Scilab Textbook Companion for Thermodynamics by C. P. Arora[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 2

THERMODYNAMIC CONCEPTS AND THE ZEROTH LAW

Scilab code Exa 2.1 MASS OF PISTON

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

Scilab code Exa 2.2 INCLINED MANOMETER

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

```
clc;
V=0.01; // Volume of water in a rigid vessel in m^3
m=4.5; // Mass of water+ steam in a rigid vessel in
   kg
T=35; // Temperature of water in a rigid vessel in
   degree celcius
// (a)
v=V/m; // specific volume of water
// From steam table
vf=0.001006; vg=25.22; // specific volume in m^3/kg
x=(v-vf)/(vg-vf); // Quality of steam
x1=1-x; // Quality of water
mg=x*m; // Mass of steam
mf=x1*m; // Mass of water
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)   ");
// (b)
```

```
vc=0.003155; //  Crictical volume for water in m^3/
    kg
disp ("The level of liquid water will rise in the
    vessel. Since v < vc and refer figure 3.21","  (b
    )  ");
// (c)
disp ("The final temperature after heating is 370.04
     oC.  Because it is constant volume process and
    refer figure 3.21","  (c)  ");
//  (d)
m1=0.45; // Mass of water in kg
v1=V/m; // specific volume of water
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

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

```
    Ammonia 550kPa and 0.31m^3/kg");
// (c).Freon 12, 0.35MPa and 0.036 m^3/kg
// From saturation table of Freon 12 at 0.35MPa
v=0.036; // specific volume of Freon 12 in m^3/kg
vf=0.000722; vg=0.049329; // specific volume of
    Freon 12 in m^3/kg
x=(v-vf)/(vg-vf); // Quality of vapour since v<vg
disp (x,"The Quality of Freon 12 = ","(c).Freon 12,
     0.35MPa and 0.036 m^3/kg");
// (d).Methane 0.5MPa and 1.0 m^3/kmol
v=1; // specific volume of Methane in m^3/kmol
// From table at 0.5 MPa molar values are
vf=0.04153; vg=2.007; // specific volume of Methane
     in m^3/kmol
x=(v-vf)/(vg-vf); // Quality of vapour since v<vg
disp (x,"The Quality of Methane = ","(d).Methane
    0.5MPa and 1.0 m^3/kmol");
```

Scilab code Exa 3.3 MASS OF AIR

```
clc;
V=300; // Volume of air in the room in m^3
p=1; // Atmospheric pressure in bar
T=25; // Temperature of air in Degree Celcius
R=287; // Characteristic constant of Air in J/kg k
m=(p*10^5*V)/(R*(T+273)); // Ideal gas equation
disp ("kg",m,"Mass of air in room");
```

Scilab code Exa 3.4 MOLECULAR WEIGHT OF THE GAS

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

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

Scilab code Exa 3.5 PRESSURE AND TEMPERATURE OF AIR

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

Scilab code Exa 3.7 DETERMINATION OF SPECIFIC VOLUME

```
clc;
p=6000; // Pressure of nitrogen gas in kPa
T=150; // Temperature of nitrogen gas in kelvin
V=250; // Volume of tank in litres
R_1=8.3143; // Universal gas constant in kJ/kmol K
M=28.1013; // Molecular mass
// (a).Beattie - Bridgeman equation of state
// Constants for nitrogen gas
c=4.2*10^4; Ao=136.2315; a=0.02617; Bo=0.05046; b
    =-0.00691;
// By substituting these values in the following
    equation
// p=(R_1*T/v^2)*(1-(c/(vT^3)))*(v+Bo*(1-(b/v)))-(Ao
    /v^2*(1-(a/v)))
// By trial and error we get
v=0.1222; // specific volume in m^3/kmol
m=(M*V/1000)/v; // Mass of nitrogen gas
disp ("m^3/kmol",v,"specific volume of nitrogen gas
    = ","kg",m,"Mass of nitrogen gas = ","(a).Beattie
     - Bridgeman equation of state");
// (b).Nitrogen tables
// From property table of nitrogen fas
v=0.004413;  // specific volume in m^3/kg
m=(V/1000)/v; //  Mass of nitrogen gas
disp ("m^3/kg",v,"specific volume of nitrogen gas =
    ","kg",m,"Mass of nitrogen gas = ","(b).Nitrogen
    tables");
// (c).Ideal gas equation of state
m=(p*V/1000)/(R_1*T/M); //Mass of nitrogen gas
disp ("kg",m,"Mass of nitrogen gas = ","(c).Ideal
    gas equation of state");
// (d).Generalized compressibility chart
// The crictical properties for nitrogen gas
Tc=126.2; // Temperature in kelvin
Pc=3.349; // Pressure in MPa
// Reduced properties are
Pr=p/Pc; Tr=T/Tc;
z=0.6; // From chart
```

```
m=(p*V/1000)/(z*R_1*T/M); //Mass of nitrogen gas
disp ("kg",m,"Mass of nitrogen gas = ","(d). Generalized compressibility chart");
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

```
clc;
T=-58.7; //Normal boling point of CF3Br in Degree Celcius
Tc=340.9; // Crictical temperature of CF3Br in K
pc=4.05; // Crictical pressure of CF3Br in MPa
M=148.9; // Moleclar mass of CF3Br
p=1.01325*10^5; // Atmospheric pressure in N/m^2
R1=8314.4; // Universal gas constant in J/kmol K
R=R1/M; // Gas constant of CF3Br
a=(0.42748*R^2*Tc^2.5)/(pc*10^6); // Constant of Redlich-Kwong equation of state
b=(0.08664*R*Tc)/(pc*10^6); // Constant of Redlich-Kwong equation of state
vi=(R*(T+273))/p; // Ideal gas volume for assigning initial value
// By substituting these values in the Redlich-Kwong equation of state
 // 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
vi_1=0.11443; // in m^3/kg
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

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

```
T2=T1*(p2/p1)^((n-1)/n); // From Polytropic process relation of final temperature
W=(m*R*(T1-T2))/(1-n); // Work done from Polytropic process relation
disp ("kJ",W,"Work done =");
```

Scilab code Exa 4.3 CALCULATION OF WORKDONE

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

Scilab code Exa 4.4 FREE EXPANSION OF FREON 12

```
clc;
patm=1; // Atmospheric pressure in bar
V1=0.0135; // Volume of Freon 12 at initial state in m^3
D=9; // Diameter of the cylinder in cm
```

```
m=90; // Mass of the piston in kg
g=9.80665; // acceleration due to gravity in m/s^2
// (a). Determination of the final pressure and volume of the system
A=%pi/4 * (D*10^-2)^2; // Area of the cylinder
p1=0.7449; // Initial pressure of saturated vapour at 30 degree celcius in MPa
v1=0.023508; // Initial specific volume of saturated vapour at 30 degree celcius in m^3/kg
p2=(patm*10^5)+(m*g)/A; // Final pressure of Freon 12
v2=0.084022; // Final specific volume from superheated table at p2 and 30 degree celcius in m^3/kg
mf=V1/v1; // Mass of Freon 12
V2=mf*v2; // Final volume of Freon 12
disp ("Pa",p2,"Final pressure = ","(a)");
disp ("m^3   (round off error)",V2,"Final volume = ");
// (b). Calculation of workdone by Freon 12 during this process
Wirrev=p2*(V2-V1);   // P dv Work done
disp ("kJ   (round off error)",Wirrev/1000,"Work done = ","(b)");
// (c). Calculation of workdone by Freon 12 during reversible process
Wrev=p1*10^6*V1*log (V2/V1);//From reversible process relation for work done
disp ("kJ   (round off error)",Wrev/1000,"Work done in reveersible process = ","(c)");
```

Scilab code Exa 4.5 CALCULATION OF POWER AND CLEARENCE VOLUMETRIC EFFICIENCY

```
clc;
```

```
p1=0.1; // Initial pressure (before compression) of
    air in MPa
T1=30; // Initial temperature (before compression)
    of air in degree celcius
p2=0.9; // Final pressure (after compression) of air
     in MPa
R=0.287; // Characteristic constant of air in kJ/kg
    k
// (i) Actual work in the flow process
// (a).Isothermal Process
w=-R*(T1+273)*log (p2/p1); // work done for
    isothermal process
disp ("kJ/kg",w,"work done = ","(a).Isothermal
    Process","(i) Actual work in the flow process");
// (b).Polytropic process
n=1.4; // Index of polytropic process
T2=(T1+273)*(p2/p1)^((n-1)/n); // From Polytropic
    process relation for final temperature
w=(n/(1-n))*R*(T2-(T1+273)); // work done for
    polytropic process
disp ("kJ/kg",w,"compression work = ","(b).
    Polytropic process");
// (ii).Nonflow work
// (a).Isothermal Process
w=-R*(T1+273)*log (p2/p1); // work done for
    isothermal process
disp ("kJ/kg",w,"work done = ","(a).Isothermal
    Process","(ii).Nonflow work");
// (b).Polytropic process
w=(1/(1-n))*R*(T2-(T1+273));// work done for
    polytropic process
disp ("kJ/kg",w,"compression work = ","(b).
    Polytropic process");
```

Scilab code Exa 4.6 WORK OF COMPRESSION

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

```
disp ("%",er,"Error (Error in textbook)= ");
// (c).Clearance volumetric efficiency
C=Vc/Vp;
eff = 1+C+-C*(p2/p1)^(1/n); // Clearance volumetric efficiency
disp ("%",eff*100,"Clearance volumetric efficiency = ","(c).Clearance volumetric efficiency");
```

Scilab code Exa 4.7 WORK OF STEAM ENGINE

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

Scilab code Exa 4.8 INDICATOR WORK

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

Scilab code Exa 4.9 DOUBLE ACTING STEAM ENGINE

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

```
kgf
BP=F*9.81*d/2*2*%pi*N/60; // Brake power of Engine
eff=BP/IP *100 ; // Mechanical efficiency
disp ("kW",BP/1000,"Brake power of Engine = ","(b)");
disp ("%",eff,"Mechanical efficiency of Engine =");
```

Scilab code Exa 4.10 ECONOMISER SURFACE AREA

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

```
// Counter flow
del_Tm=((th1-Tc2)-(th2-Tc1))/log((th1-Tc2)/(th2-Tc1
    )); // Logarthamic Mean Temperature Difference in
     degree celcius
A=Q*10^3/(U*del_Tm); // Economiser surface area
disp("degree celcius",del_Tm,"Logarthamic Mean
    Temperature Difference=","(b) Counter flow");
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

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

Scilab code Exa 5.2 BOMB CALORIMETER

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

Scilab code Exa 5.3 CALCULATION OF HEAT TRANSFER

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

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

Scilab code Exa 5.4 CALCULATION OF OVERALL HEAT TRANSFER AND WORKDONE

```
clc;
V1=0.3; // Initial volume of water upto stop 1 in m
    ^3
p1=1; // Initial pressure of water in bar
```

```
x1=0.2; // Dryness fraction at initial state (1)
p2=3; // Pressur required to lift the piston in bar
V4=0.45; // Volume of water upto stop 2 in m^3
vf1=0.001043; // Specific volume at state (1) from steam table in m^3/kg
vg1=1.694; // Specific volume at state (1) from steam table in m^3/kg
v1=vf1+x1*(vg1-vf1); // Total Specific volume at state (1) from steam table in m^3/kg
m=V1/v1; // Mass of water
v3=V4/m; // Specific volume at stop 2
v2=v1; p3=p2; v4=v3; V3=V4; V2=V1; // From process diagram
//  (a)
p4=0.361; // Final Pressure at v4 from steam table in Mpa
disp ("MPa",p4,"Fianl pressure = ","(a)");
//  (b)
W14=p2*10^2*(V3-V2); // Work done in process
uf1=417.36; // Specific internal energ at initial state in kJ/kg
ufg1=2088.7; // Specific internal energ at initial state in kJ/kg
u1=uf1+x1*ufg1;  // Total Specific internal energr at initial state in kJ.kg
u4=2550.2; // Specific internal energ at final state in kJ/kg
Q14=m*(u4-u1)+W14; // From first law of thermodynamics
disp ("kJ",W14,"Work done during the process = ","(b)");
disp ("kJ",Q14,"Heat transfer during the process = ");
```

Scilab code Exa 5.5 WORKDONE IN A POLYTROPIC COMPRESSION PROCESS

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

Scilab code Exa 5.6 COOLING OF ICE

```
clc;
tS=-10; // initial temperature of ice in degree
```

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

Scilab code Exa 5.7 CHANGE IN ENTHALPY OF AIR

```
clc;
T1=300; // Temperature of air at state 1 in Kelvin
T2=500; // Temperature of air at state 2 in Kelvin
m_=28.966; // Molecular weight oh air in kg
Cpoav=1.017; // Average value of specific heat of
    air in kJ/kg K
// (a). change in enthalpy
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
h=h_/m_; // change in enthalpy during process in kJ/
    kg
disp ("kJ/kg",h,"(a).change in enthalpy during
    process = ");
// (b).change in enthalpy
h=Cpoav*(T2-T1); // change in enthalpy in kJ/kg
disp ("kJ/kg",h,"(b).change in enthalpy during
```

```
process with average specfic heat = ");
```

Scilab code Exa 5.8 DIRECTION AND MAGNITUDE OF WORKDONE

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

Scilab code Exa 5.9 QUASI EQUILIBRIUM PROCESS

```
clc;
p=1; // pressure inside piston cylinder arrangement
    in MPa
// stae 1 = saturated liquid
// state 2 = saturated vapour
// state 3 = superheated vapour
```

```
v1=0.001127; // specific volume at state 1 in m^3/kg
v2=0.19444; // specific volume at state 2 in m^3/kg
v3=0.4011; // specific volume at state 3 in m^3/kg
u1=761.68; // specific internal energy at state 1 in kK/kg
u2=2583.6; // specific internal energy at state 2 in kK/kg
u3=3296.8; // specific internal energy at state 3 in kK/kg
h1=762.81; // specific enthalpy at state 1 in kJ/kg
h2=2778.1; // specific enthalpy at state 2 in kJ/kg
h3=3697.9; // specific enthalpy at state 3 in kJ/kg
w12=p*10^3*(v2-v1); // Work done during process 1-2
w23=p*10^3*(v3-v2); // Work done during process 2-3
wtotal=w12+w23; // Total work done
disp ("kJ/kg",wtotal,"Work done = ");
// Calculation of heat transfer
// Method I
q12=(u2-u1)+w12; // Heat transfer during process 1-2
q23=(u3-u2)+w23; // Heat transfer during process 2-3
qtotal=q12+q23; // Total Heat transfer
disp ("kJ/kg",qtotal,"Heat Transfer = ","Method I","Calculation of Heat Transfer");
// Method II
q12=h2-h1; // Heat transfer during process 1-2
q23=h3-h2; // Heat transfer during process 2-3
qtotal=q12+q23; // Total Heat transfer
disp ("kJ/kg",qtotal,"Heat Transfer = ","Method II");
```

Scilab code Exa 5.10 CALCULATION OF WORKDONE AND HEAT TRANSFER

```
clc;
p1=1; // initial pressure of air in piston cylinder
```

```
arrangement in bar
T=300; // Temperature of air in piston cylinder arrangement in kelvin
p2=10; // Final pressure of air in piston cylinder arrangement in bar
R=0.287; // Characteristic gas constant of air in kJ/kg K
disp("The change in internal energy during the isothermal process is zero");
w=R*T*log (p1/p2); // Work done
disp ("kJ/kg",w,"Work done = ");
q=w; // From first law of thermodynamics
disp ("kJ/kg",q,"Heat transfer = ");
```

Scilab code Exa 5.12 EXPANSION OF AIR

```
clc;
p1=65;// (Error in textbook) // Pressure of air at state 1 in bar
v1=0.0135; // Volume of air at state 1 in m^3
v2=0.1; // Volume of air at state 2 in m^3
R=0.287; // Characteristic gas constant of air in kJ/kg K
Cvo=0.7165; // Specific heat at constant volume in kJ/kg K
// (a).Adiabatic process
k=1.4; // Index of adiabatic process
p2=p1*(v1/v2)^k; // Pressure of air at state 2
T1=p1*10^2*v1/R;// Tempewrature of air at state 1
T2=p2*10^2*v2/R;// Tempewrature of air at state 2
w=R*(T2-T1)/(1-k); // work done
q=0; // Adiabatic expansion process
delta_u=Cvo*(T2-T1); // Change in internal energy of air
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");
// (b).Polytropic  process
n=1.3; // Index of adiabatic process
p2=p1*(v1/v2)^n; // Pressure of air at state 2
T1=p1*10^2*v1/R;// Tempewrature of air at state 1
T2=p2*10^2*v2/R;// Tempewrature of air at state 2
w=R*(T2-T1)/(1-n); // work done
delta_u=Cvo*(T2-T1); // Change in internal energy of air
q=delta_u+w; // Adiabatic expansion process
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");
// (c).Isothermal process
T1=p1*10^2*v1/R;// Tempewrature of air at state 1
T2=T1; // Tempewrature of air at state 2
p2=p1*(v1/v2); // Pressure of air at state 2
w=R*T1*log (v2/v1); // work done
delta_u=Cvo*(T2-T1); // Change in internal energy of air
q=delta_u+w; // Adiabatic expansion process
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

```
clc;
m=10; // mass flow rate of chilled water in kg/s
V1=50; //velocity of chilled water at section 1 in m/s
```

```
z1=30; // Elevation of section 1 in m
V2=10; //velocity of chilled water at section 2 in m
    /s
z2=60; // Elevation of section 2 in m
h1=21; // Enthalpy of chilled water at section 1 in
    kJ/kg
h2=43; // Enthalpy of chilled water at section 2 in
    kJ/kg
W=35; // Rate of work done by pump in kW
g=9.80665; // Acceleration due to gravity in m/s^2
Q=m*(h2-h1)+(m*(V2^2-V1^2)/2000)+(m*g*(z2-z1)/1000)-
    W; // Steady flow energy equation
disp ("kW",Q,"The rate of Heat Transfer From
    Building (Error in textbook)= ");
```

Scilab code Exa 5.14 A RECIPROCATING COMPRESSOR

```
clc;
p1=1; // Suction pressure of air in bar
p2=5; // Delivery pressure of air in bar
T1=310; // Suction Temperature of air in kelvin
Cpo=1.0035; // Specific heat at constant pressure in
     kJ/kg K
// (a) Polytropic compression
T2=475; // Delivery Temperature of air in kelvin
Q=-0.15; // Heat loss to the cooling water in kW
Wpoly=-5.3; // Power consumption of compressor in kW
m=(-Wpoly+Q)/(Cpo*(T2-T1)); // mass flow rate of air
     from SSSF energy equation
n=1/((1-((log (T2/T1))/(log (p2/p1))))); // Index of
     polytropic process
disp (n,"Index of polytropic process = ","kg/s",m,"
    mass flow rate of air = ","(a).Polytropic
    compression");
// (b) Adiabatic compression
```

```
k=1.4; // Index of adiabatic process
Wad=-m*Cpo*T1*((p2/p1)^((k-1)/k)-1); // power
    consumption of compressor
disp ("kW",Wad,"Power consumption of compressor = ",
    "(b).Adiabatic compression");
// (c).Difference between specific work
wdiff=(abs(Wad)-abs(Wpoly))/m; // Difference between
     specific work
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

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

```
disp ("kg/s",m,"Mass flow rate of steam = ");
```

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

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

```
","bar",p3,"Pressure of air leaving turbine = ","(d).Pressure drop");
```

Scilab code Exa 5.17 DIFFUSER

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

Scilab code Exa 5.18 AREA OF DIFFUSER

```
clc;
p1=50; // Pressre of steam at diffuser inlet in kPa
T1=150; // Temperature of steam at diffuser inlet in degree celcius
V1=180; // Velocity of steam at diffuser inlet in m/s
```

```
A1=1000; // area of diffuser inlet in cm^2
V2=90; // Velocity of steam at diffuser outlet in m/s
p2=1; // Pressre of steam at diffuser outlet in bar
Q=120; // Heat loss to the surroundings in kW
v1=3.24; // Specific volume of steam from superheated steam table in m^3/kg at inlet
h1=2645.9; //  // Specific enthalpy of steam from superheated steam table in m^3/kg at inlet
m=V1*A1*10^-4/v1; // Mass flow rate of steam
q=Q/m; // Heat transfer per unit mass of steam
h2=q+h1+(V1^2-V2^2)/2000; //  Specific enthalpy of steam from SSSF energy equationat outlet
v2=1.704; // Specific volume of steam from superheated steam table in m^3/kg at outlet
A2=m*v2/V2; // Area of diffuser exit
disp ("cm^2",A2*10^4,"Area of diffuser exit (Error in textbook)= ");
```

Scilab code Exa 5.19 FLASH CHAMBER

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

```
A=[1 -1; h3 -h2];
B=[1 ; h1];
M=A\B;
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 EXHAUXT STEAM CONDENSER

```
clc;
p1=15;// Inlet pressure of condenser in kPa
x=0.92; // Quality of steam
ms=25; // mass flow rate of steam in kg/s
d_t=12; // temperature rise of water
Cpw=4.1868; // Specific heat of water in kJ/kg K
hfg=225.94; h4_3=2599.1; // specific enthalpy in kJ/
   kg
h1=(1-x)*hfg+x*h4_3; // specific enthalpy
h2=225.94; // specific enthalpy in kJ/kg
Q=ms*(h1-h2); // Heat transfer rate in condenser
mw=Q/(Cpw*d_t); // Mass flow rate of water
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

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

Scilab code Exa 6.2 CHECKING OF REVERSIBLE IRREVERSIBLE OR IMPOSSIBLE MACHINE

```
clc;
QH=325; // Heat supplied in kJ
QL=125; // Heat rejected in kJ
TH=1000; // Resorvior Temperature in kelvin
TL=400; // Resorvior Temperature in kelvin
W=200; // Work developed in kJ
e_carnot=1-TL/TH; // maximum efficiency
e_clamied=W/QH; // Efficiency clamied
disp (e_carnot,"e_carnot =");
disp (e_clamied,"e_clamied =");
if (e_carnot==e_clamied) then
    disp ("The machine is reversible");
elseif (e_carnot>e_clamied)
    disp ("The machine is irreversible");
else
    disp ("Here e_clamied > e_carnot so the cyclic
       machine is impossible.")
end
disp ("It would be reversible if its thermal
   efficiency  is equal to Carnot efficiency , and
   irreversible if it is less than Carnot efficiency
   .")
```

Scilab code Exa 6.3 A CARNOT REFRIGERATION

```
clc;
// Air conditioning unit
TL=278; // Operating temperature in kelvin
TH=318; // Operating temperature in kelvin
```

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

Scilab code Exa 6.4 YEAR ROUND AIR CONDITIONING UNIT

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

```
clc;
// (a).For the refrigerator
TL=258; // Operating temperature in kelvin
TH=313; // Operating temperature in kelvin
QL=3.5167; // Ton of refrigeration in kW
COP=TL/(TH-TL); // COP of Refrigeration unit
W=QL/COP; // Power comsumption of refrigerator
disp ("kW",W,"Power comsumption of refrigerator = ",
    "(a).For the refrigerator");
// (b). For the freezer
TL=248; // Operating temperature in kelvin
TH=313; // Operating temperature in kelvin
COP=TL/(TH-TL); // COP of Freezer unit
QL=W*COP; // Refrigeration produced
disp ("kW",QL,"Refrigeration produced = ","(b). For
    the freezer")
```

Scilab code Exa 6.6 CALCULATION OF ENTROPY OF VAPORIZATION

```
clc;
Psat=200;//Pressure of water in kPa
Tsat=393.38; // Saturation temperaure at Psat in
    kelvin
// (i).From the equation Tds=du+pdv
// Following are from steam table at Psat
ufg=2025; // specific internal energy of
    vapourization in kJ/kg
vg=0.8857; // specific volume in m^3/kg
vf=0.001061; // specific volume in m^3/kg
sfg=(ufg/Tsat)+(Psat*(vg-vf)/Tsat); // specific
    entropy of vapourization
```

```
disp ("kJ/kg K",sfg,"specific entropy of vapourization = ","(i).From the equation Tds=du+pdv ");
// (ii).From the equation Tds=dh−vdp
hfg=2201.9; // Specific enthalpy of vapourization in kJ/kg
sfg=hfg/Tsat; // specific entropy of vapourization
disp ("kJ/kg K",sfg,"specific entropy of vapourization = ","(ii).From the equation Tds=dh−vdp ");
```

Scilab code Exa 6.7 REVERSIBLE ISOTHERMAL PROCESS

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

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

```
clc;
p1=3; // initial pressure of air in bar
T1=200; // initial temperature of air in degree
    celcius
p2=1.5; // final pressure of air in bar
```

```
T2=105; // final temperature of air in degree celcius
Cpo=1.0035; // Specific heat at constant pressure in kJ/kg K
R=0.287; // characteristic gas constant of air in kJ/kg K
delta_s= Cpo*log (T2/T1)- R*log (p2/p1); // change in entropy during irreversible process
disp ("kJ/kg K",delta_s,"change in entropy during irreversible process = ");
```

Scilab code Exa 6.11 ENTROPY CHANGE OF ARGON GAS

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

```
clc;
p1=1; // Atmospheric pressure in bar
```

```
T1=348; // Atmospheric temperature in kelvin
V1=800; // Volume of air sucked into the cylinder in cm^3
p2=15; // pressure of air after compression in bar
V2=V1/8; // volume of air after compression in cm^3
p3=50; // pressure of air after heat addition in bar
Cvo=0.7165; // Specific heat at constant volme in kJ/kg K
R=0.287; // characteristic gas constant of air in kJ/kg K
//   (a).Index of compression process
n=log (p2/p1)/log (V1/V2); // Index of compression process
disp ("which is less than 1.4. The compression process is polytropic.",n,"Index of compression process = ","(a).Index of compression process");
//   (b).Change in entropy of air during each process
m=(p1*10^2*V1*10^-6)/(R*T1); // Mass of air in cylinder
T2=T1*(p2/p1)*(V2/V1); // Temperature after compression
T3=T2*(p3/p2); // Temperature after heat addition
delta_s21=m*(Cvo*log (T2/T1)+R*log (V2/V1)); // change in entropy during compression
delta_s32=m*Cvo*log (T3/T2); //change in entropy during heat addition
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");
//   (c).Heat transfer during polytropic compression process
k=1.4;// Index of isentropic preocess
Q=m*Cvo*((k-n)/(1-n))*(T2-T1); // Heat transfer during polytropic compression process
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

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

Scilab code Exa 6.15 ENTROPY CHANGE OF UNIVERSE

```
clc;
m=1; // Mass of water in kg
T1=300; // Temperature of water in kelvin
```

```
C=4.1868; // Specific heat in kJ/kg K
// (a). Heat Transfer
T2=500; // Temperature of heat reservoir in kelvin
Q=m*C*(T2-T1); // Heat transfer
del_Swater=m*C*log (T2/T1); // Entropy change of water
del_Sreservoir=-Q/T2;  // Entropy change of reservoir
del_Suniverse=del_Swater+del_Sreservoir; // Entropy change of universe
disp ("kJ/K",del_Suniverse,"Entropy change of universe =","(a).Heat Transfer");
//   (b).Heat Transfer in each reservoir
T2=400; // Temperature of intermediate reservoir in kelvin
T3=500; // Temperature of heat reservoir in kelvin
Q=m*C*(T3-T2); // Heat transfer
del_Swater=m*C*(log (T2/T1)+log (T3/T2)); // Entropy change of water
del_SreservoirI=-Q/T2;  // Entropy change of reservoir I
del_SreservoirII=-Q/T3;  // Entropy change of reservoir II
del_Suniverse=del_Swater+del_SreservoirI+del_SreservoirII; // Entropy change of universe
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 DIFFERENCE

```
clc;
m=1; // Mass of saturated steam in kg
T=100; // Teamperature of steam in degree celcius
```

```
T0=303; // temperature of Surroundings in kelvin
hfg=2257; // Latent heat of evaporation in kJ/kg
sfg=6.048; // specific entropy in kJ/kg K
// (a).Entropy change
Q=m*hfg; // Heat transfer
del_Ssystem=-m*sfg; // Change of entropy of system
del_Ssurr=Q/T0; // Change of entropy of surroundings
del_Suniverse=del_Ssystem+del_Ssurr; // Change of
    entropy of universe
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");
// (b).Effect of heat transfer
del_Suniverse=0; // process is reversible
del_Ssurr=del_Suniverse-del_Ssystem; //Change of
    entropy of surroundings
QH=hfg; // Heat transfer from the condensing steam
    to reversible heat engine
QL=T0*del_Ssurr; // Heat receiveded by the
    surroundins reversible heat engine
W=QH-QL; //work output of reversible heat engine
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 receiveded 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

```
clc;
m=1; // Mass of ice in kg
T1=258;// Temperature of ice in kelvin
```

```
Tm=273; // Melting point of ice in kelvin
T2=303; // temperature of Surroundings in kelvin
Cpice=2.095; // Specific heat of ice in kJ/kg K
hsg=333.5; // Latent heat of fusion in kJ/kg
Cpw=4.1868; // Specific heat of water in kJ/kg K
// (a).Change of entropy
Q=m*(Cpice*(Tm-T1)+hsg+Cpw*(T2-Tm));// Heat transfer
del_Ssystem=m*((Cpice*log (Tm/T1))+(hsg/Tm)+(Cpw*log
    (T2/Tm)));// Change of entropy of system
del_Ssurr=-Q/T2; // Change of entropy of
    surroundings
del_Suniverse=del_Ssystem+del_Ssurr; // Change of
    entropy of universe
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");
// (b).The minimum work of restoring water back to
    ice
QL=Q; // Refrigerating effect
W=T2*del_Ssystem-QL; // The minimum work of
    restoring water back to ice
disp ("kJ",W,"(b).The minimum work of restoring
    water back to ice = ");
```

Scilab code Exa 6.18 DIRECTION OF AIR FLOW

```
clc;
TA=323;// Temperature at section A in kelvin
PA=125; // Pressure at section A in kPa
TB=287;// Temperature at section B in kelvin
PB=100; // Pressure at section B in kPa
Cpo=1.0035; // Specific heat at constant pressure in
    kJ/kg K
R=0.287; // characteristic gas constant of air in kJ
```

```
    /kg K
SBA=(Cpo*log (TB/TA))-(R*log (PB/PA)); // Change in
    entropy
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

```
clc;
p1=12.5; // Pressure of steam at inlet in MPa
T1=500; // Temperature of steam at inlet in degree
    celcius
V1=50; // Velocity of steam at inlet in m/s
p2=10; // Pressure of steam at outlet in kPa
V2=100; // Velocity of steam at outlet in m/s
// (a).Actual expansion
x2=0.85; // Quality of steam
// From steam table
h1=3341.8; hf2=191.83; hg2=2584.7;  // specific
    enthalpy in kJ/kg
s1=6.4618; sf2=0.6493; sfg2=7.5009; // specific
    entropy in kJ/kg K
h2a=(1-x2)*hf2+x2*hg2; // specific enthalpy in kJ/kg
wa=(h1-h2a)+((V1^2-V2^2)/2000); // Actual work
    output
disp ("kJ",wa,"(a).Actual work output of turbine = "
    );
// (b).Reversible adiabatic expansion
x2s=(s1-sf2)/sfg2; // Quality of steam after
    reversible adiabatic expansion
h2s=(1-x2s)*hf2+x2s*hg2; // specific enthalpy in kJ/
    kg
ws=(h1-h2s)+((V1^2-V2^2)/2000); // Reversible
    adiabatic work output
L=ws-wa; // Lost of work
```

```
disp ("kJ/kg",L,"Lost of work due to irreversibity
    of expansion process =","kJ/kg",ws,"Reversible
    adiabatic work output = ","(b).Reversible
    adiabatic expansion");
// (c).Entropy Generation
s2a=sf2+x2*sfg2; // actual specific entropy in kJ/kg
     K
Sgen=s2a-s1; // Entropy generation
disp ("kJ/kg K",Sgen,"(c).Entropy Generation =");
```

Scilab code Exa 6.20 COMPARSION OF PUMP WORK AND COMPRESSOR WORK

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

Scilab code Exa 6.21 THROTTLING PROCESS

```
clc;
```

```
// (a).Restoring to initial state by throttling process
T1=303; //Temperature of air at state 1 in kelvin
p1=1;  //Pressure of air at state 1 in bar
p2=5; //Pressure of air at state 2 in bar
p3=1;//Pressure of air at state 3 in bar
T3=303; //Temperature of air at state 3 in kelvin
Cpo=1.0035; // Specific heat at constant pressure in kJ/kg K
R=0.287; // characteristic gas constant of air in kJ/kg K
k=1.4; // Index of reversible adiabatic compression
T2=T1*(p2/p1)^((k-1)/k); // Temperature after reversible adiabatic compression
w12=Cpo*(T2-T1); // Work of reversible adiabatic compression
s21=0; // Entropy change of air
s32=-R*log (p3/p2); // Entropy change
s31=s32; // Net entropy change of air
d_Ssurr=0; // Entropy change of surroundings because There is no heat transfer
d_Suniv=s31+d_Ssurr; // Net Entropy change of universe
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");
// (b).Restoring to initial state by by completing cycle
T0=298; // Temperature of surroundings in kelvin
d_Ssystem=0; // Entropy change of systrem is zero because it is cyclic process
q31=Cpo*(T2-T3); // Heat rejected to the surroundings
d_Ssurr=q31/T0; //  Entropy change of surroundings
d_Suniv=d_Ssystem+d_Ssurr; // Increase in entropy of the universe
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

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

```
u1=2709.9; // specific internal energy at state 1 in kJ/kg
s1=6.9247; // Specific entropy at state 1 in kJ/kg K
uf2=582.95; ug2=2548.9; // specific internal energy at state 2 in kJ/kg
sf2=1.7245; sg2=6.9405; // Specific entropy at state 2 in kJ/kg K
u2=(1-x2)*uf2+x2*ug2; // specific internal energy at state 2
s2=(1-x2)*sf2+x2*sg2; // specific enropy  at state 2
Q=m*(u2-u1); // Heat transferred
S21=m*(s2-s1); // Entropy change
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");
//   (b).Air
Cvo=0.7165; // Specific heat at constant volume in kJ/kg K
R=0.287; // characteristic gas constant of air in kJ/kg K
m=(p1*10^3*V)/(R*(T1+273)); // Mass of air
T2=(p2/p1)*(273+T1); // Final temperature of air
Q=m*Cvo*(T2-(T1+273)); // Heat transferred
S21=m*Cvo*log (T2/(273+T1)); // Change in entropy
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

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

```
    degree celcius
m=0.5; // Mass of the fluid in kg
p2=p1; // Constant pressure process
//   (a).Steam
x1=0.8; // Quality of the steam at state 1
// Following are the values taken from steam table
vf1=0.001127; vfg1=0.1929; // specific volume of the
     steam in m^3/kg
hf1=763.2; hfg1=2015; // specific enthalpy in kJ/kg
sf1=2.1396; sfg1=4.4460; // specific entropy in kJ/
    kg K
v1=vf1+x1*vfg1; // specific volume in m^3/kg
h1=hf1+x1*hfg1; // specific enthalpy in kJ/kg
s1=sf1+x1*sfg1; // specific entropy in kJ/kg K
v2=2*v1; // Final volume of the fluid
t2=410.5; // Final temperature of steam in degree
    celcius (from superheated steam table)
h2=3286.4; // specific enthalpy in kJ/kg
s2=7.525; // specific entropy in kJ/kg K
S21=m*(s2-s1); // Change in entropy
W=m*p1*10^3*(v2-v1); // Work done
Q=m*(h2-h1); // Heat transferred
disp ("kJ",Q,"Heat transferred = ","kJ",W,"Work done
     = ","kJ/K",S21,"Change in entropy = ","K",t2
    +273,"Final Temperature = ","(a).Steam");
// (b).Air
Cpo=1.0035; // Specific heat at constant pressure in
     kJ/kg K
R=0.287; // characteristic gas constant of air in kJ
    /kg K
V1=m*R*(T1+273)/(p1*10^3); // Initil volume
V2=2*V1; // Final volume
T2=(T1+273)*V2/V1; // Final temperature
S21=m*Cpo*log (V2/V1); // Change in entropy
W=p1*10^3*(V2-V1); // Work done
Q=m*Cpo*(T2-(T1+273));// Heat transferred
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

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

```
volume
S21=m*R*log (v2/v1); // Change in entropy
Q=(T1+273)*(S21); // Heat transferred
W=Q; // Work done
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

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

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

Scilab code Exa 7.5 REVERSIBLE AND POLYTROPIC PROCESS

```
clc;
m=1.5; // Mass of the fluid in kg
p1=1.6; // Initial pressure of fluid in MPa
T1=250; // Initial temperture of fluid in degree celcius
p2=150; // Initial pressure of the fluid in kPa
n=1.25; // Index of polytropic process
//    (a).Steam
// Following are the values taken from steam table
// state 1 is superheated
u1=2692.3; // specific internal energy in kJ/kg
s1=6.6732; // specific entropy in kJ/kg K
v1=0.14184; // specific volume of the steam in m^3/kg
v2=v1*(p1/(p2*10^-3))^(1/n); // specific volume of the steam at state 2
// State 2 is wet
T2=111.37; // Final temperature of steam in degree celcius
vf2=0.0010531; vfg2=1.1582; // specific volume of the steam in m^3/kg
x2=(v2-vf2)/vfg2; // Quality of steam at state 2
sf2=1.4336; sfg2=5.7897; // specific entropy in kJ/
```

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

```
clc;
m=1; // Massflow rate of the steam in kg/s
p1=3.5; // Pressure at inlet in MPa
T1=400; // Temperature at inlet in degree celcius
V1=250; // Velocity of stesm at inlet in m/s
p2=50; // Pressure at outlet in kPa
T2=100; // Temperature at outlet in degree celcius
```

```
V2=30; // Velocity of stesm at outlet in m/s
// For actual expansion in the turbine
h1=3222.3; h2=2682.5; // specific enthalpy in kJ/kg at inlet and exit
wa=h1-h2+(V1^2-V2^2)/2000; // Work done
W=m*wa; // Power output
disp ("kW",W,"Power output of the turbine = (Error in textbook)");
// For reversible adiabatic expansion
// Following are the values taken from steam table
s1=6.8405; // specific entropy in kJ/kg K
s2s=s1; // Isentropic expansion
sf2=1.091; sfg2=6.5029; // specific entropy in kJ/kg K
hf2=340.49; hfg2=2305.4; // specific enthalpy in kJ/kg
x2s=(s1-sf2)/sfg2; // Quality of steam at state 2
h2s=hf2+x2s*hfg2; // specific enthalpy in kJ/kg
ws=h1-h2s+(V1^2-V2^2)/2000; // Isentropic Work done
eff_isen=wa/ws; // Isentropic efficiency of the turbine
disp("%",eff_isen*100,"Isentropic efficiency of the turbine = (Error in textbook)")
```

Scilab code Exa 7.7 POWER OF AIRTRBINE

```
clc;
m=1; // Massflow rate of the steam in kg/s
p1=3.5; // Pressure at inlet in bar
T1=160; // Temperature at inlet in degree celcius
p2=1; // Pressure at outlet in bar
Cpo=1.005; // Specific heat at constant pressure in kJ/kg K
eff_isen=0.85; // Isentropic efficiency of the turbine
```

```
k=1.4; // index of isentropic process
T2s=(T1+273)*(p2/p1)^((k-1)/k); // Final temperature
    after isentropic expansion
Ws=m*Cpo*((T1+273)-T2s); // Isentropic power
   developed
Wa=eff_isen*Ws; // Actual power developed
T2=(T1+273)-(Wa/(m*Cpo)); // Final temperature after
    expansion
disp ("K",T2,"Final temperature after expansion = ",
   "kW",Wa,"Actual power developed (Error in
   textbook)=");
```

Scilab code Exa 7.8 ADIABATIC EFFICIENCY OF COMPRESSOR

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

```
h2s=216.14; // specific enthalpy in kJ/kg
ws=(h2s-h1); // Reversible adiabatic work
wa=W/m; // Actual work
eff_com=abs (ws/wa); // Adiabatic efficiency
disp ("%",eff_com*100,"(b).Adiabatic efficiency of the compressor = ");
```

Scilab code Exa 7.9 COMPRESSOR OF GAS TURBINE

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

Scilab code Exa 7.10 NOZZLE VELOCITY

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

```
.Air");
```

Scilab code Exa 7.11 DIFFUSION PROCESS

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

Scilab code Exa 7.12 REVERSIBLE ADIABATIC EFFICIENCY OF DIFFUSER

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

```
clc;
```

```
m=18; // mass flow rate of air in kg/s
p1=3.6; // Pressure of fluid at inlet of turbine in MPa
T1=800; // Temperature of fluid at inlet of turbine in Kelvin
V1=100; // Velocity of fluid at inlet of turbine in m/s
V2=150; // Velocity of fluid at outlet of turbine in m/s
W=3.6; // Power output of turbine in MW
p3=1.01; // pressure at diffuser outlet in bar
k=1.4; // Index of reversible adiabatic process
Cpo=1.0035; // Specific heat at constant pressure in kJ/kg K
// (a)   Pressure at diffuser inlet
T2=((Cpo*T1)-((W*10^3)/m+(V2^2-V1^2)/2000))/Cpo; // Temperature at outlet of turbine
T3=(T2+273)+((V2^2)/(2*Cpo*10^3)); // Temperature of fluid at diffuser inlet
p2=p3*((T2+273)/T3)^(k/(k-1)); //pressure at diffuser inlet
disp ("bar",p2,"(a).pressure at diffuser inlet =");
```

Scilab code Exa 7.14 FLASHING DURING THROTTLING

```
clc;
T1=35; // Temperature of freon 12 before throttling in degree celcius
T2=5; // Temperature of freon 12 after throttling in degree celcius
// from property table of freon 12
h1=69.49;// specific enthalpy in kJ/kg
hf2=40.66; hfg2=148.86; // specific enthalpy in kJ/kg
h2=h1; // throttling process
```

```
x2=(h2-hf2)/hfg2; // Quality of Freon 12 vapour
disp (x2,"Quality of Freon 12 vapour = ");
```

Scilab code Exa 7.15 SEPARATING AND THROTTLING CALORIMETER

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

Chapter 8

VAPOUR CYCLES

Scilab code Exa 8.1 A CARNOT STEAM CYCLE

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

```
qH=h3-h2; // Heat added
rw=wnet/wT; // Ratio of net work to trbine work
eff_th=wnet/qH; // Thermal efficiency
SSC=3600/wnet; // specific steam consumption
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

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

```
SSC=3600/wnet; // specific steam consumption
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

```
clc;
TH=311.06; // Source temperature in degree celcius
p2=10; // Boiler pressure in MPa
TL=32.88; // Sink temperature in degree celcius
p1=5; // Condenser pressure in kPa
// (a).Actual carnot cycle
eff_Tur=0.8; // Efficiency of turbine
eff_com=0.6; // Efficiency of compressure
// From steam tables at p2
h3=2724.7; // specific enthalpy in kJ/kg
s3=5.6141; // specific entropy in kJ/kg K
s2=3.3596; // specific entropy in kJ/kg K
h2=1407.56; // specific enthalpy in kJ/kg
// From steam tables at p1
hf=137.82; hfg=2423.7; // specific enthalpy in kJ/kg
sf=0.4764; sfg=7.9187; // specific entropy in kJ/kg
   K
x1=(s2-sf)/sfg; // quality of steam at state 1
x4=(s3-sf)/sfg; // quality of steam at state 4
h1=hf+x1*hfg; // specific enthalpy at state 1
h4=hf+x4*hfg; // specific enthalpy at state 4
wTs=h3-h4; // Turbine work
wT=eff_Tur*wTs; // Actual turbine work
wCs=h2-h1; // Compressor work
wC=wCs/eff_com; // Actual compressor work
wnet=wT-wC; // Net work output
h2a=h1+wC; // specific enthalpy
```

```
qH=h3-h2a; // Heat added
rw=wnet/wT; // Ratio of net work to trbine work
eff_th=wnet/qH; // Thermal efficiency
SSC=3600/wnet; // specific steam consumption
disp ("kg/kWh",SSC,"specific steam consumption =","%
   ",eff_th*100,"Thermal efficiency =",rw,"Ratio of
   net work to trbine work =","(a).Actual carnot
   cycle");
//   (b).Actual Rankine cycle
eff_Tur=0.8; // Efficiency of turbine
eff_pump=0.9; // Efficiency of Pump
// From steam tables at p1
h1=137.82; // specific enthalpy at state 1 in kJ/kg
s1=0.4764; // specific entropy at state in kJ/kgK
v1=0.001005; // specific volume in m^3/kg
wps=abs (v1*(p2*10^3-p1)); // Pump work (absolute
   value)
wp=wps/eff_pump; // Actual pmp work
h2a=h1+wp; // // specific enthalpy at state 2
wnet=wT-wp; // Net work output
qH=h3-h2a; // Heat added
rw=wnet/wT; // Ratio of net work to trbine work
eff_th=wnet/qH; // Thermal efficiency
SSC=3600/wnet; // specific steam consumption
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 EXHAST STEAM AND SSC

```
clc;
T3=450; // temperature of steam at state 3 in degree
    celcius
```

```
p3=10; // Boiler pressure in MPa
p6=5; // Condenser pressure in kPa
// From steam tables at state 1
hf=137.82; hfg=2423.7; // specific enthalpy in kJ/kg
sf=0.4764; sfg=7.9187; // specific entropy in kJ/kg K
h1=137.82; // specific enthalpy at state 1 in kJ/kg
s1=0.4764; // specific entropy at state in kJ/kgK
v1=0.001005; // specific volume in m^3/kg
wp=abs (v1*(p3*10^3-p6)); // Pump work (absolute value)
h2=h1+wp; // specific enthalpy at state 2
//   (a).Rankine cycle with superheat
// From steam tables at state 3
h3=3240.9;// specific enthalpy in kJ/kg
s3=6.419; // specific entropy in kJ/kg K
// State 4_1
x4_1=(s3-sf)/sfg; // Quality of steam at state 4_1
h4_1=hf+x4_1*hfg; // specific enthalpy at state 4_1
wT=h3-h4_1; // Turbine work
wnet=wT-wp; // Net work output
qH=h3-h2; // Heat added
eff_th=wnet/qH; // Thermal efficiency
SSC=3600/wnet; // specific steam consumption
disp ("kg/kWh",SSC,"specific steam consumption =","%",eff_th*100,"Thermal efficiency =",x4_1,"Quality of steam at exhaust = ","(a).Rankine cycle with superheat");
//   (b).Reheat cycle
s4=s3; // isentropic expansion
x4=0.975; // Quality of steam at state 4
// from steam table intermediate pressure is selected for s4 & x4 by interpolation and assumed by round value
p4=1.2; // Intermediate pressure in MPa
// From steam tables at state 4
hf4=798.6; hfg4=1986.2; // specific enthalpy in kJ/kg
```

```
h4=hf4+x4*hfg4; // specific enthalpy in kJ/kg
// From steam tables at state 5
h5=3368.5;// specific enthalpy in kJ/kg
s5=7.5266; // specific entropy in kJ/kg K
x6=(s5-sf)/sfg; // Quality of steam at state 6
h6=hf+x6*hfg; // specific enthalpy in kJ/kg
wT=(h3-h4)+(h5-h6); // Turbine work
wnet=wT-wp; // Net work output
qH=(h3-h2)+(h5-h4); // Heat added
eff_th=wnet/qH; // Thermal efficiency
SSC=3600/wnet; // specific steam consumption
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

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

```
s5=5.6141; // specific entropy at state 5 in kJ/kgK
// From steam tables at state 6
p6=791.5; // bleed steam pressure in kPa
p2=p6; p3=p6;
vf6=0.00114; // specific volume in m^3/kg
v3=vf6;
hf6=719.21; hfg6=2049.5; // specific enthalpy in kJ/kg
sf6=2.0419; sfg6=4.6244; // specific entropy in kJ/kg K
x6=(s5-sf6)/sfg6; // quality of steam at state 6
h6=hf6+x6*hfg6; // specific enthalpy at state 6
h3=hf6; // specific enthalpy at state 3
m1=(h3-h2)/(h6-h2); // Fraction of bleed steam
wLP=abs (v1*(p2-p1)); // LP work
wHP=abs (v3*(p4*10^3-p3)); // HP work
wp=(1-m1)*wLP+wHP; // Total pump work
h2=h1+wp; h4=h3+wp; // Specific Enthalpies of water
// From steam tables at pc
hf7=137.82; hfg7=2423.7; // specific enthalpy in kJ/kg
sf7=0.4764; sfg7=7.9187; // specific entropy in kJ/kg K
x7=(s5-sf7)/sfg7; // quality of steam at state 7
h7=hf7+x7*hfg7; // specific enthalpy at state 4
wT=(h5-h6)+(1-m1)*(h6-h7); // Turbine work
wnet=wT-wp; // Net work output
qH=h5-h4; // Heat added
eff_th=wnet/qH; // Thermal efficiency
SSC=3600/wnet; // specific steam consumption
disp ("kg/kWh",SSC,"specific steam consumption =","%",eff_th*100,"Thermal efficiency =");
```

Scilab code Exa 8.6 BOILER EFFICIENCY

```
clc;
ps=6.89+1; // Pressure of steam produced in bar (
    Absolute)
x=0.96; // Quality of steam produced
f=75; // Steady flow of water in litres
t=9.5; // Time consumption of water in minutes
tf=685; //Time consumption of 10 litre fuel in
    seconds
Vf=10; // consumption of fuel in litres
Sf=0.85; // specific gravity of water
CV=43125; // Calorific value of fuel in kJ/kg
ms=f/(t*60);// Steam generation
mf=Vf*Sf/tf; // consumption of fuel
// From steam tables at ps
hf=718.5; hfg=2050; // specific enthalpy in kJ/kg
hs=hf+x*hfg; // specific enthalpy of steam produced
hFW=146.7; // Enthalpy of feed water at 35 degree
    celcius
eff_boiler=(ms*(hs-hFW))/(mf*CV); // Boiler
    Efficiency
disp ("%",eff_boiler*100,"Boiler Efficiency = ");
```

Scilab code Exa 8.7 A CARNOT REFRIGERATOR

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

```
x4=(s4-sf4)/sfg4; // dryness fraction at state 4
h1=hf1+x1*hfg1; h4=hf4+x4*hfg4; // specific enthalpy
    in kJ/kg
wc=h2-h1; // work of compression
wE=h3-h4; // Work of expansion
qL=h1-h4; // Refrigerating effect
qH=h2-h3; // Heat rejected
wnet=wc-wE; // Net work
COPc=qL/wnet; // COP of the cycle
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

```
clc;
TL=-15; // Source temperature in degree celcius
TH=40; // Sink temperature in degree celcius
// From the table of properties of Freon - 12
h3=74.53; h1=180.85; h4=h3; // specific enthalpy in
   kJ/kg
s1=0.7046; s2=0.682; // specific entropy in kJ/kg K
// (a)
// (i).Condensor and Evaporator pressure
pc=0.9607; // Saturation pressure at TH in MPa
pE=0.1826; // Saturation pressure at TL in MPa
disp ("MPa",pE,"Evaporator pressure = ","MPa",pc,"
   Condensor pressure = ","(i).Condensor and
   Evaporator pressure","(a)");
// (ii).Compressor discharge temperature & Enthalpy
p2=pc; // Condensor pressure
s2=s1; // refer figure 8.25
// From the table of properties of Freon - 12 at pc
t2=46.8; // Compressor discharge temperature in
```

```
degree celcius
h2=208.3; // specific enthalpy in kJ/kg
disp ("kJ/kg",h2,"Enthalpy = ","oC",t2,"Compressor discharge temperature = ","(ii).Compressor discharge temperature & Enthalpy");
// (iii).Ratio of COP of the cycle to Carnot COP
w=h2-h1; // Compressor work
qL=h1-h4; // Refrigeration effect
COP=qL/w; // COP of the cycle
COPc=4.68; // COP of carnot cycle from example 8.7
r=COP/COPc; // Ratio of COP of the cycle to Carnot COP
disp (r,"(iii).Ratio of COP of the cycle to Carnot COP = ");
// (b)
QL=0.440; // Capacity of refrigerator in kW (1/8 ton of refrigeration)
m=QL/qL; // Mass flow rate of refrigerant
W=m*w; // Power consumption of compressor
QH=QL+W; // Heat rejected
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

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

```
disp ("K",T2,"Temperature at the end of compression =","kPa",p2,"Pressure of air at the end of compression = ","state 2");
// state 3
T3=(qH/Cvo)+T2; // Temperatue after heat addition
p3=p2*(T3/T2); // Pressure after heat addition
disp ("K  (round off error)",T3,"Temperature after heat addition =","kPa  (round off error)",p3,"Pressure after heat addition = ","state 3");
// state 4
p4=p3*(1/r)^k; // Pressure after expansion
T4=T3*(p4/p3)^((k-1)/k);// Temperature after expansion
disp ("K  (round off error)",T4,"Temperature after expansion =","kPa  (round off error)",p4,"Pressure after expansion = ","state 4");
//  (2).Thermal efficiency
qL=Cvo*(T4-T1); // Heat rejected
eff_th=1-qL/qH; // thermal efficiency
//   (3). Mean effective pressure
wnet=qH-qL; // net work
v1=R*T1/p1; // Specific volume at state 1
v2=v1/r; // Specific volume at state 2
pm=wnet/(v1-v2); // Mean effective pressure
disp ("kPa",pm,"(3).Mean effective pressure = ","% (round off error)",eff_th*100,"(2).Thermal efficienvy = ");
```

Scilab code Exa 9.2 DIESEL CYCLE

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

```
qH=1800; // Heat added to the air in kJ/kg
k=1.4; // Index of reversible adiabatic process
Cvo=0.7165; // Specific heat at constant volume in kJ/kg K
Cpo=1.0035; // Specific heat at constant pressure in kJ/kg K
R=0.287; // characteristic gas constant of air in kJ/kg K
//   Diesel cycle
// state 2
T2=T1*(r)^(k-1); // Temperature at the end of compression
p2=p1*(r)^k; // Pressure at the end of compression
// state 3
T3=(qH/Cpo)+T2; // Temperatue after heat addition
p3=p2; //constant pressure
Tmax=T3; // maximum temperature
Pmax=p3; // Maximum pressure
// state 4
v3=R*T3/p3; // Specific volume at state 3
v4=R*T1/p1; // Specific volume at state 4
T4=T3*(v3/v4)^(k-1); // Temperature after expansion
p4=p3*(v3/v4)^k; // Pressure after expansion
qL=Cvo*(T4-T1); // Heat rejected
wnet=qH-qL; // net work
eff_th=wnet/qH; // thermal efficiency
v1=R*T1/p1; // Specific volume at state 1
v2=v1/r; // Specific volume at state 2
pm=wnet/(v1-v2); // Mean effective pressure
disp ("kPa",pm,"Mean effective pressure = (Error in textbook) ","%",eff_th*100,"Thermal efficienvy = ","K",Tmax,"Maximum Temperature = ","kPa",Pmax," Maximum pressure = ");
```

Scilab code Exa 9.3 STANDARD BRAYTON CYCLE

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

Scilab code Exa 9.4 ACTUAL GAS TURBINE CYCLE

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

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

Scilab code Exa 9.5 AN IDEAL REGENERATOR

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

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

Scilab code Exa 9.6 AIR STANDARD CYCLE FOR JET PROPULSION

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

```
kJ/kg K
R=0.287; // characteristic gas constant of air in kJ/kg K
// (a).The pressure and temperature at each point of the cycle
// process 1-2 isentropic diffusion
T2=T1+(V1^2)/(2*Cpo*10^3); // Temperature at state 2
p2=p1*(T2/T1)^(k/(k-1)); // Pressure at state 2
// process 2-3 isentropic compression
p3=rp*p2; // perssure at state 3
T3=T2*(p3/p2)^((k-1)/k); // Temperature at state 3
wc=Cpo*(T3-T2); // compressor work
// process 3-4 Constant pressur heat addition
qH=Cpo*(T4-T3); // heat addition
p4=p3; // constant pressure
// process 4-5 isentropic expansion in turbine
wT=wc;
T5=T4-(wT/Cpo); // Temperature at state 5
p5=p4*(T5/T4)^(k/(k-1)); // Pressure at state 5
// process 5-6 Isentropic expansion in nozzle
p6=p1;
T6=T5*(p6/p5)^((k-1)/k); // Temperature at state 6
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");
// (b).Exit velocity of jet
V6=sqrt (2*Cpo*10^3*(T5-T6)); // Exit velocity of jet
disp ("m/s",V6,"(b).Exit velocity of jet =");
//   (c).Specific thrust and work output
F_mair=(V6-V1); // Specific thrust
w=F_mair*V1/1000; // Work output
disp ("kJ/kg",w,"Work output = ","N",F_mair,"Specific thrust =","(c).Specific thrust and work
```

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

Scilab code Exa 9.7 REVERSED BRAYTON CYCLE

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

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

Scilab code Exa 9.8 A REGENERATIVE HEAT EXCHANGER

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

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

Chapter 10

AVAILABILITY AND IRREVERSIBILITY

Scilab code Exa 10.1 AVAILABLE ENERGY

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

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

```
clc;
T=250; // Evaporation teemperature of water in degree celcius
Ta=1250; // Initial temperature of combustion gas in degree celcius
Tb=350; // Final temperature of combustion gas in degree celcius
C=1.08; // Specific heat of gas in kJ/kg K
T0=30; // temperature of Surroundings in degree celcius
hfg=1716.2; // Enthalpy of evaporation at T temperature
del_SH2O=hfg/(T+273); // Entropy change of water
mgas=hfg/(C*(Ta-Tb)); // Mass of gas
del_Sgas=mgas*C*log ((Tb+273)/(Ta+273)); // Enthalpy change of gas
del_Stotal=del_SH2O+del_Sgas; // Total entropy change
l_AE=(T0+273)*del_Stotal; // Loss of available energy
disp ("kJ",l_AE,"Loss of available energy = ");
```

Scilab code Exa 10.3 STEAM POWER PLANT

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

```
m=1; // Mass of water in kg
T0=298; // temperature of Surroundings in kelvin
// (b).mass flow rate of gases per kg of water
// From steam table
h1=2758; h2=3642;// specific enthalpy in kJ/kg
s1=5.7432; s2=7.0206; // specific entropy in kJ/kg K
mgas=(h2-h1)/(Cp*(T3-T4)); //mass flow rate of gases per kg of water
disp ("kg gas / kg water",mgas,"(b).mass flow rate of gases per kg of water =");
// (c). Degrease in Available energy
S21=s2-s1; // Change in entropy of water
S34=mgas*Cp*log (T3/T4); // Change in entropy of gases
UEgases=T0*S34; // UnAvailable energy of gas
UEsteam=T0*S21; // UnAvailable energy of steam
d_AE=UEsteam-UEgases; // Degrease in Available energy
disp ("kJ/K",-S34,"Change in entropy of gas = ","kJ/K",S21,"Change in entropy of water = ","(c).");
disp ("kJ",UEsteam,"Unavailable energy of steam =","kJ",UEgases,"Unavailable energy of gas = ");
disp ("kJ",d_AE," Degrease in Available energy = ");
```

Scilab code Exa 10.5 AVAILABLE ENERGY IN EXHAUST GAS

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

```
Cvo=Cpo-R;  // Specific heat at constant volume
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
disp ("kJ",AE,"Available energy in Exhaust gas =");
```

Scilab code Exa 10.6 IRREVERSIBILITY OF THE PROCESS

```
clc;
p1=450; // Initial pressure in kPa
T=600; // Initial temperature in kelvin
V1=0.01; // Initial volume in m^3
TR=1200; // Temperature of heat source in Kelvin
V2=0.02; // Final volume in m^3
p0=100; // Pressure of Surroundings in kPa
T0=300; // temperature of Surroundings in kelvin
// Useful Work
W=p1*V1*log (V2/V1); // Actual work
Wsurr=p0*(V2-V1); // Surrounding work
Wu=W-Wsurr; // Useful work
disp ("kJ",Wu,"Useful Work for the process =");
// Reversible work
Q=W; // For isothermal process
S21=Q/T; // Entropy change of system
Wrev=T0*S21-Wsurr+Q*(1-T0/TR); // reversible work
disp ("kJ",Wrev,"Reversible work for the provess =")
   ;
// Irreversibility of the process
I=Wrev-Wu; // Irreversibility
disp ("kJ",I,"Irreversibility of the process = ");
// Entropy generation
del_Sgen=S21-Q/TR;//Entropy generation
disp ("kJ/kg",del_Sgen,"Entropy generation of the
   process = ");
```

Scilab code Exa 10.7 IRREVERSIBILITY IN TURBINE AND COMPRESSOR

```
clc;
// (i).Irreversibility in Turbine
p1=9; // Steam pressure at turbine inlet in MPa
T1=450; // Steam temperature at turbine inlet in
    degree celcius
p2=50; // Steam pressure at turbine outlet in MPa
x2=0.95; // Quality of steam
p0=100; // Pressure of Surroundings in kPa
T0=300; // temperature of Surroundings in kelvin
q=-10; // Heat loss in kJ/kg
// (a).Decrease in availability
// from steam table
h1=3256.6; h2=2415.4;// specific enthalpy in kJ/kg
s1=6.4844; s2=6.944; // specific entropy in kJ/kg K
d_AE=(h1-h2)-(T0*(s1-s2)); // Decrease in
    availability
disp ("kJ/kg",d_AE,"(a).Decrease in availability =",
    "(i).Irreversibility in turbine");
// (b).Maxximum work output
wrev=d_AE; //Maxximum work output
disp ("kJ/kg",wrev,"(b).Maxximum work output =");
// (c).Actual work output
w=(h1-h2)+q; // From SSSF energy equation
disp ("kJ/kg",w,"(c).Actual work output  = ");
// (d).Irreversibility
I=wrev-w; //Irreversibility
disp ("kJ/kg",I,"(d).Irreversibility = ");
// (ii).Ammonia compressor
T1=-10; // Temperature at inlet in degree celcius
p2=1.554; // Pressure at outlet in MPa
T2=140; // Temperature at outlet in degree celcius
```

```
T0=298; // temperature of Surroundings in kelvin
//from ammonia tables
h1=1433; h2=1752;// specific enthalpy in kJ/kg
s1=5.477; s2=5.655; // specific entropy in kJ/kg K
wactual=-(h2-h1); // Actual work
wmin=-((h2-h1)-(T0*(s2-s1)));// mimimum work
I=wmin-wactual;// Irreversibility
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

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

```
d_AEgas=mgas*Cp*(T3-T4)-T0*S34//Decrease in
    availability of gases
disp ("kJ",d_AEgas,"(a).Decrease in availability of
    gases = ");
// (b).Decrease in availability of water
d_AEwater=(h1-h2)-T0*(s1-s2);// Decrease in
    availability of water
disp ("kJ",d_AEwater,"(b).Decrease in availability
    of water =");
// (c).Reversible work for the process
Wrev=d_AEgas+d_AEwater; //Reversible work for the
    process
disp ("kJ",Wrev,"(c).Reversible work for the process
    =");
// (d).Actual work for the process
W=0; // Actual work
disp ("kJ",W,"(d).Actual work for the process =");
// (e).Irreversibility
I=Wrev-W; //Irreversibility
disp ("kJ",I,"(e).Irreversibility = ");
```

Scilab code Exa 10.9 LOST WORK IN RANKINE CYCLE

```
clc;
TH=600; // Temperature of heat sorce in degree
    celcius
T3=311.06; // Boiler temperature in degree celcius
p3=10; // Boiler pressure in MPa
T4=32.88; // Condensor temperature in degree celcius
p4=5; // Condensor pressure in kPa
T0=288;// Temperature of surroundings in kelvin
// From steam table and refer figure 10.10 for
    states
h1=137.82; h2=147.82; h3=2724.7; hf4=197.82; hfg4
    =2423.7; h4=1913.6; // specific enthalpy in kJ/kg
```

```
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
wT=h3-h4; // Turbine work
wp=h2-h1; // Pump work
wnet=wT-wp; // Net work
qH=h3-h2; // Heat supplied in boiler
qL=h4-h1; // Heat rejected in condensor
Wrev_Wpump=T0*(s2-s1);
Wrev_Wboiler=T0*(s3-s2)-T0*qH/(TH+273);
Wrev_Wturbine=T0*(s4-s3);
Wrev_Wcondenser=T0*(s1-s4)+qL;
Wrev_Wcycle=Wrev_Wpump+Wrev_Wboiler+Wrev_Wturbine+Wrev_Wcondenser;
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

```
clc;
// State after reversible adiabatic expansion
p2=50; // pressure in kPa
s2s=6.4844; s1=6.4844; s2=6.944; // specific entropy in kJ/kg K
x2s=0.829; // Quality of steam
h2s=2252.6; h1=3256.6; // specific enthalpy in kJ/kg
T2=81.33; T0=27; // Temperature in degree celcius
ws=h1-h2s; // Reversible adiabatic work
wa=831.2; // Actual work output in kJ/kg
d_AE=979.1; // Decrease in availability in kJ/LG
```

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

Scilab code Exa 10.11 AIR COMPRESSOR

```
clc;
p1=100; // Pressure at inlet in kPa
T1=30; // Temperature at inlet in degree celcius
V1=0; // Velocity at inlet in m/s
p2=350; // Pressure at outlet in kPa
T2=141; // Temperature at exit in degree celcius
V2=90; // Velocity at exit in m/s
p0=100; // Pressure of Surroundings in kPa
T0=30; // temperature of Surroundings in degree celcius
k=1.4; // Index of the Isentropic compression process
Cpo=1.0035; // Specific heat at constant pressure in kJ/kg K
R=0.287; // characteristic gas constant of air in kJ/kg K
// (a).Adiabatic or polytropic compression
T2s=(T1+273)*(p2/p1)^((k-1)/k); // Temperature after isentropic compression
disp ("T2s>T2. Hence there is cooling . Compression is polytropic.","K",T2s,"Temperature after isentropic compression =", "(a).Adiabatic or polytropic compression");
```

```
// (b).The first law efficiency of the compressor
wa=Cpo*(T1-T2)-V2^2/2000; //Actual work of compression
wT=(-R*(T1+273)*log (p2/p1))-(V2^2/2000); //Isothermal work
eff_Ilaw=wT/wa; // The first law efficiency of the compressor
disp ("%",eff_Ilaw,"(b).The first law efficiency of the compressor = ");
// (c).Minimum work input & Irreversibility
d_AE=(Cpo*(T1-T2))+((T0+273)*((R*log (p2/p1))-(Cpo*log ((T2+273)/(T1+273)))))-V2^2/2000; // decrease in availability
wmin=d_AE; // Minimum work input
wrev=wmin;
I=wrev-wa; // Irreversibility
disp ("kJ/kg",I,"Irreversibility =","kJ/kg",wmin,"Minimum work input =","(c).Minimum work input & Irreversibility");
// (d).Second law efficiency of the compressor
eff_IIlaw=wmin/wa; // Second law efficiency of the compressor
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 CYCLE

```
clc;
T0=313; // Surroundings temperature in kelvin
TL=233; // Refrigerated space temperature in kelvin
QL=3.5167; // Refrigeration load in kW
// (a).Carnot cycle
COPcarnot=TL/(T0-TL); // COP of carnot cycle
Wcarnot=QL/COPcarnot; // Work done
```

```
Q0=QL+Wcarnot; // Heat rejected
d_SL=-QL/TL;//  Entropy change of refrigerated space
d_S0=Q0/T0; //Entropy change of surroundings
d_Sgen= d_SL+ d_S0; // Entropy generation
disp (COPcarnot,"COP of carnot cycle = ","kW",
    Wcarnot,"Work done = ","(a).Carnot cycle");
printf (" \n Entropy generation = %d  \n \n kJ/K s \
    n",d_Sgen);
// (b).Vapour compression cycle
// From Freon-12 property table & figure 10.17
p1=0.0642; p2=0.9607; // Pressure in MPa
h1=169.5; h3=74.5; // specific enthalpy in kJ/kg
s1=0.7269; s3=0.2716;// specific entropy in kJ/kg K
// By calculations s2=s1 gives the following from
    property table
t2=58.9; // Temperature in degree celcius
h2=217.6; // specific enthalpy in kJ/kg
// From h4=h3 gives the following from chart
h4=h3;
x4=0.44; // Quality of vapour
s4=0.3195;// specific entropy in kJ/kg K
m=QL/(h1-h4); // Mass flow rate of refrigerant
W=m*(h2-h1); // Work done of vapour compression
    cycle
COP=QL/W; // COP of vapour compression cycle
QH=QL+W; // Heat rejected to surroundings
d_SL=-QL/TL;//  Entropy change of refrigerated space
d_S0=QH/T0; //Entropy change of surroundings
d_Sgen= d_SL+ d_S0; // Entropy generation
disp (COP,"COP of vapour compression cycle = ","kW",
    W,"Work done = ","(b).Vapour compression cycle");
printf (" \n Entropy generation = %f \n \n kJ/K s \n
    ",d_Sgen);
// (c).Difference in work = Lost work of the cycle
d_work=W-Wcarnot; // Difference in work
LWcycle=QH-T0*QL/TL; // Lost work of the cycle
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");
// (d).Second Law efficiency of the vapour
   compression cycle
eff_II=COP/COPcarnot; //Second Law efficiency
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

```
clc;
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
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
n=16; // Total number of readings taken
// Values of constant A & B
s_y= log10 (p1*p2*p3*p4*p5*p6*p7*p8*p9*p10*p11*p12*p13*p14*p15*p16);
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);
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));
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;
B= ((n*s_xy)-(s_x*s_y))/((n*s_x2)-((s_x)^2)); //
Constant B
A=((s_y)-(B*s_x))/n; // Constant A
disp (B,"B =",A,"A =","Values of constant A & B");
// The latent heat of vapourization
T=150; // The latent heat of vapourization at this
temperature in degree celcius
d_T=20; d_p=258.7;// Temperature and pressure
difference
vg=0.3928; vf=0.0011; // specific volume in m^3/kg
hfg=(T+273)*(vg-vf)*d_p/d_T; // Clapeyron equztion
disp ("kJ/kg",hfg,"The latent heat of vapourization
at 150 oC =");
```

Scilab code Exa 11.3 ENTHALPY CALCULATION USING R K EQUATION

```
clc;
p5=6000; // Pressure of superheated steam in kPa
T5=723.15; // Temperature of superheated steam in
```

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

Scilab code Exa 11.4 ENTHALPY CALCULATION FROM GENERALIZED CHARTS

```
clc;
T2=373; // Temperature of CO2 gas in kelvin
p2=100; // Pressure of CO2 gas in atm
T1=0; // Reference state temperature in kelvin
// The crictical constants for CO2 are
Tc=304.2; // Temperature in kelvin
Pc=72.9; // Pressure in atm
zc=0.275;
// Refer figure 11.7 for state definition
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)));
Tr=T2/Tc; Pr=p2/Pc; // Reduced properties
// From generalized chart figure 11.6
hR_Tc=10.09;
h1_2=hR_Tc*Tc;
M=44; // Molecular weight
h10=h1_0/M; h12=h1_2/M;
h373=h10-h12; // The required enthalpy of CO2 gas at 373 K and 100 atm
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 GENERALIZED CAHRTS

```
clc;
p1=11; // Initial pressure in bar
T1=40; // Initial temperature in degree celcius
p2=60; //  Final pressure in bar
R_1=8.3143; // Universal gas constant  in kJ/kmol K
// The crictical properties for natural gas
```

```
Tc=161; // Temperature in kelvin
Pc=46.4; // Pressure in bar
// Reduced properties are
Pr1=p1/Pc; Pr2=p2/Pc;
Tr1=(T1+273)/Tc;
// T2=T1, The ideal gas enthalpy h2*=h1*=h1
h21=-47.5; // From generalized enthalpy departure
   chart
M=16; // Molecular weight
Sp2_1=(R_1/M)*log (p2/p1)// for the difference in
   ideal gas entropies
Sp2_Sp_2=-0.1125; Sp_2_Sp_1=-2.1276; // Entropies in
    kJ/kg K
s2_s1=(Sp2_Sp_2)+(Sp_2_Sp_1);
q=(T1+273)*s2_s1; // Heat transfer
w=q-h21; // Work of compression
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

```
clc;
p1=10; // Initial pressure in MPa
T1=263; // Initial temperature in Kelvin
p2=1.5; // Final pressure in MPa
R_1=8.3143; // Universal gas constant in kJ/kmol K
M=28; // Molecular mass
// The crictical properties for nitrogen gas
Tc=126.2; // Temperature in kelvin
Pc=3.39; // Pressure in MPa
// Reduced properties are
Pr1=p1/Pc; Pr2=p2/Pc;
Tr1=T1/Tc;
// From the generalized chart for enthalpy departure
```

```
at Pr1 & Tr1
h_11=8.7*Tc/M;
// The solution involves iteration procedure. Assume T2 and check if h2_h1=0
// First approximation T2=200 K
T2=200; // In K
Tr2=T2/Tc;
Cpr=1.046;
h_21=Cpr*(T2-T1);
// From the generalized chart for enthalpy departure at Pr1 & Tr1
h_22=1*Tc/M;
h2_h1=h_11-T2+T1-h_22;
// Second approximation
T2=190; // In K
Tr2=T2/Tc;
Cpr=1.046;
h_21=Cpr*(T2-T1);
// From the generalized chart for enthalpy departure at Pr1 & Tr1
h_22=1.5*Tc/M;
h2_h1=h_11-T2+T1-h_22;
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

```
clc;
Tcammonia=405.9;
Tcwater=647.3;
Tr=0.576; // Condition of similarity
Twater=Tcwater*Tr; // At reduced temperature
```

```
   Temperature of water
Tammonia=Tcammonia*Tr;//At reduced temperature
   Temperature of  ammonia
// From steam table at Twater
hfgwater=2257;// specific enthalpy in kJ/kg
hfgammonia=Tcammonia/Tcwater *hfgwater; // Latent
   heat of vaporization of ammonia
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

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

```
constant of dry atmospheric air
M=(y1*M1)+(y2*M2)+(y3*M3)+(y4*M4)+(y5*M5); // Average molecular mass
R=R_1/M; //Apperent gas constant of dry atmospheric air
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");
// (b).The fraction of each component
m1=(M1*y1)/M;//The fraction of N2 component
m2=(M2*y2)/M;//The fraction of O2 component
m3=(M3*y3)/M;//The fraction of Ar component
m4=(M4*y4)/M;//The fraction of CO2 component
m5=(M5*y5)/M;//The fraction of H2 component
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

```
clc;
M1=44; // Molecular mass of CO2
M2=32; // Molecular mass of O2
M3=28; // Molecular mass of CO
M4=28; // Molecular mass of N2
y1=0.1; // Part by volume of CO2 in exhaust gas
y2=0.06; // Part by volume of O2 in exhaust gas
y3=0.03; // Part by volume of CO in exhaust gas
y4=0.81; // Part by volume of N2 in exhaust gas
R_1=8.3143; // Universal gas constant in kJ/kmol K
// (a).Average molecular mass and apperent gas constant of exhaust gas
M=(y1*M1)+(y2*M2)+(y3*M3)+(y4*M4); // Average molecular mass
```

```
R=R_1/M; //Apperent gas constant of dry atmospheric
    air
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");
// (b).The fraction of each component
m1=(M1*y1)/M;//The fraction of CO2 component
m2=(M2*y2)/M;//The fraction of O2 component
m3=(M3*y3)/M;//The fraction of CO component
m4=(M4*y4)/M;//The fraction of N2 component
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

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

Scilab code Exa 12.4 MEASUREMENT OF HUMIDITY

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

```
T=25; // Temperature of air in degree celcius
// (a).partial pressure of water vapour in air
pv=1.0584; // Saturation pressure of water at DBT in kPa
disp ("kPa",pv,"(a).partial pressure of water vapour in air = ");
// (b).Specific humidity
sh=0.622*pv/(p-pv);//Specific humidity
disp ("kg of water vapour /kg of dry air",sh,"(b).Specific humidity =");
// (c).Relative humidity
pg=3.169; // Saturation pressure of water at T in kPa
RH=pv/pg; //Relative humidity
disp ("%",RH*100,"(c).Relative humidity =");
```

Scilab code Exa 12.5 CALCLATIONS OF PROPERTIES FOR THE AIR

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

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

Scilab code Exa 12.6 COOLING AND DEHUMIDIFICATION OF MOIST AIR

```
clc;
DPT1=30; // Dew point temperature at inlet in degree celcius
DPT2=15; // Dew point temperature at outlet in degree celcius
RH1=0.50; // Relative humidity at inlet
RH2=0.80; // Relative humidity at outlet
p=101.325; // Atmospheric pressure in kPa
Cpo=1.0035; // Specific heat at constant pressure in kJ/kg K
pg1=4.246; // saturation pressure of water at DBT1 in kPa
pg2=1.7051; // saturation pressure of water at DBT2 in kPa
pv1=RH1*pg1; pv2=RH2*pg2; // Partial pressure of
```

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

Scilab code Exa 12.7 MOLAR VOLUMES OF GAS MIXTURES

```
clc;
y1=0.5; // Molecular mass of CH4 in kmol
y2=0.5; // Molecular mass of C3H8 in kmol
T=363; // Temperature of gas in kelvin
p=5.06; // Pressure of gas in MPa
v=0.48; // volume of cylinder in m^3
R_1=8.3143; // Universal gas constant of air in kJ/kmol K

// (a).Using kay s rule
// let component 1 refer to methane and component 2 to propane
// the critical properties
Tc1=190.7; Tc2=370; // temperature in kelvin
Pc1=46.4; Pc2=42.7; // Pressure in bar
// using kay s rule for the mixture
Tcmix=y1*Tc1+y2*Tc2;
Pcmix=y1*Pc1+y2*Pc2;
// reduced properties
Tr=T/Tcmix; Pr=p/Pcmix;
// From generalized chart
z=0.832;
```

```
v_1=z*R_1*T/(p*10^3); // molar volume of the mixture
d=(v-v_1)/v; // Percentage deviation from actual
    value
disp ("%",d*100,"Percentage deviation from actual
    value = ","(a).Using kay s rule");
// (b).Using Redlich-Kwong equation of state
a1=0.42748*R_1*Tc1^2.5/Pc1;
a2=0.42748*R_1*Tc2^2.5/Pc2;
b1=0.08664*R_1*Tc1/Pc1;
b2=0.08664*R_1*Tc2/Pc2;
// Substituting these values in the equation 12.16
// And solving these equation by iteration method we
     get
v_1=0.47864;// molar volume of the mixture
d=(v-v_1)/v; // Percentage deviation from actual
    value
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

```
clc;
ln_piCH4=-0.0323;
pi_CH4=0.9683;
p=6895; // Pressure in kPa
T=104.4; // Temperature in degree celcius
a=0.784;
f_CH4=pi_CH4*a*p; // Faguacity
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 MIXTURE

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

```
plot (x1,f,x1,x1); // plot comment
title ("(a).y−x diagram for the mixture at 40 oC","fontsize",4,"color","blue");
xlabel(" x1 ","fontsize",4,"color","blue");
ylabel(" y1 ","fontsize",4,"color","blue");
legend(["y1";"x1"],[2]);
disp ("Refer window 1","(a). y−x diagram at 40 oC");
// (b). p−x−y diagram at 40 oC
 // By using the following relation calculate p value for various value of x1,y1
 // p=(x1*P1sat)+(1−x1)*P2sat
x1=[0,0.2,0.5,0.8,1];
y1=[0,0.285,0.615,0.865,1];
p=[9.607,10.7526,12.471,14.1894,15.335];
xset('window',2);
plot (x1,p,y1,p);
title ("(b).P−y−x diagram for the mixture at 40 oC","fontsize",4,"color","blue");
xlabel(" x1 & y1 ","fontsize",4,"color","blue");
ylabel(" p in bar ","fontsize",4,"color","blue");
legend(["Liquid out";"Vapour"],[2]);
disp ("Refer window 2","(b). p−x−y diagram at 40 oC");
// (c).t−x−y diagram at 10 bar
// for any value of x1 at p=10 bar, the bubble temperature can be found by trial and error from the following relation
 // p=10 bar =(x1*P1sat)+(1−x1)*P2sat
T1sat=23.7; // Saturation temperature of Freon 22 at 10 bar in oC
T2sat=41.6; // Saturation temperature of Freon 12 at 10 bar in oC
// Thus, for x1=0.5, we find that t=31 oC.
x1=0.5; // Let assume
P1sat=12.186; // Saturation pressure of Freon 22 at 31oC in bar
P2sat=7.654; // Saturation pressure of Freon 12 at 31oC in bar
```

```
a=P1sat/P2sat;
y1=(a*x1)/(1+x1*(a-1)); // y Function
// For different value of x1 the values of t,y1 are calculated by above expression and given below
x1=[0,0.5,1]; y1=[0,0.614,1]; t=[41.6,31,23.7];
xset('window',3);
plot (x1,t,y1,t);
title ("(c).t-y-x diagram for the mixture at 10 bar","fontsize",4,"color","blue");
xlabel(" x1 & y1 ","fontsize",4,"color","blue");
ylabel(" t in oC ","fontsize",4,"color","blue");
legend(["f";"g"]);
disp ("Refer window 3","(c).t-x-y diagram at 10 bar");
```

Scilab code Exa 13.2 CALCULATION OF THE STANDARD STATE FUGACITY

```
clc;
T=573.15; // Temperature of the water with another liquid in kelvin
R=8.3144/18; // Characteristic gas constant
// (a).4 MPa
P_1=10; // By Method II , The lowest possible pressure at which date available in steam table for 300 oC temperature in kPa
h_i=3076.5; // Specific enthalphy at P_1 in kJ/kg
s_i=9.2813; // Specific entropy at P_1 in kJ/kg K
// from superheat table at p=4 MPa and t=300 oC
hi=2960.7; // Specific enthalphy in kJ/kg
si=6.3615; // Specific entropy in kJ/kg K
fi=P_1*exp ((((hi-h_i)/T)-(si-s_i))/R); // Standard state fugacity of water
disp ("kPa  (round off error)",fi,"Standard state fugacity of water = ","(a).4 MPa");
```

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

Scilab code Exa 13.3 CALCULATIONS OF AMMONIA WATER SYSTEM

```
clc;
// Let take NH3 as component 1 and H2O as component 2
// (a) & (b)
// Calculation of f1sat = pi1sat*p1sat for ammonia
P_1=50; // low reference state pressure in kPa
P1sat=614.95; // Saturation Pressure of ammonia at 10 oC in kPa
h1sat=1453.3; // Specific enthalpy at 10 oC in kJ/kg
s1sat=5.2104; // Specific entropy at 10 oC in kJ/kg K
R=8.3144/17; // Characteristic gas constant
T=283; // Temperature in kelvin
```

```
// At 10 oC and P_1=50 kPa for ammonia
h_1sat=1499.2; // Specific enthalpy in kJ/kg
s_1sat=6.5625; // Specific entropy in kJ/kg K
f1sat=P_1*exp ((((h1sat-h_1sat)/T)-(s1sat-s_1sat))/R
    ); // Standard state fugacity of Ammonia
disp ("kPa",f1sat,"Standard state fugacity of
    Ammonia = ","(a) & (b)");
// Calculation of f2sat = pi2sat*p2sat for water
P2sat=1.2276; // Saturation Pressure at 10 oC in kPa
     for water
pi2sat=1; // At low pressure for water
f2sat = pi2sat*P2sat; // Standard state fugacity of
    water
disp ("kPa",f2sat,"Standard state fugacity of water
    = ");
// Calulations of ViL/RT
// For ammonia and water at 10 oC
v1L=0.001601; v2L=0.001; // Specific volume in m^3/
    kg
v1L_RT=v1L/(R*T); v2L_RT=v2L/(R*T);
disp (v2L_RT,"v2L/RT = ","(answer mentioned in the
    textbook is wrong)",v1L_RT,"v1L/RT = ");
// Calculations of activity coefficients
// Expression for activity coefficients of ammonia
    and water become in given by respectively
// r_1=(y1*p/(x1*569.6))*exp (-4.34*10^-6*(p-p1sat))
    ; for ammonia
//  r_2=(y2*p/(x2*1.2276))*exp (-7.65*10^-6*(p-p2sat
    )); for water
// The values thus calculated for r_1,r_2,lny_1,
    lnr_2 are calculated and plotted in window 1
// Note that the values of pyonting factors are
    negligibly small
x1=[0,0.2,0.3,0.4,0.5,0.6,0.8,1.0];
y1=[0,0.963,0.986,0.9958,0.9985,0.9993,0.9999,1.0];
lnr_1
    =[-3.1,-1.845,-1.295,-0.75,-0.33,-0.065,-0.035,-0];
```

```
lnr_2=[0,-0.1397,-0.2767,-0.507,-0.709,-0.952,-1.613,-2.2];

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

gE_x1x2RT=[-3.1,-2.92,-2.83,-2.74,-2.65,-2.56,-2.38,-2.2];
xset('window',1); // For Plotting  Diagram
plot (x1,lnr_1,"b*-",x1,lnr_2,"g*-",x1,gE_RT,"r",x1,gE_x1x2RT,"k*-");
title ("(a)&(b).Activity coefficients for NH3/H2O at 10 oC","fontsize",4,"color","blue");
xlabel(" x1      ","fontsize",4,"color","blue");
ylabel(" ln          ","fontsize",4,"color","blue");
legend(["ln   1";"ln   2";"gE/RT";"gE/x1x2 RT"],[4]);
disp ("Refer window 1 for plots");
// As x1  0 , x2  1 , gE_x1x2RT  A=ln r_1^
// As x1  1 , x2  0 , gE_x1x2RT  B=ln r_2^
A=-3.1; B=-2.2; // THe Margules constants
disp (B,"B = ",A,"A = ","The Margules constants ");
disp ("From window 1 for ammonia/water mixture which is characteristic of systems with negative deviation from Roault law. Because   i <=1   and   ln   i <=0");
// (c).
// Assuming ideal vapour phase, and at low pressures
```

```
we have
// y1P= 1 *x1*p1sat; y2p= 2 * x2* p2sat;
// Now the activity coefficients can be found from Margules equations and given below
x1=[0,0.2,0.3,0.4,0.5,0.6,1.0];
y1=[0,0.963,0.986,0.9958,0.9985,0.9999,1.0];
p=[1.2276,8.6597,30.6598,54.6845,150.6458,278.1549,614.95];

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

Scilab code Exa 13.4 ENTHALPY CALCULATIONS FOR NH3 H2O SYSTEM

```
clc;
x1=0.9; // mole fraction of NH3
x2=0.1; // Mole fraction of H2O
p=490.3; // Pressure in kPa
T=280.1; // Temperature in kelvin
lam12_11=-2131; lam21_22=-2726; // In kJ/kmol
```

```
R_1=8.3144; // Universal gas constant  in kJ/kmol K
// (a).Enthalpy of saturated liquid Mixture at L/B at bubble temperature
V1L=0.0016; V2L=0.001; //from properties of NH3 and H2O in m^3/kg
a=((V2L*18)/(V1L*17)) * exp (-lam12_11/(R_1*T));
b=((V1L*17)/(V2L*18)) * exp (-lam21_22/(R_1*T));
d_a=a*(lam12_11/(R_1*T^2)); d_b=b*(lam21_22/(R_1*T^2));
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);
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 valuses in equation
h_E=-R_1*T^2*(x1*d_lnr1+x2*d_lnr2); // Heat of mixing
x1=0.9;
M=x1*17+x2*18; // Molecular weight
hE=h_E/M;
h1L=32.5; h2L=29.4; // in kJ/kg
hL=(x1*h1L)+(x2*h2L)+hE;// Specific enthalpy of the liquid mixture
disp ("kJ/kg",hL,"Specific enthalpy of the liquid mixture = ","(a).Enthalpy of saturated liquid Mixture at L/B at bubble temperature");
// (b).Enthalpy of saturated vapour at V in Equilibrium with liquid at L/B
// From property table of ammonia and water at 0 oC
T1=273.15; // Temperature in kelvin
p1sat=429.4; p2sat=0.6108; // Pressure in kPa
hfg1=1262.4; hfg2=2501.4;// specific enthalpy in kJ/kg
vg1=0.2895; vg2=206.3; // specific volume in m^3/kg
// Referring to fig 13.15 , we have
hb1=1262.4; hb2=2501.4;// specific enthalpy in kJ/kg
M=17;
// The crictical properties
Tc1=405.3; Tc2=647.3;// Temperature in kelvin
```

```
pc1=11.28; pc2=22.09; // Pressure in MPa
z1=(p1sat*vg1/(R_1*T1/M)); z2=(p2sat*vg2/(R_1*T/M));
A2_1=(0.4278/(pc1*10^3))*(Tc1/T1)^2.5; // Constants
B_1=(0.0867/(pc1*10^3))*(Tc1/T1); // Constants
h1R=R_1*(T1/M)*(((-3/2)*(A2_1/B_1)*log (1+(B_1*p1sat
   /z1)))+z1-1);
A2_2=(0.4278/(pc2*10^3))*(Tc2/T1)^2.5; // Constants
B_2=(0.0867/(pc2*10^3))*(Tc2/T1); // Constants
h2R=-0.2;
hc1=hb1-h1R; hc2=hb2-h2R; // Enthalpies at 0 oC
Cpo1=14.86; Cpo2=12.92; // In kJ/kg
A2_1=(0.4278/(pc1*10^3))*(Tc1/T)^2.5; // Constants
B_1=(0.0867/(pc1*10^3))*(Tc1/T); // Constants
A2_2=(0.4278/(pc2*10^3))*(Tc2/T)^2.5; // Constants
B_2=(0.0867/(pc2*10^3))*(Tc2/T); // Constants
y1=0.9999; y2=0.0001;
Tc=y1*Tc1+y2*Tc2;
z=0.957;
hR=R_1*(T/M)*(((-3/2)*(A2_1/B_1)*log (1+(B_1*p/z)))+
   z-1);
hV=y1*(hc1+Cpo1)+y2*(hc2+Cpo2)+hR;
disp ("kJ/kg",hV,"(b).Enthalpy of saturated vapour
   at V in Equilibrium with liquid at L/B");
// (c).Enthalpy of saturated vapour at D after
   complete vaporization of liquid at B/L
T=359.15; // In K
Cpo1=192.2; Cpo2=160.9; // In kJ/kg
A2_1=(0.4278/(pc1*10^3))*(Tc1/T)^2.5; // Constants
B_1=(0.0867/(pc1*10^3))*(Tc1/T); // Constants
A2_2=(0.4278/(pc2*10^3))*(Tc2/T)^2.5; // Constants
B_2=(0.0867/(pc2*10^3))*(Tc2/T); // Constants
y1=0.9; y2=0.1;
Tc=y1*Tc1+y2*Tc2;
z=0.9768;
hR=R_1*(T/M)*(((-3/2)*(A2_1/B_1)*log (1+(B_1*p/z)))+
   z-1);
hD=y1*(hc1+Cpo1)+y2*(hc2+Cpo2)+hR;
disp ("kJ/kg",hD,"(c).Enthalpy of saturated vapour
```

```
at D after complete vaporization of liquid at B/L
");
// (d).Latent Heat of Vapourization of this Liquid Mixture
hB=-0.2;
hD_hB=hD-hB; //Latent Heat of Vapourization of this Liquid Mixture
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

```
clc;
// From the Table 14.1
del_hfHCL=92307; // Enthalpy of Heat in kJ/kmol
del_hfH2O=-241818; // Enthalpy of Heat kJ/kmol
del_Ho=4*del_hfHCL-2*del_hfH2O; // The standard heat
    of reaction from enthalpy equation
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

```
clc;
del_Ho=5640000; // Heat released during the process
// From the Table 14.1
del_hfO2=-393509; del_hfH2O=-285830; // Enthalpy of
   Heat in kJ/kmol
```

```
del_hfsucrose=12*del_hfO2+11*del_hfH2O+del_Ho; // The enthalpy formation of sucrose
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

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

```
clc;
// 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
// The following matrix shows the balance of C and O
A=[1 1 ; 1 2];
B=[4 ;5.4];
a=A\B;
disp ("The equation for the combustion of butane
   with 80% theoretical air is ")
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 GASOLENE AND DEW POINT TEMPERATURE OF PRODUCTS OF COMBUSTION

```
clc;
p=101.325; // Atmospheric pressure in kPa
// The complete combustion equation for actane
 // yC8H18+ x (O2+3.76N2)        n1 CO2+n2 H2O+n3 O2+
    n3 N2
x=12.5*1.5; y=1;
n1=8; n2=9; n3=6.28; n4=70.5;
n=n1+n2+n3+n4; // Total number of moles of the
   products
AFm=(x+x*3.76)/y ;// Air fuel ratio
m=28.84;
M=116; // Molecular weight of octane
AF=AFm*m/M;
yco2=n1/n; yH2O=n2/n; yO2=n3/n; yN2=n4/n;
pH2O=p*yH2O; // Partial pressure of water vapour in
```

```
    the products
Tsat=45.21; // In oC
disp ("kg air/kg octane",AF,"Air fuel ratio = ");
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

```
clc;
// 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
a=0.14; // Composition of H2 in air
b=0.03; // Composition of CH4 in air
c=0.27; // Composition of CO in air
d=0.045; // Composition of CO2 in air
e=0.01; // Composition of O2 in air
f=0.505; // Composition of N2 in air
g=(0.265-0.01); // O2 requirement from atmospheric
    air with 1% O2 already in fuel
h=3.76; // By nitrogen balance
i=1; // mole of the air
AFvol=(g+(g*h))/i; // Air fuel ratio (theroretical)
AFv=1.1*AFvol; // Air fuel ratio on mol (volume)
    basis
disp ("kmol actual air/kmol fuel",AFv,"Air fuel
    ratio on mol (volume) basis =")
M1=2; // Molecular mass of H2
M2=16; // Molecular mass of CH4
M3=28; // Molecular mass of CO
M4=44; // Molecular mass of CO2
```

```
M5=32; // Molecular mass of O2
M=a*M1+b*M2+c*M3+d*M4+e*M5+f*M3; // Molecular mass of Fuel
Ma=28.84; // Molecular mass of air
AFm=AFv*Ma/(i*M); // Air fuel ratio on mass basis
disp ("kg air / kg fuel",AFm,"Air fuel ratio on mass basis = ");
```

Scilab code Exa 14.7 ACTUAL COMBUSTION OF PROPANE

```
clc;
//From table 14.2 at 25 oC and 1 atm for C8H8
del_Ho=-2039.7; // LHV in MJ/kmol
// Combustion equation is C3H8+ 5O2 +18.8N2      3CO2 +4H2O +18.8N2
// From table 14.3
h333_C3H8=2751; // h333_h298 of C3H8 in kJ/kmol
h333_O2=147; // h333_h298 of O2 in kJ/kmol
h333_N2=145; // h333_h298 of N2 in kJ/kmol
h1333_CO2=52075; // h1333_h298 of CO2 in kJ/kmol
h1333_H2O=32644; // h1333_h298 of H2O in kJ/kmol
h1333_N2=32644; // h1333_h298 of N2 in kJ/kmol
M=44; // molecular mass of C3H8
Ha_H1=h333_C3H8+5*h333_C3H8+18.8*h333_N2; // The enthalpy differences
Hb_H2=3*h1333_CO2+4*h1333_H2O+18.8*h1333_N2; // The enthalpy differences
Q=(del_Ho+Hb_H2/1000-Ha_H1/1000)/M; // Heat transfer from combustion chamber
disp ("MJ/kg C3H8",abs (Q),"Heat transfer from combustion chamber =");
```

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

```
clc;
Ha_H1=6220; // From example 14.7 in kJ/kmol
del_Ho=-2039.7; // From example 14.7 LHV in MJ/kmol
Hb_H2=-del_Ho+Ha_H1; // For adiabatic combustion of
    C3H8
// 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
Tad=2300;// The adiabatic flame temperature in
    kelvin
disp ("K",Tad,"The adiabatic flame temperature");
```

Scilab code Exa 14.9 ENTROPY GENERATION IN A CARBON COMBUSTION REACTION

```
clc;
// (a).Entropy change per kmol of C
// From table 14.1 at 298 K and 1 atm
s_c=5.686; // Absolute entropies of C in kJ/kmol K
s_o2=205.142; // Absolute entropies of o2 in kJ/kmol
     K
s_co2=213.795; // Absolute entropies of CO2 in kJ/
    kmol K
del_s=s_co2-(s_c+s_o2); // The entropy change
disp ("kJ/K/kmol C",del_s,"(a).The entropy change =
    ");
// (b).Entropy change of universe
Tsurr=298; // Temperature of surroundings in kelvin
// From table 14.1
del_Ho=-393509; // del_hfco2 in kJ/kmol CO2
Q=abs (del_Ho);
```

```
del_Ssurr=Q/Tsurr; // Entropy change of surroundings
del_Suniv=del_s+del_Ssurr; //Entropy change of universe
disp ("kJ/K",del_Suniv,"(b).Entropy change of universe = ");
```

Scilab code Exa 14.10 ENTROPY GENERATION IN A CO COMBUSTION REACTION

```
clc;
// (a).The product CO2 is also at 298K
Pco=2/3; // Paratial pressure of CO in atm
Po2=1/3; // Paratial pressure of O2 in atm
Pco2=1; // Paratial pressure of CO2 in atm
T0=298; // Temperature of surroundings in kelvin
R_1=8.3143; // Universal gas constant of air in kJ/kmol K
// From table 14.1 at 298 K and 1 atm
s_co2=213.795-R_1*log (Pco2); // entropies in kJ/kmol K
s_co=197.653-R_1*log (Pco); // entropies in kJ/kmol K
s_o2=205.03-R_1*log (Po2); // entropies in kJ/kmol K
del_Scv=s_co2-s_co-1/2*s_o2; // Entropy change of comtrol volume
// From table 14.1
del_hfco2=-393509; del_hfco=-110525; // Enthalpy of Heat in kJ/kmol
Q= del_hfco2- del_hfco; // Heat transfer (to surroundings)
del_Ssurr=abs(Q)/T0; // Entropy change of surroundings
del_Sgen=del_Scv+del_Ssurr; //Entropy change of universe
disp ("kJ/K",del_Sgen,"Entropy change of universe =
```

```
","kJ/K",del_Ssurr,"Entropy change of surroundings = ","kJ/K",del_Scv,"Entropy change of comtrol volume = ","(a).The product CO2 is also at 298K");
// (b).The reaction is adiabatic
// Let the adiabatic flame temperature be T. Then since
Q=0;
C_p=44*0.8414;
// From table A.16
T=5057.5; //adiabatic flame temperature in kelvin
s_CO2=213.795+C_p*log (T/T0); // entropies in kJ/kmol K
del_Scv=s_CO2-s_co-1/2*s_o2; // Entropy change of comtrol volume
del_Ssurr=abs(Q)/T0; // Entropy change of surroundings
del_Sgen=del_Scv+del_Ssurr; //Entropy change of universe
disp ("kJ/K",del_Sgen,"Entropy change of universe = ","kJ/K",del_Ssurr,"Entropy change of surroundings = ","kJ/K",del_Scv,"Entropy change of comtrol volume = ","(b).The reaction is adiabatic");
```

Scilab code Exa 14.11 GIBBS FNCTION OF FORMATION OF LIQID H2O

```
clc;
// The Combustion of H2 with Q2 from H2O
//H2(g)+1/2 O2 (g) H2O(l)+285830 kJ/kmol H2
T0=298; // Temperature of surroundings in kelvin
// From table 14.1 at 298 K
del_hfH2O=-285830; // Enthalpy of Heat in kJ/kmol
s_298H2O=69.94; s_298H2=130.684; s_298O2=205.142; //
```

```
entropies in kJ/kmol K
GP_GR=del_hfH2O-T0*(s_298H2O-s_298H2-1/2*s_298O2); // Formation of Gibbs function
GR=0;
GP=GP_GR-GR; // Standard Gibbs function of formation of liquid H2O
disp ("kJ/kmol",GP,"Standard Gibbs function of formation of liquid H2O = ");
```

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

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

```
    output
Wmax=Wmax/M;
disp ("kJ/kg   (round off error)",Wmax,"Maximum
    possible work output = ","(b).");
```

Chapter 15

CHEMICAL EQUILIBRIUM

Scilab code Exa 15.1 METHANE WATER REACTION

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

```
clc;
T0=298; // Given temperature in kelvin
R_1=8.314; // Universal gas constant in kJ/kg mol K
```

```
// (a).CO+1/2 O2 = CO2
// From table of properties of combustion
del_hfco2=-393509;// Enthalpy of heat
del_hfco=-110525;// Enthalpy of heat
s_co2=213.795;// Entropy of heat
s_co=197.652;// Entropy of heat
s_o2=205.142;// Entropy of heat
del_Ga=(del_hfco2-del_hfco-T0*(s_co2-s_co-(1/2*s_o2)
    ));
Ka=exp (abs (del_Ga)/(R_1*1000*T0));
disp ("(a).CO+1/2 O2 = CO2");
printf ("\n The equilibrium constant at 298 K = %0.3
    f (Error in textbook) \n",Ka);
// (b).2CO + O2 = 2CO2
Kb=exp (2*abs (del_Ga)/(R_1*1000*T0));
disp ("(b).2CO + O2 = 2CO2");
printf ("\nThe equilibrium constant at 298 K = %0.3f
    (Error in textbook)",Kb);
```

Scilab code Exa 15.3 EQUILIBRIUM CONSTANT AT GIVEM TEMPERATURE

```
clc;
T0=298; // Temperature of surroundings in kelvin
R_1=8.314; // Universal gas constant in kJ/kg mol K
T=2800; // Given Temperature in kelvin
// From table of properties of combustion
del_hfco2=-393509; // Enthalpy of heat
del_hfco=-110525; // Enthalpy of heat
del_H=del_hfco2-del_hfco; // Standard enthalpy of
    reaction
Ka=1.229D+45; // The equilibrium constant From the
    example 15.2
K1=log (Ka);
K=exp(-(del_H/R_1)*((1/T)-(1/T0))+K1);
```

```
disp (K,"K =");
```

Scilab code Exa 15.5 ACTUAL COMBUSTION OF CO

```
clc;
T=2800; // Temperature of combustion in kelvin
p=1; // Pressure of combustion in atm
// For this reverse reaction at 2800K and 1atm, from
    Table 15.1
K=44.168; // K=e^3.788;
K=sqrt (K); // For stoichiometric equation CO+1/2 O2
    = CO2 which is halved
// From equation 15.24a and by the iteration process
    we get the following
a=0.198;
b=(1+a)/2;
c=1-a;
disp (c,b,a,"The balance for the actual reaction
   equation CO + O2      aCO + bO2 + cCO2 is given by
    ");
```

Scilab code Exa 15.6 EFFECT OF PLEASURE ON OBTAINING COMPLETE COMBUSTION

```
clc;
// 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
// by simple iteration process we get
a=0.095;
b=(1+a)/2;
c=1-a;
```

```
disp ("mol",c,"The equilibrium composition of CO2 = ","mol",b,"The equilibrium composition of O2 = ","mol",a,"The equilibrium composition of CO = ");
```

Scilab code Exa 15.7 EFFECT OF INERT GAS N2 IN COMBUSTION

```
clc;
T=2800; // Temperature of combustion in kelvin
p=1; // Pressure of combustion in atm
// For this reverse reaction at 2800K and 1atm, from Table 15.1
K=44.168; // K=e^3.788;
K=sqrt (K); // For stoichiometric equation CO+1/2 O2 = CO2 which is halved
// From equation 15.24a and by the iteration process we get the following
a=0.302;
b=(1+a)/2;
c=1-a;
disp (c,b,a,"The balance for the actual reaction equation CO + 1/2O2 + 1.88N2     aCO + bO2 + cCO2 +3.76N2 is given  by ");
```

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

```
clc;
T=3000; // Temperature of combustion in kelvin
p=1; // Pressure of combustion in atm
T0=298; // Temperature of surroundings in kelvin
R_1=8.314; // Universal gas constant in kJ/kg mol K
// Gibbs functions at 298K from Table 14.1
del_gNO=86550; // In kJ/kmol
```

```
del_gNO2=51310; // In kJ/kmol
// From table of properties of combustion
del_hfNO=90250; // Enthalpy of heat
del_hfNO2=33180; // Enthalpy of heat
K1=exp (-(del_hfNO/R_1)*((1/T)-(1/T0))-((del_gNO)/(
    R_1*T0)));
K2=exp (-(del_hfNO2/R_1)*((1/T)-(1/T0))-((del_gNO2)
    /(R_1*T0)));
// By solving equilibrium equations by iteration
    method
E1=0.228; E2=0.0007;
yNO=E1/4.76; // Mole fraction of NO in exhaust gas
yNO2=E2/4.76; // Mole fraction of NO2 in exhaust gas
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 ");
```