Scilab Textbook Companion for Thermodynamics by Obert[1]

Created by
Chaitanya Potti
Chemical Engineering
Chemical Engineering
IIT Bombay
College Teacher
Na
Cross-Checked by
Lavitha Pereira

June 1, 2016

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

Book Description

Title: Thermodynamics

Author: Obert

Publisher: McGraw Hill

Edition: 3

Year: 1987

ISBN: 0486603611

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

Survey of dimensions and units

Scilab code Exa 1.1 Example 1

```
clc
//Initialization of variables
v=88 //ft/s
//calculations
v2= v*3600/5280
//results
printf("velocity in mph = %d mph",v2)
```

Scilab code Exa 1.2 Example 2

```
clc
//Initialization of variables
z1=1/5280
z2=1/3600
v=88 //ft/s
//calculations
v2= v*z1/z2
//results
printf("velocity in mph = %d mph",v2)
```

Scilab code Exa 1.3 Example 3

```
clc
//Initialization of variables
m=10 //lbm
a=10 //ft/sec^2
g=32.1739
//calculations
F=m*a/g
//results
printf("Force required = %.3f lbf",F)
```

Scilab code Exa 1.4 Example 4

```
clc
//Initialization of variables
m=10 //lbm
a=32.1739 //ft/sec^2
g=32.1739
//calculations
F=m*a/g
//results
printf("Force required = %d lbf",F)
```

Scilab code Exa 1.5 Example 5

```
clc
//Initialization of variables
F=5e-9 //lbf/ft^2 hr
```

```
g=32.1739
//calculations
F2=F*3600*g
//results
printf("Force without dimensions = %.2e lbm/ft sec",
   F2)
```

Scilab code Exa 1.6 Example 6

```
clc
//Initialization of variables
g=32.1739
gam=62.305
//calculations
rho=gam/g
//results
printf("Density in FLtheta system = %.3f slugs/ft^2"
   ,rho)
```

Chapter 2

Fundamental concepts

Scilab code Exa 2.1 Example 1

```
clc
//Initialization of variables
m=32.1739 //lbm
z=100 //ft
g=32.1739
//calculations
PE=m*z
PE2=m*z/g
//results
printf("Potential energy = %.2f g/g0 ft lbf",PE)
printf("\n in other units, Potential energy = %d g
   ft slug",PE2)
```

Scilab code Exa 2.3 Example 2

```
clc
//Initialization of variables
u=100 //Btu/lbm
```

```
P=100 //psia
v=5 //ft^3
//calculations
h=u + P*v*144/778.16
//results
printf("Enthalpy of unit mass of fluid = %.1f Btu/
   lbm",h)
```

Chapter 3

The first law

Scilab code Exa 3.1 Example 1

```
clc
//Initialization of variables
f=5 //lbm/s
h2=1020 //B/lbm
h1=1000 //B/lbm
v2=50 //ft/s
v1=100 //ft/s
J=778
g=32.2
z2=0
z1=100
gc=32.2
Q=50 //Btu/s
//calculations
W=Q/f - (h2-h1) - (v2^2 -v1^2)/(2*J*gc) - g/gc *(z2-
   z1)/J
power = W*f
//results
printf("Work done = %.1f Btu/lbm",W)
printf("\n Power = %.1f Btu/s",power)
```

Scilab code Exa 3.2 Example 2

```
clc
//Initialization of variables
m=5 //lbm
v=15 //ft^3/lbm
V=100 //ft/s
//calculations
A=m*v/V
D=(4*A/%pi)^(0.5)
//results
printf("Diameter = %.1f in",D*12)
```

Chapter 4

The reversible process

Scilab code Exa 4.2 Example 1

```
clc
//Initialization of variables
T1=100 //F
T2=500 //F
//calculations
function y=cp(t)
    y=0.239 + 0.00003*t
endfunction
cpavg= 1/(T2-T1) *(intg(T1,T2,cp))
//results
printf("average value of Cp = %.3f Btu/lbm F",cpavg)
```

Chapter 5

The second law

Scilab code Exa 5.1 Example 1

```
clc
//Initialization of variables
Tr=500 //R
Ta=1000 //R
dt=100 //R
//calculations
n1=1- Tr/Ta
n2= 1-Tr/(Ta+dt)
n3 = 1- (Tr-dt)/Ta
//results
printf(" Efficiency in case 1 = %.1f percent",n1*100)
printf("\n Efficiency in case 3 = %.1f percent",n2*100)
printf("\n Efficiency in case 3 = %.1f percent",n3*100)
```

Scilab code Exa 5.2 Example 2

```
clc
//Initialization of variables
Tr=500 //R
Ta=2500 //R
Q=1000 //Btu
Ta2=1000 //R
//calculations
n1=1-Tr/Ta
w1=n1*Q
n2=1-Tr/Ta2
w2=n2*Q
dw=w1-w2
//results
printf("Work done in case 1 = %d Btu",w1)
printf("\nWork done in case 2 = %d Btu",w2)
printf("\n Excess work done in case 1 = %d Btu",dw)
```

Scilab code Exa 5.3 Example 3

```
clc
clear
//Initialization of variables
Tr=1000 //R
Ta=3000 //R
Q=300 //Btu/min
p=5 //hp
J=778
//calculations
n1=1-Tr/Ta
nt=p*33000/(J*Q)
//results
printf("Theoretical efficiency = %.3f",nt)
printf("\n Claimed efficiency = %.3f",n1)
if n1>nt then
    printf("\n Inventor claims are true")
```

```
else
    printf("\n Inventor claims are false")
end
```

Scilab code Exa 5.4 Example 4

```
clc
//Initialization of variables
W=14.5 //B/lbm
Q=141.7 //B/lbm
Tr=520 //R
Ta=1040 //R
//calculations
n1=W/Q
n2=1-Tr/Ta
Wc=n2*Q
//results
printf("Thermal efficiency = %.2f percent",n1*100)
printf("\n Work done in carnot cycle = %.1f Btu/lbm"
   ,Wc)
```

Scilab code Exa 5.5 Example 5

```
clc
//Initialization of variables
cp=0.25
T1=3460 //R
T2=520 //R
//calculations
Q=cp*(T2-T1)
ds=cp*log(T2/T1)
G= Q - T2*ds
eta= G/Q
```

```
//results
printf("Thermal efficiency = %.1f percent",eta*100)
```

Scilab code Exa 5.7 Example 6

```
clc
//Initialization of variables
T1=60+460 //R
T2=100+460 //R
m=1 //lbm
cp=1 //Btu/lbm F
//calculations
ds= m*cp*log(T2/T1)
//results
printf("Change in entropy = %.3f Btu/lbm R",ds)
```

Scilab code Exa 5.8 Example 7

```
clc
//Initialization of variables
t1=32 //F
t2=80 //F
m1=1 //lbm
m2=5 //lbm
hlf=144 //Bru/lbm
cp=1 //B/lbm F
//calculations
te=(-hlf+t1*m1+t2*cp*m2) /(m2+m1)
dsi= hlf/(t1+460) + cp*log((460+te)/(460+t1))
dsw= m2*cp*log((460+te)/(460+t2))
dss=dsi+dsw
LE=-(t1+460)*dss
```

```
G1=m2*cp*(te-t2) - m2*(460+t1)*log((460+te)/(460+t2)
   )
G2=m1*cp*(te-t1) - m1*(460+t1)*log((460+te)/(460+t1)
   )
G=G1+G2
//results
printf("Entropy change of the system = %.4f Btu/R",
   dss)
printf("\n Loss of available energy = %.1f Btu",LE)
printf("\n Net change in available energy = %.1f Btu
   ",G)
//The asnwer is a bit different due to rounding off
   error in textbook
```

Chapter 6

Properties of fluids

Scilab code Exa 6.1 Example 1

```
clc
//Initialization of variables
m=1 //lbm
T=32+460 //R
//calculations
disp("From steam tables")
hf=0
p=0.08854 //psi
vf=0.01602 //ft^3
u = hf- p*vf*144/778.16
//results
printf("Internal energy = %.7f Btu/lbm",u)
```

Scilab code Exa 6.2 Example 2

```
clc
//Initialization of variables
T=35+459.6 //R
```

```
//calculations
disp("From steam tables,")
hfg=1074.1 //Btu/lbm
ds=hfg/T
//results
printf("Change in entropy = %.4f Btu/lbm R",ds)
```

Scilab code Exa 6.3 Example 3

```
clc
//Initialization of variables
p=3 //psi
x=0.35
//calculations
printf("From steam tables,")
p=3 //psi
vf=0.01630 //ft^3/lbm
vg=118.71 //ft^3/lbm
hf=109.37 //Btu/lbm
hfg=1013.2 //Btu/lbm
vx=vf+x*(vg-vf)
hx=hf+x*(hfg)
//results
printf("specific volume = %.1f ft^3/lbm",vx)
printf("\n specific enthalpy = %.1f Btu/lbm",hx)
```

Scilab code Exa 6.4 Example 4

```
clc
//Initialization of variables
disp("From steam tables,")
T1=355.21 //F
T2=500 //F
```

```
hg=1193.4 //Btu/lbm
h=1274.8 //Btu/lbm
//calculations
Qrev=h-hg
//results
printf("Heat transferred = %.1f Btu/lbm",Qrev)
```

Scilab code Exa 6.5 Example 5

```
clc
//Initialization of variables
Qrev=81.4 //Btu/lbm
T1=355.21 //F
T2=500 //F
cp=0.562
//calculations
cp=Qrev/(T2-T1)
ds=cp*(log((460+T2)/(460+T1)))
s1=1.5728
s2=s1+ds
//results
printf("Change in entropy = %.4f Btu/lbm F",ds)
printf("\n Final entropy = %.4f Btu/lbm F",s2)
```

Scilab code Exa 6.6 Example 6

```
clc
//Initialization of variables
m=1 //lbm
P1=144 //psia
P2=150 //psia
t1=360 //F
J=778.16
```

```
//calculations
disp("From steam tables,")
v1=3.160 //ft^3/lbm
h1=1196.5 //Btu/lbm
u1=h1-P1*v1*144/J
h2=1211.4 //Btu/lbm
u2=h2 - P2*144*v1/J
Qrev=u2-u1
//results
printf("Heat transferred = %.1f Btu/lbm",Qrev)
```

Scilab code Exa 6.7 Example 7

```
clc
//Initialization of variables
sf=0.12948
dt=0.32 //F
t1=100 //F
x=0.6
//calculations
t2=t1+dt
hf=67.97
ht=2.7
hp=0.3
h2=hf+ht+hp
Wrev=hf-h2
Wact=Wrev/x
//results
printf("Actual work done = %.1f Btu/lbm",Wact)
```

Scilab code Exa 6.8 Example 8

```
clc
```

```
//Initialization of variables
p1=1000 //psia
t1=100.32 //F
h1=70.97 //Btu/lbm
p2=1000 //psia
t2=544.61 //F
h2=1191.8 //Btu/lbm
//calculations
Qrev=h2-h1
//results
printf("Heat transferred = %.1f Btu/lbm",Qrev)
```

Scilab code Exa 6.10 Example 9

```
clc
//Initialization of variables
h1=1220.4 //Btu/lbm
s1=1.6050 //Btu/lbm R
s2=1.6050 //Btu/lbm R
p2=3 //psia
sf=0.2008 //Btu/lbm R
hf=109.37
sfg=1.6855 //Btu/lbm R
hfg=1013.2 //Btu/lbm
eta=0.7
//calculations
x= (s2-sf)/sfg
h2=hf+ x*hfg
Wrev= h1-h2
w=eta*Wrev
//results
printf("Work done = %d Btu/lbm",Wrev)
printf("\n Work done in case 2 = %.1f Btu/lbm",w)
//The asnwer is a bit different due to rounding off error int he textbook
```

Scilab code Exa 6.11 Example 10

```
clc
//Initialization of variables
disp("From steam tables,")
hb=1192.8 //Btu/lbm
ha=hb
hf=330.51 //Btu/lbm
hfg=863.6 //Btu/lbm
//calculations
x=(ha-hf)/hfg
//results
printf("Quality of wet steam = %.1f percent",x*100)
```

Chapter 7

Characteristics of gases

Scilab code Exa 7.2 Example 1

```
clc
//Initialization of variables
x=1545 //ft lbf/ R mol
z=2120
//calculations
y=x/z
//results
printf("y = %.3f atm ft^2 /R mol",y)
```

Scilab code Exa 7.3 Example 3

```
clc
//Initialization of variables
P=14.7 //psi
t=60+460 //R
R0=10.73 //psia ft^3/mol R
//calculations
v=R0*t/P
```

```
m=28.96
//results
printf("volume = %d ft^3/mol",v)
printf("\n Mass = %.2f lbm",m)
```

Scilab code Exa 7.4 Example 4

```
clc
//Initialization of variables
p=20 //psi
t=100+460 //R
R0=10.73
M=28
//calculations
rho=p/(R0/M *t)
//results
printf("density of nitrogen = %.4f lbm/ft^3",rho)
```

Scilab code Exa 7.5 Example 5

```
clc
//Initialization of variables
T1=1000 //R
T2=2000 //R
//calculations
function y =cp(t)
    y=9.47 -3.47*10^3 /t + 1.16*10^6 /t^2
endfunction
cp2= 1/(T2-T1) *(intg(T1,T2,cp))
//results
printf("Specific heat = %.2f Btu/mol R",cp2)
```

Scilab code Exa 7.6 Example 6

```
clc
//Initialization of variables
R=0.73
v=0.193*44 //ft^3/mol
T=672 //R
a=924.2 //atm ft^6 /mol^2
b=0.685 //ft^3/mol
//calculations
p1= R*T/(v-b) - a/v^2
p2=R*T/v
//results
printf("Ideal gas law, pressure = %.1f atm",p2)
printf("\n Vanderwaals law, pressure = %.1f atm",p1)
```

Scilab code Exa 7.7 Example 7

```
clc
//Initialization of variables
Z=1.39
R=0.73
T=492 //R
p=500 //atm
M=28 //lbm
//calculations
v=Z*R*T/(p*M)
//results
printf("volume = %.4f ft^3/lbm",v)
```

Scilab code Exa 7.8 Example 8

```
clc
//Initialization of variables
p=50 //atm
pc= 73 //atm
t= 459.7+212 //R
tc=459.7+87.9 //R
R=0.73
M=44
v=0.193 //ft^3/lbm
//calculations
pr=p/pc
tr=t/tc
z=0.88 //from compressibility charts
p2= z*R*t/v/M
//results
printf("pressure = %.1f atm",p2)
```

Scilab code Exa 7.9 Example 9

```
clc
//Initialization of variables
pc=45.8 //atm
tc=343.9 //R
t=515 //R
v=2.2
R=0.73
//calculations
tr=t/tc
vr= pc*v/(R*tc)
//from compressibilty charts
z=0.803
pr=3
p=pr*pc
```

```
p2= R*t/v
err= (p2-p)/p
//results
printf("pressure = %d atm",p)
printf("\n percentage error = %d percent ",err*100)
//the answer varies a bit due to rounding off error
```

Chapter 8

Approximate calculations for real gases

Scilab code Exa 8.1 Example 1

```
clc
//Initialization of variables
R=1.986 //B/mol R
t2=1100 //R
t1=1000 //R
//calculations
wrev=R*(t2-t1)
//results
printf("work done = %.1f Btu/mol",wrev)
```

Scilab code Exa 8.2 Example 2

```
clc
//Initialization of variables
p1=20 //psia
p2=40 //psia
```

```
t1= 460+40 //R
m=28
R=1.986
cp=0.246 //B/lbm R
//calculations
t2= t1*p2/p1
cv=cp- (R/m)
Qrev=cv*(t2-t1)
ds= cv*log(t2/t1)
//results
printf("heat transferred = %.1f Btu/lbm",Qrev)
printf("\n change in entropy = %.3f Btu/lbm R",ds)
```

Scilab code Exa 8.3 Example 3

```
clc
//Initialization of variables
t1=500 //R
t2=1000 //R
//calculations
function y = cp1(t)
    y= 7.484 - 3.47*10^3 /t + 1.16*10^6 /t^2
endfunction
function y = cp2(t)
    y = 7.484/t - 3.47*10^3 /t^2 + 1.16*10^6 /t^3
endfunction
Q=intg(t1,t2,cp1)
ds=intg(t1,t2,cp2)
//results
printf("heat transferred = %d Btu/mole",Q)
printf("\n change in entropy = %.3f Btu/mole R",ds)
```

Scilab code Exa 8.4 Example 4

```
clc
//Initialization of variables
v1=20.9 //ft^3/mol
v2=23.2 //ft^3/mol
p=500 //psia
w1=198.6 //Btu/mol
//calculations
w=p*(v2-v1)*144/100*0.1285
err = (w-w1)/w
//results
printf("Work done in this case = %d Btu/mol",w)
printf("\n error = %.2f percent",err*100)
```

Scilab code Exa 8.5 Example 5

```
clc
//Initialization of variables
R=1.986
T=1000 //R
vr=2
//calculations
Q= R*T*log(vr)
//results
printf("heat transferred = work = %d Btu/mol",Q)
```

Scilab code Exa 8.7 Example 7

```
clc
//Initialization of variables
v2=41.8 //ft^3/mol
v1=20.9 //ft^3/mol
b=0.685 //ft^3/mol
R=0.73 //atm ft^3 / R mol
```

```
a=924.2
T=1000 //R
//calculations
vr= log((v2-b)/(v1-b))
W= R*T*vr + a*(1/v2 - 1/v1)
//results
printf("Work done = %.1f atm ft^3/mol",W)
```

Scilab code Exa 8.8 Example 8

```
clc
//Initialization of variables
R=1545
n=1.3
T1=520 //R
p2=125 //psia
p1=14.7 //psia
M=29
cv=0.171
k=1.4
//calculations
Wrev= R*T1/M/(1-n) *((p2/p1)^((n-1)/n) -1)
T2= T1*(p2/p1)^((n-1)/n)
Qrev= cv*((k-n)/(1-n))*(T2-T1)
//results
printf("Work done = %d ft lbf/lbm",Wrev)
printf("\n Heat transferred = %.1f Btu/lbm",Qrev)
```

Scilab code Exa 8.9 Example 9

```
clc
//Initialization of variables
k=1.38
```

```
R=1.986
T1=900 //R
M=29
pr=0.1
Wrev=50 //Btu/lbm
//calculations
KE = k*R*T1/M/(1-k) *(pr^((k-1)/k) -1) -Wrev
//results
printf("Change in kinetic energy = %d Btu/lbm",KE)
```

Scilab code Exa 8.10 Example 10

```
clc
//Initialization of variablesk=1.38
R=1.986
T1=900 //R
M=29
pr=0.1
Wrev=50 //Btu/lbm
cp=0.245
k=1.3
//calculations
KE = -cp*T1*(pr^((k-1)/k) -1) -Wrev
//results
printf("Change in kinetic energy = %d Btu/lbm",KE)
```

Scilab code Exa 8.11 Example 11

```
clc
//Initialization of variables
n=1.3
p2=125 //psia
m=1 //lbm
```

```
c=0.04
cv=0.171
k=1.4
p1=14.7 //psia
T2=852 //R
T1=520 //R
//calculations
eta=1+c-c*((p2/p1)^(1/n))
md=m/eta
m12=md*(c+1)
m34=m12-m
Q12=m12*cv*((k-n)/(1-n))*(T2-T1)
Q34=m34*cv*((k-n)/(1-n))*(T1-T2)
Q=Q12+Q34
//results
printf("Net heat transfer from air = %.1f Btu/lbm ",
    Q)
```

Scilab code Exa 8.12 Example 12

```
clc
//Initialization of variables
stroke=14 //in
n=1.3
rpm=130
pa=14.7 //psia
ta=80+460 //R
c=0.03
p1=pa
p4=200 //psia
R=53.3
cap=400 //cfm
m=29.4
cp=0.24
//calculations
```

```
pi=sqrt(pa*p4)
nv=1+c-c*(pi/p1)^(1/n)
Dl=cap/nv
vdl=Dl/(2*rpm)
dl=sqrt(vdl*1728*4/(%pi*stroke))
vh=cap*p1/pi
Dh=vh/nv
vdh=Dh/(2*rpm)
dh=sqrt(vdh*1728*4/(%pi*stroke))
m=p1*144*cap/R/ta
T2=ta*(pi/p1)^((n-1)/n)
Q=m*cp*(T2-ta)
//results
printf("diameter of cylinder 1 = %d in",dl)
printf("\n diameter of cylinder 2 = %.2f in",dh)
printf("\n Heat transferred = %d Btu/min",Q)
```

Scilab code Exa 8.13 Example 13

```
clc
//Initialization of variables
Pr=10
n=1.3
T1=900 //R
W=50 //Btu/lbm
//calculations
T2=T1/Pr^((n-1)/n)
h1=120.86
h2=30.69
dh=h2-h1
ke=-dh-W
//results
printf("Change in kinetic energy = %.2f Btu/lbm",ke)
```

Scilab code Exa 8.14 Example 14

```
clc
//Initialization of variables
T1=900 //R
p1=100 //psia
p2=10 //psia
w=50 //Btu/lbm
//calculations
h1=120.86 //Btu/lbm
pr1=17.374
pr2=pr1*p2/p1
disp("From equilibrium charts,")
T2=468 //R
h2=16.3 //Btu/lbm
ke=h1-h2-w
//results
printf("Change in kinetic energy = %.2f Btu/lbm",ke)
```

Scilab code Exa 8.15 Example 15

```
clc
//Initialization of variables
p1=100 //psi
p2=10 //psia
pa=14.7 //psi
T2=468 //R
T2r=528 //R
R=1.986
M=29
//calculations
disp("From air tables,")
```

```
phi1=0.06657
phi2=0.03762
ds=phi1-phi2
phi11=0.19569
phi12=0.06657
ds2= phi12-phi11 - R/M *log(p2/p1)
//results
printf("In case 1, change in entropy = %.5f Btu/lbm
   R",ds)
printf("\n In case 2, change in entropy = %.5f btu/
   lbm R",ds2)
//the answer is a bit different due to rounding off
   error in textbook
```

Scilab code Exa 8.16 Example 16

```
clc
//Initialization of variables
T1=520 //R
disp("From air table,")
vr1=5192
u1=-6.87 //Btu/lbm
pr1=2.504
vrat=6
p1=14.7
R=1.986
M=29
//calculations
vr2=vr1/vrat
T2=1050 //R
u2=86.1 //Btu/lbm
pr2=30.35
p2=p1*pr2/pr1
W=u1-u2
k=1.39
```

```
p22=p1*vrat^(k)
T22=T1*(vrat)^(k-1)
W2=R*(T22-T1)/(1-k)/M
//results
printf("in case 1, Final pressure = %d psia",p2)
printf("\n in case 1, final temperature = %d R",T2)
printf("\n in case 1, work done = %.2f Btu/lbm",W)
printf("\n in case 2, Final pressure = %d psia",p22)
printf("\n in case 2, final temperature = %d R",T22)
printf("\n in case 2, work done = %.2f Btu/lbm",W2)
//The answers are a bit different due to rounding
    off error in textbook
```

Chapter 9

The flow of fluids

Scilab code Exa 9.1 Example 1

```
clc
//Initialization of variables
h1=1329.1 //Btu/lbm
v1=6.218 //ft^3/lbm
J=778
g=32.174
m=1
//calculations
p=[80 60 54.6 40 20]
h=[ 1304.1 1273.8 1265 1234.2 1174.8]
v=[ 7.384 9.208 9.844 12.554 21.279]
Fc=1
V2=Fc*sqrt(2*J*g*(h1-h))
A=m*v ./V2
V2=[0 V2]
A=[0 A]
//results
disp('velocity = ')
disp(V2 )
disp('Area = ')
disp(A)
```

```
//The initial values of velocity and area are 0 and
    infinity respectively
```

Scilab code Exa 9.2 Example 2

```
clc
//Initialization of variables
n=1.4
p1=50 //psia
J=778
cp=0.24
T1=520 //R
k=n
R=1545/29
m=1
p2=10 //psia
//calculations
rpt=(2/(n+1))^(n/(n-1))
pt=p1*rpt
Vtrev=223.77*sqrt(cp*T1*(1- rpt^((k-1)/k)))
v1=R*T1/p1/144
vt=v1*(p1/pt)^(1/k)
At=m*vt/Vtrev
V2rev=223.77*sqrt(cp*T1*(1-(p2/p1)^((k-1)/k)))
v2=v1*(p1/p2)^(1/k)
A2=m*v2/V2rev
//results
printf("Area required = %.5f ft^2",At)
printf("\n Area in case 2 = %.5f ft^2",A2)
```

Scilab code Exa 9.3 Example 3

```
clc
```

```
//Initialization of variables
rpt=0.569
b=0.8
p1=50 //psia
cp=0.24
T1=520 //R
k=1.4
v2=12.2
v1=3.86
m=1
//calculations
pt=p1*rpt
Vtrev=223.77*sqrt(cp*T1*(1- rpt^((k-1)/k)) /(1- b^4 *(v1/v2)^2))
vt=(p1/pt)^(1/k) *v1
At=m*vt/Vtrev
//results
printf("Area of throat = %.5f ft^2",At)
```

Scilab code Exa 9.4 Example 4

```
clc
//Initialization of variables
J=778
g=32.2
pc=54.6 //psia
h1=1329.1 //Btu/lbm
h2=1265 //btu/lbm
V2rev=1790 //ft/s
cv=0.99
m=1 //lbm
cv2=0.96
//calculations
V2d=cv*V2rev
hd=cv^2 *(h1-h2)
```

```
h2d=h1-hd
v2d=9.946
A2d=m*v2d/V2d
dh=-154.3
V3=2775 //ft/s
V3d=cv2*V3
h3d= h1+ cv2^2 *dh
v3d=22.05 //ft^3/lbm
A3d=m*v3d/V3d
//results
printf("Throat area in case 2 = %.4f ft^2",A2d)
printf("\n Throat area in case 3 = %.5f ft^2",A3d)
```

Scilab code Exa 9.5 Example 5

```
clc
//Initialization of variables
p2=26.4 //psia
p1=50 //psia
p3=10 //psia
V2rev=1017 //ft/s
cv=0.99
J=778
g=32.2
cp=0.24
T1=460+60 //R
k=1.4
R=1545/29
m=1
cv2=0.92
//calculations
V2d=cv*V2rev
dhr= (V2rev^2 - V2d^2)/(2*g*J)
dtr=dhr/cp
T2=T1*(p2/p1)^((k-1)/k)
```

```
T2d=T2+dtr
v2d=R*T2d/(p2*144)
A2d= m*v2d/V2d
V3=1515
V3d=V3*cv2^0.5
T3=T1*(p3/p1)^((k-1)/k)
dhr2=(V3^2 - V3d^2)/(2*J*g)
dtr2=dhr2/cp
T3d=T3+dtr2
v3d=R*T3d/(p3*144)
A3d=m*v3d/V3d
//results
printf("Area = %.5f ft^2",A2d)
printf("\n Area in case 2= %.5f ft^2",A3d)
```

Scilab code Exa 9.6 Example 6

```
clc
//Initialization of variables
mum=0.0000121 //lbm/ft sec
D=1.820 //in
m=1.173 //lbm/sec
//calculations
Re=1.27*m*12/(D*mum)
//results
printf("Reynolds number = %d ",Re)
//The answer is a bit different due to rounding off
   error in textbook
```

Scilab code Exa 9.8 Example 8

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

```
pt=54.6 //psia
dh=64.1 //Btu/lbm
dh2=154.3 //Btu/lbm
vt=9.844 //ft^3/lbm
vt2=21.279 //ft^3/lbm
C=0.98
J=778
g=32.17
m=1 //lbm/sec
//calculations
At=m/C *sqrt(vt^2 /(2*g*J*dh))
A2=m/C *sqrt(vt2^2 /(2*g*J*dh2))
//results
printf("Throat area = %.4f ft^2",At)
printf("\n Area at part 2 = %.5f ft^2",A2)
```

Scilab code Exa 9.9 Example 9

```
clc
//Initialization of variables
k=1.4
D2=1.820
D1=6.065
p2=20.18 //psia
p1=30 //psia
g=32.2
G=13.59
zm=20
R=1545/29
C=0.68
T=520 //R
//calculations
dp=0.03609*G*zm
rp=p2/p1
bet=D2/D1
```

```
v1=R*T/(p1*144)
A2=%pi*D2^2 /(4*144)
m=C*A2/sqrt(1 - bet^4 *rp^(1.43)) *sqrt(2*g*k*p1
    *144/(k-1)/v1 *(rp^(2/k) - rp^((k+1)/k)))
//results
printf("Mass flow rate = %.3f lbm/sec",m)
//The answer is a bit different due to rounding off
    error in textbook
```

Scilab code Exa 9.10 Example 10

```
clc
//Initialization of variables
K=0.6007
Y1=0.91
D1=6.065
D2=1.820
rho1=0.156
p1=30
p2=20.18
//calculations
bet=D2/D1
m=0.525*K*Y1^2 *D2^2 *sqrt(rho1*(p1-p2))
C=K*sqrt(1-bet^4)
//results
printf("mass flow rate = %.2f lbm/sec",m)
printf("\n Coefficient of discharge = %.3f",C)
```

Scilab code Exa 9.11 Example 11

```
clc
//Initialization of variables
zm=0.216
```

```
pm=62.3 //lbm/ft^2
p1=0.0736 //lbm/ft^2
g=32.2
d=4
//calculations
H=zm*(pm-p1)/12/p1
V=sqrt(2*g*H)
m=%pi/4 *d^2 *V*p1
//results
printf("average velocity = %.1f ft/sec",V)
printf("\n mass flow rate = %.1f lbm/sec",m)
```

Scilab code Exa 9.12 Example 12

```
clc
//Initialization of variables
p1=50 //psia
pr=0.58
//calculations
p=p1*pr
s1=1.6585
h1=1174.1 //Btu/lbm
sf=0.3680
sfg=1.3313
hfg=945.3
vg=13.746
hf=218.82
x= (s1-sf)/sfg
v2=vg*x
h2=hf+x*hfg
V2rev=223.77*sqrt(h1-h2)
m=%pi/4 *1/144 *V2rev/v2
//results
printf("mass flow rate = %.3f lbm/sec",m)
```

Scilab code Exa 9.13 Example 13

```
clc
//Initialization of variables
k=1.31
p1=7200 //lbf/ft^2
v1=8.515 //ft^3/lbm
pr=0.6
m1=0.574
T1=741 //R
//calculations
V2rev=8.02*sqrt(k/(k-1) *p1*v1*(1- (pr)^((k-1)/k)))
v2=v1*(1/pr)^(1/k)
m=%pi/4 *1/144 *V2rev/v2
C=m/m1
T2=T1*(0.887)
t=250+460 //R
dt=t-T2
//results
printf("Mass flow rate = %.3f lbm/sec",m)
printf("\n Meta stable under cooling = %d F",dt)
```

Scilab code Exa 9.14 Example 14

```
clc
//Initialization of variables
C=0.98
m=1
v=12.55 //ft^3/lbm
V=1372 //ft/s
//calculations
A=m*v/(C*V) *144
```

```
D=sqrt(A*4/%pi)
//results
printf("Area = %.3f in^2",A)
printf("\n diameter = %.2f in",D)
```

Scilab code Exa 9.15 Example 15

```
clc
//Initialization of variables
nn=0.95
p1=50 //psia
p2=30 //psia
v1=8.515
m=1 //lbm
//calculations
cv=sqrt(nn)
V2rev=1372
V2act=cv*V2rev
n=1.283
v2=v1*(p1/p2)^(1/n)
A=m*v2/V2act *144
D=sqrt(A*4/%pi)
//results
printf("Area = %.2f in^2",A)
printf("\n diameter = %.3f in",D)
```

Scilab code Exa 9.16 Example 16

```
clc
//Initialization of variables
p1=100 //psia
p2=14.7 //psia
k=1.4
```

```
T1=700 //R
R=10.73/29
V=50
cv=0.171
cp=0.24
R2=1.986/29
//calculations
T2=T1/ (p1/p2)^((k-1)/k)
T2=358 //R
m1=p1*V/(R*T1)
m2=p2*V/(R*T2)
Wrev= cv*(m1*T1 - m2*T2) - (m1-m2)*(T2)*cp
Wrev2=m1*cv*(T1-T2) - m1*R2*(T2-p2/p1*T1)
//results
printf("Work done in case 1 = %d Btu",Wrev)
printf("\n Work done in case 2 = %d Btu",Wrev2)
```

Scilab code Exa 9.17 Example 17

```
clc
//Initialization of variables
hf=1187.2 //Btu/lbm
p2=100 //psia
//calculations
t=328 //F
u2=hf
disp("from steam table,")
t2=540 //F
p2=100 //psia
dt=t2-t
//results
printf("Rise in temperature = %d F",dt)
```

Chapter 10

Mixtures of gases and vapors

Scilab code Exa 10.1 Example 1

```
clc
//Initialization of variables
m1=10 //lbm
m2=15 //lnm
p=50 //psia
t=60+460 //R
M1=32
M2=28.02
R0=10.73
//calculations
n1=m1/M1
n2=m2/M2
x1=n1/(n1+n2)
x2=n2/(n1+n2)
M=x1*M1+x2*M2
R=R0/M
V=(n1+n2)*R0*t/p
rho=p/(R0*t)
rho2=M*rho
p1=x1*p
p2=x2*p
```

```
v1=x1*V
v2=x2*V
//results
disp("part a")
printf("Mole fractions of oxygen and nitrogen are %
    .3f and %.3f respectively",x1,x2)
disp("part b")
printf("Average molecular weight = %.1f ",M)
disp("part c")
printf("specific gas constant = %.4f psia ft^3/lbm R
    ",R)
disp("part d")
printf("volume of mixture = %.1f ft^3",V)
printf("density of mixture is %.5f mole/ft^3 and %.2
    f lbm/ft^3",rho,rho2)
disp("part e")
printf("partial pressures of oxygen and nitrogen are
     %.2f psia and %.2f psia respectively" ,p1,p2)
printf("\n partial volumes of oxygen and nitrogen
    are %.2f ft^3 and %.2f ft^3 respectively",v1,v2)
```

Scilab code Exa 10.2 Example 2

```
clc
//Initialization of variables
m1=5.28
m2=1.28
m3=23.52
//calculations
m=m1+m2+m3
x1=m1/m
x2=m2/m
x3=m3/m
C=12/44 *m1/ m
O=(32/44 *m1 + m2)/m
```

```
N=m3/m
//results
printf("From gravimetric analysis , co2 = %.1 f percent , o2 = %.1 f percent and n2 = %.1 f percent ",x1*100,x2*100,x3*100)
printf("\n From ultimate analysis , co2 = %.2 f percent , o2 = %.2 f percent and n2 = %.2 f percent ",C*100,O*100,N*100)
```

Scilab code Exa 10.3 Example 3

```
clc
//Initialization of variables
x1=1/3
n1=1
n2=2
x2=2/3
p=12.7 //psia
cp1=7.01 //Btu/mole R
cp2=6.94 //Btu/mole R
R0=1.986
T2=460+86.6 //R
T1=460 //R
p0=14.7 //psia
//calculations
p1=x1*p
p2=x2*p
ds1= cp1*log(T2/T1) - R0*log(p1/p0)
ds2= cp2*log(T2/T1) - R0*log(p2/p0)
S=n1*ds1+n2*ds2
//results
printf("Entropy of mixture = %.2 f Btu/R",S)
printf("the answer given in textbook is wrong. please check using a calculator")
```

Scilab code Exa 10.4 Example 4

```
clc
//Initialization of variables
c1=4.97 //Btu/mol R
c2=5.02 //Btu/mol R
n1=2
n2=1
T1=86.6+460 //R
T2=50+460 //R
//calculations
du=(n1*c1+n2*c2)*(T2-T1)
ds=(n1*c1+n2*c2)*log(T2/T1)
//results
printf("Change in internal energy = %d Btu",du)
printf("\n Change in entropy = %.3f Btu/R",ds)
```

Scilab code Exa 10.5 Example 5

```
clc
//Initialization of variables
n1=1
n2=2
c1=5.02
c2=4.97
t1=60 //F
t2=100 //F
R0=10.73
p1=30 //psia
p2=10 //psia
//calcualtions
t=(n1*c1*t1+n2*c2*t2)/(n1*c1+n2*c2)
```

```
V1= n1*R0*(t1+460)/p1
V2=n2*R0*(t2+460)/p2
V=V1+V2
pm=(n1+n2)*R0*(t+460)/V
//results
printf("Pressure of mixture = %.1f psia",pm)
```

Scilab code Exa 10.6 Example 6

```
clc
//Initialization of variables
T2=546.6 //R
T1=520 //R
T3=560 //R
v2=1389.2
v1=186.2
R0=1.986
c1=5.02
c2=4.97
n1=1
n2=2
v3=1203
//calculations
ds1=n1*c1*log(T2/T1) + n1*R0*log(v2/v1)
ds2=n2*c2*log(T2/T3)+n2*R0*log(v2/v3)
ds=ds1+ds2
//results
printf("Net change in entropy = %.3f Btu/R",ds)
//The answer is a bit different due to rounding off
   error in the textbook
```

Scilab code Exa 10.7 Example 7

```
clc
//Initialization of variables
m1=1 //lbm
m2=0.94 //lbm
M1=29
M2=18
p1=50 //psia
p2=100 //psia
t1=250 +460 //R
R0=1.986
cpa=6.96
cpb=8.01
//calculations
xa = (m1/M1)/((m1/M1)+ m2/M2)
xb=1-xa
t2=t1*(p2/p1)^(R0/(xa*cpa+xb*cpb))
d=R0/(xa*cpa+xb*cpb)
k=1/(1-d)
dsa=cpa*log(t2/t1) -R0*log(p2/p1)
dSa=(m1/M1)*dsa
dSw=-dSa
dsw=dSw*M2/m2
//results
printf("Final remperature = %d R",t2)
printf("\n Change in entropy of air = %.3f btu/mole
    R and %.5f Btu/R",dsa,dSa)
printf("\n Change in entropy of water = %.4f btu/
    mole R and %.5f Btu/R",dsw,dSw)
//The answers are a bit different due to rounding
    off error in textbook
```

Scilab code Exa 10.8 Example 8

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

```
T=250 + 460 //R
p=29.825 //psia
pt=50 //psia
vg=13.821 //ft^3/lbm
M=29
R=10.73
//calculations
pa=pt-p
V=1/M *R*T/pa
ma=V/vg
xa=p/pt
mb=xa/M *18/(1-xa)
//results
printf("In case 1, volume occupied = %.2f ft^3",V)
printf("\n In case 1, mass of steam = %.2f lbm steam
   ",ma)
printf("\n In case 2, mass of steam = %.3f lbm steam
   ",mb)
```

Scilab code Exa 10.9 Example 9

```
clc
//Initialization of variables
ps=0.64 //psia
p=14.7 //psia
M=29
M2=46
//calculations
xa=ps/p
mb=xa*9/M *M2/(1-xa)
//results
printf("percentage = %d percent",mb*100)
```

Scilab code Exa 10.10 Example 10

```
clc
//Initialization of variables
ps=0.5069 //psia
p=20 //psia
m1=0.01
m2=1
M1=18
M2=29
//calculations
xw= (m1/M1)/(m1/M1+m2/M2)
pw=xw*p
//results
printf("partial pressure of water vapor = %.3f psia"
    ,pw)
```

Scilab code Exa 10.11 Example 11

```
clc
//Initialization of variables
t1=80+460 //R
ps=0.5069 //psia
disp("from steam tables,")
vs=633.1 //ft^3/lbm
phi=0.3
R=85.6
Ra=53.3
p=14.696
//calculations
tdew=46 //F
pw=phi*ps
rhos=1/vs
rhow=phi*rhos
rhow2= pw*144/(R*t1)
```

```
pa=p-pw
rhoa= pa*144/(Ra*t1)
w=rhow/rhoa
//results
disp("part a")
printf("partial pressure of water = %.5f psia",pw)
printf("\n dew temperature = %d F",tdew)
disp("part b")
printf("density of water = %.6f lbm/ft^3",rhow)
printf("\n in case 2, density of water = %.6f lbm/ft^3",rhow2)
printf("\n density of air = %.6f lbm/ft^3",rhoa)
disp("part c")
printf("specific humidity  = %.4f lbm steam/lbm air",w)
```

Scilab code Exa 10.12 Example 12

```
clc
//Initialization of variables
p=14.696 //psia
ps=0.0505  //psia
ps2=0.5067 //psia
phi2=0.5
phi=0.6
grain=7000
//calculations
pw=phi*ps
w1=0.622*pw/(p-pw)
pw2=phi2*ps2
w2=0.622*pw2/(p-pw2)
dw=w2-w1
dwg=dw*grain
//results
printf("change in moisture content = %.6f lbm water/
```

```
    lbm dry air",dw)
printf("\n in grains , change = %.3f grains water/lbm
    dry air",dwg)
```

Scilab code Exa 10.13 Example 13

```
clc
//Initialization of variables
t1=80 //F
t2=60 //F
p=14.696 //psia
ps=0.5069 //psia
pss=0.2563 //psia
cp=0.24
//calculations
pw= pss- (p-pss)*(t1-t2)/(2830- 1.44*t2)
phi=pw/ps
w=0.622*pw/(p-pw)
ws=0.0111
hfg=1059.9
hw=1096.5
hf=28
w2= (cp*(t2-t1)+ ws*hfg)/(hw-hf)
//results
printf("relative humidity  = %d percent",phi*100)
printf("\n humidity ratio = %.5f",w)
printf("\n in case 2, humidity ratio = %.4f ",w2)
```

Scilab code Exa 10.14 Example 14

```
clc
//Initialization of variables
pw=0.15//psia
```

```
disp("using psychrometric charts,")
tdew=46 //F
//calculations
va=13.74 //ft^3/lbm dry air
rhoa=1/va
V=13.74
mw=45/7000
rhow=mw/V
w=0.00643
//results
disp("part a")
printf("partial pressure of water = %.2f psia",pw)
printf("\n dew temperature = %d F",tdew)
disp("part b")
printf("density of water = %.6f lbm/ft^3",rhow)
printf("\n density of air = %.4f lbm/ft^3",rhoa)
disp("part c")
printf("specific humidity  = %.5f lbm steam/lbm air"
    ,w)
```

Scilab code Exa 10.15 Example 15

```
clc
//Initialization of variables
t=80 //F
phi=0.3
w=0.00643
//calculations
H=0.24*t+ w*(1061+0.444*t)
//results
printf("enthalpy = %.2f Btu/lbm dry air",H)
```

Scilab code Exa 10.16 Example 16

```
clc
//Initialization of variables
disp("From psychrometric charts,")
va1=13 //ft^3/lbm dry air
va2=13.88 //ft^3/lbm dry air
flow=2000 //cfm
//calculations
ma1= flow/va1
ma2=flow/va2
t=71// F
phi=t //percent
//results
printf("humidity = %d percent",phi)
```

Scilab code Exa 10.17 Example 17

```
clc
//Initialization of variables
t=90 //F
ts=67.2 //F
phi=0.3
per=0.8
//calculations
dep=t-ts
dt=dep*per
tf=t-dt
disp("from psychrometric charts,")
phi2=0.8
//results
printf("Dry bulb temperature = %.2f F",tf)
printf("\n percent humidity  = %.2f",phi2)
```

Scilab code Exa 10.18 Example 18

```
clc
//Initialization of variables
m=1 //lbm
disp("From psychrometric charts,")
t1=82 //F
phi1=0.4
H1=30 //Btu/lbm dry air
w1=65 //grains/lbm dry air
w2=250 //grains/lbm dry air
//calculations
dmf3=(w2-w1)*0.0001427
hf3=68
hf4=43
H2=62.2
H1=30
mf4= (H1-H2+ dmf3*hf3)/(hf4-hf3)
per=dmf3/(dmf3+mf4)
//results
printf("amount of water cooled per pound of dry air
    = %.3f lbm dry air/lbm dry air",mf4)
printf("\n percentage of water lost by evaporation =
    %.2f percent",per*100)
```

Scilab code Exa 10.19 Example 19

```
clc
//Initialization of variables
R0=0.73 //atm ft^3/mol R
a1=578.9
a2=3675
b1=0.684
b2=1.944
n1=0.396 //mol
n2=0.604 //mol
V=8.518 //ft^3
```

```
T=460+460 //R
//calculations
p1=R0*n1*T/(V-n1*b1) - a1*n1^2 /V^2
p2= R0*n2*T/(V-n2*b2) -a2*n2^2 /V^2
p=p1+p2
pa=(n1+n2)*R0*T/V
err=(pa-p)/p
pb=58.7 //atm
err2= (p-pb)/p
//results
printf("Pressure = %.1f atm",p)
printf("\n error in ideal case = %.1f percent",err
    *100)
printf("\n error in  case 2 = %.1f percent",err2
    *100)
//The answer is a bit different due to rounding off
    error in textbook
```

Scilab code Exa 10.20 Example 20

```
clc
//Initialization of variables
p1=45.8 //atm
p2=36 //atm
t1=343.3 //R
t2=766.8 //R
n1=0.396 //mol
n2=0.604 //mol
V=8.518 //ft^3
R0=0.73
T=920 //R
//calcualtions
vr1=p1*(V/n1)/(R0*t1)
vr2=p2*(V/n2)/(R0*t2)
tr1=T/t1
```

```
tr2=T/t2
disp("From compressibility charts,")
z1=1
z2=0.79
Z=n1*z1+n2*z2
p=Z*R0*T/V
p2=62 //atm
err=(p-p2)/p
//results
printf("In case 1, pressure = %.1f atm",p)
printf("\n In case 2, pressure using trail and error
    method = %d atm",p2)
```

Scilab code Exa 10.21 Example 21

```
clc
//Initialization of variables
t1=343.3 //R
t2=766.8 //R
n1=0.396 //mol
n2=0.604 //mol
V=8.518 //ft^3
p1=45.8 //atm
p2=36 //atm
R0=0.73
T=920 //R
//calculations
tcd=n1*t1+n2*t2
pcd=n1*p1+n2*p2
Tr=T/tcd
Vr=pcd*V/(R0*tcd)
Z=0.87
p=Z*R0*T/V
//results
printf("Pressure = %.1f atm",p)
```

Chapter 11

Thermochemical calculations

Scilab code Exa 11.1 Example 1

```
clc
//Initialization of variables
per=87
//calculations
a=per/12
b=12
ad=4*a
bd=4*b
//results
printf("Molecule is C %d H %d",ad,bd)
```

Scilab code Exa 11.2 Example 2

```
clc
//Initialization of variables
per=0.071
//calculations
O2=8.74
```

```
N2=per/2 + 3.76*O2
//results
printf("Oxygen = %.2f and Nitrogen = %.2f",O2,N2)
```

Scilab code Exa 11.3 Example 3

```
clc
//Initialization of variables
M=29
m1=8.74
m2=32.85
fuel=100 //lbm
//calculations
mass=M*(m1+m2)
AF=mass/fuel
a2=9.75
b2=12.19
AF2=mass/(fuel+a2+b2)
//results
printf("Air fuel ratio = %.2f lbm air/lbm fuel",AF)
printf("\n In dry air , Air-fuel ratio = %.1f lbm air
    /lbm fuel as fired",AF2)
```

Scilab code Exa 11.4 Example 4

```
clc
//Initialization of variables
m1=322.3
m2=2
m3=926
basis=121.94
//calculations
m=m1+m2+m3
```

```
ratio=m/basis
dh=5776.6 //Btu/mol
h1=dh*7.364
h2=14064.3
h3=130565.5
H=h1+h2+h3
hrat=H/basis
//results
printf("Mass of dry flue gases = %.2f lbm dry flue gas/lbm fuel ash and moisture free",ratio)
printf("\n Energy carried away = %.1f btu/mol coal as fired  = %.1f Btu/lbm mol coal ",H, hrat)
```

Scilab code Exa 11.5 Example 5

```
clc
//Initialization of variables
ns=2
n=100
nco=10
nn=88
//calculations
xs=ns/n
conden=(ns-(nn+ns)*xs)/(1-xs)
co2=nco/(nn+nco) *100
//results
printf("Percentage of condensed H20 = %.3f percent",conden)
printf("\n percent of co2 in original mixture = %.3f percent",co2)
```

Scilab code Exa 11.6 Example 6

```
clc
//Initialization of variables
n1=2 //moles
n2=10.52 //moles
P=14.7 //psia
//calculations
pp=n1/n2 *P
disp("from s=psychrometric charts,")
dew=139 //F
//results
printf("dew point = %d F",dew)
```

Scilab code Exa 11.7 Example 7

```
clc
//Initialization of variables
p=14.7 //psia
ps=0.363 //psia
n2=7.52 //moles
n1=1 //moles
//calculations
x= (n1+n2)*ps/p /(1-ps/p)
//results
printf("Final orsat composition is %d CO2 + %.2f H20 + %.2f N2",n1, x, n2)
```

Scilab code Exa 11.8 Example 8

```
clc
//Initialization of variables
p=14.7 //psia
ps=0.363 //psia
n2=7.52 //moles
```

```
n1=1 //moles
//calculations
x= (n1+n2)*ps/p /(1-ps/p)
n=n1+n2+x
y1=n1/n
y2=n1/(n1+n2)
//results
printf("Percentage of co2 on a wet basis = %.1f
   percent",y1*100)
printf("\n percentage of co2 on a dry basis = %.2f
   percent",y2*100)
```

Scilab code Exa 11.9 Example 9

```
clc
//Initialization of variables
basis=100 //lbm
x1=0.6
ash=12 //lbm
N2=79.7
M=29
//calculations
x=ash/x1
C=(1-x1)*x
O2=N2/3.76
a= (14.6+0.2)/(5.83-0.75)
AF=(O2+N2)*M/(a*100)
//results
printf("Air fuel ratio = %.2f lbm air/lbm fuel as
   fired",AF)
```

Scilab code Exa 11.10 Example 10

```
clc
//Initialization of variables
N2=79.7
M=29
ba=2.12
x4=0.3
x5=3.7
x6=14.7
//calculations
O2=N2/3.76
c=14.7
b= x4*4 + x5*2 + x6*2
a=b/ba
AF=(O2+N2)*M/(a*12 + b)
//results
printf("Air fuel ratio = %.1f lbm air/lbm fuel",AF)
```

Scilab code Exa 11.11 Example 11

```
clc
//Initialization of variables
x1=8.7
x2=8.9
x3=0.3
x4=0.3
x5=3.7
x6=14.7
//calculations
a=x1+x2+x3
b= x4*4 + x5*2 + x6*2
//results
printf("Molecule is C %.1f H %d + 20.8 O2 + 78.1 N2"
    ,a,b)
```

Scilab code Exa 11.12 Example 12

```
clc
//Initialization of variables
co=1.2
//calculations
H2=co/2
ch4=0.3
N2=88-H2-ch4
//results
printf("Nitrogen = %.1f percent",N2)
```

Scilab code Exa 11.13 Example 13

```
clc
//Initialization of variables
dn=-0.5
R0=1.986
T=537 //R
Qp=-121664
//calculations
Qv= Qp- dn*R0*T
//results
printf("Heat of reaction at constant volume = %d Btu
    /mol",Qv)
```

Scilab code Exa 11.14 Example 14

```
clc
```

```
//Initialization of variables
m=2362 //g
cp=1 //Btu/lbm F
T=0.83 //F
mass=0.1 //g
//calculations
Qm=m*cp*T/mass
Qv=-Qm
//results
printf("Heat transferred = %d Btu/lbm fuel",Qv)
```

Scilab code Exa 11.15 Example 15

```
clc
//Initialization of variables
y=13
x=12
M2=18
M=170
p=0.4593
vfg=694.9
J=778.2
m=1.375
U=-19650 //Btu/lbm fuel
//calculations
z=y*M2/M
hfg=1050.4 //Btu/lbm
ufg= hfg- p*vfg*144/J
dU=ufg*m //Btu/lbm
Ud=dU+U
//results
printf("Lower heating value = %d Btu/lbm",Ud)
```

Scilab code Exa 11.16 Example 16

```
clc
//Initialization of variables
H=-2199548 //Btu/mole
H1=18900 //Btu/mole
H2=-17784 //Btu/mole
//calculations
Hf=H-9*H1
Hl=Hf-H2
//results
printf("Higher heating value of gas = %d Btu/mole",
   Hf)
printf("\n Higher heating value of liquid = %d Btu/
   mole",Hl)
```

Scilab code Exa 11.17 Example 17

```
clc
//Initialization of variables
n1=8
n2=9
n3=1
n4=12.5
U11=3852
U12=118
U21=3009
U22=104
U31=24773
U32=640
U41=2539
U42=85
H=-2203279
//calculations
dU1=n1*(U11-U12)+n2*(U21-U22)
```

```
dU2=n3*(U31-U32)+n4*(U41-U42)
Q=H+dU1-dU2
//results
printf("Heat of reaction = %d Btu/mole",Q)
```

Scilab code Exa 11.18 Example 18

```
clc
//Initialization of variables
n1=8
n2=9
n3=47
h1=118
h2=104
h3=82.5
Q=2203279 //Btu
//calculations
U11=n1*h1+n2*h2+n3*h3
U12=U11+Q
T2=5271 //R
//results
printf("Upon interpolating , T2 = %d R",T2)
```

Scilab code Exa 11.19 Example 19

```
clc
//Initialization of variables
n1=0.95
n2=0.05
n3=0.025
P=147 //psia
pa=14.7 //psia
//calculations
```

```
n=n1+n2+n3
p1=n1/n *P/pa
p2=n2/n *P/pa
p3=n3/n *P/pa
Kp1= p1/(p2*p3^0.5)
Kp2= p1^2 /(p2^2 *p3)
//results
printf("In case 1, Equilibrium constant = %.1f ",Kp1
   )
printf("\n In case 2, Equilibrium constant = %.1f ",
   Kp2)
```

Scilab code Exa 11.20 Example 20

```
clc
//Initialization of variables
kp=5
//calculations
x=poly(0,"x")
vec=roots(24*x^3 + 3*x-2)
x=vec(3)
y=poly(0,"y")
vec2=roots(249*y^3 +3*y-2)
y=vec2(3)
//results
printf("degree of dissociation = %.2f",x)
printf("\n If pressure =10 . degree of dissociation
   = %.2f",y)
```

Scilab code Exa 11.21 Example 21

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

```
x=poly(0,"x")
vec=roots(24*x^3 +48*x^2 + 7*x -4)
x=vec(3)
//results
printf("degree of dissociation = %.2f",x)
```

Scilab code Exa 11.22 Example 22

```
clc
//Initialization of variables
T=77+460 //R
x1=0.21
x2=1-x1
G=-169557 //Btu/mole
n1=1
n2=3.76
R0=1.986
v=0.0885
pi=14.7
J=778
//calculations
dg1=-n1*R0*T*log(x1)
dg2=-n2*R0*T*log(x2)
dg=dg1+dg2
dG=dg+G
W=-dG
W2=-G
p=0.0004 //atm
G1=-n1*R0*T*log(1/p)
W3= -(dg1+G+G1)
dgf=v*pi*144/J
//results
printf("In case 1,Work done = %d Btu/mole C",W)
printf("\n In case 2,Work done = %d Btu/mole C",W2)
printf("\n In case 3,Work done = %d Btu/mole C",W3)
```

```
printf("\n In case 4,Work done = %.2f Btu/mole C",
    dgf)
```

Scilab code Exa 11.23 Example 23

```
clc
//Initialization of variables
H=-169182 //Btu/mole
s1=1.3609 //Btu/mole R
s2=49.003 //Btu/mole R
s3=51.061 //Btu/mole R
T=537 //R
//calculations
dG=H-T*(s3-s2-s1)
//results
printf("Change in Gibbs energy = %d Btu/mole carbon"
    ,dG)
```

Chapter 12

Power cycles vapor

Scilab code Exa 12.1 Example 1

```
clc
//Initialization of variables
p1=600 //psia
p2=0.2563 //psia
t1=486.21 //F
t2=60 //F
//calculations
disp("from steam tables,")
h1=1203.2
hf1=471.6
hfg1=731.6
h2=1088
hf2=28.06
hfg2=1059.9
s1=1.4454
sf1=0.6720
sfg1=0.7734
s2=2.0948
sf2=0.0555
sfg2=2.0393
xd=(s1-sf2)/sfg2
```

```
hd=hf2+xd*hfg2
xa=0.3023
ha=hf2+xa*hfg2
wbc=0
wda=0
wcd=h1-hd
wab=ha-hf1
W=wab+wcd+wbc+wda
Wrev=hfg1- (t2+459.7)*sfg1
etat=(t1-t2)/(t1+459.7)
etac=W/Wrev
etae=W/Wrev
Wr=Wrev/(wcd)
//results
printf("Thermal efficiency = %d percent",etat*100)
printf("\n Compression efficiency = %d percent",etac
    *100)
printf("\n Expansion efficiency = %d percent",etae
    *100)
printf("\n Work ratio = %.2f ",Wr)
```

Scilab code Exa 12.2 Example 2

```
clc
//Initialization of variables
dhab=-122.6
ha=348.5
eta=0.85
hf=471.6
hfg=731.6
hc=1203.2
dhcd=384.4
hf2=28.06
hfg2=1059.9
//calculations
```

```
hbd= ha - dhab/eta
x=(hbd-hf)/hfg
sbd=0.6944
hdd=hc- dhcd/eta
xdd=(hdd-hf2)/hfg2
sdd=1.5768
Qa=hc-hbd
etat=(dhcd+dhab/eta)/Qa
W=dhcd+dhab/eta
rw= W/dhcd
//results
printf("theoretical efficiency = %.1f percent",etat
   *100)
printf("\n Work ratio = %.3f",rw)
```

Scilab code Exa 12.3 Example 3

```
clc
//Initialization of variables
vf=0.01604 //ft^3/lbm
p1=600 //psia
p2=0.2563 //psia
J=778.16
//calculations
W=-vf*(p1-p2)*144/J
disp("From steam tables")
ha=28.06
hb=29.84
hd=1203.2
he=750.5
sa=0.0555
sb=0.0555
sd=1.4454
se=1.4454
Qa=hd-hb
```

```
Qr=ha-he
W2=Qr+Qa
Wt=hd-he
Wp=ha-hb
etat=W2/Qa
rw= W2/(Wt)
//results
printf("theoretical efficiency = %.1f percent",etat
   *100)
printf("\n Work ratio = %.3f",rw)
```

Scilab code Exa 12.4 Example 4

```
clc
//Initialization of variables
Wisen=-1.78
eta=0.85
t2=60 //F
t1=486.21 //F
//calculations
Wact=Wisen/eta
dsabd= (Wact+Wisen)/(t2+459.7)
disp("From steam tables,")
ha=28.06
hb=30.15
hd=1203.2
he=818.4
sa=0.0555
sb=0.0561
sd=1.4454
se=1.576
Qa=hd-hb
Qr=ha-he
W2=Qr+Qa
Wt=hd-he
```

```
Wp=ha-hb
etat=W2/Qa
rw= W2/(Wt)
//results
printf("theoretical efficiency = %.1f percent",etat
    *100)
printf("\n Work ratio = %.3f",rw)
```

Scilab code Exa 12.5 Example 5

```
clc
//Initialization of variables
sh=1.6070
ph=94.8 //psia
th=324 //F
tr=60 //F
hh=1186.2
pi=94.8 //psia
hi=1399.5
si=1.8265
//calculations
Q=hi-hh
Hr=-(tr+459.7)*(si-sh)
work= Q+Hr
eff=work/Q
Qa1=1557.5
W1=637.1
etat=W1/Qa1
he=1374
hj=948
Whp=he-hh
Wlp=hi-hj
//results
printf("Thermal efficiency in case 1= %.1f percent",
    eff*100)
```

```
printf("\n Thermal efficiency in case 1= %.1f
    percent",etat*100)
printf("\n High pressure work = %.1f Btu/lbm",Whp)
printf("\n Low pressure work = %.1f Btu/lbm",Wlp)
```

Scilab code Exa 12.6 Example 6

```
clc
//Initialization of variables
p2=600 //psia
p1=44 //psia
te=486.21 //F
tb=273.1 //F
J=778.16
p3=0.25 //psia
//calculations
hc=241.9
hj=834.6
y=1-0.805
v1=0.0172
v2=0.016
ha=28.06
hd=hc+v1*(p2-p1)*144/J
hb=ha+v2*(p1-p3)*144/J
hh=1374
Qa=hh-hd
Qr=(ha-hj)*(1-y)
etat=(Qa+Qr)/Qa
//results
printf("thermal efficiency = %.1f percent",etat*100)
```

Scilab code Exa 12.7 Example 7

```
clc
//Initialization of variables
cp=0.25
t2=3460 //R
t1=946.2 //R
etat=0.45
Q=-489
t3=520 //R
etat2=0.384
//calculations
Qa=cp*(t2-t1)
w=etat*Qa
eps=-w/Q
I=w+Q
Qa2= cp*(t2-t3)
W2=etat2*Qa2
eps2=-W2/Q
I2=W2+Q
//results
printf("In case 1, Effectiveness of cycle = %d
   percent",eps*100)
printf("\n in case 1, loss in available energy = %d
   Btu/lbm",I)
printf("\n in case 2, loss in available energy = %d
   Btu/lbm",I2)
```

Scilab code Exa 12.8 Example 8

```
clc
//Initialization of variables
W=481 //Btu/lbm
hh=1374
hd=243.7
sh=1.6070
sd=0.4
```

```
t=519.7 //R
//calculations
Q=(hh-hd) - t*(sh-sd)
eta=W/Q
I=-Q+W
//resu;ts
printf("Efficiency = %.1f percent",eta*100)
printf("\n Energy = %.1f Btu/lbm",I)
```

Scilab code Exa 12.9 Example 9

```
clc
clear
//Initialization of variables
b1=480.9
h1=1306.9
s1=1.5894
h2=1122
s2=s1
s3=1.6522
b3=310.9
h3=1169.5
//calculations
W=h3-h1
db=b3-b1
dh=h1-h2
etae=abs(W/dh)
eps=abs(W/db)
I=db-W
//results
printf("Engine efficiency = %.1f percent",etae*100)
printf("\n Effectiveness = %.1f percent",eps*100)
printf("\n Loss of available energy = %.1f Btu/lbm",
   I)
```

Scilab code Exa 12.10 Example 10

```
clc
//Initialization of variables
ha=348.5
hb=471.6
sa=0.6720
sb=sa
sbd=0.6944
hbd=492.7
etac=0.85
T0=60+460
//calculations
eps=abs(((hbd-ha)-T0*(sbd-sa))/(-(hbd-ha)))
I=(hbd-ha)-T0*(sbd-sa)-(hbd-ha)
//results
printf("Effectiveness = %.1f percent",eps*100)
printf("\n loss of available energy = %.1f btu/lbm",
    I)
```

Scilab code Exa 12.11 Example 11

```
clc
//Initialization of variables
y=0.195
bc=34.07
bb=-0.65
bi=290.85
//calculations
eps=abs((1-y)*(bc-bb)/(y*(bc-bi)))
I=(1-y)*(bc-bb)+ (y*(bc-bi))
//results
```

```
printf("Effectiveness = %.1f percent",eps*100)
printf("\n loss of available energy = %.1f btu/lbm",
   I)
```

Chapter 13

Power cycles gas

Scilab code Exa 13.1 Example 1

```
clc
//Initialization of variables
ta=780 //F
tr=80//F
Qa=195 //Btu
pd=14.7 //psia
R=1.986/29
k=1.4
J=778
g=32.174
//calculations
etat=(ta-tr)/(ta+459.7)
W=etat*Qa
vd=R*(tr+460)/pd
va=vd*exp(-(Qa-W)/R/(tr+460))
vb=va*((tr+460)/(ta+460))^(1/(k-1))
vc=vd/va*vb
rv=vd/vb
rv2=vc/vb
rv3=va/vb
imep= W*J/(144*(vd-vb))/5.77
```

```
//5.77 is conversion factor
//results
printf("cycle expansion ratio = %.1f ",rv)
printf("\n isothermal expansion ratio = %.1f",rv2)
printf("\n isentropic expansion ratio = %.1f",rv3)
printf("\n imep = %.1f lbf/in^2",imep)
```

Scilab code Exa 13.2 Example 2

```
clc
//Initialization of variables
rv=8
k=1.4
Qa=1280
pa=14.7 //psia
R=10.73/29
Ta=540 //R
J=778
cv=0.17 //Btu/lbm R
//calculations
etat=1-1/rv^(k-1)
W=etat*Qa
va=R*Ta/pa
vb=va/rv
Tb=Ta*rv^(k-1)
dt=Qa/cv
Tc=Tb+dt
pb=pa*(rv)^(k-1)
pc= Tc*pb/Tb
Td=Tc*(1/rv)^(k-1)
pd=pa*Td/Ta
imep = W*J/144/(va-vb)
//results
printf("Thermal efficiency = %.1f percent",etat*100)
printf("\n Work done = %d btu/lbm air",W)
```

```
printf("\n Imep = %d lbf/in^2",imep)
printf("\n Pressure and temperature at A = %.1f psia
    and %d R",pa,Ta)
printf("\n Pressure and temperature at B = %d psia
   and %d R",pb,Tb)
printf("\n Pressure and temperature at C = %d psia
   and %d R",pc,Tc)
printf("\n Pressure and temperature at D = %d psia
   and %d R",pd,Td)
printf("\n The pressures given in textbook are wrong
   . Please check using a calculator")
```

Scilab code Exa 13.3 Example 3

```
clc
clear
//Initialization of variables
ha=1033
hbd=1403+1589
hc=7823
hdd=5142
lhv=2733000
M=29
//calculations
wt=hc-hdd
wc=ha-hbd
wnet=wt+wc
heat=hc-hbd
etat=wnet*100/heat
mr=heat/lhv *142/M
AF=1/mr
//results
printf("Thermal efficiency = %.1f percent",etat)
printf("\n Air fuel ratio = %.1f lbm air/lbm fuel",
   AF)
```

Chapter 14

Refrigeration

Scilab code Exa 14.1 Example 1

```
clc
//Initialization of variables
Ta=500 //R
Tr=540 //R
//calculations
cop=Ta/(Tr-Ta)
hp=4.71/cop
disp("From steam tables,")
ha=48.02
hb=46.6
hc=824.1
hd=886.9
Wc=-(hd-hc)
We=-(hb-ha)
//results
printf("Coefficient of performance = %.1f ",cop)
printf("\n horsepower required per ton of
    refrigeration = %.3f hp/ton refrigeration",hp)
printf("\n Work of compression = %.1f Btu/lbm",Wc)
printf("\n Work of expansion = %.2f Btu/lbm",We)
```

Scilab code Exa 14.3 Example 3

```
clc
//Initialization of variables
hc=613.3//btu/lbm
hb=138.9//btu/lbm
ha=138.9//btu/lbm
hd=713.4 //btu/lbm
ta=464.7 //R
t0=545.7 //R
v=8.150 //ft^3/lbm
//calculations
Qa=hc-hb
Qr=ha-hd
Wcd=Qa+Qr
cop=abs(Qa/Wcd)
hp=abs(4.71/cop)
carnot=abs(ta/(t0-ta))
rel=abs(cop/carnot)
mass=200/Qa
C=mass*v
//results
printf("Work done = %.1f Btu/lbm",Wcd)
printf("\n horsepower required per ton of
    refrigeration = %.3f hp/ton refrigeration",hp)
printf("\n Coefficient of performance actual = %.2f
    ",cop)
printf("\n Ideal cop = %.3f",carnot)
printf("\n relative efficiency = %.3f",rel)
printf("\n Mass flow rate = %.3f lbm/min ton",mass)
printf("\n Compressor capacity = %.2f cfm/ton",C)
```

Scilab code Exa 14.4 Example 4

```
clc
//Initialization of variables
k=1.29
R=1.986/17.024
T1=464.7
pr=4.94
//calculations
Wrev= k*R*T1/(1-k) *(pr^((k-1)/k) -1)
Wold=-100.1 //Btu/lbm
err=(Wrev-Wold)/Wrev
//results
printf("Work done = %.1f Btu/lbm",Wrev)
printf("\n error = %.1f percent",err*100)
```

Scilab code Exa 14.5 Example 5

```
clc
//Initialization of variables
hc=73.5
hb=26.28
hd=91.58
hc2=190.7
hd2=244.3
hb2=44.4
m1=1 //lbm
m2=0.461 //lbm
hc1=73.5
hd1=83.35
hc2=197.58
hd2=224
hb1=12.55
//Calculations
w1=hc-hd
```

```
qa1=hc-hb
cop1=abs(qa1/(w1))
hp1=4.71/cop1
w2=hc2-hd2
qa2=hc2-hb2
cop2=abs(qa2/(w2))
hp2=4.71/cop2
qa3=m1*(hc1-hb1)
w3=m1*(hc1-hd1) + m2*(hc2-hd2)
cop3=abs(qa3/w3)
hp3=4.71/cop3
//results
disp("part a")
printf("Work done = %.2f Btu/lbm",w1)
printf("\n Heat = %.2f Btu/lbm",qa1)
printf("\n horsepower required per ton of
   refrigeration = %.3f hp/ton refrigeration",hp1)
printf("\n Coefficient of performance actual = %.2f
   ",cop1)
printf("\n Work done = %.1f Btu/lbm",w2)
printf("\n Heat = %.2f Btu/lbm",qa2)
printf("\n horsepower required per ton of
   refrigeration = %.3f hp/ton refrigeration",hp2)
printf("\n Coefficient of performance actual = %.2f
   ",cop2)
disp("part b")
printf("\n Work done = %.1f Btu/lbm",w3)
printf("\n Heat = %.2f Btu/lbm",qa3)
printf("\n horsepower required per ton of
   refrigeration = %.3f hp/ton refrigeration",hp3)
printf("\n Coefficient of performance actual = %.2f
   ",cop3)
```

Scilab code Exa 14.6 Example 6

```
clc
//Initialization of variables
ha=44.36
hc=18.04
hj=197.58
hh=213.5
hd=hc
he=190.66
hk=241.25
//calculations
m=(hc-ha)/(ha-hj)
hi=(m*hj+hh)/(1+m)
Qa=he-hd
W=he-hh + (1+m)*(hi-hk)
cop=abs(Qa/W)
hp=4.71/cop
//results
printf("\n horsepower required per ton of
    refrigeration = %.3f hp/ton refrigeration",hp)
printf("\n Coefficient of performance actual = %.2f
    ",cop)
```

Scilab code Exa 14.7 Example 7

```
clc
//Initialization of variables
pc=0.6982 //psia
pe=0.1217 //psia
m=200 //gal/min
qual=0.98
h1=23.07 //Btu/lbm
h2=8.05  //Btu/lbm
hw=1071.3
//calculations
rp=pc/pe
```

```
m2=m/0.01602 *0.1388 //Conversion of units
m2=1670
dh=15.02
Qa=m2*(h1-h2)
h3=h2 + qual*hw
m3=Qa/(h3-h1)
v=0.016+ qual*2444
C=m3*v
//results
printf("Pressure ratio = %.2f",rp)
printf("\n Heat = %d Btu/min",Qa)
printf("\n Water make up required = %.2f lbm/min",m3
    )
printf("\n Volume of vapor entering ejector = %d ft
    ^3/min",C)
//The answers are a bit different due to rounding
    off error in textbook
```