Scilab Textbook Companion for Thermodynamics by J. P. Holman[1]

Created by
Jeevan Lal
Chemical engineering
Computer Engineering
IIT Bombay
College Teacher
Na
Cross-Checked by
Lavitha Pereira

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Book Description

Title: Thermodynamics

Author: J. P. Holman

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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

Scilab code Exa 1.1 example 1

```
clc
//Initialization of variables
d=8 //in
ir=16 //in
MW=28.97
T=70+460 //R
P=30+14.7 //psia
//calculations
V=%pi^2 *d^2 *(d+ir)/4
V=V*10/12^3
Rair=1545/MW
m=P*144*V/(Rair*T)
//results
printf("Mass of air = %.2f lbm",m)
```

Scilab code Exa 1.2 example 2

```
clc
```

```
//Initialization of variables
V=4 //in^3
P=30 //psia
T=500//R
MW=32
//calculations
disp("Metric unit conversion,")
V=V*2.54^3 *10^-3
P=30*4.448/(2.54^2 *10^-4)
T=5*(T-32)/9 +273
n=P*V/(8314.5*T)
eta=n*1000
N=eta*6.025*10^23
m=eta*MW
//results
printf("No. of molecules of oxygen = %.3e molecules"
    ,N)
printf("\n Mass of molecules = %.1f g",m)
//The answer in the textbook is a bit different due
    to rounding off error
```

Scilab code Exa 1.3 example 3

```
clc
//Initialization of variables
P=14.7 //psia
T=70+460 //R
M=32
//calculations
Ro=1545/M
V2=3*Ro*T
V2=V2*32.174
vrms=sqrt(V2)
//results
printf("rms velocity = %d ft/sec",vrms)
```

Chapter 2

The first law of Thermodynamics

Scilab code Exa 2.1 example 1

```
clc
//Initialization of variables
P1=200 //psia
P2=15 //psia
V1=1 //ft^3
g=1.3
//calculations
V2=V1*(P1/P2)^(1/g)
W=-(144*(P2*V2 - P1*V1)/(g-1))
//results
printf("Work done = %.2e ft. lbf",W)
```

Scilab code Exa 2.2 example 2

```
clc
//Initialization of variables
```

```
L=0.305 //m
v=4.58 //m/s
i=10 //A
B=1 //W/m^2
//calculations
F=i*B*L
W=F*v
//results
printf("Force necessary = %.2f N",F)
printf("\n Work per unit time = %.2f W",W)
```

Scilab code Exa 2.3 example 3

```
clc
//Initialization of variables
U=2545 //B/hr
m=50 //lbm
cv=1
//calculations
dT=U/(m*cv)
//results
printf("Change in temperature = %.1f F",dT)
```

Scilab code Exa 2.4 example 4

```
clc
//Initialization of variables
P1=14.7 //psia
V1=1 //ft^3
P2=14.7 //psia
M=28.97
T1=70+460 //R
T2=500+460 //R
```

```
cp=0.24 //B/lbm F
//calculations
m=P1*144*V1*M/(1545*T1)
Qp=m*cp*(T2-T1)
V2=V1*P1*T2/(P2*T1)
W=P1*144*(V2-V1)
W=-W/778
dU=Qp+W
//results
printf("Work done = %.2f Btu",W)
printf("\n Heat added = %.2f Btu",Qp)
printf("\n Change in internal energy = %.2f Btu",dU)
```

Scilab code Exa 2.5 example 5

```
clc
//Initialization of variables
l=20
b=25
h=8
Vp=2.5
n=20
P=14.7//psia
T=530 //R
t=15 //min
Qp=375 //B/hr
cv=0.1715 //B/lbm F
//calculations
Vroom=l*b*h
Vair=Vroom-Vp*n
m=P*Vair*144/(53.35*T)
dU=n*Qp
U=t*dU/60
dT=U/(m*cv)
//results
```

```
printf("Air temperature rise = %d F",dT+1)
```

Chapter 3

Macroscopic properties of pure substances

Scilab code Exa 3.1 example 1

```
clc
//Initialization of variables
V=1 //ft^3
m=30 //lbm
//calculations
v=V/m
vf1=0.01665
vfg1=32.38 //ft^3/lbm
x1=0.000515
uf1=169.92
ufg1=904.8
u1=uf1+x1*ufg1
vfg=0.0216
vfg2=0.4240
v2=v
x2=0.0277
uf2=538.4
ufg2=571
u2=uf2+x2*ufg2
```

```
Q=m*(u2-u1)
//results
printf("Heat transfer = %d Btu",Q)
```

Scilab code Exa 3.2 example 2

```
clc
//Initialization of variables
V2=2.5 //ft^3
V1=0.5 //ft^3
P=100 //psia
x1=0.5
//calculations
W=-P*144*(V2-V1)
vf1=0.01774
vfg1=4.414
v1=vf1+x1*vfg1
m=V1/v1
v2=V2/m
disp("From tables ,")
uf1=298.08
ufg1=807.1
u1=uf1+x1*ufg1
h2=1747.9
u2=h2-P*144*v2/778
Q=m*(u2-u1)
//results
printf("Amount of heat = %d Btu",Q)
//The answer for u2 is given wrong in the textbook.
    Please use a calculator to find it
```

Scilab code Exa 3.3 example 3

```
clc
//Initialization of variables
V1=1.735*10^-4 //ft^3
v1=0.016080 //ft^3/lbm
h1=70.61 //B/lbm
P1=100 //psia
V2=1 //ft^3
//calculations
u1=h1-P1*v1*144/778
m=V1/v1
v2=V2/m
vf2=0.01613
vfg2=350.3
x2=(v2-vf2)/vfg2
hf2=67.97
hfg2=1037.2
h2=hf2+x2*hfg2
P2=0.9492
u2=h2- P2*144*v2/778
Q=m*(u2-u1)
//results
printf("Enthalpy change = %.2f Btu",Q)
```

Scilab code Exa 3.4 example 4

```
clc
//Initialization of variables
P=20 //psia
V=1 //ft^3
T=560 //R
cv=0.1715
Q=10//Btu
//calculations
m=P*144*V/(53.35*T)
T2=Q/(m*cv) +T
```

```
P2=m*53.35*T2/V
//results
printf("Fina pressure = %d lbf/ft^2",P2)
```

Scilab code Exa 3.5 example 5

```
clc
//Initialization of variables
T1=560 //R
T2=3460  //R
m=28.02 //lb
cv=0.248
//calculations
function [q]=fun(T)
    q=9.47 - 3.29*10^3 /T +1.07*10^6 /T^2
endfunction
Q1=intg(T1,T2,fun)
Q2=m*cv*(T2-T1)
Error=(Q1-Q2)/Q1
//results
printf("Percentage error = %.1f percent",Error*100)
```

Scilab code Exa 3.6 example 6

```
clc
//Initialization of variables
rate=20 //gal/min
P1=20 //psia
P2=1000 //psia
T=100+460 //R
//calculations
vf=0.01613
disp("From table A-8")
```

```
dv=-5.2*10^-5 //ft^3/lbm
K=-dv/(vf*P2*144)
wt=K*vf*(P2^2 - P1^2)*144*144*10^4 /2
m=rate*8.33
Wt=wt*m
Wthp=Wt/33000
//results
printf("Pump power required = %d hp",Wthp)
```

Chapter 4

principles of energy analysis

Scilab code Exa 4.1 example 1

```
clc
//Initialization of variables
m=1
he=1148.8 //B/lbm
hi=1357 //B/lbm
Ve=100 //ft/sec
Vi=800 //ft/sec
//calculations
dW= m*(he-hi) + m*(Ve^2 - Vi^2)/(2*32.2*778)
dWhr=dW*3600
hp=-dWhr/2545
//results
printf("Horsepower output = %d hp",hp+1)
```

Scilab code Exa 4.2 example 2

```
clc
//Initialization of variables
```

```
rate=80 //lbm/min
T1=100 //F
P1=100 //psia
P2=1000 //psia
//calculations
disp("From the tables,")
v=0.01613 //ft^3/lbm
W=rate*(P2-P1)*144*v
//results
printf("Work done = %.2f ft-lbf/min",W)
```

Scilab code Exa 4.3 example 3

```
clc
//Initialization of variables
disp("from saturated steam tables,")
hi=1279.1 //B/lbm
//calculations
u2=hi
T2=564 //F
//results
printf("Temperature of steam = %d F",T2)
```

Scilab code Exa 4.4 example 4

```
clc
//Initialization of variables
P1=20 //psia
P2=100 //psia
V=3 //ft^3
T=560 //R
ma=0.289
//calculations
```

```
ma=P1*V/(53.35*T)
Wa=-ma*53.35*T*log(P1/P2)
Qa=-Wa
Va2=3/5
V2s=V-Va2
hi=1279.1 //B/lbm
T2s=536 //F
//results
printf("Final temperature = %d F",T2s)
```

Scilab code Exa 4.5 example 5

```
clc
//Initialization of variables
P1=200 //psia
P2=100 //psia
T1=300+460 //R
g=1.4
cp=0.24
//calculations
T2=(T1)*(P2/P1)^((g-1)/g)
V2=sqrt(2*32.2*778*cp*(T1-T2))
//results
printf("Final velocity = %d ft/sec",V2)
```

Scilab code Exa 4.6 example 6

```
clc
//Initialization of variables
T1=500+460 //R
P1=50 //psia
P2=15 //psia
g=1.4
```

```
cp=0.24
//calculations
T2=T1*(P2/P1)^((g-1)/g)
W=cp*(T2-T1) + (T1-460)^2 /(2*32.2*778)
//results
printf("Net work output from turbine = %.1f B/lbm",W
   )
```

Scilab code Exa 4.7 example 7

```
clc
//Initialization of variables
T1=150+460 //R
T1=40+460 //R
//calculations
disp("from freon tables,")
h2=43.850 //B/lbm
hf2=17.273
hfg2=64.163
x2=(h2-hf2)/hfg2
//results
printf("Quality of freon vapor = %.3f",x2)
```

Chapter 5

principles of statistical thermodynamics

Scilab code Exa 5.1 example 1

```
clc
//Initialization of variables
N1=1
N2=1
N3=3
N4=1
//calculations
N=N1+N2+N3+N4
sig=factorial(N) /(factorial(N1) *factorial(N2)*
   factorial(N3)*factorial(N4))
//results
printf("No. of ways of arranging = %d ",sig)
```

Scilab code Exa 5.2 example 2

```
clc
```

```
//Initialization of variables
N=6
g=4
//calculations
sig=factorial(g+N-1)/(factorial(g-1)*factorial(N))
//results
printf("No. of ways of arranging = %d ",sig)
```

Scilab code Exa 5.3 example 3

```
clc
//Initialization of variables
N=6
g=8
//calculations
sig=factorial(g)/(factorial(N)*factorial(g-N))
//results
printf("No. of ways  = %d ",sig)
```

Scilab code Exa 5.4 example 4

```
clc
//Initialization of variables
N0=1
//calculations
N1=3/%e
N2=6/%e^2
N3=10/%e^3
N=N0+N1+N2+N3
ei=[0 1 2 3]
eid=ei+1
f0=N0/N
f1=N1/N
```

```
f2=N2/N
f3=N3/N
fi=[f0 f1 f2 f3]
//results
printf("fractional population of level 0 = %.3f",f0)
printf(" \n fractional population of level 1 = %.3f"
    ,f1)
printf(" \n fractional population of level 2 = %.3f"
    ,f2)
printf(" \n fractional population of level 3 = %.3f"
    ,f3)
xtitle('fractional populations vs Energy levels','
    Energy levels ei','fractional population Ni/N')
bar(ei,fi,0.1)
```

Chapter 6

The second law of thermodynamics

Scilab code Exa 6.1 example 1

```
clc
//Initialization of variables
m=5 //lbm
P=50 //psia
T=500 + 460 //R
//calculations
disp("From saturated steam tables,")
s1=0.4110 //B/lbm R
s2=1.7887 //B/lbm R
dS=m*(s2-s1)
//results
printf("Change in entropy = %.3f B/R",dS)
```

Scilab code Exa 6.2 example 2

```
clc
```

```
//Initialization of variables
P=20 //psia
T=227.96+ 459.69 //R
//calculations
disp("from saturation tables,")
sfg=1.3962 //B/ R lbm
Q=T*sfg
//results
printf("heat transfer = %.1f B/lbm",Q)
```

Scilab code Exa 6.3 example 3

```
clc
//Initialization of variables
T1=100+460 //R
P1=15//psia
P2=50 //psia
n=1.3
cp=0.24
//calculations
T2=T1*(P2/P1)^((n-1)/n)
dS=cp*log(T2/T1) - 53.35/778 *log(P2/P1)
//results
printf("Change in entropy = %.3f B/lbm R",dS)
//the answer given in textbook is wrong. Please
   check it using a calculator
```

Scilab code Exa 6.4 example 4

```
clc
//Initialization of variables
T1=85+460 //R
T2=T1
```

```
cp=0.24
P2=15 //psia
P1=30 //psia
//calculations
dS=cp*log(T2/T1) - 53.35/778 *log(P2/P1)
//results
printf("Change in entropy = %.4f B/lbm R",dS)
```

Scilab code Exa 6.5 example 5

```
clc
//Initialization of variables
Qh=-1000 //Btu
Ql=1000 //Btu
Th=1460 //R
Tl=960 //R
//calculations
Sh=Qh/Th
Sl=Ql/Tl
S=Sh+Sl
//results
printf("Change in entropy of the universe = %.3f B/R
   ",S)
```

Scilab code Exa 6.6 example 6

```
clc
//Initialization of variables
disp("from steam tables,")
h1=1416.4 //B/lbm
s1=1.6842 //B/lbm R
//calculations
s2=s1
```

```
P2=50 //psia
T2=317.5 //F
h2=1193.7
W=h2-h1
//results
printf("Work calculated = %.1f B/lbm",W)
```

Chapter 7

equations of state and general thermodynamic relations

Scilab code Exa 7.1 example 1

```
clc
//Initialization of variables
disp("Using gas tables,")
T1=1160 //R
h1=281.14 //B/lbm
Pr1=21.18
P2=30 //psia
P1=100 //psia
//calculations
Pr2=Pr1*P2/P1
T2=833 //R
h2=199.45 //B/lbm
dh=h2-h1
//results
printf("Change in enthalpy = %.2f B/lbm",dh)
```

Scilab code Exa 7.2 example 2

```
clc
//Initialization of variables
T2=860 //R
phi1=0.78767
phi2=0.71323
P2=30 //psia
P1=100 //psia
//calculations
dS=phi2-phi1- 53.35/778 *log(P2/P1)
//results
printf("Net change of entropy = %.5f B/lbm R",dS)
```

Scilab code Exa 7.3 example 3

```
clc
//Initialization of variables
T1=540 //R
T2=960 //R
disp("From gas tables,")
h2=231.06 //B/lbm
h1=129.06 //B/lbm
cp=0.24
//calculations
W=h2-h1
dh=cp*(T2-T1)
//results
printf("Change in enthalpy = %.1f B/lbm",dh)
```

Scilab code Exa 7.4 example 4

```
clc
```

```
//Initialization of variables
T1=420 //R
T2=380 //R
hig=1221.2
P1=0.0019
//calculations
lnp=hig*778*(1/T1 - 1/T2)/85.6
pra=exp(lnp)
P2=pra*P1
//results
printf("Final pressure = %.3e psia",P2)
```

Scilab code Exa 7.5 example 5

```
clc
//Initialization of variables
disp("from critical constant tables")
pc=482//psia
Tc=227 //R
vc=1.44 //ft^3/lbm mol
P=600 //psia
T=310 //R
//calculations
Pr=P/pc
Tr=T/Tc
disp("From Z tables,")
Z=0.83
v=Z*55.12*T/(P*144)
rho=1/v
//results
printf("Density = %.1f lbm/ft^3",rho)
```

Scilab code Exa 7.6 example 6

```
clc
//Initialization of variables
T=-150+460 //R
v=0.6 //ft^3/lbm
vc=1.44
Tc=227 //R
Pc=482 //psia
//calculations
disp("From tables of z")
vr=v/vc
Tr=T/Tc
Pr=1.75
P=Pr*Pc
//results
printf("Final pressure = %d psia",P)
```

Scilab code Exa 7.7 example 7

```
clc
//Initialization of variables
disp("Critical tables suggest,")
Tc=344 //R
Pc=673 //psia
P1=20 //psia
P2=500 //psia
M=16
T=560 //R
//calculations
pr1=P1/Pc
pr2=P2/Pc
Tr=T/Tc
dh2=0.65*Tc
dsp=0.35 //B/lbm mol R
dsp2=0.018-dsp- 1545/778 *log(P2/P1)
W=dh2-dsp2*T
```

```
W2=W/M
//results
printf("Work per pound mass = %d B/lbm",W2)
//The answer is a bit different due to rounding off
   error
```

Scilab code Exa 7.8 example 8

```
clc
//Initialization of variables
P=1000 //psia
T1=100 + 460 //R
T2=800+460 //R
//calculations
pc=1070 //psia
Tc=548 //R
pr1=P/pc
Tr1=T1/Tc
Tr2=T2/Tc
M=44
disp("from fig 7.7")
h1=4235.8 //B/lbm mol
h2=11661 //B/lbm mol
h2bar=3.5 //B/lbm mol
h1bar=0.48 //B/lbm mol
dhbar=Tc*(h2bar-h1bar) + h2-h1
Q=dhbar/M
cp=0.202 //B/lbm F
Q2=cp*(T2-T1)
Error=(Q-Q2)/Q
//results
printf("Error in calculation = %d percent",Error
   *100)
```

Chapter 8

applications of statistical thermodynamics

Scilab code Exa 8.1 example 1

```
clc
//Initialization of variables
T=70 //K
Tr=85.5 //K
//calculations
disp("From fig 8.2")
cvrot=1.1
cvtra=1.5
cv=cvtra+cvrot
//results
printf("Cv total = %.1f R",cv)
```

Scilab code Exa 8.2 example 2

```
clc
//Initialization of variables
```

```
T=2000 //K
Tr=3340 //K
//calculations
disp("From fig 8.2")
cvrot=0.85
cvtra=1.5
cvvib=1
cv=cvtra+cvrot+cvvib
//results
printf("Cv total = %.2f R",cv)
```

Scilab code Exa 8.3 example 3

```
clc
//Initialization of variables
T=200 //K
the=398 //K
//calculations
ratio=T/the
disp("from fig 8.6")
cv=4.9
//results
printf("Specific heat of aluminium = %.1f cal/g mol
   K",cv)
```

Scilab code Exa 8.4 example 4

```
clc
//Initialization of variables
T=10 //K
td=315 //K
//calculations
cv=464.4 *(T/td)^3
```

```
//results
printf("specific heat of copper = %.5f cal/g mol K",
   cv)
```

Scilab code Exa 8.5 example 5

```
clc
//Initialization of variables
N0=6.025*10^23
M=63.57
d=8.94 //g/cc
h=6.624*10^-27
me=9.1*10^-28
//calculations
NbyV=N0*d/M
mu0=h^2 *(3*NbyV/ %pi)^(2/3) /(8*me)
e0=0.6*mu0*10^-7
Teq=2*e0/(3*1.38*10^-23)
//results
printf("Equivalent temperature = %d K",Teq)
```

Scilab code Exa 8.6 example 6

```
clc
//Initialization of variables
T=300 //K
mu=1.13*10^-18
k=1.38*10^-23
//calculations
cv=%pi^2 *k*T/(2*mu)
//results
printf("Electron contribution = %.4f R",cv)
```

Scilab code Exa 8.7 example 7

```
clc
//Initialization of variables
sig=5.668*10^-5
T1=1000 //K
T2=2000 //K
//calculations
Eb1=sig*T1^4 *10^-7
Eb2=sig*T2^4 *10^-7
//results
printf("total energy emitted in case 1 = %.3f Watts/cm^2",Eb1)
printf("\n total energy emitted in case 2 = %.3f Watts/cm^2",Eb2)
```

Chapter 9

Kinetic theory and transport phenomena

Scilab code Exa 9.1 example 1

```
clc
//Initialization of variables
N0=6.025*10^26
M=32
k=1.38*10^-23
T=300 //K
//calculations
m=M/N0
vavg=sqrt(8*k*T/(%pi*m))
vrms=sqrt(3*k*T/m)
vm=sqrt(2*k*T/m)
//results
printf("Average velocity = %d m/sec",vavg)
printf("\n RMS velocity = %d m/sec",vrms)
printf("\n Most probable velocity = %d m/sec",vm)
```

Scilab code Exa 9.2 example 2

```
clc
//Initialization of variables
T=300 //K
dv=0.02
vm=395 //m/s
m=5.32*10^-26 //kg
k=1.38*10^-23
vrms=483 //m/s
//calculations
N1=sqrt(2/%pi) *(m/(k*T))^(3/2) *vm^2 *exp(-1) *dv*
    vm
N2=sqrt(2/%pi) *(m/(k*T))^(3/2) *vrms^2 *exp(-3/2) *
    dv*vrms
//results
printf("Fraction of oxygen molecules at v most
    probable speed = %.4f ",N1)
printf("\n Fraction of oxygen molecules at v rms
    speed = %.4f ",N2)
```

Scilab code Exa 9.3 example 3

```
clc
//Initialization of variables
p=1.013*10^5 //N/m^2
k=1.38*10^-23
T=300 //K
v=445 //m/s
A=0.001*10^-6 //m^2
//calculations
n=p/(k*T)
J=n*v/4
escaping=J*A
//results
```

```
printf("No. of molecules escaping per unit time = %
    .2e mol/sec",escaping)
```

Scilab code Exa 9.4 example 4

```
clc
//Initialization of variables
d=3.5*10^-10 //m
n=2.45*10^25
//calculations
sig=%pi*d^2
lambda=1/(sqrt(2) *sig*n)
frac=exp(-2)
//results
printf("Mean free path = %.2e m",lambda)
printf("\n fraction of molecules = %.3f",frac)
```

Scilab code Exa 9.5 example 5

```
clc
//Initialization of variables
P=1 //atm
T=300 //K
//calculations
cv=4.97
vavg=1580 //ft/s
sig=4.13*10^-18 //ft^2
N0=6.025*10^26 *0.4536
K=vavg*3600*cv/(3*N0*sig)
//results
printf("Thermal conductivity  = %.2e B/hr ft F",K)
```

Scilab code Exa 9.6 example 6

```
clc
//Initialization of variables
m=5.32*10^-26 //kg
v=445 //m/s
sigma=3.84*10^-19 //m^2
//calculations
mu=m*v/(3*sigma)
//results
printf("Dynamic viscosity of oxygen = %.2e newton
    sec/m^2",mu)
```

Chapter 10

Gaseous Mixtures

Scilab code Exa 10.1 example 1

```
clc
//Initialization of variables
m=2
M=28
M2=32
PN=300 //psia
Pt=400 //psia
//calculations
nN=m/M
PO=Pt-PN
nO=nN*PO/PN
mO=M2*nO
//results
printf("Mass of oxygen added = %.3f lbm",mO)
```

Scilab code Exa 10.2 example 2

```
clc
```

```
//Initialization of variables
n=0.0714
R=1545
T=560 //R
P=400 //psia
//clculations
VN=n*R*T/(P*144)
VO=(0.0238)*R*T/(P*144)
V=VN+VO
//results
printf("Total volume = %.3f ft^3",V)
```

Scilab code Exa 10.3 example 3

```
clc
//Initialization of variables
m1=5
m2=2
cp1=0.248
cp2=0.203
T11=300 //F
T12=100 //F
P=10 //psia
Pi=20 //psia
Pf=15 //psia
//calculations
T2=(m1*cp1*T11 + m2*cp2*T12)/(m1*cp1+m2*cp2)
n1=m1/28
n2=m2/44
n=n1+n2
P1=P*n1/n
P2=P*n2/n
dS=m2*(cp2*log((T2+460)/(T12+460)) - 35.1/778 *log(
    P2/Pi)) +m2*(cp2*log((T2+460)/(T12+460)) -
    55.2/778 *log(P1/Pf))
```

```
//results
printf("change in enthalpy = %.2f B/R",dS)
```

Scilab code Exa 10.4 example 4

```
clc
//Initialization of variables
Pg=2.8886 //psia
P=25 //psia
phi=0.5
//calculations
pv=phi*Pg
pa=P-pv
w=0.622*pv/pa
x=(w)/(1+w)
//results
printf("Mass fraction of water vapor in the mixture
   = %.4f lbm vapor/ lvm mixture",x)
```

Scilab code Exa 10.5 example 5

```
clc
//Initialization of variables
pgw=0.5069 //psia
p=14.696 //psia
Td=100 //F
Tw=80 //F
//calculations
pv= pgw- (p-pgw)*(Td-Tw)/(2800-Tw)
pg=0.9492 //psia
phi=pv/pg
//results
```

```
printf("relative humidity of air stream = %.1f
    percent",phi*100)
```

Scilab code Exa 10.6 example 6

```
clc
//Initialization of variables
w1=0.0176 //lbm
w2=0.0093 //lbm
T2d=73//F
T2=55 //F
//calculations
disp("From steam tables,")
hv1=1061+0.445*100
hv2=1061+0.445*55
hf=23.06
q1=20
q2=4.88
//results
printf("Heat removed in cooling section = %d Btu/lbm
    ",q1)
printf("Heat added in heating section = %.2f Btu/lbm
    ",q2)
```

Scilab code Exa 10.7 example 7

```
clc
//Initialization of variables
Tdb=115 //F
ph=0.05

Twb=67 //F
//results
```

```
disp("From steam tables , Twb=67 F")
```

Scilab code Exa 10.8 example 8

```
clc
//Initialization of variables
w1=206
w2=55
ma1=2
ma2=3
//calculations
w3= (ma1*w1 + ma2*w2)/(ma1+ma2)
disp("From psychrometric chart,")
Tdb3=82 //F
TWb3=74.55 //F
phi3=70 //percent
//results
printf("relative humidity = %d percent",phi3)
printf("\n Dry bulb temperature = %d F",Tdb3)
printf("\n Wet bulb temperature = %.2f F",TWb3)
```

Chapter 11

Chemical Thermodynamics and Equilibrium

Scilab code Exa 11.1 example 1

```
clc
//Initialization of variables
x=1.5
P=14.696 //psia
m=28.96
//calculations
mf=114 // lbm/mol fuel
ma=x*12.5*(1+3.76)*m
AF=ma/mf
n1=8
n2=9
n3=(x-1)*12.5
n4= x*3.76*12.5
np=n1+n2+n3+n4
x1=n1/np
x2=n2/np
x3=n3/np
x4=n4/np
ph=x2*P
```

```
Td=113.5 //F
//results
printf("Air fuel ratio = %.1f lbm air/lbm fuel",AF)
printf("\n Mole fraction of CO2 = %.2f percent",x1)
printf("\n Mole fraction of H2O = %.2f percent",x2)
printf("\n Mole fraction of O2 = %.2f percent",x3)
printf("\n Mole fraction of N2 = %.2f percent",x4)
disp("From tables of saturation pressure")
printf("Dew point  = %.1f F",Td)
```

Scilab code Exa 11.2 example 2

```
clc
//Initialization of variables
x1=9
x2=1.2
x3=1.5
x4=88.3
//calculations
a=x1+x2
b=2*a
xO=(2*x1 + x2+ 2*x3 + b)/2
xN=x4/3.76
ratio=xO/a
percent=ratio/2 *100
//results
printf("Percent theoretical air = %.1f percent",
   percent)
```

Scilab code Exa 11.3 example 3

```
clc
//Initialization of variables
```

```
T=440 //F
//calculations
disp("From steam tables,")
h1=-169290
h2=7597.6
h3=4030.2
ht=h1+h2-h3
//results
printf("Molal enthalpy of CO2 = %d Btu/lbm mole",ht)
```

Scilab code Exa 11.4 example 4

```
clc
//Initialization of variables
T=77 //F
//calculations
Hr=-36420 //B
hc=-169290 //B/lb mol
hh=-122970 //B/lb mol
Hp=2*hc+3*hh
Q=Hp-Hr
//results
printf("Heat transfer = %d B/mol fuel",Q)
```

Scilab code Exa 11.5 example 5

```
clc
//Initialization of variables
T2=440 //F
T1=77 //F
Mch4=16
Mw=18
//calculations
```

```
h77=3725.1
ht=6337.9
ht2=7597.6
h772=4030.2
hwt=1260.3
h77w=45.02
hr77=-383040 //B/lbm mol
dHR=1*Mch4*0.532*(T1-T2) + 2*(h77-ht)
dHp=1*(ht2-h772) + 2*Mw*(hwt - h77w)
hrp=dHp+hr77+dHR
//results
printf("Enthalpy of combustion of gaseous methane =
    %d B/lbm mol fuel",hrp)
//The calculation in textbook is wrong Please check
    it using a calculator.
```

Scilab code Exa 11.6 example 6

```
clc
//Initialization of variables
Hr=-107530 //B/mol fuel
disp("By iteration of temperatures, T=2700 R")
T=2700 //R
//results
printf("Adiabatic flame temperature = %d R",T)
```

Scilab code Exa 11.7 example 7

```
clc
//Initialization of variables
Kp=0.668
y=Kp^2
//calculations
```

```
x=poly(0,"x")
vec=roots(x^3 + y*x^3 + 2*y*x^2 -y*x -2*y)
eps=vec(1)
x1=(1-eps)/(1+ eps/2)
x2=eps/(1+eps/2)
x3=eps/2/(1+ eps/2)
//results
printf("degree of reaction = %.3f ",eps)
printf("\n Equilibrium concentration of CO2 = %.3f "
    ,x1)
printf("\n Equilibrium concentration of CO = %.3f ",
    x2)
printf("\n Equilibrium concentration of O2 = %.3f ",
    x3)
//the answers are a bit different due to
    approximation in textbook
```

Scilab code Exa 11.8 example 8

```
clc
//Initialization of variables
Kp=15.63
y=Kp
//calculations
x=poly(0,"x")
vec=roots(x^2 + y*x^2 - y)
eps=vec(1)
x1=(1-eps)/(1+eps)
x2=eps/(1+eps)
x3=eps/(1+eps)
//results
printf(" Equilibrium concentration of Cs = %.4f ",x1
    )
printf("\n Equilibrium concentration of Cs+ = %.4f "
    ,x2)
```

```
printf("\n Equilibrium concentration of e- = %.4f ",
    x3)
//the answers are a bit different due to
    approximation in textbook
```

Chapter 12

conventional power and refrigeration cycles

Scilab code Exa 12.1 example 1

```
clc
//Initialization of variables
disp("From Mollier diagram,")
h1=1357 //500 psia , 700 F
h2=935 //P2=2 psia
h3=93.99 //sat liq at 2 psia
vf=0.01613
P4=500 //psia
P3=2 //psia
//calculations
dh4=vf*(P4-P3)*144/778
h4=h3+dh4
eta= ((h1-h2)-(h4-h3))/(h1-h4)
//results
printf("Thermal efficiency = %.1f percent ",eta*100)
```

Scilab code Exa 12.2 example 2

```
clc
//Initialization of variables
disp("From molier diagram,")
h1=1357 //500 psia 700F
h2=1194 //P2=100 psia
h3=1379 //100 psia, 700 F
h4=1047 //p4=2 psia
h5=93.99 //sat liq at 2 psia
h6=95.02 //example 12.1
//calculations
W=h1-h2+h3-h4-(h6-h5)
Q=(h1-h6)+(h3-h2)
eta=W/Q
//results
printf("Thermal efficiency = %.2f percent",eta*100)
```

Scilab code Exa 12.3 example 3

```
clc
//Initialization of variables
P=100 //psia
//calculations
disp("From mollier diagram,")
h1=1357 //500 psia, 700F
h2=1194 //100 psia
h3=935//2 psia
h4=93.99 //sat liq at 2 psia
vf=0.01613
vf2=0.01774
P5=100 //psia
P4=2 //psia
dh4=vf*(P5-P4)*144/778
h5=h4+dh4
```

```
h6=298.4
P7=500 //psia
P6=100 //psia
dh6=vf2*(P7-P6)*144/778
h7=dh6+h6
m=(h6-h5)/(h2-h5)
W=h1-h2 + (1-m)*(h2-h3) - (1-m)*(h5-h4) -(h7-h6)
Q=h1-h7
etath=W/Q
//results
printf("Thermal efficiency = %.1f percent",etath*100)
```

Scilab code Exa 12.4 example 4

```
clc
//Initialization of variables
x=0.8
//calculations
disp("From molier diagram,")
h1=1357 //500 psia 700F
h2=1194 //P2=100 psia
h3=1379 //100 psia, 700 F
h4=1047 //p4=2 psia
h5=93.99 //sat liq at 2 psia
h6=95.02 //example 12.1
h2d=h1- x*(h1-h2)
h4d=h3- x*(h3-h4)
W=(h1-h2d) +(h3-h4d) - (h6-h5)
Q=(h1-h6) + (h3-h2d)
eta=W/Q
//results
printf("Thermal efficiency = %d percent",eta*100+1)
```

Scilab code Exa 12.5 example 5

```
clc
//Initialization of variables
P4=50 //psia
P1=14.7 //psia
P3=50 //psia
P2=14.7 //psia
g=1.4
//calculations
V1r=(P4/P1)^(1/g)
V2r=(P3/P2)^(1/g)
//After solving ,
V4=5.38 //ft^3/min
V1=12.9 //ft^3/min
V2=112.9  //ft^3/min
PD=V2-V4
etavol=(V2-V1)/(V2-V4)
W32=g*P2*144*V2*((P3/P2)^((g-1)/g) -1 ) /(1-g)
W41=g*P4*144*V4*((P1/P4)^((g-1)/g) -1 ) /(1-g)
Wt=W32+W41
//results
printf("Total work = %.2e ft-lbf /min",Wt)
//The answer given in textbook is wrong . please
   verify it using a calculator
```

Scilab code Exa 12.6 example 6

```
clc
//Initialization of variables
P1=14.7 //psia
P4=100 //psia
```

```
T1=530 //R
T3=T1
g=1.4
m=10 //lbm
cp=0.24
//calculations
P2=sqrt(P1*P4)
T2=T1*(P2/P1)^((g-1)/g)
T4=T2
W=2*cp*(T2-T1)
Wt=W*m
hp=Wt*60/2545
Q=m*cp*(T2-T3)
T4=T1*(P4/P1)^((g-1)/g)
W2=m*cp*(T4-T1)
//results
printf("Work required in case 1  = %d Btu/min",Wt+1)
printf("\n Work required in case 2 = %d Btu/min",W2+1)
```

Scilab code Exa 12.7 example 7

```
clc
//Initialization of variables
g=1.4
r1=10
r2=12
r3=15
Tl=530 //R
Th=1960 //R
//calculations
eta1=1- (r1)^(1-g)
eta2=1- (r2)^(1-g)
eta3=1- (r3)^(1-g)
etac=1-Tl/Th
```

```
//results
printf("Efficiency in case 1 = %.1f percent",eta1
    *100)
printf("\n Efficiency in case 2 = %.1f percent",eta2
    *100)
printf("\n Efficiency in case 3 = %.1f percent",eta3
    *100)
printf("\n Carnot efficiency = %.2f percent",etac
    *100)
```

Scilab code Exa 12.8 example 8

```
clc
//Initialization of variables
T1=70+460 //R
P1=14.7 //psia
g=1.4
r=15
rc=2
cp=0.24
cp2=0.1715
//calculations
T2=T1*(r)^(g-1)
T3=rc*T2
T4=T3*(rc/r)^(g-1)
Qh=cp*(T3-T2)
Ql=cp2*(T4-T1)
W=Qh-Ql
eta=W/Qh
//results
printf("Work output = %d B/lbm",W)
printf("\n Efficiency = %.1f percent",eta*100)
```

Scilab code Exa 12.9 example 9

```
clc
//Initialization of variables
P1=14.7 //psia
P4=14.7 //psia
T1=530 //R
T3=1960 //R
P2=60 //psia
P3=P2
g=1.4
eta1=0.85
eta2=0.9
//calculations
T2=T1*(P2/P1)^((g-1)/g)
T4=T3*(P4/P3)^((g-1)/g)
T2d=(T2-T1)/eta1 + T1
T4d=-eta2*(T3-T4) +T3
Wact=0.24*(T3-T4d - (T2d-T1))
Qh=0.24*(T3-T2d)
etath=Wact/Qh
//results
printf("Thermal efficiency = %.1f percent",etath
   *100)
```

Scilab code Exa 12.10 example 10

```
clc
//Initialization of variables
e=0.83
//calculations
T1=530 //R
T2d=838 //R
T6d=T2d
T3=1960 //R
```

```
T4d=1375 //R
T5d=T4d
T5=e*(T5d-T2d) +T2d
W=0.24*((T3-T4d)- (T2d-T1))
Q=0.24*(T3-T5)
eta=W/Q
//results
printf("Thermal efficiency = %d percent",eta*100+1)
```

Scilab code Exa 12.11 example 11

```
clc
//Initialization of variables
T1=420 //R
T11=530 //R
T3=2460 //R
V1=300 //ft/sec
P1=5 //psia
P5=P1
P2=50 //psia
P3=5 //psia
P4=50 //psia
g=1.4
cp=0.24
m=1
//calculations
T2=T1*(P2/P1)^((g-1)/g)
T4=T3-T2+T11
T5=T3*(P3/P4)^((g-1)/g)
V5=sqrt(2*32.2*cp*(T4-T5)*778)
T=m*(V1-V5)/32.2
Qh=cp*(T3-T2)
P=-T*V1
//results
printf("Thrust = %.1f lbf",T)
```

```
printf("\n Heat input = %d B/lbm",Qh)
printf("\n Power = %d ft-lbf /sec",P)
```

Scilab code Exa 12.12 example 12

```
clc
//Initialization of variables
h1=80.419 //B/lbm
h3=36.013 //B/lbm
h4=h3
P3=172.35 //psia
P2=P3
m=5 //tons
Q=12000
//calculations
h2=91.5 //B/lbm
disp("From superheated steam tables,")
COP=(h1-h4)/(h2-h1)
W=h2-h1
md=m*Q/(h1-h4)
Wt=md*(h2-h1)
Wt2=Wt/2545
//results
printf("Coefficient of performance = %.1f",COP)
printf("\n Input work = %.1f hp",Wt2)
```

Chapter 13

Thermodynamics of irreversible processes

Scilab code Exa 13.1 example 1

```
clc
//Initialization of variables
Eab1=0
Eab2=5.87 //mV
T1=150 //F
T2=200 //F
//calculations
Eab= -1.12+ 0.035*T1
pi1=0.035*(T1+460)
pi2=0.035*(T2+460)
//results
printf("Thermocouple reading at %d F = %.2f mv",T1,
   Eab)
printf("\n Peltier coefficient at %d F = %.1f mv",T1
   ,pi1)
printf("\n Peltier coefficient at %d F = %.1f mv",T2
   ,pi2)
```

Scilab code Exa 13.2 example 2

```
clc
//Initialization of variables
T=0 //C
//calculations
de1=-72 //mV/C
de2=500 //mv/C
alpha=de1-de2
pi=-(T+273)*alpha
//results
printf("Peltier coefficient at %d C = %d mv",T,pi
   /1000)
```

Chapter 14

direct energy conversion

Scilab code Exa 14.1 example 1

```
clc
//Initialization of variables
T=25+273 //K
F=23060
//calculations
H=-68317
G=-56690
Er=-G/(2*F)
eta=G/H
W=-G
Q=H-G
//results
printf("Voltage output of the cell = %.3f volts",Er)
printf("\n Efficiency = %d percent",eta*100 +1)
printf("\n Electrical Work output = %d cal/mol H2",W
    )
printf("\n Heat transfer to the surroundings = %d
    cal/mol H2",Q)
```

Scilab code Exa 14.2 example 2

```
clc
//Initialization of variables
x1=0.75
x2=0.25
an=-190*10^-6 //volt/C
rn=1.45*10^-3 //ohm cm
zn=2*10^-3 //K^-1
ap=190*10^-6 //volt/C
rp=1.8*10^-3 //ohm cm
zp=1.7*10^-3 //K^-1
T=200+273 //K
Tc=373 //K
Th=573 //K
//calculations
Ktn=an^2/(rn*zn)
Ktp=ap^2/(rp*zp)
Z=(an-ap)^2 /(sqrt(rn*Ktn) + sqrt(rp*Ktp))^2
Ap=sqrt(Ktn*rp/Ktp/rn)
An=1
K=Ktn*An+ Ktp*Ap
R=rn/An + rp/Ap
mopt=sqrt(1+ Z*T)
RL=mopt*R
nopt=(T-273)*(mopt-1)/(Th*(mopt+ Tc/Th))
nmax=T/(Th*(1+1- T/Th/2 + 4/Th/Z))
nmax=0.0624
dT=T-273
Popt=(an-ap)^2 *dT^2 /((1+mopt)^2 *RL)
Pmax=(an-ap)^2 *dT^2 /((1+1)^2 *R)
//results
printf("Optimum efficiency = %.2f percent",nopt*100)
printf("\n Max. efficiency = %.2f percent",nmax*100)
printf("\n Optimum power = %.3f Watt",Popt)
printf("\n Maximum power = %.3f Watt",Pmax)
```

Scilab code Exa 14.3 example 3

```
clc
//Initialization of variables
phic=2.5 //V
phia=2 //V
phip=0.1//V
Th=2000 //K
Tc=1000 //K
eff=0.2
k=1.38*10^-23
e=1.6*10^-19
sigma=5.67*10^-12
//calculations
V=phic-phia-phip
Jc=1.2*10^6 *Th^2 *exp(-e*phic/(k*Th))
Ja=1.2*10^6 *Tc^2 *exp(-e*phia/(k*Tc))
J=Jc
Qc1=J*(phic + 2*k*Th/e) + eff*sigma*10^4 *(Th^4 - Tc
    ^4)
eta1=J*0.4/Qc1
eta2=(Th-Tc)/Th
//results
printf("Efficiency of the device = %.1f percent",
    eta1*100)
printf("\n Carnot efficiency = %d percent",eta2*100)
```