

Scilab Textbook Companion for  
Thermodynamics: An Engineering Approach  
(SI Units)  
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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.

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# Chapter 1

## Introduction and Basic Concept

Scilab code Exa 1.1 obtaining formulas for from unit considerations

```
1 //ques1
2 //obtaining formulas for from unit considerations
3 clear
4 clc
5 d=850; //density m^3/kg
6 V=2; //volume m^3
7 m=d*V; //mass Kg
8 printf("Mass of the sample m =%0.0f Kg",m);
```

---

Scilab code Exa 1.5 Absolute Pressure of a Vacuum Chamber

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

---

Scilab code Exa 1.6 Measuring Pressure with nanometer

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

---

Scilab code Exa 1.7 Measuring pressure with multifluid manomete

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

---

**Scilab code Exa 1.8 Measuring Atmospheric Pressure with barometer**

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

---

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

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

---

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

```
1 //ques10
2 //Hydrostatic Pressure in a Solar Pond with Variable
   Density
```

```

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

```

---

#### Scilab code Exa 1.12 Analyzing a Multifluid Manometer with EES

```

1 //ques12
2 //Analyzing a Multifluid Manometer with EES
3 clc
4 g=9.81; //acc due to gravity in m/s^2
5 Patm=85600; //Atmospheric pressure in Pa
6 h1=0.1; //height of water in metre
7 h2=0.2; //height of oil in metre
8 h3=0.35; //height of mercury in metre
9 dwater=1000; //density of water in Kg/m^3
10 doil=850; //density of oil in Kg/m^3
11 dmercury=13600; //density of mercury in Kg/m^3
12 P1=Patm-(dwater*g*h1+doil*g*h2-dmercury*g*h3); //in
    Pa
13 printf('Pressure at point 1 = %.0f Pa',P1);
14 //Now to find h3 if mercury is replaced by another
    oil
15 dmercury=1030; //Density of new mercury in Kg/m^3
16 h3=(P1-Patm+dwater*g*h1+doil*g*h2)/(g*dmercury); //in
    metre
17 printf("\n New height h3 = %.2f metres",h3);

```



## Chapter 2

# Energy Transfer and General Energy Analysis

Scilab code Exa 2.1 General energy analysis

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

---

### Scilab code Exa 2.2 Analysis of wind energy

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

---

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

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

---

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

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

---

**Scilab code Exa 2.9** Power needs of a car to accelerate

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

---

**Scilab code Exa 2.10** Cooling of hot fluid in tank

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

---

**Scilab code Exa 2.11** Acceleration of air by fan

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

---

### Scilab code Exa 2.12 Heating effect of a fan

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

---

### Scilab code Exa 2.13 Annual lighting cost of a classroom

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

---

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

```

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

```

---

#### Scilab code Exa 2.16 Performance of hydraulic turbine generator

```

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

```

```

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

```

---

**Scilab code Exa 2.17 Cost Savings Associated with High Efficiency motors**

```

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

```

---

**Scilab code Exa 2.18 Reducing air pollution by geothermal heating**

```

1 //example 18
2 //reducing air pollution by geothermal heating
3 clear

```

```

4  clc
5  s=18*106 //quantity of natural gas that will be
      saved per year in therms
6  nn=0.0047 //quantity of NOx in kg/therm
7  nc=6.4 //quantity of CO2 in kg/therm
8  sn=nn*s //NOx savings per year in kg/year
9  sc=nc*s //CO2 savings per year in kg/year
10 printf("\\n Hence,geothermal system will save %.1f
      *104 kg NOx/year. \\n",sn/104);
11 printf("\\n and = %.1f *108 kg CO2/year. \\n",sc
      /108);

```

---

#### Scilab code Exa 2.19 Heat transfer from a person

```

1  // example 19
2  // heat transfer from a person
3  clear
4  clc
5  T1=20 //room temperature in celsius
6  T2=29 //body temperature of person in celsius
7  a=1.6 //exposed surface area in m2
8  h=6 //convection heat transfer coefficient in W/m2*
      C
9  Qc=h*a*(T2-T1) //heat loss due convection in W
10 Qr=0.95*5.67*10-8*a*((T2+273)4-(T1+273)4) //heat
      loss due to radiation in W
11 Q=Qc+Qr //net heat loss from the person in W
12 printf("\\n Hence,the total rate of heat transfer is
      =%.1f W. \\n",Q)

```

---

# Chapter 3

## Properties of Pure Substances

Scilab code Exa 3.1 Pressure of Saturated Liquid in a Tank

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

---

Scilab code Exa 3.2 Temperature of Saturated Vapor in a Cylinder

```
1 //ques2
2 //Temperature of Saturated Vapor in a Cylinder
3 clc
```

```

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

```

---

### Scilab code Exa 3.3 Volume and Energy Change during Evaporation

```

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

```

---

### Scilab code Exa 3.4 Pressure and Volume of a Saturated Mixture

```

1 //ques4
2 //Pressure and Volume of a Saturated Mixture

```

```

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

```

---

### Scilab code Exa 3.5 Properties of Saturated Liquid Vapour Mixture

```

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

```

```

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

```

---

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

```

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

```

---

**Scilab code Exa 3.8** Approximating Compressed Liquid as Saturated Liquid

```

1 //ques8
2 //Approximating Compressed Liquid as Saturated
  Liquid

```

```

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

```

---

#### Scilab code Exa 3.10 Mass of Air in a Room

```

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

```

---

#### Scilab code Exa 3.11 The Use of Generalized Charts

```

1 //ques11
2 //The Use of Generalized Charts
3 clear

```

```

4  clc
5  //(a) specific volume using ideal gas equation of
    state
6  R=0.0815; //gas constant for given substance in kPa.m
    ^3/Kg.K
7  Pcr=4.059; // Critical Pressure in MPa
8  Tcr=374.2; // Critical Temp in K
9  T=323; //Temp in K
10 P=1000; //Pressure in kPa
11 v=R*T/P; //Specific Volume in m^3/Kg
12 printf(' \n(a) Specific Volume = %.6f m^3/kg ',v);
13 er=(v-0.021796)/0.021796; //error
14 printf(' \n Error = %.3f ',er);
15 //(b) specific volume using chart
16 Pr=P/Pcr; //reduced pressure
17 Tr=T/Tcr; //reduced Temperature
18 Z=0.84; //from compressibility chart
19 Videal=Z*v; //Ideal Volume in m^3/kg
20 printf(' \n(b) Ideal volume = %.6f m^3/kg ',Videal);
21 er=(Videal-0.021796)/0.021796; //error
22 printf(' \n Error = %.3f ',er);

```

---

**Scilab code Exa 3.12** Using Generalized Charts to Determine Pressure

```

1  //ques12
2  //Using Generalized Charts to Determine Pressure
3  clc
4  //(a)
5  R=0.5956; //Gas constant for a given substance in
    psia.ft^3/lbm.R
6  Pcr=3200; // Critical Pressure in psia
7  Tcr=1164.8; // Critical Temp in R
8  v=0.51431; //specific volume in ft^3/lbm
9  T=600; //Temperature in F
10 //so

```

```

11 P=1000; //Pressure in psia from Table A-6E
12 printf('\n(a) Pressure at a specified state = %.0f
    psia ',P);
13 //(b)
14 T=1060; //Temperature in F
15 P=R*T/v; //Pressure in psia
16 printf('\n(b) Pressure of the steam under specified
    condition = %.0f psia ',P);
17 //(c) using generalised compressibility chart
18 Vr=v*Pcr/(R*Tcr/Pcr); //reduced volume
19 Tr=T/Tcr; //reduced temperature
20 //so
21 Pr=0.33; //from compressibility chart
22 P=Pr*Pcr; //final Pressure in psia
23 printf('\n(c) Pressure (using generalised
    compressibility chart) = %.0f psia ',P);

```

---

### Scilab code Exa 3.13 Different Methods of Evaluating Gas Pressure

```

1 //ex13
2 //Different Methods of Evaluating Gas Pressure
3 clear
4 clc
5 T=175 //temp in K
6 v=0.00375 //specific volume in m^3/kg
7 //(a) ideal gas equation of state
8 // data from table A-1
9 R=0.2968 //gas constant for a given gas in kPa.m^3/kg
    .K
10 P=R*T/v; //Pressure in kPa
11 printf('\n(a) Pressure from Ideal gas equation = %.0
    f kPa \n',P);
12 //(b) van der waals equation
13 //a and b are van der waals constant
14 a=0.175; //m^6.kPa/Kg^2

```

```

15 b=0.00138; //m^3/Kg
16 P=R*T/(v-b)-a/v^2; //pressure in kPa
17 printf('(b) Pressure from van der waals equation = %
    .0f kPa \n',P);
18 //(c) Beattie-Bridgeman equation
19 A=102.29 //constant
20 B=0.05378 //constant
21 c=4.2*10^4; //constant
22 Ru=8.314; //universal gas constant value
23 MM=28.013 //molecular Mass of substance
24 v=0.00375 //specific volume in Kg/m^3
25 V=MM*v //Volume in m^3
26
27 P=Ru*T/V^2*(1-c/(V*T^3))*(V+B)-A/V^2; //pressure in
    KPa
28 printf('(c) Pressure from Beattie-Bridgeman equation
    = %.0f kPa \n',P);

```

---

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

```

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

```

---

# Chapter 4

## Energy Analysis of Closed Systems

Scilab code Exa 4.2 Boundary Work for a Constant Pressure Process

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

---

Scilab code Exa 4.3 Isothermal Compression of an Ideal Gas

```
1 //ques3
```

```

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

```

---

Scilab code Exa 4.4 Expansion of a Gas against a spring

```

1 //ques4
2 //Expansion of a Gas against a spring
3 clear
4 clc
5 V1=0.05//initial volume in m^3
6 V2=2*V1//final volume in m^3
7 A=0.25//area of cross section in m^2
8 k=150//spring constant in kN/m
9 //(a)
10 x=(V2-V1)/A//displacement of piston in m
11 F=k*x//Spring force in kN
12 P1=F/A//pressure in kPa due to piston
13 Po=200//initial pressure in kPa
14 P=P1+Po; //final pressure in kPa
15 printf('\n(a) Final pressure = %.0f kPa\n',P);
16 //(b)
17 w=(Po+P)/2*(V2-V1); //in kJ
18 printf('(b) Work done = %.0f kJ\n',w);
19 //(c)
20 wspring=(P-Po)/2*V1;
21 printf('(c) Fraction of work done by spring = %.0f
   kJ\n',wspring);

```

---

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

```
1 //ques5
2 //Electric Heating of a Gas at Constant Pressure
3 clear
4 clc
5 V=120//voltage in V
6 I=0.2//current in Ampere
7 t=300//time in sec
8 We=V*I*t/1000//work done in kJ
9 //1-initial condition
10 P1=400//kPa initial Pressure
11 V1=0.5//Volume in m^3
12 R=0.297//gas constant for water
13 T1=300//Temp in K
14 m=0.025;//mass in kg
15 //(a) From Energy equation  $We-Q_{out}=dH=m(h_2-h_1)$ 
16 // i.e.  $h_2=(We-Q_{out})/(m)+h_1$ 
17 //(b) Final Temperature
18 Qout=3.7//heat out in kJ
19 h1=2724.9//Initial Enthalpy in kJ/kg
20 h2=(We-Qout)/(m)+h1;//final Enthalpy in kJ/kg
21 //So from steam table A-6
22 T2=200;//Temp in C for P2=300kPa and h2
23 printf('Final Temperature T2 = %.0f C',T2);
```

---

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

```
1 //ques7
2 //Evaluation of the du of an Ideal Gas
3 clear
4 clc
```

```

5  //(a) One way of determining the change in internal
    energy of air is to read the values at T1 and T2
    from Table A17 and take the difference
6  u1=214.07; //internal energy in kJ @ 300K
7  u2=434.78; //Internal energy in kJ @ 600K
8  du=u2-u1; //Change in in internal energy in kJ
9  printf('(a) Change in Internal Energy(from air data
    table ) = %.2f kJ \n',du);
10
11 //(b) the functional form of the specific heat (
    Table A 2c)
12 //constant
13 a=28.11;
14 b=0.1967*10^-2;
15 c=0.4802*10^-5;
16 d=-1.966*10^-9;
17 Ru=8.314; //Universal gas constant
18 //Cp=a+b*T+c*T^2+d*T^3;
19 //Cv=Cp-Ru
20 T1=300; //Initial Temp in K
21 T2=600; //Final temp in K
22 U=integrate('a-Ru+b*T+c*T^2+d*T^3', 'T', T1, T2);
23 M=28.97; //molicular mass
24 u=U/M; //specific internal energy in KJ/Kg
25 printf(' (b) Change in Internal Energy using
    functional form of the specific heat = %.2f kJ\n
    ',u);
26
27 //(c)the average specific heat value (Table A 2b)
28 Tavg=(T1+T2)/2; //avg temp in K
29 Cv=0.733; //heat capacity at constant volume in kJ/K
    @Tavg from Table-2A
30 u=Cv*(T2-T1); //average change in internal energy in
    kJ/kg
31 printf(' (c) Change in Internal Energy using avg
    specific heat value = %.2f kJ/kg ',u);

```

---

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

```
1 //ques8
2 //Heating of a Gas in a Tank by Stirring
3 clear
4 clc
5 //(a)Final Temp
6 w=0.02//power in hp
7 t=0.5//time in hour
8 W=w*t*2545//paddle wheel work in Btu
9 //As  $W=m*C_{avg}*(T_2-T_1)$  ie  $T_2=W/(m*C_{avg})+T_1$ 
10 m=1.5//mass in lbm
11 T1=80//temperature in F
12 Cavg=0.753//average specific heat at constt volume
    in Btu/F
13 T2=W/(m*Cavg)+T1;//Temp in F
14 printf('(a) Temperature = %.1f F\n',T2);
15
16 //(b)The final pressure is determined from the ideal
    -gas relation
17 //P1V1/T1=P2V2/T2 temperature in rankine or kelvin
18 T1=T1+460//converted to R
19 T2=T2+460//converted to R
20 P1=50//preesure at 1st state in psia
21 P2=P1*T2/T1;//final Pressure in psia
22 printf('(b) Final Pressure = %.1f psia',P2);
```

---

Scilab code Exa 4.10 Heating of a Gas at Constant Pressure

```
1 //ques10
2 //Heating of a Gas at Constant Pressure
3 clear
```

```

4  clc
5  //(a) The final temperature can be determined by
    using the ideal-gas relation b/w state 1 and 3
6  P1=150//pressure at state 1 in kPa
7  P3=350//pressure at state 2 in kPa
8  T1=300//temperature at state 1 in K
9  //V3=2*V1
10 //T3=P3*V3/(P1*V1)*T1;
11 T3=P3*2/P1*T1;//temperature at state 2 in K
12 printf('(a) Final Temperature = %.0f K \n',T3);
13
14 //(b) The work done is area under the process curve
    on P-V diagram
15 V2=0.8//Volume at state 2 in m^3
16 V1=0.4//volume at state 1 in m^3
17 P2=350//pressure at state 2 in kPa
18 W13=(V2-V1)*P2;//workdone for process 1-3 in kJ
19 printf(' (b) Work Done = %.0f kJ \n',W13');
20
21 //(c) Mass of the system can be determined by ideal
    gas equation
22 R=0.287//gas constant for a given substance water in
    kJ/mol.K
23 m=P1*V1/(R*T1)//mass in kg
24 //from Table A-7
25 u1=214.07//internal energy at state 1 in kJ/kg @300K
26 u2=1113.52//internal energy at state 2 in kJ/kg
    @1400K
27 //from energy equation
28 Qout=140//heat output in kJ
29 Qin=Qout+m*(u2-u1);//heat input in kJ
30 printf(' (c) Heat input = %.0f kJ',Qin);

```

---

Scilab code Exa 4.11 Enthalpy of Compressed Liquid

```

1 //ques11
2 //Enthalpy of Compressed Liquid
3 clear
4 clc
5 //the water exists as a compressed liquid at the
   specified state
6 //(a) using compressed liquid table
7 P=15000;//pressure in kPa
8 T=100;//temperature in C
9 h=430.39;//heat of water in kJ/kg from Table A-7
10 printf('(a) Heat of water using compressed liquid
   table = %.2f kJ/kg \n',h);
11
12 //(b) Approximating the compressed liquid as a
   saturated liquid at 100 C
13 h=419.17;//heat of water at liquid state in kJ/Kg ie
   hf @ 100C
14 printf(' (b) Heat of Water by approximating
   compressed liquid as saturated = %.2f kJ/kg \n',h
   );
15
16 //(c) Using correction method
17 vf=0.001//specific volume of water in saturated
   liquid state @100C
18 Psat=101.42//saturated pressure in kPa from Table
19 h=h+vf*(P-Psat)//corrected value of heat of water at
   given state in kJ/kg
20 printf(' (c) Heat of water using correction method =
   %.2f kJ/kg ',h);

```

---

#### Scilab code Exa 4.12 Cooling of an Iron Block by Water

```

1 //ques12
2 //Cooling of an Iron Block by Water
3 clear

```

```

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

```

---

## Chapter 5

# Mass and Energy Analysis of Control Volumes

Scilab code Exa 5.1 water flow through garden hose nozzle

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

---

### Scilab code Exa 5.2 Discharge of water from a tank

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

---

### Scilab code Exa 5.3 Energy transport by mass

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

```

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

```

---

#### Scilab code Exa 5.4 Deceleration of air in diffuser

```

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

```

```

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

```

---

### Scilab code Exa 5.5 Acceleration of steam in nozzle

```

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

```

```

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

```

---

#### Scilab code Exa 5.6 Compressing air by compressor

```

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

```

---

#### Scilab code Exa 5.7 Power generation by steam turbine

```

1 //example 7
2 // power generation by steam turbine
3 clear
4 clc
5 P1= 2 //initial pressure of steam in MPa
6 T1= 400 //initial temp. of steam in C
7 V1= 50 //initial velocity of steam in m/s
8 z1= 10 //height of inlet in metres
9 h1=3248.4 //initial specific enthalpy of air in kJ/
   kg
10 P2= 15 //final pressure of air in kPa
11 V2= 180 //final velocity of air in m/s
12 z2= 6 //exit height in m
13 x2=0.9 //quality of steam after exit
14 disp('At turbine exit ,we obviously have liquid
   vapour mixture at 15 kPa.')
```

$$h_f = 225.94 \text{ kJ/kg}$$

$$h_{fg} = 2372.3 \text{ kJ/kg}$$

$$h_2 = h_f + x_2 \cdot h_{fg} \text{ //final specific enthalpy of mixture in kJ/kg}$$

$$\Delta h = h_2 - h_1 \text{ // change in enthalpy of steam in kJ/kg}$$

$$\Delta KE = \frac{(V_2^2 - V_1^2)}{2000} \text{ //change in kinetic energy of steam in kJ/kg}$$

$$g = 9.8 \text{ //acc. due to gravity in m/s}^2$$

$$\Delta PE = g \cdot (z_2 - z_1) / 1000 \text{ //change in potential energy of steam in kJ/kg}$$

$$w_{out} = -((h_2 - h_1) + \frac{(V_2^2 - V_1^2)}{2000} + g \cdot (z_2 - z_1) / 1000) \text{ // work done per unit mass of the steam flowing through the turbine in kJ/kg}$$

$$m = 5000 / w_{out} \text{ //mass flow rate of steam in kg/s}$$

```

24 printf("\n The value of dh is = %.2f kJ/kg. \n",dh);
25 printf("\n The value of dke is = %.2f kJ/kg. \n",dke
   );
26 printf("\n The value of dpe is = %.2f kJ/kg. \n",dpe
   );
27 printf("\n The work done per unit mass of the steam
   flowing through the turbine is = %.2f kJ/kg. \n",
   wout);
```

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

---

### Scilab code Exa 5.8 Expansion of refrigerant 134a in refrigerator

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

---

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

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

---

**Scilab code Exa 5.10** Cooling of refrigerant 134a by water

```
1 //example 10
2 //cooling of refrigerant 134-a by water
3 clear
4 clc
5 disp('We take the entire heat exchanger as the
      system. This is a control volume since mass
      crosses the system boundary during the process.')
```

6 disp('For each fluid stream since there is no mixing  
 . Thus,  $m_1=m_2=m_h$  and  $m_3=m_4=m_r$ ')

```
7 mr=6 //mass flow rate of R-134a in kg/min
8 h1=62.982 //specific enthalpy of water in kJ/kg
9 h2=104.83 //specific enthalpy of water in kJ/kg
10 P3=1 //pressure of R-134a at inlet in MPa
11 T3=70 //temperature of R-134a at inlet in Celsius
```

```

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

```

---

#### Scilab code Exa 5.11 Electric heating of air in house

```

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

```

---

**Scilab code Exa 5.12** Charging of rigid tank by system

```
1 //example 12
2 //charging of rigid tank by system
3 clear
4 clc
5 disp('This process can be analyzed as a uniform-flow
      process since the properties of the steam
      entering the control volume remain constant
      during the entire process.')
```

```
6 disp('We take the tank as the system. This is a
      control volume since mass crosses the system
      boundary during the process.We observe that this
      is an unsteady-flow process since changes occur
      within the control volume')
```

```
7 m1=0 //since system is initially evacuated
8 disp('The properties of the steam at the inlet state
      are')
```

```
9 P1=1 //pressure in MPa
10 T1=300 //temp. in Celsius
11 h1=3051.6 //specific enthalpy in kJ/kg
12 P2=1 // pressure at final state in MPa
13 u2=h1 //final internal energy of the steam in kJ/kg
14 disp('From steam table ,the temp. corresponding to
      final properties are')
```

```
15 T2=456.1//final temp. in Celsius
16 printf("\n The final temp. of the steam in the tank
      is = %.1f C. \n",T2);
```

---

**Scilab code Exa 5.13** Cooking with a pressure cooker

```

1 //example 13
2 //cooking with a pressure cooker
3 clear
4 clc
5 disp('This process can be analyzed as a uniform-flow
      process since the properties of the steam
      leaving the control volume remain constant during
      the entire cooking process')
6 disp('We take the pressure cooker as the system.
      This is a control volume since mass crosses the
      system boundary during the process.We observe
      that this is an unsteady-flow process since
      changes occur within the control volume. Also,
      there is one exit and no inlets for mass flow.')
```

```

7 Pgage=75 //gage pressure inside cooker in kPa
8 Patm=100 //atmospheric pressure in kPa
9 Pabs=Pgage+Patm //absolute pressure inside pressure
      cooker in kPa
10 disp('Since saturation conditions exist in the
      cooker at all times , the cooking temperature
      must be the saturation temperature corresponding
      to this pressure.From steam table, it is')
```

```

11 Tsat=116.04 // Saturation Temp. at 175 kPa in
      Celsius
12 T=Tsatsat //Temp. at which cooking takes place
13 Qin=0.5 //Heat supplied to the pressure cooker in kJ
      /s
14 t=30*60 //time for which het is supplied to pressure
      cooker in seconds
15 qin=Qin*t //total heat supplied to pressure cooker
      in kJ
16 m1=1 //initial mass of water in kg
17 V=0.006 //volume of pressure cooker in m^3
18 V1=V/m1 // initial specific volume in kg/m^3
19 Vf=0.001 //in kg/m^3
20 Vfg=1.004-0.001 //in kg/m^3
21 x1=(V1-Vf)/Vfg //quality
22 uf=486.82 //in kJ/kg
```

```

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

```

---

# Chapter 6

## Mass and Energy Analysis of Control Volumes

Scilab code Exa 6.1 Net Power Production of a Heat Engine

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

---

Scilab code Exa 6.2 Fuel Consumption Rate of a Car

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

```

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

```

---

### Scilab code Exa 6.3 Heat Rejection by a Refrigerator

```

1 //ques3
2 //Heat Rejection by a Refrigerator
3 clear
4 clc
5 //(a)
6 Q1=6; //heat of sink in kJ/s
7 W=2; //work done on refrigerator in kW
8 COPr=Q1/W; //coefficient of performance of
    refrigerator
9 printf(' (a) The coefficient of performance of the
    refrigerator is = %.0f \n',COPr);
10
11 //(b)
12 Qh=Q1+W; //heat of reservoir in kJ/s
13 printf(' (b)The rate at which heat is rejected to
    the room that houses the refrigerator = %.0f kJ/s
    \n',Qh);

```

---

### Scilab code Exa 6.4 Heating a House by a Heat Pump

```

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

```

---

#### Scilab code Exa 6.5 Analysis of a Carnot Heat Engine

```

1 //ques5
2 //Analysis of a Carnot Heat Engine
3 clear
4 clc
5 //(a) The Carnot heat engine is a reversible heat
        engine, and so its efficiency can be determined
        as
6 Tl=303; //K temp of sink
7 Th=650+273; //K temp of source
8 n=1-Tl/Th; //efficiency of heat engine
9 printf(' (a) Efficiency = %.3f \n',n);
10
11 //(b)
12
13 Qh=500; //heat of reservoir in kJ
14 Ql=Tl/Th*Qh; //heat of sink in kJ
15 printf(' (b) The amount of heat rejected, Ql by this
        reversible heat engine = %.0f kJ \n',Ql);

```

---

Scilab code Exa 6.6 A Questionable Claim for a Refrigerator

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

---

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

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

---

Scilab code Exa 6.8 Malfunction of a Refrigerator Light Switch

```

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

```

---

# Chapter 7

## Entropy

Scilab code Exa 7.1 Entropy Change during an Isothermal Process

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

---

Scilab code Exa 7.2 Entropy Generation during Heat Transfer Processes

```
1 //ques2
2 //Entropy Generation during Heat Transfer Processes
3 clear
4 clc
```

```

5  //(a)Sink at 500K
6  Qsource=-2000//heat of source in kJ
7  Qsink=2000//heat of sink in kJ
8  Tsource=800//temperature of source in K
9  Tsink=500//temperature of sink in K
10 Ssource=Qsource/Tsource//entropy of source in kJ/K
11 Ssink=Qsink/Tsink//entropy of surce in kJ/K
12 Sgen=Ssource+Ssink;//entropy of generation of the
    process in kJ/K
13 printf(' (a) Enthalpy of generation = %.1f kJ/K \n',
    Sgen);
14
15 //(b) for sink of T=750 K
16 Qsource=-2000//heat of source in kJ
17 Qsink=2000//heat of sink in kJ
18 Tsource=800//temperature of source in K
19 Tsink=750//temperature of sink in K
20 Ssource=Qsource/Tsource//entropy of source in kJ/K
21 Ssink=Qsink/Tsink//temperature of sink in kJ/K
22 Sgen=Ssource+Ssink;//entropy of generation of system
    in kJ/K
23 printf(' (b) Enthalpy of generation = %.1f kJ/K',
    Sgen);

```

---

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

```

1  //ques3
2  //Entropy Change of a Substance in a Tank
3  clear
4  clc
5  //specific volume remains constant during this
    process
6
7  //state 1
8  P1=140//initial pressure in kPa

```

```

9 T1=20 //initial temperature in C
10 s1=1.0624//entropy in kJ/Kg.K from table
11 v1=0.16544//specific volume in m^3/Kg
12
13 //state 2
14 P2=100//pressure in kPa
15 v2=0.16544//specific volume remains same ie v2=v1
16
17 //from table
18 vf=0.0007259//specific volume of saturated water in
    m^3/kg
19 vg=0.19254//specific volume of saturated vapor in m
    ^3/kg
20
21 //Final state-saturated liquid vapor mixture
22 x2=(v2-vf)/(vg-vf); //x-factor
23 sf=0.07188//entropy of saturated water in kJ/Kg.K
24 sfg=0.87995//entropy change in kJ/kg.K
25 s2=sf+x2*sfg; //entropy at state 2 in kJ/kg.K
26 m=5//mass in Kg
27 S=m*(s2-s1); //entropy change in process in kJ
28 printf('Entropy change = %.3f kJ',S);

```

---

#### Scilab code Exa 7.4 Entropy Change during a Constant Pressure Process

```

1 //ques4
2 //Entropy Change during a Constant-Pressure Process
3 clear
4 clc
5 //approximating the compressed liquid as a saturated
    liquid
6
7 //state 1
8 P1=20//pressure in psia
9 T1=70//temperature in F

```

```

10 s1=0.07459//entropy ie sf @ 70F in Btu/lbm.R
11 h1=38.08//heat of system in Btu/lbm hf@ 70 F
12
13 //state 2
14 P2=20//pressure in psia
15 //using Qin=m*(h2-h1)
16 Qin=3450//input heat in Btu
17 m=3//mass in lbm
18 h2=Qin/m+h1//heat of system in Btu/lbm
19 s2=1.7761//entropy in Btu/lbm/R from table A-6E
20
21 S=m*(s2-s1);//change in entropy of system
22 printf('Entropy change of water during the process =
        %.3f Btu/R',S);

```

---

### Scilab code Exa 7.5 Isentropic Expansion of Steam in a Turbine

```

1 //ques5
2 //Isentropic Expansion of Steam in a Turbine
3 clear
4 clc
5 //state 1
6 P1=5//pressure in MPa
7 T1=450//temperature in C
8 h1=3317.2//heat of system in kJ/kg from table
9 s1=6.8210//entropy of system in kJ/kg.K from table
10
11 //state 2
12 P2=1.4//pressure in MPa
13 s2=6.8210//entropy of system remains same ie s2=s1
14 h2=2967.4//heat of system in kJ/Kg from table
15
16 w=h1-h2;//work output of turbine in kJ/kg
17
18 printf('The work output of the turbine per unit mass

```

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

---

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

```
1 //ques7
2 //Effect of Density of a Liquid on Entropy
3 clear
4 clc
5
6 //state 1
7 P1=1//pressure in MPa
8 T1=110//temperature in K
9 s1=4.875//entropy in kJ/Kg.K from table
10 Cp1=3.471//specific heat at constant pressure in kJ/
    Kg.K from table
11
12 //state 2
13 P2=5//pressure in MPa
14 T2=120//temperature in K
15 s2=5.145//entropy in kJ/Kg.K
16 Cp2=3.486//specific heat at constant pressure in kJ/
    Kg.K
17
18 s=s2-s1;//entropy change in kJ/kg.K
19 printf('(a) Change in entropy per unit mass = %.3f
    kJ/kg.K \n',s);
20
21 //(b) Approximating liquid methane as an
    incompressible substance
22 c=(Cp1+Cp2)/2;//average specific heat
23 s=c*log(T2/T1);//entropy change in kJ/Kg
24 printf(' (b) Entropy change per unit mass = %.3f kJ/
    kg.K',s);
```

---

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

```
1 //ques8
2 //Economics of Replacing a Valve by a Turbine
3 clear
4 clc
5
6 //state 1
7 P1=5//pressure in MPa
8 T1=115//temperature in K
9 //from table
10 h1=232.3//heat in kJ/kg
11 s1=4.9945//entropy in kJ/kg.K
12 d1=422.15//density
13
14 //state 2
15 P2=1//pressure in MPa
16 s2=4.9945//entropy s2=s1
17 h2=222.8//heat in kJ/kg from table
18 Vs=0.280//volume flow rate in m^3
19 ms=d1*Vs//mass per second in Kg/sec
20 // Ein=Eout so Wsout=ms*(h1-h2)
21 Ws=ms*(h1-h2);//power output of turbine in kJ/sec
22 printf('The power output of the turbine = %.0f kW \n
        ',Ws);
23 APP=Ws*8760//kWh/yr annual power production
24 APS=APP*0.075//$/kWh Annual power savings
25 printf(' Annual power savings = $ %.0f/yr ',APS);
```

---

### Scilab code Exa 7.9 Entropy Change of an Ideal Gas

```
1 //ques9
```

```

2 //Entropy Change of an Ideal Gas
3 clear
4 clc
5 //(a) From table (Table A 17)
6 s2=1.79783;//entropy of substance a state 2 in kJ/Kg
   .K
7 s1=1.66802;//entropy of state 2 in kJ/kg.k
8 R=0.287;//gas constant for water
9 P2=600//final pressure in kPa
10 P1=100//initial pressure in kPa
11 dS=s2-s1-R*log(P2/P1);//change in entropy in kJ/kg.k
12 printf(' (a) s2-s1 = %.4f kJ/Kg.K \n',dS);
13
14 //(b) by using a c value at the average temperature
   37 C
15 Cpavg=1.006//avg specific heat at const pressure in
   kJ/kg.K
16 T2=330//final temp in K
17 T1=290//inial temp in K
18 dS=Cpavg*log(T2/T1)-R*log(P2/P1);//kJ/kg.k
19 printf(' (b) Entropy change = %.4f kJ/kg.K',dS);

```

---

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

```

1 //ques10
2 //Isentropic Compression of Air in a Car Engine
3 clear
4 clc
5
6 //Using equation  $(T2/T1)=(v1/v2)^{(k-1)}$ 
7 T1=295//initial temp in K
8 t=8//v1/v2 ratio
9 k=1.391//isentropic ratio
10 T2=T1*(t)^(k-1);//final temp in K
11 printf('Final temperature = %.1f K \n',T2);

```

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

---

#### Scilab code Exa 7.11 Isentropic Compression of an Ideal Gas

```
1 //ques11
2 //Isentropic Compression of an Ideal Gas
3 clear
4 clc
5 //using the equation  $P_2=P_1*(T_2/T_1)^{(k/(k-1))}$ 
6 P1=14;//initial pressure in psia
7 T2=780;//final temp in R
8 T1=510;//initial temp in R
9 k=1.667;//isentropic ratio
10 P2=P1*(T2/T1)^(k/(k-1));
11 printf('Final pressure = %.1f psia ',P2);
```

---

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

```
1 //ques12
2 //Compressing a Substance in the Liquid versus Gas
  Phases
3 clear
4 clc
5 //(a)steam as a saturated liquid
6 v1=0.001043;//=vf(specific volume of fluids) @ 100
  kPa in m^3/kg
7 P2=1000;//final pressure in kPa
8 P1=100;//initial pressure in kPa
9 w=integrate('v1*P^0', 'P',P1,P2);//work done in kJ/kg
10 printf(' (a) Work done is = %.2f kJ/kg \n',w);
11
12 //(b)saturated vapor at the inlet state
13 //state 1
```

```

14 P1=100; //pressure at state 1 in kPa
15 //table A-6
16 h1=2675.0; //enthalpy of heat in kJ/kg
17 s1=7.3589; //entropy at in kJ/kg.k
18 //state 2
19 P2=1; //pressure in MPa
20 s2=7.3589; //s2=s1 entropy remains same
21 h2=3194.5; //table A-6 enthalpy of heat in kJ/kg
22
23 w=h2-h1; //work done in kJ/kg
24 printf(' (b) Work done = %.2f kJ/kg ',w);

```

---

#### Scilab code Exa 7.13 Work Input for Various Compression Processes

```

1 //ques13
2 //Work Input for Various Compression Processes
3 clear
4 clc
5 //(a) Isentropic compression with k=1.4
6 k=1.4; //isentropic ratio
7 R=0.287; //gas constant for water in kJ/K/mol/kg
8 T1=300; //initial temp in K
9 P2=900; //final pressure in kPa
10 P1=100; //initial pressure in kPa
11 w=k*R*T1/(k-1)*((P2/P1)^((k-1)/k)-1); //work done in
    compression in kJ/kg
12 printf('(a) Work done in compression = %.1f kJ/kg \n
    ',w);
13
14 //(b) Polytropic compression with k=1.3
15 w=k*R*T1/(k-1)*((P2/P1)^((k-1)/k)-1);
16 printf(' (b) Work done in compression = %.1f kJ/kg \
    n ',w);
17
18 //(c) Isothermal compression

```

```

19 w=R*T1*log(P2/P1);
20 printf(' (c) Work done = %.1f kJ/kg \n',w);
21
22 //(d) Ideal two stage compression with intercooling
    with a polytropic exponent of 1.3
23 Px=(P1*P2)^(1/2); //pressure in kPa
24 //the total compressor work is twice the compression
    work for a single stage
25 w=2*k*R*T1/(k-1)*((Px/P1)^((k-1)/k)-1);
26 printf(' (d) Work done = %.2f kJ/kg \n',w);

```

---

#### Scilab code Exa 7.14 Isentropic Efficiency of a Steam Turbine

```

1 //ques14
2 //Isentropic Efficiency of a Steam Turbine
3 clear
4 clc
5 //state 1
6 P1=3; //pressure in MPa
7 T1=400; //temperature in C
8 //from table
9 h1=3231.7; //enthalpy of heat in kJ/kg
10 s1=6.9235; //entropy in kJ/kg.k
11
12 //state 2a
13 P2a=50; //pressure in kPa
14 T2a=100; //temp in C
15 h2a=2682.4; //enthalpy of heat in kJ/kg
16
17 //state 2s
18 P2s=50; //pressure in kPa
19 s2s=6.9235; //s2s=s1 entropy remains same
20 //from table
21 sf=1.0912; //entropy of fluid state in kJ/kg.k
22 sg=7.5931; //entropy of vapor in kJ.kg.k

```

```

23 //at end,steam exists as a saturated mixture since
    sf<s2s<sg
24 hf=340.54;//enthalpy of heat of fluid state in kJ/kg
25 hfg=2304.7;//enthalpy difference of vapor and liquid
    state in kJ/kg
26 x2s=(s2s-sf)/(sg-sf);//x factor
27 h2s=hf+x2s*(hfg);//enthalpy of heat in kJ/kg
28 //using the equation 7-61 in book we get
29 n=(h1-h2a)/(h1-h2s);
30 printf('(a) Isentropic efficiency = %.1f percent \n
    ',n*100);
31
32 Wout=2000//output power in kJ/s
33 ms=Wout/(h1-h2a);//mass flow rate in kg/s
34 printf('(b) The mass flow rate of steam = %.2f kg/s
    ',ms);//through this turbine from the energy
    balance for steady-flow systems

```

---

#### Scilab code Exa 7.15 Effect of Efficiency on Compressor Power Input

```

1 //ques15
2 //Effect of Efficiency on Compressor Power Input
3 clear
4 clc
5 T1=285;//initial temperature in K
6 h1=285.14;//table A-17 initial heat of enthalpy in
    kJ/kg
7 Pr1=1.1584;//reduced pressure
8 P2=800;//final pressure in kPa
9 P1=100;//initial pressure in kPa
10 Pr2=Pr1*(P2/P1);
11 //from table corresponding to Pr2
12 h2s=517.05;//enthalpy of heat in kJ/kg
13 n=0.80;//efficiency
14 //using the formula for efficiency ')

```

```

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

```

---

### Scilab code Exa 7.16 Effect of Efficiency on Nozzle Exit Velocity

```

1 //ques16
2 //Effect of Efficiency on Nozzle Exit Velocity
3 clear
4 clc
5 //The exit velocity of the air will be a maximum
    when the process in the nozzle involves no
    irreversibilities
6 T1=950;//initial temp in K
7 P2s=80;//pressure in kPa
8 P1=200;//initial pressure in kPa
9 k=1.354;//isentropic ratio
10 T2s=T1*(P2s/P1)^(1-1/k);//temp in K
11 //using Ein = Eout we can get V2s
12 Cpavg=1.099;//avg specific heat at constant pressure
    in kJ/kg.k
13 V2s=sqrt(2000*Cpavg*(T1-T2s));//velocity in m/s
14 printf('(a) The maximum possible exit velocity = %.2
    f m/s \n',V2s);
15
16 //(b) The actual exit temperature of the air is
    higher than the isentropic exit temperature
    evaluated above
17 n=0.92;//efficiency
18 T2a=T1-n*(T1-T2s);//temp in K

```

```

19 printf(' (b) The exit temperature = %.0f K \n',T2a);
20
21 //(c) The actual exit velocity of air can be
    determined from the definition of isentropic
    efficiency of a nozzle
22 V2a=sqrt(n*V2s^2); //velocity in m/s
23 printf(' (c) Exit velocity of air = %.0f m/s ',V2a);

```

---

### Scilab code Exa 7.17 Entropy Generation in a Wall

```

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

```

---

Scilab code Exa 7.18 Entropy Generation during a Throttling Process

```
1 //ques18
2 //Entropy Generation during a Throttling Process
3 clear
4 clc
5 //state 1
6 P1=7; //MPa
7 T1=450; //C
8 //from table
9 h1=3288.3; //kJ/kg
10 s1=6.6353; //kJ/kg.K
11
12 //state 2
13 P2=3; //MPa
14 h2=3288.3; //h2=h1
15 s2=7.0046; //kJ/kg.K
16 sgen=(s2-s1);
17 printf('Entropy of generation per unit mass = %.4f
        kJ/kg.K', sgen);
```

---

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

```
1 //ques19
2 //Entropy Generated when a Hot Block Is Dropped in a
  Lake
3 clear
4 clc
5 //(a) The entropy change of the iron block
6 m=50; //mass in kg
7 Cavg=0.45; //average specific heat in kJ/kg
8 T2=285; //final temp in K
```

```

 9 T1=500; //initial temp in K
10 Siron=m*Cavg*log(T2/T1);
11 printf('(a) Entropy change of iron block = %.2f kJ/K
    \n',Siron);
12
13 //(b)
14 //The temperature of the lake water remains constant
    during this process at 285 K
15 Qout=m*Cavg*(T1-T2); //heat transfer from iron to
    lake in kJ
16 S=Qout/T2; //Entropy change of lake in kJ/K
17 printf(' (b) Entropy change of the lake = %.2f kJ/K
    \n',S);
18
19 //(c)
20 //The entropy generated during this process is
    determined by applying an entropy balance on the
    system
21 Tb=285; //temp of block in K
22 Sgen=Qout/Tb+Siron; //Entropy generation in kJ/K
23 printf(' (c) Entropy generated = %.2f kJ/K \n',Sgen)
    ;

```

---

### Scilab code Exa 7.21 Entropy Generation Associated with Heat Transfer

```

1 //ques21
2 //Entropy Generation Associated with Heat Transfer
3 clear
4 clc
5 //(a) Water undergoes an internally reversible
    isothermal process
6 Q=-600; //kJ
7 Tsys=100+273; //K
8 Ssys=Q/Tsys; //kJ/K
9 printf('(a) Entropy of system = %.2f kJ/K \n',Ssys);

```

```

10
11 //(b) The entropy generation is entirely due to
    irreversible heat transfer through a finite
    temperature difference
12 Qout=600;//heat output in kJ
13 Tb=25+273//Temperature in K
14 Sgen=Ssys+Qout/Tb;//Entropy generation in kJ/K
15 printf(' (b) Entropy of generation = %.2f kJ/K',Sgen
    );

```

---

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

```

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

```

```

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

```

---

Scilab code Exa 7.23 Reducing the Pressure Setting to Reduce Cost

```

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

```

---

## Chapter 8

# Exergy A Measure of Work Potential

Scilab code Exa 8.1 Maximum power generation by wind turbine

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

---

Scilab code Exa 8.2 Exergy transfer from a furnace

```

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

```

---

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

```

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

```

---

Scilab code Exa 8.4 Irreversibility during cooling of an iron block

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

---

Scilab code Exa 8.5 Heating potential of a hot iron block

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

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

---

#### Scilab code Exa 8.6 Second law efficiency of resistance heaters

```
1 //example 6
2 //second law efficiency of resistance heaters
3 clear
4 clc
5 T1=283 //Outdoor Temp. in K
6 Th=294 //Indoor Temp. in K
7 COPhp=1/(1-T1/Th) //coefficient of performance of
    reversible heat engine
8 COP=1 //first law efficiency
9 n=COP/COPhp //second law efficiency of resistance
    heater
10 printf("\n Hence, the second law efficiency of the
    heater is = %.1f percent. \n",n*100);
```

---

#### Scilab code Exa 8.7 Work Potential of compressed air in tank

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

```

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

```

---

Scilab code Exa 8.8 Exergy change during a compression process

```

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

```

---

Scilab code Exa 8.10 Exergy destruction during heat conduction

```

1 //example 10
2 //exergy destruction during heat conduction

```

```

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

```

---

**Scilab code Exa 8.11** Exergy destruction during expansion of steam

```

1 //example 11
2 //exergy destruction during expansion of steam
3 clear
4 clc
5 P1=1 //in MPa
6 T1=300 //in celsius
7 u1=2793.7 //kJ/kg
8 v1=0.25799 //m3/kg
9 s1=7.1246 //kJ/kg-K
10 P2=200 //in kPa
11 T2=150 //in C
12 u2=2577.1 //in kJ/kg
13 v2=0.95986 //in m3/kg

```

```

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

```

---

Scilab code Exa 8.12 exergy destroyed during stirring of gas

```

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

```

---

**Scilab code Exa 8.13** Dropping of hot iron block in water

```

1 //example 13
2 //dropping of hot iron block in water
3 clear
4 clc
5 miron=5 //mass of iron block in kg
6 mwater=100 //mass of water in kg
7 ciron=0.45 //specific heat capacity of iron in kJ/kg
    -C
8 cwater=4.18 //specific heat capacity of water in kJ/
    kg-C
9 Tiiron=350 //initial temperature of iron in Celsius
10 Tiwater=30 //initial temperature of water in Celsius
11 Tf=(miron*ciron*Tiiron+mwater*cwater*Tiwater)/(miron
    *ciron+mwater*cwater) //final equilibrium
    temperature in Celsius

```

```

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

```

---

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

```

1 //example 14
2 //exergy destruction during heat transfer to a gas
3 clear
4 clc
5 P1=350 //in kPa
6 V1=0.01 //in m^3
7 V2=0.02 //in m^3
8 Wb=P1*V1*log(V2/V1) //quasi equilibrium boundary work
    in kJ
9 P0=100 //atmospheric pressure in kPa
10 Wsurr=P0*(V2-V1) //work done against the atmospheric
    pressure in kJ

```

```

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

```

---

#### Scilab code Exa 8.15 second law analysis of steam turbine

```

1 //example 15
2 //second law analysis of steam turbine
3 clear
4 clc
5 P1=3 //in MPa
6 T1=450 //in C
7 h1=3344.9 //in kJ/kg
8 s1=7.0856 //in kJ/kg-K
9 P2=0.2 //in MPa
10 T2=150 //in C
11 h2=2769.1 //in kJ/kg
12 s2=7.2810 //in kJ/kg-K
13 P0=100 //in kPa
14 T0=25 //in C
15 h0=104.83 //in kJ/kg
16 s0=0.3672 //in kJ/kg-K

```

```

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

```

---

Scilab code Exa 8.16 exergy destroyed during mixing of fluid streams

```

1 //example 16
2 //exergy destroyed during mixing of fluid streams
3 clear
4 clc
5 m1=300 //in lbm/min
6 h1=18.07 //in Btu/lbm
7 T0=530 //temperature of atmospheric air in R
8 s1=0.03609 //Btu/lbm-R
9 m2=22.7 //in lbm/min
10 h2=1162.3 //in Btu/lbm
11 s2=1.7406 //in Btu/lbm-R
12 m3=322.7 //in lbm/min

```

```

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

```

---

**Scilab code Exa 8.17** Charging of compressed air storage system

```

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

```

---

# Chapter 9

## Gas Power Cycle

Scilab code Exa 9.2 The Ideal Otto Cycle

```
1 //ques2
2 //The Ideal Otto Cycle
3 clear
4 clc
5 //the temperature and pressure of air at the end of
   the isentropic compression process (state 2),
   using data from Table A 17
6 T1=290;//initial temp in K
7 u1=206.9;//initial internal energy in kJ/kg
8 vr1=676.1;//initial reduced volume
9 //Process 1-2 (isentropic compression of an ideal
   gas)
10 //vr2/vr1=v2/v1=1/r
11 r=8;//ratio
12 vr2=vr1/r;//reduced volume at state 2
13 //using table corresponding to vr2
14 T2=652.4;//final temp in K
15 u2=475.11;//final internal energy in kJ/kg
16 P1=100;//initial pressure in kPa
17 P2=P1*T2/T1*r;//final pressure in kPa
18 //Process 2-3 (constant-volume heat addition)
```

```

19 Qin=800;//heat input in kJ/kg
20 u2=1275.11;// intenal energy at state 2 in kJ/kg
21 u3=Qin+u2;//internal energy at state 3 in kJ/kg
22 //using tables corresponding to u3
23 T3=1575.1;//temperature at state 3 in K
24 vr3=6.108;//reduced volume at state 3
25 printf(' (a) T3, Temperature at state 3 = %.1f K \n',
        T3);
26 vr3=6.108;//reduced volume at state 3
27 P3=P2*(T3/T2)*1;//1 for v2/v3
28 printf('      Pressure P3 = %.3f MPa \n',P3/1000);
29
30 //(b)
31 vr3=r*vr3;
32 //now from table
33 T4=795.6;//temp at state 4 in K
34 u4=588.74;//internal energy at state 4 in kJ/kg
35 //Process 4-1 (constant-volume heat rejection)
36 Qout=u4-u1;//heat output in kJ/kg
37 w=Qin-Qout;//work done in kJ/kg
38 printf(' (b) Net work done = %.2f kJ/kg \n',w);
39
40 //(c)
41 nth=w/Qin;//efficiency of heat engine
42 k=1.4;//constant
43 no=1-r^(1-k);//thermal efficiency
44 printf(' (c) The thermal efficiency of the cycle is
        determined from its definition = %.3f \n',nth);
45 printf('      Under the cold-air-standard assumptions
        thermal efficiency would be = %.3f \n',no);
46
47 //(d)
48 //The mean effective pressure is determined from its
        definition
49 R=0.287//gas constant for water
50 v1=R*T1/P1//specific volume at state 1
51 MEP=w/(v1*(1-1/r));//mean effective pressure in kPa
52 printf(' (d) Mean effective pressure = %.0f kPa \n',

```

MEP);

---

### Scilab code Exa 9.3 The Ideal Diesel Cycle

```
1 //ques3
2 //The Ideal Diesel Cycle
3 clear
4 clc
5 disp('(a)');
6 //(a) the temperature and pressure of air at the end
   of each process
7 v1=117;//volume at state 1 in in^3
8 r=18;//volume ratio for 1 2 process
9 v2=v1/r;//volume at state 2 in in^3
10 rc=2;//volume ratio for 2-3 process
11 v3=rc*v2;//volume at state 3 in in^3
12 v4=v1;//volume state 4 in in^3
13 //Process 1-2 (isentropic compression of an ideal
   gas, constant specific heats)
14 T1=540;//temperature at state 1 in R
15 k=1.4;//constant
16 T2=T1*(v1/v2)^(k-1)//temperature in state 2 in R r=
   v1/v2
17 P1=14.7;//pressure at state 1 in psia
18 P2=P1*(v1/v2)^k//pressure at state 2 in psia
19 //Process 2-3 (constant-pressure heat addition to an
   ideal gas)
20 P3=P2//pressure at state 3 in psia
21 T3=T2*(v3/v2)//temp at state 3 in R rc=v3/v2
22 //Process 3-4 (isentropic expansion of an ideal gas,
   constant specific heats)
23 T4=T3*(v3/v4)^(k-1)//temp at state 4 in R
24 P4=P3*(v3/v4)^k//pressure at state 4 in psia
25
26 //(b)
```

```

27 R=0.3704//gas constant for given substance in btu/R.
    lbm
28 m=P1*v1/(R*T1)/1728;//mass in lbm
29 //Process 2-3 is a constant-pressure heat-addition
    process, for which the boundary work and du terms
    can be combined to dh
30 Cp=0.240//specific heat at constant pressure in Btu/
    lbm.R
31
32 Qin=m*Cp*(T3-T2);//heat input in Btu
33
34 //Process 4-1 is a constant-volume heat-rejection
    process
35 Cv=0.171;//specific heat capacity at constant volume
    in Btu/lbm.R
36 Qout=m*Cv*(T4-T1);//heat output in Btu
37
38 w=Qin-Qout;//work done in Btu
39 printf(' (b) Net work done = %.3f Btu \n',w);
40 nth=w/Qin;//efficiency of heat engine
41 printf('      The thermal efficiency = %.3f \n',nth);
42
43 //(c)The mean effective pressure
44 MEP=w/(v1-v2)*778*12;//mean effective pressure (
    multiplied by constants for unit conversion to
    psia)
45 printf(' (c) Mean effective pressure = %.0f psia \n '
    ,MEP);

```

---

#### Scilab code Exa 9.5 The Simple Ideal Brayton Cycle

```

1 //ques5
2 //The Simple Ideal Brayton Cycle
3 clear
4 clc

```

```

5 //Process 1-2 (isentropic compression of an ideal
   gas)
6 T1=300; //initial temp in K
7 //from table
8 h1=300.19; //enthalpy of heat at state 1 in kJ/kg
9 Pr1=1.386; //reduced pressure at state 1
10 r=8; //constant ratio
11 Pr2=r*Pr1; //reduced pressure at state 2, r=P2/P1
12 //using table corresponding to Pr2
13 T2=540; //temperature at state 2 in K
14 printf('(a) Temperature at compressor exit T2 = %.0f
   K \n',T2);
15 h2=544.35; //enthalpy of heat at state 2
16 //Process 3-4 (isentropic expansion of an ideal gas)
17 T3=1300; //temperature at state 3 in K
18 h3=1395.97; //enthalpy of heat at state 3 in kJ/kg
19 Pr3=330.9; //reduced pressure at state 3
20 Pr4=Pr3/r; //reduced pressure at state 4, 1/r=P4/P3
21 //from table
22 T4=770; //temperature at state 4 in K
23 printf('    Temperature at turbine = %.0f K \n',T4);
24 h4=789.37; //enthalpy of heat at state 4 in kJ/kg
25 //To find the back work ratio
26 Win=h2-h1 //work input in kJ/kg
27 Wout=h3-h4 //work output in kJ/kg
28 Rbw=Win/Wout; //back work ratio
29 printf(' (b) Back work ratio = %.3f \n',Rbw);
30 Qin=h3-h2; //heat input in kJ/kg
31 Wnet=Wout-Win; //net work
32 nth=Wnet/Qin; //thermal efficiency
33 printf(' (c) Thermal efficiency = %.3f ',nth);

```

---

### Scilab code Exa 9.6 An Actual Gas Turbine Cycle

```
1 //ques6
```

```

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

```

---

### Scilab code Exa 9.7 Actual Gas Turbine Cycle with Regeneration

```

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

```

```

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

```

---

### Scilab code Exa 9.8 A Gas Turbine with Reheating and Intercooling

```

1 //ques8
2 //A Gas Turbine with Reheating and Intercooling
3 clear
4 clc
5 //For two-stage compression and expansion, the work
    input is minimized and the work output is
    maximized when both stages of the compressor and
    the turbine have the same pressure ratio
6
7 //P2/P1=P4/P3=P6/P7=P8/P9=sqrt(8)=r
8 //At inlets: T1=T3 h1=h3 T6=T8 h6=h8
9 //At outlet T2=T4 h2=h4 T7=T9 h7=h9
10
11 //In the absence of any regeneration, the back work
    ratio and the thermal efficiency are determined
    by using data from Table A17

```

```

12 T1=300; //temperature at state 1 in K
13 h1=300.19; //enthalpy at state 1 in kJ/kg
14 T3=T1; //temperature at state 3 in K
15 h3=h1; //enthalpy at state 3
16 Pr1=1.386; //reduced pressure at state 1
17 r=sqrt(8); //constant ratio
18 Pr2=Pr1*r; //here r is for P2/P1
19 //from table
20 T2=403.3; //temp at state 2 in K
21 T4=T2; //temp at state 4 in K
22 h2=404.31; //enthalpy at state 2 in kJ/kg
23 h4=h2; //enthalpy at state 4
24
25 T6=1300; //temperature at state 6 in K
26 T8=T6; //temp at state 8
27 h6=1395.97; //enthalpy at state 6
28 h8=h6; //enthalpy at state 8
29 Pr6=330.9; //reduced pressure at state 6
30 Pr7=1/r*Pr6; //reduced pressure at state 7
31 T7=1006.4; //temperature at state 7 in K
32 T9=T7; //temperature at state 9 in K
33 h7=1053.33; //enthalpy at state 7 in kJ/kg
34 h5=h7; //enthalpy at state 5
35 h9=h7; //enthalpy at state 9
36 Wcompin=2*(h2-h1); //input work in compression in kJ/
    kg
37 Wturbout=2*(h6-h7); //output turbine work in kJ/kg
38 Wnet=Wturbout-Wcompin; //net work done in kJ/kg
39 Qin=(h6-h4)+(h8-h7); //input heat in kJ/kg
40 Rbw=Wcompin/Wturbout; //back work ratio
41 printf(' (a) Back work ratio = %.3f \n',Rbw);
42 nth=Wnet/Qin; //thermal efficiency
43 printf(' (b) Thermal Efficiency = %.3f \n',nth);
44
45 //(b)
46 qin=(h6-h5)+(h8-h7); //input specific heat in kJ/kg
47 nth=Wnet/qin; //thermal efficiency
48 printf(' (c) Thermal efficiency in this case = %.3f

```

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

---

### Scilab code Exa 9.9 The Ideal Jet Propulsion Cycle

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

```

    in a nozzle)
26 P6=5; //pressure at state 6 in psia
27 T6=T5*(P6/P5)^(1-1/k); //temp at state 6 in R
28 v6=sqrt(-1*2*Cp*(T6-T5)*25037); //velocity at state 6
    in ft/s
29 printf(' (b) Velocity v6 = %.0f ft/s \n',v6);
30 //The propulsive efficiency of a turbojet engine is
    the ratio of the propulsive power developed Wp to
    the total heat transfer rate to the working
    fluid
31 ms=100; //mass flow rate in lbm/s
32 Vexit=3288; //exit volume in ft^3
33 Vinlet=850; //inlet volume in ft^3
34 Vaircraft=850; //aircraft volume in ft^3
35
36 Wp=ms*(Vexit-Vinlet)*Vaircraft/25037; //power in Btu/
    s
37 Qin=ms*Cp*(T4-T3); //input heat in kJ/kg
38 np=Wp/Qin; //efficiency
39 printf(' (c) Efficiency = %.3f \n',np);

```

---

#### Scilab code Exa 9.10 Second Law Analysis of an Otto Cycle

```

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

```

```

12 P3=434.5; //pressure at state 3 in kPa
13 Qin=800; //heat input in kJ/kg
14 Qout=381.83; //heat output in kJ/kg
15 Wnet=418.17; //net work done in kJ/kg
16 s3o=3.5045; //entropy at state 3
17 s2o=2.4975; //entropy at state 2
18 R=0.287; //gas constant at kJ/kg/mol/K
19
20 s23=s3o-s2o-R*log(P3/P2); //entropy change for state
    2 -3 kJ/kg.K
21 Qin=800; //heat input in kJ/kg
22 Tsource=1700; //source temperature in K
23 xdest23=T0*(s23-Qin/Tsource); //irreversibility for
    state 2 3
24 //For process 4-1,
25 s14=-s23; //entropy change at state 1 4
26 Qout=381.83; //heat output in kJ/kg
27 Tsink=290; //temp of sink in K
28 xdest41=T0*(s14+Qout/Tsink); //irreversibility for
    state 4 1
29 xdest12=0; //irreversibility for state 1 2
30 xdest34=0; //irreversibility at state 3 4
31 xdestcycle=xdest12+xdest23+xdest34+xdest41; //net
    irreversibility
32 printf('Irreversibility of cycle = %.1f kJ/kg \n',
    xdestcycle);
33 s40=-s14; //entropy change for state 4 0 in kJ/k/kg
34 u40=Qout; //internal energy at state 4 0 in kJ/kg
35 v40=0; //specific volume at state 40 in m^3/kg
36 v41=0; //specific volume at state 41 in m^3/kg
37 P0=10; //initial pressure in kPa(junk value as P0 is
    multiplied by zero in next statement)
38 Q=u40-T0*s40+P0*v40; //heat in kJ/kg
39 printf(' Exergy distruction = %.1f kJ/kg \n',Q);

```

---

# Chapter 10

## Vapor and Combined Power Cycles

Scilab code Exa 10.2 An Actual Steam Power Cycle

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

```

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

```

---

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

```

1 //example 3
2 //Effect of Boiler Pressure and Temperature on
    Efficiency
3 clear
4 clc
5 P1=10 //pressure of steam in state 1 in kPa
6 P2=3000 //pressure of steam in state 2 in kPa
7 P3=3000 //pressure of steam in state 3 in kPa
8 P4=10 //pressure of steam in state 4 in kPa
9 T3=350 //temp. of state in state 3 in celsius
10 h3=3116.1 //specific heat enthalpy in state 3 in kJ/
    kg
11 s3=6.7450 //specific entropy in state 3 in kJ/kg-K
12 h1=191.81 //specific heat enthalpy in state 1 in kJ>
    kg
13 v1=0.00101 //specific volume in state 1 in m3>kg
14 wpumpin=3.02 //work done by the pump in kJ/kg
15 h2=h1+wpumpin //specific heat enthalpy in state 2 in
    kJ/kg
16 s3=6.7450 //specific entropy in state 3 in kJ/kg-K
17 s4=s3 //specific entropy in state 4
18 sf=0.6492 //in kJ/kg-K
19 sfg=7.4996 //in kJ/kg-K
20 x4=(s4-sf)/sfg //quality of steam in state 4
21 hf=191.81 // kJ/kg

```

```

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

```

---

#### Scilab code Exa 10.4 The Ideal Reheat Rankine Cycle

```
1 //example 4
2 //The Ideal Reheat Rankine Cycle
3 clear
4 clc
5 disp('the pump and the turbines are isentropic ,there
      are no pressure drops in the boiler and
      condenser , and steam leaves the condenser and
      enters the pump as saturated liquid at the
      condenser pressure.')
```

6 P6=10 //pressure at state 6 in kPa  
7 x6=0.896 //quality of steam in state 6  
8 sf=0.6492 // in kJ/kg-K  
9 sfg=7.4996 //in kJ/kg-K  
10 hf=191.81 //in kJ/kg  
11 hfg=2392.1 //in kJ/kg  
12 h6=hf+x6\*hfg //specific heat enthalpy in state 6 in  
kJ/kg  
13 s6=sf+x6\*sfg //specific entropy at state 6 in kJ/kg-K  
14 T5=600 // temperature in state 5 in Celsius  
15 s5=s6 //specific entropy in state 5  
16 disp(' At state 5, T5=600C,s5=s6.Hence,')

17 P5=4.0 //pressure at state 5 in MPa  
18 h5=3674.9 //specific heat enthalpy at state 5 in kJ/  
kg  
19 P1=10 //pressure at state 1 in kPa  
20 h1=191.81 //specific heat enthalpy at state 1 in kJ/  
kg  
21 v1=0.00101 //specific volume at state 1 in m3/kg  
22 P2=15000 //pressure at state 2 in kPa  
23 wpumpin=v1\*(P2-P1) //work done by pump in kJ/kg  
24 h2=h1+wpumpin //enthalpy in state 2 in kJ/kg  
25 P3=15000 //pressure in state 3 in kPa  
26 T3=600//temperature in state 3 in C  
27 h3=3583.1 //specific heat enthalpy in state 3 in kJ/  
kg

```

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

```

---

#### Scilab code Exa 10.5 The Ideal Regenerative Rankine Cycle

```

1 //example5
2 //The Ideal Regenerative Rankine Cycle
3 clear
4 clc
5 P1=10 //Pressure in state 1 in kPa
6 h1=191.81 //Specific enthalpy in state 1 in kJ/kg
7 v1=0.00101 //Specific volume in state 1 in m3/kg
8 P2=1200 //Pressure in state 2 in kPa
9 wpumpin=v1*(P2-P1) //work done by the pump 1 in kJ/
    kg
10 h2=h1+wpumpin //Specific Enthalpy in state 2 in kJ/
    kg
11 v3=0.001138 //Specific volume in state 3 in m3/kg
12 h3=798.33 //Specific enthalpy in kJ/kg
13 P3=1200 //Pressure in state 3 in kPa
14 P4=15000 //Pressure in state 4 in kPa
15 wpumpin2=v3*(P4-P3) //work done by pump 2 in kJ/kg
16 h4=h3+wpumpin2 //Specific ehntalpy in state 4 in kJ
    /kg

```

```

17 P5=15 //Pressure in state 5 in MPa
18 T5=600 //Temp. in state 5 in C
19 P6=1200 //Pressure in state 6 in kPa
20 h5=3583.1 //Specific enthalpy in state 5 in kJ/kg
21 s5=6.6796 //Specific entropy in state 5 in kJ/kg-K
22 h6=2860.2 //Specific enthalpy in state 6 in kJ/kg
23 T6=218.4 //Temp. in state 6 in C
24 sf=0.6492 //in kJ/kg-K
25 sfg=7.4996 //in kJ/kg-K
26 s5=6.6796 //Specific entropy in state 5 in kJ/kg-K
27 s6=s5 //Specific entropy in state 6
28 s7=s5 //Specific entropy in state 7
29 x7=(s7-sf)/sfg //quality of steam in state 7
30 hf=191.81 //in kJ/kg
31 hfg=2392.1 //in kJ/kg
32 h7=hf+x7*hfg //Specific enthalpy in state 7 in kJ/kg
33 y=(h3-h2)/(h6-h2) //fraction of steam extracted from
    the turbine
34 qin=h5-h4 //heat coming in in kJ/kg
35 qout=(h7-h1)*(1-y) //heat going out in kJ/kg
36 n=1-qout/qin //Thermal efficiency of the cycle
37 printf("\n Hence, the fraction of steam extracted
    from the turbine is = %.4f. \n",y);
38 printf("\n and thermal efficiency of the cycle is =
    %.3f. \n",n);

```

---

#### Scilab code Exa 10.6 The Ideal Reheat Regenerative Rankine Cycle

```

1 //example 6
2 //The Ideal ReheatRegenerative Rankine Cycle
3 clear
4 clc
5 h1=191.81 //specific heat enthalpy for state 1 in kJ
    /kg
6 h2=192.30 //specific heat enthalpy for state 2 in kJ

```

```

    /kg
7  h3=640.09 //specific heat enthalpy for state 3 in kJ
    /kg
8  h4=643.92 //specific heat enthalpy for state 4 in kJ
    /kg
9  h5=1087.4 //specific heat enthalpy for state 5 in kJ
    /kg
10 h6=1087.4 //specific heat enthalpy for state 6 in kJ
    /kg
11 h7=1101.2 //specific heat enthalpy for state 7 in kJ
    /kg
12 h8=1089.8 //specific heat enthalpy for state 8 in kJ
    /kg
13 h9=3583.1 //specific heat enthalpy for state 9 in kJ/
    kg
14 h10=3155.0 //specific heat enthalpy for state 10 in
    kJ/kg
15 h11=3674.9 //specific heat enthalpy for state 11 in
    kJ/kg
16 h12=3014.8 //specific heat enthalpy for state 12 in
    kJ/kg
17 h13=2335.7 //specific heat enthalpy for state 13 in
    kJ/kg
18 wpumpin1=0.49 //work done by pump 1 in kJ/kg
19 wpumpin2=3.83 //work done by pump 2 in kJ/kg
20 wpumpin3=13.77 //work done by pump 3 in kJ/kg
21 y=(h5-h4)/(h5-h4+h10-h6) //fraction of steam
    extracted
22 z=(1-y)*(h3-h2)/(h12-h2)
23 h8=(1-y)*h5+y*h7 //specific heat enthalpy for state
    8 in kJ/kg
24 qin=(h9-h8)+(1-y)*(h11-h10) //heat coming in in kJ/
    kg
25 qout=(1-y-z)*(h13-h1) //heat going out in kJ/kg
26 n=1-qout/qin //thermal efficiency of cycle
27 printf("\n Hence, the fraction of steam extracted
    from the turbine is = %.4f. \n",y);
28 printf("\n and thermal efficiency of the cycle is =

```

```
%.3f. \n",n);
```

---

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

```
1 //example 7
2 //Second-Law Analysis of an Ideal Rankine Cycle
3 clear
4 clc
5 xdest12=0 //irreversibility during the process 1 to
6           2 in kJ/kg
7 xdest34=0 //irreversibility during the process 3 to
8           4 in kJ/kg
9 s2=1.2132 //specific entropy for state 2 in kJ/kg-K
10 s4=6.7450 //specific entropy for state 4 in kJ/kg-K
11 s1=s2 //specific entropy for state 1 in kJ/kg-K
12 s3=s4 //specific entropy for state 3 in kJ/kg-K
13 qin23=2728.6 //heat input for the process 2 to 3 in
14           kJ/kg
15 Tsource=1600 //temperature of furnaace in K
16 To=290 //temp. of cooling medium in K
17 xdest23=To*(s3-s2-qin23/Tsource) //irreversibility
18           during the process 2 to 3 in kJ/kg
19 Tsink=To //temperature of sink
20 qout41=2018.6 //in kJ/kg
21 xdest41=To*(s1-s4+qout41/Tsink) //irreversibility
22           during the process 4 to 1 in kJ/kg
23 xdestcycle=xdest12+xdest23+xdest34+xdest41 //
24           irreversibility of cycle
25 ho=71.355 //in kJ/kg
26 so=0.2533 //in kJ/kg-K
27 h4=2403.0 //in kJ/kg
28 e4=(h4-ho)-To*(s4-so)//exergy of steam leaving the
29           turbine in kJ/kg
30 printf("\n Hence, the exergy destruction associated
31           with the rankine cycle is =%.0f kJ/kg. \n",
```

```

    xdestcycle);
24 printf("\n and exergy of steam leaving the turbine
    is = %.0f. \n",e4);

```

---

### Scilab code Exa 10.8 An Ideal Cogeneration Plant

```

1 //example 8
2 //An Ideal Cogeneration Plant
3 clear
4 clc
5 v8=0.001005 //specific volume for state 3 in m3/kg
6 P9=7000 //pressure at state9 in kPa
7 P8=5//pressure at state 8 in kPa
8 wpumpin1=v8*(P9-P8) //work done by pump 1 in kJ/kg
9 v7=0.001093 //specific volume for state 7 in m3>kg
10 P10=7000 //pressure for state 10 in kPa
11 P7=500//pressure for state 7 in kPa
12 wpumpin2=v7*(P10-P7) //work done by pump 2 in kJ/kg
13 h4=3411.4 //specific enthalpy for state 4 in kJ/kg
14 h3=h4 //specific enthalpy for state 3
15 h2=h4 //specific enthalpy for state 2
16 h1=h4 //specific enthalpy for state 1
17 h5=2739.3 //specific enthalpy for state 5 in kJ/kg
18 h6=2073.0 //specific enthalpy for state 6 in kJ/kg
19 h7=640.09 //specific enthalpy for state 7 in kJ/kg
20 h8=137.75 //specific enthalpy for state 8 in kJ/kg
21 h9=h8+wpumpin1 //specific enthalpy for state 9 in kJ
    /kg
22 h10=h7+wpumpin2 //specific enthalpy for state 10 in
    kJ/kg
23 disp('Since all the steam the boiler is throttled
    and sent to the process heater and none is sent
    to the turbine , therefore')
24 M1=15//mass flow rate for steam in kg/s
25 M4=15// in kg/s

```

```

26 M7=15 //in kg/s
27 M=M1
28 M3=0
29 M5=0
30 M6=0
31 Qpmax=M1*(h4-h7) //Maximum rate at which process
    heat can be supplied in kW
32 Wturbout=M*(h3-h6) //Work done by turbine in kW
33 Wpumpin=M*wpumpin2 //Work done by pump in kW
34 Wnetout=Wturbout-Wpumpin //power produced in kW
35 h11=144.78 //Specific enthalpy for state 11 when no
    heat is supplied
36 Qin=M1*(h1-h11)
37 Qp=0 //rate of supply of process heat in kW
38 e=(Qp+Wnetout)/Qin //utilization factor
39 disp('Now, calculating the rate of process heat
    supply when 10 percent of the steam is extracted
    before it enters the turbine and 70 percent of
    the steam is extracted from the turbine at 500
    kPa for process heating')
40 M4=0.1*15 //in kg/s
41 M5=0.7*15 // in kg/s
42 M7=M4+M5 //in kg/s
43 Qpout=M4*h4+M5*h5-M7*h7 //rate of process heat
    supply in kW
44 printf("\n Hence, the maximum rate at which process
    heat can be supplied is = %.0f kW. \n", Qpmax);
45 printf("\n The power produced when no heat is
    supplied is = %.1f MW. \n", Wnetout/1000);
46 printf("\n and utilization factor is = %.3f . \n", e)
    ;
47 printf("\n the rate of process heat supply when 10
    percent of the steam is extracted before it
    enters the turbine and 70 percent of the steam is
    extracted from the turbine at 500 kPa for
    process heating = %.1f MW. \n", Qpout/1000);

```

---

### Scilab code Exa 10.9 A Combined Gas Steam Power Cycle

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

---

# Chapter 11

## Refrigeration Cycles

Scilab code Exa 11.2 The Actual Vapor Compression Refrigeration Cycle

```
1 //ques2
2 //The Actual Vapor-Compression Refrigeration Cycle
3 clear
4 clc
5 //state 1
6 P1=0.14; //Pressure in MPa
7 T1=-10; //Temperature in C
8 h1=246.36; //enthalpy of heat in kJ/kg
9 //state 2
10 P2=0.8; //Pressure in MPa
11 T2=50; //Temperature in C
12 h2=286.69; //Enthalpy of heat in kJ/kg
13 //state 3
14 P3=0.72; //Pressure in MPa
15 T3=26; //Temperature in C
16 h3=87.83; //Enthalpy in kJ/kg
17
18 h4=h3; //throttling
19 ms=0.05; //mass flow rate in kg/s
20 Q1s=ms*(h1-h4); //heat removal in kW
21 Wins=ms*(h2-h1); //Power in kW
```

```

22 printf('(a) Rate of heat removal = %.2f kW \n',Q1s);
23 printf('      Power = %.2f kW \n',Wins);
24
25 //(b)The isentropic efficiency of the compressor is
      determined as
26 h2s=284.21;
27 nc=(h2s-h1)/(h2-h1);
28 printf(' (b) Isentropic efficiency = %.3f \n',nc);
29 COPr=Q1s/Wins;
30 printf(' (c) Coefficient of performance of the
      refrigerator = %.1f \n',COPr);

```

---

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

```

1 //ques4
2 //A Two-Stage Refrigeration Cycle with a Flash
      Chamber
3 clear
4 clc
5 h6=95.47;//Enthalpy at state 6 in kJ/kg
6 hf=55.16;//Enthalpy of liquid water in kJ/kg
7 hfg=196.71;//difference in enthalpy of water and
      vapor in kJ/kg
8 x6=(h6-hf)/hfg;
9 printf('(a) Fraction of the refrigerant that
      evaporates = %.4f \n',x6);
10 h1=239.16;//enthalpy at state 1 in kJ/kg
11 h8=55.16;//Enthalpy at state 8 in kJ/kg
12 Q1=(1-x6)*(h1-h8);//heat removal in kJ/kg
13 printf(' (b) Amount of heat removed from refrigerant
      = %.1f kJ/kg \n',Q1);
14 //The enthalpy at state 9 is determined from an
      energy balance on mixing chamber
15 //Ein=Eout ie h9=x6*h3+(1-x6)*h2
16 h3=251.88;//Enthalpy at state 3 n kJ/kg

```

```

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

```

---

### Scilab code Exa 11.5 The Simple Ideal Gas Refrigeration Cycle

```

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

```

```

22 Pr4=1/r*Pr3;//1/r = P4/P3
23 //from table
24 h4=86.7;//Btu/lbm
25 T4=363;//R
26 printf('      Temperature T4 = %.0f R \n',T4);
27 Q1=h1-h4;//Btu/lbm
28 Wturbout=h3-h4;//work output by turbine in kJ/kg
29 Wcompin=h2-h1;//work input by compressor in kJ/kg
30 Wnetin=Wcompin-Wturbout;//net work in kJ/kg
31 COPr=Q1/Wnetin;
32 printf(' (b) Coefficient of Performance = %.2f \n',
      COPr);
33 ms=0.1;//mass flow in lbm/s
34 Qrefs=ms*Q1;
35 printf(' (c) Rate of refrigeration = %.2f Bu/sec \n'
      ,Qrefs);

```

---

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

```

1 //ex6
2 //Cooling of a Canned Drink by a Thermoelectric
  Refrigerator
3 clear
4 clc
5 d=1;//density in kg/L
6 V=0.350;//volume in L
7 m=d*V;//mass in Kg
8 c=4.18;//specific heat in kJ/kg.C
9 T2=20;//Temperature in C
10 T1=4;//Temperature in C
11 Qcooling=m*c*(T2-T1);//heat of cooling in kJ
12
13 t=30*60;//sec
14 Qcoolings=Qcooling/t;//rate of cooling in kW
15 COPr=0.10;

```

```
16 Wins=Qcoolings/COPr;  
17 printf('Power = %.0f W',Wins*1000);
```

---

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

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

---

# Chapter 12

## Thermodynamic Property Relations

Scilab code Exa 12.1 Approximating Differential Quantities by Differences

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

---

Scilab code Exa 12.2 Total Differential versus Partial Differential

```
1 //example 2
```

```

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

```

---

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

```

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

```

---

**Scilab code Exa 12.6** Extrapolating Tabular Data with the Clapeyron Equation

```

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

```

---

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

```

1 //example 11
2 //dh and ds of Oxygen at High Pressures
3 clear
4 clc
5 T1=220 //Initial Temp. in K
6 P1=5 //Initial Pressure in MPa
7 T2=300 //Final Temp.in K
8 P2=10// Final Pressure in MPa
9 h2ideal=8736//in kJ/mol
10 h1ideal=6404 //in kJ/mol
11 Ru=8.314 //Universal Gas constant in kJ/kmol-K
12 s2o=205.213 //in kJ/kmol-K
13 s1o=196.1712 //in kJ/kmol-K
14 Tcr=154.8 //Critical Temp. in K
15 Pcr=5.08 //Critical Pressure in MPa
16 Tr1=T1/Tcr //Reduced initial temp.
17 Pr1=P1/Pcr //Reduced initial pressure

```

```

18 Tr2=T2/Tcr//Reduced final Temp.
19 Pr2=P2/Pcr //Reduced Final Pressure
20 Zh1=0.53
21 Zs1=0.25
22 Zh2=0.48
23 Zs2=0.20
24 dhi=h2ideal-h1ideal// Enthalpy change by assuming
    ideal gas behaviour
25 dhn=dhi-Ru*Tcr*(Zh2-Zh1) //Enthalpy change by
    accounting for deviation from ideal gas behaviour
26 dsi=s2o-s1o-Ru*log(P2/P1)// Entropy change by
    assuming ideal gas behaviour
27 dsn=dsi-Ru*(Zs2-Zs1)//Entropy change by accounting
    for deviation from ideal gas behaviour
28 printf(" Hence, by assuming ideal gas behaviour ,
    enthalpy change is = %.0f kJ/kmol ",dhi);
29 printf("and entropy change is = %.2f kJ/kmol-K. ",
    dsi);
30 printf("\n By accounting for deviation from ideal
    gas behaviour , enthalpy change is=%.0f kJ/kmol ",
    dhn);
31 printf("and entropy change is = %.2f kJ/kmol-K. \n",
    dsn);

```

---

# Chapter 13

## Gas Mixtures

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

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

```

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

```

---

### Scilab code Exa 13.2 PVT Behavior of Nonideal Gas Mixtures

```

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

```

```

19 PcrN2=3.39 //critical pressure of N2 in MPa
20 PcrCO2=7.39 //critical pressure in MPa
21 Pcrm=yN2*PcrN2+yCO2*PcrCO2 //pseodo critical
    pressure of mixture in MPa
22 Tm=300 //actual critical temp. of mixture in kelvins
23 Pm=15 //actual critical pressure of mixture in MPa
24 Tr=Tm/Tcrm //Reduced Temp. of mixture
25 Pr=Pm/Pcrm //Reduced pressure of mixture
26 Zm1=Tr/Pr //compressibility of the mixture
27 Vm1=Zm1*Vm //volume of tank on the basis of Kays rule
    in m^3
28 printf("\n Hence, the volume of the mixture on the
    basis of Kays rule is = %.3f m^3. \n",Vm1);
29 disp('Now, estimating volume of tank on the basis of
    compressibility factors and Amagats law')
30 TrN2=Tm/TcrN2 //Reduced Temp. of N2
31 PrN2=Pm/PcrN2 //Reduced Pressure of N2
32 ZN2=1.02 //compressibility factor of N2
33 TrCO2=Tm/TcrCO2 //Reduced Temperature of CO2
34 PrCO2=Pm/PcrCO2 //Reduced pressure of CO2
35 ZCO2=0.30 //compressibility factor of CO2
36 Zm2=ZN2*yN2+ZCO2*yCO2 //compressibility factor of
    the mixture
37 Vm2=Zm2*Vm //volume of the mixture in m^3
38 printf("\n Hence, the volume of the mixture on the
    basis of compressibility factors and Amagats law
    is = %.3f m^3. \n",Vm2);
39 disp('Now, estimating volume of tank on the basis of
    compressibility factors and daltons law')
40 VrN2=(Vm/NN2)/(Ru*TcrN2/(PcrN2*1000))
41 VrCO2=(Vm/NC02)/(Ru*TcrCO2/(PcrCO2*1000))
42 ZN2=0.99 //compressibility factor of N2
43 ZCO2=0.56 //compressibility factor of CO2
44 Zm3=yN2*ZN2+yCO2*ZCO2 //compressibility factor of
    the mixture
45 Vm3=Zm3*Vm //volume of the mixture in m^3
46 disp('This is 33 percent lower than the assumed
    value. Therefore, we should repeat the

```

calculations , using the new value of  $V_m$ . When the calculations are repeated we obtain  $0.738 \text{ m}^3$  after the second iteration ,  $0.678 \text{ m}^3$  after the third iteration , and  $0.648 \text{ m}^3$  after the fourth iteration. This value does not change with more iterations. Therefore')

```

47  $V_m=0.648$  //volume of the mixture in  $\text{m}^3$ 
48 printf("\\n Hence, the volume of the mixture on the
    basis of compressibility factors and Daltons law
    is = %.3f  $\text{m}^3$ . \\n", $V_m$ );

```

---

### Scilab code Exa 13.3 Mixing Two Ideal Gases in a Tank

```

1 //example 3
2 //Mixing Two Ideal Gases in a Tank
3 clear
4 clc
5 disp('We assume both gases to be ideal gases , and
    their mixture to be an ideal-gas mixture. This
    assumption is reasonable since both the oxygen
    and nitrogen are well above their critical
    temperatures and well below their critical
    pressures. ')
6  $C_{vN2}=0.743$  //Constant-Volume Specific heat of N2 in
    kJ/kg-K
7  $C_{vO2}=0.658$  //Constant-Volume Specific heat of O2 in
    kJ/kg-K
8 disp('This is a closed system since no mass crosses
    the boundary during the process. We note that the
    volume of a rigid tank is constant and thus ,
    there is no boundary work done. ')
9  $T_{1N2}=20$  // Temperature of N2 in celsius
10  $T_{1O2}=40$  // Temperature of O2 in celsius
11  $m_{N2}=4$  //mass of N2 in kg
12  $m_{O2}=7$  //mass of O2 in kg

```

```

13 Tm=(mN2*CvN2*T1N2+mO2*CvO2*T1O2)/(mN2*CvN2+mO2*CvO2)
    //Temp. of mixture in Celsius
14 printf("\n Hence, the temp. of the mixture is = %.1f
    C. \n",Tm)
15 NO2=mO2/32 //No. of kmol of O2
16 NN2=mN2/28 //No. of kmol of N2
17 Nm=NO2+NN2 //Total No. of kmol of mixture
18 Ru=8.314 //Universal Gas Constant in kPa-m^3/kmol-K
19 P1O2=100 //Initial Pressure of O2 in kPa
20 P1N2=150 //Initial Pressure of N2 in kPa
21 V02=NO2*Ru*(T1O2+273)/P1O2//Initial volume of O2 in
    m^3
22 VN2=NN2*Ru*(273+T1N2)/P1N2 //Initial volume of N2 in
    m^3
23 Vm=V02+VN2 //total volume of mixture in m^3
24 Pm=Nm*Ru*(Tm+273)/Vm //Mixture Pressure after
    equilibrium in kPa
25 printf("\n Hence, the mixture pressure after
    equilibrium is = %.1f kPa. \n",Pm)

```

---

### Scilab code Exa 13.4 Exergy Destruction during Mixing of Ideal Gases

```

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

```

```

10 yCO2=NC02/Nm //mole fraction of CO2
11 Ru=8.314 //Universal Gas Constant in kJ/kmol-K
12 dSm=-Ru*(N02*log(y02)+NC02*log(yC02)) //Entropy
    change in kJ/K
13 To=298 //Temp. of surroundings in kelvins
14 X=To*dSm //energy destruction in the process in kJ
15 printf("\n Hence, the exergy destruction in the
    process is = %.1f MJ. \n",X/10^3);

```

---

### Scilab code Exa 13.5 cooling of non ideal gas mixture

```

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

```

```

21 qout=yN2*(h1N2-h2N2)+yO2*(h1O2-h2O2) //Heat Transfer
    in kJ/kmol
22 printf("\n Hence, the heat transfer during the
    process using the ideal gas approximation is = %
    .0f kJ/kmol. \n",qout);
23 disp('calculating heat transfer per kmol of air
    using Kays law')
24 Tcrm2=yN2*TcrN2+yO2*TcrO2 //critical temp. of
    pseudopure substance
25 Pcrm2=yN2*PcrN2+yO2*PcrO2 //critical pressure of
    pseudopure substance
26 Tr1=T1/Tcrm2 //Reduced Temp. at T1
27 Tr2=T2/Tcrm2 //Reduced Temp. at T2
28 Zh1m=1.0 //Compressibility factor at T1
29 Zh2m=2.6 //Compressibility Factor at T2
30 Pr=Pm/Pcrm2 //Reduced Pressure
31 h1m=yN2*h1N2+yO2*h1O2 //Enthalpy of the mixture at
    T1 in kJ/kmol
32 h2m=yN2*h2N2+yO2*h2O2 //Enthalpy of the mixture at
    T2 in kJ/kmol
33 qout=(h1m-h2m)-Ru*Tcrm2*(Zh1m-Zh2m)//Heat transfer
    during the process in kJ/kmol
34 printf("\n Hence, the heat transfer during the
    process using Kays law is = %.0f kJ/kmol. \n",
    qout);
35 disp('calculating heat transfer per kmol of air
    using Amagats law')
36 Zh1N2=0.9 //Compressibility factor of N2 at T1
37 Zh2N2=2.4 //Compressibility factor of N2 at T2
38 Zh1O2=1.3 //Compressibility factor of O2 at T1
39 Zh2O2=4.0 //Compressibility factor of O2 at T2
40 dhN2=(h1N2-h2N2)-Ru*TcrN2*(Zh1N2-Zh2N2) //Enthalpy
    change for N2 in kJ/kmol
41 dhO2=(h1O2-h2O2)-Ru*TcrO2*(Zh1O2-Zh2O2) //Enthaloy
    change for O2 in kJ/kmol
42 qout=yN2*dhN2+yO2*dhO2 //kJ/mol //heat transfer
    during the process in kJ/kmol
43 printf("\n Hence, the heat transfer during the

```

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

---

### Scilab code Exa 13.6 obtaining fresh water from sea water

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

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

---

## Chapter 14

# Gas Vapour Mixtures and Air Conditioning

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

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

```

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

```

---

#### Scilab code Exa 14.2 Fogging of the windows in house

```

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

```

---

#### Scilab code Exa 14.3 The Specific and Relative Humidity of Air

```

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

```

---

#### Scilab code Exa 14.4 The Use of the Psychrometric Chart

```

1 //example 4
2 // The Use of the Psychrometric Chart
3 clear

```

```

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

```

---

Scilab code Exa 14.5 Heating and Humidification of Air

```

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

```

```

28 w3=0.622*x3*Pg3/(P3-x3*Pg3)//kg water/kg dry air
29 mw=ma*(w3-w2) //required mass flow rate of the steam
    in the humidifying section in kg/min
30 printf("\n Hence, the rate of heat supply in the
    heating section is=%0.0f kJ/min. \n",qin);
31 printf("\n The mass flow rate of the steam required
    in the humidifying section is=%0.3f kg/min\n",mw);

```

---

#### Scilab code Exa 14.6 Cooling and Dehumidification of Air

```

1 //example 6
2 //Cooling and Dehumidification of Air
3 clear
4 clc
5 disp('This is a steady-flow process and thus the
    mass flow rate of dry air remains constant during
    the entire process')
6 h1=85.4 //Specific enthalpy for state 1 in kJ/kg dry
    air
7 w1=0.0216 //kg water/kg dry air
8 v1=0.889 //Specific volume for state 1 in m3/kg dry
    air
9 h2=39.3 // Specific enthalpy for state 2 in kJ/kg
    dry air
10 w2=0.0100 //kg water/kg dry air
11 V1=10 //volume flow rate of air in m^3/min
12 hw=58.8 //enthalpy of saturated liquid water at 14 C
    in kJ/kg
13 ma=V1/v1 //mass flow rate of dry air in kg/min
14 mw=ma*(w1-w2) //rate of moisture removal in m^3/min
15 qout=ma*(h1-h2)-mw*hw //rate of heat removal from
    air in kJ/min
16 printf("\n Hence, the rate of moisture removal from
    dry air is = %0.3f kg/min. \n",mw);
17 printf("\n and rate of heat removal is = %0.0f kJ/min

```

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

---

### Scilab code Exa 14.8 Mixing of Conditioned Air with Outdoor Air

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

```

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

```

---

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

```

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

```

---

# Chapter 15

## Chemical Reactions

Scilab code Exa 15.1 Balancing the Combustion Equation

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

---

Scilab code Exa 15.2 Dew Point Temperature of Combustion Products

```

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

```

---

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

```

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

```

```

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

```

---

#### Scilab code Exa 15.4 Reverse Combustion Analysis

```

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

```

```

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

```

---

### Scilab code Exa 15.5 Evaluation of the Enthalpy of Combustion

```

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

```

---

### Scilab code Exa 15.6 First Law Analysis of Steady Flow Combustion

```

1 //example 6
2 //First-Law Analysis of Steady-Flow Combustion
3 clear
4 clc

```

```

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

```

---

#### Scilab code Exa 15.7 First law analysis of combustion in bomb

```

1 //example 7
2 //first law analysis of combustion in bomb
3 clear
4 clc
5 Preact=1 //initial pressure in atm
6 Nreact=4 //Mo. of lbmol of reactants
7 Treact=537 //Temp. of reactants in R
8 Nprod=4 //No. of lbmol of products
9 Tprod=1800 //Temp. of products in R
10 Pprod=Preact*Nprod*Tprod/(Nreact*Treact) //final
    pressure of products in atm

```

```

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

```

---

#### Scilab code Exa 15.8 Adiabatic Flame Temperature in Steady Combustion

```

1 //example 8
2 //Adiabatic Flame Temperature in Steady Combustion
3 clear
4 clc
5 hfC8H18=-249950 //in kJ/kmol
6 hfO2=0 //in kJ/kmol
7 hO2=8682 //in kJ/kmol
8 hfN2=0 //in kJ/kmol
9 hN2=8669 //in kJ/kmol
10 hfH2O=-241820 //in kJ/kmol
11 hH2O=9904 //in kJ/kmol
12 hfCO2=-393520 //in kJ/kmol
13 hCO2=9364 //in kJ/kmol
14 Hprod=8*hfCO2+9*hfH2O+47*hfN2 //in kJ
15 Hmol=Hprod/(8+9+47) //enthalpy per mole
16 disp('This enthalpy value corresponds to about 2650
    K for N2, 2100 K for H2O, and 1800 K for CO2. But
    since, the majority of the moles are N2, we see
    that Tprod should be close to 2650 K, but
    somewhat under it.')
17 disp('For 2400 K, the value is higher than actual
    Hprod and for 2350 K, it is lower than that value
    .By interpolation, it comes out to be Tprod=2395

```

```

    K')
18 Tprod=2395 //in K
19 printf("\n Hence,The adiabatic flame temperature for
    complete combustion with 100 percent theoretical
    air is=%0.0f K. \n",Tprod);
20 disp('Similarly , the adiabatic flame temperature
    for complete combustion with 400 percent
    theoretical air is 962 K and with 90% theoretical
    air is 2236 K.')

```

---

**Scilab code Exa 15.9** Reversible work associated with combustion process

```

1 //example 9
2 //reversible work associated with combustion process
3 clear
4 clc
5 NC02=1 //mass of CO2 in lbmol
6 gfCO2=-169680 //Enthalpy of formation for CO2 in Btu
    /lbmol
7 Wrev=-NC02*gfCO2 //Reversible work for the given
    pcess in Btu
8 printf("\n Hence, the reversible work for this
    process is = %0.0f Btu. \n",Wrev);

```

---

**Scilab code Exa 15.11** Second law analysis of isothermal combustion

```

1 //example 11
2 //second law analysis of isothermal combustion
3 clear
4 clc
5 Pv=3.1698 //Partial pressure of water vapour in kPa
6 Ptotal=101.325 //Total pressure of products in kPa
7 x=Pv/Ptotal

```

```

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

```

---

# Chapter 16

## Chemical and Phase Equilibrium

Scilab code Exa 16.1 Equilibrium Constant of a Dissociation Process

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

---

### Scilab code Exa 16.2 Dissociation Temperature of Hydrogen

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

---

### Scilab code Exa 16.6 Enthalpy of Reaction of a Combustion Process

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

```

10 hoH20=9904 //in kJ/kmol
11 hfH2=0 //standard heat of formation of H2
12 hH2=61400 //in kJ/kmol
13 hoH2=8468 //in kJ/kmol
14 hfO2=0 //standard heat of formation of O2
15 hO2=67881 //in kJ/kmol
16 hoO2=8682//in kJ/kmol
17 hr1=NH20*(hfH20+hH20-hoH20)-NH2*(hfH2+hH2-hoH2)-NO2
    *(hfO2+hO2-hoO2) //Enthalpy of reaction in kJ/
    kmol using enthalpy data
18 Ru=8.314 //Universal Gas Constant in kJ/kmol-K
19 T1=1800 //suitable temp. lower than and closest to
    2000K in K
20 T2=2200 //suitable temp. higher than and closest to
    2000K in K
21 Kp1=18509 //Equilibrium constant at T1
22 Kp2=869.6 //Equilibrium constant at T2
23 hr2=Ru*log(Kp2/Kp1)/((1/T1)-(1/T2)) //Enthalpy of
    reaction in kJ/kmol using Kp data
24 printf("\n Hence, Equilibrium Constant using Enthalpy
    data is = %.0f kJ/kmol. \n",hr1);
25 printf("\n Hence, Equilibrium Constant using Kp data
    is = %.0f kJ/kmol. \n",hr2);

```

---

### Scilab code Exa 16.7 Phase Equilibrium for a Saturated Mixture

```

1 //example 7
2 //Phase Equilibrium for a Saturated Mixture
3 clear
4 clc
5 hf=503.81 // in kJ/kg,
6 sf=1.5279 // in kJ/kg-K
7 hg=2706.0 //in kJ/kg
8 sg=7.1292 //in kJ/kg-K
9 T=393.15 //Given temp. in K

```

```

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

```

---

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

```

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

```

---

#### Scilab code Exa 16.9 The Amount of Dissolved Air in Water

```

1 //example 9
2 //The Amount of Dissolved Air in Water
3 clear
4 clc
5 Pv=1.96 //kPa

```

```

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

```

---

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

```

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

```

---

#### Scilab code Exa 16.11 Composition of Different Phases of a Mixture

```

1 //example 11
2 //Composition of Different Phases of a Mixture
3 clear

```

```
4 clc
5 yH2O1=0.3
6 yNH31=0.7
7 PH20sat=7.3851 //kPa
8 PNH3sat=1554.33 //kPa
9 PH20g=yH2O1*PH20sat //vapour pressure of h2o
10 PNH3g=yNH31*PNH3sat // vapour pressure of nh3
11 Ptotal=PH20g+PNH3g
12 yH20g=PH20g/Ptotal //mole fraction of h2o in gas
    phase
13 yNH3=PNH3g/Ptotal //mole fraction of nh3 in gas
    phase
14 printf("\\n The mole fraction of H2O in the mixture
    is = %.4f . \\n",yH20g);
15 printf("\\n The mole fraction of NH3 in the mixture
    is = %.4f . \\n",yNH3);
```

---

# Chapter 17

## Compressible Flow

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

```
1 //ques1
2 //Compression of High-Speed Air in an Aircraft
3 clear
4 clc
5 //(a) the stagnation pressure at the compressor
   inlet (diffuser exit) can be determined from Eq.
   17 5 in book
6 //state 1
7 T1=255.7;//Temperature in K
8 V1=250;//velocity in m/s
9 Cp=1.005;//specifc heat at const pressure in kJ/kg/K
10 T01=T1+V1^2/(2*Cp)/1000;//divide 1000 to convert it
   into K
11 //now from eqn 17-5
12 P1=54.05;//pressure in kPa
13
14 k=1.4;
15 P01=P1*(T01/T1)^(k/(k-1));
16 printf('(a) Pressure P01 = %.2f kPa \n',P01);
17
18 //(b) To determine the compressor work
```

```

19 r=8//P02/P01
20 T02=T01*r^(1-1/k); //Temperature in K
21 //Disregarding potential energy changes and heat
    transfer, the compressor work per unit mass of
    air is determined from Eq. 17.8
22 Win=Cp*(T02-T01); //Work input in kJ/kg
23 printf(' (b) Work input = %.1f kJ/kg \n',Win);

```

---

### Scilab code Exa 17.2 Mach Number of Air Entering a Diffuser

```

1 //ques2
2 //Mach Number of Air Entering a Diffuser
3 clear
4 clc
5 //(a) The speed of sound in air at 30 C is
    determined as
6 k=1.4;
7 R=0.287; //gas constant
8 T=303; //air temperature in K
9 c=sqrt(k*R*T*1000); //speed of light in m/s
10 printf('(a) speed = %.0f m/s \n',c);
11 //(b) Mach Number
12 V=200; //speed in m/s
13 Ma=V/c;
14 printf('(b) Mach number = %.3f ',Ma);

```

---

### Scilab code Exa 17.3 Gas Flow through a Converging Diverging Duct

```

1 //ques3
2 //Gas Flow through a Converging Diverging Duct
3 clear
4 clc

```

```

5 Cp=0.846; //specific heat at constant pressure in kJ/
  kg/K
6 R=0.1889; //gas constant for substance
7 T0=473; //temp at state 0 in K
8 T1=T0; //temp at state 1 in K
9 P0=1400; //pressure at state 0 in kPa
10 P1=P0; //pressure at state 1 in kPa
11 //from Eqn 17-5
12 P=1200; //pressure in kPa
13 k=1.289;
14 T=T0*(P/P0)^(1-1/k); //Temp in K
15 //from Eqn 17-4
16 T=457; //K
17 V=sqrt(2*Cp*(T0-T)*1000); //velocity in m/s
18 printf('Velocity = %.1f m/s \n',V);
19 //From the ideal-gas relation ,
20 d=P/(R*T);
21 printf(' Density = %.1f kg/m^3 \n',d);
22 //From the mass flow rate relation ,
23 ms=3; //mass flow in kg/s
24 A=ms/(d*V); //area in m^2
25 printf(' Area = %.1f cm^2 \n',A*10000);
26 //speed
27 k=1.289;
28 c=sqrt(k*R*T*1000); //speed in m/s
29 Ma=V/c;
30 printf(' Mach number = %.3f ',Ma);

```

---

#### Scilab code Exa 17.4 Critical Temperature and Pressure in Gas Flow

```

1 //ques4
2 //Critical Temperature and Pressure in Gas Flow
3 clear
4 clc
5 k=1.289;

```

```

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

```

---

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

```

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

```

```

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

```

---

#### Scilab code Exa 17.7 Airflow through a Converging Diverging Nozzle

```

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

```

```

19 //Since the flow is isentropic , the properties at
    the exit plane can also be calculated by using
    data from Table A 32. For Ma = 2
20 Pe=0.1278*P0; //MPa
21 Te=0.5556*T0; //K
22 de=0.23*d0; //density in kg/m^3
23 Ax=20; //cm^2
24 Ae=1.6875*Ax; //cm^2
25 Mae=2;
26 Maex=1.633;
27 Ve=Maex*Vx; //m/s
28 printf(' (b) Pe = %.4 f kPa \n',Pe);
29 printf('      Te = %.1 f K \n',Te);
30 printf('      de = %.3 f kg/m^3 \n',de);
31 printf('      Ae = %.2 f cm^2 \n',Ae);
32 printf('      Ve = %.1 f m/s \n',Ve);
33
34 //(c)
35 ms=dx*Ax*Vx*10^-4;
36 printf(' (c) Mass flow rate = %.2 f kg/s \n',ms);

```

---

### Scilab code Exa 17.9 Shock Wave in a Converging Diverging Nozzle

```

1 //ex9
2 //Shock Wave in a Converging Diverging Nozzle
3 clear
4 clc
5 //fluid property at exi nozzle
6 P01=1; //pressure in MPa
7 P1=0.1278; //pressure in MPa
8 T1=444.5; //temperature in K
9 d1=1.002; //density in Kg/m^3
10 //The fluid properties after the shock (denoted by
    subscript 2) are related to those before the
    shock through the functions listed in Table A 33

```

```

11 Ma1=2;
12 Ma2=0.5774;
13 P02=0.7209*P01;//stagnation pressure in MPa
14 P2=4.5*P1;//Static Pressure in MPa
15 T2=1.6875*T1;//Static Pressure in K
16 d2=2.6667*d1;//Static Pressure n kg/m^3
17
18 printf('(a) Stagnation pressure = %.0f MPa \n',P02);
19 printf('      Static PResure = %.4f MPa \n',P2);
20 printf('      Static Temperature = %.1f K \n',T2);
21 printf('      static density = %.2f kg/m^3 \n',d2);
22 //(b)
23 R=0.287;
24 Cp=1.005;//specific heat at constant pressure in kJ/
    kg.K
25 S=Cp*log(T2/T1)-R*log(P2/P1);//entropy change in kJ/
    kg.K
26 printf(' (b) The entropy change across the shock = %
    .4f kJ/kg.K \n',S);
27 //(c)
28 k=1.4;
29 V2=Ma2*sqrt(k*R*T2*1000);
30 printf(' (c) Air velocity ,V2 = %.0f m/s \n',V2);
31 ms=2.86;//same as previous example
32 printf(' (d) Mass Flow rate = %.2f kg/sec \n',ms);

```

---

#### Scilab code Exa 17.16 Steam Flow through a Converging Diverging Nozzle

```

1 //ques16
2 //Steam Flow through a Converging Diverging Nozzle
3 clear
4 clc
5 P01=2;//inlet stagnation pressure in MPa
6 Pt=0.546*P01;//throat pressure in MPa
7 //at inlet

```

```

8 P1=2; //inlet pressure in MPa
9 T1=400; //Inlet Temp in C
10 T01=T1; //stagnation temp in K
11 //from tables
12 h1=3248.4; //enthalpy in kJ/kg
13 h01=h1; //stagnation enthalpy in kJ/kg
14 s1=7.1292; //entropy in kJ/kg.K
15 st=s1; //stagnation in kJ/kg.K
16 s2s=s1; //entropy at state 2s n kJ/kg.K
17 //Also, at the throat
18 Pt=1.09; //pressure in MPa
19 st=7.1292; //entropy in kJ/kg.K
20 //from tables
21 ht=3076.8; //enthalpy in kJ/kg
22 vt=0.24196; //m^3/kg
23 //now throat velocity is determined as
24 Vt=sqrt(2*(h01-ht)*1000); //throat velocity
25 //The flow area at the throat is determined from the
    mass flow rate relation
26 ms=2.5; //mass flow rate in kg/s
27 At=ms*vt/Vt; //area in m^2
28 printf('(a) Flow area at throat = %.2f cm^2 \n', At
    *10000);
29 //At state 2s,
30 P2s=300; //presure in kPa
31 P2=P2s; //kPa
32 //from table
33 h2s=2783.6; //enthalpy at state 2s in kJ/kg
34 //from the enthalpy of the steam at the actual exit
    state is (see Chap. 7) formulae
35 n=0.93;
36 h2=h01-n*(h01-h2s); //enthalpy at state 2 in kJ/kg
37 //now from table
38 v2=0.67723; //m^3/kg
39 s2=7.2019; //entropy in kJ/kg.K
40 // the exit velocity and the exit area
41 V2=sqrt(2*(h01-h2)*1000); //Exit velocity in m^2
42 A2=(ms*v2)/V2;

```

```

43 printf('      Exit area = %.2f cm^2 \n',A2*10000);
44 //(b)
45 //c=(dP/d(1/v))^(1/2)
46 //The velocity of sound at the throat is determined
    by evaluating the specific volume at St = 7.1292
    kJ/kg K and at pressures of 1.115 and 1.065 MPa
47 Pa=1115;//kPa
48 Pb=1065;//kPa
49 va=0.23776;//m^3/kg
50 vb=0.24633;//m^3/kg
51 c=sqrt((Pa-Pb)/(1/va-1/vb)*1000);//velocity of sound
    at throat
52 V=585.8;//velocity in m/s
53 Ma=V/c;
54 printf(' (b) Mach number at the throat = %.3f \n',Ma
    );
55 //The velocity of sound and the Mach number at the
    nozzle exit are determined by evaluating the
    specific volume at St= 7.2019 kJ/kg K and at
    pressures of 325 and 275 kPa
56 Pa=325;//kPa
57 Pb=275;//kPa
58 va=0.63596;//m^3/kg
59 vb=0.72245;//m^3/kg
60 c=sqrt((Pa-Pb)/(1/va-1/vb)*1000);
61 V=929.8;//Velocity
62 Ma=V/c;
63 printf('      Mach number at nozel exit = %.3f ',Ma);

```

---