p4=p3*(T4/T3)^(k/(k-1)); // Pressure of air leaving
      nozzle
23 disp ("bar ",p4,"Pressure of air leaving nozzle =
      ", "bar",p3,"Pressure of air leaving turbine = ",
      (d).Pressure drop");

```

Scilab code Exa 5.17 DIFFUSER

```
1  clc;
2  V=1000; // Speed of aircraft in kmph
3  p1=0.35; // Ambient pressure in bar
4  T1=258; // Ambient temperature in kelvin
5  V1=V*1000/3600; // unit conversion kmph into m/s
6  p=1.01325; // Atmospheric pressure in bar
7  Cpo=1.0035; // Specific heat at constant pressure in
   kJ/kg K
8  k=1.4; // Index of compression process
9  T2=T1+(V1^2)/(2*Cpo*10^3); // The temperature after
   leaving inlet diffuser
10 p2=p1*(T2/T1)^(k/(k-1)); // Pressure after leaving
   inlet diffuser
11 r=p/p2; // Pressre ratio of compressor required for
   pressurization
12 disp ("K",T2,"The temperature after leaving inlet
   diffuser = ");
13 disp (r,"Pressre ratio of compressor required for
   pressurization = ");
```

Scilab code Exa 5.18 AREA OF DIFFUSER

```
1  clc;
2  p1=50; // Pressre of steam at diffuser inlet in kPa
3  T1=150; // Temperature of steam at diffuser inlet in
   degree celcius
4  V1=180; // Velocity of steam at diffuser inlet in m/
   s
5  A1=1000; // area of diffuser inlet in cm^2
```

```

6 V2=90; // Velocity of steam at diffuser outlet in m/
      s
7 p2=1; // Pressre of steam at diffuser outlet in bar
8 Q=120; // Heat loss to the surroundings in kW
9 v1=3.24; // Specific volume of steam from
      superheated steam table in m^3/kg at inlet
10 h1=2645.9; // // Specific enthalpy of steam from
      superheated steam table in m^3/kg at inlet
11 m=V1*A1*10^-4/v1; // Mass flow rate of steam
12 q=Q/m; // Heat transfer per unit mass of steam
13 h2=q+h1+(V1^2-V2^2)/2000; // Specific enthalpy of
      steam from SSSF energy equation at outlet
14 v2=1.704; // Specific volume of steam from
      superheated steam table in m^3/kg at outlet
15 A2=m*v2/V2; // Area of diffuser exit
16 disp ("cm^2",A2*10^4,"Area of diffuser exit (Error
      in textbook)= ");

```

Scilab code Exa 5.19 FLASH CHAMBER

```

1 clc;
2 p=0.15; // Pressure of Freon-12 gas in MPa
3 T1=10; // Temperature of Freon-12 gas in degree
      celcius
4 T2=35; // Temperature of Freon-12 gas in degree
      celcius
5 h1=196.762; // Specific enthalpy of Freon-12 from
      table at 1 in kJ/kg
6 h2=69.49; // Specific enthalpy of Freon-12 from
      table at 2 in kJ/kg
7 h3=178.54; // Specific enthalpy of Freon-12 from
      table at 3 in kJ/kg
8 // For solving Conservation of mass and SSSF energy
      equations
9 A=[1 -1; h3 -h2];

```

```

10 B=[1 ; h1];
11 M=A\B;
12 disp ("kg/s",M(1),"Mass of saturated vapour at 0.15
      MPa = ", "kg/s",M(2),"Mass of saturated liquid at
      35 oC = ");

```

Scilab code Exa 5.20 EXHAUST STEAM CONDENSER

```

1  clc;
2  p1=15; // Inlet pressure of condenser in kPa
3  x=0.92; // Quality of steam
4  ms=25; // mass flow rate of steam in kg/s
5  d_t=12; // temperature rise of water
6  Cpw=4.1868; // Specific heat of water in kJ/kg K
7  hfg=225.94; h4_3=2599.1; // specific enthalpy in kJ/
   kg
8  h1=(1-x)*hfg+x*h4_3; // specific enthalpy
9  h2=225.94; // specific enthalpy in kJ/kg
10 Q=ms*(h1-h2); // Heat transfer rate in condenser
11 mw=Q/(Cpw*d_t); // Mass flow rate of water
12 disp ("kg/s",mw,"Mass flow rate of water = ", "kW",Q,
      "Heat transfer rate in condenser = ");

```

Chapter 6

SECOND LAW OF THERMODYNAMICS AND ENTROPY

Scilab code Exa 6.1 CLAIM OF THE MANUFACTURE

```
1  clc;
2  QH=500; // Heat supplied in kJ
3  QL=200; // Heat rejected in kJ
4  TH=720; // Resorvior Temperature in kelvin
5  TL=360; // Resorvior Temperature in kelvin
6  W=260; // Work developed in kJ
7  e_max=1-TL/TH; // maximum efficiency
8  e_clamied=W/QH; // Efficiency clamied
9  if (e_clamied<e_max) then
10     disp ("It obeys the second law of thermodynamics
           .The claim is true");
11 else
12     disp ("It violates the second law of
           thermodynamics.The claim is False");
13 end
```

Scilab code Exa 6.2 CHECKING OF REVERSIBLE IRREVERSIBLE OR IMPOSSIBLE MACHINE

```
1  clc;
2  QH=325; // Heat supplied in kJ
3  QL=125; // Heat rejected in kJ
4  TH=1000; // Resorvior Temperature in kelvin
5  TL=400; // Resorvior Temperature in kelvin
6  W=200; // Work developed in kJ
7  e_carnot=1-TL/TH; // maximum efficiency
8  e_clamied=W/QH; // Efficiency clamied
9  disp (e_carnot,"e_carnot =");
10 disp (e_clamied,"e_clamied =");
11 if (e_carnot==e_clamied) then
12     disp ("The machine is reversible");
13 elseif (e_carnot>e_clamied)
14     disp ("The machine is irreversible");
15 else
16     disp ("Here e_clamied > e_carnot so the cyclic
17         machine is impossible.")
18 end
19 disp ("It would be reversible if its thermal
20     efficiency is equal to Carnot efficiency , and
21     irreversible if it is less than Carnot efficiency
22     .")
```

Scilab code Exa 6.3 A CARNOT REFRIGERATION

```
1  clc;
2  // Air conditioning unit
3  TL=278; // Operating temperature in kelvin
4  TH=318; // Operating temperature in kelvin
5  COP1=TL/(TH-TL); // COP of Air conditioning unit
```

```

6 QL=1; // For some calculation purpose
7 W1=QL/COP1; // Work input of Air conditioning unit
8 // Food refrigeration unit
9 TL=258; // Operating temperature in kelvin
10 TH=318; // Operating temperature in kelvin
11 COP2=TL/(TH-TL); // COP of Food refrigeration unit
12 W2=QL/COP2; // Work input of Food refrigeration unit
13 Wper=(W2-W1)/W1; // Increase in work input
14 disp ("%",Wper*100,"Increase in work input = ");

```

Scilab code Exa 6.4 YEAR ROUND AIR CONDITIONING UNIT

```

1 clc;
2 //(a).Summer air conditioning (cooling)
3 TL=298; // Operating temperature in kelvin
4 TH=318; // Operating temperature in kelvin
5 q=0.75; // Heat Transfer from fabric of room per
           degree of temperature difference in kW
6 QL=q*(TH-TL); // Heat Transfer from fabric of room
7 COPc=TL/(TH-TL); // COP of Air conditioning unit
8 W=QL/COPc; // Work input of Air conditioning unit
9 disp ("kW",W,"Work input of Air conditioning unit =
        ", "(a).Summer air conditioning (cooling)");
10 //(b).Winter air conditioning (recerse cycle
    heating)
11 TH=293; // Operating temperature in kelvin
12 TL=(-(-2*q*TH)-sqrt((-2*q*TH)^2-(4*q*(q*TH^2-TH))))
    /(2*q); // Lowest outdoor Temperature by root
13 disp ("K",TL,"Lowest outdoor Temperature = ", "(b).
    Winter air conditioning (recerse cycle heating)");

```

Scilab code Exa 6.5 DECREASE IN COP WITH LOWERING OF REFRIGERATION TEMPERATURE

```

1  clc;
2  // (a).For the refrigerator
3  TL=258; // Operating temperature in kelvin
4  TH=313; // Operating temperature in kelvin
5  QL=3.5167; // Ton of refrigeration in kW
6  COP=TL/(TH-TL); // COP of Refrigeration unit
7  W=QL/COP; // Power consumption of refrigerator
8  disp ("kW",W,"Power consumption of refrigerator = ",
        "(a).For the refrigerator");
9  // (b). For the freezer
10 TL=248; // Operating temperature in kelvin
11 TH=313; // Operating temperature in kelvin
12 COP=TL/(TH-TL); // COP of Freezer unit
13 QL=W*COP; // Refrigeration produced
14 disp ("kW",QL,"Refrigeration produced = ", "(b). For
        the freezer")

```

Scilab code Exa 6.6 CALCULATION OF ENTROPY OF VAPORIZATION

```

1  clc;
2  Psat=200; //Pressure of water in kPa
3  Tsat=393.38; // Saturation temperaure at Psat in
        kelvin
4  // (i).From the equation  $Tds=du+pdv$ 
5  // Following are from steam table at Psat
6  ufg=2025; // specific internal energy of
        vapourization in kJ/kg
7  vg=0.8857; // specific volume in  $m^3/kg$ 
8  vf=0.001061; // specific volume in  $m^3/kg$ 
9  sfg=(ufg/Tsat)+(Psat*(vg-vf)/Tsat); // specific
        entropy of vapourization
10 disp ("kJ/kg K",sfg,"specific entropy of
        vapourization = ", "(i).From the equation  $Tds=du+$ 
         $pdv$  ");
11 // (ii).From the equation  $Tds=dh-vdp$ 

```



```

12 hfg=2201.9; // Specific enthalpy of vapourization in
    kJ/kg
13 sfg=hfg/Tsat; // specific entropy of vapourization
14 disp ("kJ/kg K",sfg,"specific entropy of
    vapourization = ", "(ii).From the equation  $Tds=dh-
    vdp$  ");

```

Scilab code Exa 6.7 REVERSIBLE ISOTHERMAL PROCESS

```

1 clc;
2 p1=1; // Pressure of steam at state 1 in bar
3 T=473; // Temperature of steam at state 1 in kelvin
4 // (i).Pressure after compression
5 p2=1.5538; // Pressure after compression at (Psat)T
    from steam table in MPa
6 disp ("MPa",p2,"Pressure after compression = ", "(i).
    Pressure after compression");
7 // (ii).Heat Transfer and work done during the
    process
8 // Following are from steam table
9 s2=6.4323; // specific entropy of steam at state 2
    in kJ/kg K
10 s1=7.8343; // specific entropy of steam at state 1
    in kJ/kg K
11 u2=2595.3; // specific internal energy of steam at
    state 2 in kJ/kg
12 u1=2658.1; // specific internal energy of steam at
    state 1 in kJ/kg
13 q=T*(s2-s1); // Heat transfer during the process
14 w=q-(u2-u1); // Work done during the process
15 disp ("kJ",w,"Work done during the process = ", "kJ",
    q,"Heat transfer during the process = ", "(ii).
    Heat Transfer and work done during the process");

```

Scilab code Exa 6.8 ENTROPY CHANGE OF STEAM

```
1  clc;
2  p1=6; // Initial pressure of steam in MPa
3  T1=500; // Initial temperature of steam in degree
    celcius
4  p2=10; // Final pressure of steam in bar
5  // From steam tables
6  s1=6.8803; sf2=1.3026; sfg2=6.0568; // specific
    entropy in kJ/kg K
7  u1=3082.2; uf2=761.68; ufg2=1822; // specific
    internal energy in kJ/kg
8  v1=0.05665; vf2=0.001043; vg2=1.694; // specific
    volume in m^3/kg
9  x2=(v1-vf2)/(vg2-vf2); // Quality of steam
10 u2=uf2+x2*ufg2; // specific internal energy in kJ/kg
11 s2=sf2+x2*sfg2; // specific entropy in kJ/kg K
12 s21=s2-s1; // Entropy change
13 q=u2-u1; // Heat transfer
14 disp ("kJ",q,"Heat transfer for the process =", "kJ/
    kg",s21,"Entropy change of the process = ");
```

Scilab code Exa 6.10 ENTROPY CHANGE OF AIR

```
1  clc;
2  p1=3; // initial pressure of air in bar
3  T1=200; // initial temperature of air in degree
    celcius
4  p2=1.5; // final pressure of air in bar
5  T2=105; // final temperature of air in degree
    celcius
```

```

6 Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
7 R=0.287; // characteristic gas constant of air in kJ
    /kg K
8 delta_s= Cpo*log (T2/T1)- R*log (p2/p1); // change
    in entropy during irreversible process
9 disp ("kJ/kg K",delta_s,"change in entropy during
    irreversible process = ");

```

Scilab code Exa 6.11 ENTROPY CHANGE OF ARGON GAS

```

1 clc;
2 p1=5; // Initial pressure of argon gas in bar
3 T1=30; // Initial temperature of argon gas in degree
    celcius
4 v1=1; // Initial volume of argon gas in m^3 by
    assumption
5 v2=2*v1; // Final volume of argon gas in m^3
6 R=8.3144/40; // Characteristic gas constant of argon
    gas in kJ/kg K
7 p2=p1*(v1/v2); // Final pressure of argon gas
8 delta_s= R*log (v2/v1); // change in entropy (
    choosing the reversible isothermal path)
9 disp ("kJ/kg K",delta_s,"change in entropy (choosing
    the reversible isothermal path) = ", "bar",p2,"
    Final pressure of argon gas =");

```

Scilab code Exa 6.12 INTERNAL COMBUSTION ENGINE

```

1 clc;
2 p1=1; // Atmospheric pressure in bar
3 T1=348; // Atmospheric temperature in kelvin

```

```

4 V1=800; // Volume of air sucked into the cylinder in
      cm^3
5 p2=15; // pressure of air after compression in bar
6 V2=V1/8; // volume of air after compression in cm^3
7 p3=50; // pressure of air after heat addition in bar
8 Cvo=0.7165; // Specific heat at constant volume in kJ
      /kg K
9 R=0.287; // characteristic gas constant of air in kJ
      /kg K
10 // (a).Index of compression process
11 n=log (p2/p1)/log (V1/V2); // Index of compression
      process
12 disp ("which is less than 1.4. The compression
      process is polytropic.",n,"Index of compression
      process = ",(a).Index of compression process");
13 // (b).Change in entropy of air during each
      process
14 m=(p1*10^2*V1*10^-6)/(R*T1); // Mass of air in
      cylinder
15 T2=T1*(p2/p1)*(V2/V1); // Temperature after
      compression
16 T3=T2*(p3/p2); // Temperature after heat addition
17 delta_s21=m*(Cvo*log (T2/T1)+R*log (V2/V1)); //
      change in entropy during compression
18 delta_s32=m*Cvo*log (T3/T2); //change in entropy
      during heat addition
19 disp ("kJ/K",delta_s32,"change in entropy during
      heat addition = (Error in textbook)", "kJ/K",
      delta_s21,"change in entropy during compression =
      (Error in textbook)", "(b).Change in entropy of
      air during each process");
20 // (c).Heat transfer during polytropic compression
      process
21 k=1.4; // Index of isentropic process
22 Q=m*Cvo*((k-n)/(1-n))*(T2-T1); // Heat transfer
      during polytropic compression process
23 disp ("kJ",Q,"Heat transfer during polytropic
      compression process = (Error in textbook)", "(c).

```

Heat transfer during polytropic compression process");

Scilab code Exa 6.13 FREE EXPANSION OF STEAM

```
1  clc;
2  p1=0.3; // initial pressure of steam in MPa
3  T1=350; // Initial temperature of steam in degree
      celcius
4  // following are the values taken from steam table
      for initial state
5  v1=0.9535; // specific volume in m^3/kg
6  u1=2886.2; // specific internal energy in kJ/kg
7  s1=7.868; // specific entropy in kJ/kg K
8  v2=2*v1; // final specific volume of steam
9  u2=u1;
10 // following are the values taken from steam table
      final state
11 T2=349; // Final temperature of steam in degree
      celcius
12 p2=0.167; // Final pressure of steam in MPa
13 s2=8.164; // specific entropy in kJ/kg K
14 delta_s=s2-s1; // Entropy generation
15 LW=(T1+T2)/2 * delta_s; // Lost work
16 disp ("kJ",LW,"Lost work = ", "kJ/kg K",delta_s,"
      Entropy Generation =");
```

Scilab code Exa 6.15 ENTROPY CHANGE OF UNIVERSE

```
1  clc;
2  m=1; // Mass of water in kg
3  T1=300; // Temperature of water in kelvin
4  C=4.1868; // Specific heat in kJ/kg K
```

```

5 // (a). Heat Transfer
6 T2=500; // Temperature of heat reservoir in kelvin
7 Q=m*C*(T2-T1); // Heat transfer
8 del_Swater=m*C*log (T2/T1); // Entropy change of
   water
9 del_Sreservoir=-Q/T2; // Entropy change of
   reservoir
10 del_Suniverse=del_Swater+del_Sreservoir; // Entropy
   change of universe
11 disp ("kJ/K",del_Suniverse,"Entropy change of
   universe =", "(a).Heat Transfer");
12 // (b).Heat Transfer in each reservoir
13 T2=400; // Temperature of intermediate reservoir in
   kelvin
14 T3=500; // Temperature of heat reservoir in kelvin
15 Q=m*C*(T3-T2); // Heat transfer
16 del_Swater=m*C*(log (T2/T1)+log (T3/T2)); // Entropy
   change of water
17 del_SreservoirI=-Q/T2; // Entropy change of
   reservoir I
18 del_SreservoirII=-Q/T3; // Entropy change of
   reservoir II
19 del_Suniverse=del_Swater+del_SreservoirI+
   del_SreservoirII; // Entropy change of universe
20 disp ("kJ/K",del_Suniverse,"Entropy change of
   universe =", "(b).Heat Transfer in each reservoir"
   );

```

Scilab code Exa 6.16 AFFECTING REVERSIBLE HEAT TRANSFER THROUGH A FINITE TEMPERATURE

```

1 clc;
2 m=1; // Mass of saturated steam in kg
3 T=100; // Temperature of steam in degree celcius
4 T0=303; // temperature of Surroundings in kelvin
5 hfg=2257; // Latent heat of evaporation in kJ/kg

```

```

6  sfg=6.048; // specific entropy in kJ/kg K
7  // (a).Entropy change
8  Q=m*hfg; // Heat transfer
9  del_Ssystem=-m*sfg; // Change of entropy of system
10 del_Ssurr=Q/T0; // Change of entropy of surroundings
11 del_Suniverse=del_Ssystem+del_Ssurr; // Change of
    entropy of universe
12 disp ("kJ/K",del_Suniverse,"Change of entropy of
    universe =", "kJ/K",del_Ssurr,"Change of entropy
    of surroundings =", "kJ/K",del_Ssystem,"Change of
    entropy of system =", "(a).Entropy change");
13 // (b).Effect of heat transfer
14 del_Suniverse=0; // process is reversible
15 del_Ssurr=del_Suniverse-del_Ssystem; //Change of
    entropy of surroundings
16 QH=hfg; // Heat transfer from the condensing steam
    to reversible heat engine
17 QL=T0*del_Ssurr; // Heat received by the
    surroundins reversible heat engine
18 W=QH-QL; //work output of reversible heat engine
19 disp ("Difference between QH & QL is converted into
    work output in a reversible cyclic process", "kJ",
    W,"work output of reversible heat engine =", "kJ",
    QL,"Heat received by the surroundins reversible
    heat engine =", "kJ",QH,"Heat transfer from the
    condensing steam to reversible heat engine =", "(b
    ).Effect of heat transfer");

```

Scilab code Exa 6.17 ENTROPY CHANGE OF ICE

```

1  clc;
2  m=1; // Mass of ice in kg
3  T1=258; // Temperature of ice in kelvin
4  Tm=273; // Melting point of ice in kelvin
5  T2=303; // temperature of Surroundings in kelvin

```

```

6 Cpice=2.095; // Specific heat of ice in kJ/kg K
7 hsg=333.5; // Latent heat of fusion in kJ/kg
8 Cpw=4.1868; // Specific heat of water in kJ/kg K
9 // (a).Change of entropy
10 Q=m*(Cpice*(Tm-T1)+hsg+Cpw*(T2-Tm)); // Heat transfer
11 del_Ssystem=m*((Cpice*log (Tm/T1))+(hsg/Tm)+(Cpw*log
(T2/Tm))); // Change of entropy of system
12 del_Ssurr=-Q/T2; // Change of entropy of
surroundings
13 del_Suniverse=del_Ssystem+del_Ssurr; // Change of
entropy of universe
14 disp ("kJ/K",del_Suniverse,"Change of entropy of
universe =", "kJ/K",del_Ssurr,"Change of entropy
of surroundings =", "kJ/K",del_Ssystem,"Change of
entropy of system =", "(a).Entropy change");
15 // (b).The minimum work of restoring water back to
ice
16 QL=Q; // Refrigerating effect
17 W=T2*del_Ssystem-QL; // The minimum work of
restoring water back to ice
18 disp ("kJ",W,"(b).The minimum work of restoring
water back to ice = ");

```

Scilab code Exa 6.18 DIRECTION OF AIR FLOW

```

1 clc;
2 TA=323; // Temperature at section A in kelvin
3 PA=125; // Pressure at section A in kPa
4 TB=287; // Temperature at section B in kelvin
5 PB=100; // Pressure at section B in kPa
6 Cpo=1.0035; // Specific heat at constant pressure in
kJ/kg K
7 R=0.287; // characteristic gas constant of air in kJ
/kg K
8 SBA=(Cpo*log (TB/TA))-(R*log (PB/PA)); // Change in

```



```

entropy
9 disp("Hence SA>SB. Therefore B to A", "kJ/kg", SBA, "
Change in entropy from B to A =");

```

Scilab code Exa 6.19 ADIABATIC TURBINE

```

1  clc;
2  p1=12.5; // Pressure of steam at inlet in MPa
3  T1=500; // Temperature of steam at inlet in degree
celcius
4  V1=50; // Velocity of steam at inlet in m/s
5  p2=10; // Pressure of steam at outlet in kPa
6  V2=100; // Velocity of steam at outlet in m/s
7  // (a).Actual expansion
8  x2=0.85; // Quality of steam
9  // From steam table
10 h1=3341.8; hf2=191.83; hg2=2584.7; // specific
enthalpy in kJ/kg
11 s1=6.4618; sf2=0.6493; sfg2=7.5009; // specific
entropy in kJ/kg K
12 h2a=(1-x2)*hf2+x2*hg2; // specific enthalpy in kJ/kg
13 wa=(h1-h2a)+((V1^2-V2^2)/2000); // Actual work
output
14 disp ("kJ",wa,"(a).Actual work output of turbine = "
);
15 // (b).Reversible adiabatic expansion
16 x2s=(s1-sf2)/sfg2; // Quality of steam after
reversible adiabatic expansion
17 h2s=(1-x2s)*hf2+x2s*hg2; // specific enthalpy in kJ/
kg
18 ws=(h1-h2s)+((V1^2-V2^2)/2000); // Reversible
adiabatic work output
19 L=ws-wa; // Lost of work
20 disp ("kJ/kg",L,"Lost of work due to irreversibility
of expansion process =", "kJ/kg",ws,"Reversible

```

```

        adiabatic work output = ", "(b).Reversible
        adiabatic expansion");
21 // (c).Entropy Generation
22 s2a=sf2+x2*sfg2; // actual specific entropy in kJ/kg
        K
23 Sgen=s2a-s1; // Entropy generation
24 disp ("kJ/kg K",Sgen,"(c).Entropy Generation =");

```

Scilab code Exa 6.20 COMPARSION OF PUMP WORK AND COMPRESSOR WORK

```

1 clc;
2 p1=0.1; // pressure at state 1 in MPa
3 p2=6; // Pressure at state 2 in MPa
4 // (a).Pump work for water
5 vf1=0.001043; // specific volume in m^3/kg
6 wp=-vf1*(p2-p1)*10^3; // Pump work for water
7 disp ("kJ",wp,"(a).Pump work for water =");
8 // (b).For steam
9 h1=2675.5; // specific enthalpy in kJ/kg
10 s1=7.3595; // specific entropy in kJ/kg K
11 // From superheated steam table
12 t2=675; // Temperature at state 2 in degree celcius
13 h2=3835.3; // specific enthalpy in kJ/kg
14 wc=-(h2-h1); // Compressor work for steam
15 disp ("kJ/kg",wc,"(b).Compressor work for steam =");

```

Scilab code Exa 6.21 THROTTLING PROCESS

```

1 clc;
2 // (a).Restoring to initial state by throttling
        process
3 T1=303; //Temperature of air at state 1 in kelvin
4 p1=1; //Pressure of air at state 1 in bar

```

```

5 p2=5; //Pressure of air at state 2 in bar
6 p3=1; //Pressure of air at state 3 in bar
7 T3=303; //Temperature of air at state 3 in kelvin
8 Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
9 R=0.287; // characteristic gas constant of air in kJ
    /kg K
10 k=1.4; // Index of reversible adiabatic compression
11 T2=T1*(p2/p1)^((k-1)/k); // Temperature after
    reversible adiabatic compression
12 w12=Cpo*(T2-T1); // Work of reversible adiabatic
    compression
13 s21=0; // Entropy change of air
14 s32=-R*log (p3/p2); // Entropy change
15 s31=s32; // Net entropy change of air
16 d_Ssurr=0; // Entropy change of surroundings because
    There is no heat transfer
17 d_Suniv=s31+d_Ssurr; // Net Entropy change of
    universe
18 disp ("kJ/kg K",d_Suniv,"Net Entropy change of
    universe = ", "kJ/kg",w12,"Work of reversible
    adiabatic compression = ", "(a).Restoring to
    initial state by throttling process");
19 // (b).Restoring to initial state by by completing
    cycle
20 T0=298; // Temperature of surroundings in kelvin
21 d_Ssystem=0; // Entropy change of system is zero
    because it is cyclic process
22 q31=Cpo*(T2-T3); // Heat rejected to the
    surroundings
23 d_Ssurr=q31/T0; // Entropy change of surroundings
24 d_Suniv=d_Ssystem+d_Ssurr; // Increase in entropy of
    the universe
25 disp ("kJ/kg K",d_Suniv,"Net Entropy change of
    universe = ", "(b).Restoring to initial state by
    by completing cycle");

```

Chapter 7

COMBINED FIRST AND SECOND LAWS APPLICATION TO PROCESS

Scilab code Exa 7.1 CHANGE IN ENTROPY OF THE FLUID

```
1  clc;  
2  p1=1; // Initial pressure of fluid in MPa  
3  T1=250; // Initial temperture of fluid in degree  
    celcius  
4  V=0.28; // Volume of container in m^3  
5  p2=0.35; // Initial pressure of the fluid in MPa  
6  // (a).Water  
7  v1=0.2327; // specific volume of vapour from steam  
    table at state 1 in m^3/kg  
8  v2=v1; // constant volume process  
9  vf2=0.001079; vfg2=0.5232; // specific volume of  
    vapour from steam table at state 2 in m^3/kg  
10 m=V/v1; // mass of steam  
11 x2=(v2-vf2)/vfg2; // quality of steam at state 2  
12 t2=138.88; // Final temperature of fluid in degree  
    celcius (saturation temperature at p2)  
13 // following are the values taken from steam tables
```

```

14 u1=2709.9; // specific internal energy at state 1 in
    kJ/kg
15 s1=6.9247; // Specific entropy at state 1 in kJ/kg K
16 uf2=582.95; ug2=2548.9; // specific internal energy
    at state 2 in kJ/kg
17 sf2=1.7245; sg2=6.9405; // Specific entropy at state
    2 in kJ/kg K
18 u2=(1-x2)*uf2+x2*ug2; // specific internal energy at
    state 2
19 s2=(1-x2)*sf2+x2*sg2; // specific entropy at state 2
20 Q=m*(u2-u1); // Heat transferred
21 S21=m*(s2-s1); // Entropy change
22 disp ("kJ/kg K (round off error)",S21,"Entropy
    change = ", "kJ (answer mentioned in the
    textbook is wrong)",Q,"Heat transferred = ', "oC",
    t2,"Final Temperature = ", "(a).Water");
23 // (b). Air
24 Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
25 R=0.287; // characteristic gas constant of air in kJ
    /kg K
26 m=(p1*10^3*V)/(R*(T1+273)); // Mass of air
27 T2=(p2/p1)*(273+T1); // Final temperature of air
28 Q=m*Cvo*(T2-(T1+273)); // Heat transferred
29 S21=m*Cvo*log (T2/(273+T1)); // Change in entropy
30 disp ("kJ/kg K (round off error)",S21,"Entropy
    change = ", "kJ (round off error)",Q,"Heat
    transferred = ', "K ",T2,"Final Temperature = ", "(
    b). Air");

```

Scilab code Exa 7.2 EXPANSION OF FLUID

```

1 clc;
2 p1=1.0021; // Initial pressure of the fluid in MPa
3 T1=180; // Initial temperature of the fluid in

```

```

        degree celcius
4  m=0.5; // Mass of the fluid in kg
5  p2=p1; // Constant pressure process
6  // (a).Steam
7  x1=0.8; // Quality of the steam at state 1
8  // Following are the values taken from steam table
9  vf1=0.001127; vfg1=0.1929; // specific volume of the
        steam in m^3/kg
10 hf1=763.2; hfg1=2015; // specific enthalpy in kJ/kg
11 sf1=2.1396; sfg1=4.4460; // specific entropy in kJ/
        kg K
12 v1=vf1+x1*vfg1; // specific volume in m^3/kg
13 h1=hf1+x1*hfg1; // specific enthalpy in kJ/kg
14 s1=sf1+x1*sfg1; // specific entropy in kJ/kg K
15 v2=2*v1; // Final volume of the fluid
16 t2=410.5; // Final temperature of steam in degree
        celcius (from superheated steam table)
17 h2=3286.4; // specific enthalpy in kJ/kg
18 s2=7.525; // specific entropy in kJ/kg K
19 S21=m*(s2-s1); // Change in entropy
20 W=m*p1*10^3*(v2-v1); // Work done
21 Q=m*(h2-h1); // Heat transferred
22 disp ("kJ",Q,"Heat transferred = ","kJ",W,"Work done
        = ","kJ/K",S21,"Change in entropy = ","K",t2
        +273,"Final Temperature = ","(a).Steam");
23 // (b).Air
24 Cpo=1.0035; // Specific heat at constant pressure in
        kJ/kg K
25 R=0.287; // characteristic gas constant of air in kJ
        /kg K
26 V1=m*R*(T1+273)/(p1*10^3); // Initil volume
27 V2=2*V1; // Final volume
28 T2=(T1+273)*V2/V1; // Final temperature
29 S21=m*Cpo*log (V2/V1); // Change in entropy
30 W=p1*10^3*(V2-V1); // Work done
31 Q=m*Cpo*(T2-(T1+273)); // Heat transferred
32 disp ("kJ",Q,"Heat transferred = ","kJ",W,"Work done
        = ","kJ/K",S21,"Change in entropy = ","K",T2,"

```

Final Temperature = ", "(b).Air");

Scilab code Exa 7.3 CHANGE IN INTERNAL ENERGY AND ENTROPY OF FLUID

```
1  clc;
2  m=1.5; // Mass of the fluid in kg
3  p1=1; // Initial pressure of fluid in bar
4  T1=150; // Initial temperture of fluid in degree
      celcius
5  v2=0.3; // Final specific volume in m^3/kg
6  // (a).Steam
7  // Following are the values taken from steam table
8  u1=2582.8; // specific internal energy in kJ/kg
9  s1=7.6134; // specific entropy in kJ/kg K
10 vf2=0.001091; vfg2=0.3917; // specific volume of the
      steam in m^3/kg
11 sf2=1.8418; sfg2=4.9961; // specific entropy in kJ/
      kg K
12 uf2=631.7; ufg2=1927.8; // specific internal energy
      in kJ/kg
13 x2=(v2-vf2)/vfg2; // Quality of steam at state 2
14 s2=sf2+x2*sfg2; // specific entropy in kJ/kg K
15 u2=uf2+x2*ufg2; // specific internal energy in kJ/kg
16 S21=m*(s2-s1); // Change in entropy
17 U21=m*(u2-u1); // Change in internal energy
18 Q=(T1+273)*(S21); // Heat transferred
19 W=Q-U21; // Work done
20 disp ("kJ",Q,"Heat transferred = ", "kJ",W,"Work done
      = ", "kJ/K",S21,"Change in entropy = ", "kJ",U21,"
      Change in internal energy = ", "(a).Steam");
21 // (b).Air
22 R=0.287; // characteristic gas constant of air in kJ
      /kg K
23 v1=(R*(T1+273))/(p1*10^2); // initial specific
      volume
```

```

24 S21=m*R*log (v2/v1); // Change in entropy
25 Q=(T1+273)*(S21); // Heat transferred
26 W=Q; // Work done
27 disp ("kJ",Q,"Heat transferred = ", "kJ",W,"Work done
      = ", "kJ/K",S21,"Change in entropy = ", "kJ",U21,"
      Change in internal energy = ", "(b).Air");

```

Scilab code Exa 7.4 WORKDONE OF FLUID

```

1  clc;
2  m=1.5; // Mass of the fluid in kg
3  p1=1.6; // Initial pressure of fluid in MPa
4  T1=250; // Initial temperture of fluid in degree
      celcius
5  p2=150; // Initial pressure of the fluid in kPa
6  // (a).Steam
7  // Following are the values taken from steam table
8  // state 1 is superheated
9  u1=2692.3; // specific internal energy in kJ/kg
10 s1=6.6732; // specific entropy in kJ/kg K
11 v1=0.14184; // specific volume of the steam in m^3/
      kg
12 // State 2 is wet (s1=s2<sg2)
13 T2=111.37; // Final temperature of steam in degree
      celcius
14 sf2=1.4336; sfg2=5.7897; // specific entropy in kJ/
      kg K
15 uf2=466.94; ufg2=2052.7; // specific internal energy
      in kJ/kg
16 x2=(s1-sf2)/sfg2; // Quality of steam at state 2
17 u2=uf2+x2*ufg2; // specific internal energy in kJ/kg
18 W=-m*(u2-u1); // Work done
19 disp ("kJ",W,"Work done = ", "K",T2+273," Final
      temperature of steam = ", "(a).Steam");
20 // (b).Air

```



```

21 Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
22 k=1.4; // index of reversible adiabatic process
23 T2=(T1+273)*((p2*10^-3)/p1)^((k-1)/k); // Final
    temperature of air
24 W=-m*Cvo*(T2-(T1+273)); // Work done
25 disp ("kJ",W,"Work done = ", "K",T2," Final
    temperature of =", "(b).Air");

```

Scilab code Exa 7.5 REVERSIBLE AND POLYTROPIC PROCESS

```

1  clc;
2  m=1.5; // Mass of the fluid in kg
3  p1=1.6; // Initial pressure of fluid in MPa
4  T1=250; // Initial temperature of fluid in degree
    celcius
5  p2=150; // Initial pressure of the fluid in kPa
6  n=1.25; // Index of polytropic process
7  // (a).Steam
8  // Following are the values taken from steam table
9  // state 1 is superheated
10 u1=2692.3; // specific internal energy in kJ/kg
11 s1=6.6732; // specific entropy in kJ/kg K
12 v1=0.14184; // specific volume of the steam in m^3/
    kg
13 v2=v1*(p1/(p2*10^-3))^(1/n); // specific volume of
    the steam at state 2
14 // State 2 is wet
15 T2=111.37; // Final temperature of steam in degree
    celcius
16 vfg2=0.0010531; vfg2=1.1582; // specific volume of
    the steam in m^3/kg
17 x2=(v2-vfg2)/vfg2; // Quality of steam at state 2
18 sf2=1.4336; sfg2=5.7897; // specific entropy in kJ/
    kg K

```

```

19 uf2=466.94; ufg2=2052.7; // specific internal energy
    in kJ/kg
20 s2=sf2+x2*sfg2; // specific entropy in kJ/kg K
21 u2=uf2+x2*ufg2; // specific internal energy in kJ/kg
22 W=m*((p2*v2)-(p1*10^3*v1))/(1-n); // Work done
23 Q=m*(u2-u1)+W; // Heat transferred
24 S21=m*(s2-s1); // Change in entropy
25 disp ("kJ",Q,"Heat transferred = ","kJ",W,"Work done
    = ","kJ/K",S21,"Change in entropy = ","K",T2
    +273,"Final Temperature = ","(a).Steam");
26 // (b).Air
27 R=0.287; // characteristic gas constant of air in kJ
    /kg K
28 Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
29 T2=(T1+273)*((p2*10^-3)/p1)^((n-1)/n); // Final
    temperature of air
30 W=m*R*(T2-(T1+273))/(1-n); // Work done
31 Q=m*Cvo*(T2-(T1+273))+W; // Heat transferred
32 S21=m*(Cvo+R/(1-n))*log (T2/(T1+273)); // Change in
    entropy
33 disp ("kJ",Q,"Heat transferred = ","kJ",W,"Work done
    = ","kJ/K",S21,"Change in entropy = ","K",T2,"
    Final Temperature = ","(b).Air");

```

Scilab code Exa 7.6 ISENTROPIC EFFICIENCY OF TURBINE

```

1 clc;
2 m=1; // Massflow rate of the steam in kg/s
3 p1=3.5; // Pressure at inlet in MPa
4 T1=400; // Temperature at inlet in degree celcius
5 V1=250; // Velocity of stesm at inlet in m/s
6 p2=50; // Pressure at outlet in kPa
7 T2=100; // Temperature at outlet in degree celcius
8 V2=30; // Velocity of stesm at outlet in m/s

```

```

 9 // For actual expansion in the turbine
10 h1=3222.3; h2=2682.5; // specific enthalpy in kJ/kg
    at inlet and exit
11 wa=h1-h2+(V1^2-V2^2)/2000; // Work done
12 W=m*wa; // Power output
13 disp("kW",W,"Power output of the turbine = (Error
    in textbook)");
14 // For reversible adiabatic expansion
15 // Following are the values taken from steam table
16 s1=6.8405; // specific entropy in kJ/kg K
17 s2s=s1; // Isentropic expansion
18 sf2=1.091; sfg2=6.5029; // specific entropy in kJ/kg
    K
19 hf2=340.49; hfg2=2305.4; // specific enthalpy in kJ/
    kg
20 x2s=(s1-sf2)/sfg2; // Quality of steam at state 2
21 h2s=hf2+x2s*hfg2; // specific enthalpy in kJ/kg
22 ws=h1-h2s+(V1^2-V2^2)/2000; // Isentropic Work done
23 eff_isen=wa/ws; // Isentropic efficiency of the
    turbine
24 disp("%",eff_isen*100,"Isentropic efficiency of the
    turbine = (Error in textbook)")

```

Scilab code Exa 7.7 POWER OF AIRTRBINE

```

1 clc;
2 m=1; // Massflow rate of the steam in kg/s
3 p1=3.5; // Pressure at inlet in bar
4 T1=160; // Temperature at inlet in degree celcius
5 p2=1; // Pressure at outlet in bar
6 Cpo=1.005; // Specific heat at constant pressure in
    kJ/kg K
7 eff_isen=0.85; // Isentropic efficiency of the
    turbine
8 k=1.4; // index of isentropic process

```

```

9 T2s=(T1+273)*(p2/p1)^((k-1)/k); // Final temperature
    after isentropic expansion
10 Ws=m*Cpo*((T1+273)-T2s); // Isentropic power
    developed
11 Wa=eff_isen*Ws; // Actual power developed
12 T2=(T1+273)-(Wa/(m*Cpo)); // Final temperature after
    expansion
13 disp ("K",T2,"Final temperature after expansion = ",
    "kW",Wa,"Actual power developed (Error in
    textbook)=");

```

Scilab code Exa 7.8 ADIABATIC EFFICIENCY OF COMPRESSOR

```

1 clc;
2 m=0.05; // mass flowrate of Freon 12 in kg/s
3 p1=300; // Pressure of Freon 12 at inlet in kpa
4 t1=5; // Temperature of Freon 12 at inlet in degree
    celcius
5 p2=1.2; // Pressure of Freon 12 at outlet in MPa
6 t2=80; // Temperature of Freon 12 at outlet in
    degree celcius
7 W=-2.3; // Power consumption of compressor in kW
8 // (a).Heat transfer from the body of compressor
    to environment
9 // From the table of properties of Freon 12
10 h1= 190.8; h2=230.4; // specific enthalpy in kJ/kg
11 s1=0.71; s2=0.7514 // specific entropy in kJ/kg K
12 Q=m*(h2-h1)+W; // Heat transfer
13 disp ("kW",Q,"(a).Heat transfer from the body of
    compressor to environment =");
14 // (b).Adiabatic efficiency of the compressor
15 // For adiabatic compression p2=1.2Mpa,s2s=s1
16 t2s=61.7; // Temperature of Freon 12 at outlet in
    degree celcius
17 h2s=216.14; // specific enthalpy in kJ/kg

```

```

18 ws=(h2s-h1); // Reversible adiabatic work
19 wa=W/m; // Actual work
20 eff_com=abs (ws/wa); // Adiabatic efficiency
21 disp ("%",eff_com*100,"(b).Adiabatic efficiency of
the compressor = ");

```

Scilab code Exa 7.9 COMPRESSOR OF GAS TURBINE

```

1 clc;
2 p1=1; // Pressure of air at inlet of compressor in
bar
3 T1=30; // Temperature of air at inlet of compressor
in degree celcius
4 p2=12; // Delivery pressure of air in bar
5 T2=400; // Temperature of air at inlet of compressor
in degree celcius
6 V2=90; // Velocity of air at exit in m/s
7 w=3740; // Power input to compressor in kW
8 k=1.4; // Index of reversible adiabatic process
9 Cpo=1.0035; // Specific heat at constant pressure in
kJ/kg K
10 wa=Cpo*(T2-T1)+V2^2/2000; // Actual specific work
input
11 m=w/wa; // Mass flow rate of air
12 T2s=(T1+273)*(p2/p1)^((k-1)/k); // Isentropic
discharge temperature
13 ws=Cpo*(T2s-(T1+273))+V2^2/2000; // Isentropic work
14 eff_com=ws/wa; // Isentrpic efficiency
15 disp ("%",eff_com*100,"Isentrpic efficiency of
compressor =", "K",T2s,"Isentropic discharge
temperature = ");

```

Scilab code Exa 7.10 NOZZLE VELOCITY

```

1  clc;
2  p1=3; // Pressure of fluid at inlet in bar
3  T1=150; // Temperature of fluid at inlet in degree
    celcius
4  V1=90; // Velocity of fluid at inlet in m/s
5  eff_nozzle=0.85; // Nozzle efficiency
6  k=1.4; // Index of reversible adiabatic process
7  p2=1/3*p1;
8  // (a).Steam
9  // Following are taken from steam table
10 h1=2761; // specific enthalpy in kJ/kg
11 s1=7.0778; // specific entropy in kJ/kg K
12 s2s=s1; // Isentropic process
13 sf2s=1.3026; sfg2s=6.0568; // specific entropy in kJ/
    kg K
14 hf2=417.46; hfg2=2258; // specific enthalpy in kJ/kg
15 x2s=(s2s-sf2s)/sfg2s; // Quality of steam
16 h2s=hf2+x2s*hfg2;
17 V2s=sqrt (2000*(h1-h2s)+V1^2); // Isentropic
    Velocity
18 V2=sqrt (eff_nozzle) *V2s; // Actual nozzle exit
    velocity
19 disp ("m/s (round off error)",V2," Actual nozzle
    exit velocity = ", "(a).Steam");
20 // (b).Air
21 Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
22 T2s=(T1+273)*(p2/p1)^((k-1)/k); // Isentropic
    temperature
23 V2s=sqrt ((2000*Cpo*((T1+273)-T2s))+V1^2); //
    Isentropic Velocity and (answer mentioned in the
    textbook is wrong)
24 V2=sqrt (eff_nozzle) *V2s; // Actual nozzle exit
    velocity
25 disp ("m/s (answer mentioned in the textbook is
    wrong)",V2," Actual nozzle exit velocity = ", "(b)
    .Air");

```

Scilab code Exa 7.11 DIFFUSION PROCESS

```
1  clc;
2  p1=200; // Pressure of fluid at inlet in kPa
3  T1=200; // Temperature of fluid at inlet in degree
    celcius
4  V1=700; // Velocity of fluid at inlet in m/s
5  V2=70; // Velocity of fluid at outlet in m/s
6  // (a).Reversible Adiabatic process
7  // state of steam entering diffuser (superheated)
8  h1=2870.5; // specific enthalpy in kJ/kg
9  s1=7.5066; // specific entropy in kJ/kg K
10 h2=h1+(V1^2-V2^2)/2000; // From first and second
    laws
11 s2=s1; // Isentropic peocess
12 // From superheated table
13 p2s=550; // Pressure of fluid at outlet in kPa
14 T2=324; // Temperature of fluid at outlet in degree
    celcius
15 disp ("oC",T2,"Temperature of fluid at outlet =",
    kPa",p2s,"Pressure of fluid at outlet = ",
    "(a).
    Reversible adiabatic process");
16 // (b).Actual diffusion
17 // for the same change in K.E, from first law
18 h2=3113.1; // specific enthalpy in kJ/kg
19 p2=400; // Actual exit pressure in kPa
20 t2=322.4; // from superheated table in degree
    celcius
21 eff_d=(p2-p1)/(p2s-p1); // Diffuser efficiency
22 disp ("% ",eff_d*100,"Diffuser efficiency = ",
    "oC",t2
    ,"The exit temperature =",
    "(b).Actual diffusion")
    ;
```

Scilab code Exa 7.12 REVERSIBLE ADIABATIC EFFICIENCY OF DIFFUSER

```
1  clc ;
2  p1=1; // Pressure of fluid at inlet in bar
3  T1=60; // Temperature of fluid at inlet in degree
      celcius
4  p2=2.8; // Pressure of fluid at outlet in bar
5  eff_d=0.80; // Diffuser efficiency
6  k=1.4; // Index of reversible adiabatic process
7  Cpo=1.0035; // Specific heat at constant pressure in
      kJ/kg K
8  // (a).Actual Diffuser
9  p2s=((p2-p1)/eff_d)+p1; // Isentropic pressure
10 T2=(T1+273)*(p2s/p1)^((k-1)/k); // Exit temperature
11 V1=sqrt (2000*Cpo*(T2-(T1+273))); // Initial
      Velocity
12 disp ("m/s",V1," Initial Velocity =", "K",T2,"
      Temperature of air leaving diffuser =", "(a).
      Actual Diffuser");
13 // (b).Reversible Adiabatic diffuser
14 T2s=(T1+273)*(p2/p1)^((k-1)/k); // Isentropic exit
      temperature
15 V1=sqrt (2000*Cpo*(T2s-(T1+273))); // Initial
      Velocity
16 disp ("m/s",V1," Initial Velocity =", "K",T2s,"
      Temperature of air leaving diffuser =", "(b).
      Reversible Adiabatic diffuser");
```

Scilab code Exa 7.13 USE OF EXHAUST GAS DIFFUSER

```
1  clc ;
2  m=18; // mass flow rate of air in kg/s
```



```

3 p1=3.6; // Pressure of fluid at inlet of turbine in
  MPa
4 T1=800; // Temperature of fluid at inlet of turbine
  in Kelvin
5 V1=100; // Velocity of fluid at inlet of turbine in
  m/s
6 V2=150; // Velocity of fluid at outlet of turbine in
  m/s
7 W=3.6; // Power output of turbine in MW
8 p3=1.01; // pressure at diffuser outlet in bar
9 k=1.4; // Index of reversible adiabatic process
10 Cpo=1.0035; // Specific heat at constant pressure in
  kJ/kg K
11 // (a) Pressure at diffuser inlet
12 T2=((Cpo*T1)-((W*10^3)/m+(V2^2-V1^2)/2000))/Cpo; //
  Temperature at outlet of turbine
13 T3=(T2+273)+((V2^2)/(2*Cpo*10^3)); // Temperature of
  fluid at diffuser inlet
14 p2=p3*((T2+273)/T3)^(k/(k-1)); //pressure at
  diffuser inlet
15 disp ("bar",p2,"(a).pressure at diffuser inlet =");

```

Scilab code Exa 7.14 FLASHING DURING THROTTLING

```

1 clc;
2 T1=35; // Temperature of freon 12 before throttling
  in degree celcius
3 T2=5; // Temperature of freon 12 after throttling in
  degree celcius
4 // from property table of freon 12
5 h1=69.49; // specific enthalpy in kJ/kg
6 hf2=40.66; hfg2=148.86; // specific enthalpy in kJ/
  kg
7 h2=h1; // throttling process
8 x2=(h2-hf2)/hfg2; // Quality of Freon 12 vapour

```

```
9 disp (x2," Quality of Freon 12 vapour = ");
```

Scilab code Exa 7.15 SEPARATING AND THROTTLING CALORIMETER

```
1 clc;
2 p2=276; // Pressure at inlet in kPa
3 p=6.5; // gauge pressure at outlet in cm Hg
4 T3=110; // Temperature at outlet in degree celcius
5 pa=756; // Barometric pressure in mm Hg
6 mc=760; // Mass of condensed steam in g
7 ms=25; // Mass of separated water in g
8 den=13600; // Density of mercury in kg/m^3
9 g=9.81; // Acceleration due to gravity in m/s^2
10 z=(pa*10^-3)+(p*10^-2); // absolute pressure in m Hg
11 p3=den*g*z; // Pressure after throttling
12 h3=2697.4; // specific enthalpy in kJ/kg
13 hf2=545.31; hfg2=2175.2; // specific enthalpy in kJ/
   kg
14 x2=(h3-hf2)/hfg2; // Quality of steam
15 x1=(mc/(mc+ms))*x2; // Quality of steam in the main
   line
16 disp (x1," Quality of steam in the main line =");
```

Chapter 8

VAPOUR CYCLES

Scilab code Exa 8.1 A CARNOT STEAM CYCLE

```
1  clc;
2  TH=311.06; // Source temperature in degree celcius
3  pb=10; // Boiler pressure in MPa
4  TL=32.88; // Sink temperature in degree celcius
5  pc=5; // Condenser pressure in kPa
6  // From steam tables at pb
7  h2=1407.56; // specific enthalpy in kJ/kg
8  h3=2724.7; // specific enthalpy in kJ/kg
9  s2=3.3596; // specific entropy in kJ/kg K
10 s3=5.6141; // specific entropy in kJ/kg K
11 // From steam tables at pc
12 hf=137.82; hfg=2423.7; // specific enthalpy in kJ/kg
13 sf=0.4764; sfg=7.9187; // specific entropy in kJ/kg
   K
14 x1=(s2-sf)/sfg; // quality of steam at state 1
15 x4=(s3-sf)/sfg; // quality of steam at state 4
16 h1=hf+x1*hfg; // specific enthalpy at state 1
17 h4=hf+x4*hfg; // specific enthalpy at state 4
18 wT=h3-h4; // Turbine work
19 wC=h2-h1; // Compressor work
20 wnet=wT-wC; // Net work output
```

```

21 qH=h3-h2; // Heat added
22 rw=wnet/wT; // Ratio of net work to trbine work
23 eff_th=wnet/qH; // Thermal efficiency
24 SSC=3600/wnet; // specific steam consumption
25 disp ("kg/kWh",SSC,"specific steam consumption =", "%
      ",eff_th*100,"Thermal efficiency =",rw,"Ratio of
      net work to trbine work =");

```

Scilab code Exa 8.2 SIMPLE RANKINE CYCLE

```

1  clc;
2  TH=311.06; // Source temperature in degree celcius
3  p2=10; // Boiler pressure in MPa
4  TL=32.88; // Sink temperature in degree celcius
5  p1=5; // Condenser pressure in kPa
6  // From steam tables at p2
7  h3=2724.7; // specific enthalpy in kJ/kg
8  s3=5.6141; // specific entropy in kJ/kg K
9  // From steam tables at p1
10 hf=137.82; hfg=2423.7; // specific enthalpy in kJ/kg
11 sf=0.4764; sfg=7.9187; // specific entropy in kJ/kg
    K
12 x4=(s3-sf)/sfg; // quality of steam at state 4
13 h4=hf+x4*hfg; // specific enthalpy at state 4
14 h1=137.82; // specific enthalpy at state 1 in kJ/kg
15 s1=0.4764; // specific entropy at state in kJ/kgK
16 v1=0.001005; // specific volume in m^3/kg
17 wp=abs (v1*(p2*10^3-p1)); // Pump work (absolute
    value)
18 h2=h1+wp; // specific enthalpy at state 2
19 wT=h3-h4; // Turbine work
20 wnet=wT-wp; // Net work output
21 qH=h3-h2; // Heat added
22 rw=wnet/wT; // Ratio of net work to trbine work
23 eff_th=wnet/qH; // Thermal efficiency

```

```

24 SSC=3600/wnet; // specific steam consumption
25 disp ("kg/kWh",SSC,"specific steam consumption =", "%
    ",eff_th*100,"Thermal efficiency =",rw,"Ratio of
    net work to trbine work =");

```

Scilab code Exa 8.3 COMPARSION OF CARNOT AND RANKINE CYCLE

```

1  clc;
2  TH=311.06; // Source temperature in degree celcius
3  p2=10; // Boiler pressure in MPa
4  TL=32.88; // Sink temperature in degree celcius
5  p1=5; // Condenser pressure in kPa
6  // (a).Actual carnot cycle
7  eff_Tur=0.8; // Efficiency of turbine
8  eff_com=0.6; // Efficiency of compressure
9  // From steam tables at p2
10 h3=2724.7; // specific enthalpy in kJ/kg
11 s3=5.6141; // specific entropy in kJ/kg K
12 s2=3.3596; // specific entropy in kJ/kg K
13 h2=1407.56; // specific enthalpy in kJ/kg
14 // From steam tables at p1
15 hf=137.82; hfg=2423.7; // specific enthalpy in kJ/kg
16 sf=0.4764; sfg=7.9187; // specific entropy in kJ/kg
    K
17 x1=(s2-sf)/sfg; // quality of steam at state 1
18 x4=(s3-sf)/sfg; // quality of steam at state 4
19 h1=hf+x1*hfg; // specific enthalpy at state 1
20 h4=hf+x4*hfg; // specific enthalpy at state 4
21 wTs=h3-h4; // Turbine work
22 wT=eff_Tur*wTs; // Actual turbine work
23 wCs=h2-h1; // Compressor work
24 wC=wCs/eff_com; // Actual compressor work
25 wnet=wT-wC; // Net work output
26 h2a=h1+wC; // specific enthalpy
27 qH=h3-h2a; // Heat added

```

```

28 rw=wnet/wT; // Ratio of net work to trbine work
29 eff_th=wnet/qH; // Thermal efficiency
30 SSC=3600/wnet; // specific steam consumption
31 disp ("kg/kWh",SSC,"specific steam consumption =", "%
    ",eff_th*100,"Thermal efficiency =",rw,"Ratio of
    net work to trbine work =", "(a).Actual carnot
    cycle");
32 // (b).Actual Rankine cycle
33 eff_Tur=0.8; // Efficiency of turbine
34 eff_pump=0.9; // Efficiency of Pump
35 // From steam tables at p1
36 h1=137.82; // specific enthalpy at state 1 in kJ/kg
37 s1=0.4764; // specific entropy at state in kJ/kgK
38 v1=0.001005; // specific volume in m^3/kg
39 wps=abs (v1*(p2*10^3-p1)); // Pump work (absolute
    value)
40 wp=wps/eff_pump; // Actual pmp work
41 h2a=h1+wp; // // specific enthalpy at state 2
42 wnet=wT-wp; // Net work output
43 qH=h3-h2a; // Heat added
44 rw=wnet/wT; // Ratio of net work to trbine work
45 eff_th=wnet/qH; // Thermal efficiency
46 SSC=3600/wnet; // specific steam consumption
47 disp ("kg/kWh",SSC,"specific steam consumption =", "%
    ",eff_th*100,"Thermal efficiency =",rw,"Ratio of
    net work to trbine work =", "(b).Actual Rankine
    cycle");

```

Scilab code Exa 8.4 DETERMINATION OF QUALITY OF EXHAUST STEAM AND SSC

```

1 clc;
2 T3=450; // temperature of steam at state 3 in degree
    celcius
3 p3=10; // Boiler pressure in MPa
4 p6=5; // Condenser pressure in kPa

```

```

5 // From steam tables at state 1
6 hf=137.82; hfg=2423.7; // specific enthalpy in kJ/kg
7 sf=0.4764; sfg=7.9187; // specific entropy in kJ/kg
  K
8 h1=137.82; // specific enthalpy at state 1 in kJ/kg
9 s1=0.4764; // specific entropy at state in kJ/kgK
10 v1=0.001005; // specific volume in m^3/kg
11 wp=abs (v1*(p3*10^3-p6)); // Pump work (absolute
  value)
12 h2=h1+wp; // specific enthalpy at state 2
13 // (a).Rankine cycle with superheat
14 // From steam tables at state 3
15 h3=3240.9; // specific enthalpy in kJ/kg
16 s3=6.419; // specific entropy in kJ/kg K
17 // State 4_1
18 x4_1=(s3-sf)/sfg; // Quality of steam at state 4_1
19 h4_1=hf+x4_1*hfg; // specific enthalpy at state 4_1
20 wT=h3-h4_1; // Turbine work
21 wnet=wT-wp; // Net work output
22 qH=h3-h2; // Heat added
23 eff_th=wnet/qH; // Thermal efficiency
24 SSC=3600/wnet; // specific steam consumption
25 disp ("kg/kWh",SSC,"specific steam consumption =", "%
  ",eff_th*100,"Thermal efficiency =",x4_1,"Quality
  of steam at exhaust = ",(a).Rankine cycle with
  superheat");
26 // (b).Reheat cycle
27 s4=s3; // isentropic expansion
28 x4=0.975; // Quality of steam at state 4
29 // from steam table intermediate pressure is
  selected for s4 & x4 by interpolation and assumed
  by round value
30 p4=1.2; // Intermediate pressure in MPa
31 // From steam tables at state 4
32 hf4=798.6; hfg4=1986.2; // specific enthalpy in kJ/
  kg
33 h4=hf4+x4*hfg4; // specific enthalpy in kJ/kg
34 // From steam tables at state 5

```

```

35 h5=3368.5; // specific enthalpy in kJ/kg
36 s5=7.5266; // specific entropy in kJ/kg K
37 x6=(s5-sf)/sfg; // Quality of steam at state 6
38 h6=hf+x6*hfg; // specific enthalpy in kJ/kg
39 wT=(h3-h4)+(h5-h6); // Turbine work
40 wnet=wT-wp; // Net work output
41 qH=(h3-h2)+(h5-h4); // Heat added
42 eff_th=wnet/qH; // Thermal efficiency
43 SSC=3600/wnet; // specific steam consumption
44 disp ("kg/kWh",SSC,"specific steam consumption =", "%
    ",eff_th*100,"Thermal efficiency =",x6,"Quality
    of steam at exhaust = ", "(b).Reheat cycle");

```

Scilab code Exa 8.5 BLEEDING OF STEAM

```

1  clc;
2  T5=311.06; // temperature of steam at state 5 in
    degree celcius
3  p5=10; // Boiler pressure in MPa
4  p4=p5;
5  T7=32.88; // temperature of steam at state 7 in
    degree celcius
6  p7=5; // Condenser pressure in kPa
7  p1=p7;
8  // From steam tables at p7
9  h1=137.82; // specific enthalpy at state 1 in kJ/kg
10 s1=0.4764; // specific entropy at state 1 in kJ/kgK
11 v1=0.001005; // specific volume in m^3/kg
12 wp=abs (v1*(p5*10^3-p7)); // Pump work (absolute
    value)
13 h2=h1+wp; // specific enthalpy at state 2
14 T6=(T5+T7)/2; // Temperature of bleed system
15 h5=2724.7; // specific enthalpy at state 5 in kJ/kg
16 s5=5.6141; // specific entropy at state 5 in kJ/kgK
17 // From steam tables at state 6

```



```

18 p6=791.5; // bleed steam pressure in kPa
19 p2=p6; p3=p6;
20 vf6=0.00114; // specific volume in m^3/kg
21 v3=vf6;
22 hf6=719.21; hfg6=2049.5; // specific enthalpy in kJ/
    kg
23 sf6=2.0419; sfg6=4.6244; // specific entropy in kJ/
    kg K
24 x6=(s5-sf6)/sfg6; // quality of steam at state 6
25 h6=hf6+x6*hfg6; // specific enthalpy at state 6
26 h3=hf6; // specific enthalpy at state 3
27 m1=(h3-h2)/(h6-h2); // Fraction of bleed steam
28 wLP=abs (v1*(p2-p1)); // LP work
29 wHP=abs (v3*(p4*10^3-p3)); // HP work
30 wp=(1-m1)*wLP+wHP; // Total pump work
31 h2=h1+wp; h4=h3+wp; // Specific Enthalpies of water
32 // From steam tables at pc
33 hf7=137.82; hfg7=2423.7; // specific enthalpy in kJ/
    kg
34 sf7=0.4764; sfg7=7.9187; // specific entropy in kJ/
    kg K
35 x7=(s5-sf7)/sfg7; // quality of steam at state 7
36 h7=hf7+x7*hfg7; // specific enthalpy at state 4
37 wT=(h5-h6)+(1-m1)*(h6-h7); // Turbine work
38 wnet=wT-wp; // Net work output
39 qH=h5-h4; // Heat added
40 eff_th=wnet/qH; // Thermal efficiency
41 SSC=3600/wnet; // specific steam consumption
42 disp ("kg/kWh",SSC,"specific steam consumption =","%
    ",eff_th*100,"Thermal efficiency =");

```

Scilab code Exa 8.6 BOILER EFFICIENCY

```

1 clc;
2 ps=6.89+1; // Pressure of steam produced in bar (

```

```

    Absolute)
3  x=0.96; // Quality of steam produced
4  f=75; // Steady flow of water in litres
5  t=9.5; // Time consumption of water in minutes
6  tf=685; //Time consumption of 10 litre fuel in
    seconds
7  Vf=10; // consumption of fuel in litres
8  Sf=0.85; // specific gravity of water
9  CV=43125; // Calorific value of fuel in kJ/kg
10 ms=f/(t*60); // Steam generation
11 mf=Vf*Sf/tf; // consumption of fuel
12 // From steam tables at ps
13 hf=718.5; hfg=2050; // specific enthalpy in kJ/kg
14 hs=hf+x*hfg; // specific enthalpy of steam produced
15 hFW=146.7; // Enthalpy of feed water at 35 degree
    celcius
16 eff_boiler=(ms*(hs-hFW))/(mf*CV); // Boiler
    Efficiency
17 disp ("%",eff_boiler*100," Boiler Efficiency = ");

```

Scilab code Exa 8.7 A CARNOT REFRIGERATOR

```

1  clc;
2  TL=-15; // Source temperature in degree celcius
3  TH=40; // Sink temperature in degree celcius
4  // From the table of properties of Freon - 12
5  h2=203.05; h3=74.53; hf4=22.31; hg4=180.85; //
    specific enthalpy in kJ/kg
6  s1=0.682; s3=0.2716; sf4=0.0906; sg4=0.7046; sfg4=
    sg4-sf4; // specific entropy in kJ/kg K
7  sf1=sf4; sfg1=sfg4; s2=s1; s4=s3; hf1=hf4; hg1=hg4;
    hfg4=hg4-hf4; hfg1=hfg4; // refer figure 8.20
8  x1=(s1-sf1)/sfg1; // Dryness fraction at state 1
9  x4=(s4-sf4)/sfg4; // dryness fraction at state 4
10 h1=hf1+x1*hfg1; h4=hf4+x4*hfg4; // specific enthalpy

```

```

        in kJ/kg
11  wc=h2-h1; // work of compression
12  wE=h3-h4; // Work of expansion
13  qL=h1-h4; // Refrigerating effect
14  qH=h2-h3; // Heat rejected
15  wnet=wc-wE; // Net work
16  COPc=qL/wnet; // COP of the cycle
17  disp (COPc,"COP of the cycle =", "kJ/kg",qH,"Heat
        rejected =", "kJ/kg",qL,"Refrigerating effect = ",
        "kJ/kg",wE,"Work of expansion =", "kJ/kg",wc,"Work
        of compression = ");

```

Scilab code Exa 8.8 VAPOUR COMPRESSION CYCLE

```

1  clc;
2  TL=-15; // Source temperature in degree celcius
3  TH=40; // Sink temperature in degree celcius
4  // From the table of properties of Freon - 12
5  h3=74.53; h1=180.85; h4=h3; // specific enthalpy in
        kJ/kg
6  s1=0.7046; s2=0.682; // specific entropy in kJ/kg K
7  // (a)
8  // (i).Condensor and Evaporator pressure
9  pc=0.9607; // Saturation pressure at TH in MPa
10 pE=0.1826; // Saturation pressure at TL in MPa
11 disp ("MPa",pE,"Evaporator pressure = ", "MPa",pc,"
        Condensor pressure = ", "(i).Condensor and
        Evaporator pressure", "(a)");
12 // (ii).Compressor discharge temperature & Enthalpy
13 p2=pc; // Condensor pressure
14 s2=s1; // refer figure 8.25
15 // From the table of properties of Freon - 12 at pc
16 t2=46.8; // Compressor discharge temperature in
        degree celcius
17 h2=208.3; // specific enthalpy in kJ/kg

```

```

18 disp ("kJ/kg",h2," Enthalpy = ", "oC",t2," Compressor
    discharge temperature = ",(ii).Compressor
    discharge temperature & Enthalpy");
19 // (iii).Ratio of COP of the cycle to Carnot COP
20 w=h2-h1; // Compressor work
21 qL=h1-h4; // Refrigeration effect
22 COP=qL/w; // COP of the cycle
23 COPc=4.68; // COP of carnot cycle from example 8.7
24 r=COP/COPc; // Ratio of COP of the cycle to Carnot
    COP
25 disp (r,"(iii).Ratio of COP of the cycle to Carnot
    COP = ");
26 // (b)
27 QL=0.440; // Capacity of refrigerator in kW (1/8 ton
    of refrigeration)
28 m=QL/qL; // Mass flow rate of refrigerant
29 W=m*w; // Power consumption of compressor
30 QH=QL+W; // Heat rejected
31 disp ("kW",QH,"Heat rejected to surroundings = ", "kW
    ",W,"Power consumption of compressor = ", "kg/s",m
    ,"Mass flow rate of refrigerant = ", "(b)");

```

Chapter 9

GAS CYCLES

Scilab code Exa 9.1 OTTO CYCLE

```
1  clc;
2  r=8; // Compression ratio of an engine
3  p1=100; // Pressure of air before compression in lPa
4  T1=300; // Temperature air before compression in
      kelvin
5  qH=1800; // Heat added to the air in kJ/kg
6  k=1.4; // Index of reversible adiabatic process
7  Cvo=0.7165; // Specific heat at constant volume in
      kJ/kg K
8  Cpo=1.0035; // Specific heat at constant pressure in
      kJ/kg K
9  R=0.287; // characteristic gas constant of air in kJ
      /kg K
10 // Otto cycle
11 // (1) state 2
12 p2=p1*(r)^k; // Pressure at the end of compression
13 T2=T1*(p2/p1)^((k-1)/k); // Temperature at the end of
      compression
14 disp ("K",T1,"Temperature air before compression =",
      "kPa",p1,"Pressure of air before compression = ",
      "(1).state 1");
```

```

15 disp ("K",T2,"Temperature at the end of compression
    =", "kPa",p2," Pressure of air at the end of
    compression = ", "state 2");
16 // state 3
17 T3=(qH/Cvo)+T2; // Temperatue after heat addition
18 p3=p2*(T3/T2); // Pressure after heat addition
19 disp ("K (round off error)",T3,"Temperature after
    heat addition =", "kPa (round off error)",p3,"
    Pressure after heat addition = ", "state 3");
20 // state 4
21 p4=p3*(1/r)^k; // Pressure after expansion
22 T4=T3*(p4/p3)^((k-1)/k); // Temperature after
    expansion
23 disp ("K (round off error)",T4,"Temperature after
    expansion =", "kPa (round off error)",p4,"
    Pressure after expansion = ", "state 4");
24 // (2).Thermal efficiency
25 qL=Cvo*(T4-T1); // Heat rejected
26 eff_th=1-qL/qH; // thermal efficiency
27 // (3). Mean effective pressure
28 wnet=qH-qL; // net work
29 v1=R*T1/p1; // Specific volume at state 1
30 v2=v1/r; // Specific volume at state 2
31 pm=wnet/(v1-v2); // Mean effective pressure
32 disp ("kPa",pm,"(3).Mean effective pressure = ", "%
    (round off error)",eff_th*100,"(2).Thermal
    efficienvy = ");

```

Scilab code Exa 9.2 DIESEL CYCLE

```

1 clc;
2 r=18; // Compression ratio of an engine
3 p1=100; // Pressure of air before compression in lPa
4 T1=300; // Temperature air before compression in
    kelvin

```

```

5 qH=1800; // Heat added to the air in kJ/kg
6 k=1.4; // Index of reversible adiabatic process
7 Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
8 Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
9 R=0.287; // characteristic gas constant of air in kJ
    /kg K
10 // Diesel cycle
11 // state 2
12 T2=T1*(r)^(k-1); // Temperature at the end of
    compression
13 p2=p1*(r)^k; // Pressure at the end of compression
14 // state 3
15 T3=(qH/Cpo)+T2; // Temperature after heat addition
16 p3=p2; // constant pressure
17 Tmax=T3; // maximum temperature
18 Pmax=p3; // Maximum pressure
19 // state 4
20 v3=R*T3/p3; // Specific volume at state 3
21 v4=R*T1/p1; // Specific volume at state 4
22 T4=T3*(v3/v4)^(k-1); // Temperature after expansion
23 p4=p3*(v3/v4)^k; // Pressure after expansion
24 qL=Cvo*(T4-T1); // Heat rejected
25 wnet=qH-qL; // net work
26 eff_th=wnet/qH; // thermal efficiency
27 v1=R*T1/p1; // Specific volume at state 1
28 v2=v1/r; // Specific volume at state 2
29 pm=wnet/(v1-v2); // Mean effective pressure
30 disp ("kPa",pm,"Mean effective pressure = (Error in
    textbook) ", "%", eff_th*100, "Thermal efficiency =
    ", "K", Tmax, "Maximum Temperature = ", "kPa", Pmax, "
    Maximum pressure = ");

```

Scilab code Exa 9.3 STANDARD BRAYTON CYCLE

```

1  clc;
2  p1=0.1; // Pressure of air at inlet in MPa
3  T1=300; // Temperature of air at inlet in kelvin
4  p2=0.6; // Pressure of air at exit in MPa
5  T3=1200; // Maximun temperature of air in kelvin
6  k=1.4; // Index of reversible adiabatic process
7  Cvo=0.7165; // Specific heat at constant volume in
      kJ/kg K
8  Cpo=1.0035; // Specific heat at constant pressure in
      kJ/kg K
9  R=0.287; // characteristic gas constant of air in kJ
      /kg K
10 // Brayton cycle
11 rp=p2/p1; // pressure ratio
12 T2=T1*(p2/p1)^((k-1)/k); // Temperature at the end of
      compression
13 wc=Cpo*(T2-T1); // compressor work
14 T4=T3*(p1/p2)^((k-1)/k); // Temperature at the end of
      expansion
15 wT=Cpo*(T3-T4); // Turbine work
16 qH=Cpo*(T3-T2); // heat addition
17 wnet=wT-wc; // net work
18 eff_th=wnet/qH; // thermal efficiency
19 rw=wnet/wT; // worh ratio
20 disp (rw,"Work Ratio = ", "%", eff_th*100, " Thermal
      Efficiency = ");

```

Scilab code Exa 9.4 ACTUAL GAS TURBINE CYCLE

```

1  clc;
2  p1=0.1; // Pressure of air at inlet in MPa
3  T1=300; // Temperature of air at inlet in kelvin
4  p2=0.6; // Pressure of air at exit in MPa
5  T3=1200; // Maximun temperature of air in kelvin
6  k=1.4; // Index of reversible adiabatic process

```



```

7 Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
8 Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
9 R=0.287; // characteristic gas constant of air in kJ
    /kg K
10 eff_t=0.85; // Turbine efficiency
11 eff_c=0.8; // Compressor efficienct
12 // Brayton cycle
13 rp=p2/p1; // pressure ratio
14 T2s=T1*(p2/p1)^((k-1)/k); // Isentropic Temperature
    at the end of compression
15 T2=((T2s-T1)/eff_c)+T1; // Actual Temperature at the
    end of compression
16 p3=0.585; // as per given in MPa
17 p4s=0.11; // As per given in MPa
18 T4s=T3*(p4s/p3)^((k-1)/k); // Isentropic temperature
    after reversible adiabatic expansion
19 T4=T3-(eff_t*(T3-T4s)); // Actual temperature at
    state 4
20 wc=Cpo*(T2-T1); // compressor work
21 wT=Cpo*(T3-T4); // Turbine work
22 qH=Cpo*(T3-T2); // heat addition
23 wnet=wT-wc; // net work
24 eff_th=wnet/qH; // thermal efficiency
25 rw=wnet/wT; // worh ratio
26 disp (rw,"Work Ratio = ", "%", eff_th*100," Thermal
    Efficiency = ");

```

Scilab code Exa 9.5 AN IDEAL REGENERATOR

```

1 clc;
2 p1=0.1; // Pressure of air at inlet in MPa
3 T1=300; // Temperature of air at inlet in kelvin
4 p2=0.6; // Pressure of air at exit in MPa

```

```

5 T3=1200; // Maximum temperature of air in kelvin
6 k=1.4; // Index of reversible adiabatic process
7 Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
8 Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
9 R=0.287; // characteristic gas constant of air in kJ
    /kg K
10 // Brayton cycle
11 rp=p2/p1; // pressure ratio
12 T2=T1*(p2/p1)^((k-1)/k); // Temperature at the end of
    compression
13 T4=T3*(p1/p2)^((k-1)/k); // Temperature at state 4
14 Tx=T4; Ty=T2; // regenerator temperatures
15 qH=Cpo*(T3-Tx); // Heat added in the cycle with
    regenerator
16 qL=Cpo*(Ty-T1); // Heat rejected in the cycle with
    regenerator
17 eff_th=1-qL/qH; // Thermal efficiency
18 disp("%",eff_th*100,"Thermal efficiency with
    regenerator = ");

```

Scilab code Exa 9.6 AIR STANDARD CYCLE FOR JET PROPULSION

```

1 clc;
2 V1=250; // Velocoty of jet aircraft in m/s
3 p1=60; // Atmospheric pressure in kPa
4 T1=260; // Atmospheric temperature in kelvin
5 rp=8; // Pressure ratio of compressor
6 T4=1350; // Temperature of gas at turbine inlet in
    kelvin
7 k=1.4; // Index of reversible adiabatic process
8 Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
9 Cpo=1.0035; // Specific heat at constant pressure in

```

```

    kJ/kg K
10 R=0.287; // characteristic gas constant of air in kJ
    /kg K
11 // (a).The pressure and temperature at each point of
    the cycle
12 // process 1-2 isentropic diffusion
13 T2=T1+(V1^2)/(2*Cpo*10^3); // Temperature at state 2
14 p2=p1*(T2/T1)^(k/(k-1)); // Pressure at state 2
15 // process 2-3 isentropic compression
16 p3=rp*p2; // perssure at state 3
17 T3=T2*(p3/p2)^((k-1)/k); // Temperature at state 3
18 wc=Cpo*(T3-T2); // compressor work
19 // process 3-4 Constant pressur heat addition
20 qH=Cpo*(T4-T3); // heat addition
21 p4=p3; // constant pressure
22 // process 4-5 isentropic expansion in turbine
23 wT=wc;
24 T5=T4-(wT/Cpo); // Temperature at state 5
25 p5=p4*(T5/T4)^(k/(k-1)); // Pressure at state 5
26 // process 5-6 Isentropic expansion in nozzle
27 p6=p1;
28 T6=T5*(p6/p5)^((k-1)/k); // Temperature at state 6
29 disp ("K",T6,"T6 = ", "kPa",p6,"p6 = ", "state 6", "K",
    T5,"T5 = ", "kPa",p5,"p5 = ", "State 5", "K",T4,"T4
    = ", "kPa",p4,"p4 = ", "State 4", "K",T3,"T3 = ", "kPa
    ",p3,"p3 = ", "State 3", "K",T2,"T2 = ", "kPa",p2,"p2
    = ", "State 2", "K",T1,"T1 = ", "kPa",p1,"p1 = ", "
    State 1", "(a).The pressure and temperature at
    each point of the cycle");
30 // (b).Exit velocity of jet
31 V6=sqrt (2*Cpo*10^3*(T5-T6)); // Exit velocity of
    jet
32 disp ("m/s",V6,"(b).Exit velocity of jet =");
33 // (c).Specific thrust and work output
34 F_mair=(V6-V1); // Specific thrust
35 w=F_mair*V1/1000; // Work output
36 disp ("kJ/kg",w,"Work output = ", "N",F_mair,"
    Specific thrust = ", "(c).Specific thrust and work

```

```

        output");
37 // (d). Propulsion efficiency
38 eff_p=w/(w+(V6^2-V1^2)/2000); // Propulsion
    efficiency
39 disp ("% ", eff_p*100, "(d). Propulsion efficiency =");
40 // (e). Overall thermal efficiency
41 eff_th=w/qH; // Overall thermal efficiency
42 disp ("% ", eff_th*100, "(e). Overall thermal efficiency
    =");

```

Scilab code Exa 9.7 REVERSED BRAYTON CYCLE

```

1  clc;
2  p1=100; // Pressure of air at inlet in kPa
3  T1=288; // Temperature of air at inlet in kelvin
4  rp=12; // Pressure ratio of the compressor
5  k=1.4; // Index of reversible adiabatic process
6  Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
7  Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
8  R=0.287; // characteristic gas constant of air in kJ
    /kg K
9  T3=T1; // From figure
10 // process 1-2
11 p2=12*p1; // Pressure at state 2
12 T2=T1*(p2/p1)^((k-1)/k); // Temperature at state 2
13 wc=Cpo*(T2-T1); // Compressor work
14 // process 2-3
15 qH=Cpo*(T2-T3); // Heat added
16 // process 3-4
17 T4=T3*(1/rp)^((k-1)/k); // Temperature at state 4
18 // process 4-1 Refrigerating coil
19 qL=Cpo*(T1-T4); // heat rejected
20 wnet=qH-qL; // net work

```

```

21 cop=qL/wnet; // Cop of plant
22 pc=wnet/qL; // Power consumption per kW of
    refrigeration
23 disp ("kW/kW",pc,"Power consumption per kW of
    refrigeration =",cop,"COP of the cycle =");

```

Scilab code Exa 9.8 A REGENERATIVE HEAT EXCHANGER

```

1  clc;
2  p1=100; // Pressure of air at inlet in kPa
3  T1=288; // Temperature of air at inlet in kelvin
4  rp=12; // Pressure ratio of the compressor
5  T4=223; // Temperature at state 4
6  k=1.4; // Index of reversible adiabatic process
7  Cvo=0.7165; // Specific heat at constant volume in
    kJ/kg K
8  Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
9  R=0.287; // characteristic gas constant of air in kJ
    /kg K
10 T3=T1; // From figure
11 // process 1-2
12 p2=12*p1; // Pressure at state 2
13 T2=T1*(p2/p1)^((k-1)/k); // Temperature at state 2
14 wc=Cpo*(T2-T1); // Compressor work
15 // process 2-3
16 qH=Cpo*(T2-T3); // Heat added
17 // process 3-4 cooling in regenerative heat
    exchanger
18 qregen=Cpo*(T3-T4); // cooling in regenerative heat
    exchanger
19 // process 4-5 Expander
20 T5=T4*(1/rp)^((k-1)/k); // Temperature at state 5
21 wE=Cpo*(T4-T5); // Expander work
22 // process 5-6 Refrigerating coil

```

```
23 T6=T4; // From figure 9.32
24 qL=Cpo*(T6-T5); // Heat rejected
25 // process 6-1 Heating in regenerative heat
    exchanger
26 qregen=Cpo*(T1-T6); // Heat supplied
27 wnet=qH-qL; // net work
28 cop=qL/wnet; // Cop of plant
29 disp (cop,"COP of the modified cycle =");
```

Chapter 10

AVAILABILITY AND IRREVERSIBILITY

Scilab code Exa 10.1 AVAILABLE ENERGY

```
1 clc;  
2 m=100; // Mass of water in kg  
3 T0=90; // Initial temperature of water in degree  
   celcius  
4 T=30; // temperature of Surroundings in degree  
   celcius  
5 C=4.1868; // Specific heat in kJ/kg K  
6 AE=m*C*((T0-T)-(T+273)*log((T0+273)/(T+273))); //  
   Available energy  
7 Q=m*C*(T0-T); // Heat supplied  
8 UE=Q-AE; // Unavailable energy  
9 disp ("kJ",AE," Available energy =");  
10 disp ("kJ",UE," Unavailable energy = ", "kJ",Q," Heat  
   supplied = ");
```

Scilab code Exa 10.2 LOSS OF AE DURING HEAT TRANSFER IN A BOILER

```

1  clc;
2  T=250; // Evaporation teemperature of water in
        degree celcius
3  Ta=1250; // Initial temperature of combustion gas in
        degree celcius
4  Tb=350; // Final temperature of combustion gas in
        degree celcius
5  C=1.08; // Specific heat of gas in kJ/kg K
6  T0=30; // temperature of Surroundings in degree
        celcius
7  hfg=1716.2; // Enthalpy of evaporation at T
        temperature
8  del_SH20=hfg/(T+273); // Entropy change of water
9  mgas=hfg/(C*(Ta-Tb)); // Mass of gas
10 del_Sgas=mgas*C*log ((Tb+273)/(Ta+273)); // Enthalpy
        change of gas
11 del_Stotal=del_SH20+del_Sgas; // Total entropy
        change
12 l_AE=(T0+273)*del_Stotal; // Loss of available
        energy
13 disp ("kJ",l_AE,"Loss of available energy = ");

```

Scilab code Exa 10.3 STEAM POWER PLANT

```

1  clc;
2  Cp=1.1; // Specific heat of combustion gas in kJ/kg
        K
3  T3=1600; // Initial temperature of combustion gas in
        Kelvin
4  T4=1150; // Final temperature of combustion gas in
        Kelvin
5  p1=0.1; // Pressure at inlet of boiler in MPa
6  p2=8; // Pressure at outlet of boiler in MPa
7  T2=600; // Temperature at outlet of boiler in degree
        celcius

```



```

8 m=1; // Mass of water in kg
9 T0=298; // temperature of Surroundings in kelvin
10 // (b).mass flow rate of gases per kg of water
11 // From steam table
12 h1=2758; h2=3642; // specific enthalpy in kJ/kg
13 s1=5.7432; s2=7.0206; // specific entropy in kJ/kg K
14 mgas=(h2-h1)/(Cp*(T3-T4)); //mass flow rate of gases
    per kg of water
15 disp ("kg gas / kg water",mgas,"(b).mass flow rate
    of gases per kg of water =");
16 // (c). Decrease in Available energy
17 S21=s2-s1; // Change in entropy of water
18 S34=mgas*Cp*log (T3/T4); // Change in entropy of
    gases
19 UEgases=T0*S34; // UnAvailable energy of gas
20 UEsteam=T0*S21; // UnAvailable energy of steam
21 d_AE=UEsteam-UEgases; // Decrease in Available
    energy
22 disp ("kJ/K",-S34,"Change in entropy of gas = ", "kJ/
    K",S21,"Change in entropy of water = ", "(c).");
23 disp ("kJ",UEsteam,"Unavailable energy of steam = ", "
    kJ",UEgases,"Unavailable energy of gas = ");
24 disp ("kJ",d_AE," Decrease in Available energy = ");

```

Scilab code Exa 10.5 AVAILABLE ENERGY IN EXHAUST GAS

```

1 clc;
2 T=700; // Exhaust gas temperature in degree celcius
3 p=120; // Exhaust gas pressure in kPa
4 Cpo=1.089; // Specific heat at constant pressure in
    kJ/kg K
5 R=0.287; // characteristic gas constant in kJ/kg K
6 p0=100; // Pressure of Surroundings in kPa
7 T0=30; // temperature of Surroundings in degree
    celcius

```

```

8 Cvo=Cpo-R; // Specific heat at constant volume
9 AE=(Cvo*(T-T0)+(p0*R*((T+273)/p-(T0+273)/p0))-((T0
    +273)*((Cpo*log((T+273)/(T0+273)))-(R*log (p/p0))
    )); // Available energy
10 disp ("kJ",AE," Available energy in Exhaust gas =");

```

Scilab code Exa 10.6 IRREVERSIBILITY OF THE PROCESS

```

1 clc;
2 p1=450; // Initial pressure in kPa
3 T=600; // Initial temperature in kelvin
4 V1=0.01; // Initial volume in m^3
5 TR=1200; // Temperature of heat source in Kelvin
6 V2=0.02; // Final volume in m^3
7 p0=100; // Pressure of Surroundings in kPa
8 T0=300; // temperature of Surroundings in kelvin
9 // Useful Work
10 W=p1*V1*log (V2/V1); // Actual work
11 Wsurr=p0*(V2-V1); // Surrounding work
12 Wu=W-Wsurr; // Useful work
13 disp ("kJ",Wu," Useful Work for the process =");
14 // Reversible work
15 Q=W; // For isothermal process
16 S21=Q/T; // Entropy change of system
17 Wrev=T0*S21-Wsurr+Q*(1-T0/TR); // reversible work
18 disp ("kJ",Wrev," Reversible work for the proevs =")
    ;
19 // Irreversibility of the process
20 I=Wrev-Wu; // Irreversibility
21 disp ("kJ",I," Irreversibility of the process = ");
22 // Entropy generation
23 del_Sgen=S21-Q/TR; //Entropy generation
24 disp ("kJ/kg",del_Sgen," Entropy generation of the
    process = ");

```

Scilab code Exa 10.7 IRREVERSIBILITY IN TURBINE AND COMPRESSOR

```

1  clc;
2  // (i).Irreversibility in Turbine
3  p1=9; // Steam pressure at turbine inlet in MPa
4  T1=450; // Steam temperature at turbine inlet in
    degree celcius
5  p2=50; // Steam pressure at turbine outlet in MPa
6  x2=0.95; // Quality of steam
7  p0=100; // Pressure of Surroundings in kPa
8  T0=300; // temperature of Surroundings in kelvin
9  q=-10; // Heat loss in kJ/kg
10 // (a).Decrease in availability
11 // from steam table
12 h1=3256.6; h2=2415.4; // specific enthalpy in kJ/kg
13 s1=6.4844; s2=6.944; // specific entropy in kJ/kg K
14 d_AE=(h1-h2)-(T0*(s1-s2)); // Decrease in
    availability
15 disp ("kJ/kg",d_AE,"(a).Decrease in availability =",
    "(i).Irreversibility in turbine");
16 // (b).Maxximum work output
17 wrev=d_AE; //Maxximum work output
18 disp ("kJ/kg",wrev,"(b).Maxximum work output =");
19 // (c).Actual work output
20 w=(h1-h2)+q; // From SSSF energy equation
21 disp ("kJ/kg",w,"(c).Actual work output =");
22 // (d).Irreversibility
23 I=wrev-w; //Irreversibility
24 disp ("kJ/kg",I,"(d).Irreversibility =");
25 // (ii).Ammonia compressor
26 T1=-10; // Temperature at inlet in degree celcius
27 p2=1.554; // Pressure at outlet in MPa
28 T2=140; // Temperature at outlet in degree celcius
29 T0=298; // temperature of Surroundings in kelvin

```

```

30 //from ammonia tables
31 h1=1433; h2=1752;// specific enthalpy in kJ/kg
32 s1=5.477; s2=5.655; // specific entropy in kJ/kg K
33 wactual=-(h2-h1); // Actual work
34 wmin=-((h2-h1)-(T0*(s2-s1)));// mimimum work
35 I=wmin-wactual;// Irreversibility
36 disp ("kJ/kg",I," Irreversibility =", "kJ/kg",wmin,"
        Minimum work =", "kJ/kg",wactual," Actual work = ",
        "(ii).Ammonia compressor");

```

Scilab code Exa 10.8 IRREVERSIBILITY IN A BOILER

```

1  clc;
2  Cp=1.1; // Specific heat of combustion gas in kJ/kg
        K
3  T3=1600; // Initial temperature of combustion gas in
        Kelvin
4  T4=1150; // Final temperature of combustion gas in
        Kelvin
5  p1=0.1; // Pressure at inlet of boiler in MPa
6  p2=8; // Pressure at outlet of boiler in MPa
7  T2=600; // Temperature at outlet of boiler in degree
        celcius
8  m=1; // Mass of water in kg
9  T0=298; // temperature of Surroundings in kelvin
10 // From steam table
11 h1=2758; h2=3642;// specific enthalpy in kJ/kg
12 s1=5.7432; s2=7.0206; // specific entropy in kJ/kg K
13 mgas=(h2-h1)/(Cp*(T3-T4)); //mass flow rate of gases
        per kg of water
14 S21=s2-s1; // Change in entropy of water
15 S34=mgas*Cp*log (T3/T4); // Change in entropy of
        gases
16 // (a).Decrease in availability of gases
17 d_AEgas=mgas*Cp*(T3-T4)-T0*S34//Decrease in

```

```

    availability of gases
18 disp ("kJ",d_AEgas,"(a).Decrease in availability of
    gases = ");
19 // (b).Decrease in availability of water
20 d_AEwater=(h1-h2)-T0*(s1-s2); // Decrease in
    availability of water
21 disp ("kJ",d_AEwater,"(b).Decrease in availability
    of water =");
22 // (c).Reversible work for the process
23 Wrev=d_AEgas+d_AEwater; //Reversible work for the
    process
24 disp ("kJ",Wrev,"(c).Reversible work for the process
    =");
25 // (d).Actual work for the process
26 W=0; // Actual work
27 disp ("kJ",W,"(d).Actual work for the process =");
28 // (e).Irreversibility
29 I=Wrev-W; //Irreversibility
30 disp ("kJ",I,"(e).Irreversibility = ");

```

Scilab code Exa 10.9 LOST WORK IN RANKINE CYCLE

```

1 clc;
2 TH=600; // Temperature of heat source in degree
    celcius
3 T3=311.06; // Boiler temperature in degree celcius
4 p3=10; // Boiler pressure in MPa
5 T4=32.88; // Condensor temperature in degree celcius
6 p4=5; // Condensor pressure in kPa
7 T0=288; // Temperature of surroundings in kelvin
8 // From steam table and refer figure 10.10 for
    states
9 h1=137.82; h2=147.82; h3=2724.7; hf4=197.82; hfg4
    =2423.7; h4=1913.6; // specific enthalpy in kJ/kg
10 s1=0.4764; s2=s1; s3=5.6141; s4=s3; sf4=0.4764;

```

```

    sfg4=7.9187; s4=6.2782; // specific entropy in kJ
    /kg K
11 wT=h3-h4; // Turbine work
12 wp=h2-h1; // Pump work
13 wnet=wT-wp; // Net work
14 qH=h3-h2; // Heat supplied in boiler
15 qL=h4-h1; // Heat rejected in condensor
16 Wrev_Wpump=T0*(s2-s1);
17 Wrev_Wboiler=T0*(s3-s2)-T0*qH/(TH+273);
18 Wrev_Wturbine=T0*(s4-s3);
19 Wrev_Wcondenser=T0*(s1-s4)+qL;
20 Wrev_Wcycle=Wrev_Wpump+Wrev_Wboiler+Wrev_Wturbine+
    Wrev_Wcondenser;
21 disp ("kJ/kg",Wrev_Wcycle,"The lost (Wrev-W) for the
    overall cycle = ", "kJ/kg",Wrev_Wcondenser,"The
    lost (Wrev-W) for the condensor = ", "kJ/kg",
    Wrev_Wturbine,"The lost (Wrev-W) for the Turbine =
    ", "kJ/kg",Wrev_Wboiler,"The lost (Wrev-W) for the
    Boiler = ", "kJ/kg",Wrev_Wpump,"The lost (Wrev-W)
    for the Pump = ");

```

Scilab code Exa 10.10 FIRST AND SECOND LAW EFFICIENCY

```

1 clc;
2 // State after reversible adiabatic expansion
3 p2=50; // pressure in kPa
4 s2s=6.4844; s1=6.4844; s2=6.944; // specific entropy
    in kJ/kg K
5 x2s=0.829; // Quality of steam
6 h2s=2252.6; h1=3256.6; // specific enthalpy in kJ/kg
7 T2=81.33; T0=27; // Temperature in degree celcius
8 ws=h1-h2s; // Reversible adiabatic work
9 wa=831.2; // Actual work output in kJ/kg
10 d_AE=979.1; // Decrease in availability in kJ/LG
11 eff_I=wa/ws; // First law efficiency of turbine

```

```

12 eff_II=wa/d_AE; // Second law efficiency of turbine
13 disp ("% ",eff_II*100,"Second law efficiency of
    turbine = ", "% ",eff_I*100,"First law efficiency
    of turbine = ");
14 w2srev2=(T2-T0)*(s2-s1); // Negative work
15 w1rev2=ws-w2srev2; // Decrease in availability
16 disp ("kJ/kg",w1rev2,"Dcresase in Availability = ",
    "kJ/kg",w2srev2,"Negative work = ");

```

Scilab code Exa 10.11 AIR COMPRESSOR

```

1  clc;
2  p1=100; // Pressure at inlet in kPa
3  T1=30; // Temperature at inlet in degree celcius
4  V1=0; // Velocity at inlet in m/s
5  p2=350; // Pressure at outlet in kPa
6  T2=141; // Temperature at exit in degree celcius
7  V2=90; // Velocity at exit in m/s
8  p0=100; // Pressure of Surroundings in kPa
9  T0=30; // temperature of Surroundings in degree
    celcius
10 k=1.4; // Index of the Isentropic compression
    process
11 Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
12 R=0.287; // characteristic gas constant of air in kJ
    /kg K
13 // (a).Adiabatic or polytropic compression
14 T2s=(T1+273)*(p2/p1)^((k-1)/k); // Temperature after
    isentropic compression
15 disp ("T2s>T2. Hence there is cooling . Compression
    is polytropic.", "K",T2s,"Temperature after
    isentropic compression =", "(a).Adiabatic or
    polytropic compression");
16 // (b).The first law efficiency of the compressor

```

```

17 wa=Cpo*(T1-T2)-V2^2/2000; //Actual work of
    compression
18 wT=(-R*(T1+273)*log (p2/p1))-(V2^2/2000); //
    Isothermal work
19 eff_Ilaw=wT/wa; // The first law efficiency of the
    compressor
20 disp ("%",eff_Ilaw,"(b).The first law efficiency of
    the compressor = ");
21 // (c).Minimum work input & Irreversibility
22 d_AE=(Cpo*(T1-T2))+((T0+273)*((R*log (p2/p1))-(Cpo*
    log ((T2+273)/(T1+273)))))-V2^2/2000; // decrease
    in availability
23 wmin=d_AE; // Minimum work input
24 wrev=wmin;
25 I=wrev-wa; // Irreversibility
26 disp ("kJ/kg",I,"Irreversibility =", "kJ/kg",wmin,"
    Minimum work input =", "(c).Minimum work input &
    Irreversibility");
27 // (d).Second law efficiency of the compressor
28 eff_IIlaw=wmin/wa; // Second law efficiency of the
    compressor
29 disp ("%",eff_IIlaw*100,"(d).Second law efficiency
    of the compressor =");

```

Scilab code Exa 10.12 LOST WORK AND SECOND LAW EFFICIENCY OF VAPOUR COMPRESSOR CYC

```

1 clc;
2 T0=313; // Surroundings temperature in kelvin
3 TL=233; // Refrigerated space temperature in kelvin
4 QL=3.5167; // Refrigeration load in kW
5 // (a).Carnot cycle
6 COPcarnot=TL/(T0-TL); // COP of carnot cycle
7 Wcarnot=QL/COPcarnot; // Work done
8 Q0=QL+Wcarnot; // Heat rejected
9 d_SL=-QL/TL; // Entropy change of refrigerated space

```



```

10 d_S0=Q0/T0; //Entropy change of surroundings
11 d_Sgen= d_SL+ d_S0; // Entropy generation
12 disp (COPcarnot,"COP of carnot cycle = ", "kW",
        Wcarnot,"Work done = ", "(a).Carnot cycle");
13 printf ("\n Entropy generation = %d \n \n kJ/K s \
        n",d_Sgen);
14 // (b).Vapour compression cycle
15 // From Freon-12 property table & figure 10.17
16 p1=0.0642; p2=0.9607; // Pressure in MPa
17 h1=169.5; h3=74.5; // specific enthalpy in kJ/kg
18 s1=0.7269; s3=0.2716; // specific entropy in kJ/kg K
19 // By calculations s2=s1 gives the following from
        property table
20 t2=58.9; // Temperature in degree celcius
21 h2=217.6; // specific enthalpy in kJ/kg
22 // From h4=h3 gives the following from chart
23 h4=h3;
24 x4=0.44; // Quality of vapour
25 s4=0.3195; // specific entropy in kJ/kg K
26 m=QL/(h1-h4); // Mass flow rate of refrigerant
27 W=m*(h2-h1); // Work done of vapour compression
        cycle
28 COP=QL/W; // COP of vapour compression cycle
29 QH=QL+W; // Heat rejected to surroundings
30 d_SL=-QL/TL; // Entropy change of refrigerated space
31 d_S0=QH/T0; //Entropy change of surroundings
32 d_Sgen= d_SL+ d_S0; // Entropy generation
33 disp (COP,"COP of vapour compression cycle = ", "kW",
        W,"Work done = ", "(b).Vapour compression cycle");
34 printf ("\n Entropy generation = %f \n \n kJ/K s \n
        ",d_Sgen);
35 // (c).Difference in work = Lost work of the cycle
36 d_work=W-Wcarnot; // Difference in work
37 LWcycle=QH-T0*QL/TL; // Lost work of the cycle
38 disp ("which is same as Difference in work", "kW",
        LWcycle,"Lost work of the cycle= ", "kW", d_work,
        Difference in work = ", "(c).Difference in work =
        Lost work of the cycle");

```

```
39 // (d).Second Law efficiency of the vapour
    compression cycle
40 eff_II=COP/COPcarnot; //Second Law efficiency
41 disp ("%",eff_II*100,"(d).Second Law efficiency of
    the vapour compression cycle = ");
```

Chapter 11

THERMODYNAMIC PROPERTY RELATIONS

Scilab code Exa 11.1 MERECTS BOILER EXPERIMENT

```
1 clc;
2 p1=150; p2=200; p3=250; p4=300; p5=350; p6=400; p7
  =450; p8=500; p9=550; p10=600; p11=650; p12=700;
  p13=750; p14=800; p15=850; p16=900; // Pressures
  of merect's boiler experiment in kPa
3 t1=111.4; t2=120.2; t3=127.4; t4=133.6; t5=138.9; t6
  =143.6; t7=147.9; t8=151.9; t9=155.5; t10=158.9;
  t11=162; t12=165; t13=167.8; t14=170.4; t15=173;
  t16=175.4; // Temperatures of merect's boiler
  experiment in degree celcius
4 n=16; // Total number of readings taken
5 // Values of constant A & B
6 s_y= log10 (p1*p2*p3*p4*p5*p6*p7*p8*p9*p10*p11*p12*
  p13*p14*p15*p16);
7 s_x=1/(t1+273)+1/(t2+273)+1/(t3+273)+1/(t4+273)+1/(
  t5+273)+1/(t6+273)+1/(t7+273)+1/(t8+273)+1/(t9
  +273)+1/(t10+273)+1/(t11+273)+1/(t12+273)+1/(t13
  +273)+1/(t14+273)+1/(t15+273)+1/(t16+273);
8 s_xy=((log10 (p1))*1/(t1+273))+ ((log10 (p2))*1/(t2
```

```

+273))+ ((log10 (p3))*1/(t3+273))+ ((log10 (p4))
*1/(t4+273))+ ((log10 (p5))*1/(t5+273))+ ((log10
(p6))*1/(t6+273))+ ((log10 (p7))*1/(t7+273))+ ((
log10 (p8))*1/(t8+273))+ ((log10 (p9))*1/(t9+273)
)+ ((log10 (p10))*1/(t10+273))+ ((log10 (p11))
*1/(t11+273)) + ((log10 (p12))*1/(t12+273)) + ((
log10 (p13))*1/(t13+273)) + ((log10 (p14))*1/(t14
+273)) + ((log10 (p15))*1/(t15+273)) + ((log10 (
p16))*1/(t16+273));
9 s_x2=(1/(273+t1))^2+(1/(273+t2))^2+(1/(273+t3))
^2+(1/(273+t4))^2+(1/(273+t5))^2+(1/(273+t6))
^2+(1/(273+t7))^2+(1/(273+t8))^2+(1/(273+t9))
^2+(1/(273+t10))^2+(1/(273+t11))^2+(1/(273+t12))
^2+(1/(273+t13))^2+(1/(273+t14))^2+(1/(273+t15))
^2+(1/(273+t16))^2;
10 B= ((n*s_xy)-(s_x*s_y))/((n*s_x2)-((s_x)^2)); //
Constant B
11 A=((s_y)-(B*s_x))/n; // Constant A
12 disp (B,"B =",A,"A =", "Values of constant A & B");
13 // The latent heat of vapourization
14 T=150; // The latent heat of vapourization at this
temperature in degree celcius
15 d_T=20; d_p=258.7; // Temperature and pressure
difference
16 vg=0.3928; vf=0.0011; // specific volume in m^3/kg
17 hfg=(T+273)*(vg-vf)*d_p/d_T; // Clapeyron equztion
18 disp ("kJ/kg",hfg,"The latent heat of vapourization
at 150 oC =");

```

Scilab code Exa 11.3 ENTHALPY CALCULATION USING R K EQUATION

```

1 clc;
2 p5=6000; // Pressure of superheated steam in kPa
3 T5=723.15; // Temperature of superheated steam in
kelvin

```

```

4 p1=0.6113; // Pressure at reference state in kPa
5 T1=273.16; // Temperature at reference state in
kelvin
6 hfg1=2501.3; // Latent heat of vapourization of
water at reference state in kJ/kg
7 R_1=8.3143; // Universal gas constant of air in kJ/
kmol K
8 // The critical state properties of water
9 pc=2.09; // pressure in MPa
10 Tc=647.3; // Temperature in kelvin
11 h1=0; // Reference state in kJ/kg
12 h2=h1+hfg1; // specific enthalpy in kJ/kg
13 // At point 2
14 p2=p1; T2=T1;
15 z=0.9986;
16 r=18.015;
17 A2=(0.4278/(pc*10^4))*(Tc/T2)^2.5; // Constants
18 B=(0.0867/(pc*10^4))*(Tc/T2); // Constants
19 h2_h3=R_1*(T2/r)*((( -3/2)*(A2/B)*log (1+(B*p2/z))) +z
-1); // Enthalpy difference between state 2 & 3
20 // At point 5
21 z1=0.9373;
22 A2=(0.4278/(pc*10^4))*(Tc/T5)^2.5; // Constants
23 B=(0.0867/(pc*10^4))*(Tc/T5); // Constants
24 h5_h4=R_1*(T5/r)*((( -3/2)*(A2/B)*log (1+(B*p5/z1))) +
z1-1); // Enthalpy difference between state 5 & 4
25 a=1.6198; b=6.6*10^-4; // Constants
26 h4_h3=a*(T5-T1)+b*(T5^2-T1^2)/2; // Enthalpy
difference between state 3 & 4
27 h5=h2-h2_h3+h5_h4+h4_h3; // Specific enthalpy at
state 5
28 disp ("kJ/kg",h5," Specific enthalpy at state 5 = ");

```

Scilab code Exa 11.4 ENTHALPY CALCULATION FROM GENERALIZED CHARTS

```

1  clc;
2  T2=373; // Temperature of CO2 gas in kelvin
3  p2=100; // Pressure of CO2 gas in atm
4  T1=0; // Reference state temperature in kelvin
5  // The critical constants for CO2 are
6  Tc=304.2; // Temperature in kelvin
7  Pc=72.9; // Pressure in atm
8  zc=0.275;
9  // Refer figure 11.7 for state definition
10 h1_0=((-3.74*T2)+((30.53/(100^0.5))*((T2^1.5)/1.5))
      -((4.1/100)*((T2^2)/2))+((0.024/(100^2))*((T2^3)
      /3)));
11 Tr=T2/Tc; Pr=p2/Pc; // Reduced properties
12 // From generalized chart figure 11.6
13 hR_Tc=10.09;
14 h1_2=hR_Tc*Tc;
15 M=44; // Molecular weight
16 h10=h1_0/M; h12=h1_2/M;
17 h373=h10-h12; // The required enthalpy of CO2 gas at
      373 K and 100 atm
18 disp ("kJ/kg",h373,"The required enthalpy of CO2 gas
      at 373 K and 100 atm = ");

```

Scilab code Exa 11.5 CALCULATIONS FOR REVERSIBLE ISOTHERMAL COMPRESSION FROM GENER

```

1  clc;
2  p1=11; // Initial pressure in bar
3  T1=40; // Initial temperature in degree celcius
4  p2=60; // Final pressure in bar
5  R_1=8.3143; // Universal gas constant in kJ/kmol K
6  // The critical properties for natural gas
7  Tc=161; // Temperature in kelvin
8  Pc=46.4; // Pressure in bar
9  // Reduced properties are
10 Pr1=p1/Pc; Pr2=p2/Pc;

```

```

11 Tr1=(T1+273)/Tc;
12 // T2=T1, The ideal gas enthalpy h2*=h1*=h1
13 h21=-47.5; // From generalized enthalpy departure
    chart
14 M=16; // Molecular weight
15 Sp2_1=(R_1/M)*log (p2/p1)// for the difference in
    ideal gas entropies
16 Sp2_Sp_2=-0.1125; Sp_2_Sp_1=-2.1276; // Entropies in
    kJ/kg K
17 s2_s1=(Sp2_Sp_2)+(Sp_2_Sp_1);
18 q=(T1+273)*s2_s1; // Heat transfer
19 w=q-h21; // Work of compression
20 disp ("kJ/kg",w,"Work of compression = ", "kJ/kg",q,"
    Heat transfer = ");

```

Scilab code Exa 11.8 CALCULATIONS FOR COOLING IN A THROTTLING PROCESS USING GENERALIZED CHART

```

1 clc;
2 p1=10; // Initial pressure in MPa
3 T1=263; // Initial temperature in Kelvin
4 p2=1.5; // Final pressure in MPa
5 R_1=8.3143; // Universal gas constant in kJ/kmol K
6 M=28; // Molecular mass
7 // The critical properties for nitrogen gas
8 Tc=126.2; // Temperature in kelvin
9 Pc=3.39; // Pressure in MPa
10 // Reduced properties are
11 Pr1=p1/Pc; Pr2=p2/Pc;
12 Tr1=T1/Tc;
13 // From the generalized chart for enthalpy departure
    at Pr1 & Tr1
14 h_11=8.7*Tc/M;
15 // The solution involves iteration procedure. Assume
    T2 and check if h2_h1=0
16 // First approximation T2=200 K

```

```

17 T2=200; // In K
18 Tr2=T2/Tc;
19 Cpr=1.046;
20 h_21=Cpr*(T2-T1);
21 // From the generalized chart for enthalpy departure
    at Pr1 & Tr1
22 h_22=1*Tc/M;
23 h2_h1=h_11-T2+T1-h_22;
24 // Second approximation
25 T2=190; // In K
26 Tr2=T2/Tc;
27 Cpr=1.046;
28 h_21=Cpr*(T2-T1);
29 // From the generalized chart for enthalpy departure
    at Pr1 & Tr1
30 h_22=1.5*Tc/M;
31 h2_h1=h_11-T2+T1-h_22;
32 disp ("Here also h2-h1 != 0. Therefore the
    temperature is dropping.Thus Joule-Thomson
    coefficient is positive.There is cooling in this
    process");

```

Scilab code Exa 11.9 CALCULATIONS OF LATENT HEAT BY SIMILARITY METHOD

```

1 clc;
2 Tcammonia=405.9;
3 Tcwater=647.3;
4 Tr=0.576; // Condition of similarity
5 Twater=Tcwater*Tr; // At reduced temperature
    Temperature of water
6 Tammonia=Tcammonia*Tr; //At reduced temperature
    Temperature of ammonia
7 // From steam table at Twater
8 hfgwater=2257; // specific enthalpy in kJ/kg
9 hfgammonia=Tcammonia/Tcwater *hfgwater; // Latent

```



```
    heat of vaporization of ammonia
10 disp ("kJ/kg",hfgammonia,"Latent heat of
    vaporization of ammonia =");
```

Chapter 12

NON REACTING MIXTURES OF GASES AND LIQUIDS

Scilab code Exa 12.1 PROPERTIES OF DRY AIR

```
1  clc;
2  M1=28.02; // Molecular mass of N2
3  M2=32; // Molecular mass of O2
4  M3=39.91; // Molecular mass of Ar
5  M4=44; // Molecular mass of CO2
6  M5=2.02; // Molecular mass of H2
7  y1=0.7803; // Part by volume of N2 in dry
   atmospheric air
8  y2=0.2099; // Part by volume of O2 in dry
   atmospheric air
9  y3=0.0094; // Part by volume of Ar in dry
   atmospheric air
10 y4=0.0003; // Part by volume of CO2 in dry
   atmospheric air
11 y5=0.0001; // Part by volume of H2 in dry
   atmospheric air
12 R_1=8.3143; // Universal gas constant of air in kJ/
   kmol K
13 // (a). Average molecular mass and apperent gas
```

```

    constant of dry atmospheric air
14 M=(y1*M1)+(y2*M2)+(y3*M3)+(y4*M4)+(y5*M5); //
    Average molecular mass
15 R=R_1/M; //Apperent gas constant of dry atmospheric
    air
16 disp ("kJ/kg K",R," Apperent gas constant of dry
    atmospheric air =", "kmol",M," Average molecular
    mass = ", "(a). Average molecular mass and apperent
    gas constant of dry atmospheric air");
17 // (b).The fraction of each component
18 m1=(M1*y1)/M; //The fraction of N2 component
19 m2=(M2*y2)/M; //The fraction of O2 component
20 m3=(M3*y3)/M; //The fraction of Ar component
21 m4=(M4*y4)/M; //The fraction of CO2 component
22 m5=(M5*y5)/M; //The fraction of H2 component
23 disp (m5,m4,m3,m2,m1,"(b).The fraction of N2,O2,Ar,
    CO2,H2 components are given below respectively ")
    ;

```

Scilab code Exa 12.2 EXHAUST GAS ANALYSIS

```

1 clc;
2 M1=44; // Molecular mass of CO2
3 M2=32; // Molecular mass of O2
4 M3=28; // Molecular mass of CO
5 M4=28; // Molecular mass of N2
6 y1=0.1; // Part by volume of CO2 in exhaust gas
7 y2=0.06; // Part by volume of O2 in exhaust gas
8 y3=0.03; // Part by volume of CO in exhaust gas
9 y4=0.81; // Part by volume of N2 in exhaust gas
10 R_1=8.3143; // Universal gas constant in kJ/kmol K
11 // (a).Average molecular mass and apperent gas
    constant of exhaust gas
12 M=(y1*M1)+(y2*M2)+(y3*M3)+(y4*M4); // Average
    molecular mass

```

```

13 R=R_1/M; //Apperent gas constant of dry atmospheric
    air
14 disp ("kJ/kg K",R,"Apperent gas constant of dry
    atmospheric air =", "kmol",M,"Average molecular
    mass = ", "(a). Average molecular mass and apperent
    gas constant of exhaust gas");
15 // (b).The fraction of each component
16 m1=(M1*y1)/M; //The fraction of CO2 component
17 m2=(M2*y2)/M; //The fraction of O2 component
18 m3=(M3*y3)/M; //The fraction of CO component
19 m4=(M4*y4)/M; //The fraction of N2 component
20 disp (m4,m3,m2,m1,"(b).The fraction of CO2,O2,CO,N2
    components are given below respectively ");

```

Scilab code Exa 12.3 MINIMUM WORK OF SEPARATION OF GASES

```

1 clc;
2 y1=0.79; // Volume of Nitrogen in 1 kg of air
3 y2=0.21; // Volume of Oxygen in 1 kg of air
4 R_1=8.3143; // Universal gas constant of air in kJ/
    kmol K
5 T0=298; // temperature of Surroundings in kelvin
6 del_Sgen=-R_1*((y1*log (y1))+(y2*log (y2))); //
    Entropy generation
7 LW=T0*del_Sgen; // Minimum work
8 disp ("kJ/kmmol K",LW,"The minimum work required for
    separation of two gases = ");

```

Scilab code Exa 12.4 MEASUREMENT OF HUMIDITY

```

1 clc;
2 DPT=8; // Dew point temperature in degree celcius
3 p=100; // Pressure of air in kPa

```

```

4 T=25; // Temperature of air in degree celcius
5 // (a).partial pressure of water vapour in air
6 pv=1.0584; // Saturation pressure of water at DBT in
   kPa
7 disp ("kPa",pv,"(a).partial pressure of water vapour
   in air = ");
8 // (b).Specific humidity
9 sh=0.622*pv/(p-pv); // Specific humidity
10 disp ("kg of water vapour /kg of dry air",sh,"(b).
   Specific humidity =");
11 // (c).Relative humidity
12 pg=3.169; // Saturation pressure of water at T in
   kPa
13 RH=pv/pg; //Relative humidity
14 disp ("% ",RH*100,"(c).Relative humidity =");

```

Scilab code Exa 12.5 CALCULATIONS OF PROPERTIES FOR THE AIR

```

1 clc;
2 DBT=35; // Dry bulb temperature in degree celcius
3 WBT=23; // Wet bulb temperature in degree celcius
4 P=100; // Pressure of air in kPa
5 Cpo=1.0035; // Specific heat at constant pressure in
   kJ/kg K
6 R=0.287; // characteristic gas constant of air in kJ
   /kg K
7 // (a).Humidity ratio
8 hv=2565.3; // specific enthalpy hg at DBT in kJ/kg
9 hfWBT=96.52; hfgWBT=2443; // specific enthalpy at
   WBT in kJ/kg
10 PsatWBT=2.789; // Saturation pressure at WBT in kPa
11 shWBT=0.622*PsatWBT/(P-PsatWBT); // specific humidity
12 sh=((Cpo*(WBT-DBT))+ (shWBT*hfgWBT))/(hv-hfWBT); //
   Humidity ratio
13 disp ("kg w.v /kg d.a",sh,"(a).Humidity ratio =");

```

```

14 // (b).Relative Humidity
15 pv=sh*P/(0.622+sh); // Partial pressure of water
    vapour
16 pg=5.628; // Saturation pressure at DBT in kPa
17 RH=pv/pg; //Relative Humidity
18 disp ("%",RH*100,"(b).Relative Humidity =");
19 // (d).Dew point temperature
20 DPT=17.5; // Saturation temperature at pg in degree
    celcius
21 disp ("oC",DPT,"(d).Dew point temperature =");
22 // (e).Specific volume
23 v=(R*(DBT+273))/(P-pv); // Specific volume
24 disp ("m^3/kg",v,"(e).Specific volume = ");
25 // (d).Enthalpy of air
26 h=(Cpo*DBT)+(sh*hv); //Enthalpy of air
27 disp ("kJ/kg d.a",h,"(d).Enthalpy of air =");

```

Scilab code Exa 12.6 COOLING AND DEHUMIDIFICATION OF MOIST AIR

```

1 clc;
2 DPT1=30; // Dew point temperature at inlet in degree
    celcius
3 DPT2=15; // Dew point temperature at outlet in
    degree celcius
4 RH1=0.50; // Relative humidity at inlet
5 RH2=0.80; // Relative humidity at outlet
6 p=101.325; // Atmospheric pressure in kPa
7 Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
8 pg1=4.246; // saturation pressure of water at DBT1
    in kPa
9 pg2=1.7051; // saturation pressure of water at DBT2
    in kPa
10 pv1=RH1*pg1; pv2=RH2*pg2; // Partial pressure of
    water vapour in air at inlet and outlet

```

```

11 sh1=0.622*pv1/(p-pv1); sh2=0.622*pv2/(p-pv2); //
    Specific humidities at inlet and outlet
12 hv1=2556.3; // specific enthalpy hg at DBT1 in kJ/kg
13 hv2=2528.9; // specific enthalpy hg at DBT2 in kJ/kg
14 hv3=63; // specific enthalpy hf at DBT 2in kJ/kg
15 q=(Cpo*(DPT2-DPT1))+(sh2*hv2)-(sh1*hv1)+((sh1-sh2)*
    hv3); // Heat transfer
16 disp ("kJ/kg of dry air",q,"Heat removed from the
    air =");

```

Scilab code Exa 12.7 MOLAR VOLUMES OF GAS MIXTURES

```

1 clc;
2 y1=0.5; // Molecular mass of CH4 in kmol
3 y2=0.5; // Molecular mass of C3H8 in kmol
4 T=363; // Temperature of gas in kelvin
5 p=5.06; // Pressure of gas in MPa
6 v=0.48; // volume of cylinder in m^3
7 R_1=8.3143; // Universal gas constant of air in kJ/
    kmol K
8
9 // (a).Using k a y s rule
10 // let component 1 refer to methane and component 2
    to propane
11 // the critical properties
12 Tc1=190.7; Tc2=370; // temperature in kelvin
13 Pc1=46.4; Pc2=42.7; // Pressure in bar
14 // using k a y s rule for the mixture
15 Tcmix=y1*Tc1+y2*Tc2;
16 Pcmix=y1*Pc1+y2*Pc2;
17 // reduced properties
18 Tr=T/Tcmix; Pr=p/Pcmix;
19 // From generalized chart
20 z=0.832;
21 v_1=z*R_1*T/(p*10^3); // molar volume of the mixture

```

```

22 d=(v-v_1)/v; // Percentage deviation from actual
    value
23 disp ("%",d*100,"Percentage deviation from actual
    value = ", "(a).Using k a y s rule");
24 // (b).Using Redlich-Kwong equation of state
25 a1=0.42748*R_1*Tc1^2.5/Pc1;
26 a2=0.42748*R_1*Tc2^2.5/Pc2;
27 b1=0.08664*R_1*Tc1/Pc1;
28 b2=0.08664*R_1*Tc2/Pc2;
29 // Substituting these values in the equation 12.16
30 // And solving these equation by iteration method we
    get
31 v_1=0.47864; // molar volume of the mixture
32 d=(v-v_1)/v; // Percentage deviation from actual
    value
33 disp ("%",d*100,"Percentage deviation from actual
    value = ", "(b).Using Redlich-Kwong equation of
    state");

```

Scilab code Exa 12.8 FUGACITY FROM COMPRESSIBILITY DATA OF A MIXTURE

```

1 clc;
2 ln_piCH4=-0.0323;
3 pi_CH4=0.9683;
4 p=6895; // Pressure in kPa
5 T=104.4; // Temperature in degree celcius
6 a=0.784;
7 f_CH4=pi_CH4*a*p; // Faguacity
8 disp("kPa",f_CH4,"The Required Faguacity = ");

```

Chapter 13

PHASE EQUILIBRIUM VAPOUR LIQUID EQUILIBRIUM OF MIXTURES

Scilab code Exa 13.1 CALCULATIONS FOR FREON 22 AND FREON 12 SYSTEM AS IDEAL MIXTURES

```
1 clc ;
2 // Take freon 22 as component 1 and Freon 12 as
  component 2
3 // (a). y-x diagram at 40 oC
4 P1sat=15.335; // Saturation pressure of Freon 22 at
  40oC in bar
5 P2sat=9.607; // Saturation pressure of Freon 12 at
  40oC in bar
6 a=P1sat/P2sat;
7 xset('window',1); // For Plotting y-x Diagram
8 function y1=f(x1)
9     y1=(a*x1)/(1+x1*(a-1)); // y Function
10 endfunction
11 x1=linspace(0,1.0,3);
12 plot (x1,f,x1,x1); // plot comment
```

```

13 title ("(a).y-x diagram for the mixture at 40 oC",
        "fontsize",4,"color","blue");
14 xlabel(" x1 ", "fontsize",4,"color","blue");
15 ylabel(" y1 ", "fontsize",4,"color","blue");
16 legend(["y1";"x1"],[2]);
17 disp ("Refer window 1","(a). y-x diagram at 40 oC");
18 // (b). p-x-y diagram at 40 oC
19 // By using the following relation calculate p
    value for various value of x1,y1
20 //  $p=(x1*P1sat)+(1-x1)*P2sat$ 
21 x1=[0,0.2,0.5,0.8,1];
22 y1=[0,0.285,0.615,0.865,1];
23 p=[9.607,10.7526,12.471,14.1894,15.335];
24 xset('window',2);
25 plot (x1,p,y1,p);
26 title ("(b).P-y-x diagram for the mixture at 40 oC",
        "fontsize",4,"color","blue");
27 xlabel(" x1 & y1 ", "fontsize",4,"color","blue");
28 ylabel(" p in bar ", "fontsize",4,"color","blue");
29 legend(["Liquid out";"Vapour"],[2]);
30 disp ("Refer window 2","(b). p-x-y diagram at 40 oC"
    );
31 // (c).t-x-y diagram at 10 bar
32 // for any value of x1 at p=10 bar, the bubble
    temperature can be found by trial and error from
    the following relation
33 //  $p=10 \text{ bar}=(x1*P1sat)+(1-x1)*P2sat$ 
34 T1sat=23.7; // Saturation temperature of Freon 22 at
    10 bar in oC
35 T2sat=41.6; // Saturation temperature of Freon 12 at
    10 bar in oC
36 // Thus, for x1=0.5, we find that t=31 oC.
37 x1=0.5; // Let assume
38 P1sat=12.186; // Saturation pressure of Freon 22 at
    31oC in bar
39 P2sat=7.654; // Saturation pressure of Freon 12 at
    31oC in bar
40 a=P1sat/P2sat;

```

```

41 y1=(a*x1)/(1+x1*(a-1)); // y Function
42 // For different value of x1 the values of t,y1 are
    calculated by above expression and given below
43 x1=[0,0.5,1]; y1=[0,0.614,1]; t=[41.6,31,23.7];
44 xset('window',3);
45 plot(x1,t,y1,t);
46 title("(c).t-y-x diagram for the mixture at 10 bar"
    , "fontsize",4,"color","blue");
47 xlabel(" x1 & y1 ", "fontsize",4,"color","blue");
48 ylabel(" t in oC ", "fontsize",4,"color","blue");
49 legend(["f";"g"]);
50 disp ("Refer window 3","(c).t-x-y diagram at 10 bar"
    );

```

Scilab code Exa 13.2 CALCULATION OF THE STANDARD STATE FUGACITY

```

1  clc;
2  T=573.15; // Temperature of the water with another
    liquid in kelvin
3  R=8.3144/18; // Characteristic gas constant
4  // (a).4 MPa
5  P_1=10; // By Method II, The lowest possible
    pressure at which data available in steam table
    for 300 oC temperature in kPa
6  h_i=3076.5; // Specific enthalpy at P_1 in kJ/kg
7  s_i=9.2813; // Specific entropy at P_1 in kJ/kg K
8  // from superheat table at p=4 MPa and t=300 oC
9  hi=2960.7; // Specific enthalpy in kJ/kg
10 si=6.3615; // Specific entropy in kJ/kg K
11 fi=P_1*exp (((hi-h_i)/T)-(si-s_i))/R); // Standard
    state fugacity of water
12 disp ("kPa (round off error)",fi,"Standard state
    fugacity of water = ", "(a).4 MPa");
13 // (b).equal to saturation pressure at 300 oC
14 Psat=8.581; // Saturation pressure at 300 oC in MPa

```

```

15 // From steam table at Psat=8.581 MPa and t=300 oC
16 hi=2749; // Specific enthalpy in kJ/kg
17 si=5.7045; // Specific entropy in kJ/kg K
18 fi=P_1*exp (((hi-h_i)/T)-(si-s_i))/R); // Standard
    state fugacity of water
19 pisat=fi/(Psat*10^3); // fugacity coefficient
20 disp (pisat,"fugacity coefficient =", "kPa",fi,"
    Standard state fugacity of water = ", "(b).Equal
    to saturation pressure at 300 oC");
21 // (c).10 MPa
22 // Applying Method I
23 viL=0.001404; // Specific volume at 300 oC in m^3/kg
24 fi=pisat*Psat*10^3*exp ((viL*(P_1-Psat)*10^3)/(R*T))
    ; // Standard state fugacity of water
25 disp ("kPa",fi,"Standard state fugacity of water = "
    ,"(a).10 MPa");

```

Scilab code Exa 13.3 CALCULATIONS OF AMMONIA WATER SYSTEM

```

1 clc;
2 // Let take NH3 as component 1 and H2O as component
    2
3 // (a) & (b)
4 // Calculation of flsat = pilsat*plsat for ammonia
5 P_1=50; // low reference state pressure in kPa
6 P1sat=614.95; // Saturation Pressure of ammonia at
    10 oC in kPa
7 h1sat=1453.3; // Specific enthalpy at 10 oC in kJ/kg
8 s1sat=5.2104; // Specific entropy at 10 oC in kJ/kg
    K
9 R=8.3144/17; // Characteristic gas constant
10 T=283; // Temperature in kelvin
11 // At 10 oC and P_1=50 kPa for ammonia
12 h_1sat=1499.2; // Specific enthalpy in kJ/kg
13 s_1sat=6.5625; // Specific entropy in kJ/kg K

```

```

14 f1sat=P_1*exp (((h1sat-h_1sat)/T)-(s1sat-s_1sat))/R
    ); // Standard state fugacity of Ammonia
15 disp ("kPa",f1sat,"Standard state fugacity of
    Ammonia = ", "(a) & (b)");
16 // Calculation of f2sat = pi2sat*p2sat for water
17 P2sat=1.2276; // Saturation Pressure at 10 oC in kPa
    for water
18 pi2sat=1; // At low pressure for water
19 f2sat = pi2sat*P2sat; // Standard state fugacity of
    water
20 disp ("kPa",f2sat,"Standard state fugacity of water
    = ");
21 // Calculations of ViL/RT
22 // For ammonia and water at 10 oC
23 v1L=0.001601; v2L=0.001; // Specific volume in m^3/
    kg
24 v1L_RT=v1L/(R*T); v2L_RT=v2L/(R*T);
25 disp (v2L_RT,"v2L/RT = ", "(answer mentioned in the
    textbook is wrong)",v1L_RT,"v1L/RT = ");
26 // Calculations of activity coefficients
27 // Expression for activity coefficients of ammonia
    and water become in given by respectively
28 // r_1=(y1*p/(x1*569.6))*exp (-4.34*10^-6*(p-p1sat))
    ; for ammonia
29 // r_2=(y2*p/(x2*1.2276))*exp (-7.65*10^-6*(p-p2sat
    )); for water
30 // The values thus calculated for r_1,r_2,lny_1 ,
    lnr_2 are calculated and plotted in window 1
31 // Note that the values of pyonting factors are
    negligibly small
32 x1=[0,0.2,0.3,0.4,0.5,0.6,0.8,1.0];
33 y1=[0,0.963,0.986,0.9958,0.9985,0.9993,0.9999,1.0];
34 lnr_1
    =[-3.1,-1.845,-1.295,-0.75,-0.33,-0.065,-0.035,-0];
35 lnr_2
    =[0,-0.1397,-0.2767,-0.507,-0.709,-0.952,-1.613,-2.2];

```

```

36 // similarly the excess function gE/RT and gE/x1x2RT
    are also calculated using the following
    expression respectively
37 // gE_RT=x1*lnr_1+x2*lnr_2; // the excess function
    from 12.51
38 // gE_x1x2RT=(lnr_1/x2)+(lnr_2/x1);
39 // since gE=0 & x1x2=0 both at x1=0 and x1=1.
    However its values in between x1=0 & x1=1
40 // By substituting these values in the above
    expression and given below
41 gE_RT
    =[0, -0.481, -0.582, -0.604, -0.5195, -0.4198, -0.2925, 0];

42 gE_x1x2RT
    =[-3.1, -2.92, -2.83, -2.74, -2.65, -2.56, -2.38, -2.2];
43 xset('window',1); // For Plotting Diagram
44 plot(x1,lnr_1,"b*-",x1,lnr_2,"g*-",x1,gE_RT,"r",x1,
    gE_x1x2RT,"k*-");
45 title("(a)&(b). Activity coefficients for NH3/H2O at
    10 oC", "fontsize",4, "color", "blue");
46 xlabel(" x1", "fontsize",4, "color", "blue");
47 ylabel(" ln", "fontsize",4, "color", "blue");
48 legend(["ln 1 "; "ln 2 "; "gE/RT"; "gE/x1x2 RT"], [4])
    ;
49 disp ("Refer window 1 for plots");
50 // As x 1 0 , x 2 1 , gE_x1x2RTA=ln r_1 ^
51 // As x 1 1 , x 2 0 , gE_x1x2RTB=ln r_2 ^
52 A=-3.1; B=-2.2; // THE Margules constants
53 disp (B,"B = ",A,"A = ", "The Margules constants ");
54 disp ("From window 1 for ammonia/water mixture which
    is characteristic of systems with negative
    deviation from Roault law. Because  $i \leq 1$  and
     $\ln i \leq 0$ ");
55 // (c).
56 // Assuming ideal vapour phase, and at low pressures
    we have
57 // y1P= 1 *x1*plsat; y2p= 2 * x2* p2sat;
58 // Now the activity coefficients can be found from

```

```

    Margules equations and given below
59 x1=[0,0.2,0.3,0.4,0.5,0.6,1.0];
60 y1=[0,0.963,0.986,0.9958,0.9985,0.9999,1.0];
61 p
    =[1.2276,8.6597,30.6598,54.6845,150.6458,278.1549,614.95];

62 // The ideal solution pressure
63 // PRaoult=x1*P1sat+x2*P2sat;
64 PRaoult=[1.2276,614.95]; x_1=[0,1]; // For Ideal
    solution pressure
65 xset('window',2); // For Plotting Diagram
66 plot (x1,p,"r*-",y1,p,"b*-",x_1,PRaoult,"g");
67 title("(c).p-x-y diagram of NH3/H2O at 10 oC",
    fontsize",4,"color","blue");
68 xlabel(" x1      & y1      ", "fontsize",4,"color",
    "blue");
69 ylabel(" p, kPa      ", "fontsize",4,"color",
    "blue");
70 legend(["p-x1";"p-y1";"PRaoult"],[2]);
71 disp ("For p-x-y diagram refer window 2","(c).")
72 disp ("From window 2 The actual pressure p < pRaoult
    . It is thus seen that the mixture has negative
    deviation from Raoult's law.");

```

Scilab code Exa 13.4 ENTHALPY CALCULATIONS FOR NH3 H2O SYSTEM

```

1  clc;
2  x1=0.9; // mole fraction of NH3
3  x2=0.1; // Mole fraction of H2O
4  p=490.3; // Pressure in kPa
5  T=280.1; // Temperature in kelvin
6  lam12_11=-2131; lam21_22=-2726; // In kJ/kmol
7  R_1=8.3144; // Universal gas constant in kJ/kmol K
8  // (a).Enthalpy of saturated liquid Mixture at L/B
    at bubble temperature
9  V1L=0.0016; V2L=0.001; //from properties of NH3 and

```

```

    H2O in m3/kg
10 a=((V2L*18)/(V1L*17)) * exp (-lam12_11/(R_1*T));
11 b=((V1L*17)/(V2L*18)) * exp (-lam21_22/(R_1*T));
12 d_a=a*(lam12_11/(R_1*T^2)); d_b=b*(lam21_22/(R_1*T
    ^2));
13 d_lnr1=(-(a*x2^2*d_a/(x1+(a*x2))^2)-(x2*d_b/(b*x1+
    x2))+b*x1*x2*d_b/(b*x1+x2)^2);
14 d_lnr2=(-b*x1^2*d_b/(b*x1+x2)^2)-(x1*d_a/(x1+a*x2))
    +(a*x1*x2*d_a/(x1+a*x2)^2); x1=0.728; // By
    substituting these values in equation
15 h_E=-R_1*T^2*(x1*d_lnr1+x2*d_lnr2); // Heat of
    mixing
16 x1=0.9;
17 M=x1*17+x2*18; // Molecular weight
18 hE=h_E/M;
19 h1L=32.5; h2L=29.4; // in kJ/kg
20 hL=(x1*h1L)+(x2*h2L)+hE; // Specific enthalpy of the
    liquid mixture
21 disp ("kJ/kg",hL," Specific enthalpy of the liquid
    mixture = ",(a).Enthalpy of saturated liquid
    Mixture at L/B at bubble temperature");
22 // (b).Enthalpy of saturated vapour at V in
    Equilibrium with liquid at L/B
23 // From property table of ammonia and water at 0 oC
24 T1=273.15; // Temperature in kelvin
25 p1sat=429.4; p2sat=0.6108; // Pressure in kPa
26 hfg1=1262.4; hfg2=2501.4; // specific enthalpy in kJ/
    kg
27 vg1=0.2895; vg2=206.3; // specific volume in m3/kg
28 // Referring to fig 13.15 , we have
29 hb1=1262.4; hb2=2501.4; // specific enthalpy in kJ/kg
30 M=17;
31 // The critical properties
32 Tc1=405.3; Tc2=647.3; // Temperature in kelvin
33 pc1=11.28; pc2=22.09; // Pressure in MPa
34 z1=(p1sat*vg1/(R_1*T1/M)); z2=(p2sat*vg2/(R_1*T1/M));
35 A2_1=(0.4278/(pc1*10^3))*(Tc1/T1)^2.5; // Constants
36 B_1=(0.0867/(pc1*10^3))*(Tc1/T1); // Constants

```



```

37 h1R=R_1*(T1/M)*((( -3/2)*(A2_1/B_1)*log (1+(B_1*p1sat
    /z1))))+z1-1);
38 A2_2=(0.4278/(pc2*10^3))*(Tc2/T1)^2.5; // Constants
39 B_2=(0.0867/(pc2*10^3))*(Tc2/T1); // Constants
40 h2R=-0.2;
41 hc1=hb1-h1R; hc2=hb2-h2R; // Enthalpies at 0 oC
42 Cpo1=14.86; Cpo2=12.92; // In kJ/kg
43 A2_1=(0.4278/(pc1*10^3))*(Tc1/T)^2.5; // Constants
44 B_1=(0.0867/(pc1*10^3))*(Tc1/T); // Constants
45 A2_2=(0.4278/(pc2*10^3))*(Tc2/T)^2.5; // Constants
46 B_2=(0.0867/(pc2*10^3))*(Tc2/T); // Constants
47 y1=0.9999; y2=0.0001;
48 Tc=y1*Tc1+y2*Tc2;
49 z=0.957;
50 hR=R_1*(T/M)*((( -3/2)*(A2_1/B_1)*log (1+(B_1*p/z))))+
    z-1);
51 hV=y1*(hc1+Cpo1)+y2*(hc2+Cpo2)+hR;
52 disp ("kJ/kg",hV,"(b).Enthalpy of saturated vapour
    at V in Equilibrium with liquid at L/B");
53 // (c).Enthalpy of saturated vapour at D after
    complete vaporization of liquid at B/L
54 T=359.15; // In K
55 Cpo1=192.2; Cpo2=160.9; // In kJ/kg
56 A2_1=(0.4278/(pc1*10^3))*(Tc1/T)^2.5; // Constants
57 B_1=(0.0867/(pc1*10^3))*(Tc1/T); // Constants
58 A2_2=(0.4278/(pc2*10^3))*(Tc2/T)^2.5; // Constants
59 B_2=(0.0867/(pc2*10^3))*(Tc2/T); // Constants
60 y1=0.9; y2=0.1;
61 Tc=y1*Tc1+y2*Tc2;
62 z=0.9768;
63 hR=R_1*(T/M)*((( -3/2)*(A2_1/B_1)*log (1+(B_1*p/z))))+
    z-1);
64 hD=y1*(hc1+Cpo1)+y2*(hc2+Cpo2)+hR;
65 disp ("kJ/kg",hD,"(c).Enthalpy of saturated vapour
    at D after complete vaporization of liquid at B/L
    ");
66 // (d).Latent Heat of Vapourization of this Liquid
    Mixture

```

```
67 hB=-0.2;
68 hD_hB=hD-hB; //Latent Heat of Vapourization of this
    Liquid Mixture
69 disp ("kJ/kg mixture",hD_hB,"(d). Latent Heat of
    Vapourization of this Liquid Mixture = ");
```

Chapter 14

CHEMICAL REACTIONS AND COMBUSTION

Scilab code Exa 14.1 THE STANDARD HEAT OF REACTION

```
1 clc;  
2 // From the Table 14.1  
3 del_hfHCL=92307; // Enthalpy of Heat in kJ/kmol  
4 del_hfH20=-241818; // Enthalpy of Heat kJ/kmol  
5 del_Ho=4*del_hfHCL-2*del_hfH20; // The standard heat  
   of reaction from enthalpy equation  
6 disp ("kJ (answer mentioned in the textbook is  
   wrong)",del_Ho,"The standard heat of reaction for  
   the process = ");
```

Scilab code Exa 14.2 ENTHALPY OF FORMATION OF SUCROSE

```
1 clc;  
2 del_Ho=5640000; // Heat released during the process  
3 // From the Table 14.1  
4 del_hfO2=-393509; del_hfH20=-285830; // Enthalpy of  
   Heat in kJ/kmol
```

```

5 del_hfsucrose=12*del_hfO2+11*del_hfH2O+del_Ho; //
  The enthalpy formation of sucrose
6 disp ("kJ/kmol (answer mentioned in the textbook
  is wrong)",del_hfsucrose,"The enthalpy formation
  of sucrose = ");

```

Scilab code Exa 14.3 BALANCING A COMBUSTION EQUATION

```

1 clc;
2 // (a).Balancing of chemical equation
3 // The unbalanced equation for the process is C8H18
  + O2 + N2      CO2 + H2O + N2
4 x=8; // Carbon balance
5 y=9; // Hydrogen balance
6 z=12.5; // Oxygen balance in reverse order
7 n=z*3.76; // Nitrogen Balance
8 disp ("(a).Balancing of chemical equation");
9 printf ("\n C8H18 + %0.1f O2 + %d N2      %d CO2 + %d
  H2O + %d N2 \n ",z,n,x,y,n);
10 // (b).The theoretical air-fuel ratio
11 a=1; // Mole of C8H18
12 AF1=(z+n)/a; //The theoretical air-fuel ratio on
  mole basis
13 ma=28.84; // Molecular mass of air
14 mc=114; // Molecular mass of C8H18
15 AF2=(AF1*ma)/(a*mc); // The theoretical air-fuel
  ratio on mass basis
16 disp ("kg air / kmol C8H18",AF2,"The theoretical air
  -fuel ratio on mass basis = ","kmol air / kmol
  C8H18",AF1,"The theoretical air-fuel ratio on
  mole basis = ","(b).The theoretical air-fuel
  ratio");

```

Scilab code Exa 14.4 CHEMICAL EQUATION FOR INCOMPLETE COMBUSTION WITH DEFICIENT AIR

```
1 clc;
2 // The combustion equation for C4H10 with 80%
   theoretical air is C4H10 +5.2(O2 + 3.76 N2)      a
   (1)CO + a(2)CO2 + 5H2O + 19.55N2
3 // The following matrix shows the balance of C and O
4 A=[1 1 ; 1 2];
5 B=[4 ;5.4];
6 a=A\B;
7 disp ("The equation for the combustion of butane
   with 80% theoretical air is ")
8 printf ("\n C4H10 +5.2(O2 + 3.76 N2)      %0.1f CO +
   %0.1f CO2 + 5H2O + 19.55N2",a(1),a(2));
```

Scilab code Exa 14.5 AIR FUEL RATIO FOR COMBUSTION OF GASOLINE AND DEW POINT TEMPERATURE

```
1 clc;
2 p=101.325; // Atmospheric pressure in kPa
3 // The complete combustion equation for octane
4 // yC8H18+ x (O2+3.76N2)      n1 CO2+n2 H2O+n3 O2+
   n3 N2
5 x=12.5*1.5; y=1;
6 n1=8; n2=9; n3=6.28; n4=70.5;
7 n=n1+n2+n3+n4; // Total number of moles of the
   products
8 AFm=(x+x*3.76)/y ;// Air fuel ratio
9 m=28.84;
10 M=116; // Molecular weight of octane
11 AF=AFm*m/M;
12 yco2=n1/n; yH2O=n2/n; yO2=n3/n; yN2=n4/n;
13 pH2O=p*yH2O; // Partial pressure of water vapour in
   the products
14 Tsat=45.21; // In oC
15 disp ("kg air/kg octane",AF,"Air fuel ratio = ");
```

```

16 disp ("If the products are cooled below 25 oC then ,
        the water vapour will condense. Because the
        cooled temperature is less than dew point
        temperature of water vapour i.e., T < Tsat.");

```

Scilab code Exa 14.6 AIR FEL RATIO FOR COMBUSTION OF PRODUCER GAS

```

1  clc;
2  // The complete chemical equation is
        // [0.14H2+0.03CH4+0.27CO+0.045CO2+0.01O2+0.505N2
        // ]+0.255(O2+3.75N2)  0  .2H2O+0.345CO2+1.44N2
3  a=0.14; // Composition of H2 in air
4  b=0.03; // Composition of CH4 in air
5  c=0.27; // Composition of CO in air
6  d=0.045; // Composition of CO2 in air
7  e=0.01; // Composition of O2 in air
8  f=0.505; // Composition of N2 in air
9  g=(0.265-0.01); // O2 requirement from atmospheric
        air with 1% O2 already in fuel
10 h=3.76; // By nitrogen balance
11 i=1; // mole of the air
12 AFvol=(g+(g*h))/i; // Air fuel ratio (theroretical)
13 AFv=1.1*AFvol; // Air fuel ratio on mol (volume)
        basis
14 disp ("kmol actual air/kmol fuel",AFv," Air fuel
        ratio on mol (volume) basis =")
15 M1=2; // Molecular mass of H2
16 M2=16; // Molecular mass of CH4
17 M3=28; // Molecular mass of CO
18 M4=44; // Molecular mass of CO2
19 M5=32; // Molecular mass of O2
20 M=a*M1+b*M2+c*M3+d*M4+e*M5+f*M3; // Molecular mass
        of Fuel
21 Ma=28.84; // Molecular mass of air

```

```

22 AFm=AFv*Ma/(i*M); // Air fuel ratio on mass basis
23 disp ("kg air / kg fuel",AFm,"Air fuel ratio on mass
      basis = ");

```

Scilab code Exa 14.7 ACTUAL COMBUSTION OF PROPANE

```

1  clc;
2  //From table 14.2 at 25 oC and 1 atm for C3H8
3  del_Ho=-2039.7; // LHV in MJ/kmol
4  // Combustion equation is C3H8+ 5O2 +18.8N2      3CO2
      +4H2O +18.8N2
5  // From table 14.3
6  h333_C3H8=2751; // h333_h298 of C3H8 in kJ/kmol
7  h333_O2=147; // h333_h298 of O2 in kJ/kmol
8  h333_N2=145; // h333_h298 of N2 in kJ/kmol
9  h1333_CO2=52075; // h1333_h298 of CO2 in kJ/kmol
10 h1333_H2O=32644; // h1333_h298 of H2O in kJ/kmol
11 h1333_N2=32644; // h1333_h298 of N2 in kJ/kmol
12 M=44; // molecular mass of C3H8
13 Ha_H1=h333_C3H8+5*h333_C3H8+18.8*h333_N2; // The
      enthalpy differences
14 Hb_H2=3*h1333_CO2+4*h1333_H2O+18.8*h1333_N2; // The
      enthalpy differences
15 Q=(del_Ho+Hb_H2/1000-Ha_H1/1000)/M; // Heat transfer
      from combustion chamber
16 disp ("MJ/kg C3H8",abs (Q),"Heat transfer from
      combustion chamber =");

```

Scilab code Exa 14.8 ADIABATIC FLAME TEMPERATURE OF PROPANE WITH THEORETICAL AIR

```

1  clc;
2  Ha_H1=6220; // From example 14.7 in kJ/kmol
3  del_Ho=-2039.7; // From example 14.7 LHV in MJ/kmol

```

```

4 Hb_H2=-del_Ho+Ha_H1; // For adiabatic combustion of
  C3H8
5 // Hb_H2=3*h1333_CO2+4*h1333_H2O+18.8*h1333_N2 By
  iteration process and making use of the values
  from Table A.3, A.13, A.15 we can get the
  adiabatic flame temperature is
6 Tad=2300; // The adiabatic flame temperature in
  kelvin
7 disp ("K",Tad,"The adiabatic flame temperature");

```

Scilab code Exa 14.9 ENTROPY GENERATION IN A CARBON COMBUSTION REACTION

```

1 clc;
2 // (a).Entropy change per kmol of C
3 // From table 14.1 at 298 K and 1 atm
4 s_c=5.686; // Absolute entropies of C in kJ/kmol K
5 s_o2=205.142; // Absolute entropies of o2 in kJ/kmol
  K
6 s_co2=213.795; // Absolute entropies of CO2 in kJ/
  kmol K
7 del_s=s_co2-(s_c+s_o2); // The entropy change
8 disp ("kJ/K/kmol C",del_s,"(a).The entropy change =
  ");
9 // (b).Entropy change of universe
10 Tsurr=298; // Temperature of surroundings in kelvin
11 // From table 14.1
12 del_Ho=-393509; // del_hfco2 in kJ/kmol CO2
13 Q=abs (del_Ho);
14 del_Ssurr=Q/Tsurr; // Entropy change of surroundings
15 del_Suniv=del_s+del_Ssurr; //Entropy change of
  universe
16 disp ("kJ/K",del_Suniv,"(b).Entropy change of
  universe = ");

```

Scilab code Exa 14.10 ENTROPY GENERATION IN A CO COMBUSTION REACTION

```

1  clc;
2  // (a).The product CO2 is also at 298K
3  Pco=2/3; // Paratial pressure of CO in atm
4  Po2=1/3; // Paratial pressure of O2 in atm
5  Pco2=1; // Paratial pressure of CO2 in atm
6  T0=298; // Temperature of surroundings in kelvin
7  R_1=8.3143; // Universal gas constant of air in kJ/
    kmol K
8  // From table 14.1 at 298 K and 1 atm
9  s_co2=213.795-R_1*log (Pco2); // entropies in kJ/
    kmol K
10 s_co=197.653-R_1*log (Pco); // entropies in kJ/kmol
    K
11 s_o2=205.03-R_1*log (Po2); // entropies in kJ/kmol K
12 del_Scv=s_co2-s_co-1/2*s_o2; // Entropy change of
    control volume
13 // From table 14.1
14 del_hfco2=-393509; del_hfco=-110525; // Enthalpy of
    Heat in kJ/kmol
15 Q= del_hfco2- del_hfco; // Heat transfer (to
    surroundings)
16 del_Ssurr=abs(Q)/T0; // Entropy change of
    surroundings
17 del_Sgen=del_Scv+del_Ssurr; //Entropy change of
    universe
18 disp ("kJ/K",del_Sgen,"Entropy change of universe =
    ", "kJ/K",del_Ssurr,"Entropy change of
    surroundings = ", "kJ/K",del_Scv,"Entropy change
    of control volume = ", "(a).The product CO2 is
    also at 298K");
19 // (b).The reaction is adiabatic
20 // Let the adiabatic flame temperature be T. Then

```

```

    since
21 Q=0;
22 C_p=44*0.8414;
23 // From table A.16
24 T=5057.5; //adiabatic flame temperature in kelvin
25 s_CO2=213.795+C_p*log (T/T0); // entropies in kJ/
    kmol K
26 del_Scv=s_CO2-s_co-1/2*s_o2; // Entropy change of
    control volume
27 del_Ssurr=abs(Q)/T0; // Entropy change of
    surroundings
28 del_Sgen=del_Scv+del_Ssurr; //Entropy change of
    universe
29 disp ("kJ/K",del_Sgen,"Entropy change of universe =
    ", "kJ/K",del_Ssurr,"Entropy change of
    surroundings = ", "kJ/K",del_Scv,"Entropy change
    of control volume = ", "(b).The reaction is
    adiabatic");

```

Scilab code Exa 14.11 GIBBS FNCTION OF FORMATION OF LIQUID H2O

```

1  clc;
2  // The Combustion of H2 with Q2 from H2O
3  //H2(g)+1/2 O2 (g) H2O (l)+285830 kJ/kmol H2
4  T0=298; // Temperature of surroundings in kelvin
5  // From table 14.1 at 298 K
6  del_hfH20=-285830; // Enthalpy of Heat in kJ/kmol
7  s_298H20=69.94; s_298H2=130.684; s_298O2=205.142; //
    entropies in kJ/kmol K
8  GP_GR=del_hfH20-T0*(s_298H20-s_298H2-1/2*s_298O2);
    // Formation of Gibbs function
9  GR=0;
10 GP=GP_GR-GR; // Standard Gibbs function of formation
    of liquid H2O
11 disp ("kJ/kmol",GP,"Standard Gibbs function of

```

formation of liquid H2O = ");

Scilab code Exa 14.12 MAXIMUM POSSIBLE WORK OUTPUT OF A COMBUSTION PROCESS

```
1  clc;
2  // the combustion equation
3  // n1C3H8+n2O2+n3 N2      n4 CO2+ n5 H2O+n6 O2+n7 N2
4  T0=298; // Temperature of surroundings in kelvin
5  // (a).Product species at 25 oC and 1 atm
6  d_gfC3H8=-24290; d_gfCO2=-394359; d_gfH2O=-228570;
   // in kJ/kmol
7  GR=d_gfC3H8;
8  GP=3*d_gfCO2+4*d_gfH2O;
9  Wmax=GR-GP; // Maximum possible work output
10 M=44; //Molecular weight
11 Wmax=Wmax/M;
12 disp ("kJ/kg fuel (answer mentioned in the
   textbook is wrong)",Wmax,"Maximum possible work
   output = ", "(a).");
13 // (b).The actual partial pressures of products
14 n1=1; n2=20; n3=75.2;
15 n4=3; n5=4; n6=15; n7=75.2; // refer equation
16 SR=19233; SP=19147; // in kJ/K from table
17 HR=-104680; // in kJ/kmol fuel
18 d_h0fCO2=-393509; d_h0fH2O=-241818; // in kJ/kmol
19 HP=3*d_h0fCO2+4*d_h0fH2O;
20 Wmax=HR-HP-T0*(SR-SP); // Maximum possible work
   output
21 Wmax=Wmax/M;
22 disp ("kJ/kg (round off error)",Wmax,"Maximum
   possible work output = ", "(b).");
```

Chapter 15

CHEMICAL EQUILIBRIUM

Scilab code Exa 15.1 METHANE WATER REACTION

```
1 clc;  
2 // (b).Number of moles of each constituents  
3 nCH4=2; // Number of moles of CH4  
4 E=3-nCH4; // Amount of reaction from (a) and refer  
   example 15.1 (a)  
5 nH2O=1-E; // Number of moles of H2O  
6 nCO=1+E; // Number of moles of CO  
7 nH2=4+3*E; // Number of moles of H2  
8 disp (nH2,"Number of moles of H2 = ",nCO,"Number of  
   moles of CO = ",nH2O,"Number of moles of H2O = ",  
   "(b).Number of moles of each constituents");
```

Scilab code Exa 15.2 EQUILIBRIUM CONSTANTS FOR COMBUSTION OF CO

```
1 clc;  
2 T0=298; // Given temperature in kelvin  
3 R_1=8.314; // Universal gas constant in kJ/kg mol K  
4 // (a).CO+1/2 O2 = CO2
```

```

5 // From table of properties of combustion
6 del_hfco2=-393509; // Enthalpy of heat
7 del_hfco=-110525; // Enthalpy of heat
8 s_co2=213.795; // Entropy of heat
9 s_co=197.652; // Entropy of heat
10 s_o2=205.142; // Entropy of heat
11 del_Ga=(del_hfco2-del_hfco-T0*(s_co2-s_co-(1/2*s_o2)
    ));
12 Ka=exp (abs (del_Ga)/(R_1*1000*T0));
13 disp ("(a).CO+1/2 O2 = CO2");
14 printf ("\n The equilibrium constant at 298 K = %0.3
    f (Error in textbook) \n",Ka);
15 // (b).2CO + O2 = 2CO2
16 Kb=exp (2*abs (del_Ga)/(R_1*1000*T0));
17 disp ("(b).2CO + O2 = 2CO2");
18 printf ("\n The equilibrium constant at 298 K = %0.3 f
    (Error in textbook)",Kb);

```

Scilab code Exa 15.3 EQUILIBRIUM CONSTANT AT GIVEN TEMPERATURE

```

1 clc;
2 T0=298; // Temperature of surroundings in kelvin
3 R_1=8.314; // Universal gas constant in kJ/kg mol K
4 T=2800; // Given Temperature in kelvin
5 // From table of properties of combustion
6 del_hfco2=-393509; // Enthalpy of heat
7 del_hfco=-110525; // Enthalpy of heat
8 del_H=del_hfco2-del_hfco; // Standard enthalpy of
    reaction
9 Ka=1.229D+45; // The equilibrium constant From the
    example 15.2
10 K1=log (Ka);
11 K=exp(-(del_H/R_1)*((1/T)-(1/T0))+K1);
12 disp (K,"K =");

```

Scilab code Exa 15.5 ACTUAL COMBUSTION OF CO

```
1 clc;
2 T=2800; // Temperature of combustion in kelvin
3 p=1; // Pressure of combustion in atm
4 // For this reverse reaction at 2800K and 1atm, from
   Table 15.1
5 K=44.168; //  $K=e^{3.788}$ ;
6 K=sqrt (K); // For stoichiometric equation  $\text{CO} + 1/2 \text{O}_2$ 
   =  $\text{CO}_2$  which is halved
7 // From equation 15.24a and by the iteration process
   we get the following
8 a=0.198;
9 b=(1+a)/2;
10 c=1-a;
11 disp (c,b,a,"The balance for the actual reaction
   equation  $\text{CO} + \text{O}_2 \rightleftharpoons a\text{CO} + b\text{O}_2 + c\text{CO}_2$  is given by
   ");
```

Scilab code Exa 15.6 EFFECT OF PLEASURE ON OBTAINING COMPLETE COMBUSTION

```
1 clc;
2 // By driving the equation for equilibrium constant
   as shown in example 15.6 we get  $6.646(6)^{(1/6)}$ 
    $=((1-a)/a)((3+a)/(1+a))^{1/2}$ 
3 // by simple iteration process we get
4 a=0.095;
5 b=(1+a)/2;
6 c=1-a;
7 disp ("mol",c,"The equilibrium composition of  $\text{CO}_2 =$ 
   ", "mol",b,"The equilibrium composition of  $\text{O}_2 =$  ",
   "mol",a,"The equilibrium composition of  $\text{CO} =$  ");
```

Scilab code Exa 15.7 EFFECT OF INERT GAS N2 IN COMBUSTION

```
1 clc;
2 T=2800; // Temperature of combustion in kelvin
3 p=1; // Pressure of combustion in atm
4 // For this reverse reaction at 2800K and 1atm, from
   Table 15.1
5 K=44.168; //  $K=e^{3.788}$ ;
6 K=sqrt(K); // For stoichiometric equation  $CO+1/2 O_2$ 
   =  $CO_2$  which is halved
7 // From equation 15.24a and by the iteration process
   we get the following
8 a=0.302;
9 b=(1+a)/2;
10 c=1-a;
11 disp(c,b,a,"The balance for the actual reaction
   equation  $CO + 1/2O_2 + 1.88N_2$  aCO + bO2 + cCO2
   +3.76N2 is given by ");
```

Scilab code Exa 15.8 FORMATION OF NITROGEN OXIDES NO_x IN IC ENGINES

```
1 clc;
2 T=3000; // Temperature of combustion in kelvin
3 p=1; // Pressure of combustion in atm
4 T0=298; // Temperature of surroundings in kelvin
5 R_1=8.314; // Universal gas constant in kJ/kg mol K
6 // Gibbs functions at 298K from Table 14.1
7 del_gNO=86550; // In kJ/kmol
8 del_gNO2=51310; // In kJ/kmol
9 // From table of properties of combustion
10 del_hfNO=90250; // Enthalpy of heat
```

```

11 del_hfNO2=33180; // Enthalpy of heat
12 K1=exp (-(del_hfNO/R_1)*((1/T)-(1/T0))-((del_gNO)/(
    R_1*T0)));
13 K2=exp (-(del_hfNO2/R_1)*((1/T)-(1/T0))-((del_gNO2)
    /(R_1*T0)));
14 // By solving equilibrium equations by iteration
    method
15 E1=0.228; E2=0.0007;
16 yNO=E1/4.76; // Mole fraction of NO in exhaust gas
17 yNO2=E2/4.76; // Mole fraction of NO2 in exhaust gas
18 disp ("%",yNO2*100,"Mole fraction of NO2 in exhaust
    gas = ","%",yNO*100,"Mole fraction of NO in
    exhaust gas = ","Percentage of NOx present in the
    exhaust gas ");

```
