

Scilab Textbook Companion for
Thermodynamics an Engineering Approach
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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 Concepts

Scilab code Exa 1.2 Obtaining Formulas from Unit Considerations

```
1 clc; clear;  
2 //Example 1.2  
3  
4 //given values  
5 p=850;  
6 V=2;  
7  
8 //calculation  
9 m=p*V; //mass, density and volume calculation  
10 disp(m, 'the amount of oil in tank is (in kg)')
```

Scilab code Exa 1.3 The Weight of One Pound Mass

```
1 clc; clear;  
2 //Example 1.3  
3
```

```

4 //constants used
5 g=32.174; //gravitational constant in ft/s^2
6
7 //given values
8 m=1;
9
10 //calculation
11 w=(m*g)/g; //weight is mass times the local value of
    gravitational acceleration
12 disp(m, 'the weight on earth is (in lbf)')

```

Scilab code Exa 1.4 Expressing Temperature Rise in Different Units

```

1 clc; clear;
2 //Example 1.4
3
4 //given values
5 Tc=10; //change in temp in Celcius
6
7 //calculation
8 Tk=Tc;
9 Tr=1.8*Tk;
10 Tf=Tr;
11 //calculated using the corealtions b/w these scales
12 disp(Tk, 'the corresponding change in K');
13 disp(Tr, 'the corresponding change in R');
14 disp(Tf, 'the corresponding change in F')

```

Scilab code Exa 1.5 Absolute Pressure of a Vacuum Chamber

```

1 clc; clear;
2 //Example 1.5
3

```

```

4 //given values
5 Patm=14.5;
6 Pvac=5.8;
7
8 //calculation
9 Pabs=Patm-Pvac;//pressure in vaccumm is always
   treated to be negative
10 disp(Pabs,'the absolute pressure in the chamber in
   psi is')

```

Scilab code Exa 1.6 Measuring Pressure with a Manometer

```

1 clc;clear;
2 //Example 1.6
3
4 //constants used
5 pw=1000;//density of water in kg/m^3;
6 g=9.81;//acceleration due to gravity in m/s^2;
7
8 //given values
9 SG=0.85;
10 h=55/100;//converting height from cm to m
11 Patm=96;
12
13 //calculation
14 p=SG*pw;
15 Ptank=Patm+(p*g*h/1000);//calculating pressure using
   liquid at same height have same pressure
16 disp(Ptank,'absolute pressure in tank in kPa is')

```

Scilab code Exa 1.7 Measuring Pressure with a Multifluid Manometer

```

1 clc;clear;

```

```

2 //Example 1.7
3
4 //constants used
5 g=9.81;//acceleration due to gravity in m/s^2;
6
7 //given values
8 h1=0.1;
9 h2=0.2;
10 h3=0.35;//respective heights in m
11 pw=1000;
12 pHg=13600;
13 poil=800;//density of water , mercury and oil in kg/m
    ^3
14 Patm=85.6;
15
16 //calculation
17 P1=Patm-(pw*g*h1+poil*g*h2-pHg*g*h3)/1000;//
    calculating pressure using liquid at same height
    have same pressure
18 disp(P1,'the air pressure in tank in kPa is ')

```

Scilab code Exa 1.8 Measuring Atmospheric Pressure with a Barometer

```

1 clc;clear;
2 //Example 1.8
3
4 //constants used
5 g=9.81;//acceleration due to gravity in m/s^2;
6
7 //given values
8 pHg=13570;
9 h=74/100;//converting height into m from mm
10
11 //calculation
12 Patm=pHg*g*h/1000;//standard pressure formula

```

```
13 disp(Patm, 'the atmospheric pressure in kPa is')
```

Scilab code Exa 1.9 Effect of Piston Weight on Pressure in a Cylinder

```
1 clc;clear;
2 //Example 1.9
3
4 //constants used
5 g=9.81;//acceleration due to gravity in m/s^2;
6
7 //given values
8 m=60;
9 Patm=0.97;
10 A=0.04;
11
12 //calculation
13 P=Patm+(m*g/A)/10^5;//standard pressure formula
14 disp(P, 'the pressure inside the cylinder in bar is')
```

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

```
1 clc;clear;
2 //Example 1.10
3
4 //constants used
5 g=9.81;//acceleration due to gravity in m/s^2;
6
7 //given values
8 p=1040;
9 h1=0.8;
10 H=4;
11 x0=0;
```



```
12 x1=4; // x0 & x1 are limits of integration
13
14 // calculation
15 P1=p*g*h1/1000; //standard pressure determination
    formula
16 P2=integrate('p*g*(sqrt(1+(tan(3.14*z/4/H)^2)))','z',
    ,x0,x1); //integrant
17 P2=P2/1000; //converting into kPa
18 P=P1+P2;
19 P=ceil(P); //roundingoff to match answer
20 disp(P,'the gage pressure at the bottom of gradient
    zone in kPa is')
```

Chapter 2

Energy Conversion and General Energy Analysis

Scilab code Exa 2.1 A Car Powered by Nuclear Fuel

```
1  clc; clear;
2  //Example 2.1
3
4  //constants used
5  Hu=6.73*10^10; //Energy liberated by 1 kg of uranium
6
7  //given values
8  p=0.75; //assuming the avg density of gasoline in kg/
   L
9  V=5;
10 Hv=44000;
11 mu=0.1; //mass of uranium used
12
13 //calculation
14 mgas=p*V; //mass of gasoline required per day
15 Egas=mgas*Hv;
16 Eu=mu*Hu;
17 d=Eu/Egas;
18 d=ceil(d);
```

```
19 disp(d, 'the number of days the car can run with  
    uranium')
```

Scilab code Exa 2.2 Wind Energy

```
1  clc;clear;  
2  //Example 2.2  
3  
4  //given values  
5  v=8.5;  
6  m=10;  
7  mf=1154;  
8  
9  //calculation  
10 e=v^2/2;  
11 disp(e, 'wind energy per unit mass J/kg');  
12 E=m*e;  
13 disp(E, 'wind energy for 10kg mass in J');  
14 E=mf*e/1000;  
15 disp(E, 'wind energy for mass flow are of 1154kg/s in  
    kW')
```

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

```
1  clc;clear;  
2  //Example 2.7  
3  
4  //given values  
5  T=200;  
6  n=4000/60; //converting rpm into rps  
7  
8  //calculation  
9  Wsh=2*3.14*n*T/1000;
```

```
10 disp(Wsh, 'Power transmitted in kW')
```

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

```
1  clc;clear;
2  //Example 2.8
3
4  //constants used
5  g=9.81;//acceleration due to gravity in m/s^2;
6
7  //given values
8  m=1200;
9  V=90/3.6;//converting km/h into m/s
10 d=30;
11
12 //calculation
13 Vver=V*sind(d);//velocity in vertical direction
14 Wg=m*g*Vver/1000;
15 disp(Wg, 'the additional power in kW')
```

Scilab code Exa 2.9 Power Needs of a Car to Accelerate

```
1  clc;clear;
2  //Example 2.9
3
4  //given values
5  m=900;
6  v1=0;
7  v2=80/3.6;//converting km/h into m/s
8  t=20;
9
10 //calculation
11 Wa=m*(v2^2-v1^2)/2/1000;
```

```
12 Wavg=Wa/t;
13 disp(Wavg, 'the average power in kW')
```

Scilab code Exa 2.10 Cooling of a Hot Fluid in a Tank

```
1 clc;clear;
2 //Example 2.10
3
4 //given values
5 Win=100;
6 Qout=500;
7 U1=800;
8
9 //calculationu
10 // Win - Qout = U2- U1 i.e change in internal energy
11 U2=U1-Qout+Win
12 disp(U2, 'final internal of the system in kJ-')
```

Scilab code Exa 2.11 Acceleration of Air by a Fan

```
1 clc;clear;
2 //Example 2.11
3
4 //given values
5 Win=20;
6 mair=0.25;
7
8 //calculation
9 v=sqrt(Win/2/mair)//Win = 1/2*m*v^2
10 if(v >= 8)
11     disp('True');
12 else
13     disp('False')
```

Scilab code Exa 2.12 Heating Effect of a Fan

```
1  clc;clear;
2  //Example 2.12
3
4  //given values
5  Win=200;
6  U=6;
7  A=30;
8  To=25;
9
10 //calculation
11 Ti= (Win/U/A)+To;// Win = Qout = U*A*(Ti - To)
12 disp(Ti,'the indoor air temperature in Celcius')
```

Scilab code Exa 2.13 Annual Lighting Cost of a Classroom

```
1  clc;clear;
2  //Example 2.13
3
4  //given values
5  Plamp=80;
6  N=30;//no of lamps
7  t=12;
8  y=250;//days in a year
9  UC=0.07;//unit cost in USD
10
11 //calculation
12 LP=Plamp * N/1000;//Lighting power in kW
13 OpHrs=t*y;//Operating hours
14 LE=LP * OpHrs;//Lighting energy in kW
```

```
15 LC=LE*UC; //Lighting cost
16 disp(LC , 'the annual energy cost in USD is ')
```

Scilab code Exa 2.15 Cost of Cooking with Electric and Gas Ranges

```
1  clc;clear;
2  //Example 2.15
3
4  //given values
5  Ein=2;
6  n1=0.73;
7  n2=0.38; //efficiency n1 and n2
8  CinH=0.09;
9  CinB=0.55; //unit cost of electricity and natural gas
10
11 //calculation
12 QutH= Ein * n1;
13 disp(QutH, 'rate of energy consumption by the heater
    in kW');
14 CutH= CinH / n1;
15 disp(CutH, 'the unit cost of utilized energy for
    heater in USD');
16 QutB= QutH / n2 ;
17 disp(QutB, 'rate of energy consumption by the burner
    in kW');
18 CutB= CinB / n2 / 29.3; // 1 therm = 29.3 kWh
19 disp(CutB, 'the unit cost of utilized energy for
    burner in USD')
```

Scilab code Exa 2.16 Performance of a Hydraulic Turbine Generator

```
1  clc;clear;
2  //Example 2.16
```

```

3 //answers vary due to round off error
4
5 //constants used
6 g=9.81;//acceleration due to gravity in m/s^2;
7
8 //given values
9 h=50;
10 m=5000;
11 Wout=1862;
12 ngen=0.95;//efficiency of turbine
13
14 //calculation
15 X=g*h/1000;// X stands for the difference b/w change
    in mechanical energy per unit mass
16 R=m*X;//rate at which mech. energy is supplied to
    turbine in kW
17 nov=Wout/R;//overall efficiency i.e turbine and
    generator
18 disp(nov,'overall efficiency is');
19 ntu=nov/ngen;//efficiency of turbine
20 disp(ntu,'efficiency of turbine is');
21 Wsh=ntu*R;//shaft output work
22 disp(Wsh,'shaft power output in kW')

```

Scilab code Exa 2.17 Cost Savings Associated with High Efficiency Motors

```

1 clc;clear;
2 //Example 2.17
3
4 //given values
5 Pstd=4520;
6 Phem=5160;//prices of std and high eff motor in USD
7 R=60*0.7457;//rated power in kW from hp
8 OpHrs=3500;//Operating hours

```



```

 9 Lf=1; //Load Factor
10 nsh=0.89;
11 nhem=0.932; //efficiency of shaft and high eff. motor
12 CU=0.08; //per unit cost in USD
13
14 //calculation
15 PS=R*Lf*(1/nsh-1/nhem); //Power savings = W electric
    in, standard - W electric in, efficient
16 ES=PS*OpHrs; //Energy savings = Power savings *
    Operating hours
17 ES=floor(ES); //rounding off
18 disp(ES, 'Energy savings in kWh/year');
19 CS=ES*CU;
20 CS=floor(CS); //rounding off
21 disp(CS, 'Cost savings per year in USD');
22 EIC=Pphem-Pstd; //excess intial cost
23 Y=EIC/CS;
24 disp(Y, 'simple payback period in years')

```

Scilab code Exa 2.18 Reducing Air Pollution by Geothermal Heating

```

1  clc;clear;
2  //Example 2.18
3
4  //given values
5  //NOx details
6  m1=0.0047;
7  N1=18*10^6;
8  //CO2 details
9  m2=6.4;
10 N2=18*10^6;
11
12 //calculation
13 NOxSav=m1*N1;
14 disp(NOxSav, 'NOx savings in kg/year');

```

```
15 CO2Sav=m2*N2;
16 disp(CO2Sav,'CO2 savings in kg/year')
```

Scilab code Exa 2.19 Heat Transfer from a Person

```
1  clc;clear;
2  //Example 2.19
3
4  //constants used
5  e=.95;//Emissivity
6  tc=5.67*10^-8;//thermal conductivity in W/m^2 K^4
7
8  //given values
9  h=6;
10 A=1.6;
11 Ts=29;
12 Tf=20;
13
14 //calculation
15 //convection rate
16 Q1=h*A*(Ts-Tf);
17 //radiation rate
18 Q2=e*tc*A*((Ts+273)^4-(Tf+273)^4)
19 Qt=Q1+Q2;
20 disp(Qt,'the total rate of heat transfer in W')
```

Chapter 3

Properties of Pure Substances

Scilab code Exa 3.1 Pressure of Saturated Liquid in a Tank

```
1  clc;clear;
2  //Example 3.1
3
4  //given values
5  m=50;
6  T=90;
7
8  //Values from Table A-4
9  P=70.183;//in kPa
10 v=0.001036;//in m3/kg
11
12 //calculation
13 disp(P,'pressure in the tank in kPa')
14 V=m*v;//equating dimensions
15 disp(V,'total volume of tank becomes in m3')
```

Scilab code Exa 3.2 Temperature of Saturated Vapor in a Cylinder

```

1  clc;clear;
2  //Example 3.2
3
4  //given values
5  V=2;
6  P=50;
7
8  //Values from Table A-5E
9  T=280.99; //in F
10 v=8.5175; //in ft^3/lbm
11
12 //caluclation
13 m=V/v; //dimension analysis
14 disp(m, 'mass of vapour inside cylinder in lbm');
15 disp(T, 'temp inside cylinder in F')

```

Scilab code Exa 3.3 Volume and Energy Change during Evaporation

```

1  clc;clear;
2  //Example 3.3
3
4  // constants used
5  Hfg=2257.5; //enthalpy of vaporization in kJ/kg
6
7  //given values
8  m=200/1000; //converting in kg
9  P=100;
10
11 //Values from Table A-5
12 vg=1.6941;
13 vf=0.001043; //specific vol of sat liq and vapor
14
15 //caluclation
16 vfg=vg-vf;
17 V=m*vfg;

```

```
18 disp(V, 'the volume change in m^3');
19 E=m*Hfg;
20 disp(E, 'amount of energy transferred to the water in
    kJ')
```

Scilab code Exa 3.4 Pressure and Volume of a Saturated Mixture

```
1 clc;clear;
2 //Example 3.4
3
4 //given values
5 mt=10;
6 mf=8;
7 T=90;
8
9 //Values from Table A-4
10 P=70.183;//in kPa
11 vf=0.001036;
12 vg=2.3593;
13
14 //caluclation
15 mg=mt-mf;
16 V=mf*vf+mg*vg;// V= Vg + Vf
17 disp(V, 'the volume of the tank in m^3');
18 disp(P, 'the pressure in the tank in kPa')
```

Scilab code Exa 3.5 Properties of Saturated Liquid Vapor Mixture

```
1 clc;clear;
2 //Example 3.5
3
4 //given values
5 m=4;
```

```

6 V=80/1000; //converting into m^3
7 P=160;
8
9 //Values from Table A-12
10 vf=0.0007437;
11 vg=0.12348;
12 T=-15.60;
13 hf=31.21;
14 hfg=209.90;
15
16 //caluclation
17 v=V/m;
18 //vg>v>vf therefore it is a saturated mix
19 //hence temp will same as saturation temp
20 disp(T, 'the temperature in celcius')
21 x=(v-vf)/(vg-vf); //x=vg/vfg i.e the dryness fraction
22 disp(x, 'the quality');
23 h=hf+x*hfg;
24 disp(h, 'the enthalpy of the refrigerant in kJ/kg');
25 mg=x*m;
26 Vg=mg*vg;
27 disp(Vg, 'the volume occupied by the vapor phase in m
    ^3')

```

Scilab code Exa 3.7 Temperature of Superheated Vapor

```

1 clc;clear;
2 //Example 3.7
3
4 //given values
5 P=0.5;
6 h=2890;
7
8 //from Table A 6
9 //at P=0.5 MPa

```

```

10 T1=200;
11 h1=2855.8;
12 T2=250;
13 h2=2961.0;
14 // we need linear interpolation
15
16 //calculation
17 //by interpolation we can say that
18 //h=h1+(T-T1)/(T2-T1)*(h2-h1)
19 //we have to find T
20 T=(h-h1)/(h2-h1)*(T2-T1)+T1;
21 disp(T,'temperature of water in celcius')

```

Scilab code Exa 3.8 Approximating Compressed Liquid as Saturated Liquid

```

1  clc;clear;
2  //Example 3.8
3
4  //given values
5  T=80;
6  P=5;
7
8  //from Table A 7
9  //at compressed liq given conditions
10 u=333.82;
11
12 //from Table A-4
13 //at saturation
14 usat=334.97;
15
16 //calculation
17 e=(usat-u)/u*100;
18 disp(u,'internal energy of compressed liquid water
      using data from the compressed liquid table in kJ

```

```

    /kg ');
19 disp(usat, 'internal energy of compressed liquid
    water using saturated liquid data in kJ/kg ');
20 disp(e, 'the % error involved in the second case is '
    )

```

Scilab code Exa 3.9 The Use of Steam Tables to Determine Properties

```

1  clc;clear;
2  //Example 3.9
3
4  //part a
5  disp('Part a');
6
7  //given values
8  P=200;
9  x=0.6;
10
11 //from Table A-5
12 T=120.21;
13 uf=504.50;
14 ufg=2024.6;
15
16 //calcualtions
17 u=uf+(x*ufg);
18 disp(T, 'temperature in Celcius ');
19 disp(u, 'internal energy in kJ/kg');
20 disp('saturated liquid vapor mixture at a pressure
    of 200 kPa');
21
22
23 //part b
24 disp('Part b');
25
26 //given values

```



```

27 T=125;
28 u=1600;
29
30 //from Table A 4
31 uf=524.83;
32 ug=2534.3;
33 //ug>u>ufg so its aturated liquid vapor mixture
34 P=232.23;
35
36 //calculation
37 ufg=ug-uf;
38 x=(u-uf)/ufg;
39 disp(P, 'Pressure in kPa');
40 disp(x, 'x is ');
41 disp('saturated liquid vapor mixture at a temp of
      125 of celcius');
42
43
44 //part c
45 disp('Part c');
46
47 //given values
48 P=1000;
49 u=2950;
50
51 //from Table A 6
52 uf=761.39;
53 ug=2582.8;
54 //u>ug so its superheated steam
55 T=395.2;
56
57 //calculation
58 disp(T, 'temperature in Celcius');
59 disp('superheated vapor at 1MPa ');
60
61 //part d
62 disp('Part d');
63

```

```

64 //given values
65 T=75;
66 P=100;
67
68 //from Table A 5
69 Tsat=151.83;
70 //T<Tsat so it is a compressed liquid
71 //the given pressure is much lower than the lowest
    pressure value in the compressed liquid table i.e
    5 MPa
72 //assuming, the compressed liquid as saturated
    liquid at the given temperature
73
74 //from Table A-4
75 u=313.99;
76 disp(u, 'Internal energy in kJ/kg');
77 disp('the compressed liquid condition');
78
79
80 //Part e
81 disp('Part e');
82
83 //given values
84 P=850;
85 x=0;
86
87 //x=0 therefore it is a saturated liquid condition
88 //from Table A-5
89 T=172.94;
90 u=731.00;
91 disp(T, 'temperature in Celcius');
92 disp(u, 'Internal energy in kJ/kg');
93 disp('saturated liquid condition')

```

Scilab code Exa 3.10 Mass of Air in a Room

```

1  clc;clear;
2  //Example 3.10
3
4  //constants used
5  R=0.287// in kPa m^3/kg K
6
7  //given values
8  l=4;
9  b=5;
10 h=6;
11 P=100;
12 T=25+273;//in Kelvin
13
14 //calculation
15 V=l*b*h;
16 m=P*V/R/T;
17 disp(m,'the mass of the air in kg')

```

Scilab code Exa 3.11 The Use of Generalized Charts

```

1  clc;clear;
2  //Example 3.11
3
4  //given values
5  P=1;
6  T=50+273;//converting into Kelvin
7  vgiv=0.021796;//specific vol. given
8
9  //from Table A-1
10 R=0.0815;
11 Pcr=4.059;
12 Tcr=374.2;
13
14 //calculation
15

```

```

16 //Part A
17 v1=R*T/(P*1000);
18 disp(v1,'specific volume of refrigerant -134a under
    the ideal-gas assumption in m^3/kg');
19 e=(v1-vgiv)/vgiv;
20 disp(e,'an error of');
21
22 //Part B
23 //determine Z from the compressibility chart, we
    will calculate the reduced pressure and
    temperature
24 Pr=P/Pcr;
25 Tr=T/Tcr;
26 //from chart
27 Z=0.84;
28 v=Z*v1;
29 disp(v,'specific volume of refrigerant -134a under
    the generalized compressibility chart in m^3/kg')
    ;
30 e=(v-vgiv)/vgiv;
31 disp(e,'an error of');

```

Scilab code Exa 3.12 Using Generalized Charts to Determine Pressure

```

1 clc;clear;
2 //Example 3.12
3
4 //given values
5 v=0.51431;
6 T=600;
7
8 //from Table A-1E
9 R=0.5956;
10 Pcr=3200;
11 Tcr=1164.8;

```

```

12
13 //calculation
14
15 //Part A
16 //from Table A-6E
17 P=1000;//in psia
18 disp(P,'from the steam tables in psia');
19
20 //Part B
21 T=1060;//converted into R from F
22 P=R*T/v;
23 disp(P,'from the ideal-gas equation in psia');
24
25 //Part C
26 //calculating the pseudo-reduced specific volume and
    the reduced temperature
27 Vr=v/(R*Tcr/Pcr);
28 Tr=T/Tcr;
29 //from the compressibility chart
30 Pr=0.33;
31 P=Pr*Pcr;
32 disp(P,'from the generalized compressibility chart.
    in psia')

```

Scilab code Exa 3.13 Different Methods of Evaluating Gas Pressure

```

1 clc;clear;
2 //Example 3.13
3 //Answer of part c-d are having slight difference
    due to approximation in molar volume in the
    textbook which here is calculated to the
    approximation of 7 decimal digits
4
5 //given values
6 T=175;

```

```

7 v=0.00375;
8 Pex=10000; //experimentaion determination
9
10 //from Table A-1
11 R=0.2968 // in kPa m^3/kg K
12
13 //calculating
14
15 //Part-a
16 P=R*T/v;
17 disp(round(P), 'using the ideal-gas equation of state
    in kPa');
18 e=(P-Pex)/Pex*100;
19 disp(e, 'error is');
20
21
22 //Part-b
23 //van der Waals constants from Eq. 3-23
24 a=0.175;
25 b=0.00138;
26 //from van der waal eq.
27 P=R*T/(v-b)-a/v^2;
28 disp(round(P), 'using the van der Waals equation of
    state, ');
29 e=(P-Pex)/Pex*100;
30 disp(e, 'error is');
31
32 //Part-c
33 //constants in the Beattie-Bridgeman equation from
    Table 3 4
34 A=102.29;
35 B=0.05378;
36 c=4.2*10^4;
37 Ru=8.314; //in kPa m^3/kmol K
38 M=28.013; //molecular weight in kg/mol
39 vb=M*v; //molar vol.
40 P=(Ru*T)/(vb^2)*(1-((c)/(vb*T^3)))*(vb+B)-(A/vb^2);
41 disp(round(P), 'using the Beattie-Bridgeman equation ')

```

```

    );
42 e=(P-Pex)/Pex*100;
43 disp(e, 'error is ');
44
45 //Part-d
46 //constants of Benedict-Webb-Rubin equation from
    Table 3 4
47 a=2.54;
48 b=0.002328;
49 c=7.379*10^4;
50 alp=1.272*10^-4;
51 Ao=106.73;
52 Bo=0.040704;
53 Co=8.164*10^5;
54 gam=0.0053;
55 P= ((Ru*T)/vb) + ( (Bo*Ru*T) - Ao - Co/T^2 )/ vb^2 +
    (b*Ru*T-a)/vb^3 +( a*alp/vb^6) + (c/(vb^3*T^2))
    * (1 + (gam/vb^2)) * exp(-gam/vb^2);
56 disp(round(P), 'using Benedict-Webb-Rubin equation ');
57 e=(P-Pex)/Pex*100;
58 disp(e, 'error is ')

```

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

```

1  clc;clear;
2  //Example 3.14
3
4  //given value
5  T=25;
6
7  //from table 3-1
8  Psat=3.17; //on kPa
9
10 //calculations
11

```

```
12 //Relative Humidity 10%
13 Pv1=0.1*Psat
14 //Relative Humidity 80%
15 Pv2=0.8*Psat
16 //Relative Humidity 100%
17 Pv3=1*Psat
18
19 // from table 3-1 Tsat at these Pressures are
20 T1=-8;
21 T2=21.2;
22 T3=25;
23 disp(T1,'With relative humidity 10%the water temp in
    celcius is ');
24 disp(T2,'With relative humidity 80%the water temp
    in celcius is ');
25 disp(T3,'With relative humidity 100% the water temp
    in celcius is ')
```

Chapter 4

Energy Analysis Of Closed Systems

Scilab code Exa 4.2 Boundary Work for a Constant Pressure Process

```
1  clc; clear;
2  //Example 4.2
3
4  //given values
5  m=10;
6  Po=60;
7  T1=320;
8  T2=400;
9
10 //from Table A 6 E
11 v1=7.4863; //at 60 psia and 320 F
12 v2=8.3548; //at 60 psia and 400 F
13
14 //calculations
15 //W = P dV which on integrating gives  $W = m * P * ($ 
     $V2 - V1)$ 
16 W=m*Po*(v2-v1)/5.404; //converting into Btu from psia-
    ft^3
17 disp(W, 'work done by the steam during this process')
```

in Btu')

Scilab code Exa 4.3 Isothermal Compression of an Ideal Gas

```
1  clc;clear;
2  //Example 4.3
3
4  //given data
5  P1=100;
6  V1=0.4;
7  V2=0.1;
8
9  //calculations
10 //for isothermal  $W = P1*V1* \ln(V2/V1)$ 
11 W=P1*V1*log(V2/V1);
12 disp(W,'the work done during this process in kJ')
```

Scilab code Exa 4.4 Expansion of a Gas against a Spring

```
1  clc;clear;
2  //Example 4.4
3
4  //given data
5  V1=0.05;
6  P1=200;
7  k=150;
8  A=0.25;
9
10 //calculations
11
12 //Part - a
13 V2=2*V1;
14 x2=(V2-V1)/A;//displacement of spring
```

```

15 F=k*x2;//compression force
16 P2=P1+F/A;//additional pressure is equivalent the
    compression of spring
17 disp(P2,'the final pressure inside the cylinder in
    kPa');
18
19 //Part - b
20 //work done is equivalent to the area of the P-V
    curve of Fig 4-10
21 W=(P1+P2)/2*(V2-V1);//area of trapezoid = 1/2 * sum
    of parallel sides * dist. b/w them
22 disp(W,'the total work done by the gas in kJ');
23
24 //Part - c
25 x1=0;//intial compression of spring
26 Wsp=0.5*k*(x2^2-x1^2);
27 disp(Wsp,'the fraction of this work done against the
    spring to compress it in kJ')

```

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

```

1  clc;clear;
2  //Example 4.5
3
4  //given values
5  m=0.025;
6  V=120;
7  I=0.2;
8  t=300;//total time taken in sec
9  P1=300;
10 Qout=3.7;
11
12 //from Table A 5
13 //at P1 the conditon is sat. vap
14 h1=2724.9;

```

```

15
16 // Calculations
17
18 // Part - a
19 // theoretical proving
20
21 // Part - b
22 We=V*I*t/1000; // electrical work in kJ
23 // from eqn 4-18 i.e derived in earlier part
24 // it states it  $E_{in} - E_{out} = E_{system}$ 
25 // it applies as  $W_{in} - Q_{out} = H = m (h_2 - h_1)$ 
26  $h_2 = (W_e - Q_{out}) / m + h_1$ ;
27 // from Table A 5
28 // at  $h_2$  we get
29 P2=300;
30 T=200;
31 disp(T, 'the final temperature of the steam in C')

```

Scilab code Exa 4.6 Unrestrained Expansion of Water

```

1 clc; clear;
2 // Example 4.6
3
4 // given data
5 m=5;
6 P1=200;
7 T=25;
8
9 // from Table A 4
10 // the liq. is in compressed state at 200 kPa and 25
   C
11 vf=0.001;
12 vg=43.340;
13 uf=104.83;
14 ufg=2304.3;

```

```

15 v1=vf;
16 u1=uf;
17
18 // calculations
19
20 //Part - a
21 V1=m*v1;
22 Vtank=2*V1;
23 disp(Vtank,'the volume of the tank in m^3');
24
25 //Part - b
26 V2=Vtank;
27 v2=V2/m;
28 //from Table A 4
29 // at T=25 vf=0.101003 m^3/kg and vg=43.340 m^3/kg
30 // vf<v2<vg therefore it is saturated liquid vapor
    mixture
31 P2=3.1698;
32 disp(P2,'the final pressure in kPa');
33
34 //Part - c
35 //Ein - Eout = Esystem
36 //Qin= dU = m(u2 - u1)
37 x2=(v2-vf)/(vg-vf);
38 u2=uf+x2*ufg;
39 Qin=m*(u2 - u1);
40 disp(Qin,'the heat transfer for this process in kJ')

```

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

```

1  clc;clear;
2  //Example 4.7
3
4  //given data
5  T1=300;

```

```

6 P=200;
7 T2=600;
8 M=28.97;
9 Ru=8.314;
10
11 //Part - a
12 //from Table A 17
13 u1=214.07;
14 u2=434.78;
15 du=u2-u1;//change in internal energy
16 disp(du,'change in internal energy from data from
    the air table in kJ/kg');
17
18 //Part - b
19 //from Table A 2c
20 a=28.11;
21 b=0.1967*10^-2;
22 c=0.4802*10^-5;
23 d=-1.966*10^-9;
24 // by equation Cp(T)=a+bT+cT^2+dT^3
25 dubar=integrate('(a-Ru)+b*T+c*T^2+d*T^3','T',T1,T2);
    //integrant
26 du=dubar/M;
27 disp(du,'change in internal energy the functional
    form of the specific heat in kJ/kg');
28
29 //Part - c
30 //from Table A 2b
31 Cavg=0.733;
32 du=Cavg*(T2-T1);
33 du=ceil(du);
34 disp(du,'change in internal energy the functional
    form the average specific heat value in kJ/kg');

```

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

```

1  clc;clear;
2  //Example 4.8
3
4  //given data
5  m=1.5;
6  T1=80;
7  P1=50;
8  W=0.02;
9  t=30/60;//converting into hrs from min
10
11 //from Table A 2Ea
12 Cv=0.753;
13
14 //calculations
15
16 //part a
17 Wsh=W*t*2545;//in Btu
18 //Ein - Eout = Esystem
19 //Wsh = dU = m (u2 - u1) = m * Cv * (T2 - T1)
20 T2= Wsh/(m*Cv)+T1;
21 disp(T2,'the final temperature in F');
22
23 //part b
24 //using ideal gas eqn
25 // P1 * V1 / T1 = P2 * T2 /V2
26 P2= 50 * (T2 +460)/ (T1+460);
27 // temp should in R therefore + 460
28 disp(P2,'the final pressure in psia')

```

Scilab code Exa 4.9 Heating of a Gas by a Resistance Heater

```

1  clc;clear;
2  //Example 4.9
3
4  //given data

```

```

5 V1=0.5;
6 P=400;
7 T1=27;
8 I=2;
9 t=5*60; //converting into s from min
10 V=120;
11 Qout=2800/1000; //in kJ
12 R=0.297;
13
14 //from Table A 2 a
15 Cp=1.039;
16
17 //calculations
18 P1=P;
19 We=V*I*t/1000; //in kJ
20 m=P1*V1/(R*(T1+273));
21 //Ein - Eout = Esystem
22 // We,in - Qout = dH = m (h2 - h1) = m * Cp * (T2 -
    T1)
23 T2=(We-Qout)/(m*Cp)+T1;
24 disp(T2,'the final temperature of nitrogen in C')

```

Scilab code Exa 4.10 Heating of a Gas at Constant Pressure

```

1 clc;clear;
2 //Example 4.10
3
4 //given data
5 P1=150;
6 P2=350;
7 T1=27+273; //in K
8 V1=400/1000; // in m^3
9 R=0.287;
10
11 //from Table A 17

```



```

12 u1=214.07;
13 u2=1113.52;
14
15 //calculations
16
17 //part a
18 V2=2*V1;
19 //using ideal gas eqn
20 // P1 * V1 / T1 = P2 * T2 /V2
21 T2=P2*V2*T1/(P1*V1);
22 disp(T2,'the final temperature in K');
23
24 //part b
25 // Work done is Pdv
26 W=P2*(V2-V1);
27 disp(W,'the work done by the air im kPa');
28
29 //part c
30 //Ein - Eout = Esystem
31 //Qin - Wout = dU = m(u2 - u1)
32 m= P1* V1 /(T1 * R);
33 Q= m*(u2 - u1)+ W;
34 Q=ceil(Q);
35 disp(Q,'the total heat transferred to the air in kJ'
    )

```

Scilab code Exa 4.11 Enthalpy of Compressed Liquid

```

1 clc;clear;
2 //Example 4.11
3
4 //given data
5 T=100;
6 P=15;
7

```

```

8 //from Table A 7
9 //at P=15 mPa and T = 100 C
10 hg=430.39;
11 hf=419.17
12 vf=0.001;
13 Psat=101.42; //in kPa
14
15 //calculations
16
17 //part a
18 h=hg;
19 disp(h,'enthalpy of liquid water by using compressed
      liquid tables in kJ/kg');
20
21 //part b
22 //Approximating the compressed liquid as a saturated
      liquid at 100 C
23 h=hf;
24 disp(h,'enthalpy of liquid water by approximating it
      as a saturated liquid in kJ/kg');
25
26 //part c
27 h=hf + vf*(P*1000 - Psat );
28 disp(h,'enthalpy of liquid water by using the
      correction given by Eq. 4 38 in kJ/kg');

```

Scilab code Exa 4.12 Cooling of an Iron Block by Water

```

1 clc;clear;
2 //Example 4.12
3
4 //given data
5 mi=50;
6 T1i=80; //suffix i for iron
7 Vw=0.5;

```

```

8 T1w=25; //suffix w for water
9 v=0.001; //specific volume of liquid water at or
    about room temperature
10
11 //from Table A 3
12 ci=0.45;
13 cw=4.18;
14
15 //calculations
16 mw=Vw/v;
17 //Ein - Eout = Esystem
18 // du = 0 i.e (mcdT)iron + (mcdT)water = 0
19 // mi * ci * (T - T1i) + mw *cw * (T-T1w)
20 //on rearranging above equn
21 T= (mi*ci*T1i + mw*cw*T1w)/(mi*ci+mw*cw);
22 disp(T, 'the temperature when thermal equilibrium is
    reached in C')

```

Scilab code Exa 4.13 Temperature Rise due to Slapping

```

1 clc;clear;
2 //Example 4.13
3
4 //given data
5 maf=0.15;
6 caf=3.8;
7 dTaf=1.8; //suffix af for affected tissue
8 mh=1.2; //suffix h for hand
9
10 //calculations
11 //Ein - Eout = Esystem
12 //dUaffected tissue - KEhand = 0
13 //from above equation we can deduce that
14 Vhand= sqrt(2*maf*caf*dTaf*1000/mh); //for conversion
    factor mutiplying by 1000 to get m^2/s^2

```

```
15 disp(Vhand, 'the velocity of the hand just before
    impact in m/s');
```

Scilab code Exa 4.14 Burning Off Lunch Calories

```
1  clc;clear;
2  //Example 4.14
3
4  //given data
5  m=90;
6
7  //from Tables 4  1  and 4  2
8  Ehb=275;//hamburger
9  Ef=250;//fries
10 Ec=87;//cola
11
12 //calculation
13
14 //part a
15 Ein=2*Ehb+Ef+Ec;
16 //The rate of energy output for a 68-kg man watching
    TV is to be 72 Calories/h
17 Eout=m*72/68;
18 t=Ein/Eout;
19 disp(t, 'by watching TV in hours');
20
21 //part b
22 //The rate of energy output for a 68-kg man watching
    TV is to be 860 Calories/h
23 Eout=m*860/68;
24 t=Ein/Eout*60//converting in min
25 t=ceil(t);
26 disp(t, 'by fast swimming in mins');
27
28 //for last question
```

```
29 disp('answers be for a 45-kg man energy takes twice  
as long in each case');
```

Scilab code Exa 4.15 Losing Weight by Switching to Fat Free Chips

```
1 clc;clear;  
2 //Example 4.15  
3  
4 //given data  
5 E=75;//in Cal/day  
6  
7 //calculation  
8 Ereduced=E*365;  
9 //The metabolizable energy content of 1 kg of body  
fat is 33,100 kJ  
10 Ec=33100;  
11 mfat=Ereduced/Ec*4.1868;  
12 disp(mfat,'weight this person will lose in one year  
in kg')
```

Chapter 5

Mass and Energy Analysis of Control Volumes

Scilab code Exa 5.1 Water Flow through a Garden Hose Nozzle

```
1  clc;clear;
2  //Example 5.1
3
4  //given data
5  V=10;
6  t=50;
7  p=1;//in kg/L
8  re=0.8/2/100;//in m
9
10 //calculations
11 Vd=V/t*3.7854;//factor of 3.7854 for gal to L
12 disp(Vd,'volumne flow rate through hose in L/s');
13 m=p*Vd;
14 disp(m,'mass flow rate through hose in kg/s');
15 Ae=%pi*re^2;
16 Ve=Vd/Ae/1000;//factor of 1000 for L to m^3
17 disp(Ve,'average velocity at the nozzle in m/s');
```

Scilab code Exa 5.2 Discharge of Water from a Tank

```
1  clc; clear;
2  //Example 5.2
3
4  //given data
5  Dtank=3*12; //in inches
6  Djet=0.5;
7  h0=2;
8  h1=4;
9
10 //constants used
11 g=32.2; //in ft/s^2
12
13 //calculations
14 //min - mout = dmCV/dt
15 //mout = p*(2*g*h*Ajet)^2
16 //mCV = p*Atank*h
17 //from these we get dt = Dtank^2/Djet^2 * (dh/(2*g*h
    )^2)
18 t=integrate('Dtank^2/Djet^2*(1/sqrt(2*g*h))', 'h', h0,
    h1);
19 t=(t/60); //in min
20 disp(t, 'time taken to drop to 2ft in min')
```

Scilab code Exa 5.3 Energy Transport by Mass

```
1  clc; clear;
2  //Example 5.3
3
4  //given data
5  P=150;
```

```

6 Vliquid=0.6/1000; //in m^3
7 t=40*60; //in sec
8 Ac=8*10^-6;
9
10 //from Table A-5
11 //from P = 150 kPa
12 h=2693.1;
13 ug=2519.2;
14 vf=0.001053;
15 vg=1.1594;
16
17 //calculations
18 m=Vliquid/vf;
19 md=m/t;
20 disp(md, 'mass flow rate in kg/s');
21 V=md*vg/(Ac);
22 disp(V, 'exit velocity in m/s');
23 Eflow=h-ug;
24 Et=h;
25 disp(Eflow, 'flow energy in kJ/kg');
26 disp(Et, 'total energy in kJ/kg');
27 Emass=md*Et;
28 disp(Emass, 'rate at which energy leaves the cooker
      in kW')

```

Scilab code Exa 5.4 Deceleration of Air in a Diffuser

```

1 clc;clear;
2 //Example 5.4
3
4 //given data
5 T1=283; //in K
6 P1=80;
7 V1=200;
8 A1=0.4;

```



```

9
10 //constants used
11 R=0.287;//in kPa-m^3/kg-K
12
13 //calculations
14 v1=R*T1/P1;
15 m=V1*A1/v1;
16 disp(m, 'mass flow rate of air in kg/s');
17 // Ein - Eout = dEsystem / dt
18 //from Table A-17
19 h1=283.14;
20 V2=0;
21 h2=h1-(V2^2 - V1^2)/2/1000;//factor of 1000 to
    convert to kJ/kg
22 //from Table A-17 at this value of h2
23 T2=303;
24 disp(T2, 'the temperature in K is');

```

Scilab code Exa 5.5 Acceleration of Steam in a Nozzle

```

1 clc;clear;
2 //Example 5.5
3
4 //given data
5 P1=250;
6 T1=700;
7 A1=0.2;
8 qout=1.2;
9 m=10;
10 P2=200;
11 V2=900;
12
13 //from Table A-6E
14 v1=2.6883;
15 h1=1371.4;

```

```

16
17 //calculations
18 V1=m*v1/A1;
19 disp(V1,'the inlet velocity in ft/s');
20 // Ein - Eout = dEsystem / dt
21 h2=h1-qout-(V2^2 - V1^2)/2/25037;//factor of 25037
    to convert to Btu/lbm
22 //at this value h2, from Tablw A-6E
23 T2=662;
24 disp(T2,'exit temperature in F')

```

Scilab code Exa 5.6 Compressing Air by a Compressor

```

1  clc;clear;
2  //Example 5.6
3
4  //given data
5  T1=280;
6  P1=100;
7  m=0.02;
8  qout=16;
9  P2=600;
10 T2=400;
11
12 //from Table A-17
13 h1=280.13;
14 h2=400.98;
15
16 //calculations
17 // Ein - Eout = dEsystem / dt
18 Win=m*qout+m*(h2-h1);
19 disp(Win,'the input power of compressor in kW')

```

Scilab code Exa 5.7 Power Generation by a Steam Turbine

```
1  clc; clear;
2  //Example 5.7
3
4  //given data
5  P1=2;
6  T1=400;
7  V1=50;
8  z1=10;
9  P2=15;
10 x2=0.9;
11 V2=180;
12 z2=6;
13 Wout=5*1000; //in kJ
14
15 //from Table A-6
16 h1=3248.4;
17 //similarly for P2
18 hf=225.94;
19 hfg=2372.3;
20
21 //constants used
22 g=9.8; //in m/s^2
23
24 //calcualtions
25 h2=hf+x2*hfg;
26 disp((h2-h1), 'difference in enthalpies in kJ/kg');
27 disp((V2^2-V1^2)/2/1000, 'difference in kinetic
    energy in kJ/kg'); //factor of 1000 to convert to
    kJ/kg
28 disp(g*(z2-z1)/1000, 'difference in potential energy
    in kJ/kg'); //factor of 1000 to convert to kJ/kg
29 wout=-((h2-h1)+(V2^2-V1^2)/2/1000+g*(z2-z1)/1000); //
    factor of 1000 to convert to kJ/kg
30 disp(wout, 'work done per unit of mass in kJ/kg');
31 m=Wout/wout;
32 disp(m, 'mass flow rate in kg/s')
```

Scilab code Exa 5.8 Expansion of Refrigerant 134a in a Refrigerator

```
1  clc; clear;
2  //Example 5.8
3
4  //given data
5  P1=0.8;
6  P2=0.12;
7
8  //from Table A-12
9  //sat. liq at P1
10 T1=31.31;
11 h1=95.47;
12 //since process is insentropic and at P2
13 h2=h1;
14 hf=22.49;
15 hg=236.97;
16 T2=-22.32;
17
18 //calculations
19 x2=(h2-hf)/(hg-hf);
20 disp(x2, 'the final state is ');
21 dT=T2-T1;
22 disp(dT, 'temperature drop in C')
```

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

```
1  clc; clear;
2  //Example 5.9
3
4  //given data
```

```

5 T1=140;
6 T2=50;
7 T3=110;
8 P=20;
9
10 //for a compressed liq at given temp
11 h1=107.99;
12 h2=18.07;
13 h3=78.02;
14
15 //calculations
16 //Mass balance min = mout So, m1+m2 = m3
17 //Energy balance Ein = Eout So, m1*h1 + m2*h2 = m3*
    h3
18 //combining realations
19 //m1*h1 + m2*h2 = (m1+m2)*h3
20 //dividing by m2 and y=m1/m2
21 //we get, yh1 + h2 = (y+1)*h3
22 y=(h3-h2)/(h1-h3);
23 y=round(y);
24 disp(y, 'the ratio of mass flow rates')

```

Scilab code Exa 5.10 Cooling of Refrigerant 134a by Water

```

1 clc;clear;
2 //Example 5.10
3
4 //given data
5 T1=15;
6 P1=300;
7 T2=25;
8 T3=70;
9 P3=1000; //in kPa
10 T4=35;
11 mr=6;

```

```

12
13 //from Table A-4, A-13 and A-11
14 h1=62.982;
15 h2=104.83;
16 h3=303.85;
17 h4=100.87;
18
19 //calculations
20 //mass balance m1=m2=mw and m3=m4=mr
21 //energy balance m1*h1 + m3*h3 = m2*h2 + m4*h4
22 //combining them mw*(h1-h2) = mr*(h4-h3)
23 mw= mr*(h4-h3)/(h1-h2);
24 disp(mw,'mass flow rate of cooling water in kg/min')
    ;
25 Qin=mw*(h2-h1);
26 Qin=round(Qin);
27 disp(Qin,'heat transfer rate in kJ/min')

```

Scilab code Exa 5.11 Electric Heating of Air in a House

```

1 clc;clear;
2 //Example 5.11
3
4 //giaven data
5 T1=17+273;//in K
6 P1=100;
7 V1=150;
8 Win=15;
9 Qout=200/1000;//in kJ/s
10
11 //constants used
12 R=0.287;//in kPa-m^3/kg-K
13 cp=1.005;//in kJ/kg C
14
15 //calculations

```

```

16 v1=R*T1/P1;
17 m=V1/v1/60;//factor of 6 to convert to s
18 // Win - Qout = m*cp*(T2-T1)
19 T2= T1 + (Win - Qout)/(m*cp);
20 disp((T2-273), 'exit temperature in C')

```

Scilab code Exa 5.12 Charging of a Rigid Tank by Steam

```

1  clc;clear;
2  //Example 5.12
3
4  //given data
5  Pi=1;
6  Ti=300;
7  P2=1;
8
9  //from Table A-6
10 hi=3051.6;
11
12 //calculations
13 //mass balance mi=m2
14 //energy balance mi*hi= m2*u2
15 //combining them we get ,
16 u2=hi;
17 //from Table A-6
18 //we know P2 and u2, so
19 T2=456.1;
20 disp(T2, 'final temperature in tank in C')

```

Scilab code Exa 5.13 Cooking with a Pressure Cooker

```

1  clc;clear;
2  //Example 5.13

```

```

3
4 //given data
5 V=6/1000;//in m^3
6 Pgage=75;
7 Patm=100;
8 m1=1;
9 Qind=0.5;//d stands for .
10 t=30*60;//in s
11
12 //calculation
13 Pabs=Pgage+Patm;
14 //from Table A-5, the saturation temp
15 T=116.04;
16 disp(T,'the temperature at which cooking takes place
    in C');
17 //mass balance me=(m1-m2)cv
18 //energy balance Qin - mehe = (m2u2 - m1u1)cv
19 Qin=Qind*t;
20 //from Table A-5
21 he=2700.2;
22 vf=0.001;
23 vg=1.004;
24 uf=486.82;
25 ufg=2037.7;
26 v1=V/m1;
27 x1=(v1-vf)/(vg-vf);
28 u1=uf+x1*ufg;
29 U=m1*u1;
30 //Qin = (m1 - V/v2)*he + (V/v2*u2 - m1*u1)
31 //v2=vf + x2*(vg-vf)
32 //u2=uf + x2*ufg
33 //combining these equations we get
34 //solved using EES
35 x2=0.009;
36 v2=vf + x2*(vg-vf);
37 m2=V/v2;
38 disp(m2,'amount of water left in kg')

```

Chapter 6

The Second Law of Thermodynamics

Scilab code Exa 6.1 Net Power Production of a Heat Engine

```
1  clc;clear;
2  //Example 6.1
3
4  //givrn data
5  QH=80;
6  QL=50;
7
8  //calculations
9  Wnet=QH-QL;
10 disp(Wnet,'net power output in MW')
11 nth=Wnet/QH;
12 disp(nth,'the thermal efficiency')
```

Scilab code Exa 6.2 Fuel Consumption Rate of a Car

```
1  clc;clear;
```

```

2 //Example 6.2
3
4 //given data
5 Wnet=65;
6 nth=0.24;
7 HV=19000;
8
9 //calculations
10 QH=Wnet/nth*2545;//factor of 2545 to convert to Btu/
    h
11 m=QH/HV;
12 disp(m,'the engine must burn at fuel rate in lbm/h')

```

Scilab code Exa 6.3 Heat Rejection by a Refrigerator

```

1 clc;clear;
2 //Example 6.3
3
4 //given data
5 Wnet=2;
6 QL=360;
7
8 //calculations
9 COPR=QL/Wnet/60;//factor of 60 to convert kW to kJ/
    min
10 disp(COPR,'coefficient of performance of
    refrigerator');
11 QH=QL+Wnet*60;//factor of 60 to convert kW to kJ/min
12 disp(QH,'heat rejection rate in kJ/min')

```

Scilab code Exa 6.4 Heating a House by a Heat Pump

```

1 clc;clear;

```

```

2 //Example 6.4
3
4 //given data
5 COP=2.5;
6 QH=80000;
7
8 //calculations
9 Wnet=QH/COP;
10 disp(Wnet,'the power consumed in kJ/h')
11 QL=QH-Wnet;
12 disp(QL,'the rate at which heat is absorbed in kJ/h'
    )

```

Scilab code Exa 6.5 Analysis of a Carnot Heat Engine

```

1 clc;clear;
2 //Example 6.5
3
4 //given data
5 QH=500;
6 TL=30+273;//in C
7 TH=652+273;//in C
8
9 //calculations
10 nth=1-TL/TH;
11 disp(nth,'the thermal efficiency of carnot engine');
12 QL=TL*QH/TH;
13 QL=round(QL);
14 disp(QL,'the amount of heat rejected to the sink per
    cycle in kJ')

```

Scilab code Exa 6.6 A Questionable Claim for a Refrigerator

```

1  clc;clear;
2  //Example 6.6
3
4  //given data
5  COP=13.5;
6  TH=75+460; //in R
7  TL=35+460; //in R
8
9  //calculations
10 COPR=1/(TH/TL-1);
11 if(COPR>=COP)
12     disp('claim is true');
13 else
14     disp('claim is false')

```

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

```

1  clc;clear;
2  //Example 6.7
3
4  //given data
5  TL=-5+273; //in C
6  TH=21+273; //in C
7  QH=37.5;
8
9  //calculations
10 COPHP=1/(1-TL/TH);
11 Wnet=QH/COPHP;
12 disp(Wnet, 'minimum power required in kW')

```

Scilab code Exa 6.8 Malfunction of a Refrigerator Light Switch

```

1  clc;clear;

```

```

2 //Example 6.8
3
4 //given data
5 Qrefrig=40;
6 COPR=1.3;
7 Wlight=40;
8
9 //calculation
10 Wrefrig=Qrefrig/COPR;
11 Wt=Wrefrig+Wlight;
12 AnHr=365*24;//annual hours
13 NOH=20*30/3600*365;//normal operating hours
14 AOP=AnHr-NOH;//additional operating hours
15 APC=Wt*AOP/1000;//additional power consumption;
    fator of 1000 to convert to kW
16 APC=round(APC);
17 disp(APC,'increase in power consumption in kWh/yr');
18 disp((APC)*0.08,'increase in cost in Dollar/yr')

```

Chapter 7

Entropy

Scilab code Exa 7.1 Entropy Change during an Isothermal Process

```
1  clc;clear;
2  //Example 7.1
3
4  //given data
5  Q=750;
6  Tsys=300;
7
8  //calculations
9  dSsys=Q/Tsys;
10 disp(dSsys, 'Entropy change in the process in kJ/K')
```

Scilab code Exa 7.2 Entropy Generation during Heat Transfer Processes

```
1  clc;clear;
2  //Example 7.2
3
4  //given data
5  Qsink=2000;
```

```

6 Qsource=-Qsink;
7 Tsource=800;
8
9 //calculations
10 //part - a
11 Tsink=500;
12 dSsource=Qsource/Tsource;
13 dSsink=Qsink/Tsink;
14 Sgena=dSsource+dSsink;
15 disp(Sgena,'entropy generated in part a in kJ/K is ');
16 //part - b
17 Tsink=750;
18 dSsource=Qsource/Tsource;
19 dSsink=Qsink/Tsink;
20 Sgenb=dSsource+dSsink;
21 disp(Sgenb,'entropy generated in part b in kJ/K is ');
22 if(Sgena>Sgenb)
23     disp('part a is more irreversible');
24 elseif(Sgena == Sgenb)
25     disp('heat transfer is equally irreversible');
26 else
27     disp('part b is more irreversible');
28 end,

```

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

```

1 clc;clear;
2 //Example 7.3
3
4 //given data
5 m=5;
6 P1=140;
7 T1=20;

```

```

8 P2=100;
9
10 //from refrigerant -134a data
11 //at P1 and T1
12 s1=1.0624;
13 v1=0.16544;
14 //at P2
15 v2=v1;
16 vf=0.0007529;
17 vg=0.19254;
18 sf=0.07188;
19 sfg=0.87995;
20
21 //calculations
22 // vf < v2 <vg
23 x2=(v2-vf)/(vg-vf);
24 s2=sf+x2*sfg;
25 dS=m*(s2-s1);
26 disp(dS,'entropy change in the process in kJ/k')

```

Scilab code Exa 7.4 Entropy Change of a Substance in a Tank

```

1 clc;clear;
2 //Example 7.4
3
4 //given data
5 m=3;
6 P1=20;
7 T1=70+460;//in R
8 Qin=3450;
9
10 //from Table A-6E
11 //at P1 and T1
12 s1=0.07459;
13 h1=38.08;

```



```

14
15 //calculations
16 //Ein - Eout = dEsystem
17 //Qin = m*(h2 - h1)
18 h2=Qin/m+h1;
19 //from Table A-6E
20 //At P2 and h2
21 s2=1.7761;
22 dS=m*(s2-s1);
23 disp(dS, 'entropy change in Btu/R');

```

Scilab code Exa 7.5 Isentropic Expansion of Steam in a Turbine

```

1 clc;clear;
2 //Example 7.5
3
4 //given data
5 P1=5;
6 T1=450;
7 P2=1.4;
8
9 //calculations
10 //Ein - Eout = dEsystem/dt
11 //Ein = Eout
12 //Wout = m*(h1-h2)
13 //At P1 and T1
14 h1=3317.2;
15 s1=6.8210;
16 s2=s1;
17 //At P2 and s2
18 h2=2967.4;
19 Wout=h1-h2;
20 disp(Wout, 'work output per unit mass in kJ/kg')

```

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

```
1  clc; clear;
2  //Example 7.7
3
4  //given data
5  P1=1;
6  T1=110;
7  P2=5;
8  T2=120;
9
10 //from Table
11 //At P1 and T1
12 s1=4.875;
13 cp1=3.471;
14 //at P2 and T2
15 s2=5.145;
16 cp2=3.486;
17
18 //calculations
19 //part - a
20 dSa=s2-s1;
21 disp(dSa, 'change in entropy in kJ/kg K using
    tabulated properties');
22 //part - b
23 cavg=(cp1+cp2)/2;
24 dSb=cavg*log(T2/T1);
25 disp(dSb, 'change in entropy in kJ/kg K approximating
    liquid methane as an incompressible substance');
26 E=(dSb-dSa)/dSa*100;
27 disp(E, 'Error % is')
```

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

```
1  clc; clear;
2  //Example 7.8
3
4  //given data
5  P1=5;
6  V1=0.280;
7  T1=115;
8  P2=1;
9  dt=8760; //time in h/yr
10 UC=0.075; //unit cost in dollar
11
12 //from Table
13 //at P1 and T1
14 h1=232.3;
15 s1=4.9945;
16 p1=422.15;
17 s2=s1;
18 //at P2 and s2
19 h2=222.8;
20
21 //calculations
22 m=p1*V1;
23 //Ein - Eout = dEsystem/dt
24 //Ein = Eout
25 //Wout = m*(h1-h2)
26 Wout = m*(h1-h2);
27 disp(round(Wout), 'maximum amount of power that can
    be produced in kW')
28 APP=Wout*dt; //annual power production
29 APS=APP*UC; //annual power savings
30 disp(APS, 'Annual power savings in $/year')
```

Scilab code Exa 7.9 Entropy Change of an Ideal Gas

```

1  clc;clear;
2  //Example 7.9
3
4  //given data
5  P1=100;
6  T1=290;
7  P2=600;
8  T2=330;
9
10 //from Table A-17
11 s02=1.79783;
12 s01=1.66802;
13 //Table A-2b
14 cpavg=1.006;
15
16 //constants used
17 R=0.287; //in kJ/kg -K
18
19 //calculations
20 //part-a
21 s21=s02-s01-R*log(P2/P1); //stands for s2 - s1
22 disp(s21,'entropy change using property values from
      air table in kJ/kg-K');
23 s21=cpavg*log(T2/T1)-R*log(P2/P1); //stands for s2 -
      s1
24 disp(s21,'entropy change using average specific heat
      in kJ/kg-K')

```

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

```

1  clc;clear;
2  //Example 7.10
3
4  //given data
5  P1=95;

```

```

6 T1=295;
7 r=8; //ratio of V1/V2
8
9 //calculations
10 //for closed systems V2/V1 = v2/v1
11 //At T1
12 vr1=647.9;
13 vr2=vr1/r;
14 //at vr2
15 T2=662.7;
16 disp(T2,'the final temperature in K')

```

Scilab code Exa 7.11 Isentropic Compression of an Ideal Gas

```

1 clc;clear;
2 //Example 7.11
3
4 //given data
5 P1=14;
6 T1=50+460;
7 T2=320+460;
8
9 //constants used
10 k=1.667;
11
12 //calculations
13 P2=P1*(T2/T1)^(k/(k-1));
14 disp(P2,'exit pressure in psia')

```

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

```

1 clc;clear;

```

```

2 //Example 7.12
3
4 //given data
5 P2=1000;
6 P1=100;
7
8 //from Table A-5
9 //At P2
10 v1=0.001043;
11
12 //calculations
13 Wrev=v1*(P2-P1);
14 disp(Wrev,'compressor work as saturated liquid at
      inlet in kJ/kg')
15 //from Table A-5
16 //at P1 as sat. vapour
17 h1=2675.0;
18 s1=7.3589;
19 s2=s1
20 //from Table A-6
21 //at P2 and s2
22 h2=3194.5;
23 Wrev=h2-h1;
24 disp(Wrev,'compressor work as saturated vapor at
      inlet in kJ/kg')

```

Scilab code Exa 7.13 Work Input for Various Compression Processes

```

1 clc;clear;
2 //Example 7.13
3
4 //given data
5 P1=100;
6 T1=300;
7 P2=900;

```

```

8
9 //constants used
10 R=0.287;//in kJ/kg -K
11
12 //calculations
13 //part - a
14 k=1.4;
15 Wcomp=k*R*T1/(k-1)*((P2/P1)^((k-1)/k)-1);
16 disp(Wcomp,'compression work in case of isentropic
    compression in kJ/kg');
17 //part - b
18 n=1.3;
19 Wcomp=n*R*T1/(n-1)*((P2/P1)^((n-1)/n)-1);
20 disp(Wcomp,'compression work in case of polytropic
    compression in kJ/kg');
21 //part - c
22 Wcomp=R*T1*log(P2/P1);
23 disp(Wcomp,'compression work in case of isothermal
    compression in kJ/kg');
24 //part - d
25 Ps=sqrt(P1*P2);
26 Wcomp=2*n*R*T1/(n-1)*((Ps/P1)^((n-1)/n)-1);
27 disp(Wcomp,'compression work in case of two-stage
    compression with intercooling in kJ/kg');

```

Scilab code Exa 7.14 Isentropic Efficiency of a Steam Turbine

```

1 clc;clear;
2 //Example 7.14
3
4 //given data
5 P1=3000;// in kPa
6 T1=400;
7 P2=50;
8 T2=100;

```

```

9 Wout=2000; //in kW
10
11 //from Table A-6
12 //at P1
13 h1=3231.7;
14 s1=6.9235;
15 //at 2a
16 h2a=2682.4;
17 //from Table A-6
18 //at 2s
19 s2s=s1;
20 sf=1.0912;
21 sg=7.5937;
22 hf=340.54;
23 hfg=2304.7
24 x2s=(s2s-sf)/(sg-sf);
25 h2s=hf+x2s*hfg;
26 nT=(h1-h2a)/(h1-h2s);
27 disp(nT,'isentropic efficiency is')
28 //Ein = Eout
29 m=Wout/(h1-h2a);
30 disp(m,'mass flow rate in kg/s')

```

Scilab code Exa 7.15 Effect of Efficiency on Compressor Power Input

```

1 clc;clear;
2 //Example 7.15
3
4 //given data
5 P1=100;
6 T1=285;
7 P2=800;
8 m=0.2;
9 nc=0.8;
10

```



```

11 //from Table A-17
12 //at T1
13 h1=285.14;
14 Pr1=1.1584;
15
16 //calculations
17 Pr2=Pr1*(P2/P1);
18 //at Pr2
19 h2s=517.05;
20 h2a=(h2s-h1)/nc+h1;
21 //at h2a
22 T2a=569.5;
23 disp(T2a,'exit temperature of air in K');
24 //Ein = Eout
25 Wa=m*(h2a-h1);
26 disp(round(Wa),'required power input in kW')

```

Scilab code Exa 7.16 Effect of Efficiency on Nozzle Exit Velocity

```

1 clc;clear;
2 //Example 7.16
3
4 //given data
5 P1=200;
6 T1=950;
7 P2=80;
8 nN=0.92;
9
10 //from Table A-2b
11 cp=1.099;
12 k=1.354;
13
14 //calculations
15 T2s=T1*(P2/P1)^((k-1)/k);
16 //ein = eout

```

```

17 V2s=sqrt(2*cp*(T1-T2s)*1000); //factor of 1000 for
    conversion to m^2/s^2
18 disp(floor(V2s), 'maximum possible exit velocity in m
    /s ');
19 T2a=T1-nN*(T1-T2s);
20 disp(round(T2a), 'exit temperature in K');
21 V2a=sqrt(nN*V2s^2);
22 disp(floor(V2a), 'actual exit velocity in m/s')

```

Scilab code Exa 7.17 Entropy Generation in a Wall

```

1 clc;clear;
2 //Example 7.17
3
4 //given data
5 Qin=1035;
6 Tin=20+273; //in K
7 Qout=Qin;
8 Tout=5+273; //in K
9
10 //calculations
11 // Sin - Sout + Sgen = dSsystem/dt
12 Sgen=(Qout/Tout)-(Qin/Tin);
13 disp(Sgen, 'entropy generation in the wall in W/K');
14 Ts1=300;Ts2=273; //Boundary temperatures
15 Sgen=(Qout/Ts2)-(Qin/Ts1);
16 disp(Sgen, 'total entropy generation in W/K');

```

Scilab code Exa 7.18 Entropy Generation during a Throttling Process

```

1 clc;clear;
2 //Example 7.18
3

```

```

4 //given data
5 P1=7;
6 T1=450;
7 P2=3;
8
9 //from steam tables
10 //at P1 and T1
11 h1=3288.3;
12 s1=6.6353;
13 //at P2
14 h2=h1;
15 s2=7.0046;
16
17 //calculations
18 // Sin - Sout + Sgen = dSsystem/dt
19 Sgen=s2-s1;
20 disp(Sgen, 'the entropy generated in kJ/kg-K')

```

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

```

1 clc;clear;
2 //Example 7.19
3
4 //given data
5 m=50;
6 T1=500;
7 T2=285;
8
9 //from Table A-3
10 Cavg=0.45;
11
12 //calculations
13 dSiron=m*Cavg*log(T2/T1);
14 disp(dSiron, 'entropy change of the iron block in kJ/

```

```

    K');
15 // Ein - Eout = dEsystem
16 Qout=m*Cavg*(T1-T2);
17 dSlake=Qout/T2;
18 disp(dSlake,'entropy change of the lake in kJ/K');
19 // Sin - Sout + Sgen = dSsystem/dt
20 Sgen=(Qout/T2)+dSiron;
21 disp(Sgen,'entropy change in the process in kJ/K')

```

Scilab code Exa 7.20 Entropy Generation in a Mixing Chamber

```

1  clc;clear;
2  //Example 7.20
3
4  //given data
5  P=20;
6  T1=50+460;//in R
7  T2=240;
8  T3=130;
9  m1=300;
10 Qout=180;
11
12 //from steam tables
13 //at P and T1
14 h1=18.07;
15 s1=0.03609;
16 //at P and T2
17 h2=1162.3;
18 s2=1.7406;
19 //at P and T3
20 h3=97.99;
21 s3=0.18174;
22
23 //calculations
24 // Qout = m1*h1 + m2*h2 - (m1+m2)*h3

```

```

25 m2= (Qout-m1*h1+m1*h3)/(h2-h3);
26 m3=m1+m2;
27 // Sin - sout + Sgen = dSsystem/dt
28 Sgen=m3*s3-m1*s1-m2*s2+Qout/T1;
29 disp(Sgen,'the rate of entropy generation in Btu/min
      R')

```

Scilab code Exa 7.21 Entropy Generation Associated with Heat Transfer

```

1  clc;clear;
2  //Example 7.21
3
4  //given data
5  T=100+273;//in K
6  Q=-600;
7  Tb=25+273;//in K
8
9  //calculation
10 dSsys=Q/T;
11 disp(dSsys,'entropy change of water in kJ/K');
12 // Sin - sout + Sgen = dSsystem
13 Sgen= -Q/Tb + dSsys;
14 disp(Sgen,'total entropy generation in kJ/K')

```

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

```

1  clc;clear;
2  //Example 7.22
3  //difference in answers is arised due the fact the
      Energy savings have been rounded to the multiple
      of 100
4
5  //given data

```

```

6 T1=20+273;
7 T2=24+273;
8 P1=101;
9 P2=801;
10 D=3/1000; //in m
11 Cdischarge=0.65;
12 ncomp=0.8;
13 nmotor=0.92;
14 UC=0.078; //unit cost
15
16 //constants used
17 R=0.287; //in kJ/kg K
18 k=1.4;
19 n=1.4;
20
21 //calculations
22 Win=n*R*T1/(ncomp*(n-1))*((P2/P1)^((n-1)/n)-1);
23 A=%pi*D^2/4;
24 mair=Cdischarge*(2/(k+1))^(1/(k-1))*P2*A/(R*T2)*sqrt
    (k*R*1000*2/(k+1)*T2); //factor of 1000 to m^2/s^2
25 PW=mair*Win; //Power wasted
26 ES=PW*4200/nmotor; //4200 is operating hours ES
    stands for Energy savings
27 disp(ES,'Energy savings in kWh/yr');
28 CS=ES*UC;
29 disp(ceil(CS),'cost savings in Dollar/yr')

```

Scilab code Exa 7.23 Reducing the Pressure Setting to Reduce Cost

```

1 clc;clear;
2 //Example 7.23
3
4 //given data
5 P1=85.6;
6 P2=985.6;

```

```
7 P2r=885.6;
8 CC=12000; //current cost
9
10 //constants used
11 n=1.4;
12
13 //calulation
14 freduction=1-(((P2r/P1)^((n-1)/n)-1)/((P2/P1)^((n-1)
    /n)-1));
15 CS=CC*freduction;
16 disp(round(CS), 'cost savings in Dollar/yr')
```

Chapter 8

Exergy A Measure of Work Potential

Scilab code Exa 8.1 Maximum Power Generation by a Wind Turbine

```
1  clc;clear;
2  // Example 8.1
3
4  // given data
5  D=12;
6  V=10;
7
8  // density of air at 25C & 1atm
9  p=1.18;
10
11 //calculations
12 ke=(V^2)/2/1000; //factor of 1000 for converting J
    into kJ
13 m=p*pi*[D ^2]*V/4;
14 MP=m*(ke);
15 disp(MP, 'Maximum power in kW')
```

Scilab code Exa 8.2 Exergy Transfer from a Furnace

```
1  clc; clear;
2  //Example 8.2
3
4  //given values
5  TH=2000;
6  T0=77+460; //in R
7  Qin=3000;
8
9  //calculation
10 nth=1-(T0/TH);
11 Wmax=nth*Qin;
12 Wmax=round(Wmax)
13 disp(Wmax, 'the rate of energy flow in Btu/s')
```

Scilab code Exa 8.3 The Rate of Irreversibility of a Heat Engine

```
1  clc; clear;
2  //Example 8.3
3
4  //given data
5  Tsink=300;
6  Tsource=1200;
7  Qin=500;
8  Wuout=180;
9
10 //calculations
11 Wrev=(1-Tsink/Tsource)*Qin;
12 disp(Wrev, 'The reversible power in kW');
13 I=Wrev-Wuout;
14 disp(I, 'the irreversibility rate in kW')
```

Scilab code Exa 8.4 Irreversibility during the Cooling of an Iron Block

```
1  clc; clear;
2  //Example 8.4
3
4  //given data
5  m=500;
6  T1=473;
7  T0=300;
8  Wu=0;
9
10 //from Table A-3
11 cavg=0.45;
12
13 //calculations
14 Wrev=integrate('(1-T0/T)*(-m*cavg)', 'T', T1, T0); //
    intergrant
15 Wrev=floor(Wrev);
16 disp(Wrev, 'The reversible power in kJ');
17 I=Wrev-Wu;
18 disp(I, 'the irreversiblity rate in kJ');
```

Scilab code Exa 8.5 Heating Potential of a Hot Iron Block

```
1  clc; clear;
2  //Example 8.5
3
4  //given data
5  Wrev=8191;
6  Wtotal=38925;
7  TL=278;
8  TH=300;
9
10 //calculations
11 Wrm=Wtotal-Wrev; //work remaining
```

```

12 COPHP=1/(1-TL/TH);
13 Wd=COPHP*Wrev; //work delivered
14 PS=Wd+Wrm;
15 PS=round(PS/1000); //factor of 1000 for converting kJ
    into MJ
16 disp(PS, 'Maximum amount of heat in MJ')

```

Scilab code Exa 8.6 Second Law Efficiency of Resistance Heaters

```

1 clc;clear;
2 //Example 8.6
3
4 //given data
5 COP=1;
6 TL=283; //in K
7 TH=294; //in K
8
9 //calculations
10 COPHP=1/(1-TL/TH);
11 nII=COP/COPHP;
12 disp(nII, 'the second law efficiency')

```

Scilab code Exa 8.7 Work Potential of Compressed Air in a Tank

```

1 clc;clear;
2 //Example 8.7
3
4 //given data
5 P1=1000;
6 V=200;
7 T1=300;
8 T0=T1;
9 P0=100;

```

```

10
11 //constants used
12 R=0.287; //in kPa m^3/kg K
13
14 //calculations
15 m1=P1*V/(R*T1);
16 O1=R*T0*(P0/P1-1)+R*T0*log(P1/P0); // O refers to
    exergy
17 X1=m1*O1/1000; //factor of 1000 for converting kJ
    into MJ
18 X1=round(X1);
19 disp(X1, 'work obtained in MJ')

```

Scilab code Exa 8.8 Exergy Change during a Compression Process

```

1  clc; clear;
2  //Example 8.8
3
4  //given data
5  T0=20+273; //in K
6  P1=0.14;
7  T1=-10;
8  P2=0.8;
9  T2=50;
10
11 //the properties of refrigerant
12 //at inlet
13 h1=246.36;
14 s1=0.9724;
15 //at outlet
16 h2=286.69;
17 s2=0.9802;
18 d0=h2-h1-T0*(s2-s1); // O refers to exergy
19 d0=round(d0);
20 disp(d0, 'the exergy change of the refrigerant in kJ/

```

```

    kg')
21 wmin=d0;
22 disp(wmin,'the minimum work input that needs to be
    supplied is in kJ/kg')

```

Scilab code Exa 8.10 Exergy Destruction during Heat Conduction

```

1  clc;clear;
2  //Example 8.10
3
4  //given values
5  Q=1035;
6  T0=273;
7  Tin=293;
8  Tout=278;
9  T1=300;
10
11 //calculations
12 //Xin - Xout - Xdestroyed = dX/dt
13 Xdestroyed=Q*(1-T0/Tin)-Q*(1-T0/Tout);
14 Xdestroyed=round(Xdestroyed);
15 disp(Xdestroyed,'the rate of exergy destroyed in W')
    ;
16 //the total rate of exergy destroyed
17 Xdestroyed=Q*(1-T0/T1)-Q*(1-T0/T0);
18 disp(Xdestroyed,'the otal total of exergy destroyed
    in W');

```

Scilab code Exa 8.11 Exergy Destruction during Expansion of Steam

```

1  clc;clear;
2  //Example 8.11
3

```

```

4 //given data
5 m=0.05;
6 P1=1000;
7 T1=300+273;//in K
8 P2=200;
9 T2=150+273;//in K
10 P0=100;
11 T0=25+273;//in K
12 Qout=2;
13
14 //from Table A-6 & A-4
15 u1=2793.7;
16 v1=0.25799;
17 s1=7.1246;
18 u2=2577.1;
19 v2=0.95986;
20 s2=7.2810;
21 u0=104.83;
22 v0=0.00103;
23 s0=0.3672;
24
25 //calculations
26 X1=m*(u1-u0-T0*(s1-s0)+P0*(v1-v0));
27 X2=m*(u2-u0-T0*(s2-s0)+P0*(v2-v0));
28 disp(X1,'exergy of intial state in kJ');
29 disp(X2,'exergy of final state in kJ');
30 dX=X2-X1;
31 disp(dX,'exergy change in system in kJ');
32 Wout=-Qout-m*(u2-u1);
33 Wu=Wout-P0*m*(v2-v1);
34 Xdestroyed=X1-X2-Wu;
35 disp(Xdestroyed,'the exergy destroyed in kJ');
36 nII=Wu/(X1-X2);
37 disp(nII,'second law efficiency of this process')

```

Scilab code Exa 8.12 Exergy Destroyed during Stirring of a Gas

```
1  clc;clear;
2  //Example 8.12
3
4  //given data
5  m=2;
6  T0=70+460;//in R
7  P1=20;
8  T1=70+460;//in R
9  T2=130+460;//in R
10
11 //constants used
12 Cv=0.172;//in Btu/lbm - F
13
14 //calculations
15 Xdestroyed=T0*m*Cv*log(T2/T1);
16 disp(Xdestroyed,'exergy destroyed in Btu');
17 Wrev=integrate('(1-T0/T)*m*Cv','T',T1,T2);
18 Wrev=round(Wrev);
19 disp(Wrev,'the reversible work in Btu')
```

Scilab code Exa 8.13 Dropping a Hot Iron Block into Water

```
1  clc;clear;
2  //Example 8.13
3
4  //given data
5  T0=20+273;//in K
6  P0=100;
7  Tiw=30+273;//in K
8  mw=100;
9  Tii=350+273;//in K
10 mi=5;
11
```

```

12 //constants used(Table A-3)
13 cw=4.18;//in kJ/kg C
14 ci=0.45;//in kJ/kg C
15
16 //calculations
17 Tfk=(mi*ci*Tii+mw*cw*Tiw)/(mw*cw+mi*ci);
18 Tfc=Tfk-273;//in C
19 disp(Tfc,'the final equilibrium temperature in C');
20 X1i=mi*ci*(Tii-T0-T0*log(Tii/T0));
21 X1w=mw*cw*(Tiw-T0-T0*log(Tiw/T0));
22 X1t=X1i+X1w;//total exergy
23 disp(X1t,'intial exergy of combined systems in kJ');
24 X2i=mi*ci*(Tfk-T0-T0*log(Tfk/T0));
25 X2w=mw*cw*(Tfk-T0-T0*log(Tfk/T0));
26 X2t=X2i+X2w;//total exergy
27 disp(X2t,'intial exergy of combined systems in kJ');
28 Xdestroyed=X1t-X2t;
29 disp(Xdestroyed,'the wasted work in kJ')

```

Scilab code Exa 8.14 Exergy Destruction during Heat Transfer to a Gas

```

1 clc;clear;
2 //Example 8.14
3
4 //given data
5 TR=1200;
6 T0=300;
7 P0=100;
8 Tsys=400;
9 P1=350;
10 V1=0.01;
11 V2=2*V1;
12
13 //calculations
14 W=P1*V1*log(V2/V1);

```



```

15 Wsurr=P0*(V2-V1);
16 Wu=W-Wsurr;
17 disp(Wu,'the useful work output in kJ');
18 // Qin - W = m*Cv*dT, Since dt=0
19 Q=W;
20 Sgen=Q/Tsys-Q/TR;
21 Xdestroyed=T0*Sgen;
22 disp(Xdestroyed,'the exergy destroyed in kJ/K');
23 Wrev=T0*Q/Tsys-Wsurr+(1-T0/TR)*Q;
24 disp(Wrev,'the reversible work is done in the
    process in kJ');

```

Scilab code Exa 8.15 Second Law Analysis of a Steam Turbine

```

1  clc;clear;
2  //Example 8.15
3  //calculation error in textbook in part - b which
   changes all the following answers
4
5  //given data
6  m=8;
7  T0=25+273;//in K
8  P0=100;
9  P1=3000;
10 T1=450;
11 P2=200;
12 T2=150;
13 Qout=300;
14
15 //from Table A-6 and A-4
16 h1=3344.9;
17 s1=7.0856;
18 h2=2769.1;
19 s2=7.2810;
20 h0=104.83;

```

```

21 s0=0.3672;
22
23 // calculations
24 // Ein = Eout
25 Wout=m*(h1-h2)-Qout;
26 disp(Wout,'the actual power output in kW');
27 // Xin = Xout
28 Wrev=m*((h1-h2)-T0*(s1-s2));
29 disp(Wrev,'the maximum possible work output in kW');
30 nII=Wout/Wrev;
31 disp(nII,'second law efficiency');
32 Xdestroyed=Wrev-Wout;
33 disp(Xdestroyed,'the exergy destroyed in kW');
34 X1=h1-h0-T0*(s1-s0);
35 disp(X1,'the exergy of the steam at inlet conditions
    in kJ/kg')

```

Scilab code Exa 8.16 Exergy Destroyed during Mixing of Fluid Streams

```

1  clc;clear;
2  //Example 18.16
3
4  //given data
5  T0=70+460;
6  T1=50;
7  T2=240;
8  T3=130;
9  //as dicussed in example 7-20
10 m1=300;
11 m2=22.7;
12 m3=322.7;
13
14 //from steam tables
15 h1=18.07;
16 s1=0.03609;

```

```

17 h2=1162.3;
18 s2=1.7406;
19 h3=97.99;
20 s3=0.18174;
21
22 //calculations
23 Wrev=m1*(h1-T0*s1)+m2*(h2-T0*s2)-m3*(h3-T0*s3);
24 Wrev=round(Wrev);
25 disp(Wrev,'the reversible power in Btu/min')
26 Xdestroyed=Wrev;
27 disp(Xdestroyed,'the rate of exergy destruction in
    Btu/min')

```

Scilab code Exa 8.17 Charging a Compressed Air Storage System

```

1  clc;clear;
2  //Example 8.17
3
4  //given data
5  V=200;
6  P1=100;
7  P2=1000;
8  P0=100;
9  T=300;
10
11 //constants used
12 R=0.287;//in kPa m^3/kg K
13
14 //calculations
15 //Xin - Xout = Xdestroyed = X2 - X1
16 m2=P2*V/(R*T);
17 X2=R*T*(log(P2/P0)+P0/P2-1);
18 Wrev=m2*X2/1000;
19 Wrev=round(Wrev);
20 disp(Wrev,'Work requirement in MJ')

```


Chapter 9

Gas Power Cycles

Scilab code Exa 9.2 The Ideal Otto Cycle

```
1  clc;clear;
2  //Example 9.2
3
4  //given data
5  T1=17+273;//in K
6  P1=100;
7  r=8;//compression ratio i.e v1/v2
8  Qin=800;
9
10 //constants used
11 R=0.287;//in kPa-m^3/kg-K
12
13 //from Table A-17
14 //at T1
15 u1=206.91;
16 vr1=676.1;
17
18 //calculations
19 //Process 1-2
20 vr2=vr1/r;
21 //at this vr2
```

```

22 T2=652.4;
23 u2=475.11;
24 P2=P1*(T2/T1)*(r);
25 //Process 2-3
26 u3=qin+u2;
27 //at this u3
28 T3=1575.1;
29 vr3=6.108;
30 P3=P2*(T3/T2)*1;//factor of 1 as v3=v2
31 disp(T3,'maximum temperature in the cycle in K');
32 disp(P3/1000,'maximum pressure in MPa');//factor of
    1000 to convert into MPa
33 //Process 3-4
34 vr4=r*vr3;
35 //at this vr4
36 T4=795.6;
37 u4=588.74;
38 //Process 4-1
39 qout=u4-u1;
40 Wnet=qin-qout;
41 disp(Wnet,'net work output in kJ/kg');
42 nth=Wnet/qin;
43 disp(nth,'thermal efficiency');
44 v1=R*T1/P1;
45 MEP=Wnet/(v1*(1-1/r));
46 MEP=round(MEP);
47 disp(MEP,'mean effective pressure in kPa')

```

Scilab code Exa 9.3 The Ideal Diesel Cycle

```

1 clc;clear;
2 //Example 9.3
3
4 //given data
5 V1=117;

```

```

6 T1=80+460; //in R
7 P1=14.7;
8 r=18;
9 rc=2;
10
11 //constants used
12 R=0.3704; //in psia ft^3/lbm R
13 cp=0.240; //in Btu/lbm R
14 cv=0.171; //in Btu/lbm R
15
16 //from Table A-2Ea
17 k=1.4;
18
19 //calculations
20 V2=V1/r;
21 V3=rc*V2;
22 V4=V1;
23 //Process 1-2
24 T2=T1*(V1/V2)^(k-1);
25 P2=P1*(V1/V2)^k;
26 T2=round(T2);
27 P2=round(P2);
28 disp('Process 1-2');
29 disp(T2,'temperature in R');
30 disp(P2,'pressure in psia');
31 //Process 2-3
32 P3=P2;
33 T3=T2*(V3/V2);
34 T3=round(T3);
35 P3=round(P3);
36 disp('Process 2-3');
37 disp(T3,'temperature in R');
38 disp(P3,'pressure in psia');
39 //Process 3-4
40 T4=T3*(V3/V4)^(k-1);
41 P4=P3*(V3/V4)^k;
42 T4=round(T4);
43 P4=round(P4);

```

```

44 disp('Process 3-4');
45 disp(T4,'temperature in R');
46 disp(P4,'pressure in psia');
47 m=P1*V1/(R*T1)/1728;//factor of 1728 to covert to ft
    ^3 from in^3
48 Qin=m*cp*(T3-T2);
49 Qout=m*cv*(T4-T1);
50 Wnet=Qin-Qout ;
51 disp(Wnet,'work output in Btu');
52 nth=Wnet/Qin;
53 disp(nth,'thermal efficiency');
54 MEP=Wnet/(V1-V2)*778.17*12;//factor of 778.17 and 12
    to convert to lbf ft and in from Btu and ft
    respectively
55 MEP=round(MEP);
56 disp(MEP,'mean effective pressure in psia')

```

Scilab code Exa 9.5 The Simple Ideal Brayton Cycle

```

1  clc;clear;
2  //Example 9.5
3
4  //given data
5  T1=300;
6  r=8;
7  T3=1300;
8
9  //calcualtions
10 //Process 1-2
11 //at T1
12 h1=300.19;
13 Pr1=1.386;
14 Pr2=r*Pr1;
15 //at Pr2
16 T2=540;

```



```

17 h2=544.35;
18 disp(T2,'temperature at exit of compressor in K');
19 //Process 3-4
20 //at T3
21 h3=1395.97;
22 Pr3=330.9;
23 Pr4=Pr3/r;
24 //at Pr4
25 T4=770;
26 h4=789.37;
27 disp(T4,'temperature at turbine exit in K');
28 Win=h2-h1;
29 Wout=h3-h4;
30 rbw=Win/Wout;
31 disp(rbw,'back work ratio');
32 Qin=h3-h2;
33 Wnet=Wout-Win;
34 nth=Wnet/Qin;
35 disp(nth,'thermal efficiency')

```

Scilab code Exa 9.6 An Actual Gas Turbine Cycle

```

1 clc;clear;
2 //Example 9.6
3
4 //from 9.5
5 Wsc=244.16; //compressor
6 Wst=606.60; //turbine
7 h1=300.19;
8 h3=1395.17;
9
10 //given data
11 nC=0.8;
12 nT=0.85;
13

```

```

14 // calculations
15 Win=Wsc/nC;
16 Wout=nT*Wst;
17 rbw=Win/Wout;
18 disp(rbw,'back work ratio is ');
19 h2a=h1+Win;
20 qin=h3-h2a;
21 Wnet=Wout-Win;
22 nth=Wnet/qin;
23 disp(nth,'thermal efficiency is ');
24 h4a=h3-Wout;
25 //from A-17 at h4a
26 T4a=853;
27 disp(T4a,'turbine exit temperature in K is ')

```

Scilab code Exa 9.7 Actual Gas Turbine Cycle with Regeneration

```

1  clc;clear;
2  //Example 9.7
3
4  //from 9.6
5  h2a=605.39;
6  h4a=880.36;
7  h3=1395.97;
8  Wnet=210.41;
9
10 //given data
11 n=0.80;
12
13 // calculations
14 //  $n = (h5 - h2a) / (h4a - h2a)$ 
15 h5=(h4a - h2a)*n+h2a;
16 qin=h3-h5;
17 nth=Wnet/qin;
18 disp(nth,'thermal efficiency is ')

```

Scilab code Exa 9.8 A Gas Turbine with Reheating and Intercooling

```
1  clc; clear;
2  //Example 9.8
3
4  //given data
5  T1=300;
6  T6=1300;
7  r=8; //overall compression ratio
8
9  //calculations
10 //as it is case of intercooling
11 ri=sqrt(r); //ri stands for  $P2/P1 = P4/P3 = P6/P7 =$ 
    P8/P9
12 //from A-17 at T1
13 h1=300.19;
14 Pr1=1.386;
15 Pr2=ri*Pr1;
16 //from A-17 at Pr2
17 T2=403.3;
18 h2=403.31;
19 //from A-17 at T6
20 h6=1395.97;
21 Pr6=330.9;
22 Pr7=Pr6/ri;
23 //from A-17 at Pr7
24 T7=1006.4;
25 h7=1053.33;
26 //at inlets
27 T3=T1; h3=h1; T8=T6; h8=h6;
28 //et exits
29 T4=T2; h4=h2; T9=T7; h9=h7; h5=h7;
30 Win=2*(h2-h1);
31 Wout=2*(h6-h7);
```

```

32 Wnet=Wout-Win;
33 qin=(h6-h4)+(h8-h7);
34 rbw=Win/Wout;
35 disp(rbw,'back work ratio');
36 nth=Wnet/qin;
37 disp(nth,'thermal efficiency is')
38 //part - b
39 disp('part - b');
40 qin=(h6-h5)+(h8-h7);
41 nth=Wnet/qin;
42 disp(nth,'thermal efficiency is')

```

Scilab code Exa 9.9 The Ideal Jet Propulsion Cycle

```

1  clc;clear;
2  //Example 9.9
3
4  //given data
5  m=100;
6  P1=5;
7  T1=-40+460;//in R
8  T4=2000+460;//in R
9  V1=850;
10 rp=10;
11
12 //constants used
13 cp=0.240;//in Btu/lbm F
14 k=1.4;
15
16 //calculations
17 //Process 1-2
18 T2=T1+V1^2/(2*cp)/25037;//factor of 25037 to covert
    to Btu/lbm
19 P2=P1*(T2/T1)^(k/(k-1));
20 //Process 2-3

```

```

21 P3=rp*P2;
22 P4=P3;
23 T3=T2*(P3/P2)^((k-1)/k);
24 //Win=Wout
25 T5=T4-T3+T2;
26 P5=P4*(T5/T4)^(k/(k-1));
27 T5=round(T5);
28 disp(T5,'temperature at turbine exit in R');
29 disp(P5,'pressure at turbine exit in psia');
30 //Process 5-6
31 P6=P1;
32 T6=T5*(P6/P5)^((k-1)/k);
33 T6=floor(T6); //round off
34 V6=sqrt(2*cp*(T5-T6)*25037); //factor of 25037 to
    covert to (ft/s)^2
35 disp(round(V6),'the velocity of nozzle exit in ft/s'
    );
36 Wp=m*(V6-V1)*V1/25037; //factor of 25037 to covert to
    Btu/lbm
37 Qin=m*cp*(T4-T3);
38 nP=Wp/Qin;
39 disp(nP*100,'propulsive efficiency % is ')

```

Scilab code Exa 9.10 Second Law Analysis of an Otto Cycle

```

1  clc;clear;
2  //Example 9.10
3
4  //from 9.2
5  r=8;
6  T0=290;
7  T1=290;
8  T2=652.4;
9  T3=1575.1;
10 P2=1.7997;

```

```

11 P3=4.345;
12 Qin=800;
13 Qout=381.83;
14 Wnet=418.17;
15 Tsource=1700;
16
17 //constants used
18 R=0.287; //in kPa-m^3/kg-K
19
20 //calculations
21 //s1=s2 ; s3=s4
22 s03=3.5045;
23 s02=2.4975;
24 s32=(s03-s02)-R*log(P3/P2); //s32 stands for s3-s2
25 xdest23=T0*(s32-Qin/Tsource);
26 Tsink=T1;
27 xdest41=T0*(-s32+Qout/Tsink);
28 xdestcycle=xdest23+xdest41;
29 disp(xdestcycle,'exergy destruction associated with
    Otto cycle inkJ/kg');
30 // X4 = (u4 - u0) - T0*(s4 - s0) + P0(v4 - v0)
31 // s4 - s0 = s4 - s1 = s32
32 // u4 - u0 = u4 - u1 = Qout
33 // v4 - v0 = v4 - v1 = 0
34 //hence x4 is
35 X4=Qout-T0*s32;
36 disp(X4,'exergy destruction of purge stream in kJ/kg
    ')

```

Chapter 10

Vapor and Combined Power Cycles

Scilab code Exa 10.1 The Simple Ideal Rankine Cycle

```
1  clc;clear;
2  //Example 10.1
3
4  //given data
5  P1=75;
6  P2=3000;//in kPa
7  P3=P2;
8  T3=350;
9  P4=P1;
10
11 //from steam tables
12 //at state 1
13 v1=0.001037;
14 h1=384.44;
15 //at state 3
16 h3=3116.1;
17 s3=6.7450;
18 //at state 4
19 s4=s3;
```

```

20 sf=1.2132;
21 sfg=6.2426;
22 hf=384.44;
23 hfg=2278;
24
25 // calculations
26 win=v1*(P2-P1);
27 h2=h1+win;
28 x4=(s4-sf)/sfg;
29 h4=hf+x4*hfg;
30 Qin=h3-h2;
31 Qout=h4-h1;
32 nth=1-(Qout/Qin);
33 disp(nth*100,'thermal efficiency % is ')

```

Scilab code Exa 10.2 An Actual Steam Power Cycle

```

1  clc;clear;
2  //Example 10.2
3
4  //given data
5  P1=9;
6  T1=38;
7  P2=16000;
8  P3=15.9;
9  T3=35;
10 P4=15.2;
11 T4=625;
12 P5=15;
13 T5=600;
14 nT=0.87;
15 nP=0.85;
16 m=15;
17
18 //from steam tables

```



```

19 v1=0.001009;
20 h5=3583.1;
21 h6s=2115.3;
22 h4=3647.6;
23 h3=160.1;
24
25 //calculations
26 Win=v1*(P2-P1)/nP;
27 Wout=nT*(h5-h6s);
28 Qin=h4-h3;
29 Wnet=Wout-Win;
30 nth=Wnet/Qin;
31 disp(nth, 'thermal efficiency is ');
32 Wnet=m*Wnet;
33 disp(Wnet/1000, 'power output in MW')

```

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

```

1  clc;clear;
2  //Example 10.3
3
4  //given data
5  P1=10;
6  P2=3000;
7  P3=3000;
8  T3=350;
9  P4=10;
10
11 //from steam tables
12 //at state 1
13 h1=191.81;
14 v1=0.00101;
15 //at state 2
16 //s2=s1

```

```

17 //at state 3
18 h3=3116.1;
19 s3=6.7450;
20 //at state 4
21 s4=s3;
22 sf=0.6492;
23 sfg=7.4996;
24 hf=191.81;
25 hfg=2392.1;
26
27 //calculations
28 //part - a
29 win=v1*(P2-P1);
30 h2=h1+win;
31 x4=(s4-sf)/sfg;
32 h4=hf+x4*hfg;
33 qin=h3-h2;
34 qout=h4-h1;
35 nth=1-(qout/qin);
36 disp(nth,'the thermal efficiency of this power plant
    ');
37 //part - b
38 //States 1 and 2 remain the same in this case, and
    the enthalpies at state 3 (3 MPa and 600 C) and
    state 4 (10 kPa and s4=s3) are determined to be
39 h3=3682.8;
40 h4=2380.3;
41 x4=0.915;
42 qin=h3-h2;
43 qout=h4-h1;
44 nth=1-(qout/qin);
45 disp(nth,'the thermal efficiency if steam is
    superheated to 600 instead of 350 C');
46 //part - c
47 //State 1 remains the same in this case, but the
    other states change. The enthalpies at state 2
    (15 MPa and s2 s1), state 3 (15 MPa and 600 C),
    and state 4 (10 kPa and s4 s3) are determined in

```

```

        a similar manner to be
48 h2=206.95;
49 h3=3583.1;
50 h4=2115.3;
51 x4=0.804;
52 Qin=h3-h2;
53 Qout=h4-h1;
54 nth=1-(Qout/Qin);
55 disp(nth,'the thermal efficiency if the boiler
        pressure is raised to 15 MPa while the turbine
        inlet temperature is maintained at 600 C ');

```

Scilab code Exa 10.4 The Ideal Reheat Rankine Cycle

```

1  clc;clear;
2  //Example 10.4
3
4  //given data
5  P1=10;
6  P2=15000;
7  P3=15000;
8  T3=600;
9  P4=4000;
10 T5=600;
11 P6=10;
12 x6=0.896;
13
14 //from steam table
15 //at state 1
16 h1=191.81;
17 v1=0.00101;
18 //at state 3
19 h3=3593.1;
20 s3=6.6796;
21 //at state 4

```

```

22 h4=3155;
23 T4=375.5;
24 //at state 6
25 sf=0.6492;
26 sfg=7.4996;
27 hf=191.81;
28 hfg=2392.1;
29
30 //calculations
31 s6=sf+x6*sfg;
32 h6=hf+x6*hfg;
33 //s5 = s6
34 //from tables
35 P5=4000; //in kPa
36 h5=3674.9;
37 disp(P5/1000, 'the pressure at which the steam should
      be reheated in MPa');
38 //s2 = s1
39 win=v1*(P2-P1);
40 h2=h1+win;
41 Qin=(h3-h2)+(h5-h4);
42 Qout=h6-h1;
43 nth=1-(Qout/Qin);
44 disp(nth, 'thermal efficiency is ')

```

Scilab code Exa 10.5 The Ideal Regenerative Rankine Cycle

```

1  clc;clear;
2  //Example 10.5
3
4  //given data
5  P1=10;
6  P2=1200;
7  P3=1200;
8  P4=15000;

```

```

 9 P5=15000;
10 T5=600;
11 P6=1200;
12 P7=10;
13
14 //from steam table
15 //at state 1
16 h1=191.81;
17 v1=0.00101;
18 //at state 3
19 h3=798.33;
20 v3=0.001138;
21 //at state 4
22 h4=3155;
23 T4=375.5;
24 //at state 5
25 h5=3583.1;
26 s5=6.6796;
27 //at state 6
28 h6=2860.2;
29 T6=218.4;
30 //at state 7
31 P7=10;
32 sf=0.6492;
33 sfg=7.4996;
34 hf=191.81;
35 hfg=2392.1;
36
37 //calculations
38 //s2 = s1
39 win=v1*(P2-P1);
40 h2=h1+win;
41 //s4 = s3
42 win=v3*(P4-P3);
43 h4=h3+win;
44 s7=s5;
45 x7=(s7-sf)/sfg;
46 h7=hf+(x7*hfg);

```

```

47 //y is the fraction of steam extracted from the
    turbine
48 y=(h3-h2)/(h6-h2);
49 Qin=h5-h4;
50 qout=(1-y)*(h7-h1);
51 nth=1-(qout/qin);
52 disp(y,'fraction of steam extracted');
53 disp(nth,'thermal efficiency is')

```

Scilab code Exa 10.6 The Ideal Reheat Regenerative Rankine Cycle

```

1  clc;clear;
2  //Example 10.6
3
4  //given data
5  P1=10;
6  P2=500;
7  P3=500;
8  P4=15000;
9  P5=P4;
10 P6=4000;
11 P7=P5;
12 P8=P7;
13 P9=P7;
14 P10=P6;
15 P11=P10;
16 P12=P3;
17 P13=10;
18
19 //enthalpies at the various states and the pump work
    per unit mass of fluid flowing through them are
20 h1=191.81;
21 h2=192.30;
22 h3=640.09;
23 h4=643.92;

```

```

24 h5=1087.4;
25 h6=h5;
26 h7=1101.2;
27 h8=1089.8;
28 h9=3583.1;
29 h10=3155;
30 h11=3679.9;
31 h12=3014.8;
32 h13=2335.7;
33 wIin=0.49;
34 wIIin=3.83;
35 wIIIin=13.77;
36
37 // calculations
38 y=(h5-h4)/((h10-h6)+(h5-h4));
39 z=(1-y)*(h3-h2)/(h12-h2);
40 h8=(1-y)*h5+(y*h7);
41 qin=(h9-h8)+(1-y)*(h11-h10);
42 qout=(1-y-z)*(h13-h1);
43 nth=1-(qout/qin);
44 disp(y,'fraction of steam extracted from closed
      feedwater ');
45 disp(z,'fraction of steam extracted from open
      feedwater ');
46 disp(nth,'thermal efficiency is ')

```

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

```

1 clc;clear;
2 //Example 10.7
3
4 //given data
5 T0=290;
6 Tsource=1600;
7 Tsink=T0;

```

```

8 //from Ex 10.1
9 qin=2728.6;
10 qout=2018.6;
11 h4=2403;
12
13 //from steam tables
14 s1=1.2132;
15 s3=6.7450;
16
17 //calculations
18 s2=s1;s4=s3;//isentropic processes
19 xdest12=0;
20 xdest34=0;
21 xdest23=T0*(s3-s2-(qin/Tsource));
22 xdest41=T0*(s1-s4+(qout/Tsink));
23 disp(xdest12,'exergy destruction in 1-2 in kJ/kg');
24 disp(round(xdest23),'exergy destruction in 2-3 in kJ
    /kg');
25 disp(xdest34,'exergy destruction in 3-4 in kJ/kg');
26 disp(round(xdest41),'exergy destruction in 4-1 in kJ
    /kg');
27 xdestcy=xdest12+xdest23+xdest34+xdest41;
28 disp(round(xdestcy),'exergy destruction in cycle in
    kJ/kg');
29 //from steam tables
30 //at 290 K and 100 kPa
31 h0=71.355;
32 s0=0.2533;
33 X4=(h4-h0)-T0*(s4-s0);
34 disp(round(X4),'exergy of the leaving steam in kJ/kg
    ')

```

Scilab code Exa 10.8 An Ideal Cogeneration Plant

```
1 clc;clear;
```



```

2 //Example 10.8
3
4 //given data
5 m1=15;
6 P1=7000;
7 P2=P1;
8 P3=P1;
9 P4=500;
10 P5=P4;
11 P6=5;
12 P7=500;
13 P8=5;
14 P9=7000;
15 P10=7000;
16
17 //from steam tables
18 v7=0.001005;
19 v8=0.001093;
20 h1=3411.4;
21 h2=h1;
22 h3=h1;
23 h4=h1;
24 h5=2739.3;
25 h6=2073.0;
26 h7=640.09;
27 h8=137.75;
28 h11=144.78;
29
30 //calculations
31 wIin=v8*(P9-P8);
32 wIIin=v7*(P10-P7);
33 h9=h8+wIin;
34 h10=h7+wIIin;
35 Qmax=m1*(h1-h7);
36 disp(Qmax,'the maximum rate in kW');
37 Wtout=m1*(h3-h6); //turbine
38 Wpin=m1*wIin; //pump
39 Wnet=Wtout-Wpin;

```

```

40 disp(round(Wnet/1000), 'the power produced in MW');
41 Qp=0;
42 Qin=m1*(h1-h11);
43 Eu=(Wnet+Qp)/Qin;
44 disp(Eu, 'the utilization factor');
45 m4=0.1*m1;
46 m5=0.7*m1;
47 m7=m4+m5;
48 Qout=m4*h4+m5*h5-m7*h7;
49 disp(Qout/1000, 'the rate of process heat supply in
    MW')

```

Scilab code Exa 10.9 A Combined Gas Steam Power Cycle

```

1  clc;clear;
2  //Example 10.9
3
4  //given data
5  P1=5;
6  P2=7000;
7  P3=P2;
8  T3=500;
9  P4=P1;
10
11 //gas cycle from Ex9-6
12 //d stands for '
13 h4d=880.36;
14 T4d=853;
15 qin=790.58;
16 wnetg=210.41;
17 nth=0.266
18 h5d=451.80;
19 //steam cycle
20 h2=144.78;
21 T2=33;

```

```
22 h3=3411.4;
23 T3=500;
24 wnets=1331.4;
25 nth=0.408;
26
27 //calculations
28 //Ein = Eout
29 //y is the ratio of ms/mg
30 y=(h4d-h5d)/(h3-h2);
31 disp(y,'the ratio of the mass flow rates of the
    steam and the combustion gases');
32 wnet=wnetg+y*wnets
33 nth=wnet/qin;
34 disp(nth,'the thermal efficiency of the combined
    cycle')
```

Chapter 11

Refrigeration Cycles

Scilab code Exa 11.1 The Ideal Vapor Compression Refrigeration Cycle

```
1  clc;clear;
2  //Example 11.1
3
4  //given values
5  P1=0.14;
6  P2=0.8;
7  m=0.05;
8
9  //from refrigerant -134a tables
10 h1=239.16;
11 s1=0.94456;
12 h2=275.39;
13 h3=95.47;
14
15 //calculation
16 s2=s1;//isentropic process
17 h4=h3;//throttling
18 QL=(h1-h4)*m;
19 Wm=m*(h2-h1);
20 Qh=m*(h2-h3);
21 Qh=ceil(Qh);
```

```

22 COPR=QL/Wm;
23 disp(QL,'the rate of heat removal from the
    refrigerated space in kW');
24 disp(Wm,'the power input to the compressor in kW');
25 disp(Qh,'the rate of heat rejection to the
    environment in kW');
26 disp(COPR,'the COP of the refrigerator');

```

Scilab code Exa 11.2 The Actual Vapor Compression Refrigeration Cycle

```

1  clc;clear;
2  //Example 11.2
3
4  //given data
5  m=0.05;
6  P1=0.14;
7  T1=-10;
8  P2=0.8;
9  T2=50;
10 P3=0.72;
11 T3=26;
12
13 //from refrigerant tables
14 h1=246.36;
15 h2=286.69;
16 h3=87.83;
17 h2S=284.21;//at isentropic conditions
18
19 //calculations
20 h4=h3;//throttling
21 QL=m*(h1-h4);
22 Wm=m*(h2-h1);
23 nC=(h2S-h1)/(h2-h1);
24 COPR=QL/Wm;
25 disp(QL,'the rate of heat removal from the

```

```

    refrigerated space in kW');
26 disp(Wm,'the power input to the compressor in kW');
27 disp(nC,'the isentropic efficiency of the compressor
    ');
28 disp(COPR,'he coefficient of performance of the
    refrigerator ');

```

Scilab code Exa 11.3 A Two Stage Cascade Refrigeration Cycle

```

1  clc;clear;
2  //Example 11.3
3
4  //given data
5  mA=0.05;
6  P1=0.14;
7  P5=0.32;
8  P7=0.8;
9  h1=239.16;
10 h2=255.93;
11 h3=55.16;
12 h5=251.88;
13 h6=270.92;
14 h7=95.47;
15
16 //calculations
17 h4=h3;//throttling
18 h8=h7;//throttling
19 // E out = E in
20 // mA*h5 + mB*h3 = mA*h8 + mB*h2
21 mB=mA*(h5-h8)/(h2-h3);
22 QL=mB*(h1-h4);
23 // W in = Wcomp I ,in + Wcomp II ,in
24 Win=mA*(h6-h5)+mB*(h2-h1);
25 COPR=QL/Win;
26 disp(mB,'the mass flow rate of the refrigerant

```

```

    through the lower cycle in kg/s');
27 disp(QL,'the rate of heat removal from the
    refrigerated space in kW');
28 disp(Win,'the power input to the compressor in kW');
29 disp(COPR,'the coefficient of performance of this
    cascade refrigerator');

```

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

```

1  clc;clear;
2  //Example 11.4
3
4  //given data
5  P1=0.14;
6  P5=0.32;
7  P7=0.8;
8  h1=239.16;
9  h2=255.93;
10 h3=251.88;
11 h5=95.47;
12 h7=55.16;
13
14 //from saturated liquid-vapour table
15 //at P=0.32 MPa
16 hf=55.16;
17 hfg=196.71;
18
19 //calculations
20 h8=h7;//throttling
21 h6=h5;//throttling
22 //the quality at state 6
23 x6=(h6-hf)/hfg;
24 qL=(1-x6)*(h1-h8);
25 // W in = Wcomp I,in + Wcomp II,in

```

```

26 //enthalaoy at state 9
27 // E out = E in
28 h9=x6*h3+(1-x6)*h2;
29 // s9 = s4 i.e isentropic process
30 //at 0.8MPa and s4=0.9416 kJ/kg
31 h4=274.48;
32 Win=(1-x6)*(h2-h1)+(1)*(h4-h9);
33 COPR=qL/Win;
34 disp(x6,'the fraction of the refrigerant that
    evaporates as it is throttled to the flash
    chamber');
35 disp(qL,'the amount of heat removed from the
    refrigerated space in kJ/kg');
36 disp(Win,'the compressor work per unit mass of
    refrigerant flowing through the condensor in kJ/
    kg');
37 disp(COPR,'the coefficient of performance');

```

Scilab code Exa 11.5 The Simple Ideal Gas Refrigeration Cycle

```

1  clc;clear;
2  //Example 11.5
3
4  //given data
5  m=0.1;
6  T1=0+460;
7  T3=80+460;//converting into R from F
8
9  //from Table A 17E
10 // at T1
11 h1=109.90;
12 Pr1=.7913;
13 //pressure ratio at compressor is 4
14 Pr2=4*Pr1;
15 //at Pr2

```



```

16 h2=163.5;
17 T2=683;
18 //at T3
19 h3=129.06;
20 Pr3=1.3860;
21 //pressure ratio at compressor is 4
22 Pr4=Pr3/4;
23 //at Pr4
24 h4=86.7;
25 T4=363;
26
27 //calculations
28 qL=h1-h4;
29 Wout=h3-h4;
30 Win=h2-h1;
31 COPR=qL/(Win-Wout);
32 Qrefrig=m*qL;
33 disp((T4-460), 'the minimum temperatures in the cycle
           in F');
34 disp((T2-460), 'the maximum temperatures in the cycle
           in F');
35 disp(COPR, 'the coefficient of performance');
36 disp(Qrefrig, 'the rate of refrigeration for a mass
           flow rate of 0.1 lbm/s. in Btu/s')

```

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

```

1  clc;clear;
2  //Example 11.6
3
4  //given data
5  COPR=0.1;
6  T1=20;
7  T2=4;

```

```
8 t=30*60; //converted in sec
9 V=0.350;
10
11 //constants used
12 p=1; //on kg/L
13 c=4.18; //in kJ/kg-C from Table A-3
14
15 //calculations
16 m=p*V;
17 Qcooling=m*c*(T1-T2)/t*1000; //converted in W by
    multiplying by 1000
18 Win=Qcooling/COPR;
19 Win=floor(Win);
20 disp(Win, 'the average electric power consumed by the
    thermoelectric refrigerator in W')
```

Chapter 12

Thermodynamic Property Relations

Scilab code Exa 12.1 Approximating Differential Quantities by Differences

```
1  clc; clear;
2  //Example 12.1
3
4  //given data
5  h1=305.22;
6  T1=305;
7  h2=295.17;
8  T2=295;
9
10 //calculations
11 //from the given equation we can calculate
12 cp=(h1-h2)/(T1-T2);
13 disp(cp, 'the cp of air at 300 K in kJ/ kg - K')
```

Scilab code Exa 12.2 Total Differential versus Partial Differential

```

1  clc;clear;
2  //Example 12.2
3
4  //given data
5  dT=302-300;
6  dv=0.87-0.86;
7  T=(302+300)/2;
8  v=(0.87+0.86)/2; //average values
9
10 //constants used
11 R=0.287; //in kJ/kg-K
12
13 //calculations
14 //using eq 12-3 by differentiating  $P = R*T/v$ 
15 dP= R*dT/v - R*T*dv/v^2;
16 disp(dP, 'the change in the pressure of air in kPa');

```

Scilab code Exa 12.5 Evaluating the hfg of a Substance from the P v T Data

```

1  clc;clear;
2  //Example 12.5
3
4  //given data
5  T=20+273.15; //converted into K
6
7  //from Table A 11
8  vf=0.0008161;
9  vg=0.035969;
10
11 //calculations
12 //using Eq 12-22
13 // hfg= T*vfg*(dP/dT) sat
14 // (dP/dT) sat b/w 24 C - 16 C
15 dPT=(646.18-504.58)/(24-16); //dP/dT ; values from

```

Table A 11

```
16 vfg=vg-vf;  
17 hfg=T*vfg*dPT;  
18 disp(hfg,'the value of the enthalpy of vaporization  
of refrigerant -134a in kJ/kg')
```

Scilab code Exa 12.6 Extrapolating Tabular Data with the Clapeyron Equation

```
1 clc;clear;  
2 //Example 12.6  
3  
4 //given data  
5 T1=-40+460;  
6 T2=-50+460;//converted into R from F  
7 R=0.01946;  
8  
9 //from Table A-11E  
10 P1=7.432;  
11 hfg=97.100;  
12  
13 //calculation\  
14 //using Equation 12 24  
15 //ln(P2/P1)= hfg/R *(1/T1 - 1/T2)  
16 P2=P1*exp(hfg/R *(1/T1 - 1/T2));  
17 disp(P2,'the saturation pressure of refrigerant -134a  
in psia')
```

Scilab code Exa 12.11 The dh and ds of Oxygen at High Pressures

```
1 clc;clear;  
2 //Example 12.11  
3
```

```

4 //given data
5 T1=220;
6 P1=5;
7 T2=300;
8 P2=10;
9
10 //constants used
11 Ru=8.314;//on kJ/kmol-K
12
13 //from Table A 1
14 Tcr=154.8;
15 Pcr=5.08;
16
17 //calculations
18
19 //part - a
20 disp('part - a');
21 //by assuming ideal-gas behavior
22 //from Table A 19
23 h1=6404;
24 h2=8736;
25 s2=205.213;
26 s1=196.171;
27 h21i=h2-h1;//h2 - h1 ideal
28 s21i=(s2-s1)-Ru*log(P2/P1);//s2 - s1 ideal
29 disp(h21i,'the enthalpy change in kJ/kmol');
30 disp(s21i,'the entropy change in kJ/kmol-K');
31
32 //part - b
33 disp('part - b');
34 //by accounting for the deviation from ideal-gas
   behavior
35 TR1=T1/Tcr;
36 Pr1=P1/Pcr;
37 //from the generalized charts at each state
38 Zh1=0.53;
39 Zs1=0.25;
40 TR2=T2/Tcr;

```

```
41 Pr2=P2/Pcr;
42 //from the generalized charts at each state
43 Zh2=0.48;
44 Zs2=0.20;
45 h21=h21i-Ru*Tcr*(Zh2-Zh1);
46 s21=s21i-Ru*(Zs2-Zs1);
47 disp(h21,'the enthalpy change in kJ/kmol');
48 disp(s21,'the entropy change in kJ/kmol-K');
```

Chapter 13

Gas Mixtures

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

```
1  clc;clear;
2  //Example 13.1
3
4  //given data
5  mO2=3;
6  mN2=5;
7  mCH4=12;
8  //molecular masses
9  MO2=32;
10 MN2=28;
11 MCH4=16;
12
13 //constants used
14 Ru=8.314; //in kJ/kg - K
15
16 //calculations
17
18 //part - a
19 mm=mO2+mN2+mCH4;
20 mfO2=mO2/mm;
21 mfN2=mN2/mm;
```



```

22 mfCH4=mCH4/mm;
23 disp(mfO2,'mass fraction of oxygen is ');
24 disp(mfN2,'mass fraction of nitrogen is ');
25 disp(mfCH4,'mass fraction of methane is ');
26
27 //part - b
28 NO2=mO2/MO2;
29 NN2=mN2/MN2;
30 NCH4=mCH4/MCH4;
31 Nm=NO2+NN2+NCH4;
32 yO2=NO2/Nm;
33 yN2=NN2/Nm;
34 yCH4=NCH4/Nm;
35 disp(yO2,'mole fraction of oxygen is ');
36 disp(yN2,'mole fraction of nitrogen is ');
37 disp(yCH4,'mole fraction of methane is ');
38
39 //part - c
40 Mm=mm/Nm;
41 disp(Mm,'average molecular mass in kg/kmol');
42 Rm=Ru/Mm;
43 disp(Rm,'gas constant of mixture in kJ/kg - K')

```

Scilab code Exa 13.2 P v T Behavior of Nonideal Gas Mixtures

```

1  clc;clear;
2  //Example 13.2
3
4  //given data
5  NN2=2;
6  NCO2=6;
7  Tm=300;
8  Pm=15000;
9
10 //constants used

```

```

11 Ru=8.314; //in kJ/kmol - K
12
13 //calculations
14
15 //part - a
16 Nm=NN2+NC02;
17 Vm=Nm*Ru*Tm/Pm;
18 disp(Vm, 'the volume of the tank on the basis of the
        ideal-gas equation of state in m^3');
19
20 //part - b
21 //from Table A-1
22 //for nitrogen
23 TcrN=126.2;
24 PcrN=3390;
25 //for Carbondioxide
26 TcrC=304.2;
27 PcrC=7390;
28 yN2=NN2/Nm;
29 yC02=NC02/Nm;
30 Tcr=yN2*TcrN+yC02*TcrC;
31 Pcr=yN2*PcrN+yC02*PcrC;
32 Tr=Tm/Tcr;
33 Pr=Pm/Pcr;
34 //from Fig A-15b
35 Zm=0.49;
36 Vm=Zm*Nm*Ru*Tm/Pm;
37 disp(Vm, 'the volume of the tank on the basis Kay s
        rule in m^3');
38
39 //part - c
40 //for nitrogen
41 TrN=Tm/TcrN;
42 PrN=Pm/PcrN;
43 //from Fig A-15b
44 Zn=1.02;
45 //for Carbondioxide
46 TrC=Tm/TcrC;

```

```

47 PcrC=Pm/PcrC;
48 //from Fig A-15b
49 Zc=0.3;
50 Zm=yN2*Zn+yCO2*Zc;
51 Vm=Zm*Nm*Ru*Tm/Pm;
52 disp(Vm,'the volume of the tank on the basis
      compressibility factors and Amagat s law in m^3
      ');
53
54 //part - d
55 VRN=(Vm/NN2)/(Ru*TcrN/PcrN);
56 VRC=(Vm/NC02)/(Ru*TcrC/PcrC);
57 //from Fig A-15b
58 Zn=0.99;
59 Zc=0.56;
60 Zm=yN2*Zn+yCO2*Zc;
61 Vm=Zm*Nm*Ru*Tm/Pm;
62 //When the calculations are repeated we obtain 0.738
      m3 after the second iteration , 0.678 m3 after
      the third iteration , and 0.648 m3 after the
      fourth iteration .
63 Vm=0.648;
64 disp(Vm,'compressibility factors and Dalton s law
      the volume of the tank on the basis in m^3');

```

Scilab code Exa 13.3 Mixing Two Ideal Gases in a Tank

```

1  clc;clear;
2  //Example 13.3
3
4  //given data
5  mN=4;
6  T1N=20;
7  P1N=150;
8  mO=7;

```

```

9  T10=40;
10 P10=100;
11 //molecular masses
12 M0=32;
13 MN=28;
14
15 //constants used
16 Ru=8.314; //in kJ/kg - K
17
18
19 //from Table A-2a
20 CvN=0.743;
21 CvO=0.658;
22
23 //calculations
24
25 //part - a
26 //Ein - Eout = dEsystem
27 //(m*cV*dT)N2 + (m*cV*dT)= 0;
28 Tm= (mN*CvN*T1N+ mO*CvO*T10)/(mN*CvN+mO*CvO);
29 disp(Tm,'the mixture temperature in C');
30
31 //part - b
32 NO=mO/MO;
33 NN=mN/MN;
34 Nm=NO+NN;
35 VO=NO*Ru*(T10+273)/P10;
36 VN=NN*Ru*(T1N+273)/P1N;
37 Vm=VO+VN;
38 Pm=Nm*Ru*(Tm+273)/Vm;
39 disp(Pm,'the mixture pressure after equilibrium has
    been established in kPa')

```

Scilab code Exa 13.4 Exergy Destruction during Mixing of Ideal Gases
 An insulated rigid tank is divided into two compartments by a

```

1  clc;clear;
2  //Example 13.4
3
4  //given data
5  NO=3;
6  NC=5; //moles of oxygen and carbondioxide
      repectively
7  T0=25+273; //in K
8
9  //constants used
10 Ru=8.314; //in kJ/kg - K
11
12 //calculations
13 Nm=NO+NC;
14 yO=NO/Nm;
15 yC=NC/Nm;
16 //dSm= -Ru*(NO*log (yO)+NC*log (yC))
17 Sm=-Ru*(NO*log (yO)+NC*log (yC));
18 disp(Sm,'the entropy change in kJ/K');
19 Xdestroyed=T0*Sm/1000;
20 disp(Xdestroyed,'exergy destruction associated in MJ
      ')

```

Scilab code Exa 13.5 Cooling of a Nonideal Gas Mixture

```

1  clc;clear;
2  //Example 13.5
3
4  //given data
5  T1=220;
6  T2=160;
7  Pm=10;
8  yN=0.79;
9  yO=0.21; //mole fractions of nitrogen and oxygen
      repectively

```

```

10 //critical properties
11 //for Nitrogen
12 TcrN=126.2;
13 PcrN=3.39;
14 //for Oxygen
15 TcrO=154.8;
16 PcrO=5.08;
17
18 //constants used
19 Ru=8.314;//in kJ/kg - K
20
21 //from Tables A-18 & 19
22 //at T1
23 h1N=6391;
24 h1O=6404;
25 //for T2
26 h2N=4648;
27 h2O=4657;
28
29 //calculations
30 //part - a
31 qouti=yN*(h1N-h2N)+yO*(h1O-h2O);
32 qouti=ceil(qouti);
33 disp(qouti,'the heat transfer during this process
      using the ideal-gas approximation in kJ/kmol');
34
35 //part - b
36 Tcrm=yN*TcrN+yO*TcrO;
37 Pcrm=yN*PcrN+yO*PcrO;
38 Tr1=T1/Tcrm;
39 Tr2=T2/Tcrm;
40 Pr=Pm/Pcrm;
41 //at these values we get
42 Zh1=1;
43 Zh2=2.6;
44 qout=qouti-Ru*Tcrm*(Zh1-Zh2);
45 qout=ceil(qout);
46 disp(qout,'the heat transfer during this process

```

```

        using Kay's rule in kJ/kmol');
47
48 //part - c
49 //for nitrogen
50 TrN1=T1/TcrN;
51 TrN2=T2/TcrN;
52 PrN=Pm/PcrN;
53 //from Fig A-15b
54 Zh1n=0.9;
55 Zh2n=2.4;
56 //for Oxygen
57 TrO1=T1/TcrO;
58 TrO2=T2/TcrO;
59 PcrO=Pm/PcrO;
60 //from Fig A-15b
61 Zh10=1.3;
62 Zh20=4.0;
63 //from Eq 12-58
64 h12N=h1N-h2N-Ru*TcrN*(Zh1n-Zh2n); // h1 - h2 for
    nitrogen
65 h120=h10-h20-Ru*TcrO*(Zh10-Zh20); // h1 - h2 for
    oxygen
66 qout=yN*h12N+yO*h120;
67 qout=ceil(qout);
68 disp(qout, 'the heat transfer during this process
    using Amagat's law in kJ/kmol');

```

Scilab code Exa 13.6 Obtaining Fresh Water from Seawater

```

1  clc;clear;
2  //Example 13.6
3  //13.6 (d) answer not matching as float datatype is
    giving more accurate answer in comparison to
    textbook that has given approximate due to
    rounding off to two decimal places

```

```

4
5 //given data
6 mfs=0.0348;
7 mfw=0.9652;
8 T0=288.15;
9
10 //constants used
11 Mw=18;
12 Ms=58.44;
13 Rw=0.4615;
14 pm=1028;
15 Ru=8.314;
16
17 //calculations
18 //part - a
19 Mm=1/((mfs/Ms)+(mfw/Mw));
20 yw=mfw*Mm/Mw;
21 ys=1-yw;
22 disp(yw,'the mole fraction of the water');
23 disp(ys,'the mole fraction of the saltwater');
24
25 //part - b
26 wmin=-Ru*T0*(ys*log(ys)+yw*log(yw));
27 wm=wmin/Mm;
28 disp(wm,'the minimum work input required to separate
      1 kg of seawater completely into pure water and
      pure salts in kJ');
29
30 //part - c
31 wmin=Rw*T0*log(1/yw);
32 disp(wmin,'the minimum work input required to obtain
      1 kg of fresh water from the sea in kJ');
33
34 //part - d
35 Pmin=pm*Rw*T0*log(1/yw);
36 disp(Pmin,'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 ')

Chapter 14

Gas Vapor Mixtures and Air Conditioning

Scilab code Exa 14.1 The Amount of Water Vapor in Room Air

```
1  clc;clear;
2  //Example 14.1
3
4  //given data
5  V=5*5*3;//volume of the room
6  RH=0.75;
7  P=100;
8  T=25;
9
10 //constants used
11 Ra=0.287;//in kPa.m3 / kg.k
12 Rv=0.4615;//in kPa.m3 / kg.k
13
14 //from Table A-2a and A-4
15 cp=1.005;
16 Psat=3.1698;
17 hg=2564.6;
18
19 //calculation
```

```

20 Pv=RH*Psat;
21 Pa=P-Pv;
22 w=0.622*Pv/(P-Pv);
23 h=cp*T+w*hg;
24 ma=V*Pa/(Ra*(T+273));
25 mv=V*Pv/(Rv*(T+273));
26 disp(Pa, 'the partial pressure of dry air in kPa');
27 disp(w, 'the specific humidity in kg water/kg of dry
    air');
28 disp(h, 'the enthalpy per unit mass of the dry air in
    kJ');
29 disp(ma, 'mass of air in kg');
30 disp(mv, 'mass of water vapour in kg');

```

Scilab code Exa 14.2 Fogging of the Windows in a House

```

1  clc;clear;
2  //Example 14.2
3
4  //given data
5  T=20;
6  RH=0.75;
7
8  //from Table A-4
9  Psat=2.3392;
10 Pv=RH*Psat;
11 //thus at this from Eq 14-13
12 Tdp=15.4;
13 disp(Tdp, 'window temperature in C')

```

Scilab code Exa 14.3 The Specific and Relative Humidity of Air

```

1  clc;clear;

```

```

2 //Example 14.3
3
4 //given data
5 T1=25;
6 T2=15;
7 P2=101.325;
8
9 //from Table A-2a & A-4
10 //at T1
11 Psat1=3.1698;
12 hg1=2546.5;
13 //at T2
14 Psat2=1.7057;
15 hfg2=2465.4;
16 hf2=62.982;
17 cp=1.005;
18
19 //calculations
20 w2=0.622*Psat2/(P2-Psat2);
21 w1=(cp*(T2-T1)+w2*hfg2)/(hg1-hf2);
22 disp(w1,'the specific humidity in kg water/kg of dry
    ai ');
23 RH1=w1*P2/((0.622+w1)*Psat1);
24 disp(RH1,'the relative humidity');
25 h=cp*T1+w1*hg1;
26 disp(h,'the enthalpy of the air in kJ/kg of dry air '
    )

```

Scilab code Exa 14.5 Heating and Humidification of Air

```

1 clc;clear;
2 //Example 14.5
3 //difference in first part is due to selective
    roundingoff to particular decimals in h1 and h2
4

```

```

5 //given data
6 RH1=0.3;
7 P1=100;
8 V1=45;
9 T1=10;
10 T2=22;
11 RH3=0.6;
12 T3=25;
13
14 //from Table A-2a & A-4
15 cp=1.005;
16 Ra=0.287;
17 Pg1=1.2281;
18 hg1=2519.2;
19 hg2=2541.0;
20 Pg3=3.1698;
21
22 //calculations
23 Pv1=RH1*Pg1;
24 Pa1=P1-Pv1;
25 v1=Ra*(T1+273)/Pa1;
26 ma=V1/v1;
27 w1=0.622*Pv1/(P1-Pv1);
28 h1=cp*T1+w1*hg1;
29 w2=w1;
30 h2=cp*T2+w2*hg2;
31 Q=ma*(h2-h1);
32 // ma2*w2 + mw = ma3*w3
33 //which reduces to mw = ma * (w3 - w2)
34 w3=0.622*RH3*Pg3/(P1-(RH3*Pg3));
35 mw=ma*(w3-w2);
36 disp(Q, 'the rate of heat supply in the heating
    section in kJ/min');
37 disp(mw, 'the mass flow rate of the steam required in
    the humidifying section in kg/min')

```

Scilab code Exa 14.6 Cooling and Dehumidification of Air

```
1  clc; clear;
2  //Example 14.6
3
4  //given data
5  V1=10;
6  T1=30;
7  RH1=0.8;
8  T2=14;
9  RH2=1;
10
11 //from Table A-4
12 hw=58.8;
13 h1=85.4;
14 h2=39.3;
15 w1=0.0216;
16 w2=0.0100;
17 v1=0.889;
18
19 //calculations
20 //mw= ma*(w1-w2)
21 //Qout=ma*(h1-h2) - mw*hw
22 ma=V1/v1;
23 mw= ma*(w1-w2);
24 Qout=ma*(h1-h2) - mw*hw;
25 disp(mw, 'rates of moisture removal from the air in
      kg/min ');
26 disp(Qout, 'rate of moisture removal from the air in
      kJ/min ');
```

Scilab code Exa 14.8 Mixing of Conditioned Air with Outdoor Air

```

1  clc;clear;
2  //Example 14.8
3
4  //given values
5  V1=50;
6  T1=14;
7  V2=20;
8  T2=32;
9  RH2=60;
10
11 //from psychrometric chart
12 h1=39.4;
13 w1=0.010;
14 v1=0.826;
15 h2=79;
16 w2=0.0182;
17 v2=0.889;
18
19 //calculations
20 ma1=V1/v1;
21 ma2=V2/v2;
22 ma3=ma1+ma2;
23 //from Eq 14-24
24 w3=(w2*ma2+w1*ma1)/(ma1+ma2);
25 h3=(h2*ma2+h1*ma1)/(ma1+ma2);
26 disp(w3,'the specific humidity in kg of water/kg of
    dry air ');
27 //from psychrometric chart
28 T3=19;
29 RH3=0.89;
30 v3=0.844;
31 V3=ma3*v3;
32 disp(RH3,'the relative humidity');
33 disp(T3,'the dry-bulb temperature in C');
34 disp(V3,'the volume flow rate of the mixture in m^3/
    min ')

```

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

```
1  clc; clear;
2  //Example 14.9
3
4  //given data
5  m=100;
6  T1=20;
7  P1=1;
8  RH1=60;
9  T2=30;
10 RH2=1;
11 T3=35;
12 T4=22;
13
14 //from Table A-4
15 h1=42.2;
16 w1=0.0087;
17 v1=0.842;
18 h2=100;
19 w2=0.0273;
20 h3=146.64;
21 h4=92.28;
22
23 //calculations
24 //Dry air balane = ma1 = ma2 = ma
25 //Water balance = m3 - m4 = ma*(w2 - w1)
26 //Energy balance = ma1*h1 + m3*h3 = ma2*h2 + m4*h4
27 ma= m*(h3-h4)/(h2-h1-(w2-w1)*h4);
28 V1=ma*v1;
29 mmakeup=ma*(w2-w1);
30 disp(V1, 'the volume flow rate of air into the
        cooling tower in m^3/s');
31 disp(mmakeup, 'the mass flow rate of the required
```


makeup water in kg/s ')

Chapter 15

Chemical Reactions

Scilab code Exa 15.1 Balancing the Combustion Equation

```
1  clc;clear;
2  //Example 15.1
3
4  //given data
5  nO2i=20;
6  nC8H18i=1;//intial moles of air and octane
7
8  //from Table A-1
9  Mair=29;
10 MC=12;
11 MH=2;
12
13 //calculations
14 // Chemical Reaction
15 // C8H18 + 20(O2+3.76N2)= xCO2 + yH2O + zO2 + wN2
16 //by elemental balance of moles
17 x=8;
18 y=18/2;
19 z=20*2-2*x-y;
20 w=20*3.76;
21 disp(x, 'kmoles of CO2');
```

```

22 disp(y, 'kmoles of H2O');
23 disp(z, 'kmoles of O2');
24 disp(w, 'kmoles of N2');
25 //thus equn becomes
26 // C8H18 + 20(O2+3.76N2)= 8CO2 + 9H2O + 7.5O2 +75.2
    N2
27 AF=nO2i*4.76*Mair/(x*MC + y*MH);
28 disp(AF, 'air-fuel ratio of combustion process in kg
    air/kg fuel')

```

Scilab code Exa 15.2 Dew Point Temperature of Combustion Products

```

1  clc;clear;
2  //Example 15.2
3
4  //given data
5  P=100;
6
7  //from Table A-1
8  Mair=29;
9  MC=12;
10 MH=2;
11
12 //calculations
13 //Chemical reaction
14 //C2H6 + 1.2at(1O2 + 3.76) =2CO2 + 3H2O + 0.2athO2 +
    (1.2*3.76)athN2
15 //ath is the stoichiometric coefficient for air
16 //Oxygen balance gives
17 // 1.2ath = 2 + 1.5 + 0.2ath
18 ath=(2+1.5)/(1.2-0.2);
19 AF=(1.2*ath)*4.76*Mair/(2*MC+3*MH);
20 disp(AF, 'air-fuel ratio of combustion process in kg
    air/kg fuel');
21 //C2H6 + 4.2(O2 + 3.76N2) = 2CO2 + 3H2O + 0.7O2 +

```

```

    15.79N2;
22 Nprod=2+3+0.7+15.79;
23 //for dew point water vapour condenses
24 Nv=3;
25 Pv=Nv/Nprod*P;
26 //at this Pv
27 Tdp=52.3;
28 disp(Tdp, 'the dew-point in C')

```

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

```

1  clc;clear;
2  //Example 15.3
3
4  //given data
5  P=101.325;
6  RH=0.8;
7  T1=20;
8
9  //from Table A-4
10 Psat=2.3392;
11
12 //calculations
13 //consedering 1 kmol of fuel
14 // 0.72CH4 + 0.09H2 + 0.14N2 + 0.02O2 + 0.03CO2 +
    ath(O2 + 3.76N2) = xCO2 + yH2O + zN2
15 //element balance
16 x=0.72+0.03
17 y=(0.72*4+0.09*2)/2;
18 ath=x+y/2-0.02-0.03;
19 z=0.14+3.76*ath;
20 Pv=RH*Psat;
21 // Nv, air = Pv, air / Ptotal * Ntotal
22 Nvair=Pv/P*6.97/(1-(Pv/P));
23 //0.72CH4 + 0.09H2 + 0.14N2 + 0.02O2 + 0.03CO2 +

```

```

    1.465(O2 + 3.76N2) + 0.131H2O = 0.75CO2 + 1.661
    H2O + 5.648N2
24 Pvprod=1.661/8.059*P;
25 //at this Pvprod
26 Tdp=60.9;
27 disp(Tdp, 'the dew-point in C')

```

Scilab code Exa 15.4 Reverse Combustion Analysis

```

1  clc;clear;
2  //Example 15.4
3
4  //given data
5  Pprod=100;
6
7  //from Table A-1
8  Mair=29;
9  MC=12;
10 MH=2;
11
12 //from Table A-4
13 Psat=3.1698;
14
15 //calculations
16 //consedering 100 kmol of dry products
17 // xC8H18 + a (O2 + 3.76N2) = 10.02CO2 + 0.88C0 +
    84.48N2 + bH2O
18 //from mass balamces
19 a=83.48/3.76;
20 x=(0.88+10.02)/8;
21 b=18*x/2;
22 // 1.36C8H18 + 22.2 (O2 + 3.76N2) = 10.02CO2 + 0.88
    C0 + 84.48N2 + 12.24H2O
23 // 1 mol conversion
24 // C8H18 + 16.32 (O2 + 3.76N2) = 7.37CO2 + 4.13C0 +

```

```

        61.38N2 + 9H2O
25 AF= 16.32*4.76*Mair/(8*MC+9*MH);
26 disp(AF,'air-fuel ratio of combustion process in kg
        air/kg fuel')
27 // C8H18 + ath (O2 + 3.76N2) = 8CO2 + 9H2O + 3.76
        athN2
28 ath=8+4.5;
29 Pth=16.32/ath*4.76/4.76*100;
30 Pth=ceil(Pth);
31 disp(Pth,'percentage of theoretical air');
32 Nprod=7.37+0.65+4.13+61.98+9;
33 // Nv/Nprod = Pv/Pprod
34 Pv=Psat;
35 Nw= (Nprod*Pv-9*Pprod)/(Pv-Pprod);
36 disp(Nw,'the amount of H2O that condenses as the
        products in kmol')

```

Scilab code Exa 15.5 Evaluation of the Enthalpy of Combustion

```

1  clc;clear;
2  //Example 15.5
3  //round off error
4
5  //from Table A-6
6  HCO2=-393520;
7  HH20=-285830;
8  HC8H18=-249950;
9
10 //calculations
11 // C8H18 + ath (O2 + 3.76N2) = 8CO2 + 9H2O + 3.76
        athN2
12 //N2 and O2 are stable elements, and thus their
        enthalpy of formation is zero
13 //hc = Hprod - Hreact
14 hc= 8*HCO2 + 9*HH20 - HC8H18;

```

```
15 disp(hc, 'the enthalpy of combustion of liquid octane
    in kJ/kmol')
```

Scilab code Exa 15.6 First Law Analysis of Steady Flow Combustion

```
1  clc;clear;
2  //Example 15.6
3
4  //given data
5  mfuel=0.05;
6
7  //from Table A-1
8  Mair=29;
9  MC=12;
10 MH=2;
11
12 //calculation
13 //stoichiometric reaction
14 //C3H8 + ath(O2 + 3.76N2) = 3CO2 + 4H2O + 3.76athN2
15 //O2 balance
16 ath=3+5;
17 //50 percent excess air and some CO in the products
18 //C3H8 + 7.5(O2 + 3.76N2) = 2.7CO2 + 0.3CO + 4H2O +
    2.65O2+ 28.2N2
19 AF=7.5*4.76*Mair/(3*MC+4*MH);
20 mair=AF*mfuel;
21 disp(mair, 'the mass flow rate of air in kg air/min')
    ;
22 //from property tables
23 //C3H8 designated as p
24 hfp=-118910;
25 //oxygen as o
26 hfo=0;
27 ho280=8150;
28 ho298=8682;
```

```

29 ho1500=49292;
30 //nitrogen as n
31 hfn=0;
32 hn280=8141;
33 hn298=8669;
34 hn1500=47073;
35 //water as w
36 hfw=-241820;
37 hw298=9904;
38 hw1500=57999;
39 //carbondioxide as c
40 hfc=-393520;
41 hc298=9364;
42 hc1500=71078;
43 //carbon monoxide as co
44 hfco=-110530;
45 hco298=8669;
46 hco1500=47517;
47 qout=1*(hfp)+7.5*(hfo+ho280-ho298)+28.2*(hfn+hn280-
      hn298)-2.7*(hfc+hc1500-hc298)-0.3*(hfco+hco1500-
      hco298)-4*(hfw+hw1500-hw298)-2.65*(hfo+ho1500-
      ho298)-28.2*(hfn+hn1500-hn298);
48 //for kg of propane
49 qout=qout/44;
50 Qout=mfuel*qout/60;
51 disp(Qout,'the rate of heat transfer from the
      combustion chamber in kW')

```

Scilab code Exa 15.7 First Law Analysis of Combustion in a Bomb

```

1  clc;clear;
2  //Example 15.7
3  //error of 0.17% in (b) part calulation error in
   textbook
4

```



```

5 //given data
6 Preact=1;
7 Treact=77+460;
8 Tprod=1800;
9
10 //constants used
11 Ru=1.986;
12
13 //calculation
14 //CH4 + 3O2 = CO2 + 2H2O + O2
15 Nreact=4;
16 Nprod=4;
17 Pprod=Preact*Nprod/Nreact*Tprod/Treact;
18 disp(Pprod,'the final pressure in the tank in atm');
19 //from std. values of heat of formation and ideal
    gasses in Appendix
20 //CH4 as m
21 hfm=-32210;
22 //O2 as o
23 hfo=0;
24 h537o=3725.1;
25 h1800o=13485.8;
26 //water as w
27 hfw=-104040;
28 h537w=4528;
29 h1800w=15433;
30 //carbondioxide as c
31 hfc=-169300;
32 h537c=4027.5;
33 h1800c=18391.5;
34 Qout=1*(hfm-Ru*Treact)+3*(hfo-Ru*Treact)-1*(hfc+
    h1800c-h537c-Ru*Tprod)-2*(hfw+h1800w-h537w-Ru*
    Tprod)-1*(hfo+h1800o-h537o-Ru*Tprod);
35 disp(Qout,'the heat transfer during this process in
    Btu/lbmol')

```

Scilab code Exa 15.8 Adiabatic Flame Temperature in Steady Combustion

```
1  clc;clear;
2  //Example 15.8
3  //this involves EES hence the below code explains a
   approach with approximation
4
5  //calculations
6
7  //part - a
8  //C8H18 + 12.5 (O2 + 3.76N2) = 8CO+ 9H2O + 47N2
9  //from std. values of heat of formation and ideal
   gasses in Appendix
10 //octane as oc
11 hfoc=-249950;
12 //oxygen as o
13 hfo=0;
14 h298o=8682;
15 //nitrogen as n
16 hfn=0;
17 h298n=8669;
18 //water as w
19 hfw=-241820;
20 h298w=9904;
21 //carbondioxide as c
22 hfc=-393520;
23 h298c=9364;
24 //x refers to 8hCO2 + 9hH2O + 47hN2
25 xac=1*(hfoc)+8*(h298c-hfc)+9*(h298w-hfw)+47*(h298n-
   hfn);
26 //from EES the Tprod is determined by trial and
   error
27 //at 2400K
```

```

28 x2400=5660828;
29 //at 2350K
30 x2350=5526654;
31 //the actual value of x is xac and T can be
    determined by interpolation
32 Tprod=(xac-x2350)*(2400-2350)/(x2400-x2350)+2350;
33 Tprod=ceil(Tprod);
34 disp(Tprod,'adiabatic flame temperature for complete
    combustion with 100 percent theoretical air,in K
    ');
35
36 //part - b
37 //C8H18 + 50 (O2 + 3.76N2) = 8CO+ 9H2O + 37.5O2 +
    188N2
38 //solved similarly using EES and approximation and
    interpolation
39 //similarly we can solve the part - c
40 //the above concept is applied

```

Scilab code Exa 15.9 Reversible Work Associated with a Combustion Process

```

1  clc;clear;
2  //Example 15.9
3
4  //from Table A-26E
5  //Gibbs function of formation at 77 F
6  gfc=0;//for carbon
7  gfo=0;//for oxygen
8  gfco=-169680;//for carbondioxide
9
10 //calculations
11 // C + O2 = CO2
12 Wrev=1*gfc+1*gfo-1*gfco;
13 disp(Wrev,'the reversible work for this process in

```

Btu ')

Scilab code Exa 15.10 Second Law Analysis of Adiabatic Combustion

```
1  clc;clear;
2  //Example 15.10
3
4  //given values
5  T0=298;//in K
6
7  //constants used
8  Ru=8.314;//in kJ/kmol K
9
10 //calculations
11 // CH4 + 3(O2 + 3.76N2) = CO2 + 2H2O + O2 + 11.28N2
12 //from std. values of heat of formation and ideal
    gasses in Appendix
13 //methane as m
14 hfm=-74850;
15 //oxygen as o
16 hfo=0;
17 h298o=8682;
18 //nitrogen as n
19 hfn=0;
20 h298n=8669;
21 //water as w
22 hfw=-241820;
23 h298w=9904;
24 //carbondioxide as c
25 hfc=-393520;
26 h298c=9364;
27 //x refers to hCO2 + 2hH2O + 11.28hN2
28 xac=1*(hfm)+1*(h298c-hfc)+2*(h298w-hfw)+11.28*(h298n
    -hfn);
29 //from EES the Tprod is determined by trial and
```

```

    error
30 Tprod=1789;
31 disp(Tprod,'the temperature of the products in K');
32 //entropy calculations by using table A-26
33 //Si = Ni*(si - Ru*ln yiPm
34 //reactants
35 Sm=1*(186.16-Ru*log(1*1));
36 So=3*(205.04-Ru*log(0.21*1));
37 Sn=11.28*(191.61-Ru*log(.79*1));
38 Sreact=Sm+So+Sn;
39 //products
40 Nt=1+2+1+11.28;//total moles
41 yc=1/Nt;
42 yw=2/Nt;
43 yo=1/Nt;
44 yn=11.28/Nt;
45 Sc=1*(302.517-Ru*log(yc*1));
46 Sw=2*(258.957-Ru*log(yw*1));
47 So=1*(264.471-Ru*log(yo*1));
48 Sn=11.28*(247.977-Ru*log(yn*1));
49 Sprod=Sc+Sw+So+Sn;
50 Sgen=Sprod-Sreact;
51 disp(Sgen,'exergy destruction in kJ/kmol - K');
52 Xdestroyed=T0*Sgen/1000;//factor of 1000 for
    converting kJ to MJ
53 Xdestroyed=ceil(Xdestroyed);
54 disp(Xdestroyed,'in MJ/kmol');
55 //This process involves no actual work. Therefore,
    the reversible work and energy destroyed are
    identical
56 Wrev=Xdestroyed;
57 disp(Wrev,'the reversible work in MJ/kmol')

```

Scilab code Exa 15.11 Second Law Analysis of Isothermal Combustion

```

1  clc;clear;
2  //Example 15.11
3
4  //given values
5  Tsur=298;//in K
6
7  //constants used
8  Ru=8.314;//in kJ/kmol K
9
10 //calculations
11
12 //part - a
13 // CH4 + 3(O2 + 3.76N2) = CO2 + 2H2O + O2 + 11.28N2
14 //The amount of water vapor that remains in the
    products is determined as in Example 15 3
15 Nv=0.43;//moles of water vapour
16 Nw=1.57;//moles of water in liquid
17 //hf values
18 //methane as m
19 hfm=-74850;
20 //carbondioxide as c
21 hfc=-393520;
22 //water vapour as v
23 hfv=-241820;
24 //water in liquid as w
25 hfw=-285830;
26 Qout=1*hfm-1*hfc-Nv*hfv-Nw*hfw;
27 disp(Qout,'in kJ/kmol')
28
29 //part - b
30 //entropy calculations by using table A-26
31 //Si = Ni*(si - Ruln yiPm
32 //reactants
33 Sm=1*(186.16-Ru*log(1*1));
34 So=3*(205.04-Ru*log(0.21*1));
35 Sn=11.28*(191.61-Ru*log(.79*1));
36 Sreact=Sm+So+Sn;
37 //products

```

```

38 Nt=Nv+1+1+11.28; //total moles
39 yw=1;
40 yc=1/Nt;
41 yv=Nv/Nt;
42 yo=1/Nt;
43 yn=11.28/Nt;
44 Sw=Nw*(69.92-Ru*log(yw*1));
45 Sc=1*(213.80-Ru*log(yc*1));
46 Sv=Nv*(188.83-Ru*log(yv*1));
47 So=1*(205.04-Ru*log(yo*1));
48 Sn=11.28*(191.61-Ru*log(yn*1));
49 Sprod=Sc+Sw+So+Sn+Sv;
50 Sgen=Sprod-Sreact+Qout/Tsurr;
51 Sgen=ceil(Sgen);
52 disp(Sgen, 'exergy destruction in kJ/kmol - K');
53 Xdestroyed=Tsurr*Sgen/1000; //factor of 1000 for
    converting kJ to MJ
54 Xdestroyed=floor(Xdestroyed);
55 disp(Xdestroyed, 'in MJ/kmol');
56 //This process involves no actual work. Therefore,
    the reversible work and energy destroyed are
    identical
57 Wrev=Xdestroyed;
58 disp(Wrev, 'the reversible work in MJ/kmol')

```

Chapter 16

Chemical and Phase Equilibrium

Scilab code Exa 16.1 Equilibrium Constant of a Dissociation Process

```
1  clc; clear;
2  //Example 16.1
3  //round off error
4
5  //given data
6  T=298.15;
7
8  //from Table A-26
9  g=455510;
10
11 //constants used
12 R=8.314; //in kJ/kmol K
13
14 //calculations
15 // N2 = 2N
16 dG=2*g;
17 lnKp=-dG/(R*T);
18 disp(lnKp, 'in comparison to Table A-28 ln Kp value
    of -367.5 our result is');
```



```
19 Kp=exp(lnKp);
20 disp(Kp, 'the equilibrium constant is')
```

Scilab code Exa 16.2 Dissociation Temperature of Hydrogen

```
1 clc;clear;
2 //Example 16.2
3
4 //given data
5 vH2=1;
6 vH=2;
7 P=10;
8
9 //calculations
10 // H2 = 0.9H2 + 0.2H
11 NH=0.2;
12 NH2=0.9;
13 Nt=NH+NH2;
14 //from Eq. 16-15
15 Kp=((NH^vH)/(NH2^vH2))*(P/Nt)^(vH-vH2);
16 //at this value of Kp from Table A-28
17 T=3535;
18 disp(T, 'temperature in K is')
```

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

```
1 clc;clear;
2 //Example 16.6
3
4 //reaction
5 // H2 + 0.5O2 = H2O
6 //enthalpy data
7 //of H2
```

```

8 hfH=-241820;
9 h2000H=82593;
10 h298H=9904;
11 //of O2
12 hf0=0;
13 h20000=61400;
14 h2980=8468;
15 //of H2O
16 hfw=0;
17 h2000w=67881;
18 h298w=8682;
19 //Kp data from A-28
20 Kp2=869.6;
21 Kp1=18509;
22 T1=1800;
23 T2=2200;
24
25 //constants used
26 Ru=8.314; //in kJ/kmol K
27
28 //calculations
29 //part - a
30 hR=1*(hfH+h2000H-h298H)-1*(hf0+h20000-h2980)-0.5*(
      hfw+h2000w-h298w);
31 disp(floor(hR), 'enthalpy of the reaction in kJ/kmol
      using enthalpy data');
32 //part - b
33 hR=Ru*(T1*T2)/(T2-T1)*log(Kp2/Kp1);
34 disp(round(hR), 'enthalpy of the reaction in kJ/kmol
      using Kp data');

```

Scilab code Exa 16.7 Phase Equilibrium for a Saturated Mixture

```

1 clc;clear;
2 //Example 16.7

```

```

3
4 //given data
5 T=120+273.15; //in K
6
7 //from Table A-4
8 hf=503.81;
9 hg=2706;
10 sf=1.5279;
11 sg=7.1292;
12
13 //calculations
14 disp('liquid phase');
15 gf=hf-T*sf;
16 disp(gf, 'gf value in kJ/kg');
17 disp('vapour phase');
18 gg=hg-T*sg;
19 disp(gg, 'gg value in kJ/kg');

```

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

```

1 clc;clear;
2 //Example 16.8
3
4 //given data
5 T=15;
6 P=92;
7
8 //from Table A-4
9 Pv=1.7057;
10
11 //calculations
12 yv=Pv/P;
13 disp(yv, 'mole fraction of water vapor at the surface
14     ');
14 yw=1-yv;

```

```
15 yw=round(yw)
16 disp(yw,'mole fraction of water in the lake')
```

Scilab code Exa 16.9 The Amount of Dissolved Air in Water

```
1 clc;clear;
2 //Example 16.9
3
4 //given data
5 T=17;
6 P=92;
7
8 //from Table A-4
9 Pv=1.96;
10
11 //constants from Table 16-2
12 H=62000;
13
14 //calculations
15 Pda=P-Pv;//dry air
16 yda=Pda/H/100;//in bar
17 disp(yda,'mole fraction of air')
```

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

```
1 clc;clear;
2 //Example 16.10
3
4 //given data
5 T=358;
6 P=300/100;//in bar
7
8 //constants used
```

```

9 M=2;
10 s=0.00901; //solubility in kmol/m^3 bar
11 p=0.027;
12
13 //calculations
14 pH2=s*P;
15 disp(pH2, 'molar density of H2 in kmol/m^3');
16 pH2=p*M;
17 disp(pH2, 'mass density of H2 in kg/m^3')

```

Scilab code Exa 16.11 Composition of Different Phases of a Mixture

```

1 clc;clear;
2 //Example 16.11
3
4 //given data
5 yw=0.30; //w for water
6 ya=0.70; //a for ammonia
7 T=40;
8
9 //saturation pressure
10 pw=7.3851;
11 pa=1554.33;
12 //calculations
13 Pw=yw*pw;
14 Pa=ya*pa;
15 Pt=Pw+Pa;
16 yw=Pw/Pt;
17 ya=Pa/Pt;
18 disp(yw, 'mole fraction of water vapour');
19 disp(ya, 'mole fraction of ammonia')

```

Chapter 17

Compressible Flow

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

```
1  clc;clear;
2  //Example 17.1
3
4  //given data
5  V1=250;
6  T1=255.07;
7  P1=54.05;
8  h=5000;
9
10 //from Table A-2a
11 cp=1.005; //in kJ/kg-K
12 k=1.4;
13
14 //calculations
15 T01=T1+V1^2/(2*cp*1000); //factor of 1000 to convert
    kJ to J
16 P01=P1*(T01/T1)^(k/(k-1));
17 //given pressure ratio in compressor *
18 // T02 = T01*(P02/P01)^((k-1)/k)
19 T02 = T01*(8)^((k-1)/k);
20 win=cp*(T02-T01);
```

```
21 disp(P01,'the stagnation pressure at the compressor
    inlet in kPa');
22 disp(win,'the required compressor work per unit mass
    in kJ/kg')
```

Scilab code Exa 17.2 Mach Number of Air Entering a Diffuser

```
1  clc;clear;
2  //Example 17.2
3
4  //given data
5  V=200;
6  T=30+273;//converted in K
7
8  //from Table A-2a
9  R=0.287;//in kJ/kg-K
10 k=1.4;
11
12 //calculations
13 c=sqrt(k*R*T*1000);//factor of 1000 to convert kJ to
    J
14 c=ceil(c);
15 disp(c,'the speed of sound in m/s');
16 Ma=V/c;
17 disp(Ma,'the Mach number at the diffuser inlet')
```

Scilab code Exa 17.3 Gas Flow through a Converging Diverging Duct

```
1  clc;clear;
2  //Example 17.3
3
4  //given data
5  T0=200+273;//converted in K
```

```

6 P0=1400;
7 //stagnant temp. & pressure is same as inlet due to
  small inlet velocity
8 P=1200;
9 m=3;
10
11 //from Table A-2a
12 cp=0.846; //in kJ/kg-K
13 R=0.1889; //in kJ/kg-K
14 k=1.289;
15
16 //calculations
17 T=T0*(P/P0)^((k-1)/k);
18 V=sqrt(2*cp*(T0-T)*1000); //factor of 1000 to convert
  kJ to J
19 p=P/(R*T);
20 A=m/(p*V);
21 c=sqrt(k*R*T*1000); //factor of 1000 to convert kJ to
  J
22 Ma=V/c;
23 disp(V, 'velocity in m/s');
24 disp(p, 'density in kg/m^3');
25 disp((A*10000), 'flow area in cm^2');
26 disp(Ma, 'Mach number');

```

Scilab code Exa 17.4 Critical Temperature and Pressure in Gas Flow

```

1 clc;clear;
2 //Example 17.4
3
4 //given data
5 T0=200+273; //converted in K
6 P0=1400;
7
8 //from Table A-2a

```



```

9 k=1.289;
10
11 //calculations
12 //Tc & Tr stands for critical temp and ratio
    respectively
13 //Pc & Pr stands for critical temp and ratio
    respectively
14 Tr=2/(k+1);
15 Pr=(2/(k+1))^(k/(k-1));
16 Tc=Tr*T0;
17 Pc=Pr*P0;
18 Tc=floor(Tc);
19 Pc=ceil(Pc);
20 disp(Tc,'critical temperature in K');
21 disp(Pc,'critical pressure on kPa')

```

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

```

1 clc;clear;
2 //Example 17.5
3
4 //given data
5 Vi=150;
6 Ti=600+273;
7 Pi=1;
8 At=50/10000;//converted into m^2
9
10 //from Table A-2a
11 R=0.287;//in kJ/kg-K
12 cp=1.005;//in kJ/kg-K
13 k=1.4;
14
15 //calculations
16 Toi=Ti+Vi^2/(2*cp*1000);//factor of 1000 to convert
    kJ to J

```

```

17 Poi=Pi*(Toi/Ti)^(k/(k-1));
18 //flow is isentropic
19 //stagnation temp. and pressure values remain
    constant
20 To=Toi;
21 Po=Poi;
22 //from Table 17  2
23 //The critical-pressure ratio is 0.5283
24
25 //Part a
26 Pb=0.7;
27 Pca=Pb/Po;
28 // Pca > 0.5283
29 //exit plane pressure is equal to the back pressure
30 Pt=Pb;
31 //from Table A  32
32 Mat=0.778;
33 //Tt/To = 0.892
34 Tt=0.892*To;
35 pt=Pt*1000/(R*Tt); //factor of 1000 to convert MPa to
    kPa
36 Vt=Mat*sqrt(k*R*Tt*1000); //factor of 1000 to convert
    kJ to J
37 ma=pt*At*Vt;
38 disp(ma,'the mass flow rate through the nozzle when
    the back pressure is 0.7 MPa in kg/s');
39
40 //Part b
41 Pb=0.4;
42 Pca=Pb/Po;
43 // Pca < 0.5283
44 //sonic conditions exists at the exit
45 Ma=1;
46 mb=At*(Po*1000)*(sqrt(k*1000/(R*To)))*(2/(k+1))^((k
    +1)/(2*(k-1))); //factor of 1000 to convert MPa to
    kPa and kJ to J
47 disp(mb,'the mass flow rate through the nozzle when
    the back pressure is 0.4 MPa in kg/s');

```

Scilab code Exa 17.6 Gas Flow through a Converging Nozzle

```
1  clc;clear;
2  //Example 17.6
3
4  //given data
5  T1=400;
6  P1=100;
7  Ma1=0.3;
8  A21=0.8; //A2/A1
9
10 //assumption
11 k=1.4;
12
13 //from Table A 32
14 //at Ma1=0.3
15 //s stands for * symbol
16 A1s = 2.0351; //A1/As
17 T10 = 0.9823; //T1/T0
18 P10 = 0.9305; //P1/P0
19 A2s = A21*A1s; //A2/As
20 //at this value of A2/As
21 T20=0.9701; //T2/T0
22 P20=0.8993; //P2/P0
23 Ma2=0.391;
24
25 //calculations
26 T2=T1*T20/T10;
27 T2=floor(T2);
28 P2=P1*P20/P10;
29 disp(Ma2, 'Ma2 is ');
30 disp(T2, 'T2 in K is ');
31 disp(P2, 'P2 in kPa is ')
```

Scilab code Exa 17.7 Airflow through a Converging Diverging Nozzle

```
1  clc; clear;
2  //Example 17.7
3
4  //given data
5  T0=800;
6  P0=1;
7  Vi=0; //negligible
8  At=20;
9  Mae=2
10
11 //from Table A-2a
12 R=0.287; //in kJ/kg-K
13 k=1.4;
14
15 //calculations
16
17 //part - a
18 // Mach no. at exit is 2 hence sonic conditions at
   throat
19 p0=P0*1000/(R*T0); //factor of 1000 to convert MPa to
   kPa
20 //from Table A-32 at Mat=1
21 //s stands for * symbol
22 Ps0 = 0.5283; //Ts/T0
23 Ts0 = 0.8333; //Ps/P0
24 ps0=0.6339; //ps/p0
25 Ps=Ps0*P0;
26 Ts=Ts0*T0;
27 ps=ps0*p0;
28 As=At;
29 Vs=sqrt(k*R*Ts*1000); //factor of 1000 to convert kJ
   to J
```

```

30 disp('the throat conditions');
31 disp(Ps, 'Presssure in MPa');
32 disp(Ts, 'Temperature in K');
33 disp(ps, 'density in kg/m^3');
34 disp(As, 'area in cm^2');
35 disp(Vs, 'velocity in m/s');
36
37 //part - b
38 //from Table A-32
39 //at Mae=2
40 Te0 = 0.5556; //Te/T0
41 Pe0 = 0.1278; //Pe/P0
42 pe0= 0.2300; //pe/p0
43 Ae0= 1.6875; //Ae/Ao
44 Pe=Pe0*P0;
45 Te=Te0*T0;
46 pe=pe0*p0;
47 Ae=Ae0*At;
48 Ve=Mae*sqrt(k*R*Te*1000); //factor of 1000 to convert
    kJ to J
49 disp('the exit plane conditions , including the exit
    area');
50 disp(Pe, 'Presssure in MPa');
51 disp(Te, 'Temperature in K');
52 disp(pe, 'density in kg/m^3');
53 disp(Ae, 'area in cm^2');
54 disp(Ve, 'velocity in m/s');
55
56 //part - c
57 m=ps*As*Vs/10000; //factor of 10000 to convert cm^2
    to m^2
58 disp(m, 'the mass flow rate through the nozzle in kg/
    s');

```

Scilab code Exa 17.9 Shock Wave in a Converging Diverging Nozzle

```

1  clc;clear;
2  //Example 17.9
3
4  //given data
5  m=2.86;
6  Ma1=2;
7  P01=1;
8  P1=0.1278;
9  T1=444.5;
10 p1=1.002;
11
12 //from Table A-2a
13 R=0.287; //in kJ/kg-K
14 cp=1.005; //in kJ/kg-K
15 k=1.4;
16
17 //calculations
18
19 //part - a
20 //from Table A-33 at Ma1=2.0
21 Ma2=0.5774;
22 P0201=0.7209; //P02/P01
23 P21=4.5; //P2/P1;
24 T21=1.6875; //T2/T1
25 p21=2.6667; //p2/p1
26 P02=P0201*P01;
27 P2=P21*P1;
28 T2=T21*T1;
29 p2=p21*p1;
30 disp(P02,'the stagnation pressure in MPa');
31 disp(P2,'the static pressure in MPa');
32 disp(T2,'static temperature in K');
33 disp(p2,'static density in kg/m^3');
34
35 //part - b
36 //s21 = s2 - s1
37 s21=cp*log(T2/T1)-R*log(P2/P1);
38 disp(s21,'the entropy change across the shock in kJ/

```

```

    kg-K');
39
40 //part - c
41 V2=Ma2*sqrt(k*R*T2*1000); //factor of 1000 to convert
    kJ to J
42 V2=ceil(V2);
43 disp(V2,'the exit velocity in m/s');
44
45 //part - d
46 disp('flow rate is not affected by presence of shock
    waves amd remains 2.86 kg/sec')

```

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

```

1  clc;clear;
2  //Example 17.10
3
4  //given data
5  //using protactor frpm Fig 17-36
6  u=19; //u stands for angle of the mach lines
7
8  //calculations
9  //by Eq. 17-47
10 //i.e u= asin(1/Ma)
11 Ma=1/sind(u);
12 disp(Ma,'The Mach number is ')

```

Scilab code Exa 17.11 Oblique Shock Calculations

```

1  clc;clear;
2  //Example 17.11
3
4  //given data

```

```

5 Ma1=2;
6 P1=75;
7 O=10; //angle b/w shock wave and normal
8
9 //constants used
10 k=1.4;
11
12 //calcualtions
13 //with given values of Ma1 and O from Eq 17-46
14 Bweak=39.3;
15 Bstrong=83.7;
16 //Weak shock
17 Ma1w=Ma1*sind(Bweak);
18 //Strong shock
19 Ma1s=Ma1*sind(Bstrong);
20 //from second part Eq 17-40
21 Ma2w=0.8032;
22 Ma2s=0.5794;
23 //pressure ratio = (2*k*Ma^2 - k + 1)/(k + 1 )
24 //Weak shock
25 P2w=P1*(2*k*Ma1w^2 - k + 1)/(k + 1 );
26 P2w=ceil(P2w);
27 disp(P2w,'pressure for weak shock in kPa');
28 //Strong shock
29 P2s=P1*(2*k*Ma1s^2 - k + 1)/(k + 1 );
30 P2s=floor(P2s);
31 disp(P2s,'pressure for strong shock in kPa');
32 //Weak shock
33 Ma2=Ma2w/sind(Bweak-O);
34 disp(Ma2,'Mach number downstream for weak shock');
35 //Strong shock
36 Ma2=Ma2s/sind(Bstrong-O);
37 disp(Ma2,'Mach number downstream for strong shock');

```

Scilab code Exa 17.12 Prandtl Meyer Expansion Wave Calculations


```

1  clc;clear;
2  //Example 17.12
3
4  //given data
5  Ma1=2;
6  P1=230;
7  O=10; //O stands for angle of the mach lines
8
9  //constants used
10 k=1.4;
11
12 //calculations
13 //Eq. 17 49 for the upstream Prandtl Meyer
    function
14 vMa1=sqrt((k+1)/(k-1))*atand(sqrt((k-1)*(Ma1^2-1)/(k
    +1)))-atand(sqrt(Ma1^2-1));
15 //Eq. 17 48 to calculate the downstream
    Prandtl Meyer function
16 vMa2=0+vMa1;
17 //using equation solver as implicit nature of Eq
    17-49
18 Ma2=2.385;
19 disp(Ma2, 'downstream Mach number Ma2 is ');
20 //P2 = (P2/P0)/(P1/P0) * P1
21 P2= (1 + (k-1)*Ma2^2/2 )^(-k/(k-1)) / (1 + (k-1)*Ma1
    ^2/2 )^(-k/(k-1)) * P1;
22 P2=floor(P2);
23 disp(P2, 'downstream pressure in kPa')

```

Scilab code Exa 17.15 Rayleigh Flow in a Tubular Combustor

```

1  clc;clear;
2  //Example 17.15
3
4  //given data

```

```

5 P1=480;
6 T1=550;
7 V1=80;
8 d1=15/100; //diameter in m
9 AF=40; //air to fuel ratio
10 HV=40000; //heating value in kJ/kg
11
12 //from Table A-2a
13 R=0.287; //in kJ/kg-K
14 cp=1.005; //in kJ/kg-K
15 k=1.4;
16
17 //calculations
18 p1=P1/(R*T1);
19 A1=%pi*d1^2/4;
20 mair=p1*A1*V1;
21 mfuel=mair/AF;
22 Q=mfuel*HV;
23 q=Q/mair;
24 T01=T1+V1^2/(2*cp);
25 c1=sqrt(k*R*T1*1000); //factor of 1000 to convert kJ
    to J
26 Ma1=V1/c1;
27 //exit stagnation energy equation q= Cp (T02 - T01)
28 T02=T01+q/cp;
29 //from Table A 34
30 //at Ma1
31 //s stands for * symbol
32 T0s=0.1291; //T0/Ts
33 Ts0=T01/T0s;
34 T2s=T02/Ts0; //T02/T*0
35 //from Table A 34 at this ratio
36 Ma2=0.3142;
37 //Rayleigh flow relations corresponding to the inlet
    and exit Mach no
38 //at Ma1
39 T1s=0.1541; //T1/Ts
40 P1s=2.3065; //P1/Ps

```

```

41 V1s=0.0668; //V1/Vs
42 //at Ma2
43 T2s=0.4389; //T2/Ts
44 P2s=2.1086; //P2/Ps
45 V2s=0.2082; //V2/Vs
46 T2=T2s/T1s*T1;
47 T2=floor(T2);
48 P2=P2s/P1s*P1;
49 P2=ceil(P2);
50 V2=V2s/V1s*V1;
51 V2=floor(V2);
52 disp(Ma2, 'Mach Number at exit');
53 disp(T2, 'Temperature in K');
54 disp(P2, 'Pressure in kPa');
55 disp(V2, 'Velocity in m/s')

```

Scilab code Exa 17.16 Steam Flow through a Converging Diverging Nozzle

```

1  clc;clear;
2  //Example 17.16
3
4  //given data
5  P01=2*1000; //factor of 1000 to convert MPa to kPa
6  T1=400;
7  V1=0; //negligible
8  nN=0.93;
9  m=2.5;
10 P2=300;
11
12 //calculations
13
14 //part - a
15 P201=P2/P01;
16 //critical pressure ratio at this values is 0.546

```

```

17 Pt=0.546*P01;
18 //at inlet
19 h1=3248.4;
20 h01=h1;
21 s1=7.1292;
22 //at throat
23 st=s1;
24 ht=3076.8;
25 vt=0.24196;
26 Vt=sqrt(2*(h01-ht)*1000); //factor of 1000 to convert
    kJ to J
27 At=m*vt/Vt;
28 //at state 2s
29 s2s=s1;
30 h2s=2783.6;
31 //nN = (h01 - h2)/(h01 - h2s)
32 h2=h01-nN*(h01-h2s);
33 //at P2 and h2
34 v2=0.67723;
35 s2=7.2019;
36 V2=sqrt(2*(h01-h2)*1000); //factor of 1000 to convert
    kJ to J
37 A2=m*v2/V2;
38 disp((At*10000),'throat area in cm^2');
39 disp((A2*10000),'exit area in cm^2');
40
41 //part - b
42 // at st=7.1292
43 //pressures of 1.115 and 1.065 MPa
44 //c calculated using tables
45 c=sqrt((1115-1065)/(1/0.23776 - 1/0.24633)*1000); //
    factor of 1000 to convert kPa to Pa
46 Ma=Vt/c;
47 disp(Ma,'the Mach number at the throat');
48 // at s2=7.2019
49 //pressures of 325 and 275 kPa
50 c=sqrt((325-276)/(1/0.63596 - 1/0.72245)*1000); //
    factor of 1000 to convert kPa to Pa

```

```
51 Ma=V2/c;  
52 disp(Ma,'the Mach number at the nozzle exit')
```
