Scilab Textbook Companion for Thermodynamics an Engineering Approach by M. A. Boles and Y. A. Cengel[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Introduction and Basic Concepts

Scilab code Exa 1.2 Obtaining Formulas from Unit Considerations

```
clc;clear;
//Example 1.2

//given values
p=850;
V=2;

//calculation
m=p*V;//mass, density and volumne corealtion
disp(m,'the amount of oil in tank is (in kg)')
```

Scilab code Exa 1.3 The Weight of One Pound Mass

```
clc;clear;
//Example 1.3

```

```
//constants used
g=32.174;//gravitational constant in ft/s^2

//given values
m=1;

//calculation
w=(m*g)/g;//weight is mass times the local value of gravitational acceleration
disp(m,'the weight on earth is (in lbf)')
```

Scilab code Exa 1.4 Expressing Temperature Rise in Different Units

```
clc;clear;
//Example 1.4

//given values
Tc=10;//change in temp in Celcius

//calculation
Tk=Tc;
Tr=1.8*Tk;
Tf=Tr;
//calculated using the corealtions b/w these scales
disp(Tk,'the corresponding change in K');
disp(Tr,'the corresponding change in R');
disp(Tf,'the corresponding change in F')
```

Scilab code Exa 1.5 Absolute Pressure of a Vacuum Chamber

```
clc;clear;
//Example 1.5

```

```
//given values
Patm=14.5;
Pvac=5.8;

//calculation
Pabs=Patm-Pvac;//pressure in vaccumm is always
   treated to be negative
disp(Pabs,'the absolute pressure in the chamber in
   psi is')
```

Scilab code Exa 1.6 Measuring Pressure with a Manometer

```
clc;clear;
//Example 1.6

//constants used
pw=1000;//density of water in kg/m^3;
g=9.81;//acceleration due to gravity in m/s^2;

//given values
SG=0.85;
h=55/100;//converting height from cm to m
Patm=96;

//calculation
p=SG*pw;
Ptank=Patm+(p*g*h/1000);//calculating pressure using
    liquid at same height have same pressure
disp(Ptank,'absolute pressure in tank in kPa is')
```

Scilab code Exa 1.7 Measuring Pressure with a Multifluid Manometer

```
clc;clear;
```

```
//Example 1.7

//constants used
g=9.81;//acceleration due to gravity in m/s^2;

//given values
h1=0.1;
h2=0.2;
h3=0.35;//respective heights in m
pw=1000;
pHg=13600;
poil=800;//density of water, mercury and oil in kg/m
    ^3
Patm=85.6;

//calculation
P1=Patm-(pw*g*h1+poil*g*h2-pHg*g*h3)/1000;//
    calculating pressure using liquid at same height
    have same pressure
disp(P1,'the air pressure in tank in kPa is ')
```

Scilab code Exa 1.8 Measuring Atmospheric Pressure with a Barometer

```
clc;clear;
//Example 1.8

//constants used
g=9.81;//acceleration due to gravity in m/s^2;

//given values
pHg=13570;
h=74/100;//converting height into m from mm

//calculation
Patm=pHg*g*h/1000;//standard  pressure formula
```

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

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

```
clc;clear;
//Example 1.9

//constants used
g=9.81;//acceleration due to gravity in m/s^2;

//given values
m=60;
Patm=0.97;
A=0.04;

//calculation
P=Patm+(m*g/A)/10^5;//standard  pressure formula
disp(P,'the pressure inside the cylinder in bar is')
```

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

```
clc;clear;
//Example 1.10

//constants used
g=9.81;//acceleration due to gravity in m/s^2;

//given values
p=1040;
h1=0.8;
H=4;
x0=0;
```

```
x1=4;// x0 & x1 are limits of integration

//calculation
P1=p*g*h1/1000;//standard  pressure determination
   formula
P2=integrate('p*g*(sqrt(1+(tan(3.14*z/4/H)^2)))','z'
   ,x0,x1);//integrant
P2=P2/1000;//converting into kPa
P=P1+P2;
P=ceil(P);//roundingoff to match answer
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

```
clc;clear;
//Example 2.1

//constants used
Hu=6.73*10^10;//Energy liberated by 1 kg of uranium

//given values
p=0.75;//assuming the avg density of gasoline in kg/
   L
V=5;
Hv=44000;
mu=0.1;//mass of uranium used

//calculation
mgas=p*V;//mass of gasoline required per day
Egas=mgas*Hv;
Eu=mu*Hu;
d=Eu/Egas;
d=ceil(d);
```

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

Scilab code Exa 2.2 Wind Energy

```
clc;clear;
//Example 2.2

//given values
v=8.5;
m=10;
mf=1154;

//calculation
e=v^2/2;
disp(e,'wind energy per unit mass J/kg');
E=m*e;
disp(E,'wind energy for 10kg mass in J');
E=mf*e/1000;
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

```
clc;clear;
//Example 2.7

//given values
T=200;
n=4000/60;//converting rpm into rps

//calculation
Wsh=2*3.14*n*T/1000;
```

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

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

```
 clc;clear;
//Example 2.8

//constants used
g=9.81;//acceleration due to gravity in m/s^2;

//given values
m=1200;
V=90/3.6;//converting km/h into m/s
d=30;

//calculation
Vver=V*sind(d);//velocity in vertical direction
Wg=m*g*Vver/1000;
disp(Wg,'the addtional power in kW')
```

Scilab code Exa 2.9 Power Needs of a Car to Accelerate

```
clc;clear;
//Example 2.9

//given values
m=900;
v1=0;
v2=80/3.6;//converting km/h into m/s
t=20;

//calculation
Wa=m*(v2^2-v1^2)/2/1000;
```

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

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

```
clc;clear;
//Example 2.10

//given values
Win=100;
Qout=500;
U1=800;

//calculationu
// Win - Qout = U2- U1 i.e change in internal energy
U2=U1-Qout+Win
disp(U2,'final internal of the system in kJ-')
```

Scilab code Exa 2.11 Acceleration of Air by a Fan

```
clc;clear;
//Example 2.11

//given values
Win=20;
mair=0.25;

//calculation
v=sqrt(Win/2/mair)//Win = 1/2*m*v^2
if(v >= 8)
    disp('True');
else
    disp('False')
```

Scilab code Exa 2.12 Heating Effect of a Fan

```
clc;clear;
//Example 2.12

//given values
Win=200;
U=6;
A=30;
To=25;

//calculation
Ti= (Win/U/A)+To;// Win = Qout = U*A*(Ti - To)
disp(Ti,'the indoor air temperature in Celcius')
```

Scilab code Exa 2.13 Annual Lighting Cost of a Classroom

```
clc;clear;
//Example 2.13

//given values
Plamp=80;
N=30;//no of lamps
t=12;
y=250;//days in a year
UC=0.07;//unit cost in USD

//calculation
LP=Plamp * N/1000;//Lighting power in kW
OpHrs=t*y;//Operating hours
LE=LP * OpHrs;//Lighting energy in kW
```

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

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

```
clc;clear;
//Example 2.15

//given values
Ein=2;
n1=0.73;
n2=0.38;//efficency n1 and n2
CinH=0.09;
CinB=0.55;//unit cost of electricity and natural gas

//calculation
QutH= Ein * n1;
disp(QutH,'rate of energy consumption by the heater
   in kW');
CutH= CinH / n1;
disp(CutH,'the unit cost of utilized energy for
   heater in USD');
QutB= QutH / n2 ;
disp(QutB,'rate of energy consumption by the burner
   in kW');
CutB= CinB / n2 / 29.3; // 1 therm = 29.3 kWh
disp(CutB,'the unit cost of utilized energy for
   burner in USD')
```

Scilab code Exa 2.16 Performance of a Hydraulic Turbine Generator

```
clc;clear;
//Example 2.16
```

```
//answers vary due to round off error

//constants used
g=9.81;//acceleration due to gravity in m/s^2;

//given values
h=50;
m=5000;
Wout=1862;
ngen=0.95;//efficiency of turbine

//calculation
X=g*h/1000;// X stands for the differnce b/w change
    in mechanical energy per unit mass
R=m*X;//rate at which mech. energy is supplied to
    turbine in kW
nov=Wout/R;//overall efficiency i.e turbine and
    generator
disp(nov,'overall efficiency is');
ntu=nov/ngen;//efficiency of turbine
disp(ntu,'efficiency of turbine is');
Wsh=ntu*R;//shaft output work
disp(Wsh,'shaft power output in kW')
```

Scilab code Exa 2.17 Cost Savings Associated with High Efficiency Motors

```
clc;clear;
//Example 2.17

//given values
Pstd=4520;
Phem=5160;//prices of std and high eff motor in USD
R=60*0.7457;//rated power in kW from hp
OpHrs=3500;//Operating hours
```

```
Lf=1;//Load Factor
nsh=0.89;
nhem=0.932;//efficiency of shaft and high eff. motor
CU=0.08;//per unit cost in USD

//calculation
PS=R*Lf*(1/nsh-1/nhem);//Power savings = W electric
    in,standard - W electric in,efficient
ES=PS*OpHrs;//Energy savings = Power savings *
    Operating hours
ES=floor(ES);//rounding off
disp(ES,'Energy savings in kWh/year');
CS=ES*CU;
CS=floor(CS);//rounding off
disp(CS,'Cost savings per year in USD');
EIC=Phem-Pstd;//excess intial cost
Y=EIC/CS;
disp(Y,'simple payback period in years')
```

Scilab code Exa 2.18 Reducing Air Pollution by Geothermal Heating

```
clc;clear;
//Example 2.18

//given values
//NOx details
m1=0.0047;
N1=18*10^6;
//CO2 details
m2=6.4;
N2=18*10^6;

//calculation
NOxSav=m1*N1;
disp(NOxSav,'NOx savings in kg/year');
```

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

Scilab code Exa 2.19 Heat Transfer from a Person

```
clc;clear;
//Example 2.19

//constants used
e=.95;//Emissivity
tc=5.67*10^-8;//thermal conductivity in W/m^2 K^4

//given values
h=6;
A=1.6;
Ts=29;
Tf=20;

//calculation
//convection rate
Q1=h*A*(Ts-Tf);
//radiation rate
Q2=e*tc*A*((Ts+273)^4-(Tf+273)^4)
Qt=Q1+Q2;
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

```
clc;clear;
//Example 3.1

//given values
m=50;
T=90;

//Values from Table A-4
P=70.183;//in kPa
v=0.001036;//in m^3/kg

//calculation
disp(P,'pressure in the tank in kPa')
V=m*v;//equating dimensions
disp(V,'total volumne of tank becomes in m^3')
```

Scilab code Exa 3.2 Temperature of Saturated Vapor in a Cylinder

```
clc;clear;
//Example 3.2

//given values
V=2;
P=50;

//Values from Table A-5E
T=280.99;//in F
v=8.5175;//in ft^3/lbm

//caluclation
m=V/v;//dimension analysis
disp(m,'mass of vapour inside cylinder in lbm');
disp(T,'temp inside cylinder in F')
```

Scilab code Exa 3.3 Volume and Energy Change during Evaporation

```
clc;clear;
//Example 3.3

// constants used
Hfg=2257.5;//enthalpy of vaporization in kJ/kg

//given values
m=200/1000;//converting in kg
P=100;

//Values from Table A-5
vg=1.6941;
vf=0.001043;//specific vol of sat liq and vapor

//caluclation
vfg=vg-vf;
V=m*vfg;
```

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

Scilab code Exa 3.4 Pressure and Volume of a Saturated Mixture

```
clc;clear;
//Example 3.4

//given values
mt=10;
mf=8;
T=90;

//Values from Table A-4
P=70.183;//in kPa
vf=0.001036;
vg=2.3593;

//caluclation
mg=mt-mf;
V=mf*vf+mg*vg;// V= Vg + Vf
disp(V,'the volume of the tank in m^3');
disp(P,'the pressure in the tank in kPa')
```

Scilab code Exa 3.5 Properties of Saturated Liquid Vapor Mixture

```
clc;clear;
//Example 3.5

//given values
m=4;
```

```
V=80/1000;//converting into m^3
P=160;

//Values from Table A-12
vf=0.0007437;
vg=0.12348;
T=-15.60;
hf=31.21;
hfg=209.90;

//caluclation
v=V/m;
//vg>v>vf therefore it is a saturated mix
//hence temp will same as saturation temp
disp(T,'the temperature in celcius')
x=(v-vf)/(vg-vf);//x=vg/vfg i.e the dryness fraction
disp(x,'the quality');
h=hf+x*hfg;
disp(h,'the enthalpy of the refrigerant in kJ/kg');
mg=x*m;
Vg=mg*vg;
disp(Vg,'the volume occupied by the vapor phase in m
    ^3')
```

Scilab code Exa 3.7 Temperature of Superheated Vapor

```
clc;clear;
//Example 3.7

//given values
P=0.5;
h=2890;

//from Table A 6
//at P=0.5 MPa
```

```
T1=200;
h1=2855.8;
T2=250;
h2=2961.0;
// we need linear interpolation

//calculatiom
//by interpolation we cab say that
//h=h1+(T-T1)/(T2-T1)*(h2-h1)
//we have to find T
T=(h-h1)/(h2-h1)*(T2-T1)+T1;
disp(T,'temperature of water in celcius')
```

Scilab code Exa 3.8 Approximating Compressed Liquid as Saturated Liquid

```
clc;clear;
//Example 3.8

//given values
T=80;
P=5;

//from Table A 7
//at compressed liq given conditions
u=333.82;

//from Tablw A-4
//at saturation
usat=334.97;

//calcualtion
e=(usat-u)/u*100;
disp(u,'internal energy of compressed liquid water
   using data from the compressed liquid table in kJ
```

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

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

```
clc;clear;
//Example 3.9

//part a
disp('Part a');

//given values
P=200;
x=0.6;

//from Table A-5
T=120.21;
uf=504.50;
ufg=2024.6;

//calcualtions
u=uf+(x*ufg);
disp(T,'temperature in Celcius ');
disp(u,'internal energy in kJ/kg');
disp('saturated liquid vapor mixture at a pressure
     of 200 kPa');


//part b
disp('Part b');

//given values
```

```
T=125;
u=1600;

//from Table A 4
uf=524.83;
ug=2534.3;
//ug>u>ufg so its aturated liquid vapor mixture
P=232.23;

//calculation
ufg=ug-uf;
x=(u-uf)/ufg;
disp(P,'Pressure in kPa');
disp(x,'x is');
disp('saturated liquid vapor mixture at a temp of
   125 of celcius');


//part c
disp('Part c');

//given values
P=1000;
u=2950;

//from Table A 6
uf=761.39;
ug=2582.8;
//u>ug so its superheated steam
T=395.2;

//calculation
disp(T,'temperature in Celcius');
disp('superheated vapor at 1MPa ');

//part d
disp('Part d');

```

```
//given values
T=75;
P=100;

//from Table A 5
Tsat=151.83;
//T<Tsat so it is a compressed liquid
//the given pressure is much lower than the lowest
    pressure value in the compressed liquid table i.e
     5 MPa
//assuming, the compressed liquid as saturated
    liquid at the given temperature

//from Table A-4
u=313.99;
disp(u,'Internal energy in kJ/kg');
disp('the compressed liquid condition');


//Part e
disp('Part e');

//given values
P=850;
x=0;

//x=0 therefore it is a saturateed liquid condition
//from Table A-5
T=172.94;
u=731.00;
disp(T,'temperature in Celcius');
disp(u,'Internal energy in kJ/kg');
disp('saturateed liquid condition')
```

Scilab code Exa 3.10 Mass of Air in a Room

```
clc;clear;
//Example 3.10

//constants used
R=0.287// in kPa m^3/kg K

//given values
l=4;
b=5;
h=6;
P=100;
T=25+273;//in Kelvin

//calculation
V=l*b*h;
m=P*V/R/T;
disp(m,'the mass of the air in kg')
```

Scilab code Exa 3.11 The Use of Generalized Charts

```
clc;clear;
//Example 3.11

//given values
P=1;
T=50+273;//converting into Kelvin
vgiv=0.021796;//specific vol. given

//from Table A-1
R=0.0815;
Pcr=4.059;
Tcr=374.2;

//calculation

```

```
//Part A
v1=R*T/(P*1000);
disp(v1,'specific volume of refrigerant-134a under
   the ideal-gas assumption in m^3/kg');
e=(v1-vgiv)/vgiv;
disp(e,'an error of');

//Part B
//determine Z from the compressibility chart, we
   will calculate the reduced pressure and
   temperature
Pr=P/Pcr;
Tr=T/Tcr;
//from chart
Z=0.84;
v=Z*v1;
disp(v,'specific volume of refrigerant-134a under
   the generalized compressibility chart in m^3/kg')
   ;
e=(v-vgiv)/vgiv;
disp(e,'an error of');
```

Scilab code Exa 3.12 Using Generalized Charts to Determine Pressure

```
clc;clear;
//Example 3.12

//given values
v=0.51431;
T=600;

//from Table A-1E
R=0.5956;
Pcr=3200;
Tcr=1164.8;
```

```

//calculation

//Part A
//from Table A-6E
P=1000;//in psia
disp(P,'from the steam tables in psia');

//Part B
T=1060;//converted into R from F
P=R*T/v;
disp(P,'from the ideal-gas equation in psia');

//Part C
//calculating the pseudo-reduced specific volume and
    the reduced temperature
Vr=v/(R*Tcr/Pcr);
Tr=T/Tcr;
//from the compressibility chart
Pr=0.33;
P=Pr*Pcr;
disp(P,'from the generalized compressibility chart.
    in psia')
```

Scilab code Exa 3.13 Different Methods of Evaluating Gas Pressure

```
clc;clear;
//Example 3.13
//Answer of part c-d are having slight difference
    due to approximation in molar volumne in the
    textbook which here is caluculated to the
    approximation of 7 decimal digits

//given values
T=175;
```

```
v=0.00375;
Pex=10000;//experimentaion determination

//from Table A-1
R=0.2968// in kPa m^3/kg K

//calculating

//Part-a
P=R*T/v;
disp(round(P),'using the ideal-gas equation of state
    in kPa')
e=(P-Pex)/Pex*100;
disp(e,'error is');


//Part-b
//van der Waals constants from Eq. 3-23
a=0.175;
b=0.00138;
//from van der waal eq.
P=R*T/(v-b)-a/v^2;
disp(round(P),'using the van der Waals equation of
    state,');
e=(P-Pex)/Pex*100;
disp(e,'error is');

//Part-c
//constants in the Beattie-Bridgeman equation from
    Table 3  4
A=102.29;
B=0.05378;
c=4.2*10^4;
Ru=8.314;//in kPa m^3/kmol K
M=28.013;//molecular weight in kg/mol
vb=M*v;//molar vol.
P=(Ru*T)/(vb^2)*(1-((c)/(vb*T^3)))*(vb+B)-(A/vb^2);
disp(round(P),'using the Beattie-Bridgeman equation'
```

```
    );
e=(P-Pex)/Pex*100;
disp(e,'error is');

//Part-d
//constants of Benedict-Webb-Rubin equation from
    Table 3  4
a=2.54;
b=0.002328;
c=7.379*10^4;
alp=1.272*10^-4;
Ao=106.73;
Bo=0.040704;
Co=8.164*10^5;
gam=0.0053;
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);
disp(round(P),'using Benedict-Webb-Rubin equation');
e=(P-Pex)/Pex*100;
disp(e,'error is')
```

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

```
clc;clear;
//Example 3.14

//given value
T=25;

//from table 3-1
Psat=3.17;//on kPa

//calculations

```

```
//Relative Humidity 10%
Pv1=0.1*Psat
//Relative Humidity 80%
Pv2=0.8*Psat
//Relative Humidity 100%
Pv3=1*Psat

// from table 3-1 Tsat at these Pressures are
T1=-8;
T2=21.2;
T3=25;
disp(T1,'With relative humidity 10%the water temp in
    celcius is');
disp(T2,'With relative humidity 80% the water temp
   in celcius is');
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

```
clc;clear;
//Example 4.2

//given values
m=10;
Po=60;
T1=320;
T2=400;

//from Table A 6E
v1=7.4863;//at 60 psia and 320 F
v2=8.3548;//at 60 psia and 400 F

//calculations
//W = P dV which on integrating gives W = m * P * (
    V2 - V1)
W=m*Po*(v2-v1)/5.404;//coverting into Btu from psia-
    ft^3
disp(W,'work done by the steam during this process
```

```
in Btu')
```

Scilab code Exa 4.3 Isothermal Compression of an Ideal Gas

```
clc;clear;
//Example 4.3

//given data
P1=100;
V1=0.4;
V2=0.1;

//calculations
//for isothermal W = P1*V1* ln(V2/V1)
W=P1*V1*log(V2/V1);
disp(W,'the work done during this process in kJ')
```

Scilab code Exa 4.4 Expansion of a Gas against a Spring

```
clc;clear;
//Example 4.4

//given data
V1=0.05;
P1=200;
k=150;
A=0.25;

//calculations

//Part - a
V2=2*V1;
x2=(V2-V1)/A;//displacement of spring
```

```
F=k*x2;//compression force
P2=P1+F/A;//additional pressure is equivalent the
    compression of spring
disp(P2,'the final pressure inside the cylinder in
    kPa');

//Part - b
//work done is equivalent to the area of the P-V
    curve of Fig 4-10
W=(P1+P2)/2*(V2-V1);//area of trapezoid = 1/2 * sum
    of parallel sides * dist. b/w them
disp(W,'the total work done by the gas in kJ');

//Part - c
x1=0;//intial compression of spring
Wsp=0.5*k*(x2^2-x1^2);
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

```
clc;clear;
//Example 4.5

//given values
m=0.025;
V=120;
I=0.2;
t=300;//total time taken in sec
P1=300;
Qout=3.7;

//from Table A 5
//at P1 the conditon is sat. vap
h1=2724.9;
```

```
//Calculations

//Part - a
//therotical proving

//Part - b
We=V*I*t/1000;//electrical work in kJ
//from eqn 4 -18 i.e derived in earler part
//it states it Ein - Eout = Esystem
// it applies as Win - Qout = H = m (h2 - h1)
h2=(We-Qout)/m+h1;
////from Table A 5
//at h2 we get
P2=300;
T=200;
disp(T,'the final temperature of the steam in C')
```

Scilab code Exa 4.6 Unrestrained Expansion of Water

```
clc;clear;
//Example 4.6

//given data
m=5;
P1=200;
T=25;

//from Table A 4
//the liq. is in compressed state at 200 kPa and 25
   C
vf=0.001;
vg=43.340;
uf=104.83;
ufg=2304.3;
```

```
v1=vf;
u1=uf;

//calculations

//Part - a
V1=m*v1;
Vtank=2*V1;
disp(Vtank,'the volume of the tank in m^3');

//Part - b
V2=Vtank;
v2=V2/m;
//from Table A 4
// at T=25 vf=0.101003 m^3/kg and vg=43.340 m^3/kg
// vf<v2<vg therefore it is saturated liquid vapor
   mixture
P2=3.1698;
disp(P2,'the final pressure in kPa');

//Part - c
//Ein - Eout = Esystem
//Qin= dU = m(u2 - u1)
x2=(v2-vf)/(vg-vf);
u2=uf+x2*ufg;
Qin=m*(u2 - u1);
disp(Qin,'the heat transfer for this process in kJ')
```

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

```
clc;clear;
//Example 4.7

//given data
T1=300;
```

```
P=200;
T2=600;
M=28.97;
Ru=8.314;

//Part - a
//from Table A 17
u1=214.07;
u2=434.78;
du=u2-u1;//change in internal energy
disp(du,'change in internal energy from data from
   the air table in kJ/kg');

//Part - b
//from Table A 2c
a=28.11;
b=0.1967*10^-2;
c=0.4802*10^-5;
d=-1.966*10^-9;
//  by equation Cp(T)=a+bT+cT^2+dT^3
dubar=integrate('(a-Ru)+b*T+c*T^2+d*T^3','T',T1,T2);
   //integrant
du=dubar/M;
disp(du,'change in internal energy the functional
   form of the specific heat in kJ/kg');

//Part - c
//from Table A 2b
Cavg=0.733;
du=Cavg*(T2-T1);
du=ceil(du);
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

```
clc;clear;
//Example 4.8

//given data
m=1.5;
T1=80;
P1=50;
W=0.02;
t=30/60;//convertinginto hrs from min

//from Table A 2Ea
Cv=0.753;

//calculations

//part a
Wsh=W*t*2545;//in Btu
//Ein - Eout = Esystem
//Wsh = dU = m (u2 - u1) = m * Cv * (T2 - T1)
T2= Wsh/(m*Cv)+T1;
disp(T2,'the final temperature in F');

//part b
//using ideal gas eqn
// P1 * V1 / T1 = P2 * T2 /V2
P2= 50 * (T2 +460)/ (T1+460);
// temp should in R therefore + 460
disp(P2,'the final pressure in psia')
```

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

```
clc;clear;
//Example 4.9

//given data
```

```
V1=0.5;
P=400;
T1=27;
I=2;
t=5*60;//converting into s from min
V=120;
Qout=2800/1000;//in kJ
R=0.297;

//from Table A 2a
Cp=1.039;

//calculations
P1=P;
We=V*I*t/1000;//in kJ
m=P1*V1/(R*(T1+273));
//Ein − Eout = Esystem
// We,in − Qout = dH = m (h2 − h1) = m * Cp * (T2 −
    T1)
T2=(We-Qout)/(m*Cp)+T1;
disp(T2,'the final temperature of nitrogen in C')
```

Scilab code Exa 4.10 Heating of a Gas at Constant Pressure

```
clc;clear;
//Example 4.10

//given data
P1=150;
P2=350;
T1=27+273;//in K
V1=400/1000;// in m^3
R=0.287;

//from Table A 17
```

```
u1=214.07;
u2=1113.52;

//calculations

//part a
V2=2*V1;
//using ideal gas eqn
// P1 * V1 / T1 = P2 * T2 /V2
T2=P2*V2*T1/(P1*V1);
disp(T2,'the final temperature in K');

//part b
// Work done is Pdv
W=P2*(V2-V1);
disp(W,'the work done by the air im kPa');

//part c
//Ein - Eout = Esystem
//Qin - Wout = dU = m(u2 - u1)
m= P1* V1 /(T1 * R);
Q= m*(u2 - u1)+ W;
Q=ceil(Q);
disp(Q,'the total heat transferred to the air in kJ'
    )
```

Scilab code Exa 4.11 Enthalpy of Compressed Liquid

```
clc;clear;
//Example 4.11

//given data
T=100;
P=15;

```

```
//from Table A 7
//at P=15 mPa and T = 100 C
hg=430.39;
hf=419.17
vf=0.001;
Psat=101.42;//in kPa

//calculations

//part a
h=hg;
disp(h,'enthalpy of liquid water by using compressed
    liquid tables in kJ/kg');

//part b
//Approximating the compressed liquid as a saturated
    liquid at 100 C
h=hf;
disp(h,'enthalpy of liquid water by approximating it
    as a saturated liquid in kJ/kg');

//part c
h=hf + vf*(P*1000 - Psat );
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

```
clc;clear;
//Example 4.12

//given dara
mi=50;
T1i=80;//suffix i for iron
Vw=0.5;
```

```
T1w=25;//suffix w for water
v=0.001;//specific volume of liquid water at or
    about room temperature

//from Table A 3
ci=0.45;
cw=4.18;

//calculations
mw=Vw/v;
//Ein - Eout = Esystem
// du = 0 i.e (mcdT)iron + (mcdT)water = 0
// mi * ci * (T - T1i) + mw *cw * (T-T1w)
//on rearranging above equn
T= (mi*ci*T1i + mw*cw*T1w)/(mi*ci+mw*cw);
disp(T,'the temperature when thermal equilibrium is
    reached in C')
```

Scilab code Exa 4.13 Temperature Rise due to Slapping

```
clc;clear;
//Example 4.13

//given data
maf=0.15;
caf=3.8;
dTaf=1.8;//suffix af for affected tissue
mh=1.2;///suffix h for hand

//calculations
//Ein - Eout = Esystem
//dUaffected tissue - KEhand = 0
//from above equation we can deduce that
Vhand= sqrt(2*maf*caf*dTaf*1000/mh);//for conversion
    factor mutiplying by 1000 to get m^2/s^2
```

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

Scilab code Exa 4.14 Burning Off Lunch Calories

```
clc;clear;
//Example 4.14

//given data
m=90;

//from Tables 4  1 and 4  2
Ehb=275;//hamburger
Ef=250;//fries
Ec=87;//cola

//calculation

//part a
Ein=2*Ehb+Ef+Ec;
//The rate of energy output for a 68-kg man watching
    TV is to be 72 Calories/h
Eout=m*72/68;
t=Ein/Eout;
disp(t,'by watching TV in hours');

//part b
//The rate of energy output for a 68-kg man watching
    TV is to be 860 Calories/h
Eout=m*860/68;
t=Ein/Eout*60//converting in min
t=ceil(t);
disp(t,'by fast swimming in mins');

//for last question
```

```
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

```
clc;clear;
//Example 4.15

//given data
E=75;//in Cal/day

//calculation
Ereduced=E*365;
//The metabolizable energy content of 1 kg of body
    fat is 33,100 kJ
Ec=33100;
mfat=Ereduced/Ec*4.1868;
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

```
clc;clear;
//Example 5.1

//given data
V=10;
t=50;
p=1;//in kg/L
re=0.8/2/100;//in m

//calculations
Vd=V/t*3.7854;//factor 0f 3.7854 for gal to L
disp(Vd,'volumne flow rate through hose in L/s');
m=p*Vd;
disp(m,'mass flow rate through hose in kg/s');
Ae=%pi*re^2;
Ve=Vd/Ae/1000;//factor of 1000 for L to m^3
disp(Ve,'average velocity at the nozzle in m/s');
```

Scilab code Exa 5.2 Discharge of Water from a Tank

```
clc;clear;
//Example 5.2

//given data
Dtank=3*12;//in inches
Djet=0.5;
h0=2;
h1=4;

//constants used
g=32.2;//in ft/s^2

//calculations
//min - mout = dmCV/dt
//mout = p*(2*g*h*Ajet)^2
//mCV = p*Atank*h
//from these we get dt = Dtank^2/Djet^2 * (dh/(2*g*h
    )^2)
t=integrate('Dtank^2/Djet^2*(1/sqrt(2*g*h))','h',h0,
    h1);
t=(t/60);//in min
disp(t,'time taken to drop to 2ft in min')
```

Scilab code Exa 5.3 Energy Transport by Mass

```
clc;clear;
//Example 5.3

//given data
P=150;
```

```
Vliquid=0.6/1000;//im m^3
t=40*60;//in sec
Ac=8*10^-6;

//from Table A-5
//from P = 150 kPa
h=2693.1;
ug=2519.2;
vf=0.001053;
vg=1.1594;

//calculations
m=Vliquid/vf;
md=m/t;
disp(md,'mass flow rate in kg/s');
V=md*vg/(Ac);
disp(V,'exit velocity in m/s');
Eflow=h-ug;
Et=h;
disp(Eflow,'flow energy in kJ/kg');
disp(Et,'total energy in kJ/kg');
Emass=md*Et;
disp(Emass,'rate at which energy leaves the cooker
   in kW')
```

Scilab code Exa 5.4 Deceleration of Air in a Diffuser

```
clc;clear;
//Example 5.4

//given data
T1=283;//in K
P1=80;
V1=200;
A1=0.4;
```

```

//constants used
R=0.287;//in kPa-m^3/kg-K

//calulations
v1=R*T1/P1;
m=V1*A1/v1;
disp(m,'mass flow rate of air in kg/s');
// Ein - Eout = dEsystem / dt
//from Table A-17
h1=283.14;
V2=0;
h2=h1-(V2^2 - V1^2)/2/1000;//factor of 1000 to convert to kJ/kg
//from Table A-17 at this value of h2
T2=303;
disp(T2,'the temperature in K is');
```

Scilab code Exa 5.5 Acceleration of Steam in a Nozzle

```
clc;clear;
//Example 5.5

//given data
P1=250;
T1=700;
A1=0.2;
qout=1.2;
m=10;
P2=200;
V2=900;

//from Table A-6E
v1=2.6883;
h1=1371.4;
```

```

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

Scilab code Exa 5.6 Compressing Air by a Compressor

```
clc;clear;
//Example 5.6

//given data
T1=280;
P1=100;
m=0.02;
qout=16;
P2=600;
T2=400;

//from Table A-17
h1=280.13;
h2=400.98;

//calculations
// Ein - Eout = dEsystem / dt
Win=m*qout+m*(h2-h1);
disp(Win,'the input power of compressor in kW')
```

Scilab code Exa 5.7 Power Generation by a Steam Turbine

```
clc;clear;
//Example 5.7

//given data
P1=2;
T1=400;
V1=50;
z1=10;
P2=15;
x2=0.9;
V2=180;
z2=6;
Wout=5*1000;//in kJ

//from Table A-6
h1=3248.4;
//similarly for P2
hf=225.94;
hfg=2372.3;

//constants used
g=9.8;//in m/s^2

//calcualtions
h2=hf+x2*hfg;
disp((h2-h1),'difference in enthalpies in kJ/kg');
disp((V2^2-V1^2)/2/1000,'difference in kinetic
    energy in kJ/kg');//factor of 1000 to convert to
    kJ/kg
disp(g*(z2-z1)/1000,'difference in potential energy
    in kJ/kg');//factor of 1000 to convert to kJ/kg
wout=-((h2-h1)+(V2^2-V1^2)/2/1000+g*(z2-z1)/1000);//
    factor of 1000 to convert to kJ/kg
disp(wout,'work done per unit of mass in kJ/kg');
m=Wout/wout;
disp(m,'mass flow rate in kg/s')
```

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

```
clc;clear;
//Example 5.8

//given data
P1=0.8;
P2=0.12;

//from Table A−12
//sat. liq at P1
T1=31.31;
h1=95.47;
//since process is insentropic and at  P2
h2=h1;
hf=22.49;
hg=236.97;
T2=-22.32;

//calculations
x2=(h2-hf)/(hg-hf);
disp(x2,'the final state is');
dT=T2-T1;
disp(dT,'temperature drop in C')
```

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

```
clc;clear;
//Example 5.9

//given data
```

```
T1=140;
T2=50;
T3=110;
P=20;

//for a compressed liq at given temp
h1=107.99;
h2=18.07;
h3=78.02;

//calculations
//Mass balance min = mout So, m1+m2 = m3
//Energy balance Ein = Eout So, m1*h1 + m2*h2 = m3*
   h3
//combining realations
//m1*h1 + m2*h2 = (m1+m2)*h3
//dividing by m2 and y=m1/m2
//we get, yh1 + h2 = (y+1)*h3
y=(h3-h2)/(h1-h3);
y=round(y);
disp(y,'the ratio of mass flow rates')
```

Scilab code Exa 5.10 Cooling of Refrigerant 134a by Water

```
clc;clear;
//Example 5.10

//given data
T1=15;
P1=300;
T2=25;
T3=70;
P3=1000;//in kPa
T4=35;
mr=6;
```

```
//from Table A-4, A-13 and A-11
h1=62.982;
h2=104.83;
h3=303.85;
h4=100.87;

//calculations
//mass balance m1=m2=mw and m3=m4=mr
//energy balance m1*h1 + m3*h3 =  m2*h2 + m4*h4
//combining them mw*(h1-h2) = mr*(h4-h3)
mw= mr*(h4-h3)/(h1-h2);
disp(mw,'mass flow rate of cooling water in kg/min')
    ;
Qin=mw*(h2-h1);
Qin=round(Qin);
disp(Qin,'heat transfer rate in kJ/min')
```

Scilab code Exa 5.11 Electric Heating of Air in a House

```
clc;clear;
//Example 5.11

//giaven data
T1=17+273;//in K
P1=100;
V1=150;
Win=15;
Qout=200/1000;//in kJ/s

//constants used
R=0.287;//in kPa-m^3/kg-K
cp=1.005;//in kJ/kg C

//calculations
```

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

Scilab code Exa 5.12 Charging of a Rigid Tank by Steam

```
clc;clear;
//Example 5.12

//given data
Pi=1;
Ti=300;
P2=1;

//from Table A-6
hi=3051.6;

//calculations
//mass balance mi=m2
//energy balance mi*hi= m2*u2
//combining them we get ,
u2=hi;
//from Table A-6
//we know P2 and u2, so
T2=456.1;
disp(T2,'final temperature in tank in C')
```

Scilab code Exa 5.13 Cooking with a Pressure Cooker

```
clc;clear;
//Example 5.13
```

```

//given data
V=6/1000;//in m^3
Pgage=75;
Patm=100;
m1=1;
Qind=0.5;//d stands for .
t=30*60;//in s

//calculation
Pabs=Pgage+Patm;
//from Table A-5, ths saturation temp
T=116.04;
disp(T,'the temperature at which cooking takes plac
    in C');
//mass balance me=(m1-m2)cv
//energy balance Qin - mehe = (m2u2 - m1u1)cv
Qin=Qind*t;
//from Table A-5
he=2700.2;
vf=0.001;
vg=1.004;
uf=486.82;
ufg=2037.7;
v1=V/m1;
x1=(v1-vf)/(vg-vf);
u1=uf+x1*ufg;
U=m1*u1;
//Qin = (m1 - V/v2)*he + (V/v2*u2 - m1*u1)
//v2=vf + x2*(vg-vf)
//u2=uf +  x2*ufg
//combining these equations we get
//solved using EES
x2=0.009;
v2=vf + x2*(vg-vf);
m2=V/v2;
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

```
clc;clear;
//Example 6.1

//givrn data
QH=80;
QL=50;

//calculations
Wnet=QH-QL;
disp(Wnet,'net power output in MW')
nth=Wnet/QH;
disp(nth,'the thermal efficiency')
```

Scilab code Exa 6.2 Fuel Consumption Rate of a Car

```
clc;clear;
```

```
//Example 6.2

//given data
Wnet=65;
nth=0.24;
HV=19000;

//calculations
QH=Wnet/nth*2545;//factor of 2545 to convert to Btu/
    h
m=QH/HV;
disp(m,'the engine must burn at fuel rate in lbm/h')
```

Scilab code Exa 6.3 Heat Rejection by a Refrigerator

```
clc;clear;
//Example 6.3

//given data
Wnet=2;
QL=360;

//calculations
COPR=QL/Wnet/60;//factor of 60 to convert kW to kJ/
    min
disp(COPR,'coefficient of performance of
    refrigerator');
QH=QL+Wnet*60;//factor of 60 to convert kW to kJ/min
disp(QH,'heat rejection rate in kJ/min')
```

Scilab code Exa 6.4 Heating a House by a Heat Pump

```
clc;clear;
```

```
//Example 6.4

//given data
COP=2.5;
QH=80000;

//calculations
Wnet=QH/COP;
disp(Wnet,'the power consumed in kJ/h')
QL=QH-Wnet;
disp(QL,'the rate at which heat is absorbed in kJ/h'
   )
```

Scilab code Exa 6.5 Analysis of a Carnot Heat Engine

```
clc;clear;
//Example 6.5

//given data
QH=500;
TL=30+273;//in C
TH=652+273;//in C

//calculations
nth=1-TL/TH;
disp(nth,'the thermal efficiency of carnot engine');
QL=TL*QH/TH;
QL=round(QL);
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

```
clc;clear;
//Example 6.6

//given data
COP=13.5;
TH=75+460;//in R
TL=35+460;//in R

//calculations
COPR=1/(TH/TL-1);
if(COPR>=COP)
    disp('claim is true');
else
    disp('claim is false')
```

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

```
clc;clear;
//Example 6.7

//given data
TL=-5+273;//in C
TH=21+273;//in C
QH=37.5;

//calculations
COPHP=1/(1-TL/TH);
Wnet=QH/COPHP;
disp(Wnet,'minimum power required in kW')
```

Scilab code Exa 6.8 Malfunction of a Refrigerator Light Switch

```
clc;clear;
```

```
//Example 6.8

//given data
Qrefrig=40;
COPR=1.3;
Wlight=40;

//calculation
Wrefrig=Qrefrig/COPR;
Wt=Wrefrig+Wlight;
AnHr=365*24;//annual hours
NOH=20*30/3600*365;//normal operating hours
AOP=AnHr-NOH;//addtional operating hours
APC=Wt*AOP/1000;//additional power consumption;
    fator of 1000 to convert to kW
APC=round(APC);
disp(APC,'increase in power consumption in kWh/yr');
disp((APC)*0.08,'increase in cost in Dollar/yr')
```

Chapter 7

Entropy

Scilab code Exa 7.1 Entropy Change during an Isothermal Process

```
clc;clear;
//Example 7.1

//given data
Q=750;
Tsys=300;

//calculations
dSsys=Q/Tsys;
disp(dSsys,'Entropy change in the process in kJ/K')
```

Scilab code Exa 7.2 Entropy Generation during Heat Transfer Processes

```
clc;clear;
//Example 7.2

//given data
Qsink=2000;
```

```
Qsource=-Qsink;
Tsource=800;

//calculations
//part - a
Tsink=500;
dSsource=Qsource/Tsource;
dSsink=Qsink/Tsink;
Sgena=dSsource+dSsink;
disp(Sgena,'entropy generated in part a in kJ/K is '
   );
//part - b
Tsink=750;
dSsource=Qsource/Tsource;
dSsink=Qsink/Tsink;
Sgenb=dSsource+dSsink;
disp(Sgenb,'entropy generated in part b in kJ/K is '
   );
if(Sgena>Sgenb)
    disp('part a is more irreversible');
elseif(Sgena == Sgenb)
    disp('heat transfer is equally irreversible');
else
    disp('part b is more irreversible');
end,
```

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

```
clc;clear;
//Example 7.3

//given data
m=5;
P1=140;
T1=20;
```

```
P2=100;

//from refrigerant -134a data
//at P1 and T1
s1=1.0624;
v1=0.16544;
//at P2
v2=v1;
vf=0.0007529;
vg=0.19254;
sf=0.07188;
sfg=0.87995;

//calculations
// vf < v2 <vg
x2=(v2-vf)/(vg-vf);
s2=sf+x2*sfg;
dS=m*(s2-s1);
disp(dS,'entropy change in the process in kJ/k')
```

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

```
clc;clear;
//Example 7.4

//given data
m=3;
P1=20;
T1=70+460;//in R
Qin=3450;

//from Table A-6E
//at P1 and T1
s1=0.07459;
h1=38.08;
```

```

//calculations
//Ein - Eout = dEsystem
//Qin = m*(h2 - h1)
h2=Qin/m+h1;
//from Table A-6E
//At P2 and h2
s2=1.7761;
dS=m*(s2-s1);
disp(dS,'entropy change in Btu/R');
```

Scilab code Exa 7.5 Isentropic Expansion of Steam in a Turbine

```
clc;clear;
//Example 7.5

//given data
P1=5;
T1=450;
P2=1.4;

//calculations
//Ein - Eout = dEsystem/dt
//Ein = Eout
//Wout = m*(h1-h2)
//At P1 and T1
h1=3317.2;
s1=6.8210;
s2=s1;
//At P2 and s2
h2=2967.4;
Wout=h1-h2;
disp(Wout,'work output per unit mass in kJ/kg')
```

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

```
clc;clear;
//Example 7.7

//given data
P1=1;
T1=110;
P2=5;
T2=120;

//from Table
//At P1 and T1
s1=4.875;
cp1=3.471;
//at P2 and T2
s2=5.145;
cp2=3.486;

//calculations
//part - a
dSa=s2-s1;
disp(dSa,'change in entropy in kJ/kg K using
    tabulated properties');
//part - b
cavg=(cp1+cp2)/2;
dSb=cavg*log(T2/T1);
disp(dSb,'change in entropy in kJ/kg K approximating
     liquid methane as an incompressible substance');
E=(dSb-dSa)/dSa*100;
disp(E,'Error % is')
```

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

```
clc;clear;
//Example 7.8

//given data
P1=5;
V1=0.280;
T1=115;
P2=1;
dt=8760;//time in h/yr
UC=0.075;//unit cost in dollar

//from Table
//at P1 and T1
h1=232.3;
s1=4.9945;
p1=422.15;
s2=s1;
//at P2 and s2
h2=222.8;

//calculations
m=p1*V1;
//Ein - Eout = dEsystem/dt
//Ein = Eout
//Wout = m*(h1-h2)
Wout = m*(h1-h2);
disp(round(Wout),'maximum amount of power that can
   be produced in kW')
APP=Wout*dt;//annual power production
APS=APP*UC;//annual power savings
disp(APS,'Annual power savings in $/year')
```

Scilab code Exa 7.9 Entropy Change of an Ideal Gas

```
clc;clear;
//Example 7.9

//given data
P1=100;
T1=290;
P2=600;
T2=330;

//from Table A-17
s02=1.79783;
s01=1.66802;
//Table A-2b
cpavg=1.006;

//constants used
R=0.287;//in kJ/kg -K

//calculations
//part-a
s21=s02-s01-R*log(P2/P1);//stands for s2 - s1
disp(s21,'entropy change using property values from
    air table in kJ/kg-K');
s21=cpavg*log(T2/T1)-R*log(P2/P1);//stands for s2 -
    s1
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

```
clc;clear;
//Example 7.10

//given data
P1=95;
```

```
T1=295;
r=8;//ratio of V1/V2

//calculations
//for closed systems V2/V1 = v2/v1
//At T1
vr1=647.9;
vr2=vr1/r;
//at vr2
T2=662.7;
disp(T2,'the final temperature in K')
```

Scilab code Exa 7.11 Isentropic Compression of an Ideal Gas

```
clc;clear;
//Example 7.11

//given data
P1=14;
T1=50+460;
T2=320+460;

//constants used
k=1.667;

//calculations
P2=P1*(T2/T1)^(k/(k-1));
disp(P2,'exit pressure in psia')
```

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

```
clc;clear;
```

```
//Example 7.12

//given data
P2=1000;
P1=100;

//from Table A-5
//At P2
v1=0.001043;

//calculations
Wrev=v1*(P2-P1);
disp(Wrev,'compressor work as saturated liquid at
   inlet in kJ/kg')
//from Table A-5
//at P1 as sat. vapour
h1=2675.0;
s1=7.3589;
s2=s1
//from Table A-6
//at P2 and s2
h2=3194.5;
Wrev=h2-h1;
disp(Wrev,'compressor work as saturated vapor at
   inlet in kJ/kg')
```

Scilab code Exa 7.13 Work Input for Various Compression Processes

```
clc;clear;
//Example 7.13

//given data
P1=100;
T1=300;
P2=900;
```

```
//constants used
R=0.287;//in kJ/kg -K

//calculations
//part - a
k=1.4;
Wcomp=k*R*T1/(k-1)*((P2/P1)^((k-1)/k)-1);
disp(Wcomp,'compression work in case of isentropic
   compression in kJ/kg');
//part - b
n=1.3;
Wcomp=n*R*T1/(n-1)*((P2/P1)^((n-1)/n)-1);
disp(Wcomp,'compression work in case of polytropic
   compression in kJ/kg');
//part - c
Wcomp=R*T1*log(P2/P1);
disp(Wcomp,'compression work in case of isothermal
   compression in kJ/kg');
//part - d
Ps=sqrt(P1*P2);
Wcomp=2*n*R*T1/(n-1)*((Ps/P1)^((n-1)/n)-1);
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

```
clc;clear;
//Example 7.14

//given data
P1=3000;// in kPa
T1=400;
P2=50;
T2=100;
```

```
Wout=2000;//in kW

//from Table A-6
//at P1
h1=3231.7;
s1=6.9235;
//at 2a
h2a=2682.4;
//from Table A-6
//at 2s
s2s=s1;
sf=1.0912;
sg=7.5937;
hf=340.54;
hfg=2304.7
x2s=(s2s-sf)/(sg-sf);
h2s=hf+x2s*hfg;
nT=(h1-h2a)/(h1-h2s);
disp(nT,'isentropic efficiency is')
//Ein = Eout
m=Wout/(h1-h2a);
disp(m,'mass flow rate in kg/s')
```

Scilab code Exa 7.15 Effect of Efficiency on Compressor Power Input

```
clc;clear;
//Example 7.15

//given data
P1=100;
T1=285;
P2=800;
m=0.2;
nc=0.8;

```

```
//from Table A-17
//at T1
h1=285.14;
Pr1=1.1584;

//calcualtions
Pr2=Pr1*(P2/P1);
//at Pr2
h2s=517.05;
h2a=(h2s-h1)/nc+h1;
//at h2a
T2a=569.5;
disp(T2a,'exit temperature of air in K');
//Ein = Eout
Wa=m*(h2a-h1);
disp(round(Wa),'required power input in kW')
```

Scilab code Exa 7.16 Effect of Efficiency on Nozzle Exit Velocity

```
clc;clear;
//Example 7.16

//given data
P1=200;
T1=950;
P2=80;
nN=0.92;

//from Table A-2b
cp=1.099;
k=1.354;

//calculations
T2s=T1*(P2/P1)^((k-1)/k);
//ein = eout
```

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

Scilab code Exa 7.17 Entropy Generation in a Wall

```
clc;clear;
//Example 7.17

//given data
Qin=1035;
Tin=20+273;//in K
Qout=Qin;
Tout=5+273;//in K

//calculations
// Sin - Sout + Sgen = dSsystem/dt
Sgen=(Qout/Tout)-(Qin/Tin);
disp(Sgen,'entropy generation in the wall in W/K');
Ts1=300;Ts2=273;//Boundary temperatures
Sgen=(Qout/Ts2)-(Qin/Ts1);
disp(Sgen,'total entropy generation in W/K');
```

Scilab code Exa 7.18 Entropy Generation during a Throttling Process

```
clc;clear;
//Example 7.18

```

```
//given data
P1=7;
T1=450;
P2=3;

//from steam tables
//at P1 and T1
h1=3288.3;
s1=6.6353;
//at P2
h2=h1;
s2=7.0046;

//calculations
// Sin - Sout + Sgen = dSsystem/dt
Sgen=s2-s1;
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

```
clc;clear;
//Example 7.19

//given data
m=50;
T1=500;
T2=285;

//from Table A-3
Cavg=0.45;

//calculations
dSiron=m*Cavg*log(T2/T1);
disp(dSiron,'entropy change of the iron block in kJ/
```

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

Scilab code Exa 7.20 Entropy Generation in a Mixing Chamber

```
clc;clear;
//Example 7.20

//given data
P=20;
T1=50+460;//in R
T2=240;
T3=130;
m1=300;
Qout=180;

//from steam tables
//at P and T1
h1=18.07;
s1=0.03609;
//at P and T2
h2=1162.3;
s2=1.7406;
//at P and T3
h3=97.99;
s3=0.18174;

//calculations
// Qout = m1*h1 + m2*h2 - (m1+m2)*h3
```

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

Scilab code Exa 7.21 Entropy Generation Associated with Heat Transfer

```
clc;clear;
//Example 7.21

//given data
T=100+273;//in K
Q=-600;
Tb=25+273;//in K

//calculation
dSsys=Q/T;
disp(dSsys,'entropy change of water in kJ/K');
// Sin - sout + Sgen = dSsystem
Sgen= -Q/Tb + dSsys;
disp(Sgen,'total entropy generation in kJ/K')
```

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

```
clc;clear;
//Example 7.22
//difference in answers is arised due the fact the
    Energy savings have been rounded to the multiple
    of 100

//given data
```

```
T1=20+273;
T2=24+273;
P1=101;
P2=801;
D=3/1000;//in m
Cdischarge=0.65;
ncomp=0.8;
nmotor=0.92;
UC=0.078;//unit cost

//constants used
R=0.287;//in kJ/kg K
k=1.4;
n=1.4;

//calculations
Win=n*R*T1/(ncomp*(n-1))*((P2/P1)^((n-1)/n)-1);
A=%pi*D^2/4;
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
PW=mair*Win;//Power wasted
ES=PW*4200/nmotor;//4200 is operating hours ES
    stands for Energy savings
disp(ES,'Energy savings in kWh/yr');
CS=ES*UC;
disp(ceil(CS),'cost savings in Dollar/yr')
```

Scilab code Exa 7.23 Reducing the Pressure Setting to Reduce Cost

```
clc;clear;
//Example 7.23

//given data
P1=85.6;
P2=985.6;
```

```
P2r=885.6;
CC=12000;//current cost

//constants used
n=1.4;

//calulation
freduction=1-(((P2r/P1)^((n-1)/n)-1)/((P2/P1)^((n-1)
   /n)-1));
CS=CC*freduction;
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

```
clc;clear;
// Example 8.1

// given data
D=12;
V=10;

// density of air at 25C & 1atm
p=1.18;

//calculations
ke=(V^2)/2/1000;//factor of 1000 for converting J
   into kJ
m=p*%pi*[D ^2]*V/4;
MP=m*(ke);
disp(MP,'Maximum power in kW')
```

Scilab code Exa 8.2 Exergy Transfer from a Furnace

```
clc;clear;
//Example 8.2

//given values
TH=2000;
T0=77+460;//in R
Qin=3000;

//calculation
nth=1-(T0/TH);
Wmax=nth*Qin;
Wmax=round(Wmax)
disp(Wmax,'the rate of energy flow in Btu/s')
```

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

```
clc;clear;
//Example 8.3

//given data
Tsink=300;
Tsource=1200;
Qin=500;
Wuout=180;

//calculations
Wrev=(1-Tsink/Tsource)*Qin;
disp(Wrev,'The reversible power in kW');
I=Wrev-Wuout;
disp(I,'the irreversiblity rate in kW')
```

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

```
clc;clear;
//Example 8.4

//given data
m=500;
T1=473;
T0=300;
Wu=0;

//from Table A-3
cavg=0.45;

//calculations
Wrev=integrate('(1-T0/T)*(-m*cavg)','T',T1,T0);//
   intergrant
Wrev=floor(Wrev);
disp(Wrev,'The reversible power in kJ');
I=Wrev-Wu;
disp(I,'the irreversiblity rate in kJ');
```

Scilab code Exa 8.5 Heating Potential of a Hot Iron Block

```
clc;clear;
//Example 8.5

//given data
Wrev=8191;
Wtotal=38925;
TL=278;
TH=300;

//calculations
Wrm=Wtotal-Wrev;//work remaining
```

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

Scilab code Exa 8.6 Second Law Efficiency of Resistance Heaters

```
clc;clear;
//Example 8.6

//given data
COP=1;
TL=283;//in K
TH=294;//in K

//calculations
COPHP=1/(1-TL/TH);
nII=COP/COPHP;
disp(nII,'the second law efficiency')
```

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

```
clc;clear;
//Example 8.7

//given data
P1=1000;
V=200;
T1=300;
T0=T1;
P0=100;
```

```
//constants used
R=0.287;//in kPa m^3/kg K

//calculations
m1=P1*V/(R*T1);
O1=R*T0*(P0/P1-1)+R*T0*log(P1/P0);// O refers to exergy
X1=m1*O1/1000;//factor of 1000 for converting kJ into MJ
X1=round(X1);
disp(X1,'work obtained in MJ')
```

Scilab code Exa 8.8 Exergy Change during a Compression Process

```
clc;clear;
//Example 8.8

//given data
T0=20+273;//in K
P1=0.14;
T1=-10;
P2=0.8;
T2=50;

//the properties of refrigerant
//at inlet
h1=246.36;
s1=0.9724;
//at outlet
h2=286.69;
s2=0.9802;
dO=h2-h1-T0*(s2-s1);// O refers to exergy
dO=round(dO);
disp(dO,'the exergy change of the refrigerant in kJ/
```

```
   kg')
wmin=d0;
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

```
clc;clear;
//Example 8.10

//given values
Q=1035;
T0=273;
Tin=293;
Tout=278;
T1=300;

//calculations
//Xin - Xout - Xdestroyed = dX/dt
Xdestroyed=Q*(1-T0/Tin)-Q*(1-T0/Tout);
Xdestroyed=round(Xdestroyed);
disp(Xdestroyed,'the rate of exergy destroyed in W')
   ;
//the total rate of exergy destroyed
Xdestroyed=Q*(1-T0/T1)-Q*(1-T0/T0);
disp(Xdestroyed,'the otal total of exergy destroyed
   in W');
```

Scilab code Exa 8.11 Exergy Destruction during Expansion of Steam

```
clc;clear;
//Example 8.11

```

```
//given data
m=0.05;
P1=1000;
T1=300+273;//in K
P2=200;
T2=150+273;//in K
P0=100;
T0=25+273;//in K
Qout=2;

//from Table A-6 & A-4
u1=2793.7;
v1=0.25799;
s1=7.1246;
u2=2577.1;
v2=0.95986;
s2=7.2810;
u0=104.83;
v0=0.00103;
s0=0.3672;

//calculations
X1=m*(u1-u0-T0*(s1-s0)+P0*(v1-v0));
X2=m*(u2-u0-T0*(s2-s0)+P0*(v2-v0));
disp(X1,'exergy of intial state in kJ');
disp(X2,'exergy of final state in kJ');
dX=X2-X1;
disp(dX,'exergy change in system in kJ');
Wout=-Qout-m*(u2-u1);
Wu=Wout-P0*m*(v2-v1);
Xdestroyed=X1-X2-Wu;
disp(Xdestroyed,'the exergy destroyed in kJ');
nII=Wu/(X1-X2);
disp(nII,'second law efficiency of this process')
```

Scilab code Exa 8.12 Exergy Destroyed during Stirring of a Gas

```
clc;clear;
//Example 8.12

//given data
m=2;
T0=70+460;//in R
P1=20;
T1=70+460;//in R
T2=130+460;//in R

//constants used
Cv=0.172;//in Btu/lbm - F

//calculations
Xdestroyed=T0*m*Cv*log(T2/T1);
disp(Xdestroyed,'exergy destroyed in Btu');
Wrev=integrate('(1-T0/T)*m*Cv','T',T1,T2);
Wrev=round(Wrev);
disp(Wrev,'the reversible work in Btu')
```

Scilab code Exa 8.13 Dropping a Hot Iron Block into Water

```
clc;clear;
//Example 8.13

//given data
T0=20+273;//in K
P0=100;
Tiw=30+273;//in K
mw=100;
Tii=350+273;//in K
mi=5;

```

```
//constants used(Table A-3)
cw=4.18;//in kJ/kg C
ci=0.45;//in kJ/kg C

//calculations
Tfk=(mi*ci*Tii+mw*cw*Tiw)/(mw*cw+mi*ci);
Tfc=Tfk-273;//in C
disp(Tfc,'the final equilibrium temperature in C');
X1i=mi*ci*(Tii-T0-T0*log(Tii/T0));
X1w=mw*cw*(Tiw-T0-T0*log(Tiw/T0));
X1t=X1i+X1w;//total exergy
disp(X1t,'intial exergy of combined systems in kJ');
X2i=mi*ci*(Tfk-T0-T0*log(Tfk/T0));
X2w=mw*cw*(Tfk-T0-T0*log(Tfk/T0));
X2t=X2i+X2w;//total exergy
disp(X2t,'intial exergy of combined systems in kJ');
Xdestroyed=X1t-X2t;
disp(Xdestroyed,'the wasted work in kJ')
```

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

```
clc;clear;
//Example 8.14

//given data
TR=1200;
T0=300;
P0=100;
Tsys=400;
P1=350;
V1=0.01;
V2=2*V1;

//calculations
W=P1*V1*log(V2/V1);
```

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

Scilab code Exa 8.15 Second Law Analysis of a Steam Turbine

```
clc;clear;
//Example 8.15
//calculation error in textbook in part - b which
    changes all the following answers

//given data
m=8;
T0=25+273;//in K
P0=100;
P1=3000;
T1=450;
P2=200;
T2=150;
Qout=300;

//from Table A-6 and A-4
h1=3344.9;
s1=7.0856;
h2=2769.1;
s2=7.2810;
h0=104.83;
```

```
s0=0.3672;

//calculations
// Ein = Eout
Wout=m*(h1-h2)-Qout;
disp(Wout,'the actual power output in kW');
// Xin = Xout
Wrev=m*((h1-h2)-T0*(s1-s2));
disp(Wrev,'the maximum possible work output in kW');
nII=Wout/Wrev;
disp(nII,'second law efficiency');
Xdestroyed=Wrev-Wout;
disp(Xdestroyed,'the exergy destroyed in kW');
X1=h1-h0-T0*(s1-s0);
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

```
clc;clear;
//Example 18.16

//given data
T0=70+460;
T1=50;
T2=240;
T3=130;
//as dicussed in example 7-20
m1=300;
m2=22.7;
m3=322.7;

//from steam tables
h1=18.07;
s1=0.03609;
```

```
h2=1162.3;
s2=1.7406;
h3=97.99;
s3=0.18174;

//calculations
Wrev=m1*(h1-T0*s1)+m2*(h2-T0*s2)-m3*(h3-T0*s3);
Wrev=round(Wrev);
disp(Wrev,'the reversible power in Btu/min')
Xdestroyed=Wrev;
disp(Xdestroyed,'the rate of exergy destruction in
   Btu/min')
```

Scilab code Exa 8.17 Charging a Compressed Air Storage System

```
clc;clear;
//Example 8.17

//given data
V=200;
P1=100;
P2=1000;
P0=100;
T=300;

//constants used
R=0.287;//in kPa m^3/kg K

//calculations
//Xin - Xout = Xdestroyed = X2 - X1
m2=P2*V/(R*T);
X2=R*T*(log(P2/P0)+P0/P2-1);
Wrev=m2*X2/1000;
Wrev=round(Wrev);
disp(Wrev,'Work requirement in MJ')
```

Chapter 9

Gas Power Cycles

Scilab code Exa 9.2 The Ideal Otto Cycle

```
clc;clear;
//Example 9.2

//given data
T1=17+273;//in K
P1=100;
r=8;//compression ratio i.e v1/v2
qin=800;

//constants used
R=0.287;//in kPa-m^3/kg-K

//from Table A-17
//at T1
u1=206.91;
vr1=676.1;

//calculations
//Process 1-2
vr2=vr1/r;
//at this vr2
```

```
T2=652.4;
u2=475.11;
P2=P1*(T2/T1)*(r);
//Process 2-3
u3=qin+u2;
//at this u3
T3=1575.1;
vr3=6.108;
P3=P2*(T3/T2)*1;//factor of 1 as v3=v2
disp(T3,'maximum temperature in the cycle in K');
disp(P3/1000,'maximum pressure in MPa');//factor of
   1000 to convert into MPa
//Process 3-4
vr4=r*vr3;
//at this vr4
T4=795.6;
u4=588.74;
//Process 4-1
qout=u4-u1;
Wnet=qin-qout;
disp(Wnet,'net work output in kJ/kg');
nth=Wnet/qin;
disp(nth,'thermal efficiency');
v1=R*T1/P1;
MEP=Wnet/(v1*(1-1/r));
MEP=round(MEP);
disp(MEP,'mean effective pressure in kPa')
```

Scilab code Exa 9.3 The Ideal Diesel Cycle

```
clc;clear;
//Example 9.3

//given data
V1=117;
```

```
T1=80+460;//in R
P1=14.7;
r=18;
rc=2;

//constants used
R=0.3704;//in psia ft^3/lbm R
cp=0.240;//in Btu/lbm R
cv=0.171;//in Btu/lbm R

//from Table A-2Ea
k=1.4;

//calculations
V2=V1/r;
V3=rc*V2;
V4=V1;
//Process 1-2
T2=T1*(V1/V2)^(k-1);
P2=P1*(V1/V2)^k;
T2=round(T2);
P2=round(P2);
disp('Process 1-2');
disp(T2,'temperature in R');
disp(P2,'pressure in psia');
//Process 2-3
P3=P2;
T3=T2*(V3/V2);
T3=round(T3);
P3=round(P3);
disp('Process 2-3');
disp(T3,'temperature in R');
disp(P3,'pressure in psia');
//Process 3-4
T4=T3*(V3/V4)^(k-1);
P4=P3*(V3/V4)^k;
T4=round(T4);
P4=round(P4);
```

```
disp('Process 3-4');
disp(T4,'temperature in R');
disp(P4,'pressure in psia');
m=P1*V1/(R*T1)/1728;//factor of 1728 to covert to ft^3 from in^3
Qin=m*cp*(T3-T2);
Qout=m*cv*(T4-T1);
Wnet=Qin-Qout ;
disp(Wnet,'work output in Btu');
nth=Wnet/Qin;
disp(nth,'thermal efficiency');
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
MEP=round(MEP);
disp(MEP,'mean effective pressure in psia')
```

Scilab code Exa 9.5 The Simple Ideal Brayton Cycle

```
clc;clear;
//Example 9.5

//given data
T1=300;
r=8;
T3=1300;

//calcualtions
//Process 1-2
//at T1
h1=300.19;
Pr1=1.386;
Pr2=r*Pr1;
//at Pr2
T2=540;
```

```
h2=544.35;
disp(T2,'temperature at exit of compressor in K');
//Process 3-4
//at T3
h3=1395.97;
Pr3=330.9;
Pr4=Pr3/r;
//at Pr4
T4=770;
h4=789.37;
disp(T4,'temperature at turbine exit in K');
Win=h2-h1;
Wout=h3-h4;
rbw=Win/Wout;
disp(rbw,'back work ratio');
qin=h3-h2;
Wnet=Wout-Win;
nth=Wnet/qin;
disp(nth,'thermal efficeincy')
```

Scilab code Exa 9.6 An Actual Gas Turbine Cycle

```
clc;clear;
//Example 9.6

//from 9.5
Wsc=244.16;//compressor
Wst=606.60;//turbine
h1=300.19;
h3=1395.17;

//given data
nC=0.8;
nT=0.85;

```

```
//calculations
Win=Wsc/nC;
Wout=nT*Wst;
rbw=Win/Wout;
disp(rbw,'back work ratio is');
h2a=h1+Win;
qin=h3-h2a;
Wnet=Wout-Win;
nth=Wnet/qin;
disp(nth,'thermal efficency is');
h4a=h3-Wout;
//from A-17 at h4a
T4a=853;
disp(T4a,'turbine exit temperature in K is')
```

Scilab code Exa 9.7 Actual Gas Turbine Cycle with Regeneration

```
clc;clear;
//Example 9.7

//from 9.6
h2a=605.39;
h4a=880.36;
h3=1395.97;
Wnet=210.41;

//given data
n=0.80;

//calculations
// n = (h5 - h2a) / (h4a - h2a)
h5=(h4a - h2a)*n+h2a;
qin=h3-h5;
nth=Wnet/qin;
disp(nth,'thermal efficiency is')
```

Scilab code Exa 9.8 A Gas Turbine with Reheating and Intercooling

```
clc;clear;
//Example 9.8

//given data
T1=300;
T6=1300;
r=8;//overall compression ratio

//calculations
//as it is case of intercoolimg
ri=sqrt(r);//ri stands for P2/P1 = P4/P3 = P6/P7 =
   P8/P9
//from A-17 at T1
h1=300.19;
Pr1=1.386;
Pr2=ri*Pr1;
//from A-17 at Pr2
T2=403.3;
h2=403.31;
//from A-17 at T6
h6=1395.97;
Pr6=330.9;
Pr7=Pr6/ri;
//from A-17 at Pr7
T7=1006.4;
h7=1053.33;
//at inlets
T3=T1;h3=h1;T8=T6;h8=h6;
//et exits
T4=T2;h4=h2;T9=T7;h9=h7;h5=h7;
Win=2*(h2-h1);
Wout=2*(h6-h7);
```

```
Wnet=Wout-Win;
qin=(h6-h4)+(h8-h7);
rbw=Win/Wout;
disp(rbw,'back work ratio');
nth=Wnet/qin;
disp(nth,'thermal efficiency is')
//part - b
disp('part - b');
qin=(h6-h5)+(h8-h7);
nth=Wnet/qin;
disp(nth,'thermal efficiency is')
```

Scilab code Exa 9.9 The Ideal Jet Propulsion Cycle

```
clc;clear;
//Example 9.9

//given data
m=100;
P1=5;
T1=-40+460;//in R
T4=2000+460;//in R
V1=850;
rp=10;

//constants used
cp=0.240;//in Btu/lbm F
k=1.4;

//calculations
//Process 1-2
T2=T1+V1^2/(2*cp)/25037;//factor of 25037 to covert
    to Btu/lbm
P2=P1*(T2/T1)^(k/(k-1));
//Process 2-3
```

```
P3=rp*P2;
P4=P3;
T3=T2*(P3/P2)^((k-1)/k);
//Win=Wout
T5=T4-T3+T2;
P5=P4*(T5/T4)^(k/(k-1));
T5=round(T5);
disp(T5,'temperature at turbine exit in R');
disp(P5,'pressure at turbine exit in psia');
//Process 5-6
P6=P1;
T6=T5*(P6/P5)^((k-1)/k);
T6=floor(T6);//round off
V6=sqrt(2*cp*(T5-T6)*25037);//factor of 25037 to
    covert to (ft/s)^2
disp(round(V6),'the velocity of nozzle exit in ft/s'
    );
Wp=m*(V6-V1)*V1/25037;//factor of 25037 to covert to
     Btu/lbm
Qin=m*cp*(T4-T3);
nP=Wp/Qin;
disp(nP*100,'propulsive efficiency % is')
```

Scilab code Exa 9.10 Second Law Analysis of an Otto Cycle

```
clc;clear;
//Example 9.10

//from 9.2
r=8;
T0=290;
T1=290;
T2=652.4;
T3=1575.1;
P2=1.7997;
```

```
P3=4.345;
qin=800;
qout=381.83;
wnet=418.17;
Tsource=1700;

//constants used
R=0.287;//in kPa-m^3/kg-K

//calculations
//s1=s2 ; s3=s4
s03=3.5045;
s02=2.4975;
s32=(s03-s02)-R*log(P3/P2);//s32 stands for s3-s2
xdest23=T0*(s32-qin/Tsource);
Tsink=T1;
xdest41=T0*(-s32+qout/Tsink);
xdestcycle=xdest23+xdest41;
disp(xdestcycle,'exergy destrustion associated with Otto cycle inkJ/kg');
// X4 = (u4 - u0 )- T0*(s4 - s0) + P0(v4 - v0)
// s4 - s0 = s4 - s1 = s32
// u4 - u0 = u4 - u1 = qout
// v4 - v0 = v4 - v1 = 0
//hence x4 is
X4=qout-T0*s32;
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

```
clc;clear;
//Example 10.1

//given data
P1=75;
P2=3000;//in kPa
P3=P2;
T3=350;
P4=P1;

//from steam tables
//at state 1
v1=0.001037;
h1=384.44;
//at state 3
h3=3116.1;
s3=6.7450;
//at state 4
s4=s3;
```

```
sf=1.2132;
sfg=6.2426;
hf=384.44;
hfg=2278;

//calculations
win=v1*(P2-P1);
h2=h1+win;
x4=(s4-sf)/sfg;
h4=hf+x4*hfg;
qin=h3-h2;
qout=h4-h1;
nth=1-(qout/qin);
disp(nth*100,'thermal efficency % is')
```

Scilab code Exa 10.2 An Actual Steam Power Cycle

```
clc;clear;
//Example 10.2

//given data
P1=9;
T1=38;
P2=16000;
P3=15.9;
T3=35;
P4=15.2;
T4=625;
P5=15;
T5=600;
nT=0.87;
nP=0.85;
m=15;

//from steam tables
```

```
v1=0.001009;
h5=3583.1;
h6s=2115.3;
h4=3647.6;
h3=160.1;

//calculations
Win=v1*(P2-P1)/nP;
Wout=nT*(h5-h6s);
qin=h4-h3;
Wnet=Wout-Win;
nth=Wnet/qin;
disp(nth,'thermal efficiency is');
Wnet=m*Wnet;
disp(Wnet/1000,'power output in MW')
```

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

```
clc;clear;
//Example 10.3

//given data
P1=10;
P2=3000;
P3=3000;
T3=350;
P4=10;

//from steam tables
//at state 1
h1=191.81;
v1=0.00101;
//at state 2
//s2=s1
```

```
//at state 3
h3=3116.1;
s3=6.7450;
//at state 4
s4=s3;
sf=0.6492;
sfg=7.4996;
hf=191.81;
hfg=2392.1;

//calculations
//part - a
win=v1*(P2-P1);
h2=h1+win;
x4=(s4-sf)/sfg;
h4=hf+x4*hfg;
qin=h3-h2;
qout=h4-h1;
nth=1-(qout/qin);
disp(nth,'the thermal efficiency of this power plant
   ');
//part - b
//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
h3=3682.8;
h4=2380.3;
x4=0.915;
qin=h3-h2;
qout=h4-h1;
nth=1-(qout/qin);
disp(nth,'the thermal efficiency if steam is
   superheated to 600  instead of 350 C');
//part - c
//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
h2=206.95;
h3=3583.1;
h4=2115.3;
x4=0.804;
qin=h3-h2;
qout=h4-h1;
nth=1-(qout/qin);
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

```
clc;clear;
//Example 10.4

//given data
P1=10;
P2=15000;
P3=15000;
T3=600;
P4=4000;
T5=600;
P6=10;
x6=0.896;

//from steam table
//at state 1
h1=191.81;
v1=0.00101;
//at state 3
h3=3593.1;
s3=6.6796;
//at state 4
```

```
h4=3155;
T4=375.5;
//at state 6
sf=0.6492;
sfg=7.4996;
hf=191.81;
hfg=2392.1;

//calculations
s6=sf+x6*sfg;
h6=hf+x6*hfg;
//s5 = s6
//from tables
P5=4000;//in kPa
h5=3674.9;
disp(P5/1000,'the pressure at which the steam should
    be reheated in MPa');
//s2 = s1
win=v1*(P2-P1);
h2=h1+win;
qin=(h3-h2)+(h5-h4);
qout=h6-h1;
nth=1-(qout/qin);
disp(nth,'thermal efficiency is')
```

Scilab code Exa 10.5 The Ideal Regenerative Rankine Cycle

```
clc;clear;
//Example 10.5

//given data
P1=10;
P2=1200;
P3=1200;
P4=15000;
```

```
P5=15000;
T5=600;
P6=1200;
P7=10;

//from steam table
//at state 1
h1=191.81;
v1=0.00101;
//at state 3
h3=798.33;
v3=0.001138;
//at state 4
h4=3155;
T4=375.5;
//at state 5
h5=3583.1;
s5=6.6796;
//at state 6
h6=2860.2;
T6=218.4;
//at state 7
P7=10;
sf=0.6492;
sfg=7.4996;
hf=191.81;
hfg=2392.1;

//calculations
//s2 = s1
win=v1*(P2-P1);
h2=h1+win;
//s4 = s3
win=v3*(P4-P3);
h4=h3+win;
s7=s5;
x7=(s7-sf)/sfg;
h7=hf+(x7*hfg);
```

```
//y is the fraction of steam extracted from the
   turbine
y=(h3-h2)/(h6-h2);
qin=h5-h4;
qout=(1-y)*(h7-h1);
nth=1-(qout/qin);
disp(y,'fraction of steam extracted');
disp(nth,'thermal efficiency is')
```

Scilab code Exa 10.6 The Ideal Reheat Regenerative Rankine Cycle

```
clc;clear;
//Example 10.6

//given data
P1=10;
P2=500;
P3=500;
P4=15000;
P5=P4;
P6=4000;
P7=P5;
P8=P7;
P9=P7;
P10=P6;
P11=P10;
P12=P3;
P13=10;

//enthalpies at the various states and the pump work
    per unit mass of fluid flowing through them are
h1=191.81;
h2=192.30;
h3=640.09;
h4=643.92;
```

```
h5=1087.4;
h6=h5;
h7=1101.2;
h8=1089.8;
h9=3583.1;
h10=3155;
h11=3679.9;
h12=3014.8;
h13=2335.7;
wIin=0.49;
wIIin=3.83;
wIIIin=13.77;

//calculations
y=(h5-h4)/((h10-h6)+(h5-h4));
z=(1-y)*(h3-h2)/(h12-h2);
h8=(1-y)*h5+(y*h7);
qin=(h9-h8)+(1-y)*(h11-h10);
qout=(1-y-z)*(h13-h1);
nth=1-(qout/qin);
disp(y,'fraction of steam extracted from closed
    feedwater');
disp(z,'fraction of steam extracted from open
    feedwater');
disp(nth,'thermal efficiency is')
```

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

```
clc;clear;
//Example 10.7

//given data
T0=290;
Tsource=1600;
Tsink=T0;
```

```
//from Ex 10.1
qin=2728.6;
qout=2018.6;
h4=2403;

//from steam tables
s1=1.2132;
s3=6.7450;

//calculations
s2=s1;s4=s3;//isentropic processes
xdest12=0;
xdest34=0;
xdest23=T0*(s3-s2-(qin/Tsource));
xdest41=T0*(s1-s4+(qout/Tsink));
disp(xdest12,'exergy destruction in 1-2 in kJ/kg');
disp(round(xdest23),'exergy destruction in 2-3 in kJ
    /kg');
disp(xdest34,'exergy destruction in 3-4 in kJ/kg');
disp(round(xdest41),'exergy destruction in 4-1 in kJ
    /kg');
xdestcy=xdest12+xdest23+xdest34+xdest41;
disp(round(xdestcy),'exergy destruction in cycle in
    kJ/kg');
//from steam tables
//at 290 K and 100 kPa
h0=71.355;
s0=0.2533;
X4=(h4-h0)-T0*(s4-s0);
disp(round(X4),'exergy of the leaving steam in kJ/kg
    ')
```

Scilab code Exa 10.8 An Ideal Cogeneration Plant

```
clc;clear;
```

```
//Example 10.8

//given data
m1=15;
P1=7000;
P2=P1;
P3=P1;
P4=500;
P5=P4;
P6=5;
P7=500;
P8=5;
P9=7000;
P10=7000;

//from steam tables
v7=0.001005;
v8=0.001093;
h1=3411.4;
h2=h1;
h3=h1;
h4=h1;
h5=2739.3;
h6=2073.0;
h7=640.09;
h8=137.75;
h11=144.78;

//calculations
wIin=v8*(P9-P8);
wIIin=v7*(P10-P7);
h9=h8+wIin;
h10=h7+wIIin;
Qmax=m1*(h1-h7);
disp(Qmax,'the maximum rate in kW');
Wtout=m1*(h3-h6);//turbine
Wpin=m1*wIin;//pump
Wnet=Wtout-Wpin;
```

```
disp(round(Wnet/1000),'the power produced in MW');
Qp=0;
Qin=m1*(h1-h11);
Eu=(Wnet+Qp)/Qin;
disp(Eu,'the utilization factor');
m4=0.1*m1;
m5=0.7*m1;
m7=m4+m5;
Qout=m4*h4+m5*h5-m7*h7;
disp(Qout/1000,'the rate of process heat supply in
   MW')
```

Scilab code Exa 10.9 A Combined Gas Steam Power Cycle

```
clc;clear;
//Example 10.9

//given data
P1=5;
P2=7000;
P3=P2;
T3=500;
P4=P1;

//gas cycle from Ex9-6
//d stands for '
h4d=880.36;
T4d=853;
qin=790.58;
wnetg=210.41;
nth=0.266
h5d=451.80;
//steam cycle
h2=144.78;
T2=33;
```

```
h3=3411.4;
T3=500;
wnets=1331.4;
nth=0.408;

//calculations
//Ein = Eout
//y is the ratio of ms/mg
y=(h4d-h5d)/(h3-h2);
disp(y,'the ratio of the mass flow rates of the
   steam and the combustion gases');
wnet=wnetg+y*wnets
nth=wnet/qin;
disp(nth,'the thermal efficiency of the combined
   cycle')
```

Chapter 11

Refrigeration Cycles

Scilab code Exa 11.1 The Ideal Vapor Compression Refrigeration Cycle

```
clc;clear;
//Example 11.1

//given values
P1=0.14;
P2=0.8;
m=0.05;

//from refrigerant -134a tables
h1=239.16;
s1=0.94456;
h2=275.39;
h3=95.47;

//calculation
s2=s1;//isentropic process
h4=h3;//throttling
QL=(h1-h4)*m;
Wm=m*(h2-h1);
Qh=m*(h2-h3);
Qh=ceil(Qh);
```

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

Scilab code Exa 11.2 The Actual Vapor Compression Refrigeration Cycle

```
clc;clear;
//Example 11.2

//given data
m=0.05;
P1=0.14;
T1=-10;
P2=0.8;
T2=50;
P3=0.72;
T3=26;

//from refrigerant tables
h1=246.36;
h2=286.69;
h3=87.83;
h2S=284.21;//at isentropic conditions

//calculations
h4=h3;//throttling
QL=m*(h1-h4);
Wm=m*(h2-h1);
nC=(h2S-h1)/(h2-h1);
COPR=QL/Wm;
disp(QL,'the rate of heat removal from the
```

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

Scilab code Exa 11.3 A Two Stage Cascade Refrigeration Cycle

```
clc;clear;
//Example 11.3

//given data
mA=0.05;
P1=0.14;
P5=0.32;
P7=0.8;
h1=239.16;
h2=255.93;
h3=55.16;
h5=251.88;
h6=270.92;
h7=95.47;

//calculations
h4=h3;//throttling
h8=h7;//throttling
// E out = E in
// mA*h5 + mB*h3 = mA*h8 + mB*h2
mB=mA*(h5-h8)/(h2-h3);
QL=mB*(h1-h4);
// W in = Wcomp I,in + Wcomp II,in
Win=mA*(h6-h5)+mB*(h2-h1);
COPR=QL/Win;
disp(mB,'the mass flow rate of the refrigerant
```

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

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

```
clc;clear;
//Example 11.4

//given data
P1=0.14;
P5=0.32;
P7=0.8;
h1=239.16;
h2=255.93;
h3=251.88;
h5=95.47;
h7=55.16;

//from saturated liquid-vapour table
//at P=0.32 MPa
hf=55.16;
hfg=196.71;

//calculations
h8=h7;//throttling
h6=h5;//throttling
//the quality at state 6
x6=(h6-hf)/hfg;
qL=(1-x6)*(h1-h8);
// W in = Wcomp I,in + Wcomp II,in
```

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

Scilab code Exa 11.5 The Simple Ideal Gas Refrigeration Cycle

```
clc;clear;
//Example 11.5

//given data
m=0.1;
T1=0+460;
T3=80+460;//converting into R from F

//from Table A 17E
// at T1
h1=109.90;
Pr1=.7913;
//pressure ratio at compressor is 4
Pr2=4*Pr1;
//at Pr2
```

```
h2=163.5;
T2=683;
//at T3
h3=129.06;
Pr3=1.3860;
//pressure ratio at compressor is 4
Pr4=Pr3/4;
//at Pr4
h4=86.7;
T4=363;

//calculations
qL=h1-h4;
Wout=h3-h4;
Win=h2-h1;
COPR=qL/(Win-Wout);
Qrefrig=m*qL;
disp((T4-460),'the minimum temperatures in the cycle
    in F');
disp((T2-460),'the maximum temperatures in the cycle
    in F');
disp(COPR,'the coefficient of performance');
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

```
clc;clear;
//Example 11.6

//given data
COPR=0.1;
T1=20;
T2=4;
```

```
t=30*60;//converted in sec
V=0.350;

//constants used
p=1;//on kg/L
c=4.18;//in kJ/kg-C from Table A-3

//calculations
m=p*V;
Qcooling=m*c*(T1-T2)/t*1000;//converted in W by
    multiplying by 1000
Win=Qcooling/COPR;
Win=floor(Win);
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

```
clc;clear;
//Example 12.1

//given data
h1=305.22;
T1=305;
h2=295.17;
T2=295;

//calculations
//from the given equation we can calculate
cp=(h1-h2)/(T1-T2);
disp(cp,'the cp of air at 300 K in kJ/ kg - K')
```

Scilab code Exa 12.2 Total Differential versus Partial Differential

```
clc;clear;
//Example 12.2

//given data
dT=302-300;
dv=0.87-0.86;
T=(302+300)/2;
v=(0.87+0.86)/2;//average values

//constants used
R=0.287;//in kJ/kg-K

//calculations
//using eq 12-3 by diffrentiating P= R*T/v
dP= R*dT/v - R*T*dv/v^2;
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

```
clc;clear;
//Example 12.5

//given data
T=20+273.15;//converted into K

//from Table A 11
vf=0.0008161;
vg=0.035969;

//calculations
//using Eq 12-22
// hfg= T*vfg*(dP/dT)sat
//(dP/dT)sat b/w 24 C - 16 C
dPT=(646.18-504.58)/(24-16);//dP/dT ; values from
```

```
   Table A 11
vfg=vg-vf;
hfg=T*vfg*dPT;
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

```
clc;clear;
//Example 12.6

//given data
T1=-40+460;
T2=-50+460;//converted into R from F
R=0.01946;

//from Table A-11E
P1=7.432;
hfg=97.100;

//calcualation\
//using Equation 12 24
//ln(P2/P1)= hfg/R *(1/T1 - 1/T2)
P2=P1*exp(hfg/R *(1/T1 - 1/T2));
disp(P2,'the saturation pressure of refrigerant -134a
    in psia')
```

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

```
clc;clear;
//Example 12.11

```

```
//given data
T1=220;
P1=5;
T2=300;
P2=10;

//constants used
Ru=8.314;//on kJ/kmol- K

//from Table A 1
Tcr=154.8;
Pcr=5.08;

//calculations

//part - a
disp('part - a');
//by assuming ideal-gas behavior
//from Table A 19
h1=6404;
h2=8736;
s2=205.213;
s1=196.171;
h21i=h2-h1;//h2 - h1 ideal
s21i=(s2-s1)-Ru*log(P2/P1);//s2 - s1 ideal
disp(h21i,'the enthalpy change in kJ/kmol');
disp(s21i,'the entropy change in kJ/kmol-K');

//part - b
disp('part - b');
//by accounting for the deviation from ideal-gas behavior
TR1=T1/Tcr;
Pr1=P1/Pcr;
//from the generalized charts at each state
Zh1=0.53;
Zs1=0.25;
TR2=T2/Tcr;
```

```
Pr2=P2/Pcr;
//from the generalized charts at each state
Zh2=0.48;
Zs2=0.20;
h21=h21i-Ru*Tcr*(Zh2-Zh1);
s21=s21i-Ru*(Zs2-Zs1);
disp(h21,'the enthalpy change in kJ/kmol');
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

```
clc;clear;
//Example 13.1

//given data
mO2=3;
mN2=5;
mCH4=12;
//molecular masses
MO2=32;
MN2=28;
MCH4=16;

//constants used
Ru=8.314;//in kJ/kg - K

//calculations

//part - a
mm=mO2+mN2+mCH4;
mfO2=mO2/mm;
mfN2=mN2/mm;
```

```
mfCH4=mCH4/mm;
disp(mfO2,'mass fraction of oxygen is');
disp(mfN2,'mass fraction of nitrogen is');
disp(mfCH4,'mass fraction of methane is');

//part - b
NO2=mO2/MO2;
NN2=mN2/MN2;
NCH4=mCH4/MCH4;
Nm=NO2+NN2+NCH4;
yO2=NO2/Nm;
yN2=NN2/Nm;
yCH4=NCH4/Nm;
disp(yO2,'mole fraction of oxygen is');
disp(yN2,'mole fraction of nitrogen is');
disp(yCH4,'mole fraction of methane is');

//part - c
Mm=mm/Nm;
disp(Mm,'average molecular mass in kg/kmol');
Rm=Ru/Mm;
disp(Rm,'gas constant of mixture in kJ/kg - K')
```

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

```
clc;clear;
//Example 13.2

//given data
NN2=2;
NCO2=6;
Tm=300;
Pm=15000;

//constants used
```

```
Ru=8.314;//in kJ/kmol - K

//calculations

//part - a
Nm=NN2+NCO2;
Vm=Nm*Ru*Tm/Pm;
disp(Vm,'the volume of the tank on the basis of the
   ideal-gas equation of state in m^3');

//part - b
//from Table A-1
//for nitrogen
TcrN=126.2;
PcrN=3390;
//for Carbondioxide
TcrC=304.2;
PcrC=7390;
yN2=NN2/Nm;
yCO2=NCO2/Nm;
Tcr=yN2*TcrN+yCO2*TcrC;
Pcr=yN2*PcrN+yCO2*PcrC;
Tr=Tm/Tcr;
Pr=Pm/Pcr;
//from Fig A-15b
Zm=0.49;
Vm=Zm*Nm*Ru*Tm/Pm;
disp(Vm,'the volume of the tank on the basis Kay s
    rule in m^3');

//part - c
//for nitrogen
TrN=Tm/TcrN;
PrN=Pm/PcrN;
//from Fig A-15b
Zn=1.02;
//for Carbondioxide
TrC=Tm/TcrC;
```

```
PcrC=Pm/PcrC;
//from Fig A−15b
Zc=0.3;
Zm=yN2*Zn+yCO2*Zc;
Vm=Zm*Nm*Ru*Tm/Pm;
disp(Vm,'the volume of the tank on the basis
   compressibility factors and Amagat s law in m^3
   ');

//part − d
VRN=(Vm/NN2)/(Ru*TcrN/PcrN);
VRC=(Vm/NCO2)/(Ru*TcrC/PcrC);
//from Fig A−15b
Zn=0.99;
Zc=0.56;
Zm=yN2*Zn+yCO2*Zc;
Vm=Zm*Nm*Ru*Tm/Pm;
//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 .
Vm=0.648;
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

```
clc;clear;
//Example 13.3

//given data
mN=4;
T1N=20;
P1N=150;
mO=7;
```

```
T1O=40;
P1O=100;
//molecular masses
MO=32;
MN=28;

//constants used
Ru=8.314;//in kJ/kg - K


//from Table A-2a
CvN=0.743;
CvO=0.658;

//calculations

//part - a
//Ein - Eout = dEsystem
// (m*cv*dT)N2 + (m*cv*dT)= 0;
Tm= (mN*CvN*T1N+ mO*CvO*T1O)/(mN*CvN+mO*CvO);
disp(Tm,'the mixture temperature in C');

//part - b
NO=mO/MO;
NN=mN/MN;
Nm=NO+NN;
VO=NO*Ru*(T1O+273)/P1O;
VN=NN*Ru*(T1N+273)/P1N;
Vm=VO+VN;
Pm=Nm*Ru*(Tm+273)/Vm;
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

```
clc;clear;
//Example 13.4

//given data
NO=3;
NC=5;//moles of oxygen and carbondioxide
   repesctively
T0=25+273;//in K

//constants used
Ru=8.314;//in kJ/kg - K

//calculations
Nm=NO+NC;
yO=NO/Nm;
yC=NC/Nm;
//dSm= -Ru*(NO*log(yO)+NC*log(yC))
Sm=-Ru*(NO*log(yO)+NC*log(yC));
disp(Sm,'the entropy change in kJ/K');
Xdestroyed=T0*Sm/1000;
disp(Xdestroyed,'exergy destruction associated in MJ
   ')
```

Scilab code Exa 13.5 Cooling of a Nonideal Gas Mixture

```
clc;clear;
//Example 13.5

//given data
T1=220;
T2=160;
Pm=10;
yN=0.79;
yO=0.21;//mole fractions of nitrogen and oxygen
   repesctively
```

```
//critical properties
//for Nitrogen
TcrN=126.2;
PcrN=3.39;
//for Oxygen
TcrO=154.8;
PcrO=5.08;

//constants used
Ru=8.314;//in kJ/kg - K

//from Tables A-18 & 19
//at T1
h1N=6391;
h1O=6404;
//for T2
h2N=4648;
h2O=4657;

//calculations
//part - a
qouti=yN*(h1N-h2N)+yO*(h1O-h2O);
qouti=ceil(qouti);
disp(qouti,'the heat transfer during this process
    using the ideal-gas approximation in kJ/kmol');

//part - b
Tcrm=yN*TcrN+yO*TcrO;
Pcrm=yN*PcrN+yO*PcrO;
Tr1=T1/Tcrm;
Tr2=T2/Tcrm;
Pr=Pm/Pcrm;
//at these values we get
Zh1=1;
Zh2=2.6;
qout=qouti-Ru*Tcrm*(Zh1-Zh2);
qout=ceil(qout);
disp(qout,'the heat transfer during this process
```

```
using Kay s rule in kJ/kmol');

//part - c
//for nitrogen
TrN1=T1/TcrN;
TrN2=T2/TcrN;
PrN=Pm/PcrN;
//from Fig A-15b
Zh1n=0.9;
Zh2n=2.4;
//for Oxygen
TrO1=T1/TcrO;
TrO2=T2/TcrO;
PcrO=Pm/PcrO;
//from Fig A-15b
Zh1O=1.3;
Zh2O=4.0;
//from Eq 12-58
h12N=h1N-h2N-Ru*TcrN*(Zh1n-Zh2n);// h1 - h2 for nitrogen
h12O=h1O-h2O-Ru*TcrO*(Zh1O-Zh2O);// h1 - h2 for oxygen
qout=yN*h12N+yO*h12O;
qout=ceil(qout);
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

```
clc;clear;
//Example 13.6
//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
```

```
//given data
mfs=0.0348;
mfw=0.9652;
T0=288.15;

//constants used
Mw=18;
Ms=58.44;
Rw=0.4615;
pm=1028;
Ru=8.314;

//calculations
//part - a
Mm=1/((mfs/Ms)+(mfw/Mw));
yw=mfw*Mm/Mw;
ys=1-yw;
disp(yw,'the mole fraction of the water');
disp(ys,'the mole fraction of the saltwater');

//part - b
wmin=-Ru*T0*(ys*log(ys)+yw*log(yw));
wm=wmin/Mm;
disp(wm,'the minimum work input required to separate
    1 kg of seawater completely into pure water and
   pure salts in kJ');

//part - c
wmin=Rw*T0*log(1/yw);
disp(wmin,'the minimum work input required to obtain
    1 kg of fresh water from the sea in kJ');

//part - d
Pmin=pm*Rw*T0*log(1/yw);
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

```
clc;clear;
//Example 14.1

//given data
V=5*5*3;//volume of the room
RH=0.75;
P=100;
T=25;

//constants used
Ra=0.287;//in kPa.m^3 / kg.k
Rv=0.4615;//in kPa.m^3 / kg.k

//from Table A-2a and A-4
cp=1.005;
Psat=3.1698;
hg=2564.6;

//calculation
```

```
Pv=RH*Psat;
Pa=P-Pv;
w=0.622*Pv/(P-Pv);
h=cp*T+w*hg;
ma=V*Pa/(Ra*(T+273));
mv=V*Pv/(Rv*(T+273));
disp(Pa,'the partial pressure of dry air in kPa');
disp(w,'the specific humidity in kg water/kg of dry
    air');
disp(h,'the enthalpy per unit mass of the dry air in
     kJ');
disp(ma,'mass of air in kg');
disp(mv,'mass of water vapour in kg');
```

Scilab code Exa 14.2 Fogging of the Windows in a House

```
clc;clear;
//Example 14.2

//given data
T=20;
RH=0.75;

//from Table A-4
Psat=2.3392;
Pv=RH*Psat;
//thus at this from Eq 14-13
Tdp=15.4;
disp(Tdp,'window temperature in C')
```

Scilab code Exa 14.3 The Specific and Relative Humidity of Air

```
clc;clear;
```

```
//Example 14.3

//given data
T1=25;
T2=15;
P2=101.325;

//from Table A-2a & A-4
//at T1
Psat1=3.1698;
hg1=2546.5;
//at T2
Psat2=1.7057;
hfg2=2465.4;
hf2=62.982;
cp=1.005;

//calculations
w2=0.622*Psat2/(P2-Psat2);
w1=(cp*(T2-T1)+w2*hfg2)/(hg1-hf2);
disp(w1,'the specific humidity in kg water/kg of dry
    ai');
RH1=w1*P2/((0.622+w1)*Psat1);
disp(RH1,'the relative humidity');
h=cp*T1+w1*hg1;
disp(h,'the enthalpy of the air in kJ/kg of dry air'
    )
```

Scilab code Exa 14.5 Heating and Humidification of Air

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

```

```
//given data
RH1=0.3;
P1=100;
V1=45;
T1=10;
T2=22;
RH3=0.6;
T3=25;

//from Table A-2a & A-4
cp=1.005;
Ra=0.287;
Pg1=1.2281;
hg1=2519.2;
hg2=2541.0;
Pg3=3.1698;

//calculations
Pv1=RH1*Pg1;
Pa1=P1-Pv1;
v1=Ra*(T1+273)/Pa1;
ma=V1/v1;
w1=0.622*Pv1/(P1-Pv1);
h1=cp*T1+w1*hg1;
w2=w1;
h2=cp*T2+w2*hg2;
Q=ma*(h2-h1);
// ma2*w2 + mw = ma3*w3
//which reduces to mw = ma * (w3 - w2)
w3=0.622*RH3*Pg3/(P1-(RH3*Pg3));
mw=ma*(w3-w2);
disp(Q,'the rate of heat supply in the heating
    section in kJ/min');
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

```
clc;clear;
//Example 14.6

//given data
V1=10;
T1=30;
RH1=0.8;
T2=14;
RH2=1;

//from Table A-4
hw=58.8;
h1=85.4;
h2=39.3;
w1=0.0216;
w2=0.0100;
v1=0.889;

//calculations
//mw= ma*(w1-w2)
//Qout=ma*(h1-h2) - mw*hw
ma=V1/v1;
mw= ma*(w1-w2);
Qout=ma*(h1-h2) - mw*hw;
disp(mw,'rates of moisture removal from the air in
    kg/min');
disp(Qout,'rate of moisture removal from the air in
    kJ/min');
```

Scilab code Exa 14.8 Mixing of Conditioned Air with Outdoor Air

```
clc;clear;
//Example 14.8

//given values
V1=50;
T1=14;
V2=20;
T2=32;
RH2=60;

//from psychrometric chart
h1=39.4;
w1=0.010;
v1=0.826;
h2=79;
w2=0.0182;
v2=0.889;

//calculations
ma1=V1/v1;
ma2=V2/v2;
ma3=ma1+ma2;
//from Eq 14-24
w3=(w2*ma2+w1*ma1)/(ma1+ma2);
h3=(h2*ma2+h1*ma1)/(ma1+ma2);
disp(w3,'the specific humidity in kg of water/kg of
   dry air');
//from psychrometric chart
T3=19;
RH3=0.89;
v3=0.844;
V3=ma3*v3;
disp(RH3,'the relative humidity');
disp(T3,'the dry-bulb temperature in C');
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

```
clc;clear;
//Example 14.9

//given data
m=100;
T1=20;
P1=1;
RH1=60;
T2=30;
RH2=1;
T3=35;
T4=22;

//from Table A-4
h1=42.2;
w1=0.0087;
v1=0.842;
h2=100;
w2=0.0273;
h3=146.64;
h4=92.28;

//calculations
//Dry air balane = ma1 = ma2 = ma
//Water balance = m3 - m4 = ma*(w2 - w1)
//Energy balance = ma1*h1 + m3*h3 = ma2*h2 + m4*h4
ma= m*(h3-h4)/(h2-h1-(w2-w1)*h4);
V1=ma*v1;
mmakeup=ma*(w2-w1);
disp(V1,'the volume flow rate of air into the
    cooling tower in m^3/s');
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

```
clc;clear;
//Example 15.1

//given data
nO2i=20;
nC8H18i=1;//intial moles of air and octane

//from Table A-1
Mair=29;
MC=12;
MH=2;

//calculations
// Chemical Reaction
// C8H18 + 20(O2+3.76N2)= xCO2 + yH2O + zO2 + wN2
//by elemental balance of moles
x=8;
y=18/2;
z=20*2-2*x-y;
w=20*3.76;
disp(x,'kmoles of CO2');
```

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

Scilab code Exa 15.2 Dew Point Temperature of Combustion Products

```
clc;clear;
//Example 15.2

//given data
P=100;

//from Table A-1
Mair=29;
MC=12;
MH=2;

//calculations
//Chemical reaction
//C2H6 + 1.2at(1O2 + 3.76) =2CO2 + 3H2O + 0.2athO2 + (1.2*3.76)athN2
//ath is the stoichiometric coefficient for air
//Oxygen balance gives
// 1.2ath = 2 + 1.5 + 0.2ath
ath=(2+1.5)/(1.2-0.2);
AF=(1.2*ath)*4.76*Mair/(2*MC+3*MH);
disp(AF,'air-fuel ratio of combustion process in kg air/kg fuel');
//C2H6 + 4.2(O2 + 3.76N2) = 2CO2 + 3H2O + 0.7O2 +
```

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

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

```
clc;clear;
//Example 15.3

//given data
P=101.325;
RH=0.8;
T1=20;

//from Table A-4
Psat=2.3392;

//calculations
//consedering 1 kmol of fuel
// 0.72CH4 + 0.09H2 + 0.14N2 + 0.02O2 + 0.03CO2 +
    ath(O2 + 3.76N2) = xCO2 + yH2O + zN2
//element balance
x=0.72+0.03
y=(0.72*4+0.09*2)/2;
ath=x+y/2-0.02-0.03;
z=0.14+3.76*ath;
Pv=RH*Psat;
// Nv,air = Pv,air/Ptotal * Ntotal
Nvair=Pv/P*6.97/(1-(Pv/P));
//0.72CH4 + 0.09H2 + 0.14N2 + 0.02O2 + 0.03CO2 +
```

```
    1.465(O2 + 3.76N2) + 0.131H20 = 0.75CO2 + 1.661
    H2O + 5.648N2
Pvprod=1.661/8.059*P;
//at this Pvprod
Tdp=60.9;
disp(Tdp,'the dew-point in C')
```

Scilab code Exa 15.4 Reverse Combustion Analysis

```
clc;clear;
//Example 15.4

//given data
Pprod=100;

//from Table A-1
Mair=29;
MC=12;
MH=2;

//from Table A-4
Psat=3.1698;

//calculations
//consedering 100 kmol of dry products
// xC8H18 + a (O2 + 3.76N2) = 10.02CO2 + 0.88C0 +
    84.48N2 + bH20
//from mass balamces
a=83.48/3.76;
x=(0.88+10.02)/8;
b=18*x/2;
// 1.36C8H18 + 22.2 (O2 + 3.76N2) = 10.02CO2 + 0.88
    C0 + 84.48N2 + 12.24H20
// 1 mol conversion
// C8H18 + 16.32 (O2 + 3.76N2) = 7.37CO2 + 4.13C0 +
```

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

Scilab code Exa 15.5 Evaluation of the Enthalpy of Combustion

```
clc;clear;
//Example 15.5
//round off error

//from Table A-6
HCO2=-393520;
HH2O=-285830;
HC8H18=-249950;

//calculations
// C8H18 + ath (O2 + 3.76N2) = 8CO2 + 9H2O + 3.76
    athN2
//N2 and O2 are stable elements, and thus their
    enthalpy of formation is zero
//hc = Hprod - Hreact
hc= 8*HCO2 + 9*HH2O - HC8H18;
```

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

Scilab code Exa 15.6 First Law Analysis of Steady Flow Combustion

```
clc;clear;
//Example 15.6

//given data
mfuel=0.05;

//from Table A-1
Mair=29;
MC=12;
MH=2;

//calculation
//stochiometric reaction
//C3H8 + ath(O2 + 3.76N2) = 3CO2 + 4H2O + 3.76athN2
//O2 balance
ath=3+5;
//50 percent excess air and some CO in the products
//C3H8 + 7.5(O2 + 3.76N2) = 2.7CO2 + 0.3CO + 4H2O +
   2.65O2+ 28.2N2
AF=7.5*4.76*Mair/(3*MC+4*MH);
mair=AF*mfuel;
disp(mair,'the mass flow rate of air in kg air/min')
   ;
//from property tables
//C3H8 designated as p
hfp=-118910;
//oxygen as o
hfo=0;
ho280=8150;
ho298=8682;
```

```
ho1500=49292;
//nitrogen as n
hfn=0;
hn280=8141;
hn298=8669;
hn1500=47073;
//water as w
hfw=-241820;
hw298=9904;
hw1500=57999;
//carbondioxode as c
hfc=-393520;
hc298=9364;
hc1500=71078;
//carbon monoxide as co
hfco=-110530;
hco298=8669;
hco1500=47517;
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);
//for kg of propane
qout=qout/44;
Qout=mfuel*qout/60;
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

```
clc;clear;
//Example 15.7
//error of 0.17% in (b) part calulation error in
    textbook

```

```
//given data
Preact=1;
Treact=77+460;
Tprod=1800;

//constants used
Ru=1.986;

//calculation
//CH4 + 3O2 = CO2 + 2H2O + O2
Nreact=4;
Nprod=4;
Pprod=Preact*Nprod/Nreact*Tprod/Treact;
disp(Pprod,'the final pressure in the tank in atm');
//from std. values of heat of formation and ideal
   gasses in Appendix
//CH4 as m
hfm=-32210;
//O2 as o
hfo=0;
h537o=3725.1;
h1800o=13485.8;
//water as w
hfw=-104040;
h537w=4528;
h1800w=15433;
//carbondioxide as c
hfc=-169300;
h537c=4027.5;
h1800c=18391.5;
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);
disp(Qout,'the heat transfer during this process in
   Btu/lbmol')
```

Scilab code Exa 15.8 Adiabatic Flame Temperature in Steady Combustion

```
clc;clear;
//Example 15.8
//this invovles EES hence the below code explains a
   approach with approximation

//calculations

//part - a
//C8H18 + 12.5 (O2 + 3.76N2) = 8CO+ 9H2O + 47N2
//from std. values of heat of formation and ideal
   gasses in Appendix
//octane as oc
hfoc=-249950;
//oxygen as o
hfo=0;
h298o=8682;
//nitrogen as n
hfn=0;
h298n=8669;
//water as w
hfw=-241820;
h298w=9904;
//carbondioxide as c
hfc=-393520;
h298c=9364;
//x refers to 8hCO2 + 9hH20 + 47hN2
xac=1*(hfoc)+8*(h298c-hfc)+9*(h298w-hfw)+47*(h298n-
   hfn);
//from EES the Tprod is determined by trial and
   error
//at 2400K
```

```
x2400=5660828;
//at 2350K
x2350=5526654;
//the actual value of x is xac and T can be
   determined by interpolation
Tprod=(xac-x2350)*(2400-2350)/(x2400-x2350)+2350;
Tprod=ceil(Tprod);
disp(Tprod,'adiabatic flame temperature for complete
    combustion with 100 percent theoretical air,in K
   ');

//part - b
//C8H18 + 50 (O2 + 3.76N2) = 8CO+ 9H2O + 37.5O2 +
   188N2
//solved similarly using EES and approximation and
   interpolation
//similarly we can solve the part - c
//the above concept is applied
```

Scilab code Exa 15.9 Reversible Work Associated with a Combustion Process

```
clc;clear;
//Example 15.9

//from Table A-26E
//Gibbs function of formation at 77 F
gfc=0;//for carbon
gfo=0;//for oxygen
gfco=-169680;//for carbondioxide

//calculations
// C + O2 = CO2
Wrev=1*gfc+1*gfo-1*gfco;
disp(Wrev,'the reversible work for this process in
```

Btu')

Scilab code Exa 15.10 Second Law Analysis of Adiabatic Combustion

```
clc;clear;
//Example 15.10

//given values
T0=298;//in K

//contansts used
Ru=8.314;//in kJ/kmol K

//calculations
// CH4 + 3(O2 + 3.76N2)  = CO2 + 2H2O + O2 + 11.28N2
//from std. values of heat of formation and ideal
    gasses in Appendix
//methane as m
hfm=-74850;
//oxygen as o
hfo=0;
h298o=8682;
//nitrogen as n
hfn=0;
h298n=8669;
//water as w
hfw=-241820;
h298w=9904;
//carbondioxide as c
hfc=-393520;
h298c=9364;
//x refers to hCO2 + 2hH2O + 11.28hN2
xac=1*(hfm)+1*(h298c-hfc)+2*(h298w-hfw)+11.28*(h298n
    -hfn);
//from EES the Tprod is determined by trial and
```

```
   error
Tprod=1789;
disp(Tprod,'the temperature of the products in K');
//entropy calculations by using table A-26
//Si = Ni*(si - Ruln yiPm
//reactants
Sm=1*(186.16-Ru*log(1*1));
So=3*(205.04-Ru*log(0.21*1));
Sn=11.28*(191.61-Ru*log(.79*1));
Sreact=Sm+So+Sn;
//products
Nt=1+2+1+11.28;//total moles
yc=1/Nt;
yw=2/Nt;
yo=1/Nt;
yn=11.28/Nt;
Sc=1*(302.517-Ru*log(yc*1));
Sw=2*(258.957-Ru*log(yw*1));
So=1*(264.471-Ru*log(yo*1));
Sn=11.28*(247.977-Ru*log(yn*1));
Sprod=Sc+Sw+So+Sn;
Sgen=Sprod-Sreact;
disp(Sgen,'exergy destruction in kJ/kmol - K');
Xdestroyed=T0*Sgen/1000;//factor of 1000 for
   converting kJ to MJ
Xdestroyed=ceil(Xdestroyed);
disp(Xdestroyed,'in MJ/kmol');
//This process involves no actual work. Therefore,
   the reversible work and energy destroyed are
   identical
Wrev=Xdestroyed;
disp(Wrev,'the reversible work in MJ/kmol')
```

Scilab code Exa 15.11 Second Law Analysis of Isothermal Combustion

```
clc;clear;
//Example 15.11

//given values
Tsurr=298;//in K

//contansts used
Ru=8.314;//in kJ/kmol K

//calculations

//part - a
// CH4 + 3(O2 + 3.76N2)  = CO2 + 2H2O + O2 + 11.28N2
//The amount of water vapor that remains in the products is determined as in Example 15 3
Nv=0.43;//moles of water vapour
Nw=1.57;//moles of water in liquid
//hf values
//methane as m
hfm=-74850;
//carbondioxide as c
hfc=-393520;
//water vapour as v
hfv=-241820;
//water in liquid as w
hfw=-285830;
Qout=1*hfm-1*hfc-Nv*hfv-Nw*hfw;
disp(Qout,'in kJ/kmol')

//part - b
//entropy calculations by using table A-26
//Si = Ni*(si - Ruln yiPm
//reactants
Sm=1*(186.16-Ru*log(1*1));
So=3*(205.04-Ru*log(0.21*1));
Sn=11.28*(191.61-Ru*log(.79*1));
Sreact=Sm+So+Sn;
//products
```

```
Nt=Nv+1+1+11.28;//total moles
yw=1;
yc=1/Nt;
yv=Nv/Nt;
yo=1/Nt;
yn=11.28/Nt;
Sw=Nw*(69.92-Ru*log(yw*1));
Sc=1*(213.80-Ru*log(yc*1));
Sv=Nv*(188.83-Ru*log(yv*1));
So=1*(205.04-Ru*log(yo*1));
Sn=11.28*(191.61-Ru*log(yn*1));
Sprod=Sc+Sw+So+Sn+Sv;
Sgen=Sprod-Sreact+Qout/Tsurr;
Sgen=ceil(Sgen);
disp(Sgen,'exergy destruction in kJ/kmol - K');
Xdestroyed=Tsurr*Sgen/1000;//factor of 1000 for
    converting kJ to MJ
Xdestroyed=floor(Xdestroyed);
disp(Xdestroyed,'in MJ/kmol');
//This process involves no actual work. Therefore,
    the reversible work and energy destroyed are
    identical
Wrev=Xdestroyed;
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

```
clc;clear;
//Example 16.1
//round off error

//given data
T=298.15;

//from Table A−26
g=455510;

//constants used
R=8.314;//in kJ/kmol K

//calculations
// N2 = 2N
dG=2*g;
lnKp=-dG/(R*T);
disp(lnKp,'in comparison to Table A−28 ln Kp value
   of −367.5 our result is');
```

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

Scilab code Exa 16.2 Dissociation Temperature of Hydrogen

```
clc;clear;
//Example 16.2

//given data
vH2=1;
vH=2;
P=10;

//calculations
// H2 = 0.9H2 + 0.2H
NH=0.2;
NH2=0.9;
Nt=NH+NH2;
//from Eq. 16-15
Kp=((NH^vH)/(NH2^vH2))*(P/Nt)^(vH-vH2);
//at this value of Kp from Table A-28
T=3535;
disp(T,'temperature in K is')
```

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

```
clc;clear;
//Example 16.6

//reaction
// H2 + 0.5O2 = H2O
//enthalpy data
//of H2
```

```
hfH=-241820;
h2000H=82593;
h298H=9904;
//of O2
hfO=0;
h2000O=61400;
h298O=8468;
//of H2O
hfw=0;
h2000w=67881;
h298w=8682;
//Kp data from A-28
Kp2=869.6;
Kp1=18509;
T1=1800;
T2=2200;

//constants used
Ru=8.314;//in kJ/kmol K

//calculations
//part - a
hR=1*(hfH+h2000H-h298H)-1*(hfO+h2000O-h298O)-0.5*(hfw+h2000w-h298w);
disp(floor(hR),'enthalpy of the reaction in kJ/kmol using enthalpy data');
//part - b
hR=Ru*(T1*T2)/(T2-T1)*log(Kp2/Kp1);
disp(round(hR),'enthalpy of the reaction in kJ/kmol using Kp data');
```

Scilab code Exa 16.7 Phase Equilibrium for a Saturated Mixture

```
clc;clear;
//Example 16.7
```

```
//given data
T=120+273.15;//in K

//from Table A-4
hf=503.81;
hg=2706;
sf=1.5279;
sg=7.1292;

//calculations
disp('liquid phase');
gf=hf-T*sf;
disp(gf,'gf value in kJ/kg');
disp('vapour phase');
gg=hg-T*sg;
disp(gg,'gg value in kJ/kg');
```

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

```
clc;clear;
//Example 16.8

//given data
T=15;
P=92;

//from Table A-4
Pv=1.7057;

//calculations
yv=Pv/P;
disp(yv,'mole fraction of water vapor at the surface
    ');
yw=1-yv;
```

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

Scilab code Exa 16.9 The Amount of Dissolved Air in Water

```
clc;clear;
//Example 16.9

//given data
T=17;
P=92;

//from Table A-4
Pv=1.96;

//constants from Table 16-2
H=62000;

//calculations
Pda=P-Pv;//dry air
yda=Pda/H/100;//in bar
disp(yda,'mole fraction of air')
```

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

```
clc;clear;
//Example 16.10

//given data
T=358;
P=300/100;//in bar

//constants used
```

```
M=2;
s=0.00901;//solubility in kmol/m^3 bar
p=0.027;

//calculations
pH2=s*P;
disp(pH2,'molar density of H2 in kmol/m^3');
pH2=p*M;
disp(pH2,'mass density of H2 in kg/m^3')
```

Scilab code Exa 16.11 Composition of Different Phases of a Mixture

```
clc;clear;
//Example 16.11

//given data
yw=0.30;//w for water
ya=0.70;//a for ammonia
T=40;

//saturation pressure
pw=7.3851;
pa=1554.33;
//calulations
Pw=yw*pw;
Pa=ya*pa;
Pt=Pw+Pa;
yw=Pw/Pt;
ya=Pa/Pt;
disp(yw,'mole fraction of water vapour');
disp(ya,'mole fraction of ammonia')
```

Chapter 17

Compressible Flow

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

```
clc;clear;
//Example 17.1

//given data
V1=250;
T1=255.07;
P1=54.05;
h=5000;

//from Table A-2a
cp=1.005;//in kJ/kg-K
k=1.4;

//calculations
T01=T1+V1^2/(2*cp*1000);//factor of 1000 to convert
   kJ to J
P01=P1*(T01/T1)^(k/(k-1));
//given pressure ratio in compressor *
// T02 = T01*(P02/P01)^((k-1)/k)
T02 = T01*(8)^((k-1)/k);
win=cp*(T02-T01);
```

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

Scilab code Exa 17.2 Mach Number of Air Entering a Diffuser

```
clc;clear;
//Example 17.2

//given data
V=200;
T=30+273;//converted in K

//from Table A-2a
R=0.287;//in kJ/kg-K
k=1.4;

//calculations
c=sqrt(k*R*T*1000);//factor of 1000 to convert kJ to
    J
c=ceil(c);
disp(c,'the speed of sound in m/s');
Ma=V/c;
disp(Ma,'the Mach number at the diffuser inlet')
```

Scilab code Exa 17.3 Gas Flow through a Converging Diverging Duct

```
clc;clear;
//Example 17.3

//given data
T0=200+273;//converted in K
```

```
P0=1400;
//stagnant temp. & pressure is same as inlet due to
   small inlet velocity
P=1200;
m=3;

//from Table A-2a
cp=0.846;//in kJ/kg-K
R=0.1889;//in kJ/kg-K
k=1.289;

//calculations
T=T0*(P/P0)^((k-1)/k);
V=sqrt(2*cp*(T0-T)*1000);//factor of 1000 to convert
    kJ to J
p=P/(R*T);
A=m/(p*V);
c=sqrt(k*R*T*1000);//factor of 1000 to convert kJ to
    J
Ma=V/c;
disp(V,'velocity in m/s');
disp(p,'density in kg/m^3');
disp((A*10000),'flow area in cm^2');
disp(Ma,'Mach number');
```

Scilab code Exa 17.4 Critical Temperature and Pressure in Gas Flow

```
clc;clear;
//Example 17.4

//given data
T0=200+273;//converted in K
P0=1400;

//from Table A-2a
```

```
k=1.289;

//calculations
//Tc & Tr stands for critical temp and ratio
    respectively
//Pc & Pr stands for critical temp and ratio
    respectively
Tr=2/(k+1);
Pr=(2/(k+1))^(k/(k-1));
Tc=Tr*T0;
Pc=Pr*P0;
Tc=floor(Tc);
Pc=ceil(Pc);
disp(Tc,'critical temperature in K');
disp(Pc,'critical pressure on kPa')
```

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

```
clc;clear;
//Example 17.5

//given data
Vi=150;
Ti=600+273;
Pi=1;
At=50/10000;//converted into m^2

//from Table A-2a
R=0.287;//in kJ/kg-K
cp=1.005;//in kJ/kg-K
k=1.4;

//calculations
Toi=Ti+Vi^2/(2*cp*1000);//factor of 1000 to convert
    kJ to J
```

```
Poi=Pi*(Toi/Ti)^(k/(k-1));
//flow is isentropic
//stagnation temp. and pressure values remain
    constant
To=Toi;
Po=Poi;
//from Table 17  2
//The critical-pressure ratio is 0.5283

//Part a
Pb=0.7;
Pca=Pb/Po;
// Pca > 0.5283
//exit plane pressure is equal to the back pressure
Pt=Pb;
//from Table A 32
Mat=0.778;
//Tt/To = 0.892
Tt=0.892*To;
pt=Pt*1000/(R*Tt);//factor of 1000 to convert MPa to
     kPa
Vt=Mat*sqrt(k*R*Tt*1000);//factor of 1000 to convert
     kJ to J
ma=pt*At*Vt;
disp(ma,'the mass flow rate through the nozzle when
    the back pressure is 0.7 MPa in kg/s');

//Part b
Pb=0.4;
Pca=Pb/Po;
// Pca < 0.5283
//sonic conditions exists at the exit
Ma=1;
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
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

```
clc;clear;
//Example 17.6

//given data
T1=400;
P1=100;
Ma1=0.3;
A21=0.8;//A2/A1

//assumption
k=1.4;

//from Table A 32
//at Ma1=0.3
//s stands for * symbol
A1s = 2.0351;//A1/As
T10 = 0.9823;//T1/T0
P10 = 0.9305;//P1/P0
A2s = A21*A1s;//A2/As
//at this value of A2/As
T20=0.9701;//T2/T0
P20=0.8993;//P2/P0
Ma2=0.391;

//calculations
T2=T1*T20/T10;
T2=floor(T2);
P2=P1*P20/P10;
disp(Ma2,'Ma2 is ');
disp(T2,'T2 in K is');
disp(P2,'P2 in kPa is')
```

Scilab code Exa 17.7 Airflow through a Converging Diverging Nozzle

```
clc;clear;
//Example 17.7

//given data
T0=800;
P0=1;
Vi=0;//negligible
At=20;
Mae=2

//from Table A-2a
R=0.287;//in kJ/kg-K
k=1.4;

//calculations

//part - a
// Mach no. at exit is 2 hence sonic conditions at throat
p0=P0*1000/(R*T0);//factor of 1000 to convert MPa to kPa
//from Table A-32 at Mat=1
//s stands for * symbol
Ps0 = 0.5283;//Ts/T0
Ts0 = 0.8333;//Ps/P0
ps0=0.6339;//ps/p0
Ps=Ps0*P0;
Ts=Ts0*T0;
ps=ps0*p0;
As=At;
Vs=sqrt(k*R*Ts*1000);//factor of 1000 to convert kJ to J
```

```
disp('the throat conditions');
disp(Ps,'Presssure in MPa');
disp(Ts,'Temperature in K');
disp(ps,'density in kg/m^3');
disp(As,'area in cm^2');
disp(Vs,'velocity in m/s');

//part - b
//from Table A-32
//at Mae=2
Te0 = 0.5556;//Te/T0
Pe0 = 0.1278;//Pe/P0
pe0= 0.2300;//pe/p0
Ae0= 1.6875;//Ae/Ao
Pe=Pe0*P0;
Te=Te0*T0;
pe=pe0*p0;
Ae=Ae0*At;
Ve=Mae*sqrt(k*R*Te*1000);//factor of 1000 to convert
    kJ to J
disp('the exit plane conditions, including the exit
   area');
disp(Pe,'Presssure in MPa');
disp(Te,'Temperature in K');
disp(pe,'density in kg/m^3');
disp(Ae,'area in cm^2');
disp(Ve,'velocity in m/s');

//part - c
m=ps*As*Vs/10000;//factor of 10000 to convert cm^2
   to m^2
disp(m,'the mass flow rate through the nozzle in kg/
   s');
```

Scilab code Exa 17.9 Shock Wave in a Converging Diverging Nozzle

```
clc;clear;
//Example 17.9

//given data
m=2.86;
Ma1=2;
P01=1;
P1=0.1278;
T1=444.5;
p1=1.002;

//from Table A-2a
R=0.287;//in kJ/kg-K
cp=1.005;//in kJ/kg-K
k=1.4;

//calculations

//part - a
//from Table A-33 at Ma1=2.0
Ma2=0.5774;
P0201=0.7209;//P02/P01
P21=4.5;//P2/P1;
T21=1.6875;//T2/T1
p21=2.6667;//p2/p1
P02=P0201*P01;
P2=P21*P1;
T2=T21*T1;
p2=p21*p1;
disp(P02,'the stagnation pressure in MPa');
disp(P2,'the static pressure in MPa');
disp(T2,'static temperature in K');
disp(p2,'static density in kg/m^3');

//part - b
//s21 = s2 - s1
s21=cp*log(T2/T1)-R*log(P2/P1);
disp(s21,'the entropy change across the shock in kJ/
```

```
    kg-K');

//part - c
V2=Ma2*sqrt(k*R*T2*1000);//factor of 1000 to convert
    kJ to J
V2=ceil(V2);
disp(V2,'the exit velocity in m/s');

//part - d
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

```
clc;clear;
//Example 17.10

//given data
//using protactor frpm Fig 17-36
u=19;//u stands for angle of the mach lines

//calculations
//by Eq. 17-47
//i.e u= asin(1/Ma)
Ma=1/sind(u);
disp(Ma,'The Mach number is')
```

Scilab code Exa 17.11 Oblique Shock Calculations

```
clc;clear;
//Example 17.11

//given data
```

```
Ma1=2;
P1=75;
O=10;//angle b/w shock wave and normal

//constants used
k=1.4;

//calcualtions
//with given values of Ma1 and O from Eq 17-46
Bweak=39.3;
Bstrong=83.7;
//Weak shock
Ma1w=Ma1*sind(Bweak);
//Strong shock
Ma1s=Ma1*sind(Bstrong);
//from second part Eq 17-40
Ma2w=0.8032;
Ma2s=0.5794;
//pressure ratio = (2*k*Ma^2 - k + 1)/(k + 1 )
//Weak shock
P2w=P1*(2*k*Ma1w^2 - k + 1)/(k + 1 );
P2w=ceil(P2w);
disp(P2w,'pressure for weak shock in kPa');
//Strong shock
P2s=P1*(2*k*Ma1s^2 - k + 1)/(k + 1 );
P2s=floor(P2s);
disp(P2s,'pressure for strong shock in kPa');
//Weak shock
Ma2=Ma2w/sind(Bweak-O);
disp(Ma2,'Mach number downstream for weak shock');
//Strong shock
Ma2=Ma2s/sind(Bstrong-O);
disp(Ma2,'Mach number downstream for strong shock');
```

Scilab code Exa 17.12 Prandtl Meyer Expansion Wave Calculations

```
clc;clear;
//Example 17.12

//given data
Ma1=2;
P1=230;
O=10;//O stands for angle of the mach lines

//constants used
k=1.4;

//calculations
//Eq. 17 49 for the upstream Prandtl Meyer
    function
vMa1=sqrt((k+1)/(k-1))*atand(sqrt((k-1)*(Ma1^2-1)/(k
    +1)))-atand(sqrt(Ma1^2-1));
//Eq. 17 48 to calculate the downstream
    Prandtl Meyer function
vMa2=O+vMa1;
//using equation solver as implict nature of Eq
    17-49
Ma2=2.385;
disp(Ma2,'downstream Mach number Ma2 is');
//P2 = (P2/P0)/(P1/P0) * P1
P2= (1 + (k-1)*Ma2^2/2 )^(-k/(k-1)) / (1 + (k-1)*Ma1
    ^2/2 )^(-k/(k-1)) * P1;
P2=floor(P2);
disp(P2,'downstream pressure in kPa')
```

Scilab code Exa 17.15 Rayleigh Flow in a Tubular Combustor

```
clc;clear;
//Example 17.15

//given data
```

```
P1=480;
T1=550;
V1=80;
d1=15/100;//diameter in m
AF=40;//air to fuel ratio
HV=40000;//heating value in kJ/kg

//from Table A-2a
R=0.287;//in kJ/kg-K
cp=1.005;//in kJ/kg-K
k=1.4;

//calculations
p1=P1/(R*T1);
A1=%pi*d1^2/4;
mair=p1*A1*V1;
mfuel=mair/AF;
Q=mfuel*HV;
q=Q/mair;
T01=T1+V1^2/(2*cp);
c1=sqrt(k*R*T1*1000);//factor of 1000 to convert kJ
   to J
Ma1=V1/c1;
//exit stagnation energy equation q= Cp (T02 - T01)
T02=T01+q/cp;
//from Table A 34
//at Ma1
//s stands for * symbol
T0s=0.1291;//T0/Ts
Ts0=T01/T0s;
T2s=T02/Ts0;//T02/T*0
//from Table A 34 at this ratio
Ma2=0.3142;
//Rayleigh flow relations corresponding to the inlet
    and exit Mach no
//at Ma1
T1s=0.1541;//T1/Ts
P1s=2.3065;//P1/Ps
```

```
V1s=0.0668;//V1/Vs
//at Ma2
T2s=0.4389;//T2/Ts
P2s=2.1086;//P2/Ps
V2s=0.2082;//V2/Vs
T2=T2s/T1s*T1;
T2=floor(T2);
P2=P2s/P1s*P1;
P2=ceil(P2);
V2=V2s/V1s*V1;
V2=floor(V2);
disp(Ma2,'Mach Number at exit');
disp(T2,'Temperature in K');
disp(P2,'Pressure in kPa');
disp(V2,'Velocity in m/s')
```

Scilab code Exa 17.16 Steam Flow through a Converging Diverging Nozzle

```
clc;clear;
//Example 17.16

//given data
P01=2*1000;//factor of 1000 to convert MPa to kPa
T1=400;
V1=0;//negligible
nN=0.93;
m=2.5;
P2=300;

//calculations

//part - a
P201=P2/P01;
//critical pressure ratio at this values is 0.546
```

```
Pt=0.546*P01;
//at inlet
h1=3248.4;
h01=h1;
s1=7.1292;
//at throat
st=s1;
ht=3076.8;
vt=0.24196;
Vt=sqrt(2*(h01-ht)*1000);//factor of 1000 to convert
    kJ to J
At=m*vt/Vt;
//at state 2s
s2s=s1;
h2s=2783.6;
//nN = (h01 − h2)/ (h01 − h2s)
h2=h01-nN*(h01-h2s);
//at P2 and h2
v2=0.67723;
s2=7.2019;
V2=sqrt(2*(h01-h2)*1000);//factor of 1000 to convert
    kJ to J
A2=m*v2/V2;
disp((At*10000),'throat area in cm^2');
disp((A2*10000),'exit area in cm^2');

//part − b
// at st=7.1292
//pressures of 1.115 and 1.065 MPa
//c calculated using tables
c=sqrt((1115-1065)/(1/0.23776 - 1/0.24633)*1000);//
    factor of 1000 to convert kPa to Pa
Ma=Vt/c;
disp(Ma,'the Mach number at the throat');
// at s2=7.2019
//pressures of 325 and 275 kPa
c=sqrt((325-276)/(1/0.63596 - 1/0.72245)*1000);//
    factor of 1000 to convert kPa to Pa
```

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